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# Artificial Reef Attributes and The Relationship With Natural Reefs: Evidence From The Florida Keys

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## 1. INTRODUCTION

Natural or coral reefs represent extremely valuable ecosystems supporting an estimated 25% of all marine life, providing habitat to over 1 million diverse aquatic species including numerous fisheries, protecting thousands of coastal communities from storms and other natural hazards, and serving cultural traditions of local populations (Moberg and Folke 1999; Spurgeon 1992; Allison et al. 2009). The diverse ecosystem services derived from coral reefs have led to human overuse and, subsequent degradation of the resource. Recent estimates suggest that 19% of the original area of the world's natural reefs have been lost and another 15% of reefs are at risk of being lost over the next few decades (Wilkinson 2008). In the Florida Keys, those estimates are possibly more dramatic with an overall decline of 44% of hard cover coral at monitored stations (Donahue et al 2008).

Currently, 75% of natural reefs are threatened by both natural and human stressors (Burke et al. 2011). Natural stressors include disease and storm impacts, while human stressors come in the form of runoff and other land-based sources of pollution, or from the marine-based activities such as marine transportation, fishing, and diving pressure. These stressors have had a well-recognized role in the global decline of the world's natural reef system. Policymakers and resource managers charged with protecting the existing systems are faced with the task of finding effective management strategies to minimize further decline and support future recovery.

The purpose of this research is to assess the potential for deploying additional artificial reefs as a means of shifting pressure away from natural reef structures. Diving activity can cause significant damage to natural reef systems due to reef trampling, coral touching or removal, and/or loose equipment impacts (see Hawkins et al. 1999; Schleyer and Tomalin 2000; and Tratalos and Austin 2001). We are interested in observing the effect of establishing an additional artificial reef in the Florida Keys reef inventory on diving pressure within the existing natural reef system. Specifically, does the creation of artificial reefs adjacent to an existing natural reef system act as a substitute good and shift diving activity away from natural reefs or does it act as a complementary good by enhancing the diving experience through increased site choice? If the new artificial reef acts as a complementary good, it may have an unintended consequence by attracting more divers to the area, and in turn, lead to more dives and increased pressure on natural reefs.

Florida has the most active and diverse reef system in the United States and the Florida Keys is the most popular diving destination within the state. Johns et al. (2001) estimated 7.55 million person-day dives on natural and artificial reefs in Southeast Florida for 2001. The expansive mix of natural and artificial reefs within the Florida

Keys system provides an ideal location to examine the change in diving behavior with the addition of a new artificial reef to the system. Further, in our empirical framework, we also consider the role of artificial reef depth on diving behavior. We hypothesize that artificial reef managers may need to consider site conditions when deciding upon the optimal placement of artificial reefs.

Our analysis consists of a revealed and stated preference (RP/SP) study of 121 divers that visited the Florida Keys in 2013. All sampled divers take chartered two-tank dives to reefs in the Florida Keys. Two-tank dives constitute a typical diving experience in which the boat takes divers out to the first reef (site) and the diver dives the reef. Then, depending on the depth of the first dive, he or she must spend a requisite amount of surface interval time (to off-gas nitrogen) before making a second dive (either on the same or a different reef). As such, these two-tank dives may be solely on natural or artificial reefs, or split so that one dive occurs on a natural reef and the other on an artificial reef.

Our empirical application elicits diver behavior from their most recent trip followed by contingent behavior under counterfactual conditions. Divers are asked RP/SP dive count questions regarding dives under existing conditions (status quo) and after sinking a new large ship in the area (consequential). From these responses, we develop two models of diving demand. Model 1 examines the effect of a new artificial reef deployment on dives to any reef type, while Model 2 considers deployment impacts on dives to the natural reef system only.

Despite the recent press coverage detailing the global decline of natural reef systems, there are surprisingly only two other articles in the literature that attempt to examine the impact of new artificial reefs on dives to adjacent natural reefs. Both differ from our framework as they compile actual dive counts (revealed preference) before and after deployment of the new artificial reef at specific locations. Polak and Shashar (2012) monitored the dive time spent by a relatively small sample of divers inside a nature reserve in Israel that contained natural reefs, both before and after deployment of six small concrete units at a nearby location. They found no difference in diving times around the natural reefs following deployment of the artificial reefs. In a more comprehensive study, Leeworthy, Maher, and Stone (2006) used dive charter company logbook data and on-water surveys of reef use to assess the number of person-days by reef type for the pre-and post-deployment of the Spiegel Grove (a dock landing ship) off Key Largo, FL. They found that following deployment of the Spiegel Grove, the number of diving trips in the area increased but recreational use of the surrounding natural reefs decreased. Their findings suggested that natural and artificial reefs are substitute goods, although the authors did concede that the logbook data excluded the two busiest recreational use months (June and July), so if use patterns in those months differ compared to the rest of the year, their conclusion might not hold.


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Our analysis adds significant weight to this small, existing literature investigating the behavioral response of divers to artificial reef deployment. We use the contrasting strengths of combining and jointly estimating RP/SP data to examine diver behavior under different stated preference treatments. It has been well documented that the primary weakness of revealed preference methods is that they rely solely on historical data; therefore, analyzing site quality changes, such as changes in the size of a site or improved site access, may not be feasible because individuals may not be able to form preferences due to lack of an actual experience. To overcome this constraint, stated preference methods can be used to estimate site quality changes beyond the range of an individual's experience (see McConnell et al. 1995; Loomis 1993; Whitehead and Finney 2003). A major strength of a stated preference approach is its flexibility; however, the hypothetical nature of the approach is also recognized as a weakness. Overall, the strengths of both approaches can be exploited through joint estimation of RP/SP data. Essentially, joint estimation has the advantage of allowing the measurement of preferences outside of an individual's historical experience while anchoring the stated preference responses to actual behavior (Rosenberg and Loomis 1999; Grijalva et al. 2002; Whitehead 2005; Egan and Herriges 2006). Our RP/SP approach enables us to not only measure the effect of a future deployment of a large ship artificial reef on diving behavior, but also to consider the deployment effect under two different sinking depth scenarios to investigate whether, from a policy perspective, deployment depth is an influential component of diving demand.

## 2. ARTIFICIAL REEF DEPLOYMENT UNDER THE U.S. DEPARTMENT OF MARITIME ADMINISTRATION

The national defense reserve fleet was established after World War II to serve as an inventory of vessels available for use in national emergencies and for national defense. As of August 2013, there were approximately 124 vessels in the fleet. Vessels are periodically examined and reclassified. During that process some vessels are moved into a "non-retention" status and targeted for disposal. According to the U.S. Department of Transportation Maritime Administration (MARAD 2013) vessel disposal program report, there were 24 vessels in non-retention status - MARAD vessels that no longer have a useful application and are pending disposition.

There are a number of options available for ship disposal including vessel donation and sale, dismantling (domestic and foreign recycling/scrapping), sinking as an artificial reef and deep-sinking in the U.S. Navy SINKEX Program.[1] Hess et al. (2005) examined

[1] Under the SINKEX Program, ships are cleaned to EPA deep water disposal standards and then sunk in a live fire exercise at least 50 miles off shore and in at least 6,000 feet of water.

the disposal options for the fleet of decommissioned vessels that were stored at various naval yards throughout the country. They concluded that reefing was the best option available. In particular, Hess et al. noted that if agencies focus on the various costs and offsetting revenues associated with domestic recycling, international recycling, and reefing disposal options, reefing is "very promising" and one of the "least expensive" disposal options available to MARAD and the Navy. Hess et al. also reiterated a key argument made by Hynes, Peters, and Rushworth (2004) that the potential benefits from the reef disposal option may lead communities to share in the costs of the disposal process. Reefing can spur various types of economic benefits in the form of reef use by local residents as well as visiting divers.

In our stated preference treatment, we ask respondents to consider their diving behavior in the Keys given the sinking of the SS Cape John - a Modular Cargo Delivery Ship. The Cape John was assigned to MARAD's inventory after her 2003 deployment in support of the second Gulf War and was downgraded into non-retention status in 2011. As such, our hypothetical stated preference treatment was based on an actual vessel ready for disposal under the MARAD Program.

## 3. SURVEY FRAMEWORK

Because no formal records are kept on the total number of private and commercial dive trips taken in the Florida Keys, the only plausible method available to value the recreational opportunity is to survey a known sample of the divers about their past and expected future trips. To accomplish this, seven local charter boat companies (distributed geographically from Key Largo in the North to Key West in the south) agreed to help recruit survey respondents. The sampling process was conducted in November and December, 2013.

When divers checked in with the charter companies for their trips, they were offered, free of charge, a two-sided laminated card that they could attach to their gear. On one side of the card was a map of the reef system. On the other side, pictures of the fish species found in Florida Keys waters. In the charter boat stores, these cards retail for approximately $7 and are popular items for divers to purchase prior to a dive. In return for the gift (reciprocity), divers were told that they would be contacted by researchers interested in an economic study of the reef system and be asked to complete a survey. If the diver agreed, they were given the card. They then filled in their physical and email address on a piece of paper attached to the card. These address slips were all collected at the dive shop during the liability release form completion process and mailed back to the researchers. In total we purchased 350 cards to be distributed to divers across the seven dive operators.


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The online survey was developed in the Qualtrics Inc. software framework. This enabled the series of necessary skip patterns and randomizations to be accomplished. Respondents were sent an email request to complete the survey with a cover letter describing the research team and our research goals. Respondents were told that the survey would take approximately 10 to 15 minutes to complete. Along with some basic demographic and diver experience questions, the survey asked respondents four dive-count related questions – one revealed preference and three stated preference questions. The dive-count questions were first asked regarding the total number of dives made to any reef.[2] The initial revealed preference question asked respondents to report their actual number of dives in the Florida Keys over the past year. Respondents were then asked hypothetical questions regarding total dive counts that they expect to take over the next 12 months under existing conditions. In estimation, inclusion of a status quo stated preference count provides a means to control for potential hypothetical bias in individual responses (Whitehead et al. 2008). Next, respondents were asked to state their expected dive counts during the next 12 months with either a $50 or $100 increase (varied randomly across respondents) in the dive boat fee due to a fuel surcharge. Respondents were then presented with information regarding the potential sinking of a new artificial reef, followed by a final expected dive count question. Specifically, in this SP scenario, respondents were shown a picture of the Cape John and provided with its dimensions. They were then told:

"If reefed it would become the world's second largest artificial reef (after the USS Oriskany) and push the Vandenberg to third largest. Suppose that Florida acquires this vessel, cleans it appropriately for reefing and sinks it in 135 feet of water so that the deck would be at 90 feet and the shallowest point at 60 feet. Further suppose that its location is in the vicinity of where you plan to take any future diving trips.

Assuming now that dive boat fees are not higher due to a fuel surcharge and thinking about the [DIVE_SP] dives you stated that you expect to take to the Keys over the next 12 months, do you think you would take more, less, or about the same number of dives to the Keys over the next 12 months, assuming that the SS Cape John, as described above, is sunk as an artificial reef and available to dive today?"

The software would automatically enter the [DIVE_SP] number of dives that related to the status quo expected number of dives. After each of the four dive-count questions, respondents were also asked to indicate how many of the stated dives were on/would be on a natural reef. From these questions, four dive count responses were elicited for both dives to any reef type and dives only to natural reefs.

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[2] Divers were informed that "a dive is defined as a dive of any type taken at the Keys during a trip where there was a surface interval that followed. As such, if you go out on a charter and make a two-tank dive with a surface interval between dives, this constitutes two dives."

To examine the effect of depth of a new reef on diver behavior, under the new ship deployment scenario, each respondent received one of two possible depth scenarios. The above script represents the “deep” sinking scenario. A “shallow” scenario describes a sinking in 120 feet of water with the deck at 75 feet and the shallowest point at 45 feet. The two depth scenarios were randomly varied across respondents.

By survey design, respondents were asked a series of diver preference questions using a Likert scale of 1 (strongly disagree) to 5 (strongly agree). Table 1 (see next page) presents a description of these questions. The average responses indicate that most divers perceive the quality of diving in the Keys to be excellent, although there is strong agreement that the natural reef system is threatened by both natural and human stressors. The vast majority of divers believe that the artificial reef system in the Florida Keys is important in reducing human-related stress on the natural reef system, but that more vessels should be placed as artificial reefs in the system. In terms of diver preferences, it seems most divers, on their two-tank dives, prefer to dive one artificial and one natural reef, rather than two of the same type. Moreover, there’s a preference toward diving a large vessel artificial reef.


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*Table 1.* Diver Beliefs on Reef and Behavioral Questions (Responses in Percentages)

| Question | Strongly Disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree |
|---|---|---|---|---|---|
| The overall quality of diving natural reefs in the Florida Keys is excellent. | 1.0 | 10.2 | 15.8 | 47.2 | 26.0 |
| The overall quality of diving natural reefs in the Florida Keys is much better now than it was when I first dove here. | 4.8 | 17.5 | 64.3 | 10.3 | 3.2 |
| The natural reef system in the Florida Keys is threatened by natural stressors (e.g. disease, storms). | 1.0 | 3.9 | 22.8 | 48.0 | 24.4 |
| The natural reef system in the Florida Keys is threatened by human-related stressors (e.g. pollution, fishing, diving). | 1.0 | 1.6 | 12.7 | 41.3 | 43.7 |
| The artificial reef system in the Florida Keys is important in reducing human-related stress on the natural reef system. | 1.0 | 2.4 | 14.2 | 45.7 | 37.0 |
| There should be more vessels placed as artificial reefs in the Florida Keys. | 1.6 | 3.2 | 15.8 | 33.1 | 46.5 |
| When I make a two-tank dive I prefer to do both tanks on natural reefs. | 8.0 | 28.6 | 45.2 | 12.7 | 5.6 |
| When I make a two-tank dive I prefer to do both tanks on artificial reefs. | 3.2 | 24.6 | 56.4 | 10.3 | 5.6 |
| When I make a two-tank dive I prefer one on an artificial reef and the other on a natural reef. | 1.0 | 8.0 | 44.8 | 27.2 | 19.2 |
| I prefer to dive the large vessel artificial reefs in the Florida Keys. | 1.0 | 5.5 | 33.1 | 33.1 | 27.6 |

From 350 emails sent out to divers, we received 155 responses (a 44% response rate).[3] From these, there were 24 incomplete responses, leaving a total of 121 observations. In Table 2 we summarize the RP/SP responses. Divers make an annual average of 13 dives in the Keys, of which 8 are on the natural reef system. They expect to make approximately 15 dives next year (9 on natural reefs), falling to an average of 12 dives (7 on natural reefs) with a fee increase (either $50 or $100), increasing to 19 dives (10 on natural reefs) following deployment of the Cape John (across both depth scenarios).

*Table 2.* Revealed and Stated Preference Data and Variable Summary for Divers

| | | All Dives | | Dives on Natural Reef | |
|---|---|---|---|---|---|
| Variable | Description | Mean | Min, Max | Mean | Min, Max |
| RP1 | Dives Over Past 12 Months | 13.2 | 1, 100 | 8.2 | 1, 75 |
| SP1 | Dives Under Status Quo Next 12 Months | 15.1 | 0, 109 | 8.6 | 0, 90 |
| SP2 | Dives with Increased Dive Boat Fee | 12.4 | 0, 109 | 7.2 | 0, 80 |
| SP3 | Dives Following Deployment of Artificial Reef | 18.5 | 0, 300 | 9.8 | 0, 100 |
| Fee | Annual fee surcharge | 75.2 | 50,100 | | |
| Age | Age of Respondent | 43.6 | 18, 70 | | |
| Male | Dummy if respondent is male (0/1) | 0.72 | 0, 1 | | |
| Income | Respondent income in $thousands | 95.7 | 5, 200 | | |
| House | Number of persons in respondent's home | 2.4 | 1, 7 | | |
| Recreational Diver | Dummy if respondent is a recreational diver (0/1) | 0.75 | 0, 1 | | |
| Dives | Total number of dives taken anywhere | 551.3 | 1, 5000 | | |
| More Vessels | Scaled dummy variable representing respondent belief that more vessels should be placed as artificial reefs in Keys; 1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree | 4.2 | 1, 5 | | |
| SP | Dummy variable denoting the trip count was elicited through a stated preference question (0/1) | 0.75 | 0, 1 | | |
| Newship | Dummy variable denoting trip counts elicited under the assumption that the SS Cape John would be sunk in the Keys (0/1) | 0.25 | 0, 1 | | |
| Depth | Dummy if sinking is at a deeper depth (0/1) | 0.12 | 0, 1 | | |

Table 2 also provides descriptive statistics for the sample. Across the whole sample of divers, 72% are male. The average diver is 44 years of age, lives in a household with an average of 2.4 persons, a college graduate, earning over $95,000. Based on previous research, the sample population would appear to be representative of divers in the U.S.

[3] Response rate was augmented via follow-up reminder emails sent out two weeks after the original email.

(see Morgan and Huth 2011; Morgan, Massey, and Huth 2009). That is, our sample generates a typically high-income earning, well educated, middle-aged cohort. Approximately three-quarters of the sample are recreational divers, as opposed to technical divers. Recreational divers stay within 130 feet of the surface, within no decompression limits. Technical diving requires much more training and equipment than recreational diving, and all technical divers have various different advanced diving certifications. The ordinary recreational diver will usually have what is termed a basic or advanced open water certification, and some might be certified to dive simple nitrox gas mixes. Most operators require or recommend that the diver have at least the basic open water certification and a minimum number of dives before performing an advanced dive, such as deeper large-ship reefs, like the USS Vandenberg off of Key West or the USS Spiegel Grove off of Key Largo. Finally, the average diver in the sample has taken over 600 total dives anywhere in the world.

Following the stated preference dive count questions, we asked several debriefing questions (see Table 3 on next page). The first was “how sure would you say that you are about your answers regarding future dives?” Over 85% of respondents indicated that they were either “somewhat sure” or “very sure” about their answers regarding future dives. We also asked respondents “when you answered the hypothetical trip questions, did you tell us the number of dives that you hope to take in the future or the number of dives that you really think you will be able to take in the future?” Approximately 62% also indicated that they believed that they were stating dives that they “think” they will take, rather than that they “hoped” they would take. Furthermore, the broad literature suggests that people tend to overstate their values in hypothetical settings (Little and Berrens 2004; Murphy, Stevens and Weatherhead 2005; Whitehead 2005). To examine the potential for the existence of “hypothetical bias”, we asked three questions to examine respondents’ perceived consequentialism of their survey responses. Research has indicated that respondents are more likely to reveal true preferences if they expect their responses to influence policy (Cummings and Taylor 1998; Carson et al. 2004; Vossler and Watson 2013). We asked three questions to elicit respondents’ thoughts on the consequentiality of the survey. Eighty-seven percent of respondents “agreed” or “strongly agreed” that the results of the survey will be shared with Florida Fish and Wildlife (FWC) policy makers. Sixty-seven percent of respondents “agreed “or “strongly agreed” that results of the survey could affect decisions on artificial reef policy in Florida, while 70% of respondents “agreed “or “strongly agreed” to having confidence in the ability of FWC to achieve the goals of artificial reef policy. As such, for all three questions, there is a strong indication that respondents believed that their responses were important, and therefore consequential, to policy decisions. Moreover, only 1 respondent “strongly disagreed” with each question. Given that typically only those who strongly disagree are dropped from estimation, we do not make any adjustment for consequentiality. Instead, potential hypothetical bias is accounted for through the status quo stated preference treatment.

*Table 3.* Debriefing Questions (Responses in Percentages)

| **Questions** | **Responses** | | | | |
|---|---|---|---|---|---|
| | Not sure at all | | Somewhat sure | | Very sure |
| Now that the hypothetical questions are over, how sure would you say that you are about your answers regarding future trips? | 7.5 | | 48.3 | | 44.2 |
| | Trips that I hope to take | | | Trips that I think I will take | |
| When you answered the hypothetical trip questions, did you tell us the number of trips that you hope to take in the future or the number of trips that you really think you will be able to take in the future? | 38.3 | | | 61.7 | |
| | Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree |
| I believe that the results of this survey will be shared with Florida Fish and Wildlife Conservation Commission policy makers | 0.8 | 0.8 | 13.3 | 53.3 | 31.7 |
| I believe that the results of this survey could affect decisions about artificial reef policy in Florida | 0.8 | 4.2 | 25.0 | 48.3 | 21.7 |
| I have confidence in the ability of Florida Fish and Wildlife Conservation Commission to achieve the goals of artificial reef policy | 0.8 | 4.2 | 20.8 | 57.5 | 16.7 |

## 4. CONCEPTUAL FRAMEWORK

The online survey instrument was used to collect RP and SP data for analysis, and Model 1 is a general reef model that examines diving behavior across both reef types (artificial and natural). Model 2 only considers dives on the natural reef system. For brevity, in order to describe the conceptual framework, we initially focus here on Model 2. We construct Model 1 in an identical manner.

The RP data captures the actual annual number of dives on a natural reef system in the Florida Keys and the SP data measures the expected number of dives resulting from price changes and the deployment of the SS Cape John as an artificial reef. SP dive questions are asked about future annual number of dives: (1) under status quo conditions, (2) with a dive fee increase, and (3) with the deployment of the new artificial reef.

As the dependent variable is a nonnegative integer with a high frequency of low dive counts, a linear count panel data specification is estimated. Following Haab and McConnell (2003), the basic model is written as:

$$y_i = (P_i, \boldsymbol{z}_i, \boldsymbol{c}_i, SP)$$

*Equation 1*

in which the actual/expected number of dives by diver $i$, is a function of the dive price, $P_i$, a vector of dive experience-related variables, $\boldsymbol{z}_i$, a vector of socio-demographic attributes, $\boldsymbol{c}_i$, and a stated preference elicitation dummy variable, *SP*. Within the stated preference literature, research has shown that values for non-market goods derived from stated preference survey techniques often exceed those elicited using revealed preferences (List and Gallet 2001; Murphy et al. 2005). Therefore, our model specification includes a dummy variable representing those observations elicited using our stated preference methodology. This allows our model to account for and measure any hypothetical bias that might be present in the stated preference trip counts (Egan and Herriges 2006; Whitehead 2005).

The Poisson model is typically used to study data of this nature. However, a critical and limiting assumption of the Poisson model is that the conditional mean of the dependent variable, $\lambda$, equals the conditional variance. Although the underlying assumption of Poisson regression necessitates a variance-mean ratio of unity (often called the equidispersion property), many empirical applications exhibit overdispersion, where the conditional variance is greater than the conditional mean. As such, overdispersion represents a form of heterogeneity in empirical settings.

A less restrictive model is the negative binomial model, which is a generalized version of the Poisson model in which unobserved heterogeneity is addressed through the additional of a multiplicative random effect. For recreation demand, one of the most common forms of negative binomial models addresses overdispersion through the inclusion of a Gamma distributed error term in the mean (Haab and McConnell 2003). It has been shown that as the dispersion falls to zero, the negative binomial model approaches the Poisson distribution (Agresti 1990). Given that the Poisson model is a special case of the negative binomial model, a standard likelihood ratio test can be used to compare the models.

Following Haab and McConnell (2003) the appropriate negative binomial model probability function with a gamma distributed error term in the mean for an individual can be expressed as:

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

*Equation 2*

in which $\Gamma$ denotes a gamma distribution, $\alpha$ is the overdispersion parameter, and the parameter, $\lambda$, is the expected number of dives and is assumed to be a function of the variables specified in the model. Usually, $\lambda$ takes a log-linear form to ensure nonnegative dive counts and may be written as:

$$ln\lambda_{it} = \beta_0 + \beta_1 P_i + \beta_2 \mathbf{z}_i + \beta_3 SP + \beta_4 \mathbf{c}_i + \beta_5 NEWSHIP + \beta_6 DEPTH + \mu_i$$

*Equation 3*

in which the $\beta$'s are the coefficients to be estimated. Specifically, individuals are indexed $i$ = 1, …,121; and $t$ = 1, …,4 denotes annual dives to the Florida Keys' natural reef system under RP status quo, SP status quo, SP fee increase, and an SP information treatment regarding the sinking of a new large ship artificial reef, respectively, in the pseudo-panel data. Dummy variables *NEWSHIP* (*NEWSHIP* = 1 when $t$ = 4), and *DEPTH* (*DEPTH* = 1 when $t$ = 4 and the deployment SP treatment uses the deeper depth scenario) are demand shift variables for the sinking and depth treatment scenarios. The *SP* dummy variable is included to test for hypothetical bias where *SP* = 0 for revealed preference dive data (t = 0) and *SP* = 1 for hypothetical dive data ($t$ = 2, …, 4). $\beta_0 - \beta_6$ are coefficients to be estimated in the model. Pooling the data suggests that panel data methods be used to account for differences in variance across sample individuals, $i$, and scenarios, $t$. That is, we recognize that there are likely unobserved individual specific factors that are correlated across respondents' four responses. We estimate a balanced negative binomial panel model with random effects to allow the error term in the model to be correlated across consumption choice scenarios for each individual.

For both models we use the estimated coefficients to calculate per-person consumer surplus (CS), or use value measures. These are estimated as the difference between a diver's total willingness to pay for the dives and the total dive price. Using the specified


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log-linear model, per-person per-dive CS is estimated as $\frac{1}{-\beta_1}$ and the corresponding annual consumer surplus is $\frac{\lambda}{-\beta_1}$ where $\lambda$ is the annual predicted number of dives. Finally, following Whitehead et al. (2008), the economic benefit of adding the SS Cape John as a new artificial reef can be estimated as $\frac{\lambda^{*}-\lambda}{-\beta_1}$, in which $\lambda^{*}$ is the predicted number of dives associated with adding the SS Cape John at the site. For each model, uncorrected CS estimates (in which SP=1) and a hypothetical bias-corrected CS estimates (in which SP=0) are provided (see Table 5 on next page).

## 5. RESULTS

Table 4 (below) presents the results from two random effects negative binomial models of recreational diving demand. Model 1 includes the annual actual and expected counts for dives on any reef type in the Florida Keys as the dependent variable, while Model 2 only includes annual dive counts on the natural reef structure as the dependent variable.

*Table 4*. Results from Negative Binomial Regressions with Random Effects

| | Model 1 All Dives | | | Model 2 Dives on Natural Reef | | |
|---|---|---|---|---|---|---|
| | Coefficient | Standard Error | *p*-value | Coefficient | Standard Error | *p*-value |
| Constant | 2.054 | .483 | 0.000 | 1.586 | 0.417 | 0.000 |
| Fee | -0.003 | 0.001 | 0.008 | -0.003 | 0.003 | 0.026 |
| Male | -0.108 | 0.204 | 0.597 | -0.372 | 0.233 | 0.109 |
| Age | -0.002 | 0.009 | 0.854 | -0.001 | 0.007 | 0.938 |
| Inc | 0.001 | 0.002 | 0.845 | 0.002 | 0.002 | 0.352 |
| House | -0.081 | 0.078 | 0.296 | -0.066 | 0.075 | 0.384 |
| Rec | -0.470 | 0.308 | 0.127 | -0.054 | 0.271 | 0.841 |
| Dives | 0.000 | 0000 | 0.955 | 0.000 | 0.000 | 0.831 |
| More Vessels | 0.329 | 0.122 | 0.007 | 0.264 | 0.097 | 0.006 |
| SP | 0.151 | 0.089 | 0.087 | 0.056 | 0.110 | 0.613 |
| New Ship | 0.181 | 0.106 | 0.087 | 0.074 | 0.168 | 0.660 |
| Depth | 0.034 | 0.103 | 0.739 | 0.077 | 0.143 | 0.590 |
| alpha | 3.105 | 0.390 | 0.000 | 2.912 | 0.413 | 0.000 |
| Log lik | -1432.2 | | | -1256.3 | | |
| Obs | 484 | | | 484 | | |

Across both models, the coefficients on FEE indicate that divers behave in line with economic theory with an increase in dive boat fees reducing diving demand. The coefficients on the FEE variable are also of the same order of magnitude across models, indicating average WTP per dive to a reef of any type at about \$304 and \$300 per dive on a natural reef (see Table 5). To provide a comparison of estimates, Morgan, Massey, and

Huth (2009) estimated the consumer surplus associated with diving the USS Oriskany at $717 per trip. Given that Oriskany is the world's largest artificial reef, one would expect a larger consumer surplus estimate. We also present 95% confidence intervals for per-dive and annual estimates. All confidence intervals are constructed using a parametric bootstrapping procedure (Krinsky and Robb 1986). The procedure generates 10,000 random variables from the distribution of the estimated parameters and generates 10,000 consumer surplus estimates. The estimates are sorted in ascending order and the 95% confidence intervals are found by dropping the bottom and top 2.5% of the estimates.

*Table 5.* Consumer Surplus Estimates (with 95% Confidence Intervals)

| | **Diving on All Reef Types** | | **Diving on Natural Reefs** | |
|---|---|---|---|---|
| | Standard Model (SP=1) | Corrected Model (SP=0) | Standard Model (SP=1) | Corrected Model (SP=0) |
| **Predicted Dives (λ)** | | | | |
| Baseline NEWSHIP = 0) | 18.5 | 17.5 | 11.1 | 10.9 |
| With New Ship | 19.6 | 18.3 | 11.4 | 11.5 |
| **Per-Dive Value** | $303.5<br>($79.4, $527.5) | | $300.2<br>($35.9, $564.6) | |
| **Annual Value** | | | | |
| Baseline (NEWSHIP = 0) | $6,163<br>($1,469, $9,759) | $5,819<br>($1,390, $9,231) | $3,685<br>($398, $6,267) | $3,535<br>($391, $6,154) |
| With New Ship | $6,531<br>($1,556, $10,339) | $6,109<br>($1,453, $9,653) | $3,802<br>($409, $6,436) | $3,646<br>($413, $6,493) |
| **Marginal Annual Value of Sinking SS Cape John** | $368 | $317 | $116 | $110 |

Due to our sampling strategy, our data likely suffer from onsite sampling bias such as avidity bias. With any on-site sampling procedures aimed at estimating single site recreation demand, data likely suffer from both endogenous stratification and truncation issues. In our context, endogenous stratification refers to over-sampling of divers that visit the Keys more frequently.[4] Also, as we only sample participants, we do not observe

[4] Another potential source of avidity bias could exist if divers sampled in the November/December period differ in terms of behavior from other months. However, the Keys are more like Caribbean Island destinations than other domestic diving destinations such that in the Fall/Winter period, the only substitutes

any zero revealed preference dive counts. In addition to the potential influence of onsite sampling biases on the estimation of revealed preferences, our onsite sampling routine may also influence the estimation of stated preferences. Both Moeltner and Shonkwiler (2010) and Hynes and Greene (2013) argue that RP/SP models must account for an "avidity carryover" in SP questions. The avidity carryover manifests itself as sampled individuals' relatively stronger preferences for the site carries over to their contingent behavior via stated preference counts. To account for this potential avidity bias, Hynes and Greene (2013) develop an estimation routine for a negative binomial panel model that deals with both truncation and endogenous stratification. However, in their application, all individuals expect to take trips to the site in the future, so all stated preference counts are non-zero. In our application, a subset of sampled divers do not anticipate future trips under the different stated preference treatments. As a result, we cannot apply the Hynes and Greene (2013) avidity bias correction to our data. The authors are unaware of a developed statistical procedure to account for onsite sampling bias when a subset of sampled participants choose non-participation under contingent scenarios (zero counts for stated preference questions).

In the absence of any correction, our data likely suffer from onsite sampling bias, which may inflate welfare estimates. In an attempt to test the sensitivity of our results to this bias, we estimate a corrected and uncorrected model using only RP data. We estimate a standard, uncorrected negative binomial model and compare it to a second negative binomial model with the Hynes and Greene correction for onsite sampling bias. We compare individual per-trip consumer surplus measures for the two models and find that failing to account for potential onsite sampling bias in the RP data inflated welfare measures by approximately 10%. If we assume that avidity carryover has a similar impact within the SP data, our failure to correct for onsite sampling bias in our RP/SP data may lead to consumer surplus estimates presented in Table 5 to be inflated by roughly 10%.

Based on the annual predicted number of dives, aggregating the per-dive estimates equates to an annual consumer surplus estimate, per diver, for dives on all reef types, of $6,163, and falls to $5,819 when we adjust for potential hypothetical bias (SP=0). For dives on natural reefs, the annual consumer surplus estimate, per diver, is $3,685, and it falls to $3,535 when we adjust for potential hypothetical bias.

Across both models, results on the dive-related variables are similar. Both the number of total dives made anywhere and being a recreational diver with no decompression limits

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for general diving activity would be southern hemisphere or Caribbean locations. Anecdotally, we understand that these months are like the summer months in terms of diving demand and that the divers in our sample are not necessarily more avid but just choosing the Keys in their vacation decisions.

(as opposed to a technical diver) does not impact behavior. However, those with a preference for more vessels to be sunk as artificial refs positively influence diving demand for both reef types in the Keys. Also in both models the socio-demographic variables do not influence diving demand. For dives on any reef type, the stated preference is significant, so divers expect to make significantly more dives next year.

Our model results provide interesting insights for assessing the impact of large ship deployment as an artificial reef on diving behavior, and in particular, diving pressure on the natural reef system. For dives on any reef type, the addition of a new large ship artificial reef increases the number of dives. This is not a surprising result and supports earlier work by Morgan, Massey, and Huth (2009) and Morgan and Huth (2011). For example, Morgan, Massey, and Huth (2009) found that the addition of a large artificial reef influenced the magnitude of travel cost preference parameters recreators use to determine their expected number of dive trips. As a result, the addition of a large ship reef lessened the disutility associated with accessing the dive site, made the site more attractive and subsequently increasing the number of dive trips. In terms of economic value, the new ship deployment increased annual consumer surplus, per diver, by approximately $368 in the corrected model to $6,109.

In our scenario, the depth of deployment does not seem to be an important factor for divers. For dives on any reef types, the depth of deployment of the SS Cape John has no impact on diver behavior. Of course, this result is specific to the deployment depths used in our SP treatment. We varied the depth of the deck from 75 feet (shallow) to 90 feet (deep). A contingent design with greater variation may induce behavioral change.

Since one of our primary objectives is to measure the effect of artificial reef management interventions on diving pressure on the natural reef system, it is important to understand whether the increase in diver activity on the artificial reef system corresponds with increased use of the natural reef. In Model 2, deployment of the SS Cape John has no statistical effect on the number of dives taken to natural reefs in the Florida Keys' area. As such, our results indicate that the deployment of artificial reefs does not alter the diving pressure on the natural reef system.

When viewed holistically, the small literature on the economics of reef diving provides key insights for policy makers. Leeworthy, Maher, and Stone (2006) found deployment of a large ship artificial reef increased the overall number of diving trips in the Florida Keys but reduced trips to the natural reef system. When compared and contrasted with their findings, both sets of results suggest that in terms of diving demand, artificial and natural reefs are not complimentary goods. That is, new artificial reefs do not increase diving demand on the adjacent natural reef system. Our results differ from those of Leeworthy, Maher, and Stone (2006) in that our results do not indicate any substitution effects, but rather find that new dives occur exclusively on the artificial reef system. Both sets of results also provide a similar intuition as to the overall economic


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benefits from additional artificial reefs. As diving areas such as the Florida Keys add to the existing inventory of artificial reefs, we can expect welfare gains by divers as a result of new recreational opportunities. In terms of reef conservation, these additions do not appear to increase diving pressure on the natural reef system in the form of environmental spillovers. Our results indicate that the welfare gains that are realized by adding more large vessels reefs are not mitigated by additional pressure on, and degradation of, the adjacent natural reef system. It should be noted that our results are likely influenced by sampling strategy and model choice. Future efforts that address these methodological issues can provide additional clarity on policy implications of additional artificial reefs.

## 6. CONCLUSION

Given that approximately 75% of natural reefs are under threat from human and natural stressors, policymakers and resource managers charged with protecting the existing systems need to find effective management strategies to minimize further decline and to promote future recovery. As diving activity is well recognized as a source of stress on natural reef systems, managers should pursue policies that shift pressure away from the natural reef system, while also providing alternative diving opportunities. At its core, managers must balance the conservation of the coral resource with the economic and social benefits of coral reef users. This necessitates analytical tools that can provide insight as to how management interventions affect demand for these resources.

The highly active and diverse artificial and natural reef system off the coastline of the Florida Keys provides an ideal platform to investigate one such management intervention due to the potential for expanding the existing artificial reef system in order to re-direct divers away from natural reefs. With the existing threat to worldwide natural reef systems, there is a surprising lack of research examining the impact of new artificial reefs on diving behavior. Using revealed and stated preference data collected from surveys of individuals that have dived the Florida Keys' reef system, we seek to fill the void by examining the effect of creating a new artificial reef on the behavior of divers. In doing so we specifically examine the impact of sinking the SS Cape John, a Modular Cargo Delivery Ship that is currently in MARAD's inventory of decommissioned vessels. As such, our hypothetical stated preference treatment is realistic is the sense that it was based on an actual vessel ready for disposal under the MARAD Program.

From survey responses, two models of diving demand were developed. The first model assessed the impact of a new artificial reef on diving behavior for all reef types. The second model only considered natural reef dives. Results indicated that sinking a large ship to create a new artificial reef increases diving demand; however, and more importantly from a policy perspective, diving demand on the adjacent natural reef system is not affected. This finding provides important feedback for local resource managers, as additional large vessel artificial reefs increased diving demand, and therefore revenue for the local communities, without any associated negative impacts on the natural reef system. By varying the new reef stated preference treatment across respondents we also looked to disentangle any effect of deployment depth of the new reef on behavior. We used two depth scenarios in the SP treatment. The shallower depth scenario placed the deck of the SS Cape John in 75 feet of water while the deeper deployment provided a 90-foot deck depth. Results indicated that depth variation in our treatments did not alter diving behavior on any reef type. Again, this result is specific to the deployment depths used in our SP treatment. Further investigation might consider examining the role of different deployment depths on diving behavior and the associated impact on natural reef use.

Finally, this research provides a useful starting point for investigating the impact of future artificial reef development on diving demand on any adjacent natural reef systems. However, more work is needed. Using these findings for policy purposes should note the modest sample size and need for an adequate avidity bias correction. Moreover, significant further research is required to assess the complexities of reef and site attributes on diving behavior. It is highly likely that attributes such as distance from the shoreline to the reefs, size of the reefs, water temperature, depth, etc., all play a role in divers' choice of sites and potentially in any substitution or complementarities that exist between diving the two reef structures. Resource managers may learn more about the potential for future sinkings to reduce demand on natural reefs through research on the role of these attributes in divers' demand decisions.


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