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Abstract

Natural or coral reefs represent extremely valuable ecosystems supporting an estimated 25 percent of all marine life, yet recent reports suggest that 75 percent of the world's natural reefs are under threat from both natural and human stressors. In areas such as Key West, Florida, that boasts an expansive mix of natural and artificial reefs, recreational diving on the system provides an important economic contribution to the local community but also potentially contributes to the stress of the existing natural reef system. We develop a revealed and stated preference modeling framework of diver behavior and find that deployment of an additional large ship reef increases overall diving activity but does not impact diving behavior on the natural reef system. We also investigate potential diver behavior heterogeneity in response to the new reef and find that diver beliefs on the role of human stressors can alter diving behavior.

Introduction

Natural or coral reefs represent extremely valuable ecosystems supporting an estimated 25 percent of all marine life, habitat to over 1 million diverse aquatic species, support fisheries and provide storm protection for thousands of coastal communities, and serve cultural traditions of local populations (Moberg and Folke 1999; Spurgeon 1992; Allison et al. 2009). Recent estimates suggest that 19 percent of the original area of the world's natural reefs have been lost (2000). Also, currently 75 percent 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 land-based pollution, or fishing and diving pressure. The well-recognized effects of stressors on the global decline in the world's natural reef system means that policymakers and resource managers charged with protecting the existing systems need to find effective management strategies to minimize further decline and support their future recovery.

The purpose of this research is to estimate the potential for deployment of additional artificial reefs to impact diver behavior on both artificial and adjacent natural reef structures. As diving activity is known to be a cause of significant damage to a natural reef system due to reef trampling, touching or removing coral, or loose equipment impacts etc. (see Hawkins et al. 1999; Schleyer and Tomalin 2000; and Tratalos and Austin 2001), we are interested in observing the effect of adding an additional artificial reef to the Key West reef inventory on diving pressure on the existing natural reef system. That is, disposal of artificial reefs adjacent to an existing natural reef system may act as a substitute good and shift diving activity away from natural reefs. On the other hand, they may be complementary, as an enhanced artificial reef system may attract more divers to the area, and in turn, lead to more dives on natural reefs. Florida has the most active and diverse reef system in the United States, and Key West is the most popular diving destination within the state. The expansive mix of natural and artificial reefs within the Key West system provides an ideal arena to examine the change in diving behavior with the addition of a new artificial reef to the system. Further, in the empirical framework, we consider whether the impact on diving behavior in response to a new artificial reef is a function of the depth of the new artificial reef.

Our analysis is a revealed and stated preference (RP/SP) study of 121 divers that visited Key West in 2013. All sampled divers take chartered two-tank dives to reefs in the Key West area. Two-tank dives constitute a typical diving experience where the boat takes divers out to the first reef (site), the diver dives the reef, then dependent on the depth of the first dive, must spend a requisite amount of decompression time before making a second dive (either on the same or a different reef). As such, these two-tank dives may be both on either natural or artificial reefs, or one dive on a natural reef and one on an artificial reef. Divers are asked RP/SP dive count questions regarding dives under status quo conditions and after sinking a new large ship in the area. From these responses, two models of diving demand are developed to examine the effect of a new artificial reef at relatively shallow and deep depths on total dives to any reef type, and to only the natural reef system.

With the recent press coverage on 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) monitor the dive time spent by a relatively small sample of divers inside a nature reserve in Israel that contains natural reefs, both before and after deployment of six small concrete units at a nearby location. They find 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) use 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 find 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 suggest natural and artificial reefs are substitute goods, although the authors do concede that the logbook data excludes the two busiest recreational use months (June and July), so if use patterns in those months differ compared to the rest of the year, this conclusion may not hold.

Our analysis adds significant weight to the small literature base on understanding diving behavior to a natural reef system following deployment of an additional artificial reef. 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 so analyzing site quality changes, such as changes in the size of a site or improved site access, might 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 not only the effect of a future deployment of a large ship artificial reef on diving behavior to be examined, but also, to consider the effect of future deployments under two different depth scenarios to investigate whether, from a policy perspective, depth deployment is an influential component of diving demand.

Artificial Reef Deployment under the U.S. Department of Transportation 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 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) examine the disposal options for the fleet of decommissioned vessels that were stored at various naval yards throughout the country at the time and concluded that reefing was the best option available. In particular, Hess et al. note that if one focuses on the 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 discuss Hynes, Peters, and Rushworth (2004) reiterated the potential benefits from the reef disposal option and suggested that communities might be willing to cost share in the disposal process due to fiscal benefits from use after reef establishment.

In our stated preference treatment, respondents are asked 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 is based on an actual vessel ready for disposal under the MARAD Program.

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 is a map of the reef system. On the other, pictures of the fish species found in Key West 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, 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

[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.

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 boat shop and mailed back to the researchers. In total we purchased 350 cards to be distributed to divers across the seven dive operators.

The online survey was developed in the Qualtrics Inc. software framework. This enabled the series of necessary skip patterns 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] trips 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 trips 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

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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."

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.

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 at 120 feet of water with the deck at 75 feet and the shallowest point at 45 feet. The 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 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 a 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 also there should be more vessels 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. Also, there's a preference toward diving a large vessel artificial reef.

From 350 emails sent out to divers, we received 155 responses (a 44 percent 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 take 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 also provides descriptive statistics for the sample. Across the whole sample of divers, 72 percent 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. (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, with no decompression limits. Technical diving is much more training and equipment-intensive than recreational diving and all technical divers have a number of 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

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

advanced dive, such as deeper large-ship reefs, like the USS Vandenberg in the Keys. 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. The first was "how sure would you say that you are about your answers regarding future trips?" Over 85 percent of respondents indicated that they were either "somewhat sure" or "very sure" about their answers regarding future trips. We also asked respondents "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?" Approximately 62 percent also indicated that they believed that they were stating trips that they "think" they will take, rather than that they "hoped" they would take. Also, 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 also 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. Eight-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 about artificial reef policy in Florida, while 70 percent 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 there responses were important, and therefore consequential, to policy decisions. Further, only 1 respondent "strongly disagreed" to each question. As typically only those that 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.

The Conceptual Framework

The online survey instrument collects RP and SP data for analysis in two models of diving demand. Model 1 is a general reef model that examines diving behavior across both reef types (artificial and natural). Model 2 only considers natural reef diving. For brevity, in order to describe the conceptual framework, the focus is on Model 2. The model of all reef dives is constructed in an identical manner.

The RP data is based on actual annual number of dives on a natural reef system in the Florida Keys and the SP data refers to expected 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

$$y_i = (P_i, \boldsymbol{z}_i, \boldsymbol{c}_i, SP) \quad (1)$$

where 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 revealed values (List and Gallet 2001; Murphy et al., 2005). Therefore, a stated preference elicitation dummy variable is included to account for and measure any hypothetical bias that might be present in the stated preference trip counts (Egan and Herriges 2006; Whitehead 2005).

To allow for variation across oyster consumers that cannot be explained by the independent variables, we assume that the mean number of meals also depends on a random error, u_i. The random effects Poisson model imposes positive correlation across the *t* scenarios (Landry and Liu, 2011). The pooled RP/SP Poisson demand model is:

$$ln\lambda_{it} = \beta_0 + \beta_1 P_i + \beta_2 \boldsymbol{z}_i + \beta_3 SP + \beta_4 \boldsymbol{c}_i + \beta_5 NEWSHIP + \beta_5 DEPTH + \mu_i \quad (2)$$

where individuals are indexed $i = 1, \ldots, 1{,}121$; and $t = 1, \ldots, 4$ denotes annual dives to the Key West 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. *SP* = 1 for hypothetical meal data ($t = 2, \ldots, 4$) and 0 for revealed meal data ($t = 1$). $\beta_0 - \beta_5$ 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*. The distribution of dives conditioned on u_i is Poisson with conditional mean and variance, λ_{it}. If $\exp(\lambda_{it})$ is assumed to follow a gamma distribution, then the unconditional meals, x_{it}, follow a negative binomial distribution (Hausman, Hall, and Griliches 1984).

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 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 λ is the annual predicted number of trips. Finally, following Whitehead et al. (2008), the economic benefit of adding the SS Cape John as a new artificial reef can be estimated as $\frac{\lambda^{*}-\lambda}{-\beta_1}$, where λ^{*} is the number of trips associated with adding the SS Cape John at the site. For each model, uncorrected CS estimates (where SP=1) and a hypothetical bias-corrected CS estimates (where SP=0) are provided (as shown in Table 4).

We also use the survey design to consider diver heterogeneity with respect to the new reef. We interact diver stated opinion on the role of human stressors that threaten the Keys' natural reef system with NEWSHIP and DEPTH, written as

$$ln\lambda_{it} = \beta_0 + \beta_1 P_i + \beta_2 \boldsymbol{c}_i + \beta_3 SP + \beta_4 \boldsymbol{s}_i + \beta_5 NEWSHIP + \beta_6 NEWSHIP_{Stressor} + \beta_7 DEPTH + \beta_8 DEPTH_{Stressor} + \mu_i \qquad (3)$$

where $NEWSHIP_{Stressor}$ is the marginal effect of divers' opinion regarding human-stressors causing natural reef degradation on diving demand following the sinking of the SS Cape John. Likewise $DEPTH_{Stressor}$ is the marginal effect of the same opinion on diving demand when the SS Cape John is sunk at a deeper depth.

Results

Table 3 presents the results from two random effects Poisson models of recreational diving demand. Model 1 includes the annual actual and expected counts for dives on any reef type in Key West as the dependent variable, while Model 2 only includes annual dive counts on the natural reef structure as the dependent variable.

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 of about \$280, and \$285 per dive on a natural reef (see Table 4). To provide a comparison of estimates, Morgan, Massey, and Huth (2009) estimated the consumer surplus associated with diving the USS Oriskany as \$717 per trip. With the Oriskany being 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 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.

Based on the annual predicted number of trips, per-dive estimates equate to annual consumer surplus estimates, per diver, for dives on all reef types, of \$3,743, falling to \$3,340 when adjusting for potential hypothetical bias (SP=0). For dives on natural reefs, the annual consumer surplus estimate, per diver, is \$2,331, falling to \$2,109 when adjusting for potential hypothetical bias.

Across both models, results on the socio-demographic and dive-related variable are similar. Age and gender does not impact diver behavior, nor does the number of persons living in the diver household. However, results suggest that dives on both reef types and just natural reef dives are inferior goods as the coefficient on INC is negative and significant across both models. Also, in both models, being a recreational diver with no decompression limits (as opposed to a technical diver) does not impact behavior, which is also true for the experience of the diver (measured by the number of total dives taken anywhere). However, divers with stronger preferences towards more vessels being sunk tend to take more dives of both types in the Keys.

In terms of assessing the impact of deploying a large ship artificial reef on diving behavior, and in particular, diving pressure on the natural reef system, the model results provide some interesting insight. 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). In terms of economic value, the new ship deployment increases annual consumer surplus, per diver, by approximately $194 in the corrected model to $3,534. Also, the depth of deployment seems to be important. The coefficient on DEPTH indicates that divers have a marginal preference for deeper artificial reefs, as a deeper deployment further increases diving demand relative to the same deployment at shallower depths. Combined, these findings demonstrate that deploying a large ship reef such as the SS Cape John, particularly at deeper depths, has a significantly positive impact on diving behavior.

In terms of the effect on diving pressure on the natural reef system, what is important is whether the increase in diver activity on the artificial reef system trickles down to the natural reef diving activity too. In Model 2, deployment of the SS Cape John has no statistical effect on the number of dives taken to natural reefs in the Key West area. As such, it seems that deployments of artificial reefs do not alter the diving pressure on the natural reef system. This result differs somewhat to Leeworthy, Maher, and Stone (2006), who find deployment of a large ship artificial reef in the Florida Keys reduces trips to the natural reef system. The difference may be explained by proximity of the new artificial reef to the natural reef system. Leeworthy, Maher, and Stone specifically consider deployment of the Spiegel Grove ship. It's location is at the outer point of the Florida Keys reef system. This is a site where other shallower artificial reef sites are close by, therefore perhaps drawing divers to those sites and away from the more distant natural reefs. In our stated preference treatment, location is given as "in the vicinity of where you plan to take any future diving trips" so the assumption is that the deployment in our scenario is more general, where in the Keys, access to both the natural and artificial reef systems is possible. Regardless, from a policy perspective, both findings provide a similar intuition, that as diving areas such as Key West continue to add to the existing inventory of artificial reefs, this does not seem to impact diving pressure on the natural reef system. The welfare gains that are therefore realized through adding more large vessels reefs are not mitigated by additional pressure on the adjacent natural reef system.

Finally, with the natural reef system worldwide under threat from both natural and human stressors, we are also interested in providing some insight into potential heterogeneity with regard to diver behavior in response to new reef additions. Results from the two models presented in Table 3 are for the average diver in the sample but not all divers may respond to the new reef in the same manner. By survey design, we investigated diver opinion or beliefs on the role of both natural and human-related stressors threatening the natural reef system. We were curious to investigate whether these beliefs influenced diving behavior to the natural reef system. In the survey, we asked respondents to state their level of agreement or disagreement (on a five-point scale ranging from strong disagreement to strong agreement) as to whether they thought both natural and human stressors threated the natural reef system (see Table 1). By coding diver beliefs to numerical values of 1 to 5, we interact these responses with the NEWSHIP and DEPTHDUM variables in the natural reef diving demand model. Interacting diver opinion on natural stressors had no impact on diver behavior.[4] However, interacting diver opinion on human stressors indicates that for divers with stronger beliefs that human-related stressors threaten the Keys' natural reef system, diving artificial and natural reefs are complimentary goods, so creating a new large ship reef will actually increase their natural reef dives. Perhaps these divers perceive other non-diving factors (such as pollution runoff) as the contributing elements to human threats on the reefs and not their own diving behavior, or maybe these divers place a stronger value on their individual use value than the social good.

We also observe a marginal effect of stronger diver beliefs regarding human stressors on diving demand when the SS Cape John is sunk at a relatively deeper depth. The $DEPTH_{Stressor}$ interactive dummy is negative and statistically significant, so for these divers, the new reef depth is important. It seems that for divers with stronger beliefs regarding human pressure threatening the natural reef system, a relatively deeper sinking will reduce natural reef diving demand. Overall, based on the magnitude of the two marginal effects, for this group, diving activity on the natural reef system will decline if the new ship is sunk at a deeper depth.

Conclusion

With approximately 75 percent of natural reefs 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 support their future recovery. As diving activity is well recognized as a significant source of stress on natural reef systems, ongoing policies that potentially impact diver behavior can be used as an avenue for relieving pressure off the decaying natural reef system.

The highly active and diverse artificial and natural reef system off the coastline of Key West, FL, provides an ideal platform to investigate the potential for expanding the existing artificial reef system in order to re-direct divers away from natural reefs. Using revealed and stated preference data collected from surveys of individuals that have dived the Key West reef system, we examine the effect of creating a new artificial reef on the behavior of divers.

[4] Results available from authors upon request.

From survey responses, two models of diving demand were developed. Results indicated that sinking a large ship to create a new artificial reef increases diving demand across all reef types. That is, individuals make more dives. However, and more importantly from a policy perspective, diving demand on the adjacent natural reef system is not impacted. Potentially, this 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 disentangle the effect of the depth of the new reef on behavior. Results indicate that deploying artificial reefs at deeper depths increases overall diving demand but does not impact the number of dives on the natural ref system.

Finally, we consider the impact of diver beliefs regarding natural and human-related stressors on natural reef diving demand following deployment of the SS Cape John. Results indicate that divers that believe more strongly that human-related activity, such as diving, is a cause of natural reef degradation will likely split their increase in diving activity following deployment between both reef system types.

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Table 1. Diver Beliefs on Reef and Behavioral Questions

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

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		
Total Dives	Total number of dives taken anywhere	605	1, 9999		
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 3 Results from Poisson Regression with Random Effects

	Model 1 All Dives			Model 2 Dives on Natural Reef		
	Coefficient	Standard Error	*p*-value	Coefficient	Standard Error	*p*-value
Constant	1.539	0.467	0.001	1.350	0.444	0.002
Fee	-0.004	0.000	0.000	-0.004	0.001	0.000
Male	0.143	0.241	0.551	0.054	0.232	0.815
Age	0.010	0.011	0.351	0.010	0.011	0.363
Inc	-0.006	0.002	0.002	-0.007	0.002	0.001
House	-0.059	0.076	0.435	-0.028	0.082	0.733
Rec	-0.117	0.292	0.689	-0.010	0.291	0.973
Total Dives	0.000	0.000	0.209	0.000	0.000	0.763
More Vessels	0.265	0.125	0.034	0.204	0.124	0.100
SP	0.234	0.026	0.000	0.172	0.038	0.000
New Ship	0.177	0.038	0.000	0.098	0.081	0.223
Depth	0.085	0.027	0.002	0.016	0.168	0.791
alpha	0.918			1.049		
Log lik	-1603.6			-1358.1		
Obs	484			484		

Table 4 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)	13.3	11.9	8.2	7.4
With New Ship	14.2	12.6	8.4	7.8
Per-Dive Value	$280		$285	
	($216, $437)		($223, $372)	
Annual Value				
Baseline (NEWSHIP = 0)	$3,743	$3,340	$2,331	$2,109
	($3,010, $5,028)	($2,686, $4,487)	($1,769, $3,491)	($1,551, $3,128)
With New Ship	$4,002	$3,534	$2,403	$2,233
	($3,165, $5,281)	($2,822, $4,695)	($1,800, $3,776)	($1,664, 3,374)
Marginal Annual Value of Sinking SS Cape John	$259	$194	$63	$121

Table 5 Natural Reef Dives – Interactive Model

	Coefficient	Standard Error	*p*-value
Constant	1.347	0.475	0.005
Fee	-0.003	0.000	0.000
Male	0.058	0.251	0.815
Age	0.011	0.011	0.322
Inc	-0.006	0.002	0.015
House	-0.028	0.090	0.756
Rec	-0.002	0.310	0.996
Total Dives	0.000	0.000	0.777
More Vessels	0.195	0.132	0.140
SP	0.170	0.041	0.000
New Ship	-0.362	0.191	0.057
New Ship * Human Pressure	0.111	0.051	0.029
Depth	0.692	0.215	0.001
Depth * Human Pressure	-0.169	0.058	0.004
alpha	1.040		
Log lik	-1355.5		
Obs	484		