Applications of Rigs-To-Reefs: An Ecotourism Case-study in Southeast Asia

Aplicaciones de Rigs-To-Reefs: Un Estudio de Ecoturismo en el Sudeste de Asia

Applications des Rigs-To-Reefs: Une Étude de Cas d'Écotourisme en Asie du Sud-Est

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ABSTRACT

Natural reefs provide coastal protection, marine fish habitat, and the centerfold for ocean-based tourism in southeast Asia. Yet, unfortunately, natural reefs are facing a serious and global decline. Pollution, coastal development and increased human activity brought on by excessive and mismanaged tourism pose a threat to reef systems, a critical resource fueling the tourism industry. However, small-scale ecotourism presents an alternative that thrives at the intersection of environmental sustainability and economic feasibility. This study presents the Seaventures Dive Rig in Malaysia as an example of sustainable ecotourism. Seaventures is a repurposed oil rig that functions as an artificial reef below the surface and an ecotourism hotel above. Additionally, this study assesses Seaventures' ability to mimic the surrounding ecosystem as an artificial reef. Our results suggest that Seaventures adequately simulates the fish abundance found on the natural reefs in this region, successfully redirecting scuba-based tourism away from natural systems and enhancing local marine environment through the use of an artificial reef.

KEYWORDS: Abundance, artificial reef, biodiversity, ecotourism, sustainable tourism

INTRODUCTION

In March 2017, a team of marine scientists from Blue Latitudes (BL) began a study to evaluate the ecological and social value associated with an offshore oil rig converted into an ecotourism hotel, located off the coast of Sabah, Malaysia. The purpose of this study was two-fold: to quantify the degree to which the Seaventures Dive Rig platform structure contributes to species diversity and abundance and improves population demographics of localized fish communities when compared to the surrounding natural reefs found off the islands of Mabul and Sipidan; and to better understand the social and cultural value associated with the rig

Offshore oil platforms are among the largest artificial reef (AR) structures in the ocean, and they offer significant habitat for fish and benthic organisms (Claisse et al. 2014, Hamzah 2003). These offshore structures support a diverse array of ecological communities, which in some studies, have been shown to enhance both biodiversity and fisheries production (Bohnsack 1989, Jørgensen et al. 2002, Macreadie et al. 2011). However, given the global distribution of oil platforms, it is difficult to quantify how much the reef ecosystems found on offshore oil platforms increase community metrics like species diversity and abundance at a specific location. The primary limiting factors are collection bias(es) and the lack of a natural counterpart for comparison.

The world's largest network of coral reefs is found in Southeast Asia, and the value of the reef ecosystem services is estimated at \$2.3 billion annually (Tun et al. 2008). Coral reef-based tourism is an important source of revenue which can be used to preserve resources such as reef biodiversity and fisheries productivity. However, the development of reef-based tourism can also have a negative impact on coral reefs by increasing development, pollution and physical damage (Zhang et al. 2016).

Mabul island is a small island in the Celebes Sea with a population of a little over 2,000 (Mapjabil 2010). Despite its location within the Coral Triangle, an area with some of the highest coral diversity in the world, the corals found off Mabul island are only in fair condition (27% live coral coverage), as compared to the rest of East Malaysia where reefs boast an estimated 41% live coral coverage, these diminished coral conditions are due in part to rapid resort development on Mabul island (Reef Check Malaysia Bhd 2012). There are a variety of management practices that may be used to protect the naturally occurring reefs found around the island of Mabul. One such technique involves diverting recreational diver pressure away from stressed natural coral reefs to AR areas (Wilhelmsson et al. 1998). Several dive resorts on Mabul island have already constructed their own artificial house reefs that have become popular shore diving sites. The Seaventures Dive Rig off of Mabul island is an oil platform that has been converted into both an ecotourism resort and an AR, and is an excellent example of the efforts put forth to relieve the pressure on the natural reefs in the area.

The Seaventures oil platform was originally built in Panama as a jack-up accommodation module and was used by the Petronas Oil Corporation until it was retired and decommissioned in 1985. Subsequently, the platform was towed to its final destination in the waters offshore of Mabul Island. The Seaventures Dive Rig stands 16 meters off the seafloor, near sub-tidal communities such as coral reefs. This makes Seaventures an excellent case study for a direct comparison of the biological community attached to its subsurface structure and the equivalent natural habitat of the adjacent coral reefs. To correct for collection bias(es) a diver operated stereo video camera system and customized software were used to produce highly accurate fish length estimates. Unlike traditional underwater visual census techniques, stereo video technology reduces inter-observer variability, improves accuracy of fish length estimates, increases sampling rate and is more efficient.

The objectives of this research are three-fold:

i) To present stereo video technology as a low cost, effective and reliable technique for ecosystem monitoring on oil platforms and other artificial reef sites, and discuss its applications in the field;
ii) To examine the use and effectiveness of converting a retired oil platform into an AR for tourism purposes in Southeast Asia and
iii) To visually assess how the marine environment on the Seaventures platform compares to the surrounding natural and ARs in regards to fish biodiversity and abundance.

Stereo-Video Technology

Typically, diver-based underwater visual census (UVC) has been used to gather non-destructive data on fish lengths, where divers trained to accurately estimate fish size underwater have been able to monitor the change in size frequency distribution of populations over space and time (Thompson and Mapstone 1997). However, the limitations of using humans to estimate length of objects and animals underwater include: the need for the same observer(s) to perform the surveys over time and space, the cost of training and re-training to ensure precision and accuracy, intra-and inter- observer bias, and the depth limitations of SCUBA (Edgar et al. 2004, Harvey et al. 2001, Thompson and Mapstone 1997).

Stereo-video technology, used as either baited remote underwater video systems (BRUVS, Cappo et al. 2003) or as diver operated stereo-video systems (stereo-DOVs, Davis et al. 2015), overcomes these observer-based limitations (Harvey et al. 2004). Stereo-video uses two video cameras that are separated by a known distance and directed in the same direction with a slight convergence inwards. Using custom software, these two cameras are calibrated to understand the distortion in the lenses and their location in space relative to each other (Shortis and Harvey 1998, Boutros et al. 2015). The resulting video footage can be used to calculate lengths by simply identifying the appropriate landmarks (i.e., tip of rostrum to the start of the caudal lobe for standard length) in both the left and right cameras. The software uses these digitized landmark coordinates in combination with the calibration parameters to calculate the length. Studies have demonstrated that this process can yield extremely accurate measurements of subjects at distances as far as 10 m from the camera (Boutros et al. 2015).

Seaventures Oil Platform

The Seaventures oil platform was originally built in Panama as a jack-up accommodation module and was used by the Petronas Oil Corporation until it was retired and decommissioned in 1985. The structure was purchased and initially used as a fishing platform and hotel in Labuan. Subsequently, the platform was towed over 500 nautical miles to its final destination offshore of Mabul Island.

Other Artificial Reefs

A principal reason for the deployment of such reefs is to improve, increase or maintain the fisheries resources in a local area. Malaysia began constructing ARs in the 1970s primarily to increase productivity in the marine environment and to promote the recovery of fisheries in coastal areas that had previously been depleted (Saharuddin et al. 2011). Over the past 40 years, the Government of Malaysia has utilized tires, derelict fishing vessels, fiberglass reinforced concrete, Polyvinyl Chloride (PVC), fiberglass, ceramic and reef balls to establish artificial reefs (Saharuddin et al. 2011). While recent study has shown that the latest design of artificial reefs has yielded increased fish productivity, further research is needed to understand how to manage the existing ARs in a sustainable manner (Chou 1997, Saharuddin et al. 2011).

Rigs to Reefs

Rigs to Reefs (R2R) provides an alternative to complete rig removal in which an obsolete, non-productive offshore oil and gas structures is modified so that it may continue to support marine life as an AR. Typically when a structure is decommissioned using the R2R option, the oil well is capped and all drilling and production equipment is removed from the marine environment for proper disposal. The jacket component of the structure, which extends from the seafloor to above the waterline and is used to support the deck and topsides equipment, remains in place and is then utilized to create an AR (Figure 1). Steel jackets are among the most stable and durable reef materials available and have been deployed for reefing in the Gulf of Mexico and Brunei. Several other areas of the world are developing a R2R protocol, such as the North Sea, Australia, Africa, and Thailand.

Malaysia has pivoted away from traditional R2R options by converting an offshore oil and gas platform into an ecotourism dive destination, an innovative and seemingly technique of conserving the thriving reef ecosystems that

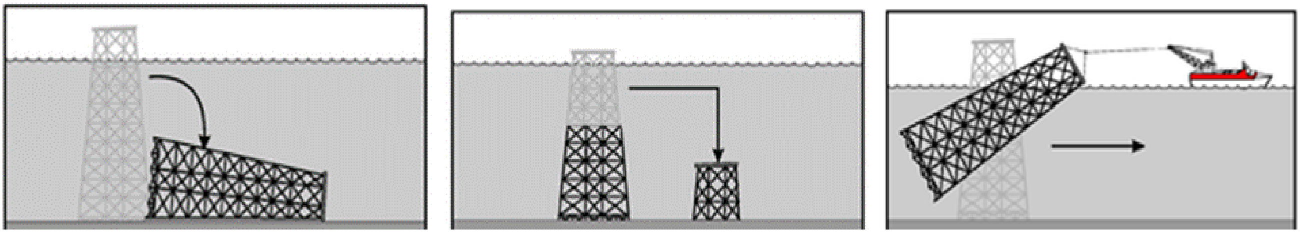

Figure 1. Traditional R2R options include: toppled in place, left in place with the upper portion removed or towed to alternative reefing site.

had developed below the surface. It is a method that is not yet well understood, and most importantly, one that has not been well documented as an alternative to traditional platform reefing options.

METHODS

The scientific dive team followed American Academy of Underwater Science (AAUS) standards for scientific diving in all survey methodology. Dive surveys using stereo video technology were conducted on the Seaventures Dive Rig and on neighboring artificial reef and natural reef sites. Usually 2 dives were made in the morning and 1 or 2 dives were made in the afternoon and early evening. In the evenings and between dives, the team focused on data entry.

The U.S. Embassy in Malaysia granted all necessary permission to conduct this research. No vertebrate sampling or collection was conducted and therefore no permit was required by the Sabah Biodiversity Council.

Equipment and Set-Up

The stereo-video (SV) 'rig' consists of two GoPro Hero 3+ cameras mounted on an aluminum bar (Figure 2). The cameras (b & d) are attached to the bar (c) at an inward angle of about 4 degrees each, and separated by about 750 mm. The checkered board (a) was used prior to camera deployment to calibrate the system. Recently, new methods of calibrating the cameras and the use of open source software and GoPros has reduced the overall cost and transportability of stereo-video systems to enable more researchers to access this technology. The principle concept behind a SV setup is to use information from two different views of the same object to reconstruct features visible in both views into 3D. A single view of an object has information on the shape of features along the two dimensions of the image plane but not along the third dimension (going into and out of the image plane). Thus, by combining the information from two different views, the full three-dimensional shape of a feature can be reconstructed.

Calibration

The two cameras are calibrated based on a checkerboard pattern (a). The checkerboard provides a sampling of points in a plane that can easily be detected automatically. This saves the user time by not having to manually digitize calibration points. Calibrations were conducted in a pool prior to conducting transects in the field. During calibration, the checkered board is moved throughout the field of view and at variable distances from the SV cameras. Previous trials of this system conducted in the pool and field yielded extremely accurate results that rival far more ex pensive and complicated systems. Pool trials were conducted to measure objects of known lengths and the data showed that the system produced consistently accurate measurements between 100mm and 1700mm with no increase in error with size. The average absolute error was less than 1% of the true size of the object.

Practice runs were conducted to run trials to ensure safe diving practice while using the SV equipment on four types of diving landscapes.

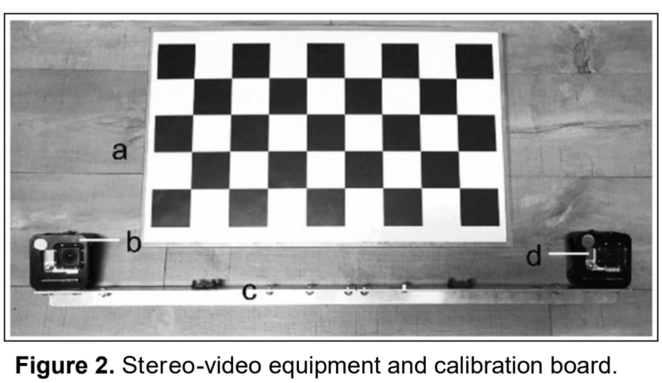

Figure 2. Stereo-video equipment and calibration board.

30-Meter Horizontal Transects

All horizontal transects required two (or three) divers, one 30 meter transect line, two flashlights and the SV rig. First, the diver pair descends to a depth of 13 meters on the reef. Then the transect line is deployed by one diver swimming horizontal to the reef, maintaining a steady depth until the line is taut. Communication between divers was conducted by use of flashlights and hand signals underwater. The second diver either secures the line or gives it to a third support diver to hold taut, and then proceeds down the transect line with the SV rig angled at a 45 degree tilt towards the reef.

30-Meter Pelagic Transects

All pelagic transects were horizontal and required two (or three) divers, one 30 meter transect line, two flashlights and the SV rig. First, the diver pair descends to a depth of 13 meters. Then the transect line is deployed by one diver swimming horizontal to the seafloor, maintaining a steady depth till the line is taut. Communication between divers is conducted by use of flashlights and signals underwater. The second diver either secures the line or gives it to a third support diver to hold taut, and then proceeds down the transect line with the SV rig held at a 90 degree angle to the seafloor.

Vertical Circumference Transects

All vertical circumference transects were conducted on the oil platform legs (pilings) and required two (or three) divers, two flashlights and the SV rig. First, the diver pair descends to a depth of 15 meters. Communication between divers is conducted by use of flashlights and signals underwater. The first diver holds the rig and swims around the circumference of the vertical pilings, gradually increasing in depths till the second diver notifies the first that they have reached a height of 12 meters. The second diver's responsibility is to observe the first diver's swimming to ensure that buoyancy and distance from the piling structures are maintained consistently. The SV rig held at a 90 degree angle to the seafloor, facing directly at the piling.

Structural Transects

All structural transects were conducted on artificial reefs and required two (or three) divers, two flashlights and the SV rig. First, the diver pair descends to a depth of 15 meters. Communication between divers is conducted by use of flashlights and signals underwater. The first diver holds the rig and swims around the circumference of the artificial reef, gradually increasing in depths till the second diver notifies the first that they have reached a height of 12 meters. The second diver's responsibility is to observe the first diver's swimming to ensure that buoyancy and distance from the artificial reefs are maintained consistently. The SV rig held at a 90 degree angle to the seafloor, facing directly at the artificial reefs. Other structural transects were conducted with the same methodology of the horizontal transects, but without the 30 meter transect line.

Site Descriptions

Site 1: Seaventures Dive Rig — Seaventures Dive Rig is a dive platform and resort based near Sipadan, Borneo, Malaysia. Originally built in Panama, the Seaventures 'Rig' is a jack-up accommodation module previously used in the oil and gas industry. It was towed and used for oil rigs in different locations until decommissioning in 1985 when it was brought to the it final destination, the island of Mabul. The structure has 6 standing legs, each with a circumference of 4.5 meters, and stands in about 13 meters of water.

Site 2: Kapalai Island — Kapalai is not a true island but rather a sandbar that resorts have built upon to form a true water resort. Kapalai consists of a small sloping reef approximately 15 meters deep. Below the shallow sloping reef is a sandy plateau, where several artificial reefs have been placed.

Site 3: Mabul Island — Mabul Island offers coral wall habitats, gently sloping coral reefs, artificial reefs, and several artificial reefs in the form of sunken ships.

Data Processing

Due to the variation in transect length and lack of repetition, this team was not able to collect a dataset that was compatible with the stereo-video calibration methodology (Delacy et al. 2017, Shortis and Harvey 1998). Therefore, the collected data was reframed to be conducive for more traditional analysis methods. Additionally, while two GoPros were used in the stereo-video apparatus, as described in the data collection methods, the second GoPro was ultimately excluded from analysis. This measure was taken to eliminate the treat of pseudoreplication in the data set. Each transect was reviewed and each fish was counted and identified down to the species level. The analysis window for the transect review was 1.5 m deep, 3 m tall and 4 m wide (approximately 1.5 me away from the GoPro) and the identification was reviewed along transects. In certain cases on rig sites, transects of exactly 30 m couldn't be guaranteed, so the circumference of the rig piling was used to project a distance of 30 m.

When identifying and counting each fish species in, not all individuals could be accurately identified. In this case, the fish were identified as "Small Unknown" (≤ 20 cm), "Medium Unknown" (20cm - 50 cm), or "Large Unknown" (≥ 50 cm) and categorized as their own species group.

Fish Species and Abundance Composition

All of the 37 transects were analyzed using the footage from both GoPros in the Stereo-Video system. The number of species found and number of fish found was recorded for each transect and this information was important into the computer software (R i386 3.4.2). R i386 3.4.2 and RStudio were both used to generate a Summary Statistics and run an Analysis of Variance test (ANOVA) that produced a p-value for both the "species observed" and the "fish observed" data. Box-and-whisker plots were also produced to display the median value for each habitat type as well as the interquartile ranges (IQR) and outlying data points. For each of these two datasets, a Tukey's honestly significant difference (HSD) post hoc test was conducted to generate a p-value between each of the four habitat types for both the "species observed" and "fish observed" data sets.

Finally, the Simpson's Reciprocal Index (1/ Ds) was calculated for each of the four habitat types (Artificial Reef, Natural Reef, Rig, and Pelagic Rig). This index was chosen because it gives more weight to dominant species and is widely used in a range of ecological studies (Hill 1973, Partanen et al. 2010, Robert et al. 2015, Zhou et al. 2002). This calculation can be represented as $(1/Ds) = N(N-1) / \sum n(n-1)$, where N=the total number of individuals observed along the transect, n= the number of individuals observed of a certain species along the transect, and (1-Ds) = the Simpson's Reciprocal Index value. In this calculation, the larger values represent more biodiversity.

RESULTS

A total of 37 transects were analyzed in this study, in which 1,598 fish of 126 distinct species were observed. The comparison between Natural Reef and Rig habitats reflects the highest p-values for species observed (p = 0.944) and the comparison between Pelagic Rig and Rig has the highest p-value for amount of fish observed (p = 0.964) (Table 1, 4, 5). Therefore, the data gathered at these sites are furthest away from being significantly different.

Conversely, when comparing the Pelagic Rig site to the Artificial Reef site, the amount of species observed is described with a p-value of 0.061, the lowest in the data set. Also, comparing the number of fish observed on Natural Reef sites to that on Artificial Reef habitat produces a p-value of 0.081. While there is no significant difference here (Table 4, 5), these two habitat types are the closest to being significantly different from one another, making it a notable observation. Analysis of this dataset in RStudio reflected no statistically significant trends. However, important conclusions can be drawn based on the observational data collected in this study. Observationally, the Artificial Reef sites have most fish and species abundance when compared to the other three habitat type sites (Figures 3, 4; Table 3). On the other hand, the Pelagic

Rig and Rig habitat types both have the lowest median value of species observed (Figure 3) and the Natural Reef habitat type has the lowest median value of fish observed (Figure 4; Table 3).

When examining the abundance box plots across all four habitat types, there are multiple outliers (Figures 3, 4). These values are notable because they fall outside the interquartile range (IQR) for their respective boxplot. The Rig sites reflect two transects that have fish abundance values higher than the IQR (House Reef, Sea Ventures Dive Rig; 96 fish observed, 97 fish observed; Fig. 4) and the Artificial Reef habitat type has one transect that reflects fish abundance values above IQR (Kapalai Artificial Reef, South Mabul Island; 261 fish observed). Additionally, the Pelagic Rig sites contained one transect that reflected both fish and species abundance values above the IQR (Sea Ventures Dive Rig; 184 fish observed, 13 species observed; Fig. 3, 4). The Natural Reef sites had no outliers with respect to either fish or species abundance.

When applying the Simpson's Reciprocal Index to the four habitat types (Artificial Reef, Reef, Rig and Pelagic Rig), the Natural Reef habitat yielded most biodiversity (0.946) and the Pelagic Rig habitat type yielded the least biodiversity (0.772) (Table 2). When comparing the four Simpson's Reciprocal Indices values to one another, the Artificial Reef and the Natural Reef are the least different, only differing in biodiversity by 0.045. This is closely followed by the relationship between the Artificial Reef habitat type and the Rig habitat type, which only differ in this index by 0.051 (Table 2).

DISCUSSION

Evaluation of fish abundance can differ between varying SV methods. Using stereo on a BRUV system does not allow the user to collect a true measure of abundance (Cappo et al. 2003). Instead, the user will assess the maximum number of individuals seen in any one frame during the sampling period. This is because BRUVs are stationary and unable to discern whether the same fish continue to swim around the cameras repeatedly.

When SV is used for transects, as it was for the purposes of this study, abundance is easily able to be obtained. In fact, transect-based SV may be more accurate as the user can define the survey boundaries far more precisely (the width) based on the 3D position of the animal in space based on the length calculation, thus we can exclude individuals if they fall outside of a pre-defined transect width. This offers a better unit area estimate of abundance. Previous studies have assessed the bias of divers to include individuals that fall outside of a defined transect width (Edgar et al. 2004, Harvey et al. 2001, Thompson and Mapstone 1997), especially if they were target species while surveying inside a MPA, compared to if they were in a fished zone. These studies indicate a human tendency towards a positive result. This bias is challenging to overcome when trying to asses MPAs.

Additionally, the speed at which a SV transect is completed can be significantly faster as compared to a UVC transect or recording observations underwater. UVC transects require the diver to count fish underwater which

Table 1. shows the relationship between each of the four habitat types. The p-values are listed for both a species comparison and fish abundance comparison. When the P-value is less than or equal to 0.05, we reject the null hypothesis and can say that there is a significant difference between the data of two sites. These values were generated using the Tukey' HSD Test and ANOVA Tests (Table 4, 5) in the RStudio computer program.

Site comparison	P-value: Species observed	P-value: Fish individuals observed
Natural Reef – Artificial Reef	0.398	0.081
Rig – Artificial Reef	0.224	0.268
Pelagic Rig – Artificial Reef	0.061	0.535
Rig – Natural Reef	0.944	0.951
Pelagic Rig – Natural Reef	0.537	0.734
Pelagic Rig – Rig	0.874	0.964
Total data ANOVA	0.0829	0.113

Table 2. shows the Simpson's Reciprocal Index Value for biodiversity at each of the four habitat sites. In this analysis, the Reef site has most biodiversity and the Pelagic Rig site has the least biodiversity.

Site	Simpson's Reciprocal Index Value ($1/D_s$)
Artificial Reef	0.901
Natural Reef	0.946
Rig	0.850
Pelagic Rig	0.772

Table 3. provides descriptions of the Summary Statistics. These results were calculated using the RStudio Software for both "Species Observed" and "Fish Observed" data sets.

Species Observed

Min	1Q	Median	Mean	3Q	Max
0.00	4.00	8.00	7.92	10.00	21.00

Rig	
Minimum	0
1st Quartile	3
Median	4
Mean	7
3rd Quartile	11
Maximum	21

Pelagic Rig	
Minimum	3
1st Quartile	4
Median	4
Mean	5.25
3rd Quartile	4.5
Maximum	13

Natural Reef	
Minimum	4
1st Quartile	6
Median	9
Mean	8.15
3rd Quartile	10
Maximum	13

Artificial Reef	
Minimum	2
1st Quartile	9
Median	10
Mean	11.71
3rd Quartile	16
Maximum	20

Fish Observed

Min	1Q	Median	Mean	3Q	Max
0.00	16.00	25.00	43.19	45.00	261.00

Rig	
Minimum	0
1st Quartile	13
Median	25
Mean	35.89
3rd Quartile	31
Maximum	97

Pelagic Rig	
Minimum	16
1st Quartile	20
Median	23.5
Mean	47.5
3rd Quartile	38.25
Maximum	184

Natural Reef	
Minimum	6
1st Quartile	9
Median	23
Mean	24.31
3rd Quartile	36
Maximum	50

Artificial Reef	
Minimum	3
1st Quartile	30.5
Median	57
Mean	82.71
3rd Quartile	98.5
Maximum	261

Table 4. provides descriptions of one-way Analysis of Variance (ANOVA) tests. These results were calculated using the RStudio Software for both "Species Observed" and "Fish Observed" data sets.

Species Observed

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Site	3	166.1	55.38	2.428	0.083
Residuals	33	752.6	22.81	--	--

Fish Observed

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Site	3	166199	5400	2.147	0.113
Residuals	33	82993	2515	--	--

Table 5. provides descriptions of the Tukey's Honest Significant Difference (HSD) tests. These results were calculated using the RStudio Software for both "Species Observed" and "Fish Observed" data sets.

Species Observed

	Diff	Lwr	Upr	P adj
Natural Reef-Artificial Reef	-3.56044	-9.61642	2.495539	0.397866
Pelagic Rig-Artificial Reef	-6.46429	-13.14991	0.221333	0.061082
Rig-Artificial Reef	-4.71429	-11.22427	1.795695	0.224078
Pelagic Rig-Natural Reef	-2.90385	-8.70859	2.900897	0.536772
Rig-Natural Reef	-1.15385	-6.75540	4.447706	0.943922
Rig-Pelagic Rig	1.75000	-4.52694	8.026944	0.874243

Fish Observed

	Diff	Lwr	Upr	P adj
Natural Reef-Artificial Reef	-58.4066	-122.0007	5.18755	0.081148
Pelagic Rig-Artificial Reef	-35.2143	-105.4203	34.99175	0.534570
Rig-Artificial Reef	-46.8254	-115.1871	21.53626	0.267718
Pelagic Rig-Natural Reef	23.1923	-37.7636	84.14822	0.733736
Rig-Natural Reef	11.5812	-47.2410	70.40339	0.95051
Rig-Pelagic Rig	-11.6111	-77.5256	54.30340	0.963749

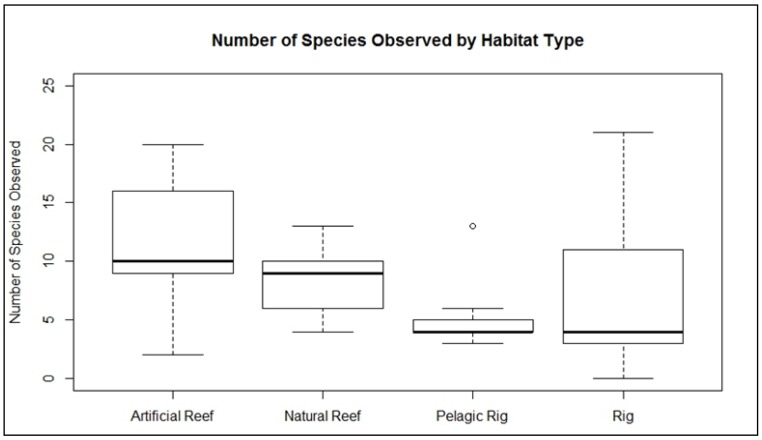

Figure 3. shows the number of species present when comparing the four different habitat sites. Here, the Artificial Reef site reflects highest median value (10 species observed; Table 3) while Pelagic Rig and Rig habitat types both have the lowest median value (4 species observed; Table 3). Outliers are represented by dots, placed above the whiskers. These values were much higher those present in the IQR, as seen in the Reef and Pelagic Rig sites.

can be time-consuming, relative to a SV transect which captures everything within the field of view quickly and is later analyzed onshore. As a result of the diver spending more time underwater to make identifications in-situ, it is likely that more fish will swim across the transect during a UVC transect, when compared to a SV transect. As a result, abundance estimates may be inflated in UVC transects. Our results indicate that horizontal SV transects are not compatible with vertical SV transects. The primary constraint was the inability of the SV methodology to equate a two-dimensional surface with a three-dimensional, cylindrical surface.

Indicator Species

Indicator species are marine organisms that are widely distributed on coral reefs, are easy for non-scientists to identify and provide information about the health of a coral reef. Reef Check Malaysia Bhd, an organization that works with various stakeholders to conserve coral reefs and has been conducting coral reef surveys in Malaysia for over 10 years, has identified several indicator fish species for the area because of their desirability for various types of fishing Reef Check Malaysia Bhd, 2012. These species include:

i) Butterfly fish (BF): targeted for the aquarium trade
ii) Humphead Wrasse (HW), Bumphead Parrotfish (BP): targeted for the live-food fish trade
iii) Sweetlips (SL), Snapper (SN), Barramundi Cod (BC), Parrotfish (PF), Moray Eel (ME), Grouper (GR): targeted as food -fish.

Interpretation of Results

Analysis of this dataset in R-Studio reflected no statistically significant trends. This is most likely due to high levels of variability in the dataset and low replication. However, our ANOVA observations are still notable because they reflect that the species richness, as represented by the "Species Observed" column (p = 0.0829) is more dissimilar than fish abundance, as represented by the "Fish Observed" column (p = 0.113). These results convey that we can more closely identify similarities between the amounts of fish observed at the four habitat types than the amount of species observed at the four habitat types. The smallest p-value identified in our Tukey's HSD analysis was comparing the species richness of the Pelagic Rig habitat type to that of the Artificial Rig habitat type. This result is notable because it was the closest to achieving statistical significance (p = 0.061) and suggests that there could be a difference between the amount of species found in the Pelagic Rig habitat and the Artificial Reef habitat, but our dataset was unable to identify statistical significance.

Conversely, the largest p-value in our Tukey's HSD analysis was identified when comparing the fish abundance of the Pelagic Rig sites to that of the Rig sites (p = 0.964). This result is notable because it was furthest away from achieving statistical significance. Therefore, this data suggests that there is no statistically significant difference between Pelagic Rig and Rig habitat types. Additionally, when comparing both species richness and fish abundance between Rig habitat and Natural Reef habitat, the high p-values indicate that there is no statistical significance present (p = 0.944 and p = 0.951, respectively). This suggests that our dataset could not determine any significant difference between the habitat on the Sea Ventures Dive Rig and the habitat on a local natural reef.

When observing the number of species present across the four habitat types, both Pelagic Rig and Rig habitat types reflect median values that are equivalent and lower than either the Artificial Reef and Natural Reef values (Figure 3, Table 3). On the other hand, when observing the number of fish observed across the four habitat types, the median values were closer in value (Figure 4, Appendix A1). In this case, the median number of fish observed in the Natural Reef sites (23) is comparable to both the Rig

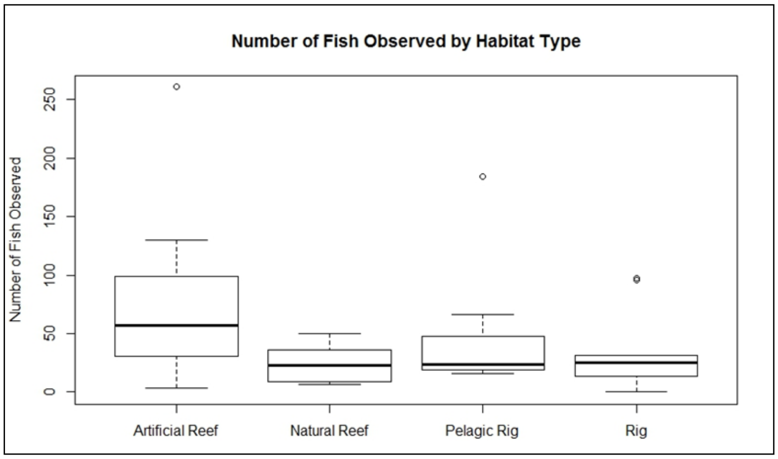

Figure 4. shows the abundance of fish when comparing the four different habitat sites. The bold bar represents the median of the data and is surrounded by a box that represents the middle 50 % of the data, known as the interquartile range (IQR). Observationally, the Artificial Reef site has the highest median (57 fish observed; Table 3) when compared to the other three sites. Conversely, the Natural Reef habitat types have the lowest median (23 fish observed; Table 3).

sites (25) and the Pelagic Rig sites (23.5) (Table 3). This is notable because it suggests that the Seaventures Dive Rig creates an environment that mimics that of a natural reef in terms of fish abundance values, but not in terms of species richness.

Another critical observation was that the relatively uncomplex structure provided by Seaventures reflects the limited species abundance and biodiversity. Previous studies have indicated that increased structural complexity is an effective way to increase species richness, abundance and biomass of fish assemblages associated with extremely simple reef units. In this case, Seaventures previously functioned as a "Jack-Up" rig, only transporting crew and supplies. This is likely why the platform has a very simple structural design, consisting only of 6 pylons, no beams and no cross beams, thereby limiting the species abundance and biodiversity on this habitat. These observations are supported by earlier conclusions regarding the critical role that habitat complexity has on the ecological effectiveness of artificial reefs (Bohnsack 1989, Gorham and Alevizon 1989, Helvey and Smith 1985, Hixon and Beets 1989, Sherman et al. 2002, Shulman 1984).

Future Directions

For the purposes of this study, the stereo-video methodology proved to be a cost-effective means to collect field data. This apparatus only requires 2-3 divers to operate, is relatively low-budget and can ensure more accurate species identification and population counts. On the other hand, stereo-video does require calibration before use in the field, can be less effective when the team experiences a strong current and can only accurately collect data when transects are laid out in a straight line. Our expedition team experienced difficulty on days when the current was strong and swimming straight transects was problematic (around circular oil platform pilings). Also, in this study, SV methodology was not compatible with vertical transects

While this study was able to communicate valuable results regarding the abundance and species richness of the fish habitat on the Seaventures Dive Rig in Malaysia, future studies should be conducted to investigate these trends further. Specifically, more horizontal transects should be swam within each of the habitat types to provide a more robust dataset for analysis. Similarly, the same number of transects should be swam for each transect type and for the same distance. Additionally, future projects should address the species of fish observed across the habitat types being analyzed. This information would be helpful in determining the types of habitats being fostered and the stakeholders that would benefit most from them (ie: fishermen vs ecotourism, etc).

CONCLUSIONS

Repurposing oil and gas platforms as ecotourism resorts may be the innovative solution Southeast Asia has been looking for to address the challenge of conserving the reef communities that thrive quietly below the surface. While our team rejected the use of SV as a plausible methodology for this type of field research, our study yielded observational results that suggest that the habitat created by oil rigs in this region can mimic the fish abundance of natural reefs. Additional benefits may include increased local biological productivity, creation of local jobs, and perhaps a respite for natural reefs.

This project concluded that conducting a 'siting' study, or an assessment of the substrate and ecology prior to artificial reef placement, should be a critical consideration prior to any reefing construction. When placed appropriately, an artificial tends to reflect a similar reef community as the natural surrounding environment in which it is placed (Perkol-Finkel et al. 2005). In this case, the Seaventures structure mimicked the silty, natural reefs found off Mabul.

The results from our expedition are critical as they broaden the dialogue on the potential positive ways to repurpose offshore structures for the benefit of the environment through ecotourism. Furthermore, this expedition engaged communities, local conservation groups, and biologists that have similar conservation challenges regarding the future management of the unique ocean resources that thrives below offshore oil and gas platforms and who wish to develop similar R2R programs in their own countries.

ACKNOWLEDGEMENTS

We would like to thank The Matador Network, The Explorers Club, and the team at the Seaventures Dive Rig for their continued collaboration and efforts in conducting this study.

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