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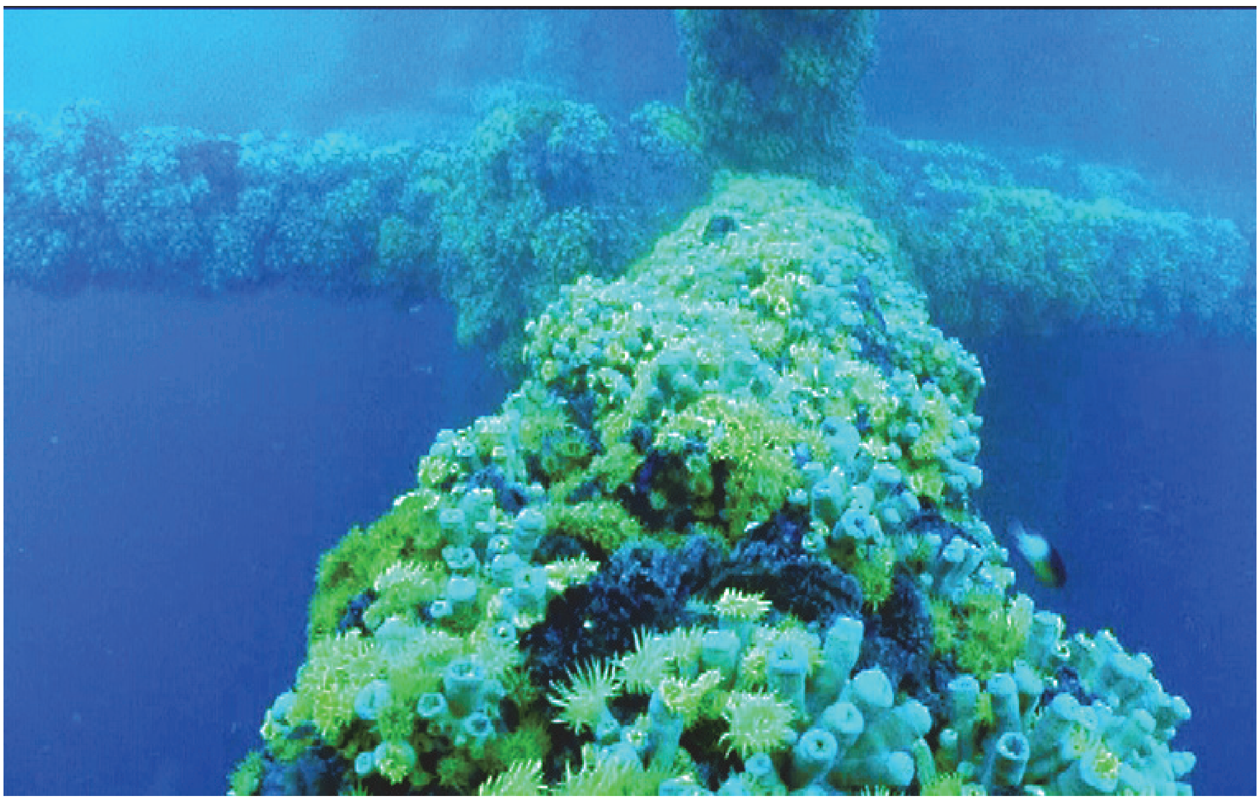
Coastal Marine Institute

Deepwater Coral Distribution and Abundance on Active Offshore Oil and Gas Platforms and Decommissioned Rigs-to-Reefs Platforms



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Bureau of Ocean Energy Management

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Coastal Marine Institute
Louisiana State University

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Deepwater Coral Distribution and Abundance on Active Offshore Oil and Gas Platforms and Decommissioned Rigs-to-Reefs Platforms

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EXECUTIVE SUMMARY

Thousands of oil platforms in the northern Gulf of Mexico (GOM) provide hard substratum which has not been present in GOM shallow water for thousands of years. These platforms, acting as numerous artificial islands throughout the region, have facilitated the geographic expansion of Caribbean reef coral populations. The U.S. DOI Bureau of Ocean Energy Management (BOEM) has provided for the "reefing" of -platforms as artificial reefs to create additional hard substratum habitat in this region, with the ultimate objective being to promote fisheries development. We assessed the effectiveness of these Rigs-to-Reef structures in promoting coral community development on the toppled platforms in deep water using ROV reconnaissance (max. depth ~110 m). We compared coral community development on five toppled platforms with two active, standing production platforms.

The corals found on the platforms were the hermatypic/zooxanthellate *Madracis decactis* and several ahermatypic/azooxanthellate: *Tubastraea coccinea, Oculina diffusa,* and *Phyllangia americana*.

Comparisons of standing and toppled platforms show no significant difference in total coral density. This was due primarily to varying, non-correlated, opposing species-specific changes in abundance between the two types of structures. That is, *M. decactis* and *T. coccinea* densities were significantly higher on toppled Rigs-to-Reefs structures. In the latter case, the corals were found on the "bottom" portion of the legs that had been up-ended during the toppling process, presumably having settled and grown there after toppling. On the other hand, *P. americana* was more abundant on standing platforms than on the toppled ones. The densities of *O. diffusa* were found to be equivalent on both types of structures.

With respect to depth distribution, when all corals were considered together, they were distributed more deeply on standing platforms than on toppled Rigs-to-Reefs structures. This was particularly true in *O. diffusa*, *P. americana,* and *T. coccinea.* There was no significant difference between depth distributions between the two types of structures in *M. decactis*. All corals of this species were found to occur in depths of $\leq$ 50 m. This was most likely due to this species being zooxanthellate and requiring light for survival and growth. It is believed that the density reduction of all coral colonies on the Rigs-to-Reefs structures in deeper water may be due to physical disturbance upon removal of the platform and additional disturbance during deployment of the structures at their new site.

The above data suggest that Rigs-to-Reefs structures do function as a substrate for coral settlement. The probability of continued growth of the corals, however, varies by species-specifically between structure types. Toppling did not appear to enhance development of hermatypic coral populations, increase coral abundances in general, or create a three-dimensional reef-like habitat (as observed by ROV) which could promote demersal fish community development.

1.0 INTRODUCTION

1.1 GENERAL BACKGROUND: PLATFORMS IN THE NORTHERN GULF OF MEXICO AND THE FLOWER GARDEN BANKS

At present, there are approximately 3,200 oil and gas production platforms operating in the northern Gulf of Mexico (GOM) Dauterive, 2000 a,b; Francois, 1993; Knott, 1995). The shelf there is almost entirely soft sediment, and the platforms provide hard substratum, reaching through shallow water, where little exists or has existed for tens of thousands of years (Blum et al., 2001; Curray, 1965a, b; also see Blum et al. 1998; Frost, 1977; Schroeder et al., 1995). There are many banks in this region, 37 or so; some are composed of calcium carbonate and house coral populations (Hickerson et al., 2006; Rezak et al., 1985; Schmahl et al., 2005; Schmahl and Hickerson, 2006a, b), but most are drowned reefs from the Pleistocene epoch (Aharon, 2003; Rezak et al., 1985; Winker and Buffler, 1988). The platforms have provided new habitat for a variety of epibenthic fauna and flora (Adams, 1996; Boland, 2002; Bright et al., 1991; Driessen, 1989; Gallaway and Lewbel, 1981), extending from the surface to a depth of hundreds of meters. They represent oases of hard substratum (Shinn, 1973, 1974; Shinn and Wicklund, 1989) which have been colonized by demersal fish (Childs, 1998; Love et al., 2000; Rooker et al., 1997; Schroeder et al., 2000; Sonnier et al., 1996; Winfield, 1973), and many pelagic and reef-associated fish were also attracted to these structures (McDonough and Cowan, 2006; Stanley and Wilson, 1997, 2000). Before the introduction of platforms, hard substratum was limited to scattered banks and shoals, mostly in deep water (Rezak et al., 1985). Hard-bottom organisms were restricted to those banks. These platforms represent a novel development for the GOM and have provided thousands of artificial islands.

The Flower Garden Banks (FGB) are a set of coral reefs located on two salt diapirs ~180 km southeast of Galveston, Texas and are among the most isolated coral reefs in the western Atlantic (Brazeau et al., 2005; Rezak et al., 1985; Sammarco et al., 2004; Sammarco and Brazeau, 2001; Snell et al., 1998). Other shallow coral reefs in shallow water include, off of Tampico, Mexico–the Isla de Lobos reefs, and in southern Florida–the Florida Keys, U.S. (Sammarco et al., 2012a). Separating these reefs on the continental shelf are large areas of soft bottom. Soft bottom is generally unsuitable for coral larval settlement and growth (Hunte and Wittenberg, 1992; Miller et al., 2009; Sammarco, 1980, 1991); thus, natural settlement sites for shallow-water corals in the northern GOM are relatively scarce. Coral colonization of such habitats is achieved via larval dispersal, and larvae can travel hundreds to thousands of km to settle on reefs like the FGB (Richmond 1982, 1987) or on platforms in the northern GOM.

1.2 CORALS IN THE NORTHERN GULF OF MEXICO

It is now known that oil and gas platforms have substantial coral communities both in the area of the FGB (Sammarco and Atchison, 2002; Sammarco et al., 2003, 2004) and over the entire northern GOM (Sammarco et al., 2012a; Sammarco, 2013), from the Matagorda Island (MI) lease sector, south of Corpus Christi, Texas to the Mississippi Canyon (MC) and Main Pass (MP) lease sectors, south of Mobile, Alabama. Coral species richness and abundance is moderately high there (up to 11 species), with corals exhibiting species-specific depth distributions. Recent broad-scale surveys have demonstrated that corals have colonized platforms throughout the northern continental shelf in the western and central GOM, particularly near the shelf edge. In addition, the FGB are now known to serve as a larval source for the platform colonization and most likely vice versa (Atchison, 2005; Atchison et al., 2004a, b, 2005; Sammarco et al., 2012b). The platforms are clearly facilitating "island-hopping" (Futuyma, 1998) by coral larvae as a dispersal mechanism (Atchison, 2005; Atchison et al., 2004a, b, 2008; Bright et al., 1991; Sammarco et al., 2004, 2005, 2012b; G. Boland, pers. comm., unpub. data; K. Deslarzes, pers. comm).

1.3 THE RIGS-TO-REEFS PROGRAM

Federal legislation requires that all offshore platforms be removed within one year after cessation of all production on a lease block (BOEM, 2012; Velazquez, 2010). In the mid-1970s, however, the U.S. Department of the Interior's then Minerals Management Service (MMS), now the Bureau of Ocean Energy Management (BOEM), entered into a joint agreement with each of the Gulf States entitled the Rigs-to-Reefs Program. Under this agreement, platform owners (oil and gas companies) were allowed to donate platforms into a program where they would remain on the shelf either in their original location, or could be towed to a designated artificial reef site within the EEZ, joining other "reefed" platforms. There are a number of such sites along the continental shelf of the northern GOM (Louisiana Department of Wildlife and Fisheries, 2012; Texas Parks and Wildlife, 2012), designed primarily to enhance the development of recreational and commercial fish populations (Baine, 2001; Dauterive, 1999; Pitcher and Seaman, 2000). Several options were available for the reefing of platforms, including a) cut at a depth of $\geq$26 m and leave in place, with the upper part of the platform being retrieved and returned to shore; b) cut similarly, but the upper portion may be toppled to create a supplementary artificial reef on the shelf floor; c) cut 3.5 m below the surface of the sediment and move the platform to a designated "Artificial Reef Zone" on the shelf, to be toppled there. The program has been used extensively in the northern GOM (Dauterive, 2000 a, b), particularly in Louisiana and Texas (Kaiser and Pulsipher, 2005), and has enjoyed much success in terms of recreational fishing (see Frumkes, 2002). This artificial reef system is also being used as a model for use of post-production platforms in other countries (e.g., Cripps and Aabel, 2002).

The degree of coral community development on the deeper portions of the platforms could play an important role in enhancing reef development on artificial reefs in the GOM, if known before making a decision to "reef" the platform. If so, these would add environmental value to platforms cut at 26 m. Data collected by dive teams indicated that some hermatypic (Sammarco et al., 2012a; G.S. Boland, current study) and ahermatypic (Sammarco et al., 2011; J.K. Reed, pers. comm.; also see Reed, 2002) corals occur below 33 m on the platforms. Because of the difficulty of using divers at such depths, ROVs were used extensively in this study for surveying in deeper water.

In light of this information, the following questions arise: To what extent are these lower portions colonized by scleractinian corals, and by what species? Are they hermatypic or ahermatypic corals? Are corals–shallow- and deep-water–surviving the relocation and depth-habitat change to deeper, cooler, darker waters? That is, is the Rigs-to-Reef Program being effective with respect to benthic reef community development?

1.4 OBJECTIVES

The objectives of this study are as follows:

- To examine coral community development at >33 m depth using a Remotely Operated Vehicle (ROV) on select platforms in the northern GOM, comparing active, standing, producing platforms with toppled Rigs-to-Reefs platforms;
- To examine comparative species-specific trends in densities of the coral populations; and
- To define comparative depth-distributions for hermatypic compared with ahermatypic corals on platforms in this system.

1.5 DURATION

Because of field trip delays caused by poor weather conditions, this study ran for ~5 years, including data collection through to data analysis, graphic analysis, and writing, from 2007 through 2012. A variety of delays, some caused by hurricanes, resulted in cruise delays and extended the study beyond the projected original date of completion. The first two years were spent surveying platforms. Distribution and abundance data regarding adult coral populations were analyzed. Various reports were prepared during the course of the study and submitted to BOEM.

2.0 MATERIALS AND METHODS

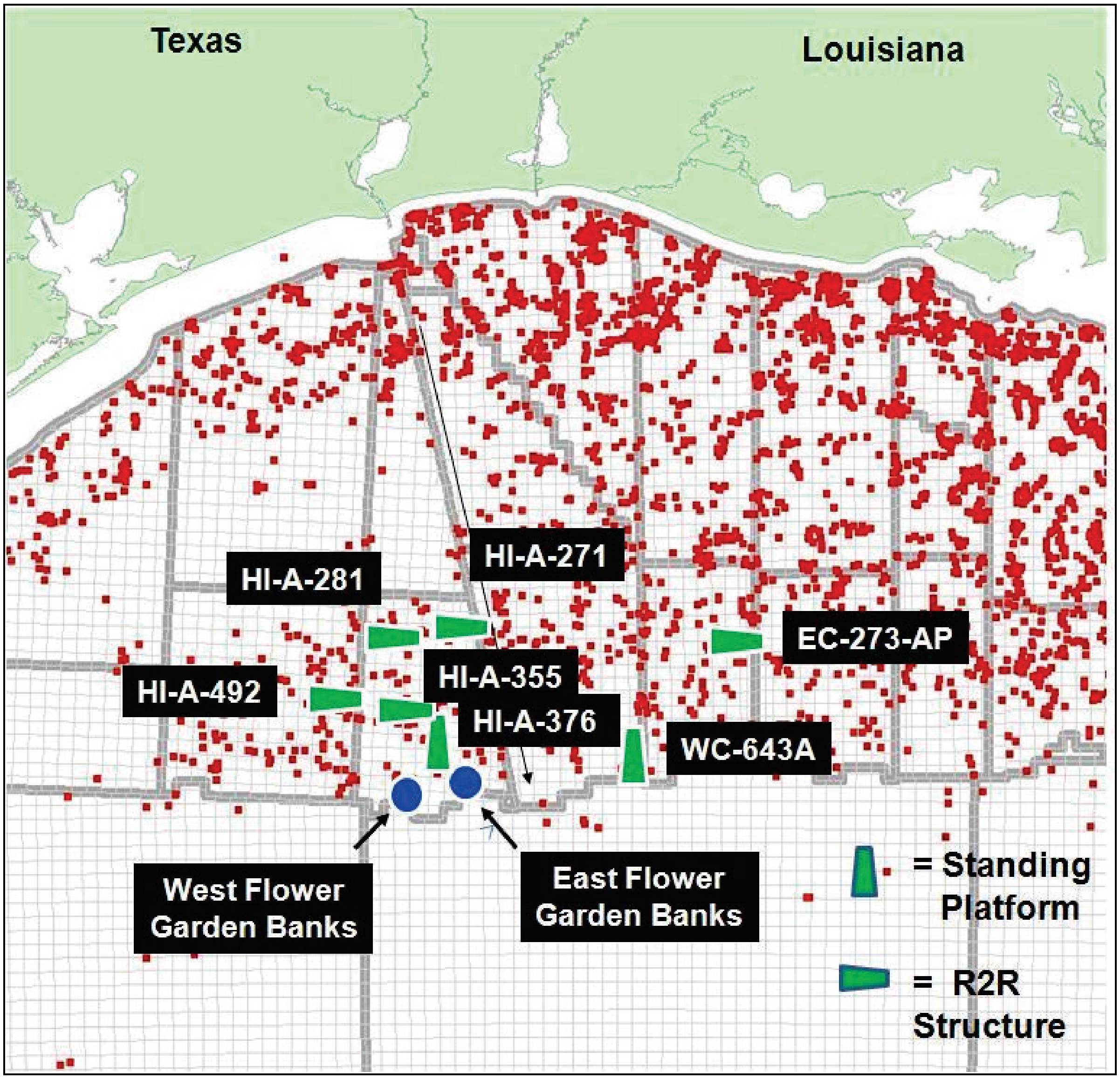
2.1 STUDY SITES

The study focused on the High Island and West Cameron lease areas, because this is where high densities of corals are known to occur on platforms (Sammarco et al., 2004, 2012a). It is also where a number of Rigs-to-Reefs zones are located. The two standing platforms studied were those known to possess marked coral community development in shallow water (Table 1). Such communities occur on platforms generally on the outer 25% of the shelf, primarily in the central and western portions of the northern GOM (i.e., south of Port Arthur, Texas and Terrebonne Bay, Louisiana; Sammarco et al. 2012a). Five toppled platforms were also assessed within areas designated as Rigs-to-Reefs zones (see Figure 1 and Table 1 for details of names and locations). We accessed platforms by a charter vessel (M/V *Fling*, Freeport, Texas).

2.2 ROV SURVEYS

Surveys were performed using a Deep Ocean Engineering Phantom 2 ROV, a SeaBotix LBV-300 ROV, and a Video-Ray. Both vehicles had red laser beams directed downward or forward, respectively, in parallel, a certain distance apart to be used as a linear scale reference for size. On standing platforms, surveys were run from 20 m depth to the bottom of the platforms, a maximum of 110 m. Vertical pilings on the down-current side of the platform were surveyed along with the outer portions of two sets of horizontal struts, usually at depths of 13–17 m, and 21–27 m. This side of the platform was surveyed for safety purposes: to help keep the ROV on the outside of the structure and to avoid tangling the ROV umbilical in the jacket of the platform. On reefed platforms, the minimum depth surveyed was ~25m.

ROV videos and still photos were taken during each excursion. Videos were processed in the laboratory using Adobe® Premiere® CS5 on a Dell Precision T-3400, dual core graphics computer. The video was stopped every 2 m of surveyed substratum and the associated still was analyzed for the presence of scleractinian corals. Counts of corals were taken and recorded in a Microsoft® Excel® spreadsheet (Sammarco, 2012a, 2013). The total for each taxon was tallied for each quadrat, quantified on the computer screen with a grid and standardized to a spatial scale. Densities were standardized to no./10 m^2. Relative abundance was also calculated for each group for the platform, and depth distribution was determined. Horizontal struts included many more quadrats than vertical pilings; thus, their area was estimated and standardized for, prior to calculating densities of any species. Colony counts of all coral species were also taken for each quadrat to provide density data. These procedures were followed for both standing and toppled platforms. Data were logged using Microsoft® Excel®.



Small squares represent other standing, producing platforms. Standing platforms designated by vertical trapezoid; toppled platforms designated by a horizontal one. Location of the East and West FGB are also shown.

Figure 1. Map of platforms surveyed in this study for scleractinian corals.

Table 1.

List of oil and gas platforms on the continental shelf of the northern GOM surveyed during this study

Platform Type	Platform Code	Owner	Latitude	Longitude
Standing Production Platforms	HI-A-376	Apache Oil	27.96197	-93.67089
	WC-643-A	Chevron-Texaco Oil	27.98137	-93.03419
Toppled Rigs-to-Reefs Platforms	EC-273-A	Texas Parks and Wildlife Dept.	28.2550	-92.3930
	HI-A-271	Texas Parks and Wildlife Dept.	28.364160	-93.785320
	HI-A-281	Texas Parks and Wildlife Dept.	28.439490	-93.716940
	HI-A-355	Texas Parks and Wildlife Dept.	28.0414	-93.7086
	HI-A-492	Texas Parks and Wildlife Dept.	28.2266	-94.0583

2.3 STATISTICAL ANALYSES

Data were analyzed by both parametric and non-parametric statistical techniques using Rohlf and Slice's (1999) BIOMStat V3.3. Procedures included basic descriptive statistical calculations, RxC G-tests, Kruskal-Wallis tests, and the Mann-Whitney U-tests (see Sokal and Rohlf, 1981). Statistical results, including data transformations, are provided in figure legends. Density data were transformed by square root (Y + 0.5) in graphs for normalization purposes, to facilitate visualization of differences discerned.

2.4 TECHNICAL CONSIDERATIONS AND ALTERATION OF ORIGINAL PLAN

Survey plans needed to be altered due to a variety of factors. Poor or severe weather conditions caused truncation or cancellation and re-scheduling of cruises in the interests of safety of the scientific and ship's crew. This resulted in changes in survey dates and number of platforms to be surveyed. Statistical analyses were adjusted accordingly to accommodate changes in experimental design.

3.0 RESULTS

3.1 CORAL SPECIES COMPOSITION

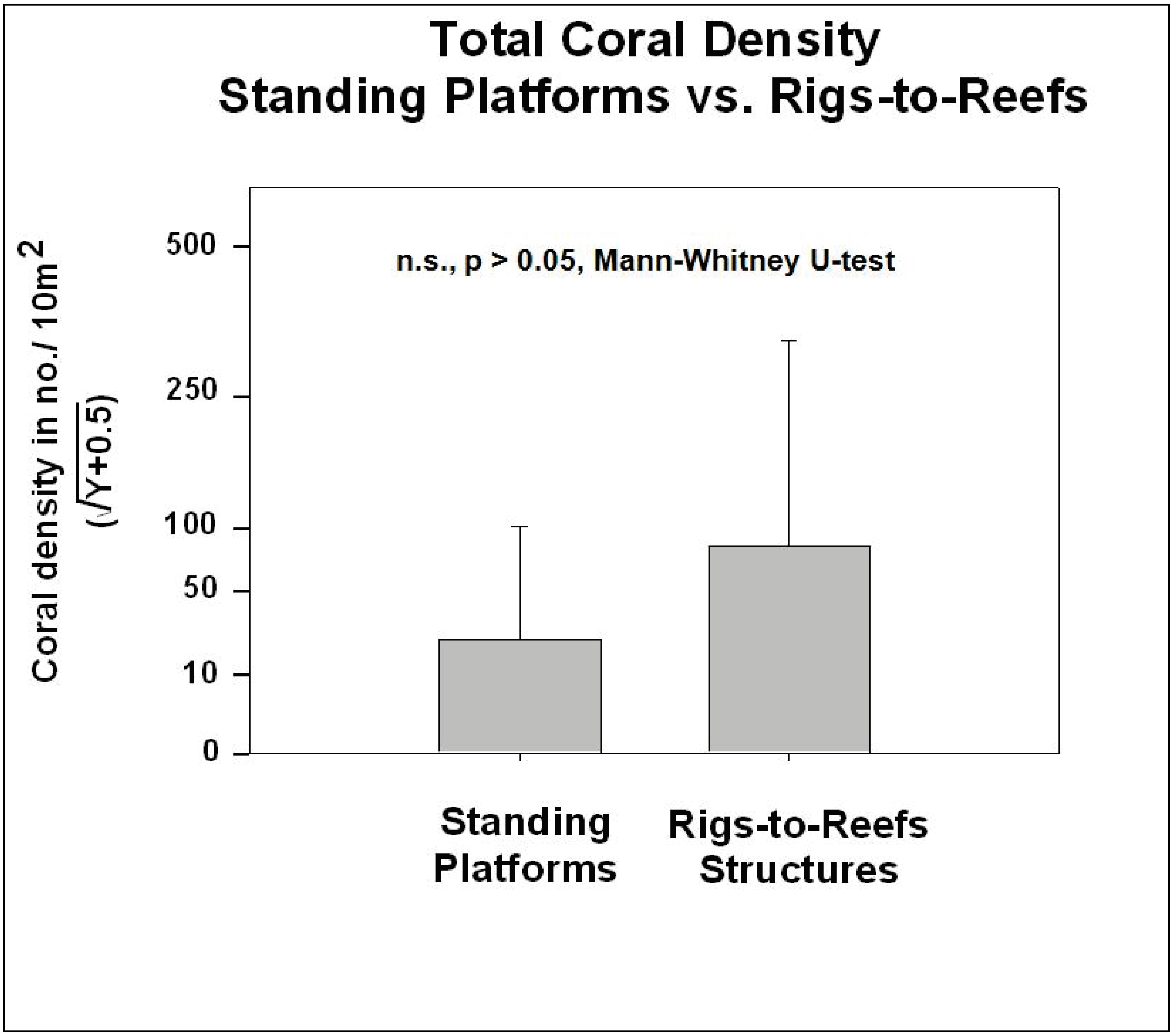
Four species of coral were encountered during this study. One was a zooxanthellate, hermatypic coral, *Madracis decactis* (Lyman 1859). Two were azooxanthellate, ahermatypic corals, *Tubastraea coccinea* (Lesson 1829) and *Phyllangia americana* (Edwards and Haime 1849). The fourth was a facultative zooxanthellate coral, *Oculina diffusa* (Lamarck 1816). *T. coccinea* is an Indo-Pacific coral, introduced into the western Atlantic in the early 1940s (Cairns, 2000; Humann and DeLoach, 2002). It has since spread unchecked throughout the tropical and sub-tropical western Atlantic; it arrived in the GOM in the 1990s (Fenner, 2001; Fenner and Banks, 2004). The other three species are common in the GOM and Caribbean regions.

3.2 CORAL DENSITY

Average total coral density on the standing platforms was approximately $20/10m^2$, while that on the toppled Rigs-to-Reefs structures was $\sim 90/10m^2$ (Figure 2). Despite this apparent difference in densities, high variances resulted in their being no significant difference in total coral density between these two types of structures.

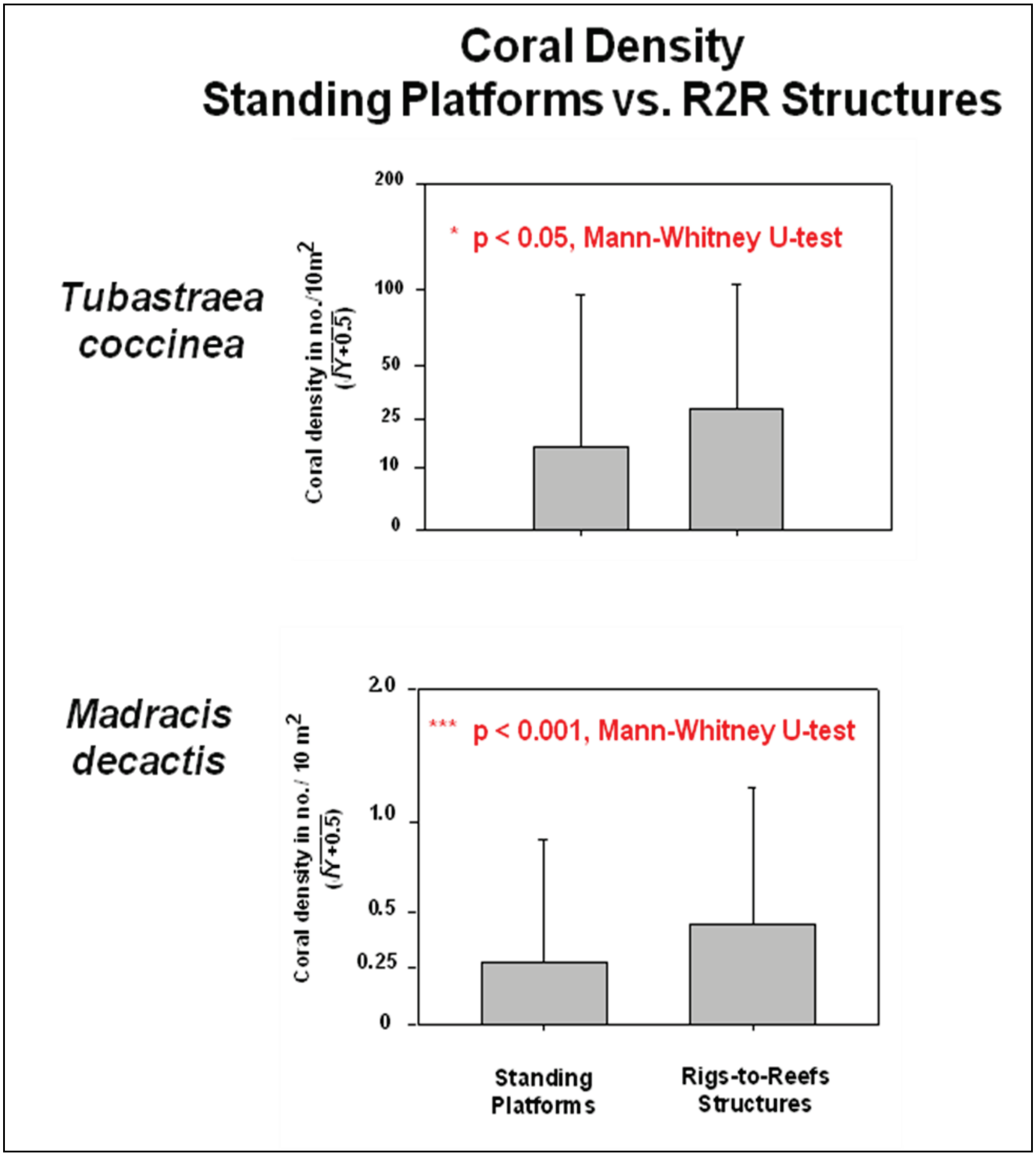
Significant differences did appear, however, between these two types of platform structures when individual species densities were considered. In both *M. decactis* and *T. coccinea*, coral densities were significantly higher on the toppled Rigs-to-Reefs platforms than on the standing production platforms (Figure 3).

The trends evident in *M. decactis* and *T. coccinea* were not paralleled, however, by the other two scleractinian coral species assessed in this study. Densities of *P. americana* were $\sim 4/10m^2$ on standing platforms and were significantly higher than on toppled Rigs-to-Reefs structures (Figure 4). Densities of *O. diffusa* upon first look appeared to have a similar pattern, but there was no significant difference in the two average densities. This was due to high variances in the data.



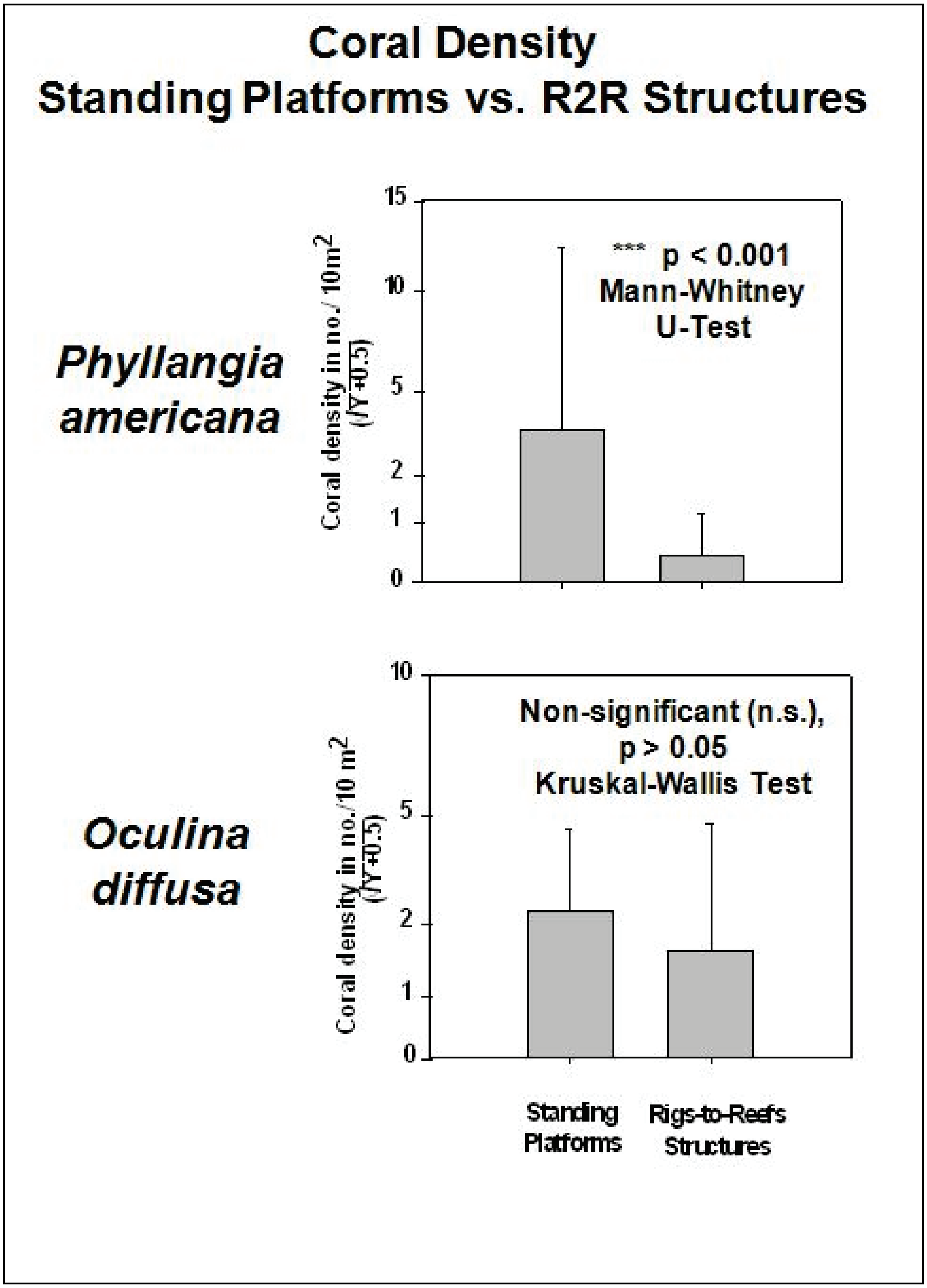
Note: Mean shown along with 95% confidence limits. Coral density transformed by square root (Y+0.5) for normalization purposes (Sokal and Rohlf, 1981).

Figure 2. Graph showing the total coral density in no./10m2 on standing and toppled Rigs-to-Reefs platforms on the northern GOM outer continental shelf.



Note: Mean plus 95% confidence limits shown. Coral density transformed by square root (Y+0.5) for normalization purposes (Sokal and Rohlf, 1981).

Figure 3. Graph showing coral density in no./10m^2 in two scleractinian species: *Tubastraea coccinea* (upper graph), an azooxanthellate coral, and *Madracis decactis* (lower), a zooxanthellate one.



Note: Mean plus 95% confidence limits shown. Coral density transformed by square root (Y+0.5) for normalization purposes (Sokal and Rohlf, 1981).

Figure 4. Graph depicting coral density in no./10m^2 in two azooxanthellate scleractinian coral species: *Phyllangia americana* (upper graph) and *Oculina diffusa* (lower).

3.3 CORAL DEPTH DISTRIBUTION

Depth distribution of total corals revealed different patterns of distribution between the two sets of platform types. The standing platforms exhibited a tri-modal distribution, with relative abundances of corals peaking at 30, 40, and 75 m depth (Figure 5). The depth range of the corals extended to 95 m, near the bottom of the jackets. However, on the Rigs-to-Reefs structures, densities were restricted to shallower depths, exhibiting a unimodal pattern, with a peak at 30-35 m depth. The depth range of the corals on these structures extended only to 55 m.

The only hermatypic coral found on the platforms surveyed was *M. decactis*, a zooxanthellate coral. On both the standing platforms and the Rigs-to-Reefs structures, the relative abundances of this species of coral peaked at 35–40 m depth (Figure 6). In both cases, this accounted for a total of ~75–80% of all of the colonies observed. The depth of *M. decactis* extended slightly deeper on standing platforms to 50 m when compared to the Rigs-to-Reefs structures (40 m). This species is distributed shallow, most likely due to its need for light – irrespective of type of structure. It would appear that any hermatypic coral colonies present on the standing platforms that were introduced into waters $\geq$ 40 m did not survive the reefing process.

The highest proportions of populations of *T. coccinea* were found in relatively shallow water, exhibiting a unimodal distribution peaking at depths of 35–40 m or less (Figure 7). There was, however, a significant difference in depth range and distribution between the Rigs-to-Reefs platform structures and the standing platforms. These corals extended much deeper on the standing platforms than on the Rigs-to-Reefs ones, although with low relative abundances.

O. diffusa also showed a deeper depth distribution on the standing platforms than on the Rigs-to-Reefs ones, but in a more pronounced fashion (Figure 8). On the standing platforms, the depth of this species extended to 95 m. In this case, corals were azooxanthellate. It exhibited a bimodal distribution, with peaks at 60 and 75 m. On the Rigs-to-Reefs structures, the distribution range was shallower. The maximum depth extension was 55 m, with a clear unimodal peak occurring at 40 m, accounting for ~60% of the corals observed.

The depth distributions of *P. americana* varied in a fashion similar to those of *O. diffusa*. That is, the standing platforms exhibited a significantly deeper range of distribution than the Rigs-to-Reefs structures (Figure 9). Populations on both types of structures had unimodal distributions, with the Rigs-to-Reefs populations peaking at 40 m depth, while the standing platform populations peaked at 75 m depth.

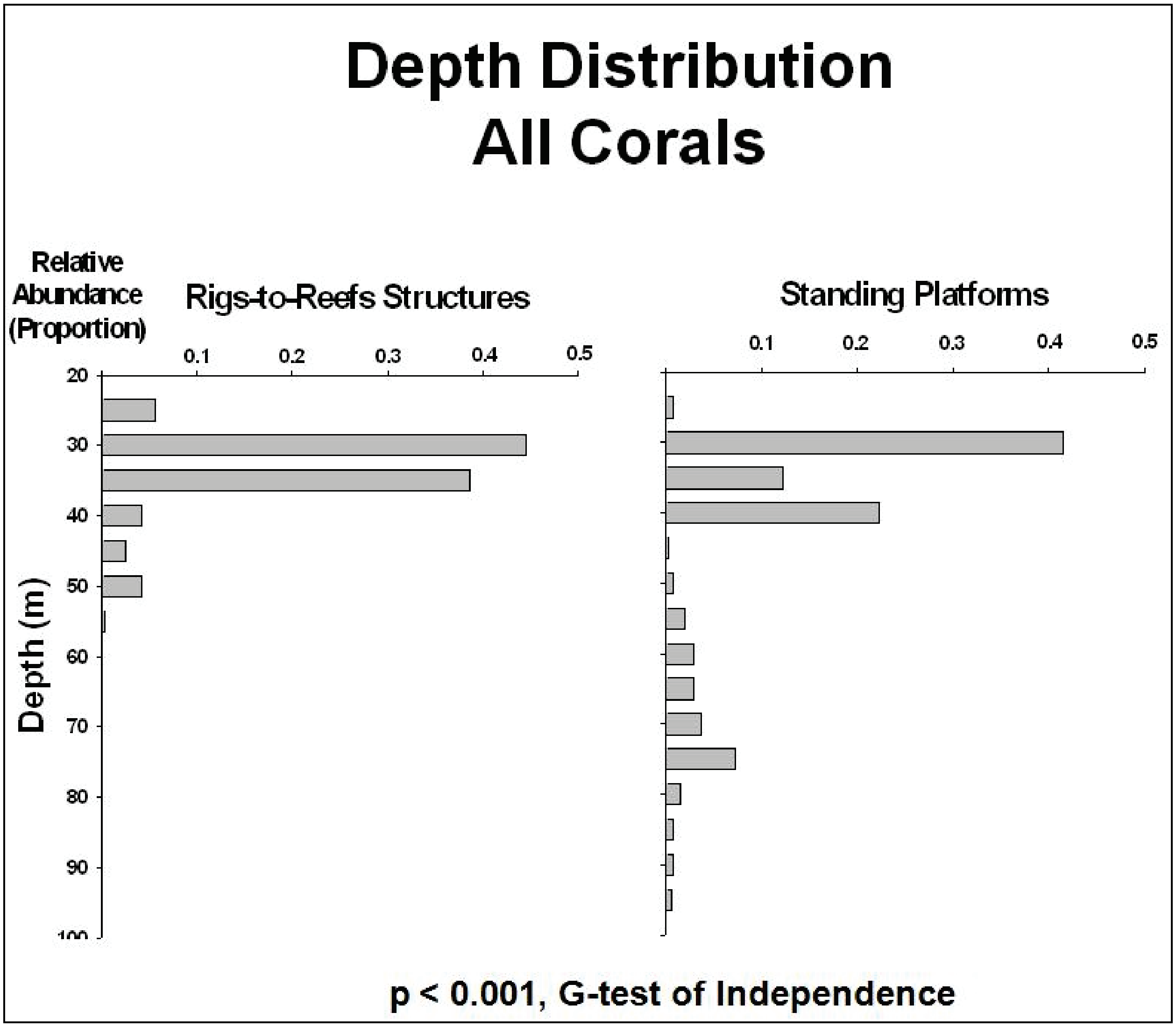


Figure 5. Depth distribution of all scleractinian corals. Corals distributed significantly deeper on the standing platforms than on the toppled Rigs-to-Reefs structures ($p < 0.001$, RxC frequency G-test).

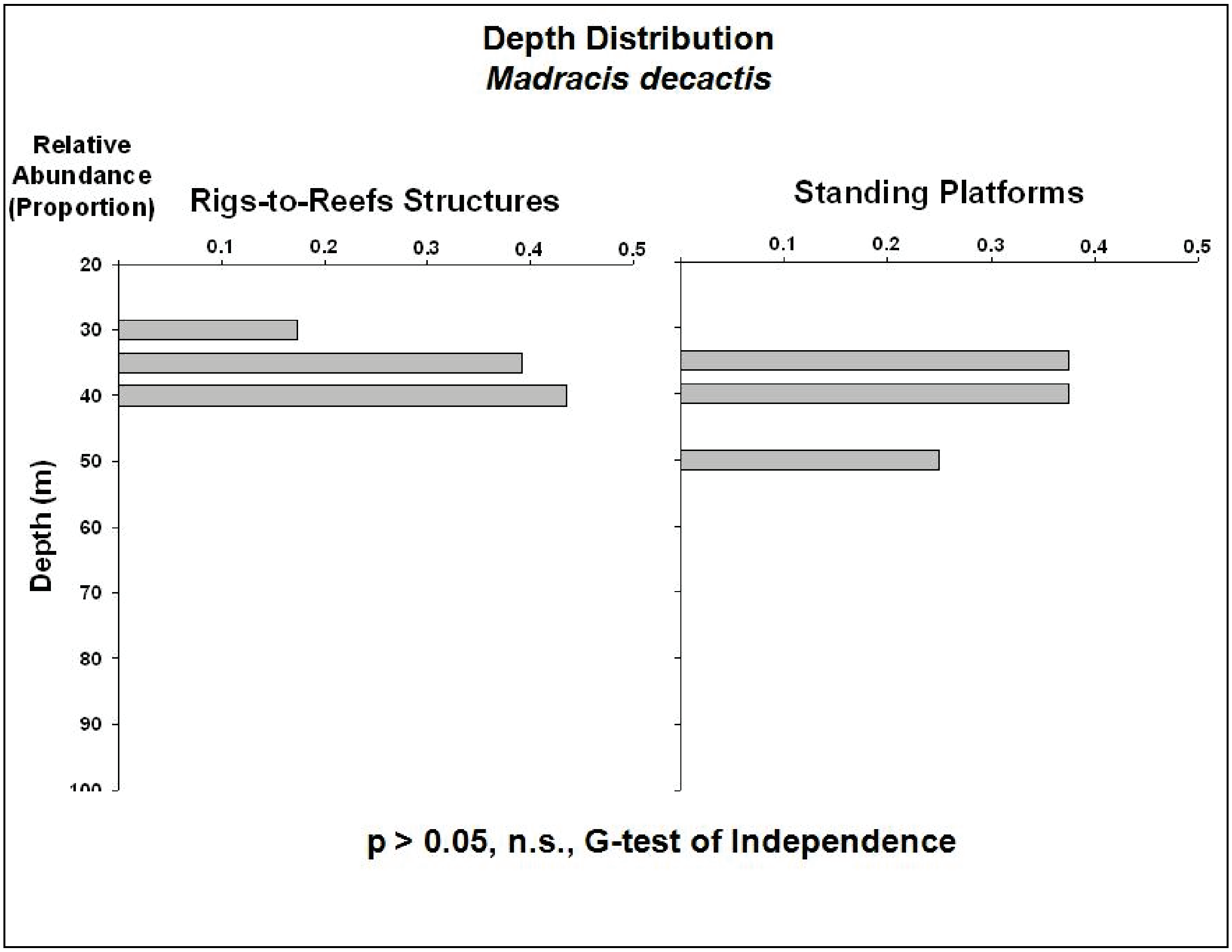


Figure 6. Depth distribution of *Madracis decactis.* No significant difference between depth distributions of this species between the two sets of structures ($p > 0.05$, RxC frequency G-test).

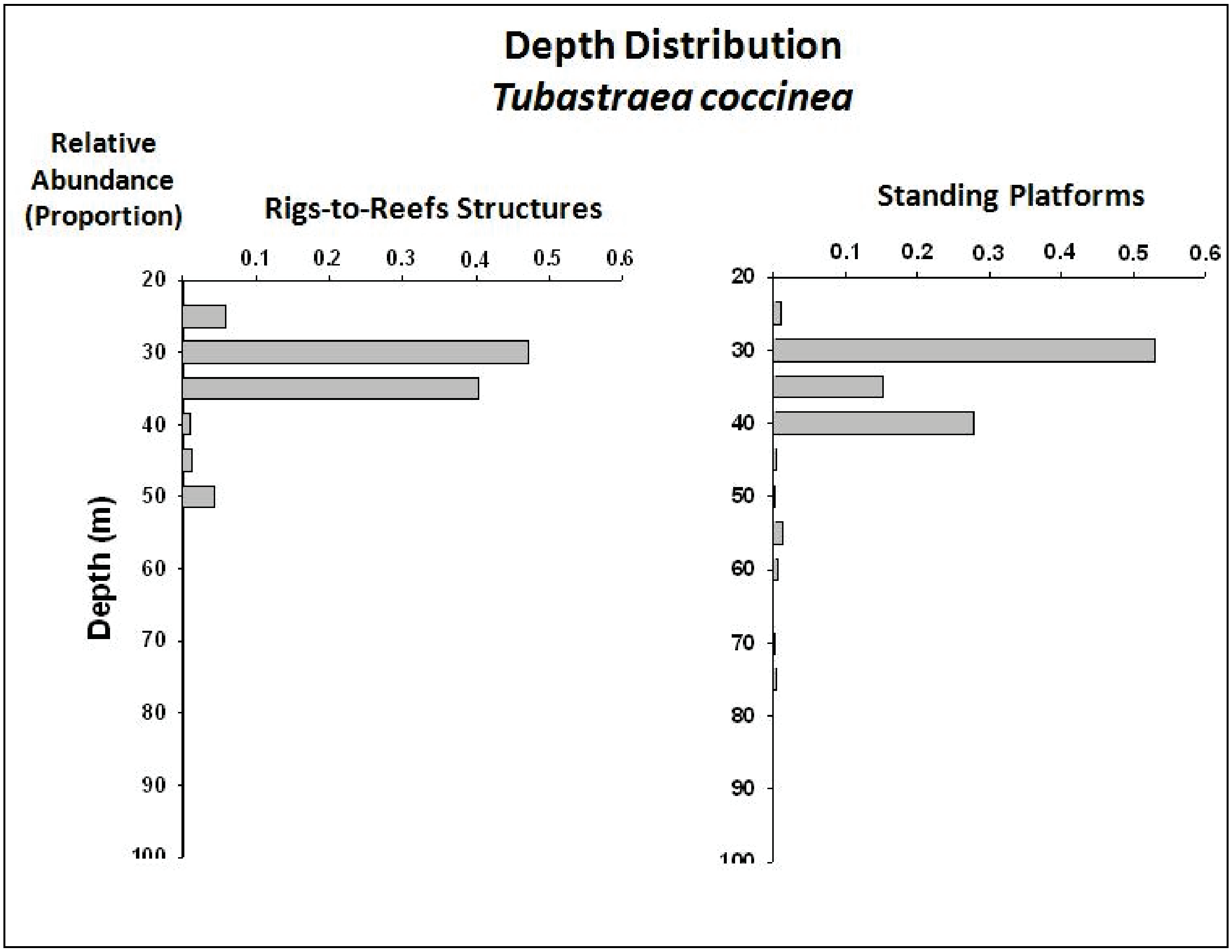


Figure 7. Depth distribution of *Tubastraea coccinea*. Highly significant difference between depth distributions of this species between the two sets of structures ($p < 0.001$, RxC frequency G-test).

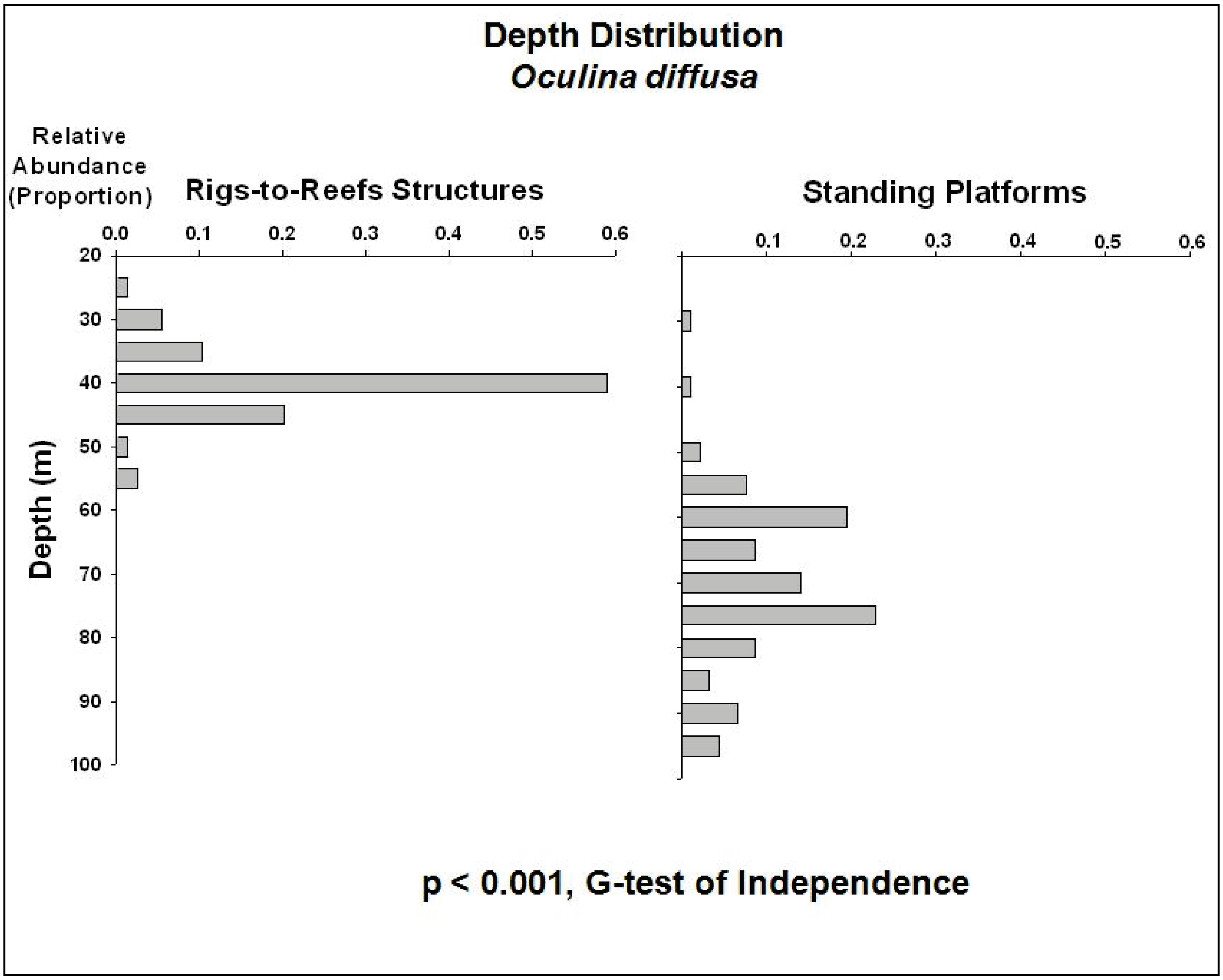


Figure 8. Depth distribution of *Oculina diffusa*. Corals distributed significantly deeper on the standing platforms than on the toppled Rigs-to-Reefs structures ($p < 0.001$, RxC frequency G-test).

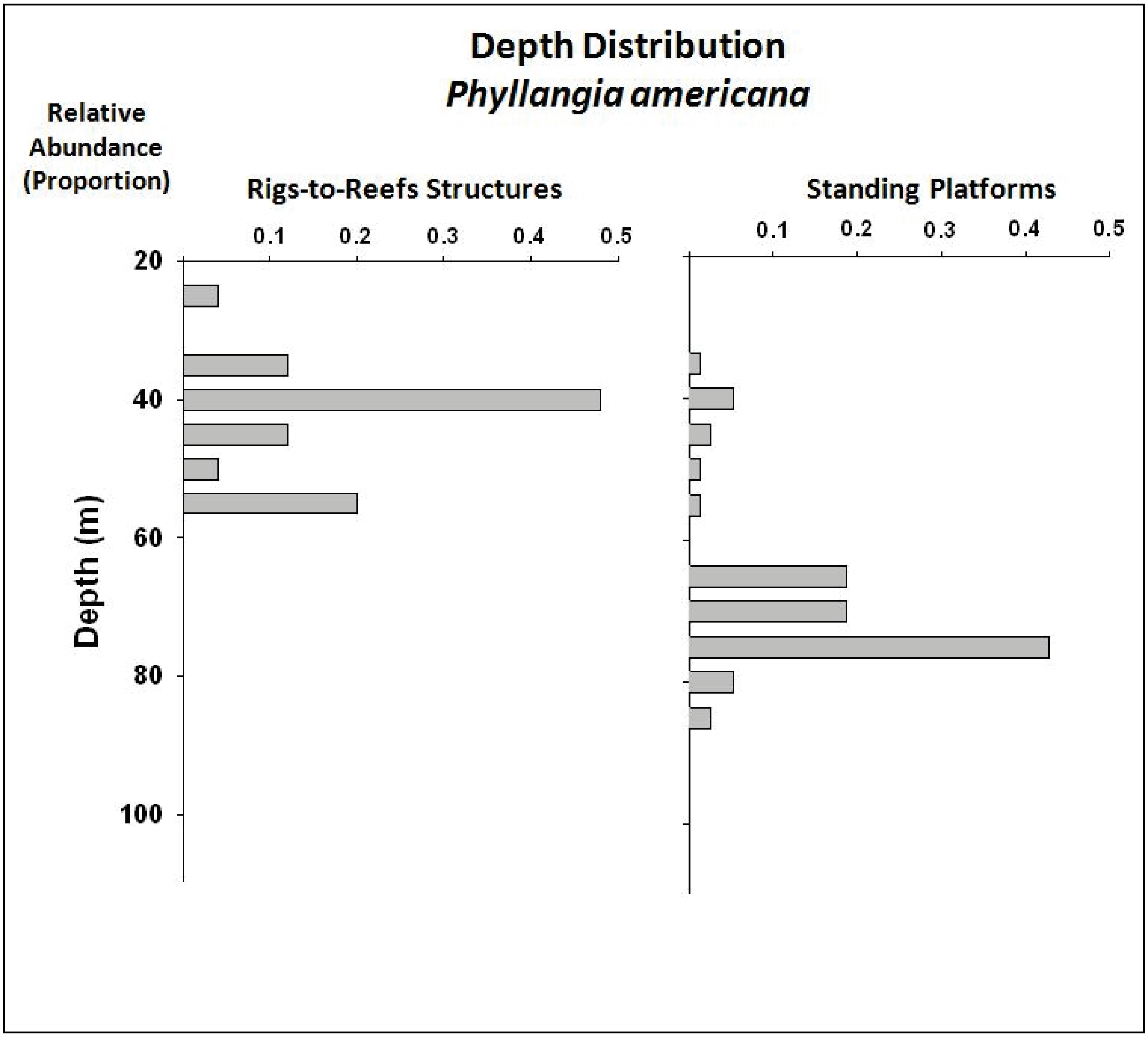


Figure 9. Depth distribution of *Phyllangia americana*. Corals distributed significantly deeper on the standing platforms than on the toppled Rigs-to-Reefs structures ($p < 0.001$, RxC frequency G-test).

4.0 DISCUSSION

4.1 OVERALL DENSITY COMPARISONS

The finding that there is no significant change in overall coral density between standing and toppled platforms is important, because, on the surface, it suggests that there is no particular advantage or disadvantage to toppling platforms and allowing the benthic community, particularly corals, to develop on them as artificial reefs. The rationale behind this lack of change, however, lies in the details of the response of different coral species to this event. That is, there has been a species-specific response to the toppling, and the responses were not parallel.

4.2 *MADRACIS DECACTIS*

First, the reason that *M. decactis* densities do not vary between the two structure types relates to its biology and resultant depth distribution, which are essentially the same on both structure types. *M. decactis* is a zooxanthellate, hermatypic coral and requires light for colony survival and growth. Whether the platform structure is upright or on its side, the colonies will survive only in shallow water. Those colonies existing on standing platforms that were transported into deeper, darker, cooler water upon toppling will not have survived. Those larvae that settled in shallower water would have a higher probability of survival than in deeper water. Thus, there is a nil effect on changes in the overall density of the coral *M. decactis* upon toppling of a platform.

4.3 *TUBASTRAEA COCCINEA*

T. coccinea populations seem to thrive more on toppled platforms than on standing ones. This seems logical, because this species is known to do particularly well not only on artificial substrata such as platforms, but also in disturbed habitats (Byers, 2002; Sheehy and Vik, 2010). A toppled platform may be considered a disturbed habitat for several reasons. First, the mode of severing from seafloor of a standing platform is often explosives set around the base of the major support pilings. This would dislodge numerous sessile and vagile epibenthic organisms from the jacket and would kill many of the demersal, pelagic, and reef-associated fish in the area due to shock. Thus, the toppled platform will have a great deal of newly available space for settlement by incoming larvae or expansion by robust surviving species. Second, upon impacting the seafloor, the toppled platform will disturb the sediment there, resulting in high sedimentation on the platform and additional mortality of both shallow and deeper water organisms, freeing up additional space for colonization or growth by *T. coccinea*.

4.4 *Oculina diffusa*

Although *O. diffusa* populations did not vary in size between standing and toppled platform structures, there was a major shift in its populations to shallower water after toppling. As mentioned above, this species is a facultative zooxanthellate one (Cairns, 1999). However, in this case, no colonies were observed to have pigmentation and they did not appear to harbor substantial zooxanthellar populations. Thus, light is not believed to have played an important role in this distribution change. It is more likely that the platform removal process played a greater role. Of all species encountered here, *O. diffusa* was the most fragile. This was because, unlike the other species, it has a thin, delicate branching morphology. Explosive removal of the platform would have caused severe damage to the *O. diffusa* colonies on it. By comparison, both *M. decactis* and *Phyllangia americana* are massive in form. Although *T. coccinea* also has a branching format, its branches are quite short, and colonies are stronger and more resistant to breakage.

4.5 *PHYLLANGIA AMERICANA*

P. americana's populations appear to suffer significantly upon toppling of a platform. Not only did the populations shrink dramatically in size, they were also restricted to shallower water. Again, this is an azooxanthellate species (Cairns, 2000) and does not require light; thus, the loss of depth range is not due to loss of light with depth.

4.6 NO EVIDENCE FOR ENHANCEMENT OF CORAL COMMUNITY STRUCTURE AND RESULTANT FISH HABITAT

Although there is no overall change in coral density between standing platforms and toppled Rigs-to-Reefs structures, significant changes in coral community structure do result from the toppling procedure. In addition, underlying those changes are species-specific responses. Some coral population densities do not change after this event; others do. Some do not change their depth distribution; others do. It is clear that toppling of platforms dramatically affects the coral communities on the platforms, changing the species composition and diversity with depth. At this point, however, it seems clear that the toppling of platforms does not enhance the development of community structure.

One of the major purposes of artificial reefs programs, and particularly the Rigs-to-Reefs program, is to facilitate development of fisheries, particularly recreational, in the offshore environment (see above). It is well known that coral development on hard bottom promotes fish population growth by providing three-dimensional relief, habitat, and refuge (Lindberg et al., 2006; Peterson et al., 2000). The lack of three-dimensional structure provided by a well-developed coral community would not provide those habitat characteristics known to enhance fish community development. In addition, it would fail to provide critical habitat cues for settlement of the larvae of demersal and reef fish (Breitburg et al., 1995). Any procedure that removes corals and three-dimensional relief from these platforms will detract from their suitability as fish habitat.

5.0 CONCLUSIONS

The conclusions of this study are as follows:

- With respect to all corals considered together, there was no significant difference between corals found on standing platforms compared with the toppled Rigs-to-Reefs platforms.
- Densities of the hermatypic/zooxanthellate coral *Madracis decactis* were significantly higher on the Rigs-to-Reefs structures than on the standing platforms.
- Densities of the ahermatypic/azooxanthellate coral *Tubastraea coccinea* were also found to be significantly higher on the Rigs-to-Reefs structures than on the standing platforms.
- Densities of the ahermatypic/azooxanthellate coral *Phyllangia americana*, however, were found to be significantly higher on the standing platforms than on the Rigs-to-Reefs structures.
- Likewise, densities of the ahermatypic/azooxanthellate coral *Oculina diffusa* were not found to be significantly different from the standing platforms.
- These opposing patterns caused the overall lack of difference in coral density between the two types of structures.
- Overall, corals were found to be distributed to significantly deeper depths on standing platforms than on Rigs-to-Reefs structures.
- There was no significant difference between depth distributions in *M. decactis* between the two types of structures. All corals of this species were found to occur in depths of $\leq$50 m. This was most likely due to this species being zooxanthellate and requiring light for survival and growth.
- *T. coccinea, O. diffusa*, and *P. americana* were all found to be distributed significantly more deeply on standing platforms than on Rigs-to-Reefs structures.
- It is believed that the reduction in density of many corals on the Rigs-to-Reefs structures in deeper water may be due to physical disturbance on removal of the platform and deployment of the structures at their new site.

REFERENCES

Aharon, P. **2003**. Meltwater flooding events in the Gulf of Mexico revisited: Implications for rapid climate changes during the last deglaciation. Paleoceanography, 18: 14 pp. DOI:10.1029/2002PA0008401, access date 16/1/13.

Adams, C.L. 1996. Species composition, abundance and depth zonation of sponges (Phylum Porifera) on an outer continental shelf gas production platform, northwestern Gulf of Mexico. Final report and MSc thesis, Texas A&M University-Corpus Christi, Center Coastal Studies.

Atchison, A.D. **2005**. Offshore oil and gas platforms as stepping stones for expansion of coral communities: A molecular genetic analysis. M.Sc. thesis, Oceanography/Coastal Sciences, Louisiana State University, Baton Rouge, 86 pp.

Atchison, A.D., Sammarco, P.W., and Brazeau, D.A. **2004a**. Coral communities on the Flower Garden Banks *vs.* drilling platforms in the northern Gulf of Mexico. Abstracts of the 10th International Coral Reef Symposium, Okinawa, Japan, 2004, p. 309.

Atchison, A.D., Sammarco, P.W., and Brazeau, D.A. **2004b**. Genetic affinities of coral populations between the Flower Garden Banks and oil and gas platforms in the northern Gulf of Mexico: Preliminary data. Proceedings of the 10th International Coral Reef Symposium, Okinawa, Japan, 2004.

Atchison, A.D., Sammarco, P.W., and Brazeau, D.A. **2005**. Genetic affinities between corals on the Flower Garden Banks *vs*. oil and gas platforms in the northern Gulf of Mexico: Implications for dispersal. U.S. Dept. Interior, Minerals Management Service Information Transfer Meeting, New Orleans, LA, January 2005.

Atchison, A.D., Sammarco, P.W., and Brazeau, D.A. **2008**. Genetic connectivity in corals on the Flower Garden Banks and surrounding oil and gas platforms, Gulf of Mexico. Journal of Experimental Marine Biology and Ecology, 365: 1-12.

Baggett, L.S., and Bright, T.J. **1985**. Coral recruitment at the East Flower Garden Reef, northwestern Gulf of Mexico. Proceedings of the 5th International Coral Reef Congress, 4: 379-384.

Baine, M. **2001**. Artificial reefs: A review of their design, application, management, and performance. Ocean and Coastal Management, 44: 241-259. http://dx.doi.org/10.1016/S0964-5691(01)00048-5, access date 16/1/13.

Blum, M.D., Misner, T.J., Collins, E.S., and Scott, D.B. **1998**. Rapid sea level rise and highstand (+2 m) during the middle Holocene, central Texas coast. Abstracts, Geological Society of America, 30: 7.

Blum, M.D., Misner, T.J., Collins, E.S., Scott, D.B., Morton, R.A., and Aslan, A. **2001**. Middle Holocene sea-level rise and highstand at 12 m, central Texas coast. Journal of Sedimentary Research, 71: 4.

BOEM. **2012**. BOEM Governing Statutes. http://www.boem.gov/Regulations/BOEM-Governing-Statutes.aspx, access date 16/1/13.

Boland, G.S. **2002**. Fish and epifaunal community observations at an artificial reef near a natural coral reef: Nineteen years at High Island platform A-389-A, from bare steel to coral habitat. Proceedings of the Gulf of Mexico Science Forum - Fish and Fisheries: Bringing together new and recent research, New Orleans, La, MMS 2002-004.

Brazeau, D.A., Sammarco, P.W. and Gleason, D.F. **2005**. A multi-locus genetic assignment technique to assess local recruitment of *Agaricia agaricites* on coral reefs. Marine Biology, 147: 1141-1148.

Breitburg, D.L., Palmer, M.A., and Loher, T. **1995**. Larval distributions and the spatial patterns of settlement of an oyster reef fish: Responses to flow and structure. Marine Ecology Progress Series, 125: 45-60.

Bright, T.J., Gittings, S.R. and Zingula, R. **1991**. Occurrence of Atlantic reef corals on offshore platforms in the northwestern Gulf of Mexico. Northeast Gulf Science, 12: 55-60.

Byers, J.E. **2002**. Impact of non-indigenous species on natives enhanced by anthropogenic alteration of selection regimes. Oikos, 97: 449-458.

Cairns, S.D. **1999**. Species richness of recent Scleractinia. Atoll Research Bulletin, Report Number 459, 46 pp.

Cairns, S.D. **2000**. Revision of the shallow-water Azooxanthellate Scleractinia of the western Atlantic. Studies of the Natural History of the Caribbean Region, 75: 1-240.

Childs, J. **1998**. Nocturnal mooring and parking behavior of three monacanthids (filefishes) at an offshore production platform in the northwestern Gulf of Mexico. Gulf of Mexico Science, 16: 228.

Cripps, S.J. and Aabel, J.P. **2002**. Environmental and socio-economic impact assessment of Ekoreef, platform rigs-to-reefs development. ICES Journal of Marine Science, 59: S300-S308.

Curray, J.R. **1965a**. Late Quaternary history, continental shelves of the United States. *In* The Quaternary of the United States, pp. 723-735, Ed. by H.E. Wright, Jr., and D.G. Frey, Princeton University Press, Princeton, New Jersey, 922 pp.

Curray, J.R. **1965b**. Sediments and history of Holocene transgression, continental shelf, northwest Gulf of Mexico: American Petroleum Institute Project 51. Proceedings of the American Association of Petroleum Geologists, Tulsa, pp. 221-266.

Dauterive, L. **1999**. Rigs-to-Reefs policy, progress, and perspective. Society of Petroleum Engineers/ Environmental Protection Agency Exploration and Production Environmental Conference, March 1999, Austin, TX, 6 pp.

Dauterive, L. **2000a**. Rigs to reefs policy, progress, and perspective. Diving for Science in the 21st Century, Proceedings of the 20th Annual Symposium of the American Academy of Underwater Science, St. Petersburg, Florida, pp. 64-66.

Dauterive, L. **2000b**. Rigs to reefs policy, progress, and perspective. New Orleans, Louisiana: U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico Outer Continental Shelf Region, OCS Study MMS 2000-073.

Driessen, P.K. **1989**. Offshore oil platforms: Mini-ecosystems. *In* Petroleum structures as artificial reefs: A compendium. 4th International Conference on Artificial Habitats for Fisheries, Rigs-to-Reefs Special Session, Miami, FL Nov. 4, 1987, pp. 3-5.

Fenner, D. **2001**. Biogeography of three Caribbean corals (Scleractinia) and the invasion of *Tubastraea coccinea* into the Gulf of Mexico. Bulletin of Marine Science, 69: 1175-1189.

Fenner, D. and Banks, K. **2004**. Orange cup coral *Tubastraea coccinea* invades Florida and the Flower Garden Banks, Northwestern Gulf of Mexico. Coral Reefs, 23: 505-507.

Francois, D.K. **1993**. Federal Offshore Statistics: 1992. Leasing, Exploration, Production, and Revenues as of Dec. 31, 1992. MMS 93-0066. U.S. Dept. Interior, Minerals Management Service, Herndon, Virginia, 155 pp.

Frost, S.H. **1977**. Oligocene reef coral biogeography Caribbean and western Tethys. *In* Second International Symposium on Corals and Fossil Coral Reefs, Paris, Ed. by M.J.A. Werger, Mémoires du Bureau de Recherches Géologiques et Minières, 89: 342-352.

Frumkes, D.R. **2002**. The status of the California Rigs-to-Reefs Programme and the need to limit consumptive fishing activities. ICES Journal of Marine Science, 59: S272-S276.

Futuyma, D.J. **1998**. Evolutionary Biology, 3rd edn. Sinauer Associates, Sunderland, Massachussetts.

Gallaway, B.J., and Lewbel, G.S. **1981**. The ecology of petroleum platforms in the northwestern Gulf of Mexico: A community profile. USFWS Office of Biology Services, Washington, D.C., FWS 10BS-82/27, Open File Report 82-03.

Hickerson, E.L., Schmahl, G.P., and Weaver, D.C. **2006**. Patterns of deep coral communities on reefs and banks in the northwestern Gulf of Mexico. EOS, Transactions of the American Geophysical Union 87 (36), supplement.

Humann, P., N. DeLoach, N. **2002**. Reef coral identification: Florida, Caribbean, Bahamas. New World Publishers, Jacksonville, Florida.

Hunte, W., and Wittenberg, M. **1992**. Effects of eutrophication and sedimentation on juvenile corals. Marine Biology, 114: 625-631.

Kaiser, M.J., and Pulsipher, A.G. **2005**. Rigs-to-Reef Programs in the Gulf of Mexico. Ocean Development and International Law, 36: 119-134.

Knott, D. **1995**. U.S. lessons for U.K. platform disposal. Oil and Gas Journal, 93: 17-18.

Lindberg, W.J., Frazer, T.K., Portier, K.M., Vose, F., Loftin, J., Murie, D.J., Mason, D.M., Ngy, B., and Hart, M.K. **2006**. Density-dependent habitat selection and performance by a large mobile reef fish. Ecological Applications, 16: 731-746.

Louisiana Department of Wildlife and Fisheries. **2012**. Louisiana artificial reef program (map). http://www.wlf.louisiana.gov/sites/default/files/pdf/page_fishing/32430-Artificial%20Reef%20Program/ldwf_reef_map_01.03.12.pdf, access date 16/1/13.

Love, M.S., Caselle, J.E., Snook, L. **2000**. Fish assemblages around seven oil platforms in the Santa Barbara Channel area. Fish. Bull. Fish. Wildl. Serv. US, 98: 96–117.

McDonough, M., and Cowan, J. **2006**. Tracking red snapper movements around an oil platform with an automated acoustic telemetry system. 59th Gulf and Caribbean Fisheries Institute, p. 159-163.

Miller, M.W., Valdivia, A., Kramer, K.L., Mason, B., Williams, D.E., and Johnston, L. **2009**. Alternate benthic assemblages on reef restoration structures and cascading effects on coral settlement. Marine Ecology Progress Series, 387: 147-156.

Peterson, C.H., Summerson, H.C., Thomson, E., Lenihan, H.S., Gravowski, J., Manning, L., Micheli, F., and Johnson, G. **2000**. Synthesis of linkages between benthic and fish communities as a key to protecting essential fish habitat. Bulletin of Marine Science, 66: 759-774.

Pitcher, T.J., and Seaman, W. Jr. **2000**. Petrarch's principle: How protected human-made reefs can help the reconstruction of fisheries and marine ecosystems. Fish and Fisheries, 1: 73-81. DOI: 10.1046/j.1467-2979.2000.00010.x

Reed, J.K. **2002**. Deep-water *Oculina* coral reefs of Florida: Biology, impacts, and management. Hydrobiologia, 471: 43-55.

Rezak, R., Bright, T.J., and McGrail, D.W. **1985**. Reefs and Banks of the Northwestern Gulf of Mexico. John Wiley and Sons, New York.

Richmond, R. **1982**. Energetic considerations in the dispersal of *Pocillopora damicornis* (Linnaeus) planulae. Proceedings of the 4th International Coral Reef Symposium, Manila, Philippines, Vol. 2, p. 153-156.

Richmond, R. **1987**. Energetics, competency, and long-distance dispersal of planula larvae of the coral *Pocillopora damicornis.* Marine Biology, 93: 527-534.

Rohlf, F.J., and Slice, D.E. **1999**. BIOMstat, Version 3.3. Exeter Software, Setauket, NY. 10 pp.

Rooker J.R., Holt, G.J., Pattengill, C.V., and Dokken, Q. **1997**. Fish assemblages on artificial and natural reefs in the Flower Garden Banks National Marine Sanctuary, USA. Coral Reefs, 16:83-92

Sammarco, P.W. **1980**. *Diadema* and its relationship to coral spat mortality: Grazing, competition, and biological disturbance. Journal of Experimental Marine Biology and Ecology, 45: 245-272.

Sammarco, P.W. **1991**. Geographically specific recruitment and post-settlement mortality as influences on coral community structure: The Cross-Shelf Transplant Experiment. Limnology and Oceanography, 36: 496-514.

Sammarco, P.W. **2013**. Corals on Oil and Gas Platforms near the Flower Garden Banks: Population Characteristics, Recruitment, and Genetic Affinity. Final Report and Executive Summary. U.S. Dept. of the Interior, Minerals Management Service, New Orleans, LA. 175 pp.

Sammarco, P.W., and Atchison, A. **2002**. Coral communities and recruitment on offshore drilling platforms in the northern Gulf of Mexico: Summary. MMS-ITM, New Orleans, LA, Jan. 2003.

Sammarco, P.W., Atchison, A., and Boland, G.S. **2003**. Drilling platforms as environmental assets: Developing an assessment protocol using adult and juvenile corals. U.S. Department of the Interior, Minerals Management Service Information Transfer Meeting, New Orleans, Louisiana, January 2002.

Sammarco, P.W., Atchison, A., and Boland, G.S. **2004**. Offshore oil and gas platforms and expansion of coral communities within the Northern Gulf of Mexico. Marine Ecology Progress Series, 280: 129-143.

Sammarco, P.W., Atchison, A.D., and Boland, G.S. **2005**. Distribution of corals colonizing oil and gas platforms in the northwestern Gulf of Mexico: A preliminary report. U.S. Dept. Interior, Minerals Management Service ITM, New Orleans, LA, Jan 2005.

Sammarco, P.W., Atchison, A.D., and Boland, G.S. **2004**. Geographic expansion and limits of corals in the NW Gulf of Mexico: Colonization of Offshore Oil and Gas Platforms Proceedings of the 10th International Coral Reef Symposium, Okinawa, Japan, 2004.

Sammarco, P.W., Atchison, A.D., and Boland, G.S., Sinclair, J., and Lirette, A. **2012a**. Geographic expansion of hermatypic and ahermatypic corals in the Gulf of Mexico, and implications for dispersal and recruitment. Journal of Experimental Marine Biology and Ecology, 436-437: 36-49. http://dx.doi.org/10.1016/j.jembe.2012.08.009, access 16/1/13.

Sammarco, P.W., Atchison, A.D., Brazeau, D.A., Boland, G.S., Sinclair, J. Lirette, A., and Tung, F. **2011**. Distribution, abundance, recruitment, and genetic affinities of corals on platforms in the Gulf of Mexico. Executive Summary. Information Transfer Meeting, February 2011, New Orleans, U.S. Dept. Interior, Bureau of Ocean Energy Management, New Orleans, LA. 7 pp.

Sammarco, P.W., and Brazeau, D.A. **2001**. Genetic affinity between corals, including spat, at three tropical W. Atlantic sites: Where do the larvae go? Proc. 30th Sci. Meeting Assn. Mar. Labs. Caribb. (AMLC), La Parguera, Puerto Rico. p. 31.

Sammarco, P.W., Brazeau, D.A., and Sinclair, J. **2012b**. Genetic connectivity in scleractinian corals across the northern Gulf of Mexico: Oil and gas platforms, and relationship to the Flower Garden Banks. Public Library of Science – One, 7(4): e30144.

Schmahl, G.P., and Hickerson, E.L. **2006a**. Ecosystem approaches to the identification and characterization of a network of reefs and banks in the northwestern Gulf of Mexico. EOS, Transactions of the American Geophysical Union 87 (36), supplement.

Schmahl, G.P., and Hickerson, E.L. **2006b**. McGrail Bank, a deep tropical coral reef community in the northwestern Gulf of Mexico. Proceedings of the 10th International Coral Reef Symposium, Japanese Coral Reef Society, Tokyo, Japan, p. 1124-1130. http://www.reefbase.org/resource_center/publication/pub_26873.aspx

Schmahl, G.P., Hickerson, E.L., and Weaver, D.C. **2005**. Identification and characterization of deepwater coral communities on continental shelf-edge reefs and banks in the northwestern Gulf of Mexico. 3rd International Symposium on Deep-sea Coral Science and Management, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, Miami, FL, USA, Nov. 28 – Dec 2, 2005.

Schroeder D.M., Ammann A.J., Harding J.A., MacDonald L.A., and Golden W.T. **2000**. Relative habitat value of oil and gas production platforms and natural reefs to shallow water fish assemblages in the Santa Maria Basin and Santa Barbara Channel, California. *In* Proceedings of the 5th California Islands Symposium, Ed. by D.R. Browne, K.L. Mitchell, and H.W. Chaney, U.S. Department of the Interior, Minerals Management Service, Pacific Outer Continental Shelf Region, Camarillo, CA, p. 493–498.

Schroeder, W.W., Shultz, A.W., and Pilkey, O.H. **1995**. Late Quaternary oyster shells and sea-level history, inner shelf, northeast Gulf of Mexico. Journal of Coastal Research, 11:664-674

Sheehy, D.J., and Vik, S.F. **2010**. The role of constructed reefs in non-indigenous species introductions and range expansions. Ecological Engineering, 36: 1-11. http://dx.doi.org/10.1016/j.ecoleng.2009.09.012, access 16/1/13.

Shinn, E.A. **1973**. Pipes, plankton, and pompano. Shell News, 17: 6-7.

Shinn, E.A. **1974**. Oil structures as artificial reefs. *In* Proceedings of the Artificial Reef Conference, Ed. by L. Colunga and R. Stone, Texas A&M Univ., Bryan, TX, (TAMU-56-74-103), p. 91-96.

Shinn, E.A., and Wicklund, R.I. **1989**. Artificial reef observations from a manned submersible off Southeast Florida. Bulletin of Marine Science, 44: 1041-1050.

Snell, T., Foltz, D., and Sammarco, P.W. **1998**. Variation in morphology *vs.* conservation of a mitochondrial gene in *Montastrea cavernosa* (Cnidaria, Scleractinia). Gulf of Mexico Science, 16: 188-195.

Sokal, R.R., and Rohlf, F.J. **1981**. Biometry. W.H. Freeman and Co., San Francisco. 859 pp.

Sonnier, F., Teerling, J., and Hoese, H.D. **1976**. Observations on the offshore reef and platform fish fauna of Louisiana. Copeia, 1: 105–111.

Stanley, D.R., and Wilson, C.A. **1997**. Seasonal and spatial variation in the abundance and size distribution of fishes associated with a petroleum platform in the northern Gulf of Mexico. Canadian Journal of Fisheries and Aquatic Science, 54: 1166-1176.

Stanley, D.R., and Wilson, C.A. **2000**. Variation in the density and species composition of fishes associated with three petroleum platforms using dual beam hydroacoustics. Fisheries Research, 47: 161-172.

Texas Parks and Wildlife Service. **2012**. Artificial reefs make it all real. http://www.tpwd.state.tx.us/landwater/water/habitats/artificial_reef/overview.phtml

Velazquez, E. **2010**. Increased permit approval time could delay future commissioning. E&P Mag., Sept. 1, 2010, http://www.epmag.com/Technology-Regulations/Increased-permit-approval-time-delay-future-decommissioning_66340

Winfield, T. **1973**. A fish story you can believe. In: Man-made oasis for fish, Shell News, 17: 1-463-6-73, 2–5.

Winker, C.D., and Buffler, R.T. **1988**. Paleogeographic evolution of early deep-water Gulf of Mexico and margins, Jurassic to Middle Cretaceous (Comanchean). American Association of Petroleum Geologists Bulletin, 72: 318-346.

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