Ecological Survey of Puhi Bay and Richardson's Ocean Center

Marine Option Program Final Report

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Abstract

On the eastern side of the Big Island of Hawaii, Keaukaha has been hypothesized to exhibit reef fish community degradation. However, there has not been a quantitative study examining whether or not the reef fish community has declined. To determine if fish communities have declined, fishes and corals were surveyed at two study sites, Puhi Bay and Richardson's Ocean Center, using 25-m strip transects from June to October 2013 and were compared to similar surveys conducted in 2001. In addition, rugosity and benthic cover data were collected at these sites to determine if changes in habitat will explain the variation in fish communities. Species richness and abundance at these sites was used to infer whether or not the reef fish are in decline and habitat data was examined as a factor to explain variation in fish community structure. Benthic structure, coral composition and fish composition differed among sites and depths. The fish species richness in 2013 was not significantly different between sites at equal depths or within sites at different depths however, the coral species richness in the same year was significantly different between depths for a given site (Richardson's Ocean Center, $t = -5.91$, $p = 0.001$; Puhi Bay $t = -4.27$, $p = 0.008$). This information is useful in the initial assessment to determine if an area has scientific justification for considering the use of Marine Protection Area (MPA) design for near shore fishery management. Although, fishery trends cannot be determined from this study, data on species differences can provide baseline data for future studies that can determine fish population trends, factors influencing these trends and management options for these fisheries can be assessed.

Introduction

Around the world near shore ecosystems are becoming depleted due to over exploitation (Friedlander et al., 2007a). Historically, Hawaiian culture recognized the importance of coral reefs and had implemented various methods such as the Kapu system to regulate fishing (Komoto & Gombos, 2007). However in recent times demographic changes have led to the deterioration of coastal reefs (Komoto & Gombos, 2007). For the past 40 years, the state of Hawaiʻi established and managed numerous Marine Protection Areas (MPAs) as a way to restore deteriorated coral reefs (Friedlander et al., 2007; Komoto & Gombos, 2007). MPAs were developed to resolve various social and economic problems between beach users as well as providing legal protection for reefs to reestablish by reducing fishing pressure from humans (Friedlander et al., 2003). The state of Hawaiʻi recognizes several types of Marine Protection Areas including "[…] marine life conservation district (MLCD), fishery management area (FMA), regional fishery management area with fisheries replenishment areas (FRAs), bottomfish restricted fishing area (BRFA), natural area reserve (NAR), cultural reserve, wildlife sanctuary, marine laboratory refuge, and marine refuge" (Komoto & Gombos, 2007). Each classified marine protection area type is designed with various objectives. Some MPAs are very similar and may only differ by the amount of restriction opposed like FMAs that allow restricted fishing and MLCDs that ban removal of all marine organisms (Komoto & Gombos, 2007). MPAs provide areas for non-consumptive recreational and tourist industries to use which can alleviate resource user conflicts (Friedlander et al., 2007a).

The main variables that are considered when determining if there is scientific justification for implementing a MPA includes the determination of the marine environment as pristine or greatly degraded, community support for protection, clearly defined boundaries and an adequate size that is large enough for fish replenishment but small enough to allow plenty of fishing areas for fisherman (Komoto & Gombos, 2007). When examining a site for MPA consideration numerous ecological variables need to be considered such as habitat type, quality, and diversity as well as fish species richness, abundance, and special distribution. Previous studies have found that dominant benthic structural type can influence the fish species composition of a site (Friedlander et al., 2007b). Areas with different benthic cover types have different species compositions making areas with heterogeneous benthic compositions ideal for protecting species richness and abundance (Friedlander et al., 2007b). Currently, MPAs in Hawaii are too small to protect the area required for important resource fish home ranges and many species actively swim between protected and open sights (Meyer 2006). Even with this active movement between MPA boundaries, MPAs have been found to contain higher fish species richness, abundance, and biomass (Meyer 2006). The amount of protection whether it was structural habitat for refugee, protection from fishing or protection from waves were all found to positively influence fish species richness and abundance (Friedlander et al., 2003).

Friedlander et al. (2007b) determined that MLCD's with high habitat complexity and good habitat quality with low macroalgae cover and high coral cover had greater fish assemblage characteristics. Habitat complexity provides more refuges for organisms thus increasing species diversity (Friedlander et al. 2007a & 2007b). It was determined that rugosity and depth were major contributions to the species richness of fish (Friedlander et al. 2007). Certain feeding guild like Apex predator fish, compose the majority of fish in certain ecosystems such as sand bottomed areas in this case (Friedlander et al. 2007). Friedlander et al. (2007) claims that Hawaiʻi protection policy has developed protection areas that are too small and shallow to adequately preserve ecosystem function and enhance fish stock. Meyer (2007) similarly recommends that MPAs need to be large enough to include the entire daily home range of reef fish. Therefore future MPAs need to address habitat complexity, depth ranges and size in the determination process.

Agardy (2000) explained that the first step in developing a MPA is based on community support and scientific studies are secondary. The newest marine protected areas focused on addressing concerns of various coastal users and integrated all of these ideas into fish management policy (Agardy 2000). Agardy claims there were three reasons marine preserves were formed, to preserve pristine habitat, alleviate user conflicts, and to replenish a degraded region. Large zoned marine conservation networks may be the best solution because large reserves are more adequate at conserving fish habitat and can be zoned to benefit multiple users (Agardy 2000). Other studies integrated roving creel survey with *in situ* interviews of fisherman to try and incorporate data from multiple user groups into MPA assessment (Meyer 2007).

In this study, two sites in Hilo, Hawaiʻi were evaluated to determine if there is scientific justification for the establishment of an MPA. The study compared Puhi Bay's fish communities with Richardson's Ocean center to assess whether they differ from each other. The study examined fish communities at Richardson's Ocean Center and Puhi Bay and compared them to two independent studies by Dr. Hallacher's and Dr. Rodger's in 2001. The rugosity, substrate types and composition and two depth classes were the variables used to try and explain any variations in the fish communities at these sites. The main hypothesis is that both sites differ from each other and that the areas with a higher percentage of live coral cover will have a greater fish species richness and abundance. In addition, rugosity is hypothesized to explain the variation in fish species richness as seen in other studies.

Methods

Biological surveys were conducted at Puhi Bay and Richardson Ocean Center. At each site two depths zones were surveyed, shallow (less than 40 feet) and deep (greater than 40 feet). Transects were placed hap-hazardly to try to include the variation in benthic structure type in each depth zone. The biological surveys methods included rugosity, benthic photo-quadrate survey and fish strip transect survey. The benthic photo-quaduat and fish strip transect will be a replicate of the Hallacher et al. (2004) study with the modifications including transect location and the use of SCUBA (self-contained underwater breathing apparatus) instead of snorkeling. The standard method for measuring rugosity (Friedlander et al., 2003; Rodgers, 2005; Friedlander et al., 2007a; Friedlander et al., 2007b) was used for comparison with Rodger (2005) study at Puhi Bay. The rugosity and photo-quadrat surveys were conducted once per transects to assess structural complexity and benthic composition while fish strip transects were surveyed a total of forty-four times; when all sites and transects are pooled, to characterize fish community composition at these sites.

The benthic composition was measured using a modified photoquadrat method (Hallacher et al. 2004) where 20 random point per quadrat was used and the quadrat was placed on every meter mark on a 25 meter transect. The photos were analyzed using Photogrid 1.0 protocols outlined in Smith & Faucci (2011). Fish strip transects followed standard protocols (Friedlander et al., 2003; Rodgers, 2005; Friedlander et al., 2007a; Friedlander et al., 2007b) with the only modification being that only 2 meters of either side were assessed instead of 2.5 meters as seen in Hallacher et al. (2004). Microsoft Excel and Minitab 16 were used to statistically analyze the data using ANOVA with Tukey test comparisons and correlations.

Results

Fish communities, benthic composition and coral cover abundance varied for site, depth and year (Table 1 & 2). The most abundant family for all sites and years are Acanthuridae except at Richardson's Ocean Center shallow site 2001 where Labridae was the most abundant (Table 1). For 2013 the most abundant fish species was *Ctenochaetus strigosus* except in Richardson's Ocean Center shallow site where *Acanthurus nigrofuscus* was more abundant. These differences in fish species composition may relate to variation in habitat type since the most abundant coral types and substrate compositions differed for each site and year (Table 2). In the past *Porites lobata* was more common and at least for Richardson's, turf algae was more common than macro algae. The presence of live coral and macro algae being the most abundant benthic cover for almost all the 2013 sites may explain why Acanthuridae, a family consisting of herbaceous reef fish were the most abundant family. In sites with either high turf algae or sand fish families with most of the represent species fell into the mobile invertebrate feeding guild like Labridae and Mullidae were more common.

Table 1: Three most abundant fish species and families at each site for each year

	Fish Family			Fish Species		
	Name	Number of Species	Abundance	Name	Mean	Standard Deviation
Puhi Bay 2001 (Rodgers 2005)	Acanthuridae	7	262	Acanthurus nigrofuscus	26.6	9
	Labridae	9	106	Thalassoma duperrey	9.4	3.3
	Pomacentridae	4	71	Stegastes fasciolatus	5.8	4.7
Puhi Bay 2013 Shallow	Acanthuridae	3	436	Ctenochaetus strigosus	7.8	1
	Pomacentridae	5	248	Acanthurus nigrofuscus	6.2	0.8
	Labridae	8	185	Stegastes fasciolatus	5.3	0.8
Puhi Bay 2013 Deep	Acanthuridae	4	68	Ctenochaetus strigosus	2.9	2.1
	Mullidae	3	25	Apogon kallopterus	1.7	1.6
	Labridae	3	20	Acanthurus nigrofuscus	1.3	1.3
Richardson's 2001 (Hallacher et al. 2004)	Labridae	-	3952	Thalassoma duperrey	2238	n/a
	Pomacentridae	-	3331	Stegastes fasciolatus	1738	n/a
	Acanthuridae	-	988	Stethojulis balteata	1418	n/a
Richardson's 2013 Shallow	Acanthuridae	3	569	Acanthurus nigrofuscus	11.7	2.6
	Pomacentridae	4	241	Ctenochaetus strigosus	7.1	2.6
	Cirrhitidae	4	207	Paracirrhites arcatus	5.6	1.6
Richardson's 2013 Deep	Acanthuridae	4	298	Ctenochaetus strigosus	15.2	4.9
	Labridae	8	112	Acanthurus nigrofuscus	5.1	3.4
	Scaridae	2	74	Thalassoma duperrey	5	3.9

Table 2: Three most abundant benthic cover types and coral species for each site and year

	Benthic Cover			Coral Cover		
	Name	Mean	Standard Deviation	Name	Mean	Standard Deviation
Puhi Bay 2001 (Rodgers 2005)	n/a			Porites lobata	0.3	n/a
	n/a			Porites compressa	0.23	n/a
	n/a			Montipora capitata	0.13	n/a
Puhi Bay 2013 Shallow	Live Coral	0.46	0.1	Porites compressa	0.11	0.03
	Macro Algae	0.23	0.1	Montipora capitata	0.08	0.05
	Sand	0.08	0.04	Porites evermanni	0.06	0.03
Puhi Bay 2013 Deep	Sand	0.66	0.12	Montipora capitata	0.03	0.02
	Rubble	0.15	0.06	Porites rus	0.02	0.03
	Live Coral	0.9	0.07	Montipora patula	0.02	0.02
Richardson's 2001 (Hallacher et al. 2004)	Turf Algae	0.49	n/a	Porites lobata	0.15	n/a
	Live Coral	0.21	n/a	Pocillopera meandrina	0.02	n/a
	Crustose Algae	0.15	n/a	Montipora flabellata	0.02	n/a
Richardson's 2013 Shallow	Live Coral	0.34	0.09	Porites evermanni	0.1	0.05
	Rubble	0.19	0.1	Montipora capitata	0.06	0.04
	Macro Algae	0.18	0.08	Porites lobata	0.05	0.03
Richardson's 2013 Deep	Macro Algae	0.28	0.13	Porites compressa	0.12	0.02
	Live Coral	0.27	0.09	Porites evermanni	0.12	0.1
	Rubble	0.27	0.07	Porites lobata	0.01	0.02

Fish species richness was found to significantly differ between sites and years (F=26.19, p<0.001) while all the differences were observed at Richardson's Ocean Center but not at Puhi Bay (Fig 1). This pattern was also seen in fish species abundance for most fish species as seen in Figure 2 (F = 228.55, p<0.001). There were a few exceptions with *C. strigosus* (F=13.83, p<0.001) being the most extreme with greater species abundance occurring in 2013 than seen in previous years (Fig. 3). The Puhi Bay deep site had a very different benthic composition compared to the other 2013 site possible explaining why *C. strigosus* abundance was not significantly different from 2001 levels (Fig. 3). Interestingly, in this study rugosity did not significantly correlate to fish species richness at any of the sites (Fig. 4) thus other factors may better explain the variation observed.

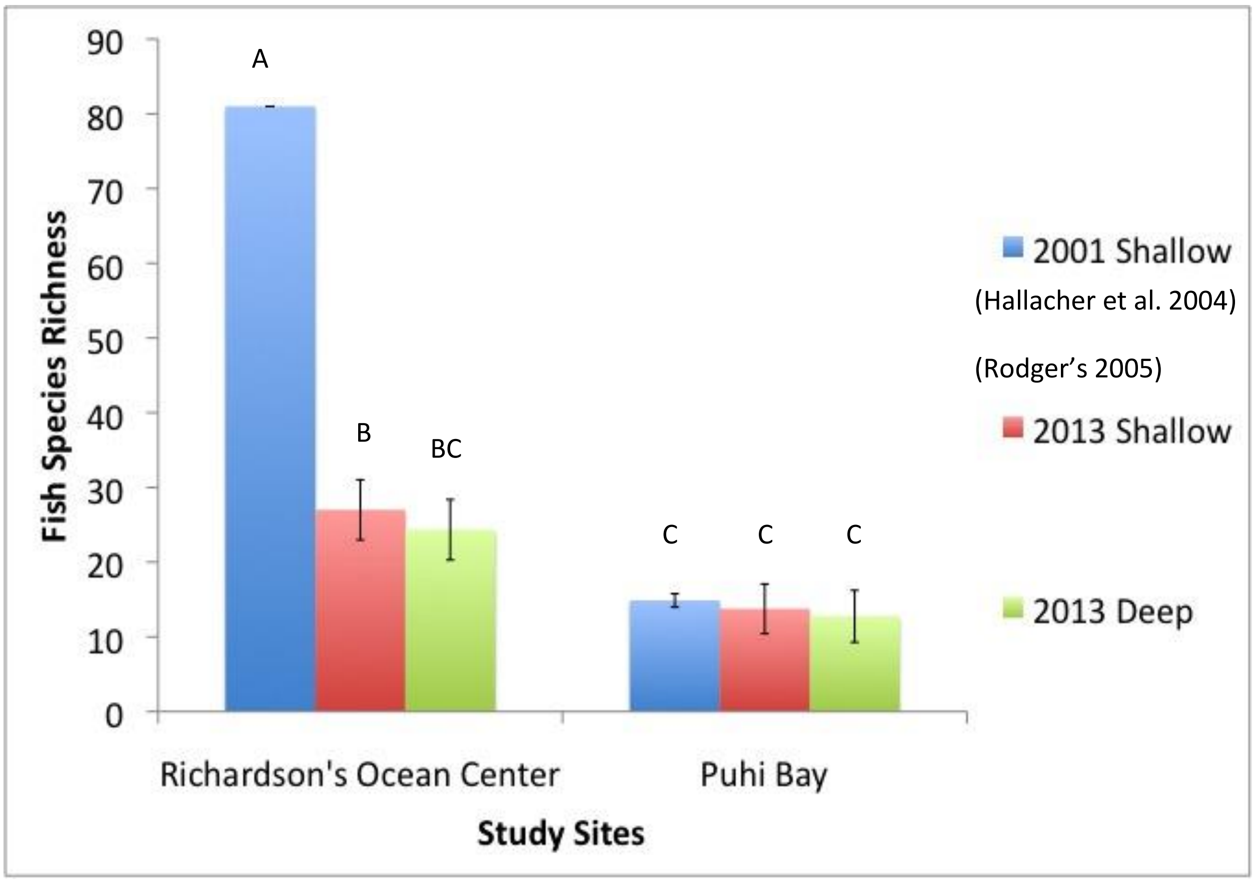

Figure 1: Fish species richness significantly differed between each site, depth and year (F=26.19, p<0.001) with Richardson's Ocean Center having significant differences while Puhi Bay did not significantly differ as seen with the Tukey's Comparison Test.

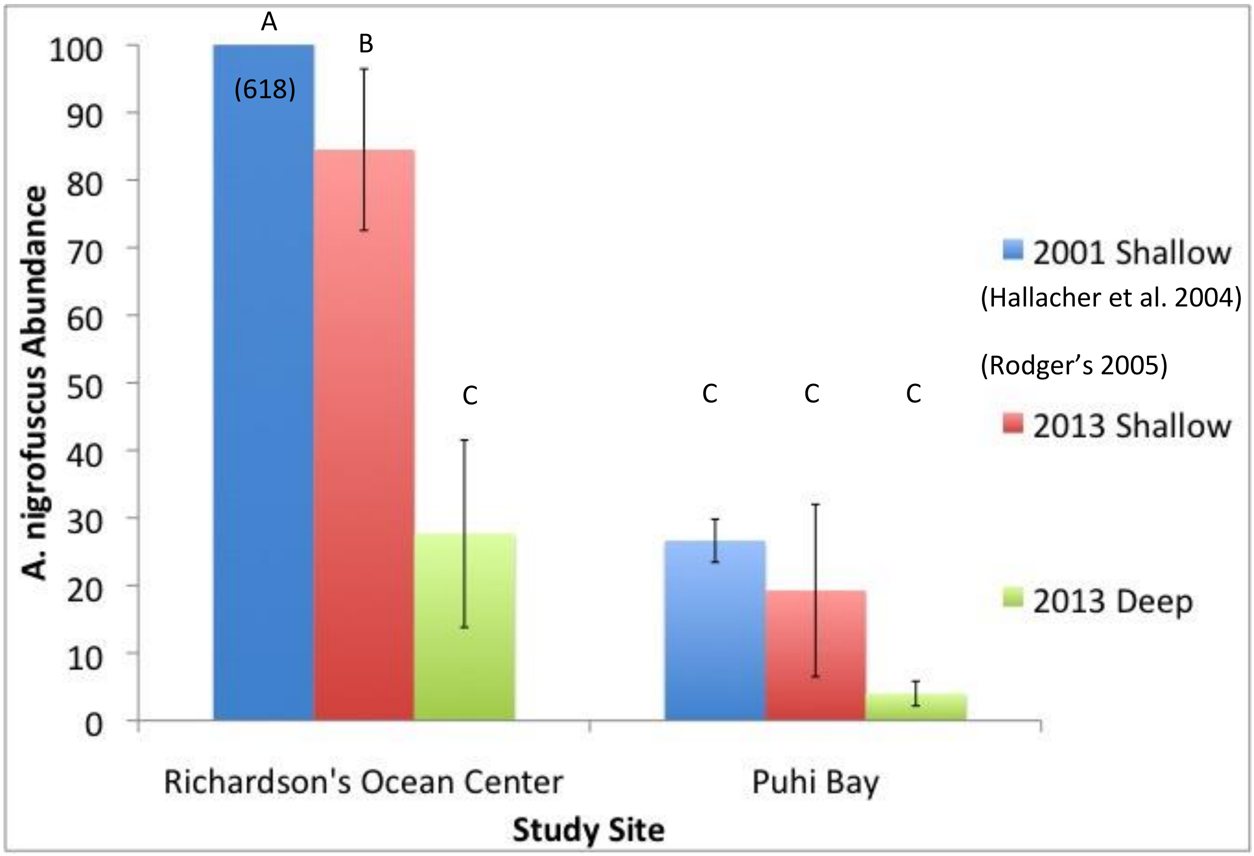

Figure 2: Typical pattern seen for fish species abundance as demonstrated by *A. nigrofuscus* where fish species abundance significantly differed between each site, depth and year (F=228.55, p<0.001) with Richardson's Ocean Center having significant differences while Puhi Bay did not significantly differ as seen with the Tukey's Comparison Test.

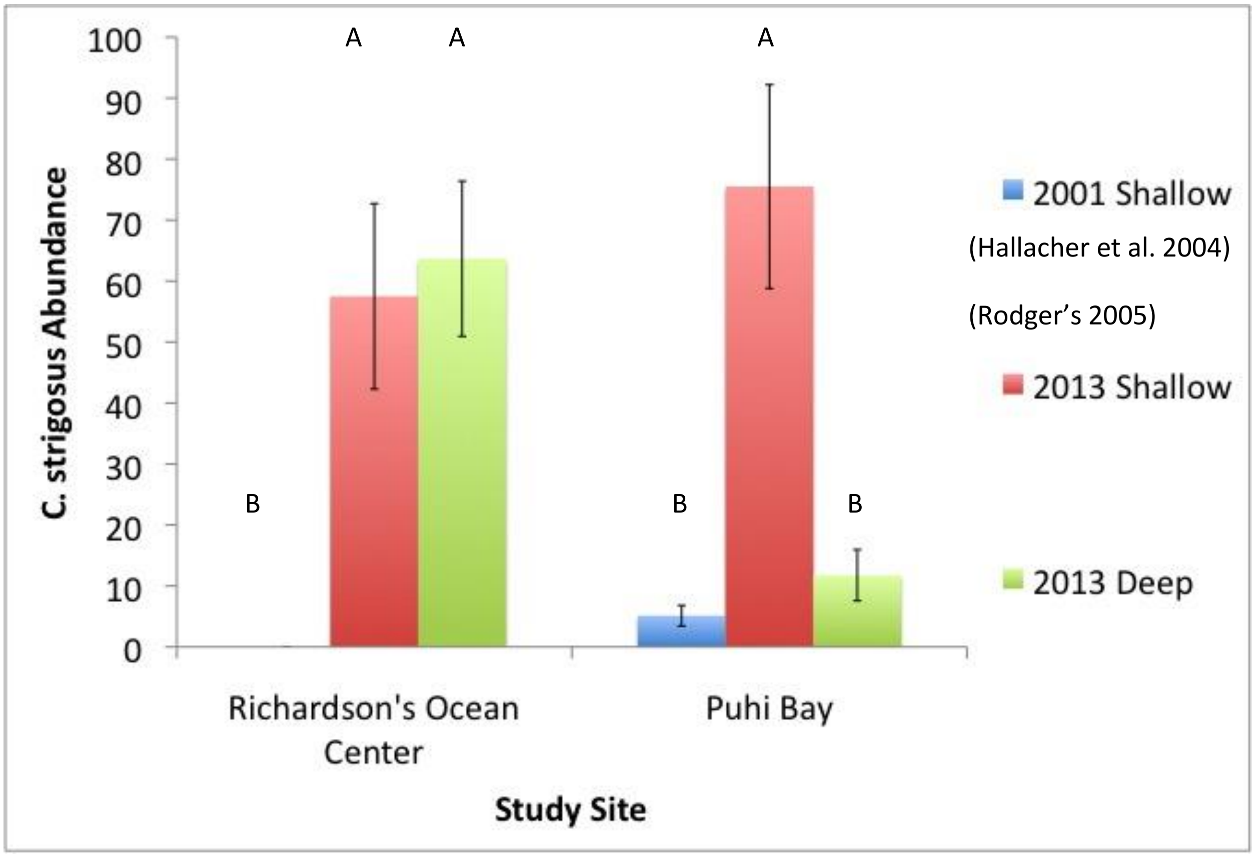

Figure 3: Notable exception to the typical pattern seen for fish species abundance as demonstrated by *C. strigosus* where fish species abundance significantly differed between each site, depth and year (F=13.83, p<0.001) with Richardson's Ocean Center having significant differences while Puhi Bay did not significantly differ as seen with the Tukey's Comparison Test.

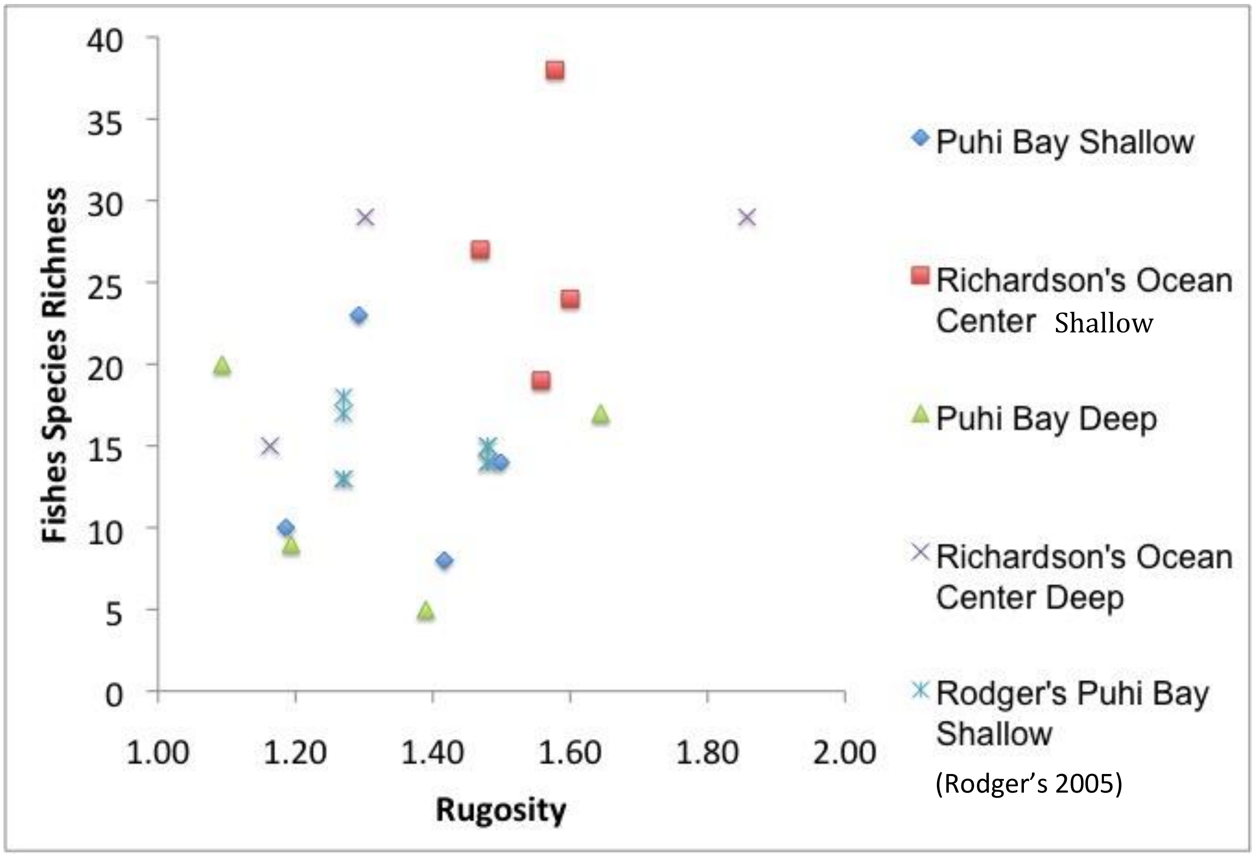

Figure 4: There were no significant correlations at any of the listed sites (Puhi Bay Shallow, r = -0.097, p = 0.903; Richardson's Ocean Center Shallow, r= 0.070, p = 0.930; Puhi Bay Deep, r = -0.066, p = 0.930; Richardson's Ocean Center Deep, r = 0.654, p = 0.546; Rodger's Puhi Bay Shallow r = -0.222, p = 0.598).

Discussion

This study found that community differences do exist between site, depth and year. The study tried to explain the variation in the ecological community by examining the structural complexity of the reef in the form of a rugosity measurement. Contrary, too many studies that support that rugosity explained the variation in fish species richness (Friedlander et al., 2003; Friedlander et al., 2007b); the results of this study indicate the rugosity did not explain the variation in fish species richness. Other reef fish community characteristics like fish species richness and abundance were found to be very site depended with both factors differing between depths and year at Richardson's Ocean Center but not at Puhi Bay. This observation was seen in Friedlander et al. (2007) study where they found that variation in fish species richness was explained by depth (64%) and dominant benthic structure (13.4%). An earlier study by Friedlander et al. (2003) found that the abundance of lobed coral had higher fish species richness. This study neither confirms nor debunks this because Puhi Bay's fish species richness was not significantly different from the previous study in 2001 even though the quantity of lobe coral was higher in the past for Richardson's Ocean Center which had both greater lobed coral cover and fish species richness in the past.

This study should be interpreted as a pilot study that contains valuable data in the event the community or government decides to consider implanting MPAs as a management strategy for these two locations. As Meyer (2007) stated that there is a lack of empirical studies of Hawaiian fringing reefs and this study examined a fringing reef that lacked adequate assessment. The study included data to expand the area that could be assessed since current MPAs are considered too small and shallow to protect biodiversity and replenish declining fish stocks (Friedlander et al., 2007a). Other studies determined that great species richness was observed in MLCDs that included a wider depth range (Friedlander et al., 2007b); indicating that future MPAs should include depth gradients into their design. MPAs design needs to incorporate areas with heterogeneous benthic composition, depth gradients and larger areas in order to adequately protect the ecosystem thus preserving fish communities (Friedlander et al., 2007b). Other studies like Tissot et al. (2004) found that marine protection areas can increase fish species richness and abundance both within and outside protection areas by means of the spillover effect. Therefore, future studies should continue to monitor areas both within and outside areas that may be considered for becoming marine protection areas so the effectiveness of marine protection has reference data. In addition Meyer (2006) found that spearfishing had higher fishing success then pole fishing and that management of the type of fishing allowed in an area can improve fish stocks. For Keaukaha, future studies should consider examining fishing success and catch by different methods to see if variation in fish species richness and abundance is explained by fish exploitation.

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