Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008
Session number 14

Variation in coral recruitment on Fijian reefs

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Abstract. Recruitment patterns of scleractinian and milleporan corals were investigated at Suva Harbour, Great Astrolabe Reef, and Taveuni. The lowest recruitment rate occurred at a site in Suva Harbour while the highest recruitment rate occurred on a reef periodically disturbed by high rates of sedimentation. Recruitment was >7 times greater in summer than winter with the greatest seasonal variation occurring in Acroporidae. Pocilloporidae, Poritidae, Faviidae and unidentified recruits had higher recruitment rates in deeper water while Acroporidae recruited primarily to shallow waters. The number of recruits from broadcast spawning acroporids was high, which was probably related to the high frequency of occurrence of the family. More than half (52%) of all recruits were acroporids.. Recruitment was unexpectedly high at a site with periodically high sedimentation levels. Seawater temperatures recorded during the study fell within the normal range for the area.

Key words: Acroporidae, planulae, Pocilloporidae, Poritidae, larva

Introduction

Fiji has one of the largest coral reef systems in the SW Pacific, with >1000 reefs. Although Fiji pos-sesses hundreds of kilometers of coral reefs that are an important source of food (Quinn & Kalangi 1998) and revenue for many people (Quinn & Davis 1998), little is known about coral recruitment processes on the reefs. Many of the ecological studies of corals in Fiji have been limited to species lists (Gawell & Seeto 1982) or surveys of bleached corals (Cummings et al. 2002). While recruitment patterns of juvenile corals are important to the overall community structure of coral reefs (Harrison & Wallace 1990), there have been no studies that examined the variation in recruitment of corals in Fiji.

This study looked at inter annual, seasonal, and geo-graphic variation in coral recruitment over two years and compared the results with other similar studies. Suspended sediment and subsurface temperature were recorded to document two factors that were considered likely to influence settlement.

Material and Methods

Survey sites

Suva Harbour (SH)

Suva Harbour contains the main port for the capital city of Fiji, Suva (Fig. 1). Two sampling sites were chosen in SH (18°07'S; 178°21'E). One was within the lagoon adjacent to the Suva Channel (SC) and the other, Fish Patch (FP), on the outer reef slope adjacent to the harbor entrance. The Suva Channel reef is near the main port in polluted water (Naidu & Morrison 1994, Davis et al. 1998), FP is in less pol-luted water, but has experienced *Acanthaster planci* infestation (Zann et al. 1990, pers. observation).

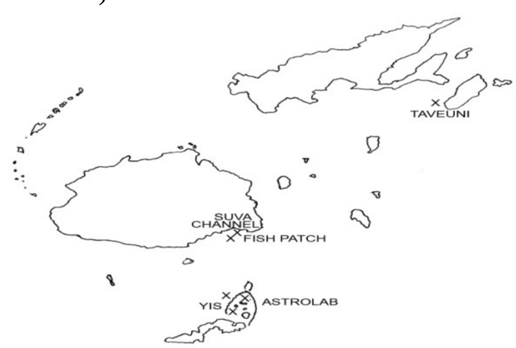

Figure 1. Sampling locations around Fiji.

Great Astrolabe Reef (GAR)

The Great Astrolabe Reef (8°45'S.; 178° 30' E) is an atoll situated 70km south of Viti Levu with a typical depth of 20m. The total human population of the villages on all the 13 islands within the reef is ~1000 people. There were three sampling sites at GAR. One was adjacent to one of the islands, Yanuyanu-i-sau (YIS) (18° 47'S; 178°30'E). YIS is a small, uninhab-ited island, <13.5 ha (Naqasima et al. 1992), that contained seven goats in 1996. The goats, put there years ago by people from the neighboring island, have eaten all of the leafy vegetation to a height of ~1.5m. Consequently, the island is bare of ground vegetation and during heavy rain from December to April the soil washes down the steep slopes onto the fringing reefs.

Taveuni (TA)

Taveuni (16°59'S.; 179°53'E.) (Fig. 1) is an island 200km north of Viti Levu. Except for a few small plantations and resorts, the island lacked any major commercial development.

Physical parameters

Suspended sediment traps 35cm long were con-structed from 5.2cm (2") diameter PVC pipes. Paired traps were deployed at all sample sites. The traps were collected periodically between May 1996 and April 1998. Animals, shells, and macro detrital material were removed and the remaining material was dried at 60°C for 24 hrs. The net weight was cal-culated as mg cm^{-2} day^{-1} representing the mean value of each pair of traps.

A Hugrun underwater temperature recorder (UTR) with an accuracy of $\pm$0.05°C monitored subsurface seawater temperatures hourly at GAR from 2 October 1997 to 12 December 1998.

Coral recruitment

Benthic recruitment arrays were constructed using PVC pipe each with four terracotta tiles as described in Quinn and Kojis (2003, 2006). Arrays were deployed at two depths around FP (15m, 25m), one depth in SC (15m), and two depths at TA (15m, 25m). Arrays were placed at three sites in GAR: off the south western outer wall (15m), on a lagoon patch reef (5m) 100m from Dravuni Island, and on a fring-ing reef near YIS (5m, 15m). The arrays were installed in late March / early April 1996. Tiles were replaced in October / November 1996 ("winter 1996"), March / April 1997 ("summer 1997"), September / October 1997 ("winter 1997") and in April 1998 ("summer 1998") and collected about six months later. Numbers of coral recruits on the top, bottom, and edges were counted (standardized to number recruits m^{-2}) and identified to family where possible.

Factors such as orientation of the substratum (Birkeland et al. 1981, Wallace 1985), depth (Babcock 1988); availability of larvae (Harriott & Fisk 1987); interorganismal competition (Harrison & Wallace 1990), browsing herbivores, and dispersal patterns (Sammarco & Andrews 1988), affect recruitment and consequently community structure. The first two factors were standardized in the experiment.

Results

Physical Parameters

Suspended sediment traps were sampled a total of 106 times. The sedimentation rate at each sampling time ranged from <0.1 mg cm^{-2} day^{-1} at GAR from July to October 1996 to 104.9 mg cm^{-2} day^{-1} at YIS from December to April 1997. All of the sites recorded the highest sedimentation rate from December to April. The mean sedimentation rate was highest at YIS and was nearly twice the levels at FP 15m and SC, sites with the next highest sedimentation rates, and 7.5 times higher than the rate recorded from nearby YIS. TA had the lowest sedimentation rate. Sedimentation was most variable within the GAR lagoon sites.

The subsurface sea temperature (S^{3}T) at Great Astrolabe Reef ranged from 23.6°C in October 1997 to 28.8°C in December 1998 (Fig. 2). The mean S^{3}T was 26.2°C (CV=4.3%; N=10503). On 15 January 1998, a cyclone passed within 100km of the site and the S^{3}T dropped 1.1°C within one hour. The mean S^{3}T during summer 1997 was 26.7°C (CV=4.5%), winter 1998 was 25.7 °C (CV =3.7%) a difference of 0.9 °C.

Figure 2: Subsurface seawater temperature at Great Astrolabe Reef

Coral recruitment

A total of 1628 scleractinian and 12 milleporan recruits settled on 72 tiles. The lowest recruitment was at SC (5 recruits m^{-2}, winter 1996) and the high-est at YIS (1749 recruits m^{-2}, summer 1997). Owing to the recruitment in summer 1997, YIS had the greatest total overall recruitment (3624 recruits m^{-2}). As expected the lowest total overall recruitment rate was at SC ($\bar{x}$=51 $\pm$SD 29 recruits m^{-2}yr^{-1}) and the highest recruitment rate was at YIS ($\bar{x}$=1812 $\pm$ S.D. 1275 recruits m^{-2} yr^{-1}). FP, 15m, had the next greatest recruitment. The shallow TA site had the third greatest recruitment. Except for the very low recruitment at SH, there was high mean recruitment at the sites (>323 recruits m^{-2} yr^{-1}).

Acroporidae dominated recruitment (52.2%), fol-lowed by Pocilloporidae (30.3%), others (13.0%), Poritidae (3.4%), Milleporidae (0.6%) and Faviidae (0.5%). There was a very large recruitment of Acroporidae at YIS in the summer of 1997 represent-ing nearly 30% of the total recruits. This was about double the amount that settled the following summer.

Recruitment rates for the different families varied with depth. Over 55% of the Acroporidae and 67% of the unidentified recruits recruited to the shallowest depth (5m) (Fig. 2). Most Pocilloporidae, Poritidae, Faviidae and others settled in deeper waters. Poritidae recruitment increased with increasing depth. Milleporidae almost exclusively settled at 15m. The rate of recruitment declined with increasing depth at most sites (Fig. 2): 5m - 271 recruits m^{-2}, 15m - 177 recruits m^{-2}, 25m - 142 recruits m^{-2}.

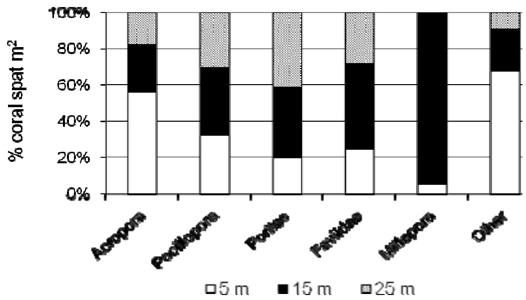

Figure 2: Percentage of coral family recruitment by depth

About six times as many coral spat recruited during the summer ($\bar{x}$=570; N=16; SD=519) compared to winter ($\bar{x}$=93; N =16; SD=101). A paired *t*-test was used to compare mean total corals for each site, there was a very highly significant difference in the rate of recruitment between seasons (*P*=0.0027; N=16). Recruitment was greater in the summer at every site (Fig. 3). The greatest difference was at YIS where recruitment was >10 greater in the summer. In contrast, the difference in the recruitment rate between summer and winter at TA was <10%.

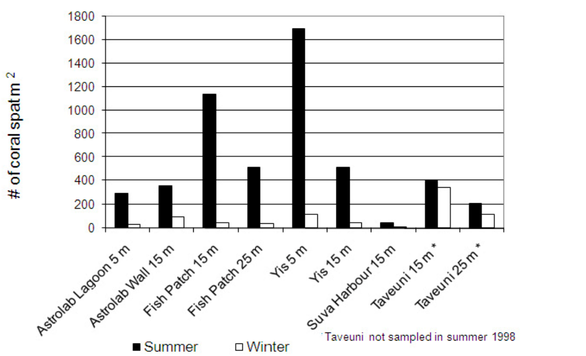

Figure 3: Total number of recruits m^{-2} by seasons and sites

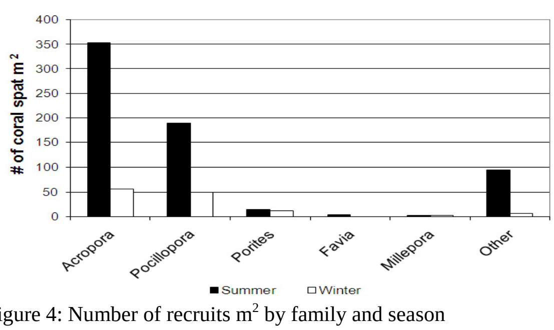

Figure 4: Number of recruits m^2 by family and season

The highest number of recruits were from the families Acroporidae and Pocilloporidae. Their recruitment rate was 7.1 and 3.9 times higher, respectively, in the summer than winter (Fig. 4). Using pooled 15m data a two way ANOVA was performed on the factors years and sites. The location factor was significant (*P* = 0.027; *df* = 4), but year was not (*P* = 0.161; *df* = 1).

The site with the greatest seasonal difference in Acroporidae recruitment (*t*=2.68; *P*=0.02, S) was YIS (Fig. 5). Seasonal recruitment differences for the Pocilloporidae (*t*=3.71; *P*=0.004; VS) were the great-est at FP (Fig. 6). Seasonal recruitment of Poritidae was variable (*t*=0.21; *P*>0.05; NS) with two sites recording more recruitment during winter than in summer (Fig. 7). The recruitment rates of both Mil-leporidae and Faviidae were much lower than other families. Faviidae recruited only in summer. Uniden-tified recruits, termed “other”, settled seven times more frequently in summer than in winter (Fig. 8).

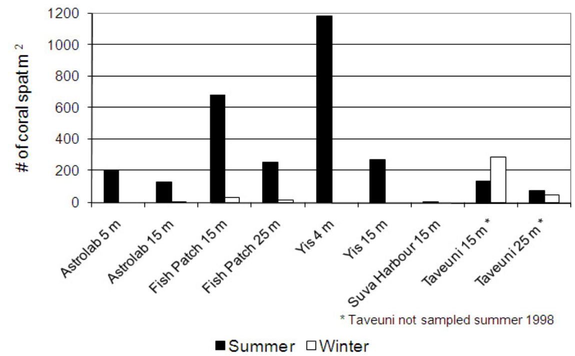

Figure 5: Number of Acroporidae recruits m^{-2} by site and season

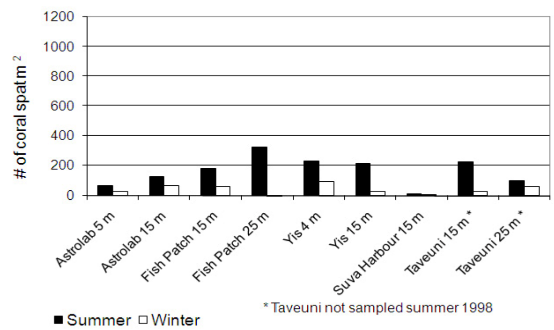

Figure 6: Number of Pocilloporidae recruits m^{-2} by site and season

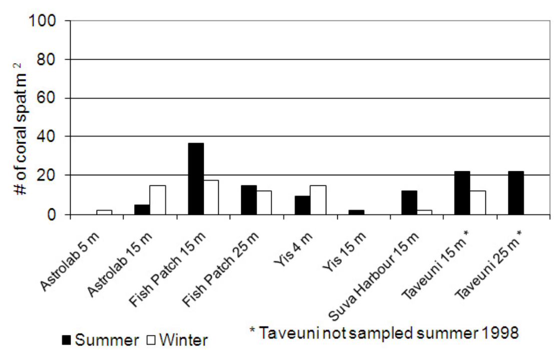

Figure 7: Number of recruits m^{-2} of Poritidae by site and season

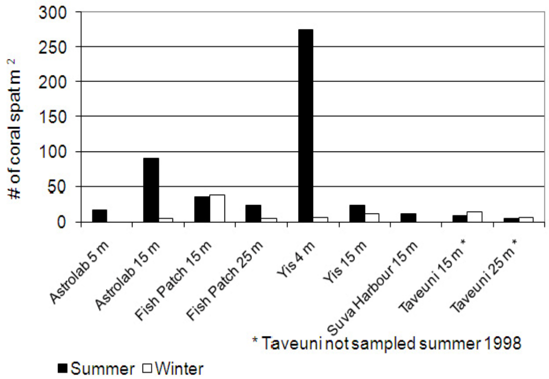

Figure 8: Number of "other" recruits m^{-2} by site and season

Discussion

The density of coral recruits at most sites in Fiji was higher than reported from other tropical sites using a similar sampling strategy (Kojis 1997, Quinn & Kojis 2002, 2003, 2008). The mean recruitment rate for summer (pooled across sites for summer 1997 and 1998) was 570m^{-2} (SD $\pm$ 519; N=9) compared with 31m^{-2} observed in Saipan; 0m^{-2}, Rota; and 35m^{-2} Tinian in the Commonwealth of the Northern Mariana Islands (CNMI) in 1995 (Quinn & Kojis 2002) and 89-160m^{-2} in the eastern Caribbean (Kojis 1997). Even the mean winter recruitment (93m^{-2}) was over three times the "summer" recruitment recorded in the CNMI. The only Fijian site with a low recruitment rate was the turbid water site in Suva Channel. Davis et al. (1998) reported finding dangerously high levels of TBT in mollusks collected in Suva Harbour and other workers have reported on the pollution in the harbor (Naidu & Morrison 1994).

Several factors probably contribute to the high recruitment rate at most sites. Firstly, the sites were on reefs with high coral cover and a rich diversity of species. Secondly, there was an abundance of healthy, fecund reefs in close proximity releasing large amounts of larvae. The number of broadcast spawning acroporids recruiting was high and was probably related to the high frequency of occurrence of the family and the large numbers of larvae they produce.

The relative abundance of the various taxa of the recruits was similar to that reported from the GBR. Acroporid recruits were dominant in Fiji (52%) and in the Cairns region (16^{o} latitude) of the GBR (65%) followed by pocilloporids: 30% - Fiji and 25% - GBR, Cairns region (Fisk & Harriott 1990). The third most abundant group was the "other". More work is required to identify young spat of many families. Poritidae spat had a higher relative abundance (3%), then on the GBR at similar latitudes, (0%) (Fisk & Harriott 1990), but were less abundant (16%) than on an isolated sub tropical reef (Lord Howe Is., 31^{o}S) (Harriott 1992). We suspect this relates to differences in the relative abundance of adults of the family on the reefs at each location.

Coral recruitment was greater in the summer than in winter and this was consistent with the pattern for the GBR (Fisk & Harriott 1990). We hypothesize that most recruitment occurred during the main coral spawning season in October/November (Fiebig & Vuki 1998). However, brooding corals often have an extended spawning season (Harrison and Wallace 1990) and this is true of pocilloporid corals (Stoddart & Black 1985), which recruited in both winter and summer.

The high number of recruits on the Taveuni tiles, which were collected in November, was probably the result of the "winter" tiles still being deployed at the start of the summer spawning season for broadcast spawning species.

The reproductive life history of milleporan corals is poorly known. It is unclear whether the sporadic milleporan recruitment that was observed was due to random settlement of relatively few larvae or the unsuitability of the settlement surface for milleporan planulae.

The GAR sites represented communities that have developed within a very limited range of environmen-tal conditions. In addition to a narrow range of temp-erature, salinity, and dissolved oxygen, they are subjected to low sedimentation rates and concomitant low nutrient levels (Charpy et al. 1996). Chevillon et al. (1996) found no lithoclasts in the sediment of the GAR and concluded that there was limited terri-genous influence in the lagoon. However, none of their sample sites were within 1km of YIS, the site with the highest sedimentation rate. Sediment from soil erosion from the island is clearly evident at YIS.

While sedimentation has been shown to reduce fecundity in corals at depth (Kojis & Quinn 1984), the high sedimentation rate at YIS did not result in low recruitment rates. Although coral larvae are trans-ported between reefs (Fisk & Harriott 1990) as well as retained on the reef by water flow patterns (Black et al. 1991), it is unexpected that such high recruit-ment would occur on the site with the highest sedimentation rate. We suspect it is likely that this is because most of the sedimentation occurs during relatively short periods of high rainfall and, the effects probably dissipate rapidly, and do not affect reproduction. Also, there was no evidence of increased coral mortality or bleaching at YIS. The conservative mixing of reef waters within the lagoon, coupled with the synchronized mass spawning of abundant acroporids, may allow for greater fertile-zation success and retention of planulae resulting in higher recruitment rates. However, this does not explain the lower recruitment rates at the other lagoonal site near Dravuni within GAR. Given that the residence time for water mass in the GAR was 15 - 25 days (MacLeod

1992) and the sedimentation rate was lower at the other lagoonal site, one might reasonably expect a more uniform availability of larvae throughout the lagoon from at least broadcast spawning species and a more uniform rate of recruitment at both lagoonal sites.

Corals are known be have adapted to various levels of short-term exposure to sedimentation (Rogers 1983). Increased long-term sedimentation is generally associated with increased erosion associated with land modification or dredging and /or an increase in resuspended sediment. Chronic stress from sedimentation will result in lower coral fecundity (Kojis & Quinn 1984), lowering the number of larvae available for recruitment and reducing a coral reef community's ability to recover from natural perturbations. Additionally, the decreased water transparency associated with higher turbidity is known to reduce the depth range of species (Kojis & Quinn 1984) and cause bleaching and the death of corals (Rogers 1979). In the case of YIS, a reef receiving a high sediment load, the summer recruitment rate was about 3.5 times greater than at the two other GAR sites. Summer recruitment rates at the other two GAR sites were within 10% of each other.

Acknowledgement

We are grateful to the people of Dravuni Village for allowing us to study their marine resources. Funding for this project came from the University of the South Pacific University Research Committee, grant #6291-1311-70766-15 and the Tropical Discoveries Foundation. P Edmunds and P Newell kindly reviewed the paper and offered many useful suggestions. This work was written while NJQ was a J.W Fulbright Fellow.

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