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TNC Pacific Island Countries
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Post-Tsunami Assessment of Zinoa Marine Conservation Area

South Choiseul, Solomon Islands

Report by:
Richard Hamilton, Peter Ramohia, Alec Hughes, Catherine Siota,
Nellie Kere, Michael Giningele, Jimmy Kereseka, Francis Taniveke,
Nelson Tanito, William Atu and Levi Tanavalu

In partnership with:

The Gabili Tribe

The Voza Community

Lauru Land Conference
of Tribal Communities

Choiseul
Provincial Fisheries

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Contact Details:

Richard Hamilton: The Nature Conservancy, 51 Edmondstone Street, South Brisbane QLD 4101 Australia
email: rhamilton@tnc.org

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I. EXECUTIVE SUMMARY

The waters surrounding Choiseul contain some of the highest diversities of coral and reef fish in the world, with the 2004 Solomon Island Marine Assessment showing that the Solomon Islands are part of the global centre for marine diversity known as the Coral Triangle. Other countries that make up the Coral Triangle are Indonesia, Philippines, parts of Malaysia, East Timor and Papua New Guinea.

Since 2004 The Nature Conservancy (TNC), the Lauru Land Conference of Tribal Community (LLCTC) and Choiseul provincial fisheries have assisted five local communities around Choiseul in their efforts to establish Marine Conservation Areas (MCA) on their traditional reefs. The first MCA to be established was the Zinoa MCA. Zinoa is located on the south-west side of Choiseul in the Solomon Islands. The Zinoa MCA was established by traditional leaders in November 2004, covering 150 hectares and consisting of two islands and associated reefs that occur approximately one kilometre offshore from Voza village on the Choiseul mainland. The reefs around Zinoa Islands are representative of this region of the South coast of Choiseul. In early 2005 sea cucumbers, trochus and giant clams around Zinoa Islands were reported by traditional reef owners to be only a tiny fraction of their former abundance and food fish populations were also reported to be in decline.

The primary objectives of establishing the Zinoa MCA were:

1. To allow populations of commercially important marine invertebrates and food fish to recover.
2. Have the Zinoa MCA act as a ‘breeding stock’ of macroinvertebrates and food fishes that provide ‘spillover’ of juveniles and adults to adjacent fished sites.
3. Conserve the marine biodiversity of the Zinoa Islands

In response to communities request, in November 2005 TNC assembled a team to conduct underwater baseline studies on commercially important macroinvertebrates, food fish and corals in and around the Zinoa area. Sites inside and outside of the Zinoa MCA were selected for long term monitoring, and scientific monitoring was repeated in October 2006.

After the 2006 monitoring the intention was to not resurvey the Zinoa MCA for several years. However, in April 2007 an earthquake of magnitude 8.1 struck the Western Solomon Islands unleashing a tsunami with a wave height of 2-10m that caused severe damage along the coastal areas of Western and Choiseul Provinces. Voza community was badly hit by a succession of waves (4-5m high) that caused severe damage to buildings, canoes and other permanent structures. The Zinoa reef complex bore the brunt force of the waves. As a result of the earthquake and tsunami, Voza Community and TNC decided to conduct a third survey to assess the damage to the coral reefs and their associated fauna and flora. A post-tsunami assessment of the Zinoa MCA was conducted in mid June 2007, six weeks after the tsunami.

This report details the findings of three years of marine surveys, and allows us to quantitatively evaluate the early effects of protection and the impact of the April 2007 tsunami on fish, invertebrates and corals in the Zinoa area.

FOOD FISH

- The April 2007 tsunami significantly reduced the density and biomass of reef food fish both in and around the Zinoa MCA. This pattern was most obvious for total biomass, with dramatic reductions in fish biomass apparent at four of the five surveyed sites in 2007. The dramatic declines in biomass indicate that large fish were most adversely affected by the tsunami. Declines in food fish appear to be due to a combination of instant fish mortality (fish thrown onto the shore by the tsunami), and habitat destruction. The significant reductions in food fish indicate that the food security of the Voza community has been detrimentally affected by the tsunami.

- An examination of data for the six most abundant families of fish revealed that the declines in total density and total biomass that were seen across all sites in 2007 were predominantly driven by declines in snappers (Lutjanidae), surgeonfishes (Acanthuridae) and to some extent emperors (Lethrinidae), the three families that made up approximately 69% of the relative density of all food fishes. Densities and biomass of drummers (Kyphosidae), goatfishes (Mullidae) and rabbitfishes (Siganidae) were not significantly different between years, indicating that these families were not significantly affected by the tsunami.
- Mean total density and mean total biomass of fish sighted on transects prior to the tsunami were never high. Relatively low densities and biomass of food fish sighted in the Zinoa region is likely to be due in part to the lack of extensive and complex reef systems in this area. Overfishing may also have played a role.
- The density of large vulnerable species sighted on long swims was also low, with the exception of the large green humphead parrotfish (*Bolbometopon muricatum*). Large green humphead parrotfish were sighted on a moderately frequent basis. This species is extremely vulnerable to overfishing and in 2007 was listed as threatened on the IUCN Red list. The large sizes and moderate densities of this species around Zinoa reflect the historically low levels of night spearfishing in this region.
- There was no evidence that fish densities or biomass increased significantly between 2005 and 2006 within the Zinoa MCA, which is perhaps not surprising given the short time frame between surveys and length of time it takes many of the target species to regenerate their populations.

MACROINVERTEBRATES

- Mean density of invertebrates on the reef flat habitat increased significantly following protection and decreased significantly after the April 2007 tsunami. Whereas mean densities of macroinvertebrates in 5-10m of water did not differ between all three years, indicating that neither protection nor the tsunami had any significant effect on their densities.
- The invertebrate data from the shallow reef flats shows that prior to the tsunami the Zinoa MCA was beginning to meet the objective of allowing macroinvertebrate populations within the MCA the chance to recover. Between 2005 and 2006 the mean total number of invertebrates in the reef flat habitat increased significantly from 3.00 per $100m^2$ (or equivalent to 300 per hectare) to 13.33 (or equivalent to 1,333 per hectare). Sea cucumbers appear to be the macroinvertebrates responding most positively to protection, with four species that were not sighted in 2005 being sighted on the reef flats in 2006.
- Although there was no evidence of such recovery in the deeper water between 2005 and 2006, it is noteworthy that nearly all of the sea cucumbers seen on the reef flat areas were juveniles, and we would expect to see an increase in sea cucumber densities in the deeper water within the Zinoa MCA over time, as juvenile sea cucumbers on the reef flats grow and subsequently make ontogenetic migrations into deeper water.
- The abundance of commercially important invertebrates in both reef flats and deeper water was low compared to that found in other parts of the Solomon Islands and the Indo-Pacific. Sea cucumbers, trochus and giant clams are all high-value species that are vulnerable to over-exploitation. The low densities of invertebrates sighted in all years support local fishers' claims that this area has been heavily over-exploited in the past. It is likely that long-term protection will be required before populations recover to their reported former abundances.
- The presence of low numbers of sea cucumbers and trochus seen on the reef flats in 2007 (coupled with invertebrate populations in the deeper water appearing to be unaffected by the tsunami) indicate that the invertebrate populations in this habitat are likely to recover over time.

BENTHIC COVER

- The benthic composition of the reef area surveyed in and outside of the Zinoa MCA is typical of turbid environments. Massive and encrusting coral species dominate the benthos and cover of branching *Acropora* corals is low.
- For presentation and analysis purposes, in this report benthic community structure data was aggregated into five major lifeforms: (1) hard coral, (2) algae, (3) abiotic (non-living), (4) soft corals and (5) other. Analysis of the 2005 and 2006 data reveal that temporal changes in the benthic composition between 2005 and 2006 occurred with varying degrees of significance depending on the lifeforms and sites examined. Hard coral cover declined significantly across all sites between 2005 and 2006, while at another exposed site algae cover increased significantly and abiotic cover decreased significantly. The location of the Zinoa MCA (close proximity to three rivers and exposure to the open sea) indicate that changes in turbidity and wave energy are the foremost forces governing the distribution and composition of these benthic communities.
- Significant and widespread changes occurred directly after the April 2007 earthquake and tsunami with a decrease in live substrate cover and an increase in abiotic cover. The April 2007 tsunami significantly reduced the percentage coverage of hard corals, algae and other lifeforms. Soft corals were not significantly impacted by the tsunami. Abiotic cover increased significantly at three of the five surveyed sites and decreased significantly at another site following the tsunami. The increase in abiotic cover was mostly from sand, silt and rubble, which is consistent with a strong succession of waves sweeping through the area and suspending and redistributing sediments.
- It is noteworthy that the reef system at Zinoa commonly endures changes in turbidity, wave action and possibly salinity, making it robust and capable of tolerating extreme events. Therefore, barring further natural or anthropogenic disturbances to the area, it is likely the reef system will recover over time.

II. CONSERVATION CONTEXT

Choiseul Province, or Lauru as it is known locally, is a large and relatively remote island in the Solomon Island Archipelago that lies west of Isabel Province. Choiseul has a population of approximately 20,000 people, the majority of whom live a subsistence-based life style. The waters surrounding Choiseul contain some of the highest diversities of coral and reef fish in the world, with the 2004 Solomon Island Marine Assessment showing that the Solomon Islands are part of the global centre for marine diversity known as the Coral Triangle (Green et al. 2006). Other countries that make up the Coral Triangle are Indonesia, Philippines, Malaysia, East Timor and Papua New Guinea.

Coastal communities in Choiseul have limited income earning opportunities and they are heavily dependent on the sea for food and as a means of generating cash. High-value, non-perishable marine export products such as beche-de-mer (dried sea cucumber), trochus and shark fin are particularly sought after commodities in rural settings. Other sources of income include logging royalties, remittances from family members working in urban centres in the Solomon Islands such as Gizo and Honiara, income from copra production and limited sale of finfish. Fishing is extremely important, with the Solomon Island 1999 census showing that 86 percent of households in Choiseul engaged in subsistence production of finfish and 39 percent engaged in market production of finfish. While most reef fish is used for subsistence purposes, some is sold within villages and through commercial fisheries centres (Graham 2002). Currently the only fisheries centres operational in Choiseul are located at Wagina and Sire at the eastern end of the province. A provincial fisheries centre is located in the capital of Taro; however it has not been in operation since 2002. Commercial export reef fisheries such as the Live Reef Food Fish Trade (LRFFT) and the aquarium trade have never operated in Choiseul Province, although interest in commencing these trades in Choiseul has been expressed in the past (Hamilton 2003).

The small number of commercial outlets for finfish coupled with the distance between many communities and local markets and fisheries centres means that in many communities in Choiseul, fishing for reef fish remains predominantly for “kaikai no mo” (for food only). A 2004 marine assessment of the Solomon Islands revealed that food fish populations were healthy in Choiseul province, a pattern that was not seen in some of the other major provinces in the Solomon Islands that have higher human populations and historically have had higher levels of artisanal and commercial fishing (Green et al. 2006). In contrast, with the exception of the Arnavon Marine Conservation Area, valuable marine invertebrates in Choiseul were over exploited, a trend that mirrored all other surveyed regions in the Solomon Islands (Ramohia 2006).

The Nature Conservancy has had a long involvement in Choiseul Province. Its primary focus in the Solomon Islands since 1992 has centred on the establishment and continuation of the Arnavon Islands Marine Conservation Area, an island group that is located between Choiseul and Isabel Province and supports one of the largest rookeries of hawksbill turtles in the world. The Arnavon Islands Marine Conservation Area was established in partnership with the Solomon Island Government, the Isabel and Choiseul Provincial Governments, and the communities of Posarae (Katupika) and Wagina in Choiseul Province and Kia in Isabel Province.

In 2003 TNC began to expand its program in Choiseul beyond the Arnavons. It initiated this process by strengthening links with the Lauru Land Conference of Tribal Community (LLCTC) and the Choiseul Provincial government. The LLCTC is a grassroots ecumenical non-government organization that has strong community support throughout Choiseul. In 2003 a Memorandum of Understanding was signed between TNC and the LLCTC, where both parties formally announced their intentions to work together on issues of common interest such as conservation, natural resource management and sustainable development within the Province of Choiseul. In the same year TNC staff also began engaging and working with Provincial fisheries staff on marine awareness-raising initiatives in Choiseul Province. In 2005 The Nature Conservancy established an office within the Lauru Land Conference of Tribal Community (LLCTC) building on Sipozae Island, Choiseul, and in 2006 an Environmental Community Conservation Officer was employed by TNC and the LLCTC. The Environmental Community Conservation Officer is based at Sipozae Island near Taro, and works closely with communities, LLCTC, the provincial fisheries department and other provincial government departments in Choiseul Province.

Since 2005 TNC, LLCTC and provincial fisheries have worked to assist five local communities in establishing MCA on their traditional reefs (Figure 1). The first MCA to be established was the Zinoa MCA. Zinoa is located on the south-west side of Choiseul in the Solomon Islands. The protected area covers 150 hectares, and consists of two islands and associated reefs that occur approximately one kilometre offshore from Voza village on the Choiseul mainland. The reefs around the Zinoa Islands are representative of inshore reefs in this region of south Choiseul.

Primary customary ownership of the Zinoa Islands belongs to the Gabili tribe, which is one of several tribes that make up the Voza community. The community incentive to conserve the Zinoa Islands was initiated in October 2004, when Ledley Medoko, a traditional owner from the Gabili tribe, participated in a trip organised by The Nature Conservancy to visit the successful community-based marine conservation project in the Arnavon Islands. After partaking in this trip, Ledley Medoko returned home to his community and shared stories of his recent experience with the rest of the Gabili tribe members and with the greater Voza community. The leaders decided to conserve the islands, and Zinoa reefs were declared a tambu (totally protected) area by traditional leaders in November 2004. Following this the elders then drafted and signed a petition asking the Lauru Land Conference of Tribal Community for assistance with community awareness and monitoring so that they could better manage their marine resources. The LLCTC subsequently contacted The Nature Conservancy for assistance. After an initial consultation with community leaders, the Conservancy assembled a team to conduct baseline studies on commercially important macroinvertebrates, food fish and corals in and around the Zinoa area. The Zinoa MCA was officially declared in November 2005 and baseline monitoring occurred immediately after. In early 2005 sea cucumbers, trochus and giant clams were reported by traditional reef owners to be only a tiny fraction of their former abundance, and food fish populations were also reported to be in decline.

The objectives of the Zinoa MCA area are:

1. To allow populations of commercially-important marine invertebrates and food fish to recover.
2. To preserve the marine populations inside the Zinoa MCA as a ‘breeding stock’ of macroinvertebrates and food fish that provides ‘spillover’ of juveniles and adults to adjacent fished sites.
3. Conserve the marine biodiversity of the Zinoa Islands.

Monitoring of the Zinoa area was repeated in October 2006. Data from 2006 showed some encouraging early signs, with invertebrates on reef flat areas within the MCA in much higher abundances then in the previous year (see “Macroinvertebrates” in this report). After The 2006 monitoring the intention was to not resurvey the Zinoa MCA for several years. However, on the 2nd of April 2007 an earthquake of magnitude 8.1 struck the western part of Solomon Islands followed by a deadly tsunami with a height of 2-10m that swept through the coastal areas of Western and Choiseul Province. The earthquake was centred at a latitude 8.481ºS and longitude 156.978ºE, about 40km SSE of Gizo Island and 205km SSE of Chirovanga village, South Choiseul (Schwarz et al. 2007). Many communities along the south coast of Choiseul were badly affected, with Voza village being among one of the worst affected villages in Choiseul. A series of waves of 4-5 m in height struck the Zinoa Islands and then Voza village at around 8am. All permanent structures on Zinoa Island and the majority of houses in Voza village were destroyed by the waves along with numerous boats, canoes and basic living utensils. Remarkably, no lives were lost in Voza, with local residents fleeing to higher ground on the mainland.

The livelihoods of individuals from Voza were severely affected by the tsunami, and shortly after traditional leaders from Voza requested that TNC and partners conduct another marine assessment, so that the impact of the disaster to the marine environment in the Zinoa MCA and surrounding area could be assessed. TNC and partners responded to this request and re-surveyed the Zinoa MCA in mid June 2007, six weeks after the tsunami. This report details the findings of three years of marine surveys, and allows us to quantitatively evaluate the early effects of protection and the impact of April 2007 tsunami on fish, invertebrates and corals in the Zinoa area.

III. TECHNICAL REPORTS

CHAPTER 1.

KEY FISHERIES SPECIES: FOOD FISHES

1.1. INTRODUCTION

Reef finfish are the mainstay of the subsistence fishery in south Choiseul and comprise a major component of the protein diet of coastal inhabitants. In 2005 traditional reef owners reported that both the volume and hourly catch rates of reef fish around the Zinoa MCA and the Voza area had dropped considerably over the past two decades. This decline in fish was attributed by many fishers to increased fishing effort, and was one of the communities' motivations for establishing the Zinoa MCA. Main fishing methods in this region include droplining, strike line and spearfishing (day and night). The dugout canoe is the main fishing vessel. By monitoring food fish stocks in the Zinoa MCA, we will over time be able to assess the effects of protection on fish density and biomass.

The baseline data collected in 2005 and 2006 also presented a unique opportunity to quantitatively assess the impact of the 2007 tsunami on food fish. Anecdotal reports indicate that the April 2007 tsunami had an immediate and dramatic impact on fish abundances in the Voza region, with large number of fish said to have been stranded on Zinoa Island and the Choiseul mainland. Local fishers reported that some areas of the bush stank of rotten fish for weeks following the tsunami, and there were accounts of large numbers of surgeonfishes, snappers and parrotfishes lodged in trees and scattered over the ground once the tsunami waves had receded. Ledley Medoko gave an interesting personal account of how while he was fleeing inland from the tsunami, he stopped to grab a large green humphead parrotfish that had been thrown over 100m inland from a previous wave. Given Voza community's dependence on coral reefs, any tsunami-related impacts on food fish (be that through habitat destruction or instant fish mortality as a result of removal from the sea), have the potential to detrimentally affect food security and livelihoods of the Voza community.

1.2. METHODS

1.2.1. STUDY SITES

The Zinoa MCA is located at the northern end of Choiseul Province, Solomon Islands (Figure 1a). It was the first of five MCAs that have been established in northern Choiseul over the past three years (Figure 1, b). Scientific surveys of the Zinoa MCA were conducted in November 2005, October 2006 and in June 2007 (following the April 2007 tsunami). Figure 1 (c) shows the approximate location of the sites that were surveyed for fish, macroinvertebrates and corals in each year.

The sites surveyed consist of three reef slopes within the MCA (MCA 1, MCA 2 and MCA 3), one reef flat area located between the two islands (Reef flat) and two reefs located outside the MCA that are open to fishing (Open 1 and Open 2). The three reef slopes within the MCA were chosen to represent exposed (MCA 1 and MCA 2) and sheltered (MCA 3) reef slopes within the MCA. All of these sites are reef slopes that end in sand at depths between 10-12m. The reef flat area within the MCA is between 0.5-1.5m deep, and consists of sand, seagrass, coral rock and some live coral. It is an important nursery area for invertebrates and fish and is the only habitat of its kind within the MCA or the surrounding vicinity. The reef flat was only surveyed for macroinvertebrates (see “macroinvertebrates”, this report). The absence of any nearby offshore islands in the vicinity of Zinoa meant that it was impossible to select sites that would act as strict control sites for the reef flat and reef slope sites located within the Zinoa MCA. Instead, we monitored two comparison sites that are located in close proximity to the Zinoa MCA. Open 1 is located on a submerged shallow reef that is an important fishing area for the Voza community. The reef is approximately 10-12m deep and made up of patches of reef interspersed with sand. Open 2 is located beside Choiseul Island near the Voza community. It consists of reef slope habitat that ends in sand at approximately 7-10m. This site receives some shelter from the Zinoa Islands and the reef profile is similar to MCA 3.

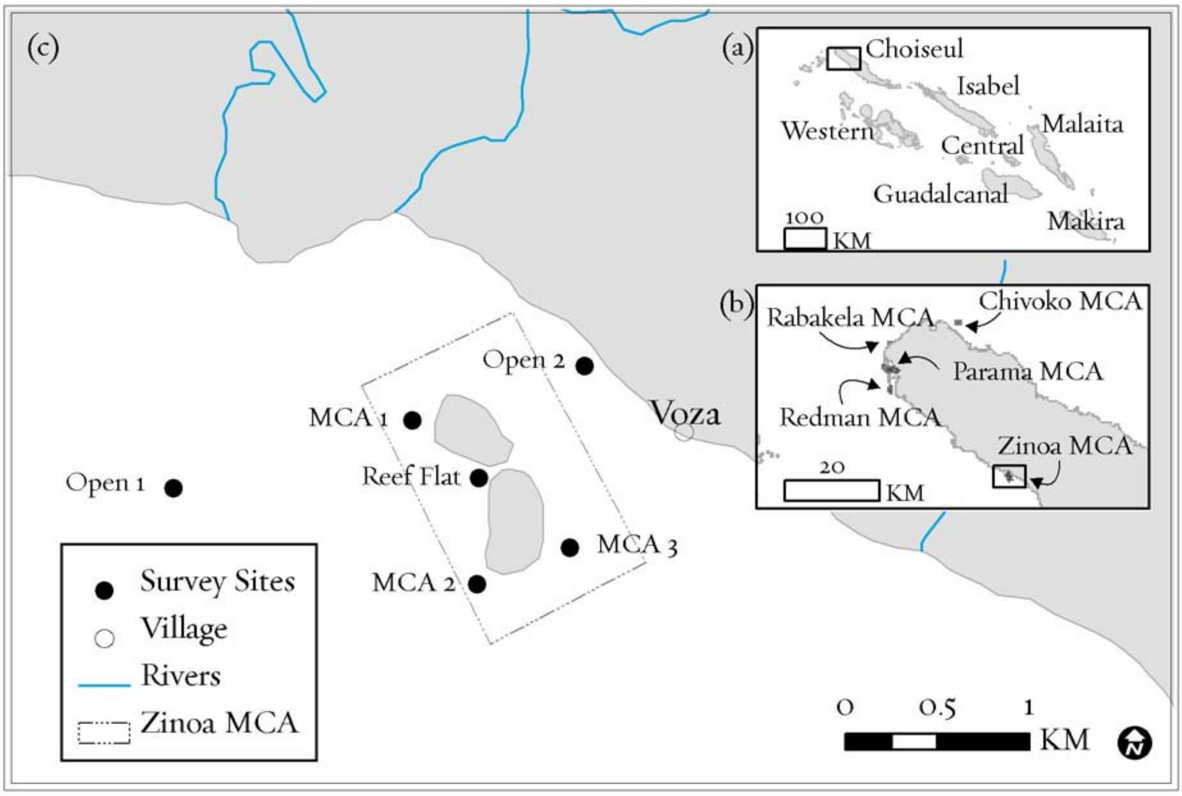


Figure 1. (a) The location of the northern tip of Choiseul (boxed), Solomon Islands. (b) The location of the Zinoa MCA and four other MCAs that have been established in northern Choiseul since 2005. (c) The locations of survey sites in and around the Zinoa MCA.

1.2.2. TARGET SPECIES

The list of key fishery species that were surveyed is shown in Table 1. For consistency and comparison purposes we adopted the list of key food fish species used in the Solomon Island 2004 Rapid Ecological Assessment (REA) (Green et al., 2006) with the only modification being that we excluded *Caesio cunning* from the species list. *Caesio cunning* was excluded as it frequently forms very large schools that are patchily distributed, and we felt that this was likely to cause very high variability in the data. Key food fish species were surveyed using underwater visual census techniques, using a combination of transects and long swims. One of the authors (RH) conducted all of the fish surveys in all years.

Table 1. Key species of food fishes surveyed

Taxa/Family	Species	Common Name
Sharks	*All species*	Sharks
Mobulidae (manta rays)	*Manta spp.*	Manta rays
Myliobatidae (eagle rays)	*Aetobatus narinari*	Spotted eagle ray
Labridae (wrasses)	*Cheilinus undulatus*	Humphead wrasse
	Cheilinus fasciatus	Redbreasted wrasse
Scaridae (parrotfishes)	*Bolbometopon muricatum*	Bumphead parrotfish

Taxa/Family	Species	Common Name
	Hipposcarus longiceps	Pacific longnose parrotfish
	Chlorurus microrhinos	Steephead parrotfish
Serranidae (groupers)	*Plectropomus areolatus*	Squaretail coral grouper
	Plectropomus laevis	Blacksaddle coral grouper
	Plectropomus oligacanthus	Highfin coral grouper
	Plectropomus leopardus	Leopard coral grouper
	Epinephelus fuscoguttatus	Brown-marbled grouper
	Epinephelus polyphekadion	Camouflage grouper
	Epinephelus lanceolatus	Giant grouper
	Cromileptes altivelis	Barramundi cod
	Variola louti	Yellow-edged lyretail
	Variola albimarginata	White-edged lyretail
	Epinephalus merra/quoyanus	Honeycomb groupers
	Cephalopholis argus	Peacock grouper
	Cephalopholis cyanostigma	Bluespotted grouper
	Cephalopholis miniata	Coral grouper
Haemulidae (sweetlips)	*Plectorhinchus albovittatus*	Giant sweetlips
	Plectorhinchus vittatus	Oriental sweetlips
	Plectorhinchus lineatus	Diagonal-banded sweetlips
	Plectorhinchus chaetodonoides	Many-spotted sweelips
Lutjanidae (snappers)	*Aprion virescens*	Green jobfish
	Lutjanus gibbus	Humpback snapper
	Lutjanus bohar	Red snapper
	Lutjanus argentimaculatus	Mangrove red snapper
	Macolor niger	Black snapper
	Macolor macularis	Midnight snapper
	Symphorichthys spilurus	Sailfin snapper
	Small yellow and spot (= L. monostigma, L. fulviflamma, L. ehrenbergii etc)	Longspot/blackspot/onespot snapper
	Small & yellow lines (= L. quinquelineatus, L. kasmira)	Five-lined/bluestripe snapper
Lethrinidae (emperors)	*Lethrinus olivaceus*	Longface emperor
	Lethrinus erythropterus	Longfin emperor
	Lethrinus rubrioperculatus	Spotcheek emperor
	Lethrinus xanthochilus	Yellowlip emperor
	Monotaxis grandoculis	Humpnose bigeye bream
	Small lethrinids (Lethrinus spp.)	Small emperors
Acanthuridae (surgeonfishes)	*Naso hexacanthus*	Sleek unicornfish
	Naso lituratus	Orangespine unicornfish
	Naso unicornis	Bluespine unicornfish
	Naso brevirostris	Spotted unicornfish
	Large ringtails (Acanthurus xanthopterus, A. mata, A. nigricauda A. dussumieri, A. blochi, A. fowleri etc)	Ringtails
	Small surgeonfish: Acanthurus lineatus and Ctenochaetus species	Lined surgeonfish and Bristletooth
Siganidae (rabbitfishes)	*Siganus lineatus*	Lined rabbitfish
	Siganus vermiculatus	Vermiculate rabbitfish
	Siganus fuscescens	Dusky rabbitfish
		Masked rabbitfish
	Siganus puellus	
Mullidae (goatfishes)	*Parupeneus bifasciatus/trifasciatus*	Doublebar/Indian doublebar goatfish
	Parupeneus cyclostomus	Goldsaddle goatfish
	Parupeneus barberinus	Dash-dot goatfish
	Parupeneus vanicolensis	Yellowfin goatfish
Kyphosidae (drummers)	*Kyphosus spp.*	Drummer
Ostracidae (boxfishes)	*Ostracion cubicus*	Yellow boxfish
Balistidae (triggerfishes)	*Balistoides viridescens*	Titan triggerfish
	Pseudobalistes flavimarginatus	Yellowmargin triggerfish

Taxa/Family	Species	Common Name
	Balistapus undulatus	Orange-lined triggerfish
Chanidae (milkfishes)	*Channos channos*	Milkfish
Holocentridae (soldierfishes and squirrelfishes[1])	*Sargocentron spiniferum*	Sabre squirrelfish
Carangidae (trevally)	*Caranx ignobilis*	Giant trevally
	Caranx sexfasciatus	Bigeye trevally
	Caranx papuensis	Brassy trevally
	Caranx melampygus	Bluefin trevally
Sphyraenidae (barracudas)	*Sphyraena* spp.	Barracuda

1.2.3. SURVEY METHODS

Key food fish species were surveyed using underwater visual census techniques that consisted of a combination of transect counts and long swims.

1.2.3.1. Transect Counts

Five replicate transects were surveyed at each site in each year. Each transect was 50m long and 10m wide, giving a total area surveyed of 500m^2 per transect. Transect lengths were measured using 50m tapes, and transect widths were visually estimated. Transect tapes were laid by an assistant following the observer to minimize disturbance to the fish communities being counted. The tapes then remained *in situ* until all surveys were completed at that site. Key macroinvertebrates and benthic communities were surveyed along the same transects after the fish counts were completed (see Commercially Important Macroinvertebrates and Benthic Communities this report). In each pass of a transect the number of individuals of each fish species was counted and recorded onto underwater paper. The size of each individual (length in cm) was also estimated and recorded. Fish identifications were based on Allen (2003).

1.2.3.2. Long Swim Surveys

Key fisheries species of food fish that are large and particularly vulnerable to overfishing were also counted (and their size estimated) using long swim methods specifically developed for this purpose (Choat and Spears 2003). This method was developed to improve estimates of the abundance of these species, since they tend to be uncommon and clumped in distribution, so smaller transects dimensions (e.g., 50m x 10m) are not suitable for obtaining reasonable estimates of their abundance. In this method, the observer surveyed a wide area during a single pass of the reef slope over a set time period (20 minutes) scanning the reef slope for these species. Average swim speeds for an observer were calculated such that the average distance covered in a timed swim could be estimated. When a standard width is used (20m), these estimates can be converted to a standardised area (density per hectare) (Green et al. 2006).

The species surveyed using the long swim method were the same as those surveyed by Green et al. (2006) but also included species from the genus *Plectropomus.* They were:

- Sharks (all species), manta rays (*Manta* spp.) and eagle rays (*Aetobatus narinari*);
- Maori wrasse (*Cheilinus undulatus*);
- Green humphead parrotfish (*Bolbometopon muricatum*) and steephead parrotfish (*Chlorurus microrhinos*);
- Large groupers (*Epinephelus fuscoguttatus, Epinephelus polyphekadion, Epinephelus lanceolatus, Cromileptes altivelis, Plectropomus areolatus, Plectropomus laevis, Plectropomus leopardus, Plectropomus oligacanthus Variola louti* and *Variola albimarginata*);
- Giant trevally (*Caranx ignobilis*); and
- Large and uncommon emperors (*Lethrinus olivaceus, Lethrinus erythropterus, Lethrinus rubrioperculatus* and *Lethrinus xanthochilus*).

1.2.4. DATA ANALYSIS

Key fisheries species were compared among sites and years based on the density and biomass of all species and key families. Fish density estimates per transect were converted to the number of individuals per hectare (ha). Fish biomass was calculated by converting estimated fish lengths to weights (Appendix 1) using the allometric length-weight conversion formulae $W=aL^b$ where a and b are constants for each species. Fish biomass per transect was converted to the biomass of fish per hectare (ha). Constants were not available for most species in the Solomon Islands, so they were obtained from Fishbase (www.fishbase.org). Typically the median value for a species was used, or when no species-specific information was available, the constants for a closely related species or the constants of the overall mean values of a genus were used.

Two-way ANOVAs, with Year and monitoring Site as fixed factors, were used to assess changes in density of the whole fish assemblage in the Zinoa area and changes in density of the six most numerically abundant families of fish (Table 2). Numerical density data +1 were log10 transformed to meet the assumptions of normality and homogeneity of variance. Where differences were significant, Tukey’s or Holm-Sidak Post Hoc tests were used to identify significant pairwise differences. In some instances transforming the density data for several families of fish still did not allow the assumptions of normality to be met. In these cases non-parametric two-way ANOVAs on ranks were run. Biomass data was non-normal and appropriate transformation of the data did not allow the assumptions of normality to be met. For this reason non-parametric two-way ANOVAs on ranks were used to assess changes in biomass of the whole fish assemblage in the Zinoa area and changes in biomass of the six most numerically abundant families of fish (Table 2). Where differences were significant, Tukey’s or Holm-Sidak Post Hoc tests were used to identify significant pairwise differences. All statistical analysis was carried out in SigmaStat3.5. Data from long swims was limited, highly variable and only replicated on a yearly basis, and as such was not statistically analysed.

1.3. RESULTS

1.3.1. FOOD FISHES SIGHTED ON TRANSECT SWIMS

In all years surveyed target food fish from the families snapper, emperor, sweetlips, surgeonfishes, rabbitfishes, goatfishes, drummers, trevally and triggerfish were well represented and in moderate densities. Barracudas, milkfishes and boxfishes were never recorded, and diversity and density of target groupers was very low. Of 15 groupers included on the survey list 9 species were never observed (*Plectropomus areolatus, Plectropomus laevis, Plectropomus oligacanthus, Plectropomus leopardus, Epinephelus polyphekadion, Epinephelus lanceolatus, Cromileptes altivelis, Variola albimarginata, Cephalopholis cyanostigma* and *Cephalopholis miniata*). Apart from *Bolbometopon muricatum*, parrotfishes were also in low abundances, and the large wrasse *Cheilinus undulatus* was never sighted.

1.3.2. DENSITY

Bony fishes were most abundant, accounting for 99.69% of the fish counted (Table 2). The most abundant families were snappers, surgeonfishes and drummers, followed by emperors, goatfishes and rabbitfishes. Sharks and rays were uncommon, accounting for 0.31% of the fishes counted (Table 2).

Table 2. Relative abundance and relative biomass of each fish family at Zinoa.

Order	Family	Common names	Relative density (% of total)	Relative biomass (% of total)
Bony Fishes	Lutjanidae	Snappers	48.84	20.89
	Acanthuridae	Surgeonfishes	13.00	9.72
	Kyphosidae	Drummers	11.04	19.88
	Lethrinidae	Emperors	6.95	5.95
	Mullidae	Goatfishes	6.37	2.03

Order	Family	Common names	Relative density (% of total)	Relative biomass (% of total)
	Siganidae	Rabbitfishes	6.32	4.45
	Carangidae	Trevallies	1.74	7.25
	Haemullidae	Sweetlips	1.65	2.64
	Balistidae	Triggerfishes	1.42	1.43
	Serranidae	Groupers	1.16	0.81
	Scaridae	Parrotfishes	0.85	6.03
	Labridae	Wrasses	0.22	0.16
	Holocentridae	Soldierfishes	0.13	0.16
	Ostracidae	Boxfishes	0.00	0.00
	Sphyraenidae	Barracudas	0.00	0.00
	Chanidae	Milkfishes	0.00	0.00
		Total	**99.69**	**81.41**
Sharks and Rays	Carcharinidae	Whaler Sharks	0.13	17.82
	Myliobatididae	Eagle Rays	0.18	0.77
	Mobulidae	Manta Rays	0.00	0.00
		Total	**0.31**	**18.59**

1.3.2.1. Density of Total Fish Assemblage

The density of bony food fishes at each site in each year is shown in Figure 2. A Two way ANOVA on the Log10 (density + 1) shows that mean total densities were significantly different between Year ($F_{2,75}$=11.692, P<0.001) and Sites ($F_{4,75}$=10.859, P<0.001). There was not a statistically significant interaction between Year and Site ($F_{8,75}$=0.536, P= 0.825). Tukey’s Post Hoc tests for the factor Year revealed that while the mean density of fish in 2005 and 2006 were not significantly different (P=0.248), the mean density of fish in 2007 was significantly lower than in 2006 (P<0.001) and 2005 (P=0.007), providing statistical evidence for a significant reduction in fish density across all five sites following the April 2007 tsunami. Densities also varied significantly between sites. Tukey’s Post Hoc tests for the factor Site revealed that densities at MCA 3 were significantly higher than MCA 1 (P=0.023), MCA 2 (P<0.001) and Open 1 (P<0.001). MCA 1 and Open 2 also had significantly higher densities of fish than Open 1 (P=0.022 and P=0.002 respectively).

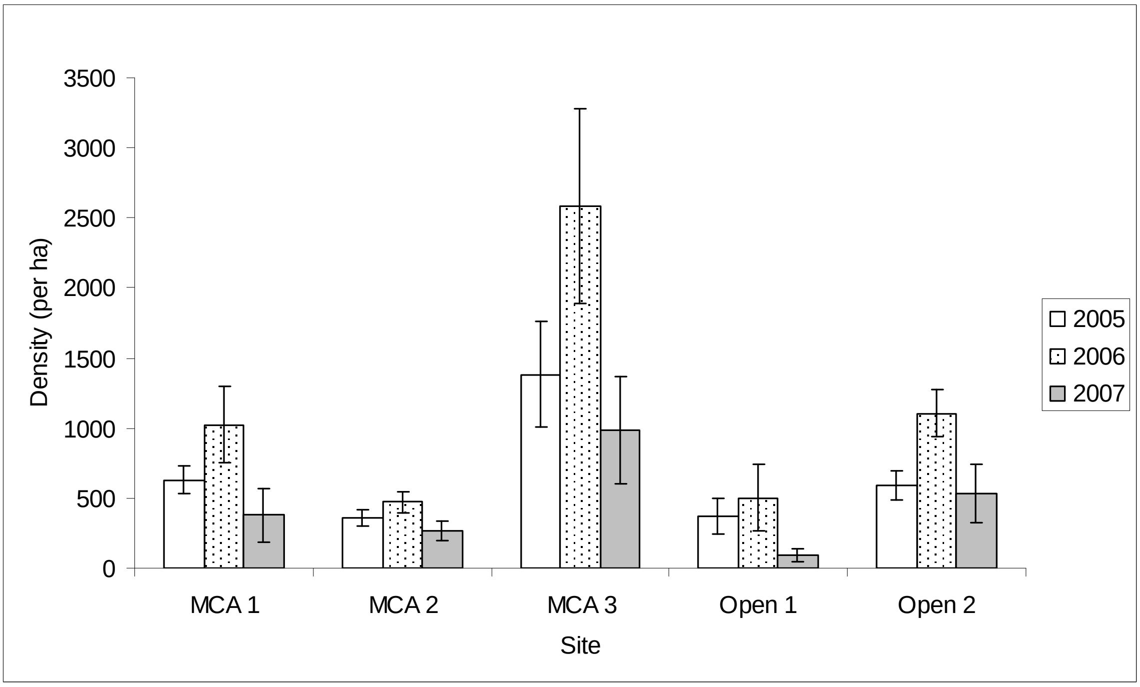


Figure 2. Mean density (+/- 1SE) of food fishes inside and outside the Zinoa MCA in 2005, 2006 and 2007.

1.3.2.2. Densities of the Six Most Abundant Families of Fish

SNAPPERS

The density of snapper at each site in each year is shown in Figure 3. A Two way ANOVA on the Log10 (density + 1) shows that mean densities of snappers were significantly different between Years ($F_{4,75}$=6.205, P=0.004), but did not differ significantly between Sites ($F_{2,75}$=0.639, P=0.225). Tukey's Post Hoc tests for the factor Year revealed that while the mean density of snappers in 2005 and 2006 were not significantly different (P=0.432), the mean density of fish in 2007 was significantly lower than in 2006 (P=0.003). Mean densities of snappers in 2007 were also lower than in 2005, and this was marginally statistically significant (P=0.074). These results provide statistical evidence for a reduction in snapper density across all five sites following the April 2007 tsunami.

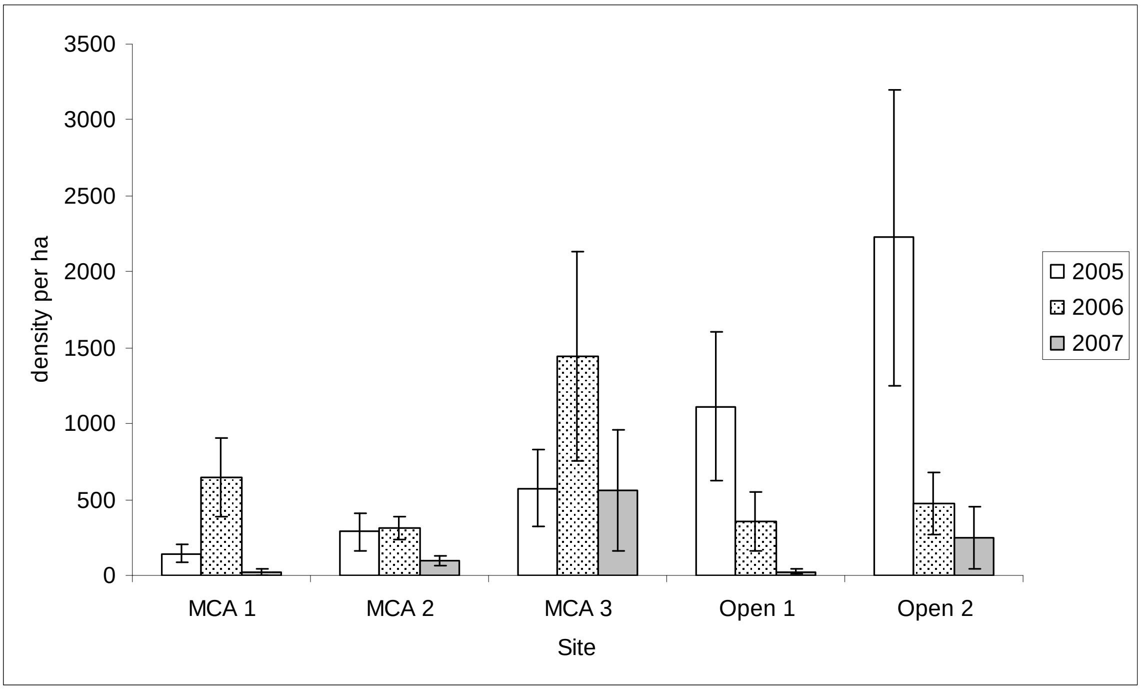


Figure 3. Mean density (+/- 1SE) of snappers inside and outside the Zinoa MCA in 2005, 2006 and 2007.

SURGEONFISHES

The density of surgeonfishes at each site in each year is shown in Figure 4. A Two way ANOVA on the Log10 (density + 1) shows that mean densities of surgeonfishes were significantly different between Years ($F_{2,75}$=3.471, P=0.037) and Sites ($F_{4,75}$=5.243, P=0.001). There was not a statistically significant interaction between Year and Site ($F_{8,75}$=1.06, P= 0.403). Tukey's Post Hoc tests for the factor Year revealed that the mean density of surgeonfishes in 2007 was significantly lower than in 2006 (P=0.038). Tukey's Post Hoc tests for the factor Site revealed that densities at MCA 1 were significantly higher than Open 1 (P=0.003), Open 2 (P=0.004) and MCA 2 (P=0.007).

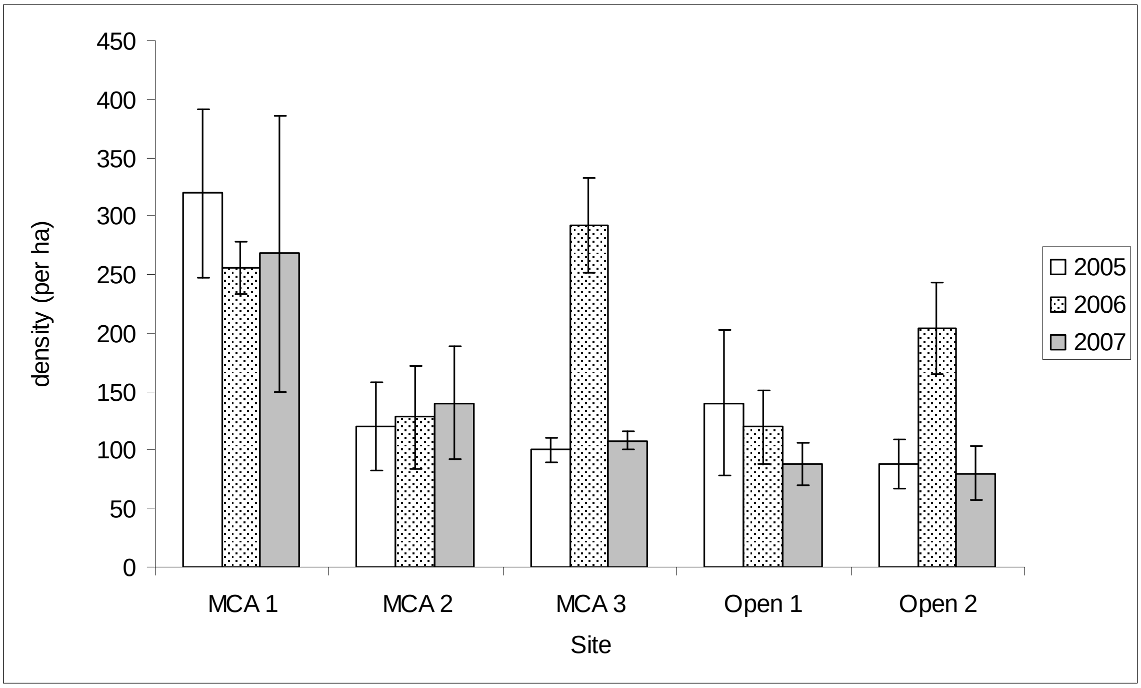


Figure 4. Mean density (+/- 1SE) of surgeonfishes inside and outside the Zinoa MCA in 2005, 2006 and 2007.

DRUMMERS

The density of drummers at each site in each year is shown in Figure 5. A Two way ANOVA on ranks shows that mean densities of drummers were significantly different between Sites ($F_{4,75}$=6.625, P<0.001) but not Years ($F_{2,75}$=1.146, P= 0.325). Holm-Sidak Post Hoc tests for the factor Site revealed that the mean densities at Open 2 were significantly higher than MCA 2 (t=3.618) and Open 1 (t=3.618). Mean densities of drummers were also significantly higher at MCA 3 then at MCA 2 (t=3.611) and Open 1 (t=3.611).

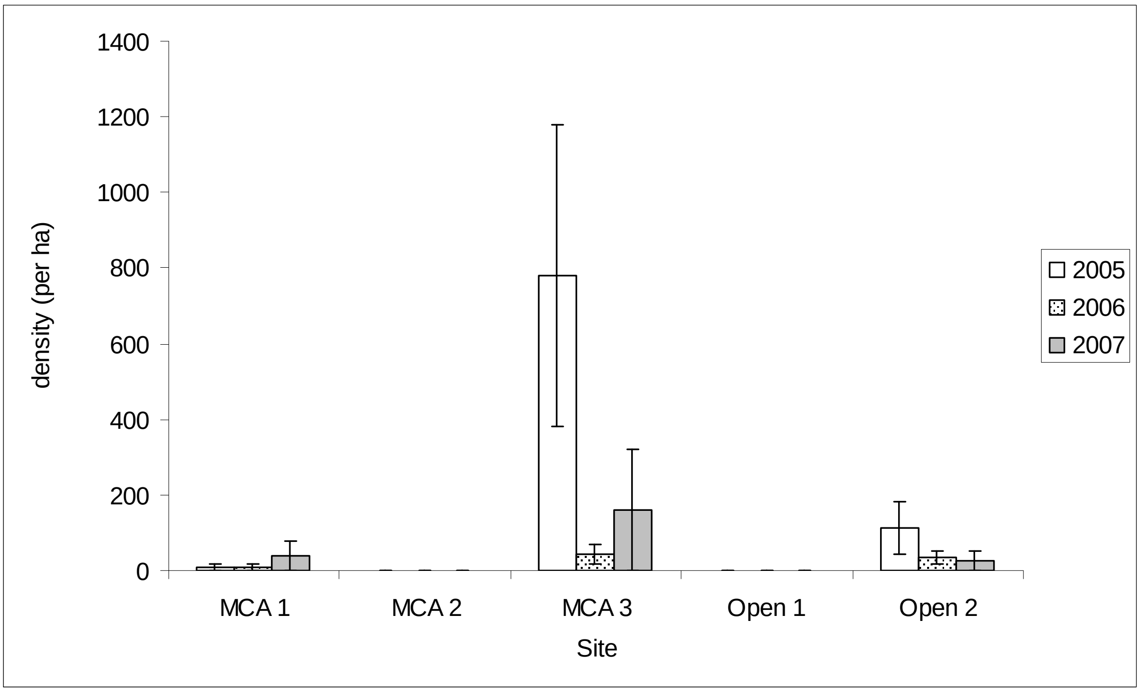


Figure 5. Mean density (+/- 1SE) of drummers inside and outside the Zinoa MCA in 2005, 2006 and 2007.

EMPERORS

The density of emperors at each site in each year is shown in Figure 6. A Two way ANOVA on ranks shows that mean densities of drummer were significantly different between Years ($F_{2,75}$=4.110, P=0.021) and Sites ($F_{4,75}$=5.279, P=0.001), but there was not a significant Year x Site interaction ($F_{2,75}$=0.300, P=0.963). Holm-Sidak Post Hoc tests for the factor Year revealed that the mean densities in 2006 were significantly higher than in both 2005 and 2007 (t=2.559 and t=2.399). A closer inspection of the raw data reveals that this difference is driven by a large school of Humpnose bigeye bream that was seen at MCA 3 in 2006. Holm-Sidak Post Hoc tests for the factor Site revealed that the mean densities at MCA 3 were significantly higher than Open 1 (t=3.855) and Open 2 (t=3.432) and MCA 2 (t=3.343).

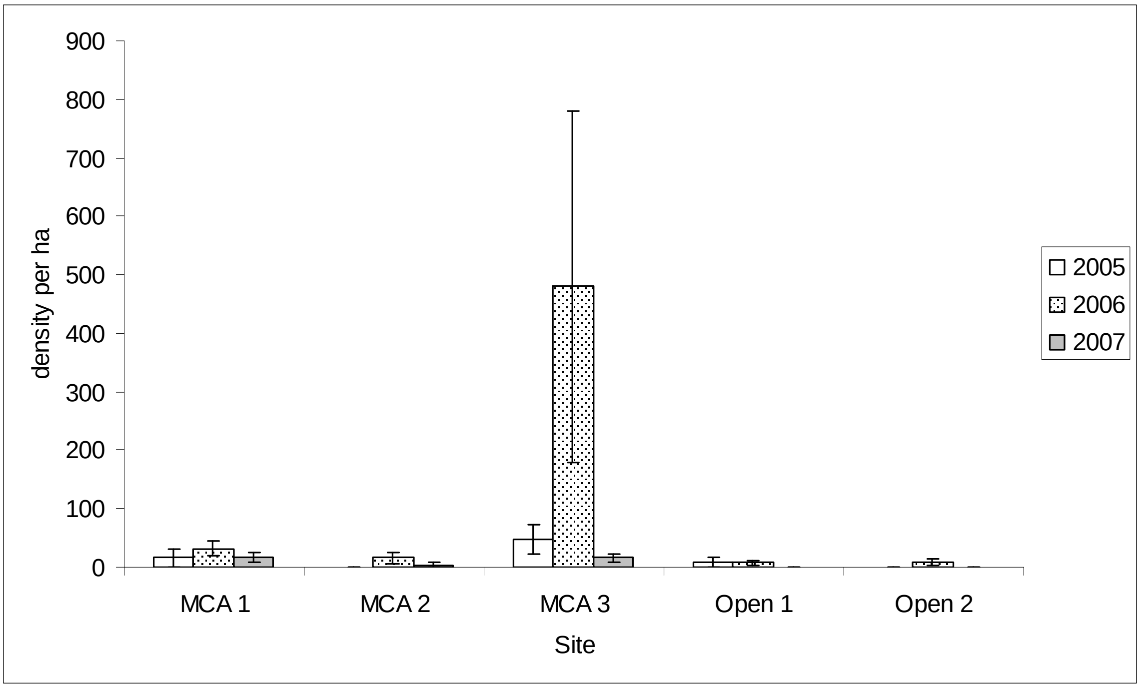


Figure 6. Mean density (+/- 1SE) of emperors inside and outside the Zinoa MCA in 2005, 2006 and 2007.

GOATFISHES

The density of goatfish at each site in each year is shown in Figure 7. A Two way ANOVA on the Log10 (density + 1) shows that mean densities goatfishes were not significantly different between Years ($F_{2,75}$=1.035, P=0.361) or Sites ($F_{4,75}$=2.596, P=0.08).

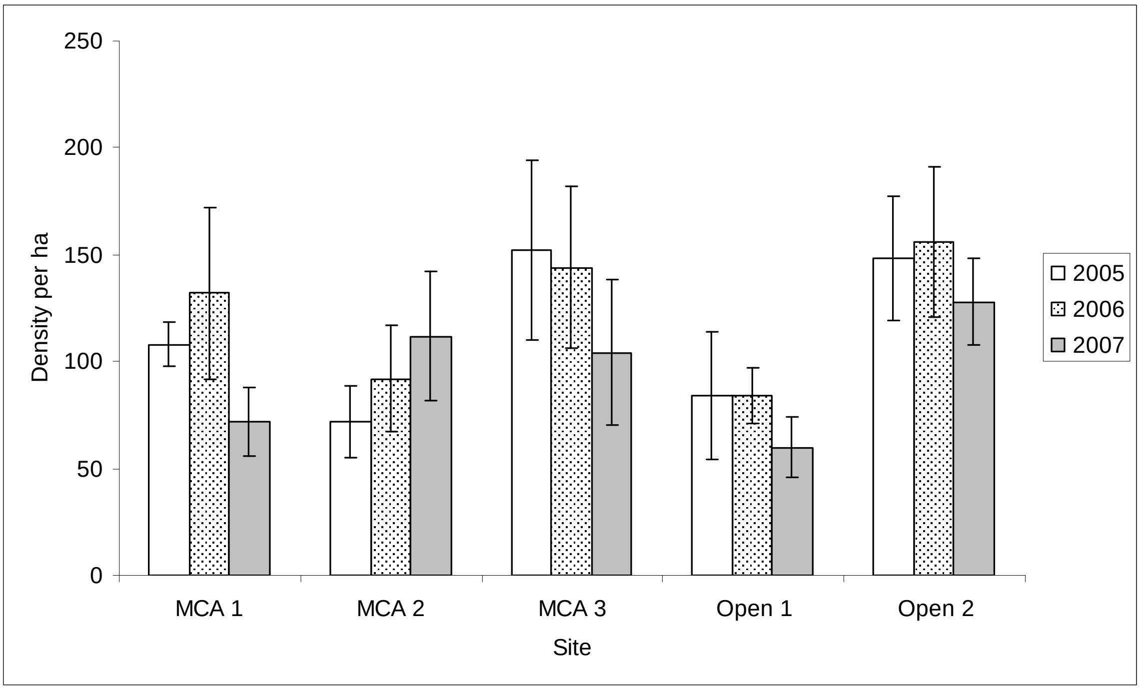


Figure 7. Mean density (+/- 1SE) of goatfishes inside and outside the Zinoa MCA in 2005, 2006 and 2007.

RABBITFISHES

The density of rabbitfishes at each site in each year is shown in Figure 8. A Two way ANOVA on ranks shows that mean densities of rabbitfishes were significantly different between Sites ($F_{4,75}$=6.129 P<0.001) but not Years ($F_{2,75}$=1.698, P= 0.192). Holm-Sidak Post Hoc tests for the factor Site revealed that the mean densities at Open 2 were significantly higher than MCA 1 (t=2.638), MCA 2 (t=3.623) and Open 1 (t=4.624).

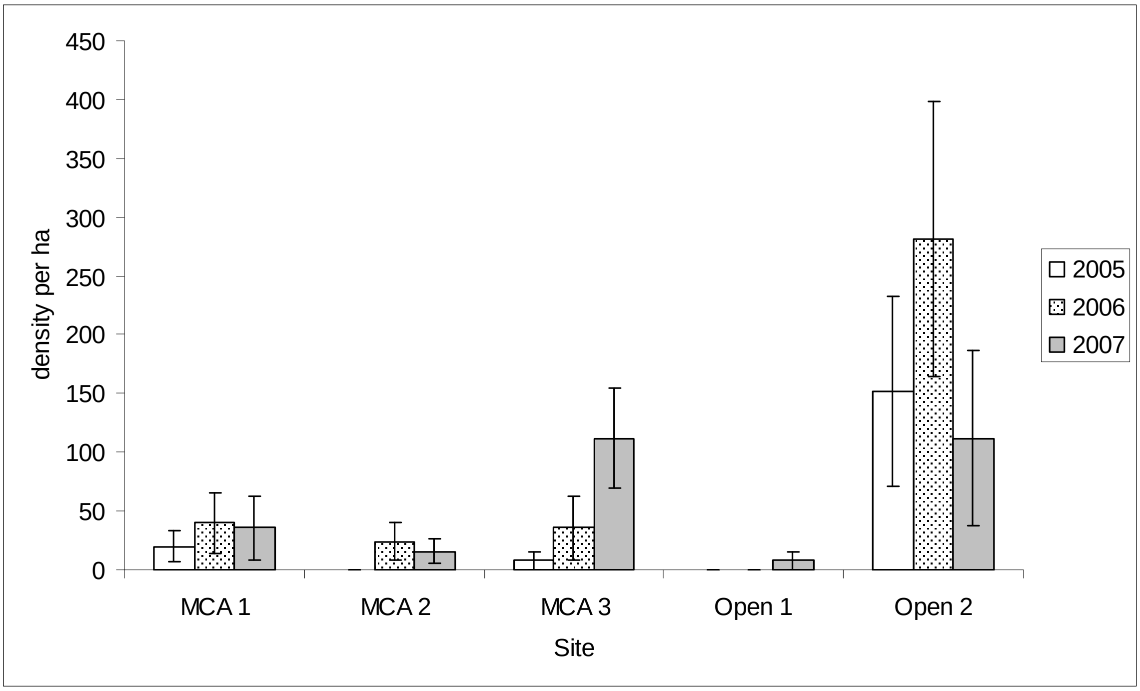


Figure 8. Mean density (+/- 1SE) of rabbitfishes inside and outside the Zinoa MCA in 2005, 2006 and 2007.

1.3.3. BIOMASS

Bony fishes accounted for most of the biomass (81.41%, Table 2) although sharks and rays were also important (18.59%, Table 2). Most of the biomass of bony fish was accounted for by snappers, drummers, surgeonfishes, emperors, trevallys, rabbitfishes, sweetlips and goatfishes. While all of the biomass of sharks and rays was accounted for by whaler sharks and eagle rays (Table 2).

1.3.3.1. Biomass of Total Fish Assemblage

The biomass of fish at each site in each year is shown in Figure 9. A Two way ANOVA on ranks shows that mean biomass of fish was significantly different between Years ($F_{2,75}$=22.019, P<0.001) and Sites ($F_{4,75}$=11.514, P<0.001). There was not a significant Year x Site interaction ($F_{8,75}$=0.682, P= 0.706). Tukey's Post Hoc tests for the factor Year revealed that while the mean biomass of fish in 2005 and 2006 were not significantly different (P=0.970), the mean biomass of fish in 2007 was significantly lower than in 2006 (P<0.001) and 2005 (P<0.001), providing statistical evidence for a significant reduction in fish biomass across all five sites following the April 2007 tsunami. Mean biomass also varied significantly between sites. Tukey's Post Hoc tests for the factor Site revealed that biomass at MCA 3 was significantly higher than MCA 1 (P=0.029), MCA 2 (P<0.001) and Open 1 (P=0.005). MCA 1 also had significantly higher mean biomass of fish than MCA 2 (P=0.013) and Open 2 had significantly higher mean biomass than MCA 2 (P<0.001).

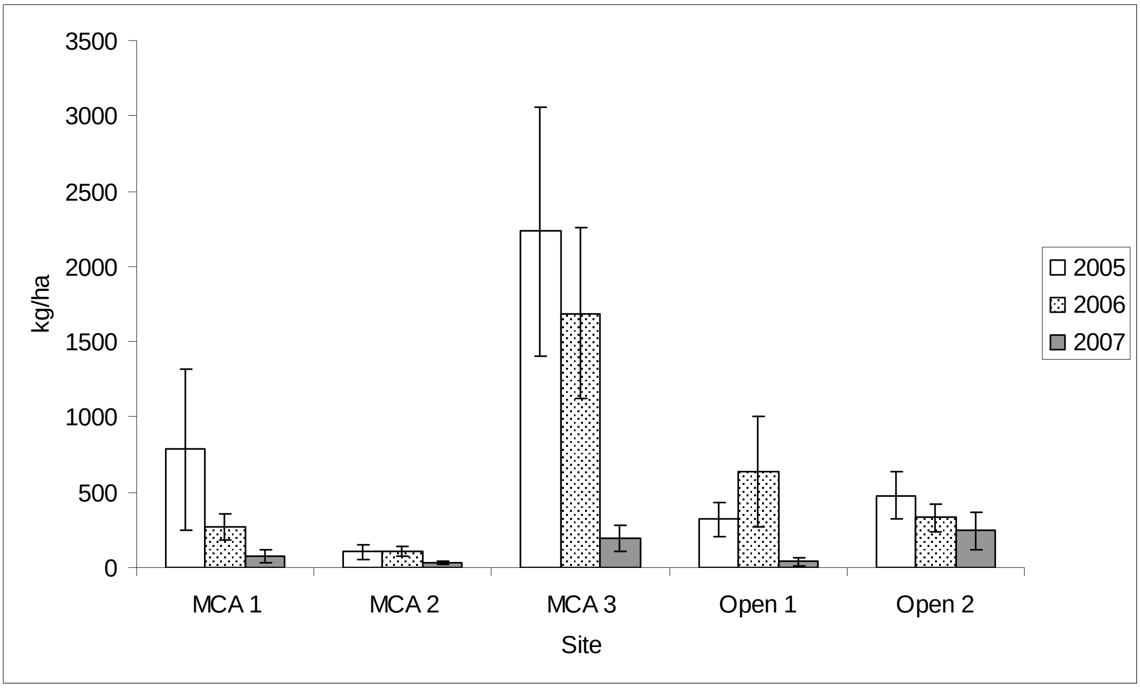


Figure 9. Mean biomass (+/- 1SE) of food fishes inside and outside the Zinoa MCA in 2005, 2006 and 2007.

1.3.3.2. Biomass of the Six Most Abundant Families of Fish

SNAPPERS

The biomass of snapper at each site in each year is shown in Figure 10. A Two way ANOVA on ranks shows that mean biomass of snapper was significantly different between Years ($F_{2,75}$=26.017, P<0.001) and Sites ($F_{4,75}$=6.523, P<0.001). There was not a significant Year x Site interaction ($F_{2,75}$=0.976, P=0.463). Holm-Sidak Post Hoc test for the factor Year show that while the mean biomass of snappers in 2005 and 2006 were not significantly different (t=0.383), the mean biomass of snappers in 2007 was significantly lower than in 2006 (t=6.430) and 2005 (t=6.047), providing statistical evidence for a significant reduction in snappers biomass across all five sites following the April 2007 tsunami. Holm-Sidak Post Hoc tests for the factor Site revealed that the mean biomass of snappers at MCA 3 was significantly higher than MCA 2 (t=4.686), Open 1 (t=3.756) and MCA 1 (t=2.873). Mean biomass of snappers at MCA 3 were also significantly higher than MCA 2 (t=2.814).

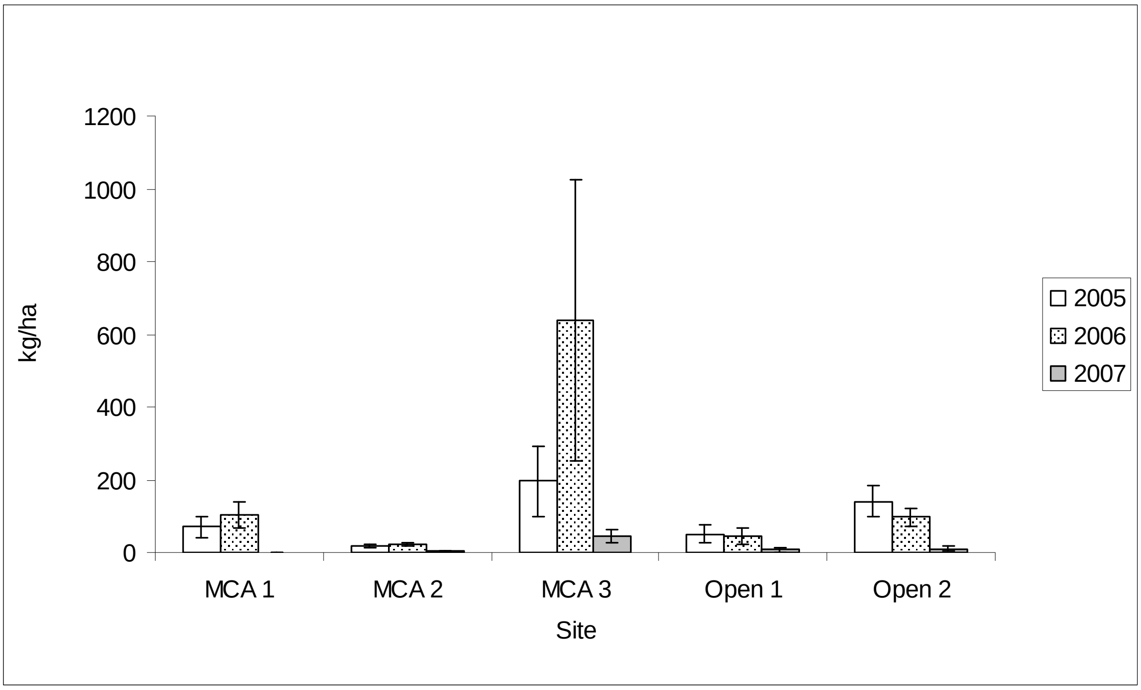


Figure 10. Mean biomass (+/- 1SE) of snappers inside and outside the Zinoa MCA in 2005, 2006 and 2007**.**

SURGEONFISHES

The biomass of surgeonfishes at each site in each year is shown in Figure 11. A Two way ANOVA on ranks shows that mean biomass of surgeonfishes was significantly different between Years ($F_{2,75}$=8.682, P<0.001) and Sites ($F_{4,75}$=6.400, P<0.001). There was not a significant Year x Site interaction ($F_{2,75}$=1.474, P=0.186). Holm-Sidak Post Hoc tests for the factor Year show that while the mean biomass of surgeonfishes in 2005 and 2006 were not significantly different (t=1.589), the mean biomass of surgeonfishes in 2007 was significantly lower than in 2006 (t=4.130) and 2005 (t=2.542), providing statistical evidence for a significant reduction in surgeonfishes biomass across all five sites following the April 2007 tsunami. Holm-Sidak Post Hoc tests for the factor Site revealed that the mean biomass of surgeonfishes at MCA 1 was significantly higher than Open 1 (t=4.302), Open 2 (t=3.970) and MCA 2 (t=3.870).

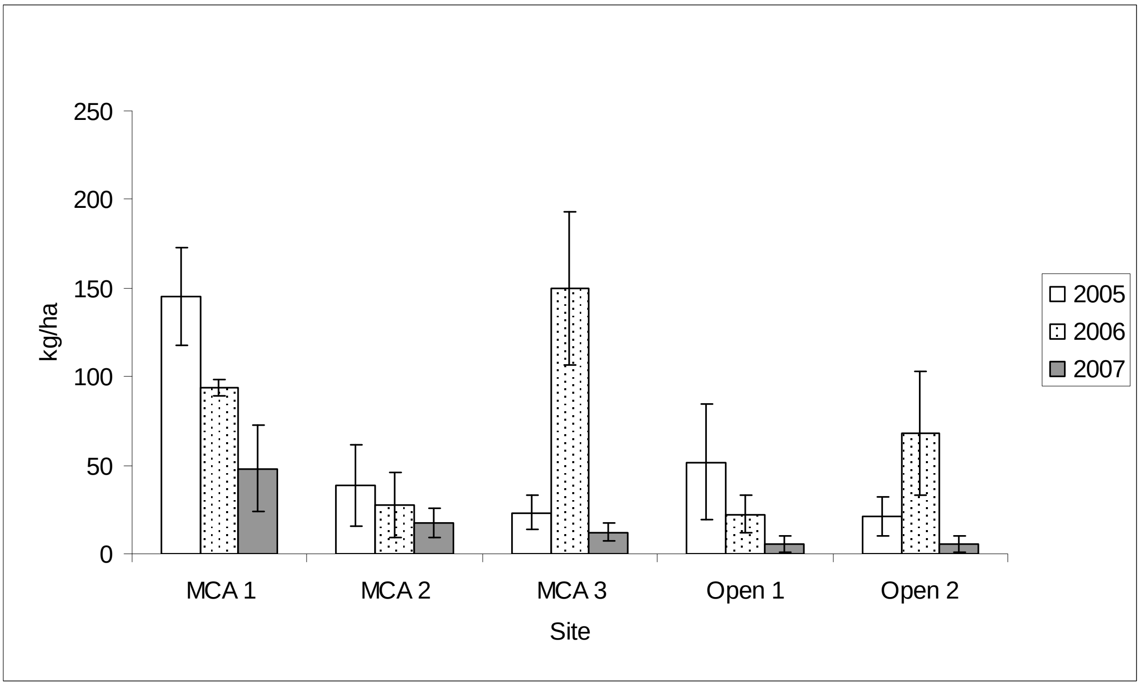


Figure 11. Mean biomass (+/- 1SE) of surgeonfishes inside and outside the Zinoa MCA in 2005, 2006 and 2007.

DRUMMERS

The biomass of drummers at each site in each year is shown in Figure 12. A Two way ANOVA on ranks shows that mean biomass of drummers was not significantly different between Years ($F_{2,75}$=1.276, P<0.287), but it was significantly different among Sites ($F_{4,75}$=7.049, P<0.001). There was not a significant Year x Site interaction ($F_{2,75}$=0.765, P=0.634). Holm-Sidak Post Hoc tests for the factor Site revealed that the mean biomass of drummers at Open 2 was significantly higher than MCA 2 (t=3.724) and Open 1 (t=3.724), and MCA 3 had higher biomass than Open 1 (t=3.698) and MCA 2(t=3.698).

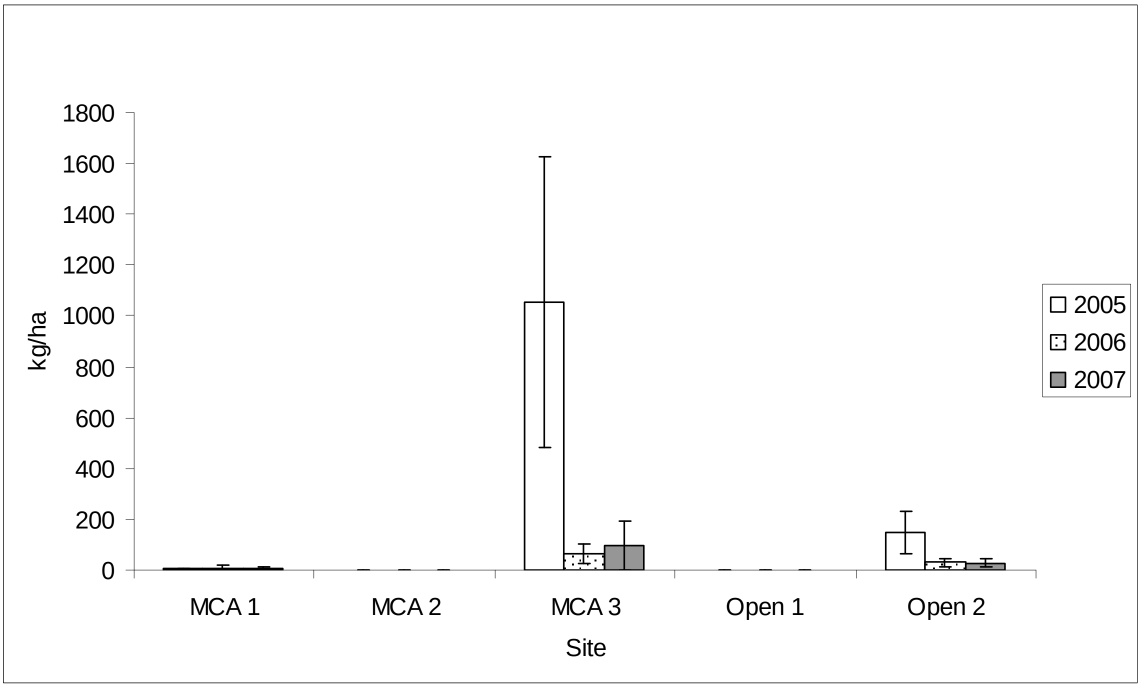


Figure 12. Mean biomass (+/- 1SE) of drummers inside and outside the Zinoa MCA in 2005, 2006 and 2007.

EMPERORS

The biomass of emperors at each site in each year is shown in Figure 13. A Two way ANOVA on ranks shows that mean biomass of emperors was significantly different between Years ($F_{2,75}$=33.622, P=0.033) and Sites ($F_{4,75}$=4.498, P=0.003). There was not a significant Year x Site interaction ($F_{2,75}$=0.312, P=0.959). Holm-Sidak Post Hoc tests for the factor Year show that the mean biomass of emperors in 2006 was significantly higher than in 2005 (t=2.320). Holm-Sidak Post Hoc tests for the factor Site revealed that the mean densities of emperors at MCA 3 were significantly higher than Open 2 (t=3.664) and MCA 2 (t=3.251).

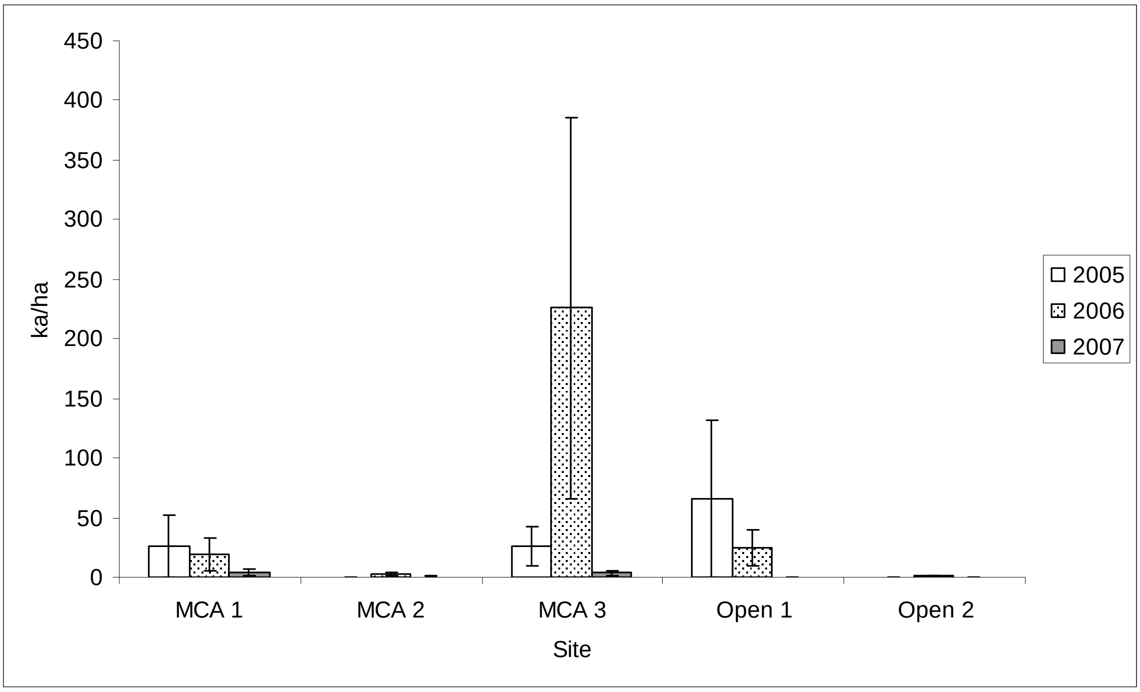


Figure 13. Mean biomass (+/- 1SE) of emperors inside and outside the Zinoa MCA in 2005, 2006 and 2007.

GOATFISHES

The biomass of goatfishes at each site in each year is shown in Figure 14. A Two way ANOVA on ranks shows that mean biomass of goatfishes was significantly different between Years ($F_{2,75}$=5.615, P=0.006) and Sites ($F_{4,75}$=4.885, P=0.002). There was not a significant Year x Site interaction ($F_{2,75}$=1.206, P=0.311). Holm-Sidak Post Hoc test for the factor Year show that the mean biomass of goatfishes in 2007 was significantly lower than in 2005 (t=3.290). Holm-Sidak Post Hoc tests for the factor Site revealed that the mean biomass of goatfishes Open 2 at MCA 3 were significantly higher than Open 1 (t=4.038 and t=3.106 respectively).

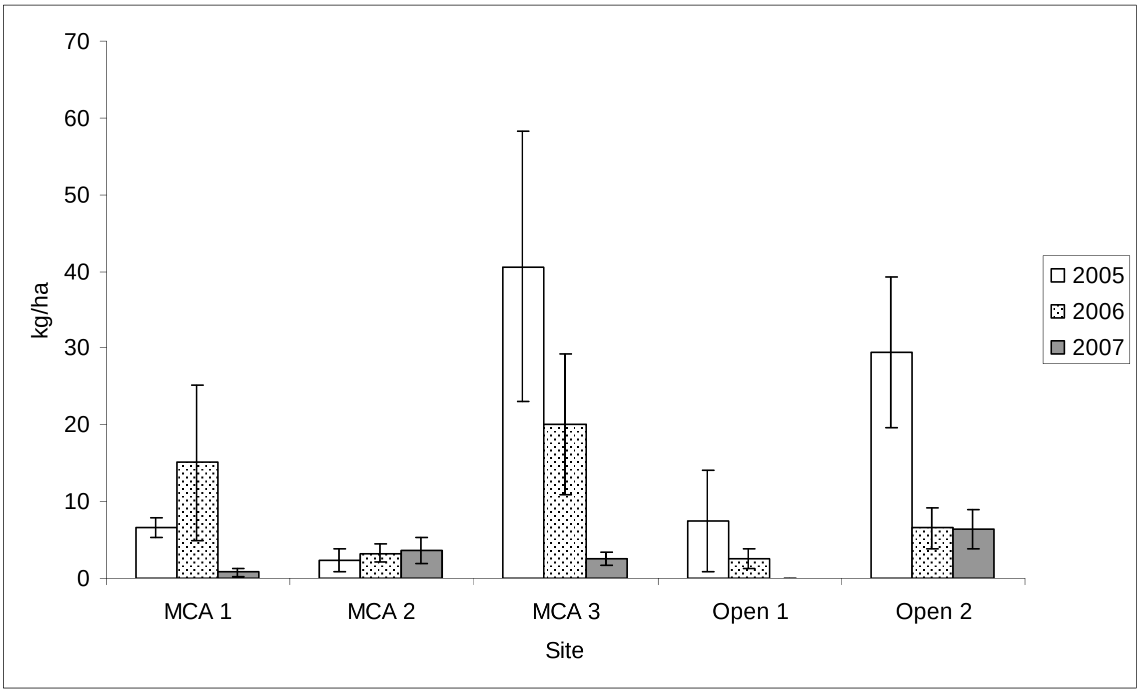


Figure 14. Mean biomass (+/- 1SE) of goatfishes inside and outside the Zinoa MCA in 2005, 2006 and 2007.

RABBITFISHES

The biomass of rabbitfishes at each site in each year is shown in Figure 15. A Two way ANOVA on ranks shows that mean biomass of rabbitfishes were significantly different between Sites ($F_{4,75}$=6.573 P<0.001) but not Years ($F_{2,75}$=0.927, P= 0.401). Holm-Sidak Post Hoc tests for the factor Site revealed that the mean densities at Open 2 were significantly higher than MCA 2 (t=3.848) and Open 1 (t=4.755).

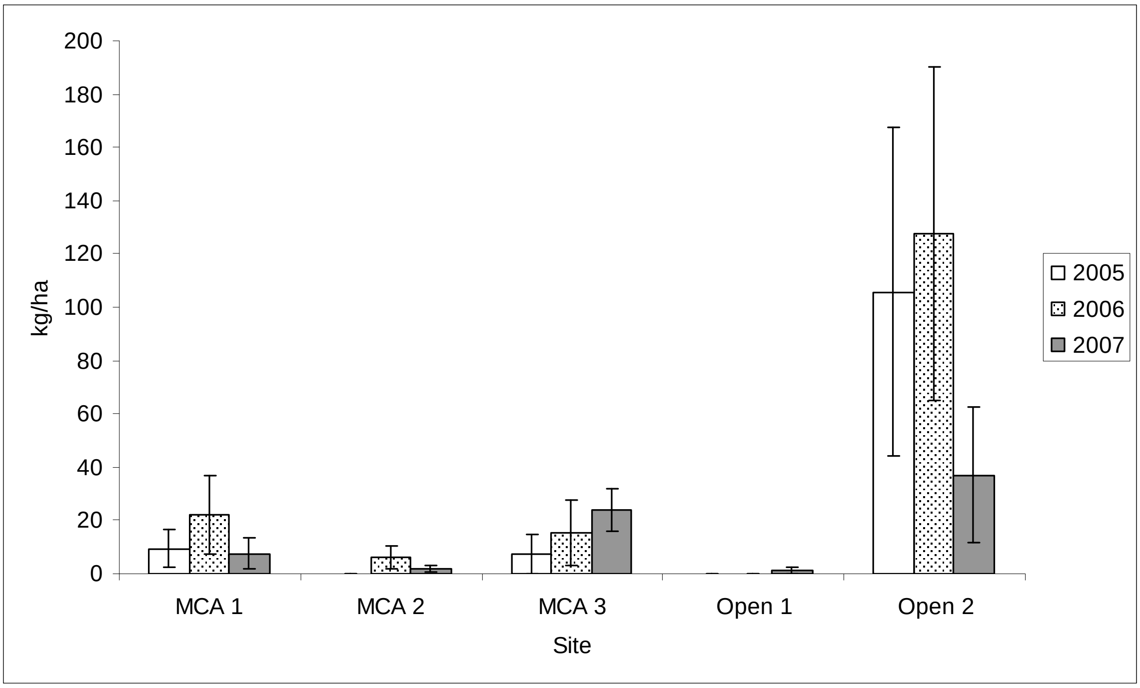


Figure 15. Mean biomass (+/- 1SE) of rabbitfishes inside and outside the Zinoa MCA in 2005, 2006 and 2007.

1.3.4. FOOD FISHES SIGHTED ON LONG SWIMS

The densities of large vulnerable species were low at all sites in all years. Only two target species, the green humphead parrotfish and the longface emperor were present in reasonable densities across sites and between years. The density of all large vulnerable food fishes sighted on long swims at each site in each year is shown in Figure 16. The biomass of all large vulnerable food fishes sighted on long swims at each site in each year is shown in Figure 17. Biomass of large vulnerable food fishes was low in at all sites in all years. Much of the variation in biomass between years and sites relates to the presence or absence of schools of green humphead parrotfish sighted on long swims.

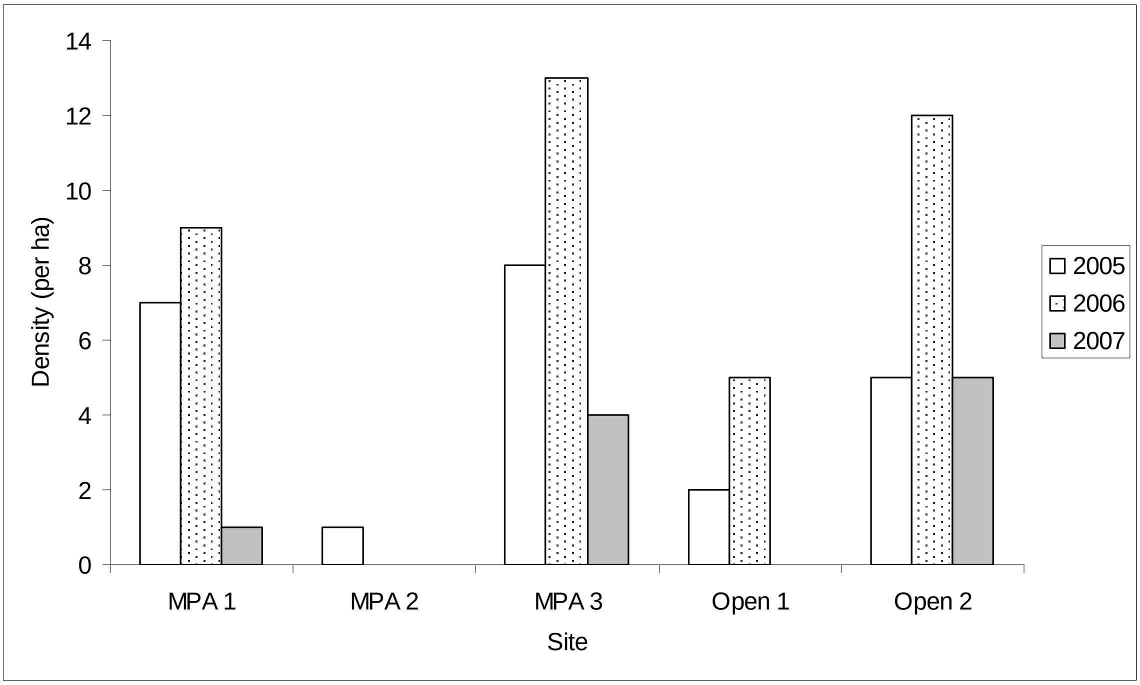


Figure 16. Number of large vulnerable fish sighted at each site in each year.

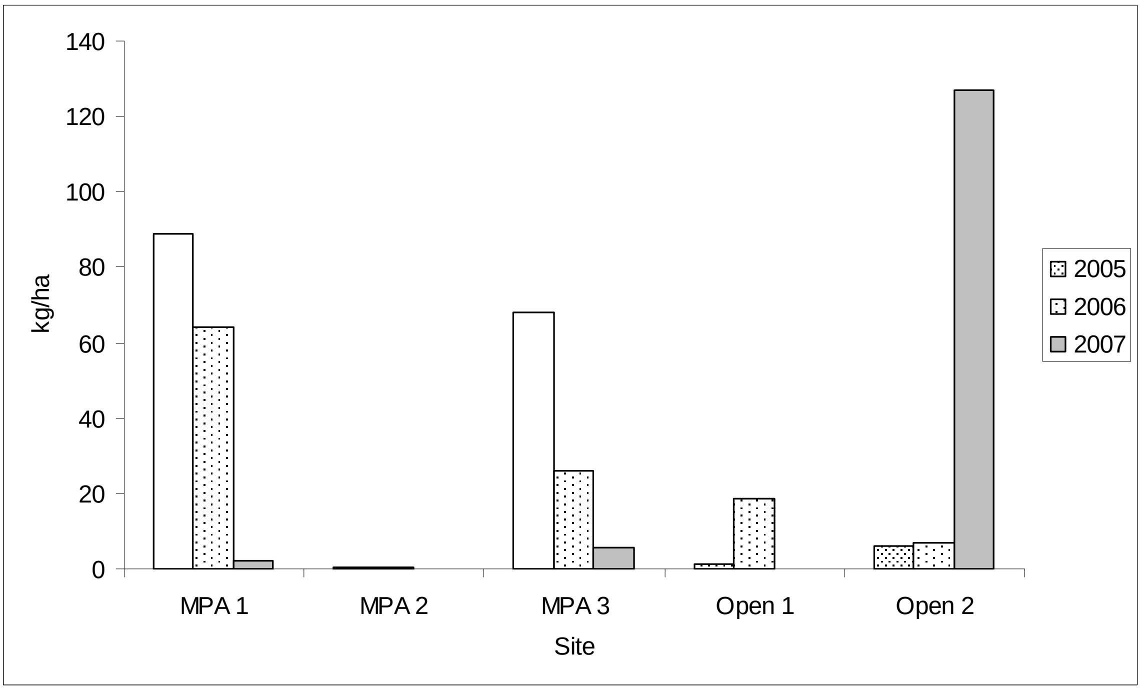


Figure 17. Biomass of large vulnerable fish sighted at each site in each year.

1.4. DISCUSSION

Analysis of the fish data collected along transects provided statistical evidence that the April 2007 tsunami significantly reduced the density and biomass of reef food fish both in and around the Zinoa MCA. This pattern was most obvious for total biomass, with dramatic reductions in fish biomass apparent at four of the five surveyed sites in 2007. The dramatic declines in biomass indicate that large fish were most adversely affected by the tsunami. Our analyses of the data found no evidence of any year and site interactions, highlighting that the reductions in density and biomass were fairly uniform across the five surveyed sites. It is noteworthy however that the statistical power to detect site and year interactions was often low, a consequence of high natural variability in fish counts and the low sample sizes at each site in each year.

An examination of data for the six most abundant families of fish revealed that the declines in total density and total biomass that were seen across all sites in 2007 were predominantly driven by declines in snappers, surgeonfishes and to some extent emperors, the three families that made up approximately 69% of the relative density of all food fish seen. Densities and biomass of drummers, goatfishes and rabbitfishes were not significantly different between years, indicating that these families were not affected by the tsunami.

Mean total densities and mean total biomass of fish sighted on transects at the five surveyed sites prior to the tsunami were never high. In most cases they were lower then the densities and biomass of food fishes sighted along transects at eight sites in Choiseul during the 2004 marine assessment (Green et al. 2006). Relatively low densities and biomass of fish sighted along transects in the Zinoa region is likely to be due in part to the lack of extensive and complex reef systems in this area. Overfishing may also have played a role. The density of large vulnerable species sighted on long swims were also lower than the mean density of large vulnerable reef fish sighted on exposed reefs in Choiseul during the 2004 marine assessment. However the biomass of large vulnerable reef fish sighted in and around Zinoa was higher than the mean biomass of large vulnerable reef fish sighted on exposed reefs in Choiseul during the 2004 marine assessment, reflecting the moderately high biomass of green humphead parrotfish sighted in the Zinoa area.

Densities and biomass of fish varied between sites. The highest total densities and total biomass of food fish were seen at MCA 3. MCA 3 had highest densities of emperors and drummers, and highest biomass of snappers, goatfishes and drummers. Densities and biomass of surgeonfish were highest at the exposed MCA 1 site. Rabbitfishes on the other hand were present in the highest densities at Open 2.

There was no evidence that fish densities or biomass increased significantly between 2005 and 2006, which is perhaps not surprising given the short time frame between surveys and the length of time it takes many of the target species to regenerate their populations. Target species such as large surgeonfishes and large parrotfishes can live in excess of 30 years (Choat et al. 1996a; 1996b), and population turnover for some species is very slow. For example, in the Solomon Islands 100% sexual maturity in female green humphead parrotfish is not reached until 11 years of age (Hamilton et al. 2007). Compounding this issue further is the fact that the home ranges of many of the large mobile target species may be significantly larger than the size of the Zinoa MCA (Kramer and Chapman 1999). Green humphead parrotfish again highlight this issue; this species can travel in excess of 5 km in one day (Hamilton 2004), and as such, this species will be offered little protection from small MCAs such as Zinoa.

CHAPTER 2.

Key Fisheries Species: Invertebrates

2.1. INTRODUCTION

The 2004 Marine Assessment showed that the Solomon Islands is an area of high conservation value where marine diversity is exceptionally high, marine habitats are in good condition and current threats are low (Green et al. 2006). Like in many other parts of the Solomon Islands, marine invertebrates form an important component of the livelihood of many coastal communities in Choiseul. Giant clams and other bivalves are used primarily as food in many communities whereas sea cucumber (beche-de-mer) and trochus shell are harvested and sold for income. Whilst maintaining the biodiversity of these species is important, the long term sustainable production of these fisheries resources is as equally important, not only for the communities in Choiseul but the Solomon Islands as a whole. In this regard, the community recognition of MCAs as an important management tool, and the establishment of MCAs such as Zinoa is a crucial step for achieving both conservation and management goals.

The interest in community-managed MCAs as a tool for recovery and enhancement of fisheries resources in Solomon Islands is increasing every year. To date, a number of community MCAs have already been established in Marau, Ngella, Roviana Lagoon, Marovo Lagoon, Tetepare and Gizo. In Choiseul, the Zinoa community-managed MCA is one of the five community MCAs that TNC has assisted communities in the province to establish in partnership with the LLCTC and Choiseul provincial fisheries (Figure 1). It is expected that many more MCAs will be established in Choiseul through this partnership. In other provinces in the Solomon Islands, MCAs continue to be established, often with assistance from international and local NGOs, and with support from the Solomon Islands Locally Managed Marine Areas Network (SILMMA).

A review of the Solomon Island beche-de-mer fishery (Ramofafia 2004) and the results from the 2004 Solomon Island marine assessment (Ramohia 2006) showed that commercially important invertebrates were heavily overfished throughout the Solomon Islands. On the basis of this information the Solomon Islands government imposed an indefinite export ban on beche-de-mer beginning on December 1, 2005. This ban was intended to give the government time to formulate a proper Management Plan for the beche-de-mer fishery before reopening it again. However this ban lasted only 17 months, as shortly after the April 2, 2007 tsunami the government reopened this export fishery.

The fishery was reopened without a proper Management Plan in place. It is clear the decision to lift the beche-de-mer export ban was a political one. Although the government may have had genuine reasons for reopening the fishery (e.g. to allow tsunami-stricken coastal communities access to a source of income) the lifting of the ban is unlikely to be beneficial for the fishery in the long term. Currently the only management measures in place relate to a ban on SCUBA and Hooka gear and minimum size limits (management measures which were introduced a decade ago). History tells us that even if these management measures could be adequately enforced, it is extremely unlikely that these measures alone would ensure sustainability of this fishery. If anything, the current scenario may lead to more serious overfishing then in the past.

The recent lifting of the export ban on beche-de-mer appears to be resulting in two confounding scenarios. Firstly, fishing effort on beche-de-mer is currently extremely high, with the incentive to fish the stocks as hard as possible being fuelled by government comments that the export ban will shortly be reintroduced. Fishers are currently going all out to harvest as much as they can during the open period. This in turn may result in an increase in the price of beche-de-mer as exporters compete to buy as much as they can during the short open period. A situation like this will no doubt lead to increased fishing effort and the subsequent over exploitation of the beche-de-mer resources and thus a loss of income for rural fishers and the country as a whole in the long term.

Secondly, as beche-de-mer stocks become increasing overfished, prices paid for these limited resources will continue to grow, and under this scenario widespread poaching in community MCAs is likely. MCAs are seen as source of sea cucumbers and other marine resources, and all of them are a target for poachers. Many communities in Solomon Islands especially in the Western, Choiseul, Isabel, Guadalcanal, and Central Islands provinces have established community MCAs as tools for enhancing and managing their marine resources. These community undertakings are done for good reasons. Should widespread poaching take place in these MCAs, the good aims of the communities will be defeated. It is through community MCAs like Zinoa that biodiversity and stocks of exploited invertebrates such as sea cucumbers, trochus and giant clams are given the opportunity to be restored, so that over time adult populations in these MCAs can export adults and larvae to overfished regions outside of the MCAs. Poaching on community MCAs as a result of the lifting of the ban could only be seen as one of the many negative impacts of this well-intended government-initiated step.

2.2. METHODS

2.2.1. STUDY SITES

The approximate location of the study sites near the Zinoa community are shown in Figure 1. The sites sampled in the Zinoa study area consisted of 1 reef flat and 3 reef slopes in the MCA and 2 open reef slopes outside the MCA. All study sites are located in the vicinity of Voza village (Figure 1). The landowning clan of Voza village was responsible for the demarcation of the MCA.

2.2.2. SURVEY PROCEDURES

The survey procedures and sampling methods used in this study are similar to those used during the 2004 Rapid Ecological Assessment survey (Ramohia 2006). A summary of the survey procedures and methods are as follows. Surveys in the reef slope habitat were conducted at depths between 5 – 10m using 50m long by 2m wide transects (an area of $100m^2$). Key invertebrates surveyed included giant clams (Genus: *Tridacna* and *Hippopus*), *Trochus niloticus* (Trochus shell), pearl oysters (Genus: *Pinctada* and *Pteria*) and several species of sea cucumbers including *Holothuria atra* (lollyfish), *Actinopyga mauritiana* (surf redfish), *Pearsonothuria graffei* (orangefish), *Bohadschia argus* (tigerfish), *Bohadschia vitiensis* (brown sandfish) and *Stichopus chloronotus* (greenfish). Indicator species such as *Acanthaster planci* (crown-of-thorns starfish), *Tectus pyramis* (false trochus) and *Charonia tritonis* (Triton shell) were also recorded. Six transects were laid haphazardly over the shallow reef slope. One team of two SCUBA divers was involved in the sampling. Table 3 gives the list of invertebrate species surveyed.

Sampling in the reef flat habitat was done at depths between 0.5 – 1.5m using 50m long by 2m wide transects (an area of $100m^2$). Six transects were laid haphazardly over the reef flat. One team of two divers, snorkelling or walking on the reef flat was involved in the sampling. Target commercial invertebrate species surveyed were the same as those listed in Table 3.

Table 3. Target invertebrate species surveyed during this study.

TAXA	COMMON NAME	SPECIES
Sea cucumbers	Deepwater redfish	*Actinopyga echinites*
Sea cucumbers	Stonefish	*Actinopyga lecanora*
Sea cucumbers	Surf redfish	*Actinopyga mauritiana*
Sea cucumbers	Blackfish	*Actinopyga miliaris*
Sea cucumbers	Tiger/Leopardfish	*Bohadschia argus*
Sea cucumbers	Chalkfish/false Teatfish	*Bohadschia similes*
Sea cucumbers	Brown sandfish	*Bohadschia vitiensis*
Sea cucumbers	Lollyfish	*Holothuria atra*
Sea cucumbers	Snakefish	*Holothuria coluber*
Sea cucumbers	Pinkfish	*Holothuria edulis*

TAXA	COMMON NAME	SPECIES
Sea cucumbers	White Teatfish	*Holothuria fuscogilva*
Sea cucumbers	Elephant’s trunkfish	*Holothuria fuscopunctata*
Sea cucumbers	Black Teatfish	*Holothuria nobilis*
Sea cucumbers	Sandfish	*Holothuria scabra*
Sea cucumbers	Orange/flowerfish	*Pearsonothuria graeffei*
Sea cucumbers	Greenfish	*Stichopus chloronotus*
Sea cucumbers	Dragonfish (Peanutfish)	*Stichopus horrens*
Sea cucumbers	Curryfish	*Stichopus hermanni*
Sea cucumbers	Brown curryfish	*Stichopus vastus*
Sea cucumbers	Prickly redfish	*Thelenota ananas*
Sea cucumbers	Amberfish	*Thelenota anax*
Sea cucumbers	Lemonfish	*Thelenota rubralineatus*
Pearl Oysters	Gold lip pearl oyster	*Pinctada maxima*
Pearl Oysters	Blacklip pearl oyster	*Pinctada margaritifera*
Pearl Oysters	Brown pearl oyster	*Pteria penquin*
Giant clams	Giant clam	*Tridacna gigas*
Giant clams	Smooth giant clam	*Tridacna derasa*
Giant clams	Fluted giant clam	*Tridacna squamosa*
Giant clams	Rugose giant clam	*Tridacna maxima*
Giant clams	Burrowing giant clam	*Tridacna crocea*
Giant clams	Horseshoe clam	*Hippopus hippopus*
Snails	Trochus	*Trochus niloticus*
Snails	False Trochus	*Pyramis tectus*
Snails	False Trochus	*Trochus maculates*
Snails	Greensnail	*Turbo marmoratus*
Snails	Triton*	*Charonia tritonis*
Starfish	Crown of Thorns*	*Acanthaster planci*

* Indicator species coral reef health

2.2.3. DATA ANALYSIS

Density data from the reef slopes was non normal and was not corrected for by transformations. Consequently, two-way ANOVA on ranks, with Year and monitoring Site as fixed factors, were used to assess changes in total density of all invertebrates, sea cucumbers, trochus and giant clams on the reef slope. One-way ANOVAs were used to compare total density of all invertebrates, sea cucumbers, trochus and giant clams on the reef flat. Where differences were significant, Tukey’s or Holm-Sidak Post Hoc tests were used to identify significant pairwise differences. All statistical analysis was carried out using SigmaStat3.5.

2.4. RESULTS

The mean range of densities of commercial invertebrate species sighted in Zinoa MCA between 2005 and 2007 is shown in Table 4. Table 5 shows the number and average sizes of common species of target invertebrates recorded in sampled transects in the Zinoa MCA within both the reef slope and reef flat habitats between 2005 and 2007.

Table 4. Range of mean densities of commercial invertebrate species recorded in the Zinoa MCA between 2005 and 2007.

Species	Range of mean density (#/ha) in Reef Slope (5 – 10m)	Range of mean density (#/ha) in Reef Flat (0.5 – 1.5m)
Sea Cucumbers		
Actinopyga miliaris	0 - 17	-
Bohadschia argus	0 - 33	117

Species	Range of mean density (#/ha) in Reef Slope (5 – 10m)	Range of mean density (#/ha) in Reef Flat (0.5 – 1.5m)
B. similes	-	117
B. vitiensis	-	167
Holothuria atra	0 - 67	33
H. coluber	-	133
H. fuscogilva	0 - 17	-
H. fuscopunctata	0 - 17	-
H. scabra		200
Thelenota ananas	0 - 17	-
Giant clams		
Tridacna crocea	0 - 17	33
T. maxima	0 - 50	17
T. squamosa	0 - 17	17
Hippopus hippopus	-	33
Gastropod		
Trochus niloticus	0 - 50	150

Table 5. Number and average sizes of common species of target invertebrates recorded in sampled transects in the Zinoa MCA within both the reef slope and reef flat habitats between 2005 and 2007.

Species	Total Number (n) recorded in the two habitats	Average Size (cm)	Range (cm)
Sea cucumbers			
Bohadschia argus	16	23.9	18 – 34.5
B. similes	9	16.8	12 – 22
B vitiensis	14	16.9	13 – 22
Holothuria atra	25	39.8	16 – 48
H. scabra	12	16.6	12 – 22
Giant clams			
Tridacna crocea	11	8.0	4 – 13
T. maxima	14	19.9	13 – 30
T. squamosa	5	33.2	26 – 42
Hippopus hippopus	3	23	22 – 23
Gastropods			
Trochus niloticus	23	9.8	7 – 12.1

2.4.1. INVERTEBRATES ON THE REEF SLOPE

2.4.1.1. Total Invertebrate Densities

The mean density of invertebrates at each site in each year is shown in Figure 18. A two-way ANOVA on the ranks of density shows that mean densities of invertebrates did not differ significantly between Years (F2,90=2.320, P<0.105), but differed significantly among Sites (F4,90=8.773, P<0.001). There was not a statistically significant interaction between Year and Site (F8,90=1.268, P=0.273). Holm-Sidak Post Hoc tests for the factor Site show that densities at Open 2 were significantly higher than Open 1 (t=5.20) and MCA 2 (t=4.101). Mean densities at MCA 1 and MCA 3 were also significantly higher than Open 1 (t=3.929 and t=3.476 respectively). To explore if different families or genera responded differentially to protection and the tsunami, we analysed each main group separately. These results are presented below.

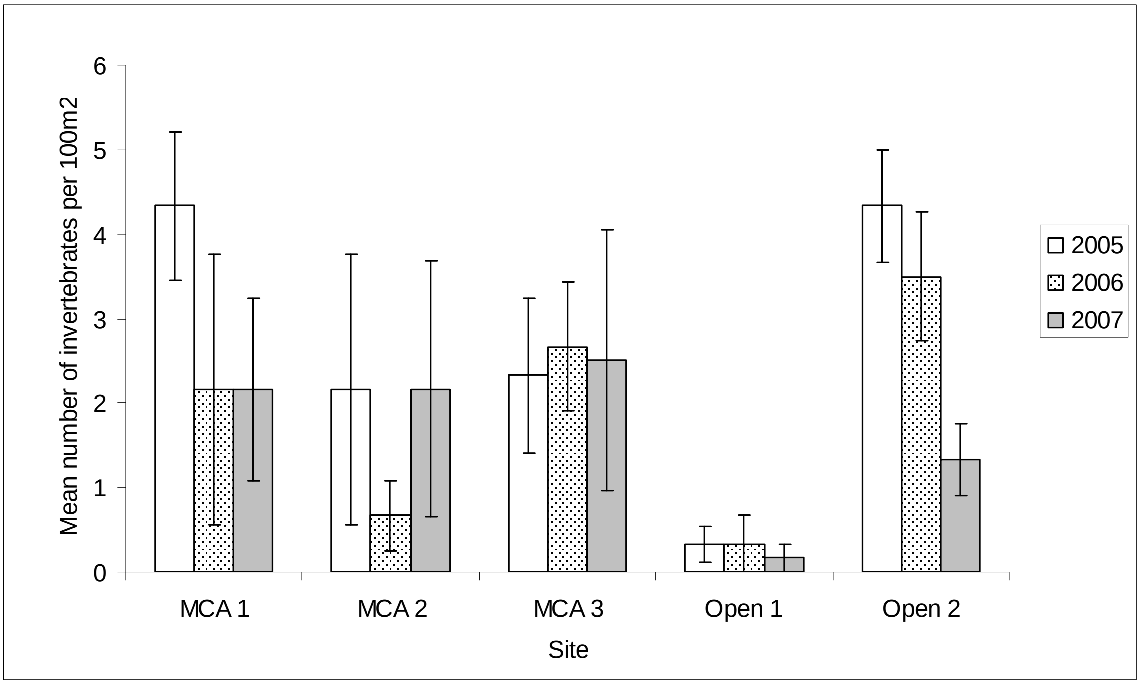


Figure 18. Mean number (±SE, n=6) of total invertebrates for each of the sites surveyed in the Zinoa MCA and open areas in the reef slope habitat.

2.4.1.2. Sea Cucumbers

Mean densities of all sea cucumbers at each site over the three years surveyed is shown in Figure 19. Mean densities were low at all sites in all years, and had a high degree of variance. A two-way ANOVA on ranks shows that mean densities of sea cucumbers did not differ significantly between Years (F2,90=1.574, P=0.214) or Sites (F4,90=0.855, P=0.495).

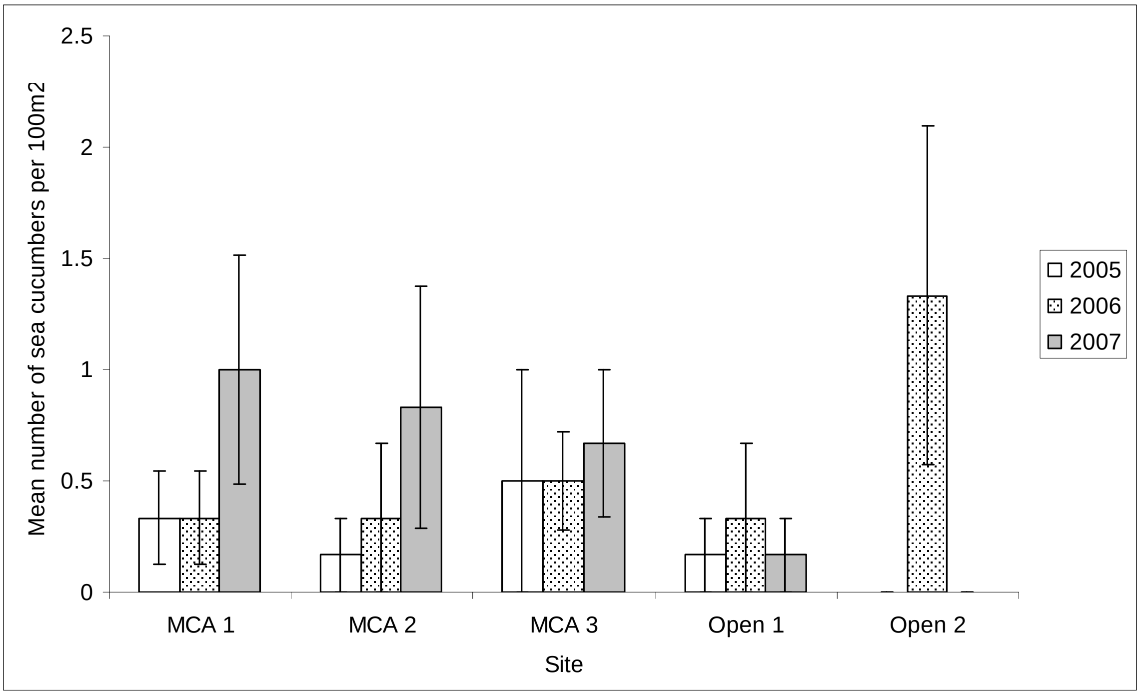


Figure 19. Mean number (±SE, n=6) of sea cucumbers for each of the sites surveyed in the Zinoa MCA and open areas in the reef slope habitat.

2.4.1.3. Giant clams

Mean densities of all giant clams at each site over the three years surveyed is shown in Figure 20. Mean densities were very low at all sites in all years, and had a high degree of variance. A Two way ANOVA on ranks shows that mean densities of giant clams did not differ significantly between Years ($F_{2,90}$=0.760, P=0.471) or Sites ($F_{4,90}$=2.004, P=0.102).

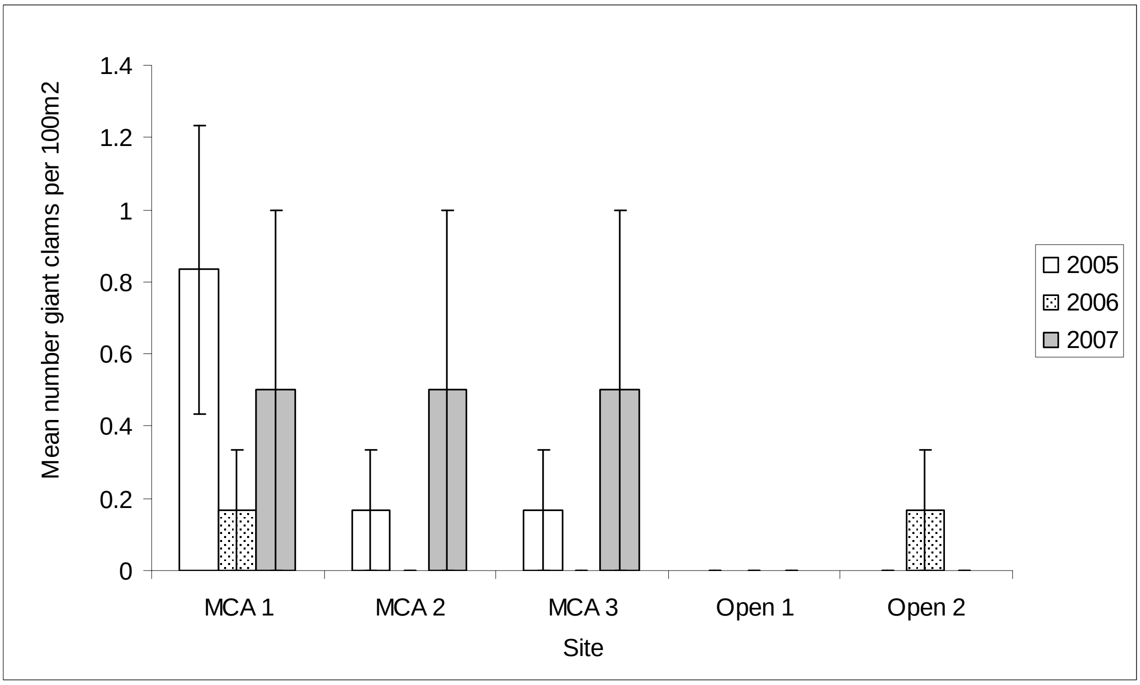


Figure 20. Mean number (±SE, n=6) of giant clams for each of the sites surveyed in the Zinoa MCA and open areas in the reef slope habitat.

2.4.1.4. Trochus

Mean densities of *Trochus niloticus* at each site over the three years surveyed is shown in Figure 21. *Trochus niloticus* was only sighted in very low numbers at MCA 1 and MCA 2 and had a high degree of variance. A two-way ANOVA on ranks shows that mean densities of *Trochus niloticus* did not differ significantly between Years ($F_{2,90}$=0.974, P=0.382) or Sites ($F_{4,90}$=1.340, P=0.263).

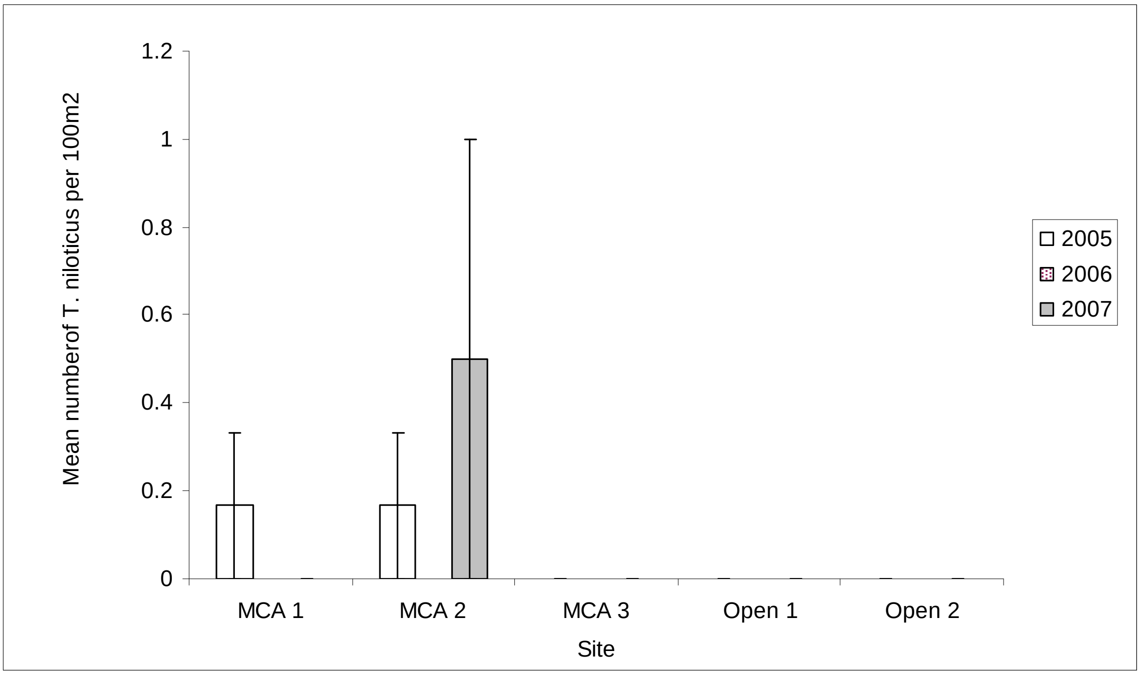


Figure 21. Mean number (±SE, n=6) of *Trochus niloticus* for each of the sites surveyed in the Zinoa MCA and open areas in the reef slope habitat.

2.4.2. INVERTEBRATES ON THE REEF FLAT

2.4.2.1. Total Invertebrate Densities

The mean invertebrate density on the reef flat in the three surveyed years is shown in Figure 22. In 2006 mean densities were four times higher than in 2005, and conversely, in 2007 mean densities were six times lower than in 2006. A one-way ANOVA shows that density differed significantly among Years (H=9.078, P=0.011). Tukey's Post Hoc tests revealed that mean densities in 2006 were significantly higher than in 2005 (P<0.05), providing statistical evidence for recovery of invertebrates in this habitat following protection. Mean densities in 2007 were significantly lower than in 2006 (P<0.05), providing statistical evidence for a significant reduction in invertebrate densities on the reef flats following the April 2007 tsunami. To explore whether different families and genera on the reef flat responded differentially to protection and the tsunami, we analysed each main group separately. These results are presented below.

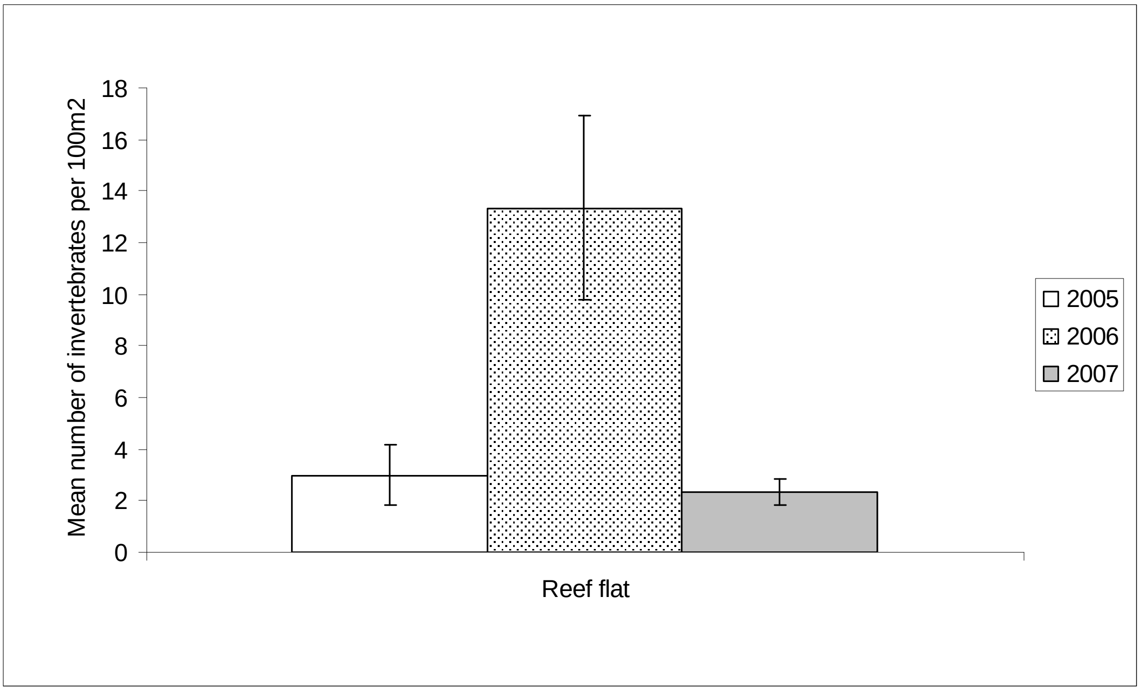


Figure 22. Mean number (±SE, n=6) of total invertebrates for the site surveyed in the Zinoa MCA reef flat.

2.4.2.2. Sea Cucumbers

Mean densities of all sea cucumbers on the reef flat over the three years surveyed is shown in Figure 23. Mean densities of sea cucumbers showed an identical trend to total invertebrate trends on the reef flat (Figure 22); however, an analysis of the data did not detect a significant difference between the three Years. Four species of sea cucumbers (brown sandfish, tiger fish, sandfish, snakefish and chalkfish) that were sighted on the reef flats between 2005 and 2007 displayed trends that indicated recovery following protection (2005 - 2006) and subsequent decline after the April 2007 tsunami (Figure 24).

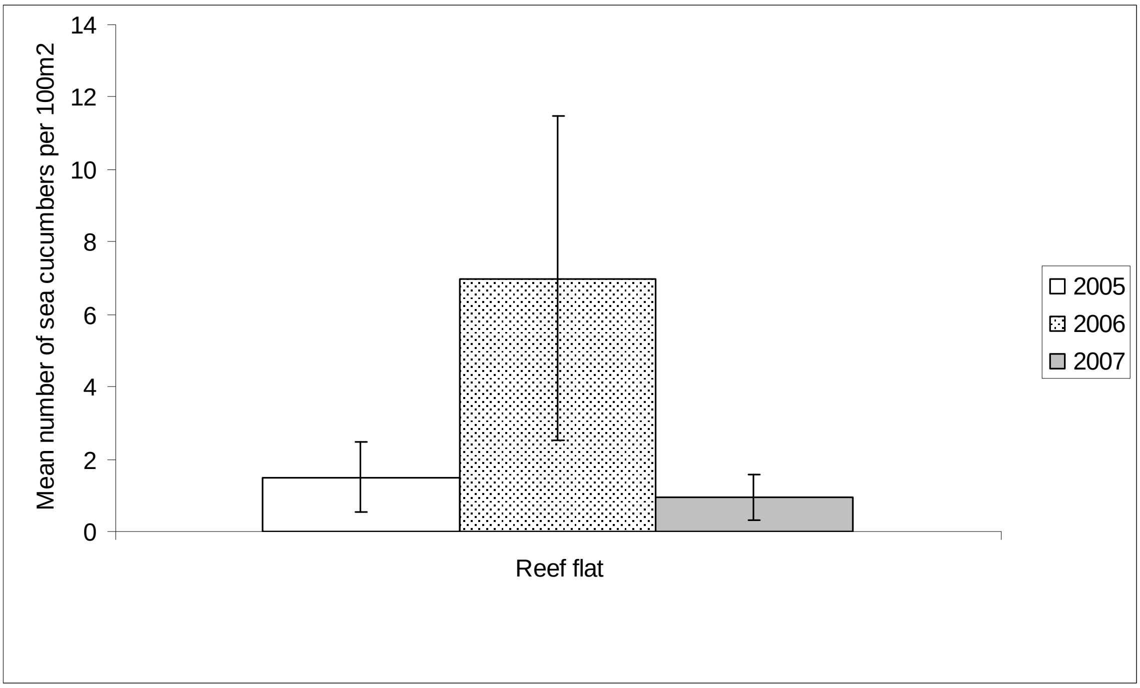


Figure 23. Mean number (±SE, n=6) of sea cucumbers for the site surveyed in the Zinoa MCA in the reef flat

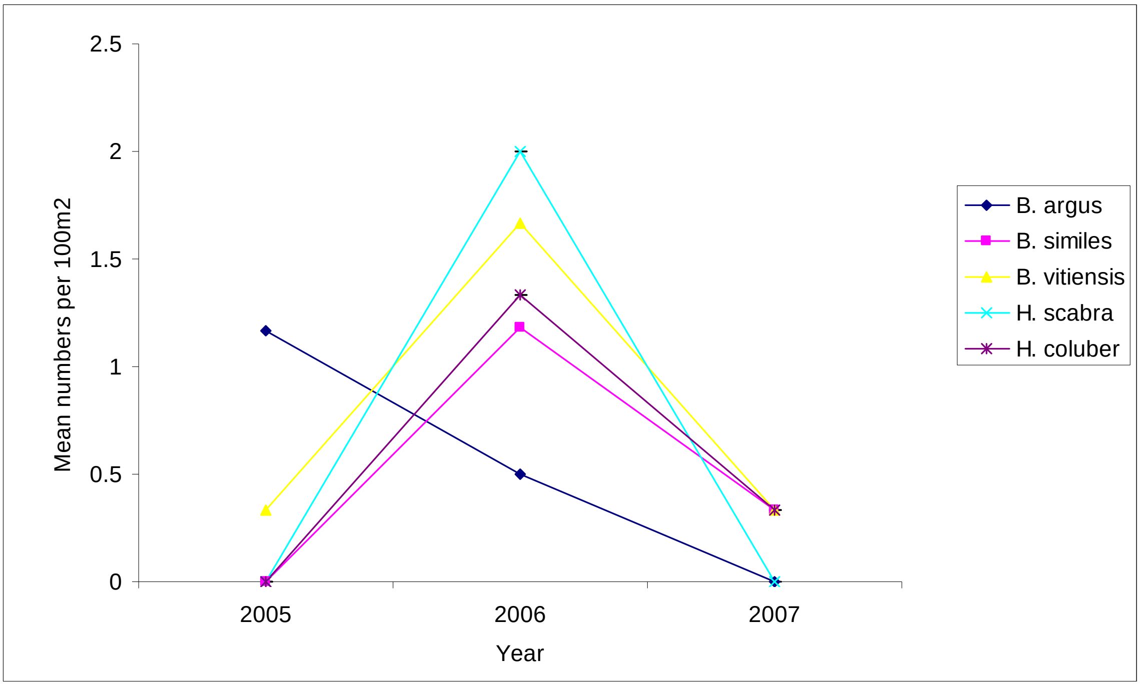


Figure 24. Mean numbers of five sea cucumber species found in the MCA Reef flat habitat during the three surveys.

2.4.2.3. Giant Clams

Mean densities of all giant clams on the reef flat over the three years surveyed is shown in Figure 25. The highest mean densities of giant clams were seen in 2006. No giant clams were sighted in 2007 indicating that the tsunami had a strong negative impact on giant clams on the reef flat. However, an analysis of the data did not find a significant difference between the three years.

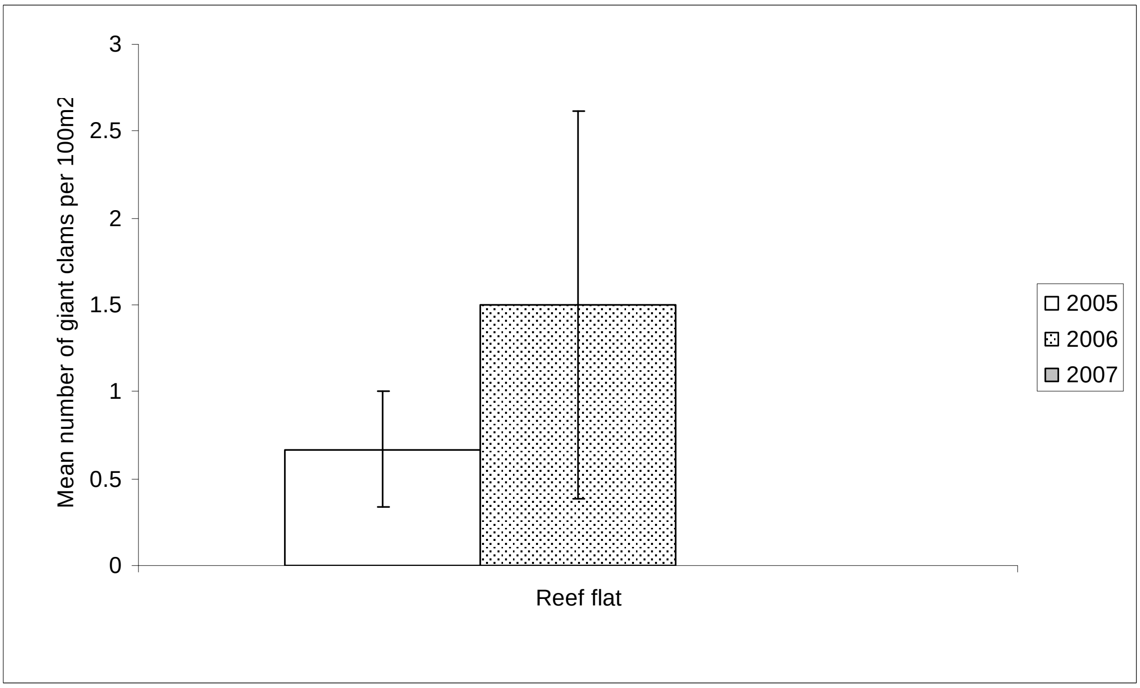


Figure 25. Mean number (±SE, n=6) of giant clams for the site surveyed in the Zinoa MCA in the reef flat.

2.4.2.4. Trochus

Mean densities of Trochus on the reef flat over the three years surveyed is shown in Figure 26. Mean densities of trochus showed a similar trend to total invertebrate trends on the reef flat (Figure 22); however an analysis of the data did not find a significant difference between the three years.

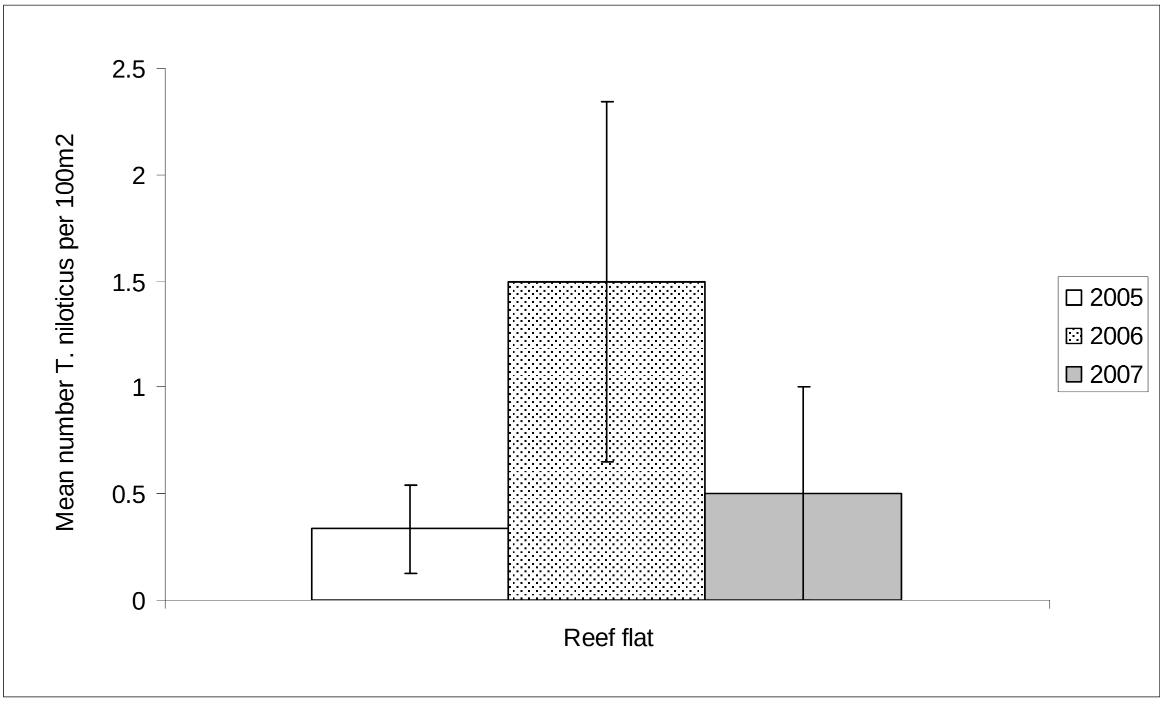


Figure 26. Mean number (±SE, n=6) of *Trochus niloticus* in the Zinoa MCA reef flat.

2.5. DISCUSSION

Analysis of the macroinvertebrate data revealed some interesting patterns. Mean density of invertebrates on the reef flat habitat increased significantly following protection and decreased significantly after the April 2007 tsunami. Whereas mean densities of macroinvertebrates in 5-10m of water did not differ between all three years, indicating that neither protection nor the tsunami had any significant effect on their densities.

The invertebrate data from the reef flats shows that prior to the tsunami the Zinoa MCA was beginning to meet the objective of allowing macroinvertebrates populations within the MCA to recover. Between 2005 and 2006 the mean total number of invertebrates in the reef flat habitat increased significantly from 3.00 per $100m^2$ (or equivalent to 300 per hectare) to 13.33 (or equivalent to 1,333 per hectare). Sea cucumbers appear to be the invertebrates responding most positively to protection, with four species that were not sighted in 2005 being sighted on the reef flats in 2006. There was no evidence of such recovery in the deeper water during this one year period. It is noteworthy however that nearly all of the sea cucumbers seen in the reef flat areas were juveniles, and we would expect to see an increase in sea cucumber densities in the deeper water within the Zinoa MCA over time, as juvenile sea cucumbers on the reef flats grow and subsequently make ontogenetic migrations down into deeper water.

The tsunami severely impacted invertebrate populations within the reef flat habitat, with invertebrate populations in 2007 six-times lower then in 2006. The negative impact of the tsunami on the reef flats is not surprising, as this was an area that was completely covered in sand immediately after the April 2007 tsunami. The presence of low numbers of sea cucumbers and trochus seen in the reef flats in 2007 (coupled with invertebrate populations in the deeper water appearing to be unaffected by the tsunami) indicate that the invertebrate populations in this habitat are likely to recover over time. Unlike the food fish populations, invertebrates in deeper water did not appear to be adversely affected by the tsunami. Indeed, at some sites such as MCA 1, the tsunami created more suitable habitat (sand) for sea cucumber species (See report below on benthic assessment).

Although the Zinoa MCA started to show positive recovery of invertebrates in the reef flat habitat following protection, the mean density of invertebrates in both reef flats and deeper water was low compared to that found in other parts of the Solomon Islands and the Indo-pacific. For example, on the reef slope *B. argus* and *H. atra* made up the majority of sea cucumbers recorded with densities ranging from 0 to 0.33 per $100m^2$ or the equivalent of 0 - 33 per hectare and 0 - 67 per hectare respectively. In contrast, the five species *Bohadschia argus*, *B. similes*, *B vitiensis*, *Holothuria atra* and *H. scabra* were the most common in the reef flat habitat with mean densities of 117, 117, 167, 33, 133 and 200 per hectare respectively in the reef flat habitat. These results may seem high for the respective species but compared to that recorded elsewhere in the region and Solomon Islands, this is low (Preston 1993; Lincoln-Smith et al. 2000; Friedman et al. 2004; Creese and Friedman 1995).

Also, considering that only a small number of sites with small numbers of transects were sampled, these densities may not represent the real situation as the presence of one specimen in the six transects sampled in the reef slope and reef flat habitats will be equivalent to a mean density of 17 per hectare respectively. A point to note is that high-value species such as white teatfish, prickly redfish, surf redfish, greenfish, black fish, black teatfish, and curryfish were either not seen or were present in very low numbers in the study area. The numbers of sea cucumber species recorded in transects during this study also recorded only a small portion of the known species exported from the Solomon Islands (Holland 1994; Ramofafia 2004).

Trochus niloticus was encountered in sampled transects at two sites in the Zinoa MCA with a mean density of 0.17 per transect or 17 per hectare respectively. This is low compared to density estimates from Lincoln-Smith and Bell (1996), Lincoln-Smith et al. (2000) and Nash et al. (1995). Lincoln-Smith et al. (2000) reported a mean density of 57 per hectare in the Arnavon Community Marine Conservation Area while Nash et al.,(1995) reported a mean density of 222 – 2016 in the Cook Islands. Although the number of *T. niloticus* recorded during this study is low, their size measurement range of 7.5 – 12.1cm indicated that all animals were sexually mature (Nash 1993).

Of the six species of giant clams known from the Solomon Islands, five were recorded in the shallow reef slope and reef flat habitats in the Zinoa MCA. These are *T. gigas*, *T. crocea*. *T. maxima*, *T. squamosa* and *Hippopus hippopus*. No clam species were recorded in the open fished sites. In the reef slope habitat, *T. maxima* had the highest mean density of 0.5 per transect or equivalent of 50 per hectare. The other two species, *T. squamosa* and *T. crocea*, were present at a mean density of 0.17 per transect or 17 per hectare. Compared to studies done elsewhere in the region and the Solomon Islands, such as Munro (1993), Creese and Friedman (1995) and Lincoln-Smith and Bell (1996), the above results indicate a low abundance. For example, Munro (1993) reported well over 1,000 individuals per hectare in French Polynesia for *T. maxima* while Creese and Friedman (1995) recorded 1,400 per hectare at Indispensable Reef in Rennell and Bellona province in the Solomon Islands. Lincoln-Smith and Bell (1996) reported up to 194 per hectare in the Arnavon Community Marine Conservation Area. Munro (1993) also reported densities well over 3,000 individuals per hectare for *T. crocea* in French Polynesia while Creese and Friedman (1995) reported densities of up to 500 per hectare at Indispensable Reef. The larger species of giant clams,*T. gigas*, was introduced to the Zinoa MCA as brook stock, but *T. derasa* was not recorded during the present survey. The size range of giant clams seen at Zinoa indicates that all animals were sexually mature.

Sea cucumbers, trochus and giant clams are all high-value species that are vulnerable overexploitation. The low densities of invertebrates sighted in all years support local fishers' claims that this area has been heavily overexploited in the past. It is likely that long-term protection will be needed to allow for population recovery to the extent of their reported former abundances.

CHAPTER 3.

BENTHIC COMMUNITY STRUCTURE OF THE ZINOA MARINE CONSERVATION AREA

3.1. INTRODUCTION

The term “coral reefs” brings to mind a picture of an ecosystem comprised of numerous coral colonies supported by large, elaborate, calcareous skeletal accumulations existing in oligotrophic waters on mid-oceanic atolls or high islands surrounded by fringing or barrier reefs to depths of >40m. However, coral reefs are also found thriving in naturally turbid waters of that contain higher amounts of nutrients and sediments in inshore habitats (Yentsch et al. 2002). No matter where they are found, coral reefs are influenced by a range of biotic factors (e.g. settlement, recruitment, mortality, competition, predation, etc.) and abiotic factors (e.g. light availability, hydrodynamics) that determine the composition of each individual reef (Birkeland 1997). An important component of the coral reef system is the benthic community structure, which typically differs among and within locations as a result of the specific responses of reef organisms to the environment.

Coral reefs found in turbid inshore habitats support unique and diverse benthic communities that tend to differ in composition from reefs found in well-flushed habitats that are more characteristic of oceanic waters and that are subject to lower levels of turbidity and sedimentation (Hughes 2006). Coral reefs in clear waters are usually dominated by branching lifeforms, mainly acroporid corals, while those in turbid environments tend to be dominated by massive forms of coral (Done 1982; Hughes 2006). High turbidity, shading and high sedimentation also result in reduced biodiversity of hard corals because fewer coral species can tolerate such conditions. Reefs in inshore and coastal areas are more prone to variable conditions including higher levels of dissolved particulate nutrients and sedimentation and hence reduced water clarity and more fluctuating salinity than oceanic reefs (Furnas 2003).

Turbidity in the water column can be caused by increased hydraulic energy (e.g. waves, currents) that is sufficient to suspend siliciclastic materials (but does not remove them from the system) and/or the rates of material input (e.g. from rivers) exceed that of removal. The resulting turbidity from the re-suspension and input of sediments can elevate coral mortality rates by smothering, abrasion and shading of adult corals (Rogers 1990; van Katwijk et al. 1993; West and Van Woesik 2001) and has a negative impact on the settlement of recruiting larvae (Babcock and Smith 2002; Cox and Ward 2002) and hence benthic community structure.

Although, the spatial pattern of distribution and diversity of reef organisms has been thoroughly addressed in parts of the Pacific (e.g. Done 1982; Harriot et al. 1994; Adjeround 1997), very little work has focussed on this in Solomon Islands. Most of the work conducted so far has been in a “snap-shot” manner without any follow-up surveys that would enable a temporal comparison of the benthic ecology.

This report documents the benthic surveys conducted during the past three years at the Zinoa Marine Conservation Area (MCA). The purpose of this benthic report is two-fold:

1. To report on the spatial trends in the benthic community structure of the Zinoa Marine Conservation Area that have occurred over the first two years.
2. To assess the extent of any possible impacts by the April 2007 earthquake and tsunami on the benthic community of Zinoa Marine Conservation Area.

3.2. METHODS

Zinoa Marine Conservation Area is remotely located off the southern coastline of the western end of Choiseul Island. The windward (southern) side of the reef complex is comprised of rocky outcrops with a few small sandy beaches surrounded by "embryonic" fringing reefs in depths that rarely exceed 10m. The shallow reef platform is made up of rocky habitat, which gently slopes into the surrounding ocean. The reef bottom is made up of patchy distributions of corals with a high abundance of macroalgae and soft corals. There are three nearby rivers that influence the salinity and turbidity of the surrounding waters.

A total of five survey sites, three within the MCA and two outside, were established in 2005. Of the sites within the MCA, two (MCA 1, 2) were located on windward (exposed) slopes and the third (MCA 3) on the leeward slope of the reef complex. The two reference or comparison sites were located on a submerged reef east of the conservation area (Open 1) and next to the coastline of Choiseul Island in close proximity to Voza community (Open 2) (Figure 1).

Prevailing winds from the south-east (trade-winds) occur between the months of April to August and have varying impacts along the exposed coastlines. The presence of nearby depression systems (sometimes from cyclones) normally occur during the months of December to February and can impact local weather patterns producing rough sea condition. However, these depressions can also occur at different times of the year and sometimes can occur during the trade-wind period. This can produce unusually rough conditions.

3.2.1. SURVEY METHODS

Benthic data were collected using a modified version of the Point Intercept Method (Hill and Wilkinson 2004). Benthic data were collected from three points every 2m along a 50m transect tape. Two points were located 1 metre on either side of the transect line and the third was below the transect. A total of five 50m transects were laid at a depth profile of 8-10m at each site. This resulted in a total collection of 75 data points for each transect, and a total of 375 data points for each site.

Benthic composition was recorded based on lifeforms consistent with the categories provided by English et al. (1997, Table 6). For ease of presentation, these were further grouped into five major categories: hard coral, algae, abiotic, soft corals and others. Note that the "others" category is a combination of the categories used by English et al. (1997) with the inclusion of sponges and zoanthids.

Table 6. Lifeform categories used to describe the benthic composition at Zinoa Marine Conservation Area.

Code	Lifeform	Code	Lifeform
ACB	Acropora Branching	AA	Algae Assemblage
ACE	Acropora Encrusting	CA	Coralline Algae
ACD	Acropora Digitate	HA	Halimeda
ACT	Acropora Tabular	MA	Macro-algae
ACS	Acropora Submassive	TA	Turf Algae
CB	Coral Branching	S	Sand
CE	Coral Encrusting	R	Rubble
CF	Coral Foliose	Si	Silt
CM	Coral Massive	DC l	Dead Coral
CS	Coral Submassive	RCK	Rock
CMR	Mushroom Coral	SC	Soft Coral
CHL	Blue Coral	SP	Sponge
CME	Fire Coral	ZO	Zoanthid
CTU	Organ Pipe Coral	OT	Others (Ascidians, anenomes, gorgonians etc)
DCA	Dead Coral with Algae		

3.2.2. DATA ANALYSIS

Two-way ANOVAs, with Year and monitoring Site as fixed factors, were used to assess changes in percentage cover of the fivemajor lifeforms: hard coral, algae, abiotic, soft corals and others. In 2007, Open 1 was not surveyed due to logistical problems in the field. For this reason, two-way ANOVAs were run on sites MCA 1, MCA 2, MCA 3 and Open 2 only. Where differences were significant, Tukey's or Holm-Sidak Post Hoc tests were used to identify significant pairwise differences. In some instances data was non normal, and in these cases two-way ANOVAs on ranks were run. All statistical analysis was carried out in SigmaStat 3.5. Only results of significant Post Hoc tests are presented in this section of the report.

3.3. RESULTS

3.3.1. HARD CORAL

The mean percentage of hard coral cover at each site in each year is shown in Figure 27. A two-way ANOVA on the rank of hard coral cover shows that mean percentage of hard coral cover was significantly different between Year ($F_{2,60}$=23.234, P<0.001) and Site ($F_{3,60}$=8.752, P<0.001). There was not a statistically significant interaction between Year and Site ($F_{6,60}$=2.046, P= 0.078). Holm-Sidak Post Hoc tests for the factor Year revealed that for the four sites considered, the mean hard coral cover differed significantly in every year, with highest percentage cover occurring in 2005, declining in 2006, and declining further in 2007 following the tsunami (Appendix 2). The most notable change occurred at MCA 1, where mean hard coral cover decreased from 24% in 2005 to 2% in 2007. Holm-Sidak Post Hoc tests for the factor Site revealed that hard coral cover at MCA 3, MCA 1 and Open 2 were significantly higher than MCA 2 (Appendix 2).

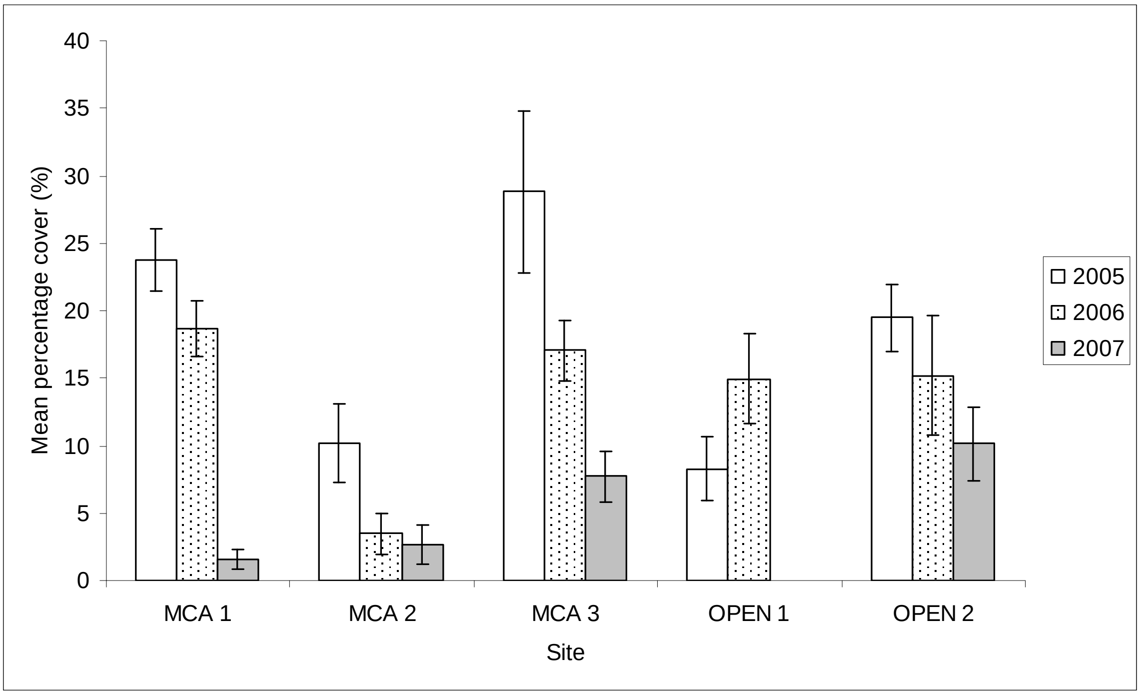


Figure 27. Mean hard coral cover at each of the 5 Zinoa sites over the 3 years of surveys (2005-2007).

3.3.2. ALGAE

The mean percentage of algal cover at each site in each year is shown in Figure 28. A two-way ANOVA on algal cover showed that a significant interaction between Site and Year exits ($F_{2,60}$=5.440, P<0.001). Post Hoc tests for the interaction Site within Year show that in 2005 algal cover at MCA 2 was significantly higher than at MCA 1, MCA 3 and Open 1. In 2006, algal cover at MCA 1 and MCA 2 was significantly higher than at MCA 3. In 2007, algal cover was again higher at MCA 2 than all other sites (Appendix 3). Post Hoc tests for the interactions Year within Site reveal the following; at MCA 1 algal cover increased significantly between 2005 and 2006, then decreased significantly in 2007. At MCA 2 algal cover did not differ significantly between years. At MCA 3 and Open 2 algal cover was not significantly different between 2005 and 2006, but had declined significantly in 2007. All algal life-forms were recorded during the surveys with the more dominant ones being dead coral with algae (DCA), halimeda (HA) and coralline algae (CA) (Figure 32, 33).

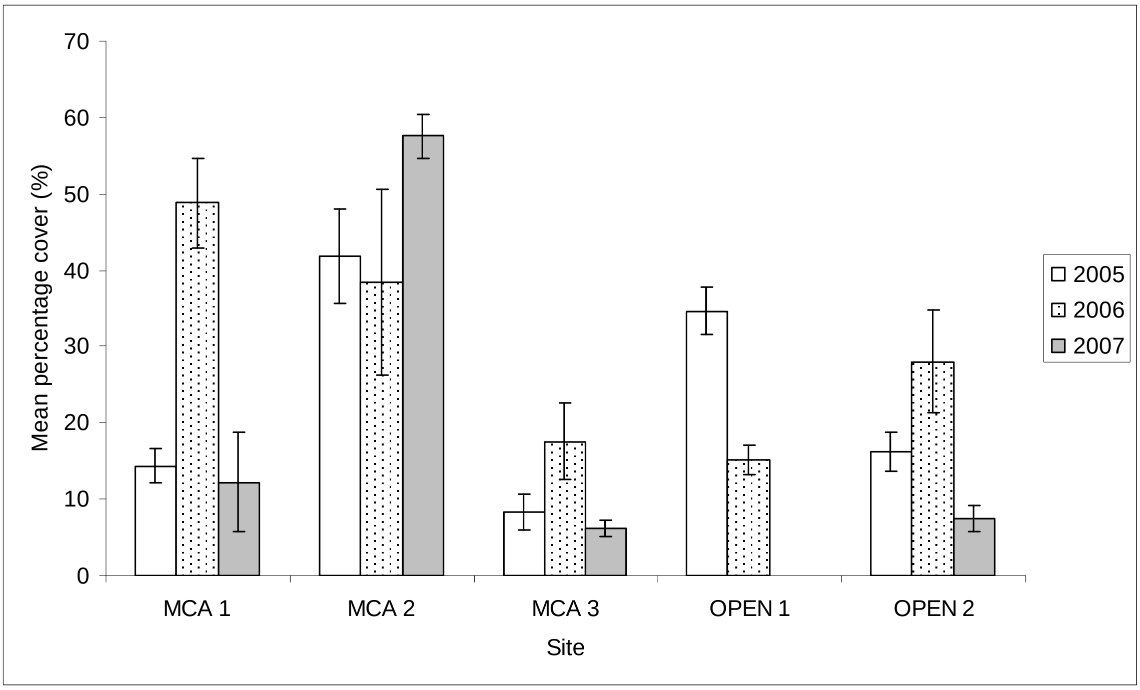


Figure 28. Mean algal cover at each of the 5 sites at Zinoa over the 3 years of surveys (2005-2007).

3.3.3. ABIOTIC

The mean percentage of abiotic cover at each site in each year is shown in Figure 29. A two-way ANOVA on abiotic cover showed that a significant interaction between Site and Year exits ($F_{2,60}$=8.670, P<0.001). Post Hoc tests for the interaction Site within Year show that in 2005 abiotic cover at Open 2 was significantly higher than at MCA 2. In 2006 abiotic cover at MCA 1 was lower than at other sites. In 2007 abiotic cover at MCA 2 was significantly lower than all other sites (Appendix 4). Post Hoc tests for the interactions Year within Site reveal the following; at MCA 1 abiotic cover decreased significantly between 2005 and 2006, then increased markedly in 2007. At MCA 2 abiotic cover decreased significantly between 2006 and 2007. At MCA 3 and Open 2 abiotic cover was not significantly different between 2005 and 2006, but had increased significantly in 2007 (Appendix 4). Increases in abiotic cover at MCA 1, MCA 3 and Open 2 in 2007 were primarily driven by the higher presence of sand (S) silt (Si) and rubble (R) (Figure 32, 33).

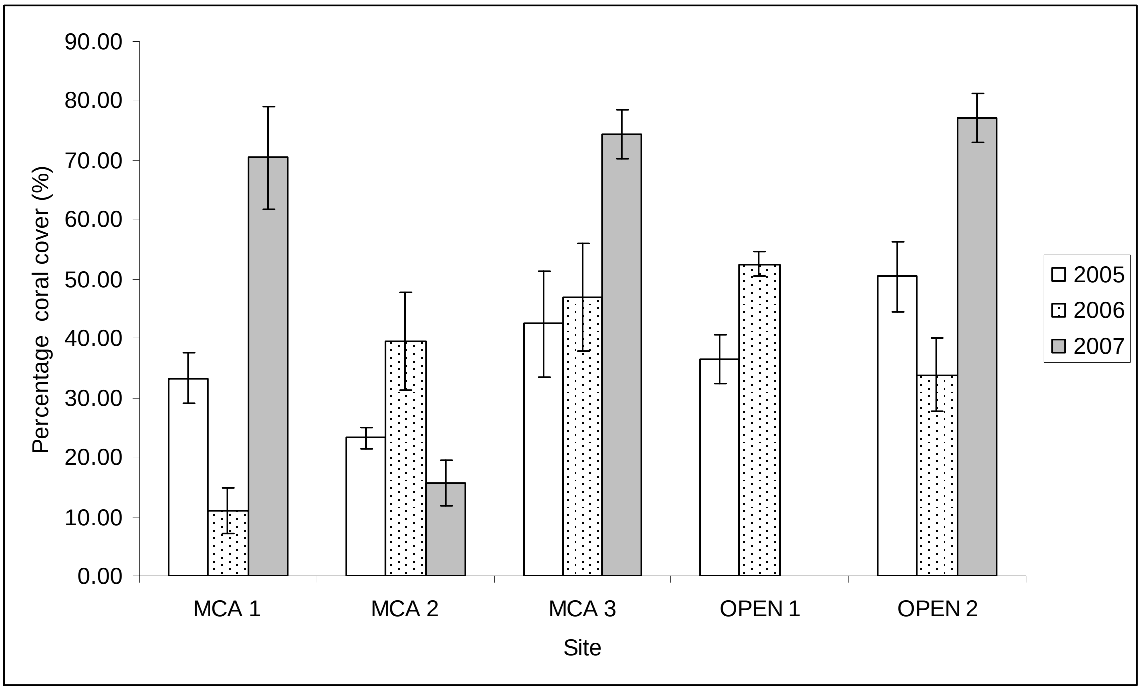


Figure 29. Mean abiotic cover at each of the 5 sites at Zinoa over 3 consecutive years (2005-2007).

3.3.4. SOFT CORAL

The mean percentage of soft coral cover at each site in each year is shown in Figure 30. A two-way ANOVA shows that mean percentage of soft coral cover was significantly different only between Sites ($F_{2,60}$=7.863, P<0.001), although it appears to have dropped substantially at Open 1 in 2007. Soft coral cover at MCA 2 was significantly higher than at Open 2 (t=4.319) and MCA 3 (t=2.636). Soft coral cover at MCA 1 was also significantly higher that at Open 1 (t=3.758).

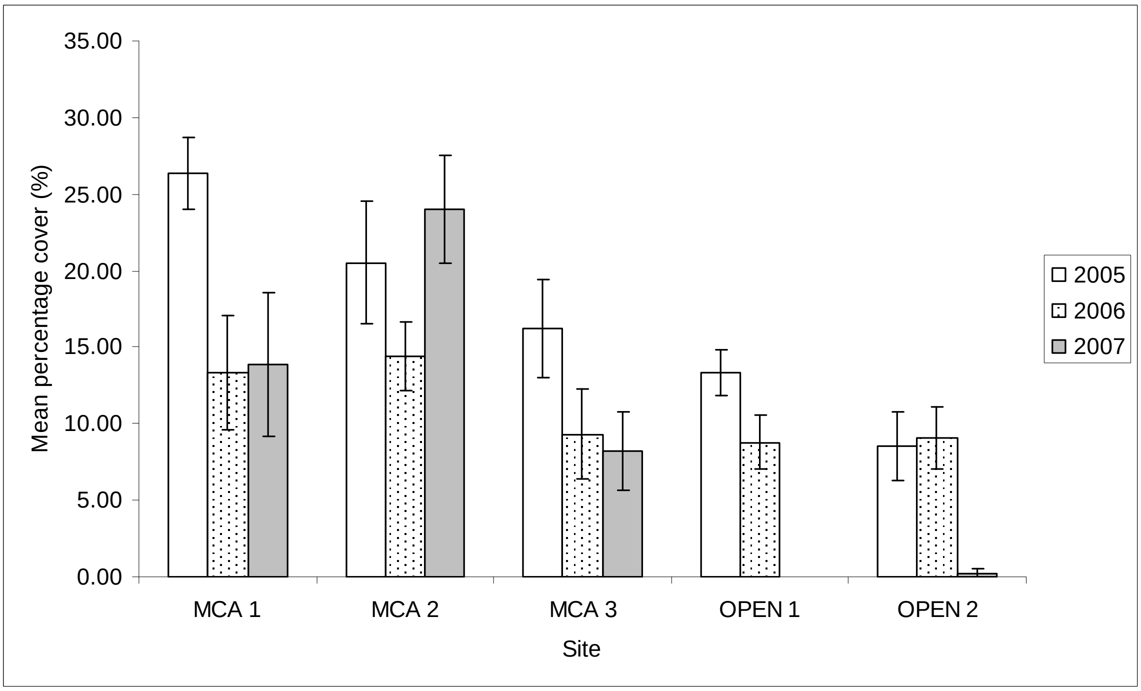


Figure 30. Mean soft coral cover at each of the 5 sites at Zinoa over 3 consecutive years (2005-2007).

3.3.5. OTHER

The mean percentage of other cover at each site in each year is shown in Figure 31. A two-way ANOVA shows that mean percentage of other cover was significantly different between Years ($F_{2,60}$=6.300, P<0.004) and Sites ($F_{3,60}$=3.671, P=0.018). There was not a statistically significant interaction between Year and Site ($F_{6,60}$=0.830, P= 0.830). Post Hoc tests for the factor Year show that mean other cover was significantly lower in 2007 than in 2006 (t=3.536). Post Hoc tests for the factor Site show that MCA 2 had significantly lower other cover than Open 2 (t=2.815).

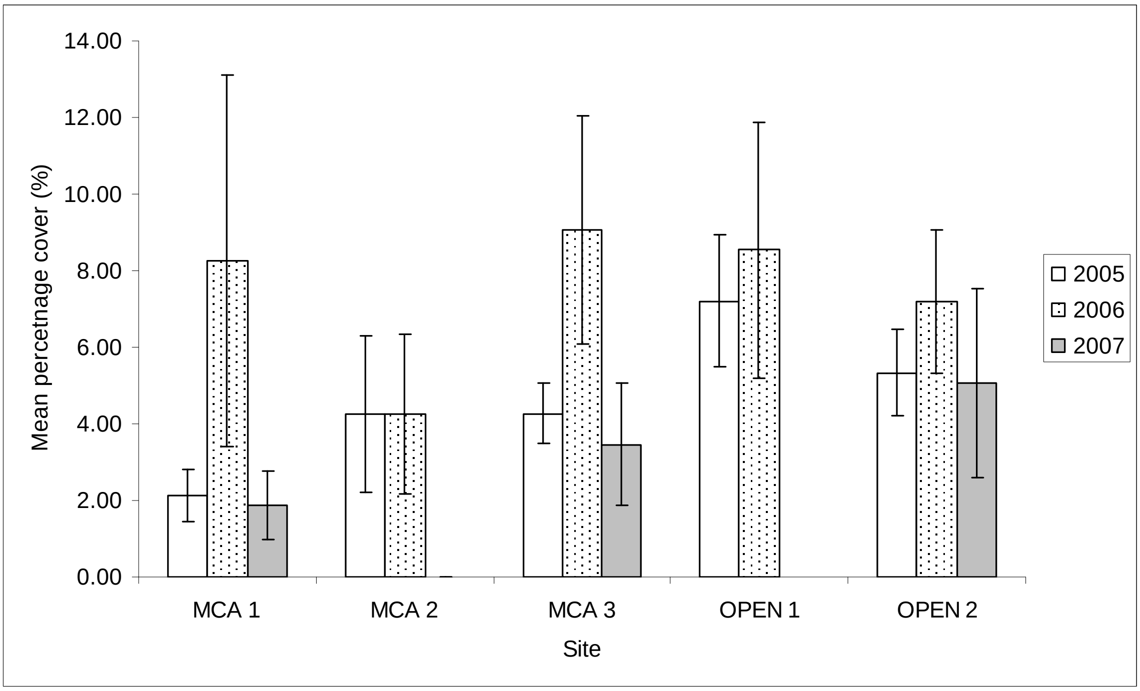


Figure 31. Mean other cover at each of the 5 sites at Zinoa over 3 consecutive years (2005-2007).

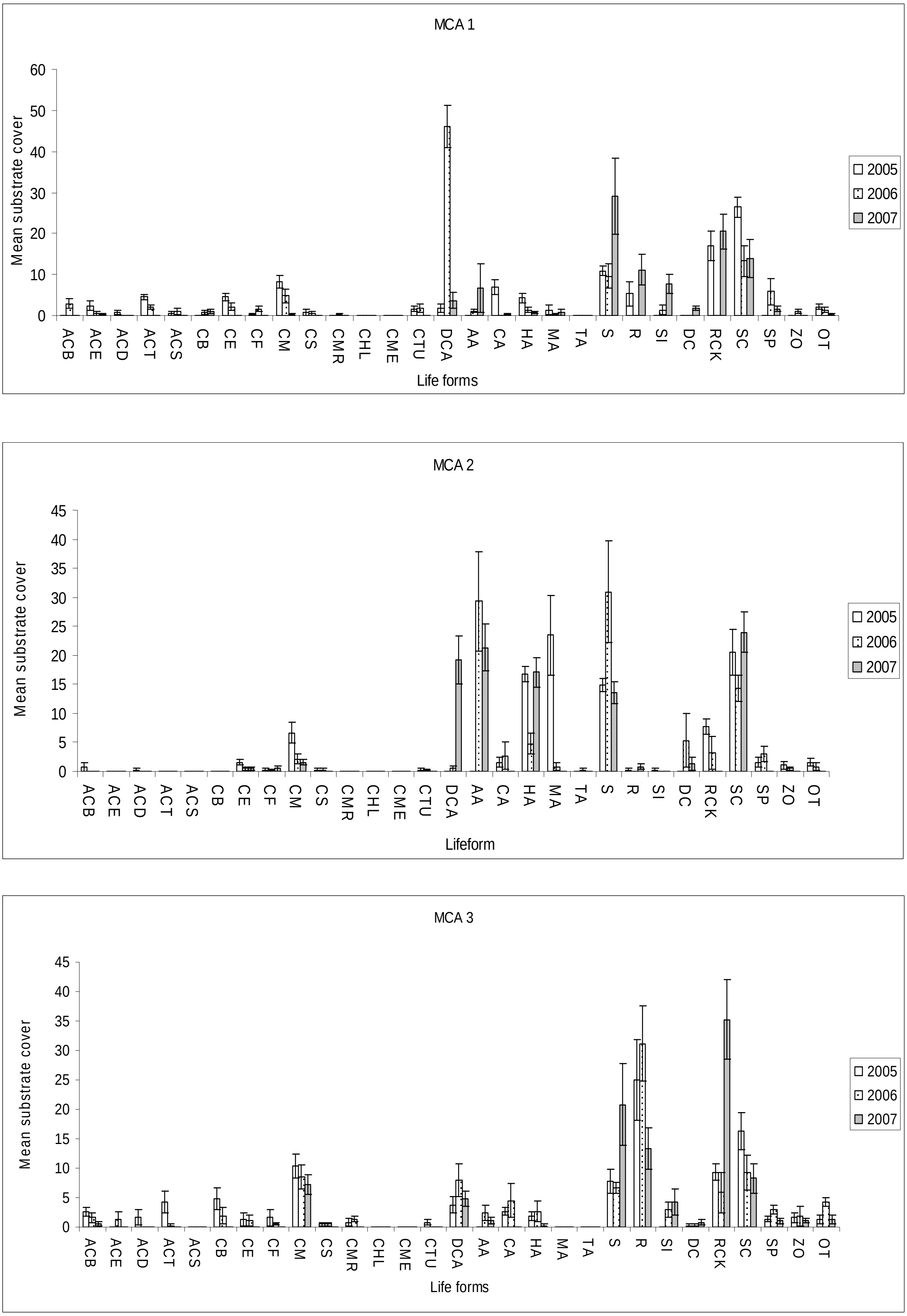
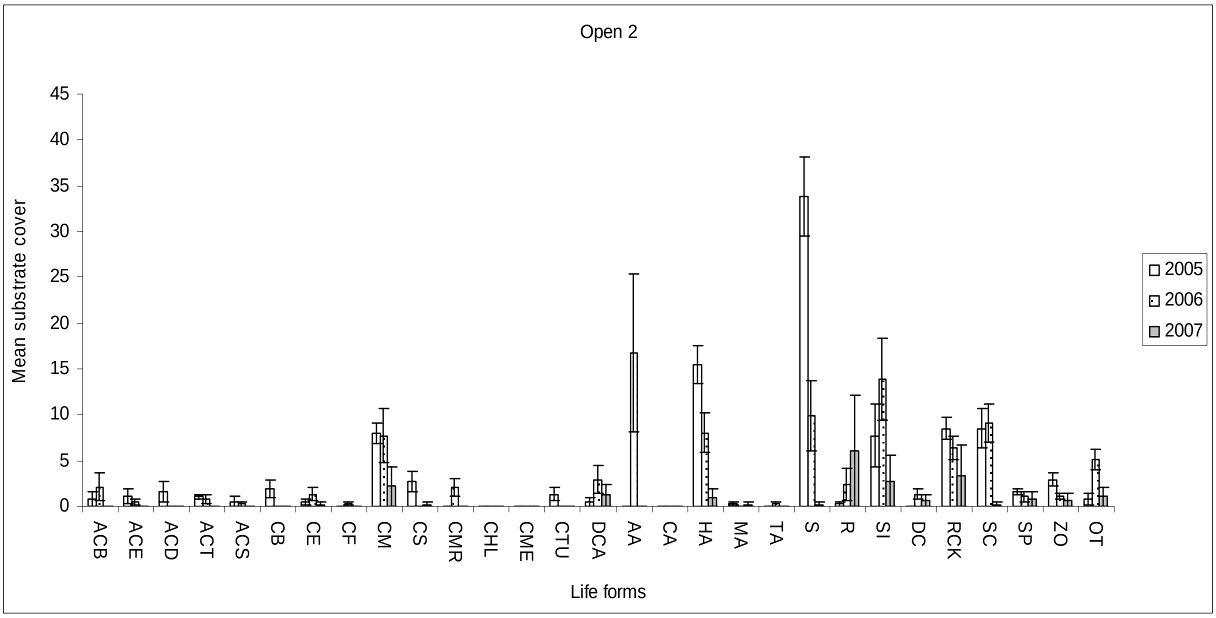


Figure 32. Mean lifeform cover for sites within the Zinoa MCA between 2005 and 2007.



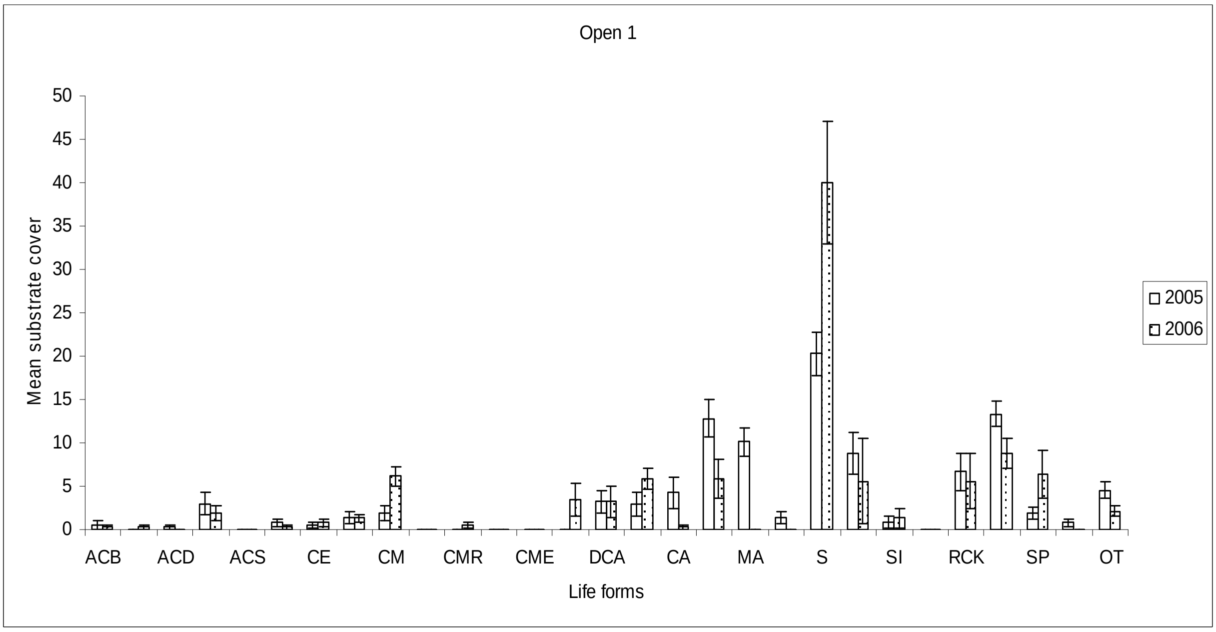


Figure 33. Mean lifeform cover for Open sites outside the Zinoa MCA between 2005 and 2007.

3.4. DISCUSSION

The benthic composition of the reef area surveyed is typical of turbid environments. Massive and encrusting coral species dominate the benthos. Acropora species are not as common as in well-flushed areas such as at Chivoko Marine Conservation Area (Hughes pers. obs.) and elsewhere in the country (Hughes 2006). Temporal changes in the benthic composition of survey sites within 2005 and 2006 occurred with varying degrees of significance depending on the lifeforms examined. However, notable changes occurred directly after the April 2007 earthquake and tsunami with a decrease in live substrate cover and an increase in abiotic cover.

The change in cover and dominance of the various lifeforms constituting the benthic community from 2005 to 2006 is most likely due to a combination of various ongoing and/or past biotic and abiotic processes common to the area. However, due to the low coral coverage and presence of predatory starfishes and molluscs at sites, it is unlikely that the biotic interactions such as predation and competition are a strong force structuring the hard coral community at this location. On the contrary, the general location of the area implies that it is more likely that changes in turbidity due to increased sedimentation and wave energy are the foremost forces governing the distribution and composition of these benthic communities. In populations subjected to increased sedimentation the rate of recruitment and presence of juvenile corals is likely to be low, having a significant impact on coral populations. A recent study examining settlement rates of *Acropora millepora* found that even slight increases in sediment loading had negative impacts on recruitment rates (Babcock and Smith 2002).

The exposed coastline of south-western Choiseul Island gets a fair share of strong sea conditions as a result of the trade-wind and cyclone seasons. These prevailing weather patterns can generate strong wave conditions that undoubtedly play an important role in structuring the benthic communities of coral reefs situated along the coastline. Consistent with theories for exposed and tropical shores (Dollar and Tribble 1993; Grigg 1998), it is suggested that removal of living and dead skeletal material by episodes of severe wave conditions is the factor most likely to inhibit reef accretion at this location. Strong sea conditions damaging or inhibiting coral development allow benthic algae to settle and dominate the substrate. The high abundance of algae cover at exposed sites is typical of environments with strong wave action (Sheppard 1982; Hughes 2006). The duration of their dominance and whether or not corals can re-settle and out-compete algae is dependent on environmental conditions such as the availability of suspended nutrients (river discharge and re-suspension) and the presence of grazing species (surgeonfishes, rabbitfishes etc.). Continued monitoring and documentation of environmental factors will be important in this sense.

The impact from the earthquake and tsunami is very noticeable from the sudden reduction of live coral cover and the increase in abiotic cover at most of the survey sites. Most sites recorded significantly higher abiotic cover compared to previous years. The increase in abiotic cover was mostly from sand silt and rubble which is consistent with a strong succession of waves sweeping through the area and redistributing sediments. The suspension and re-deposition of the sediments would have been enough to smother and significantly damage and kill live corals in the region. Even algal structure appears to have been affected with most sites having significantly lower algal cover following the tsunami.

The reef system at Zinoa commonly endures changes in turbidity, wave action and possibly salinity, making it robust and capable of tolerating extreme events. Therefore, barring further natural or anthropogenic disturbances to the area, it is likely the reef system will recover over time. The limited temporal scale (2005-2006) at which a comparison in benthic community structure can be made with this data is noted. It is hoped that through the continual monitoring of this conservation area, a better understanding of the benthic community patterns within the Zinoa reef complex will emerge, including recovery rates of hard coral and other affected lifeforms, which will provide essential background information for further monitoring and management programs.

IV.FINAL CONCLUSIONS

One of the primary purposes of establishing the Zinoa MCA was to allow macroinvertebrate and food fish populations to recover from over-exploitation. To this end the 2005 and 2006 monitoring demonstrated that the Zinoa MCA was beginning to meet this objective, with total invertebrate densities increasing markedly on the reef flat between 2005 and 2006. It is noteworthy that this first year of monitoring actually occurred a year after the Zinoa MCA was closed to fishing, and anecdotal reports indicate that invertebrate abundances on the reef flats had already improved by the time the 2005 surveys were done.

Local fishers were also adamant that fish densities and fish behaviour within the Zinoa MCA had changed following protection; however, a comparison of 2005 and 2006 data did not provide any evidence to support this contention. The fact that no differences in food fish density or biomass was detected could relate to many confounding factors such as: reasonably healthy fish populations occurring here prior to protection, high natural variance in spatial and temporal fish abundances, errors in the sampling method and low statistical power to detect changes in fish density and biomass. Given the very short time frame (11 months) between the 2005 and 2006 surveys, it is much too early to speculate on the long-term effect of protection within the Zinoa MCA. However, for some food fish at least, such as the green humphead parrotfish, the Zinoa MCA is probably too small to offer any real protection. Several well-known nocturnal aggregation sites for green humphead parrotfish are located on the mainland 5-10 km from the Zinoa MCA. These nocturnal aggregation sites are located within the customary reefs of the Gabili tribe and are sometimes targeted by night-time spear fishers. For effective protection of this species in the Voza region, these nocturnal aggregation sites should be protected from night spearfishing.

Surveys of benthic communities show that some significant changes in lifeform cover occurred both within and between sites between 2005 and 2006. At one site within the Zinoa MCA, coral cover declined and algae cover increased despite protection. It appears likely that this reduction in coral cover is a consequence of abiotic processes such as storms and changing sedimentation loads in this region.

While the effects of protection on the Zinoa MCA were limited at this early stage, the April 2007 tsunami had obvious negative impacts on areas within and outside of the MCA. Fish densities and biomass declined significantly across all sites, hard coral cover declined, sand cover increased and macroinvertebrate densities in the reef flat were significantly reduced after the reef flats were covered in sand deposited by the tsunami. Other far more extensive studies on the impacts of earthquakes and tsunamis on reef ecosystems have shown that impacts can be highly variable on small spatial scales, ranging from complete destruction of reefs to limited or undetectable damage to the reef and associated fish populations (Wilkinson et al. 2005). It appears that this is also very much the case in the Solomon Islands. After the April 2007 tsunami 80% of the fringing coral reef that surrounds Ranogga Island was uplifted above sea level (Albert et al. 2007), while in other areas of the Western Province qualitative assessments revealed that damage to reefs ranged from severe to undetectable (Schwarz et al. 2007). It appears that for the Voza region of Choiseul the impacts of the tsunami on the marine environment were moderate, and barring further natural or anthropogenic disturbances to the area, it is likely the reef system will recover over time.

RECOMMENDATIONS

1. MCAs like Zinoa can be used by coastal communities in Solomon Islands as a tool for resource recovery and maintaining biodiversity. In the long term, MCAs will support management of commercial invertebrates and food fishes. The establishment of the Zinoa MCA is therefore an important step in the right direction for the resource owners of Voza village to achieve sustainable production of commercial invertebrates and food fishes and protection of marine biodiversity in Choiseul Province. As such, it will be of paramount importance that the people of Voza continue to respect their MCA. At the same time, the support from other stakeholders such The Nature Conservancy, Choiseul Provincial government and the Lauru Land Conference of Tribal Communities for this initiative is crucial.

2. One way to maintain community interest in the Zinoa MCA is to increasingly involve the traditional owners of Zinoa in various aspects of the implementation of the MCA. One such way is to train reef owners in community based monitoring methods that can be conducted on a more regular basis then expensive and time-consuming scientific monitoring.
3. The Ministry of Fisheries and Marine Resources should now pursue the development of a Management Plan for the sea cucumber or beche-de-mer fishery. This is necessary for the proper management and long-term sustainable production of the fishery.
4. While MCAs may be sufficient to allow resource recovery and biodiversity protection, on their own they will be insufficient to prevent destruction from large-scale perturbations such as tsunamis, earthquakes and climate change. The best strategy to mitigate the threats of such events is to develop networks of interconnected MCAs.
5. Many MCAs will be too small to protect all target species, especially some of the larger species of food fish. For this reason, MCAs should be viewed for what they are; one of many management tools that can be used for achieving fisheries sustainability and biodiversity protection. To be most effective, MCAs should be nested within a broader ecosystem-based management framework.
6. Baseline monitoring should occur prior to MCA establishment in order to provide the best chance of detecting significant changes in abundances of target species. In reality this may not always be possible, as communities in Choiseul often set aside a region for protection under customary law before requesting assistance with baseline monitoring. For example, although there are currently 5 MCAs that TNC has assisted in monitoring in Choiseul, a further 7 communities have requested baseline monitoring, and many of these communities have already established MCAs.
7. The April 2007 tsunami had a devastating impact on Voza and surrounding villages on the south coast of Choiseul, and in the Voza region it also impacted on the surrounding reef systems and the fish and invertebrate communities that these reefs support. The Voza community and other affected communities along the south coast of Choiseul should be assisted by whatever means possible to rebuild their livelihoods and ensure their long-term food security.

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VI. APPENDICES

APPENDIX 1. FISH BIOMASS CONSTANTS FOR EACH FOOD FISH SPECIES.

Family	Genus and species	Biomass constant a	Biomass constant b	Source
ACANTHURIDAE	Large ringtails	0.0210	2.9435	Mean value for Genus, Fishbase
	Naso brevirostris	0.0136	3.1280	Median value, Fishbase
	N. hexacanthus	0.0202	2.9558	Median value, Fishbase
	N. lituratus	0.0487	2.8390	Median value, Fishbase
	N. unicornis	0.0228	2.9220	Median value, Fishbase
BALISTIDAE	*Balistapus undulatus*	0.0058	3.5540	Median value, Fishbase
	Balistoides viridescens	0.0244	3.0180	Median value, Fishbase
	Pseudo. flavimarginatus	0.0244	3.0180	As for *B. viridescens*
CARANGIDAE	*Caranx ignoblis*	0.0296	2.9780	Median value, Fishbase
	C. melampygus	0.0211	2.9410	Median value, Fishbase
	C. papuensis	0.0249	2.9100	Median value, Fishbase
	C. sexfasiatus	0.0318	2.9300	Median value, Fishbase
KYPHOSIDAE	*Kyphosus sps.*	0.0218	3.0053	Mean value for Genus, Fishbase
HAEMULLIDAE	*Plectorhinchus albovittatus*	0.0270	2.8848	Median value, Fishbase
	P. chaetodontoides	0.0148	3.0830	Median value, Fishbase
	P. lineatus	0.0131	3.0663	Median value, Fishbase
	P. vittatus	0.0209	2.9474	Mean value for Genus, Fishbase
HOLOCENTRIDAE	*Sargocentron spiniferum*	0.0154	3.1188	Median value, Fishbase
LABRIDAE	*Cheilinus fasiatus*	0.0318	3.0000	Median value, Fishbase
	Cheilinus undulatus	0.0123	3.1123	Median value, Fishbase
LETHRINIDAE	*L. erythropterus*	0.0219	2.9471	Mean value for Genus, Fishbase
	L. olivaceous	0.0297	2.8187	Median value, Fishbase
	L. rubrioperculatus	0.0201	2.9694	Median value, Fishbase
	L. xanthochilus	0.0219	2.9395	Median value, Fishbase
	Small Lethrinus spp.	0.0219	2.9471	Mean value for Genus, Fishbase
	Monotaxis grandoculis	0.0239	3.0110	Median value, Fishbase
LUTJANIDAE	*Aprion virescens*	0.0162	2.9050	Median value,

Family	**Genus and species**	**Biomass constant a**	**Biomass constant b**	**Source**
				Fishbase
	L. argentimaculatus	0.0071	3.1800	Median value, Fishbase
	L. bohar	0.0156	3.0587	Median value, Fishbase
	L. gibbus	0.0131	3.1375	Median value, Fishbase
	Small and yellow lines	0.0111	3.1540	L.kasmira Median value,Fishbase
	Small yellow and spot	0.0184	2.9700	L. mono Median value, Fishbase
	Macolor macularis	0.0211	3.0000	Mean value for Genus, Fishbase
	Macolor niger	0.0211	3.0000	Median value, Fishbase
	Symphorichthys spilurus	0.0189	2.9349	Mean value for Genus, Fishbase
MULLIDAE	*Mulloidichthys vanicolensis*	0.0099	3.0150	Median value, Fishbase
	Parupeneus bifasciatus/trifasciatus	0.0036	3.4510	Median value, Fishbase
	P. barberinus	0.0151	3.0780	Median value, Fishbase
	P. cyclostomus	0.0243	3.0000	Median value, Fishbase
OSTRADICIDAE	*Ostracion cubicus*	0.1010	2.5880	Median value, Fishbase
SCARIDAE	*Bolbometapon muricatum*	0.0098	3.1329	Hamilton (2004)
	Chlorurus microrhinos	0.0179	3.0448	Median value, Fishbase
	Hipposcarus longiceps	0.0198	3.0000	Mean value for Genus, Fishbase
SIGANIDAE	*S. fuscescens*	0.0137	3.0682	Median value, Fishbase
	S. lineatus	0.0219	2.9983	Median value, Fishbase
	S. puellus	0.0246	3.0000	Median value, Fishbase
	S. vermiculatus	0.0168	3.0326	Median value, Fishbase
SPYYRAENIDAE	*Sphyraena spp.*	0.0267	2.9200	Medain value, Fishbase, S. barracuda
SERRANIDAE	*Cephalopholis argus*	0.0093	3.1807	Median value, Fishbase
	C. cyanostigma	0.0164	3.0303	Mean value for Genus, Fishbase
	C. miniata			
	Cromileptes altivelis	0.0962	2.4893	Median value, Fishbase
	Epinephelus fuscoguttatus	0.0134	3.0572	Median value, Fishbase
	E. lanceolatus	0.0173	3.0000	Median value, Fishbase
	E. merra	0.0096	3.1960	Median value, Fishbase
	E. polyphekaidon	0.0124	3.0570	Median value, Fishbase
	Plectropomus areolatus	0.0079	3.1570	As for *P. leopardus*
	P. laevis	0.0059	3.2377	Median value, Fishbase
	P. leopardus	0.0079	3.1570	Median value,

Family	**Genus and species**	**Biomass constant a**	**Biomass constant b**	**Source**
				Fishbase
	P. oligocanthus	0.0132	3.0000	Median value, Fishbase
	Variola albimarginata	0.0139	3.0424	Mean value for Genus, Fishbase
	V. louti	0.0122	3.0791	Median value, Fishbase
SHARKS	*Carcharhinus amblyrhynchos*	0.0023	3.3727	Median value - fish base
	Triaenodon obesus	0.0014	3.3820	Median value - fish base
	Carcharhinus melanopterus	0.0033	3.6490	Median value, Fishbase
RAYS	*Aetobatus narinari*	0.0059	3.1300	Median value - fish base

APPENDIX 2. All Pairwise Multiple Comparison Procedures (Holm-Sidak method) for hard coral Overall significance level = 0.05

Comparisons for factor: **Year**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
2005.000 vs. 2007.000	24.925	6.788	0.0000000155	0.017	Yes
2006.000 vs. 2007.000	14.450	3.935	0.000267	0.025	Yes
2005.000 vs. 2006.000	10.475	2.853	0.00638	0.050	Yes

Comparisons for factor: **Site**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
MPA 3 vs. MPA 2	19.500	4.599	0.0000311	0.009	Yes
Open 2 vs. MPA 2	16.733	3.947	0.000258	0.010	Yes
MPA 1 vs. MPA 2	16.300	3.844	0.000355	0.013	Yes
MPA 3 vs. MPA 1	3.200	0.755	0.454	0.017	No
MPA 3 vs. Open 2	2.767	0.653	0.517	0.025	No
Open 2 vs. MPA 1	0.433	0.102	0.919	0.050	No

APPENDIX 3. ALL PAIRWISE MULTIPLE COMPARISON PROCEDURES (HOLM-SIDAK METHOD) FOR ALGAE COVER. OVERALL SIGNIFICANCE LEVEL = 0.05

Comparisons for factor: **Site within 2005**

Comparison	**Diff of Means**	**t**	**Unadjusted P**	**Critical Level**	**Significant?**
MPA 2 vs. MPA 3	32.800	5.448	0.000	0.009	Yes
MPA 2 vs. MPA 1	22.200	3.688	0.001	0.010	Yes
MPA 2 vs. Open 2	19.800	3.289	0.002	0.013	Yes
Open 2 vs. MPA 3	13.000	2.159	0.036	0.017	No
MPA 1 vs. MPA 3	10.600	1.761	0.085	0.025	No
Open 2 vs. MPA 1	2.400	0.399	0.692	0.050	No

Comparisons for factor: **Site within 2006**

Comparison	**Diff of Means**	**t**	**Unadjusted P**	**Critical Level**	**Significant?**
MPA 1 vs. MPA 3	23.800	3.953	0.000	0.009	Yes
MPA 2 vs. MPA 3	17.000	2.824	0.007	0.010	Yes
MPA 1 vs. Open 2	13.100	2.176	0.035	0.013	No
Open 2 vs. MPA 3	10.700	1.777	0.082	0.017	No
MPA 1 vs. MPA 2	6.800	1.130	0.264	0.025	No
MPA 2 vs. Open 2	6.300	1.047	0.301	0.050	No

Comparisons for factor: **Site within 2007**

Comparison	**Diff of Means**	**t**	**Unadjusted P**	**Critical Level**	**Significant?**
MPA 2 vs. MPA 3	45.100	7.492	0.000	0.009	Yes
MPA 2 vs. Open 2	42.300	7.027	0.000	0.010	Yes
MPA 2 vs. MPA 1	36.900	6.130	0.000	0.013	Yes
MPA 1 vs. MPA 3	8.200	1.362	0.180	0.017	No
MPA 1 vs. Open 2	5.400	0.897	0.374	0.025	No
Open 2 vs. MPA 3	2.800	0.465	0.644	0.050	No

Comparisons for factor: **Year within MPA 1**

Comparison	**Diff of Means**	**t**	**Unadjusted P**	**Critical Level**	**Significant?**
2006.000 vs. 2007.000	32.600	5.415	0.000	0.017	Yes
2006.000 vs. 2005.000	25.500	4.236	0.000	0.025	Yes
2005.000 vs. 2007.000	7.100	1.179	0.244	0.050	No

Comparisons for factor: **Year within MPA 2**

Comparison	**Diff of Means**	**t**	**Unadjusted P**	**Critical Level**	**Significant?**
2007.000 vs. 2006.000	11.100	1.844	0.071	0.017	No
2007.000 vs. 2005.000	7.600	1.262	0.213	0.025	No
2005.000 vs. 2006.000	3.500	0.581	0.564	0.050	No

Comparisons for factor: **Year within MPA 3**

Comparison	**Diff of Means**	**t**	**Unadjusted P**	**Critical Level**	**Significant?**
2006.000 vs. 2007.000	17.000	2.824	0.007	0.017	Yes
2006.000 vs. 2005.000	12.300	2.043	0.047	0.025	No
2005.000 vs. 2007.000	4.700	0.781	0.439	0.050	No

Comparisons for factor: **Year within Open 2**

Comparison	**Diff of Means**	**t**	**Unadjusted P**	**Critical Level**	**Significant?**
2006.000 vs. 2007.000	24.900	4.136	0.000	0.017	Yes
2005.000 vs. 2007.000	14.900	2.475	0.017	0.025	Yes
2006.000 vs. 2005.000	10.000	1.661	0.103	0.050	No

APPENDIX 4. ALL PAIRWISE MULTIPLE COMPARISON PROCEDURES (HOLM-SIDAK METHOD) FOR ABIOTIC COVER. OVERALL SIGNIFICANCE LEVEL = 0.05

Comparisons for factor: **Site within 2005**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
Open 2 vs. MPA 2	20.400	3.080	0.003	0.009	Yes
MPA 3 vs. MPA 2	14.400	2.174	0.035	0.010	No
Open 2 vs. MPA 1	12.800	1.933	0.059	0.013	No
MPA 1 vs. MPA 2	7.600	1.147	0.257	0.017	No
MPA 3 vs. MPA 1	6.800	1.027	0.310	0.025	No
Open 2 vs. MPA 3	6.000	0.906	0.370	0.050	No

Comparisons for factor: **Site within 2006**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
MPA 3 vs. MPA 1	27.000	4.077	0.000	0.009	Yes
MPA 2 vs. MPA 1	21.400	3.231	0.002	0.010	Yes
Open 2 vs. MPA 1	17.200	2.597	0.012	0.013	Yes
MPA 3 vs. Open 2	9.800	1.480	0.146	0.017	No
MPA 3 vs. MPA 2	5.600	0.846	0.402	0.025	No
MPA 2 vs. Open 2	4.200	0.634	0.529	0.050	No

Comparisons for factor: **Site within 2007**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
Open 2 vs. MPA 2	46.000	6.945	0.000	0.009	Yes
MPA 3 vs. MPA 2	44.000	6.643	0.000	0.010	Yes
MPA 1 vs. MPA 2	41.000	6.190	0.000	0.013	Yes
Open 2 vs. MPA 1	5.000	0.755	0.454	0.017	No
MPA 3 vs. MPA 1	3.000	0.453	0.653	0.025	No
Open 2 vs. MPA 3	2.000	0.302	0.764	0.050	No

Comparisons for factor: **Year within MPA 1**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
2007.000 vs. 2006.000	44.600	6.734	0.000	0.017	Yes
2007.000 vs. 2005.000	27.800	4.197	0.000	0.025	Yes
2005.000 vs. 2006.000	16.800	2.537	0.015	0.050	Yes

Comparisons for factor: **Year within MPA 2**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
2006.000 vs. 2007.000	17.800	2.688	0.010	0.017	Yes
2006.000 vs. 2005.000	12.200	1.842	0.072	0.025	No
2005.000 vs. 2007.000	5.600	0.846	0.402	0.050	No

Comparisons for factor: **Year within MPA 3**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
2007.000 vs. 2005.000	24.000	3.624	0.001	0.017	Yes
2007.000 vs. 2006.000	20.600	3.110	0.003	0.025	Yes
2006.000 vs. 2005.000	3.400	0.513	0.610	0.050	No

Comparisons for factor: **Year within Open 2**

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
2007.000 vs. 2006.000	32.400	4.892	0.000	0.017	Yes
2007.000 vs. 2005.000	20.000	3.020	0.004	0.025	Yes
2005.000 vs. 2006.000	12.400	1.872	0.067	0.050	No

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The Nature Conservancy
Indo-Pacific Resource Centre
51 Edmondstone Street
South Brisbane, QLD 4101
Australia

John D. and Catherine T.
MacArthur Foundation