Training in community-based monitoring techniques in Emau Island, North Efate,Vanuatu

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Coral Reef InitiativeS for the Pacific
Initiatives Corail pour le Pacifique

COMPONENT 2A - Project 2A2

Improve knowledge and capacity for a better management of reef ecosystems

August 2009

FINAL REPORT

Training in community-based monitoring techniques in Emau Island, North Efate, Vanuatu

Institut de recherche pour le développement

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CRISP

Coral Reef InitiativeS for the Pacific
Initiatives Corail pour le Pacifique

SPREP/PROE

The CRISP programme is implemented as part of the policy developed by the Secretariat of the Pacific Regional Environment Programme for a contribution to conservation and sustainable development of coral reefs in the Pacific.

The Initiative for the Protection and Management of Coral Reefs in the Pacific (CRISP), sponsored by France and prepared by the French Development Agency (AFD) as part of an inter-ministerial project from 2002 onwards, aims to develop a vision for the future of these unique ecosystems and the communities that depend on them and to introduce strategies and projects to conserve their biodiversity, while developing the economic and environmental services that they provide both locally and globally. Also, it is designed as a factor for integration between developed countries (Australia, New Zealand, Japan and USA), French overseas territories and Pacific Island developing countries.

The CRISP Programme comprises three major components, which are:

Component 1A: Integrated Coastal Management and Watershed Management
- 1A1: Marine biodiversity conservation planning
- 1A2: Marine Protected Areas
- 1A3: Institutional strengthening and networking
- 1A4: Integrated coastal reef zone and watershed management

Component 2: Development of Coral Ecosystems
- 2A: Knowledge, monitoring and management of coral reef ecosytems
- 2B: Reef rehabilitation
- 2C: Development of active marine substances
- 2D: Development of regional data base (ReefBase Pacific)

Component 3: Programme Coordination and Development
- 3A: Capitalisation, value-adding and extension of CRISP Programme activities
- 3B: Coordination, promotion and development of CRISP Programme

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COMPONENT 2A

Knowledge, monitoring and management of coral reef ecosytems

- **PROJECT 2A-1:**
Postlarvae (fish and crustacean) capture and culture for aquarium trade and restoking
- **PROJECT 2A-2:**
Improvement of knowledge and capacity for a better management of reef ecosystems
- **PROJECT 2A-3:**
Synopsis and extension work on indicators for monitoring the health of coral ecosystems and developing a remote sensing tool
- **PROJECT 2A-4:**
Testing of novel information feedback methods for local communities and users of reef and lagoon resources
- **PROJECT 2A-5:**
Specific studies on i) the effects on the increase in atmospheric CO2 on the health of coral formation and ii) the development of ecotourism

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This final report presents the results of the participative survey conducted in August 2008 in Emau Island (North Efate, Vanuatu) to enforce the local capacity in underwater biological monitoring techniques (fish & invertebrates).

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We also thank all people of Marow and Wiana communities for their wonderful welcome. We hope that this work will help them to improve their monitoring techniques and to better manage Emau coral reef resources and environment.

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I. General context

1.1 Introduction

The villagers in Marow (Emau Island) have been effectively involved in reef monitoring since three years. Data is used to define management options of the major marine resources (e.g. to maintain or open the tabu area for fish / invertebrates). In this context, the main objective of this short project was to provide scientific support to the Marow community to improve their underwater monitoring techniques and therefore provide relevant data for the management of their reef resources.

Given the close relationships between Marow and the neighbouring villages, and keeping in mind that participative monitoring techniques are site specific, the project finally encompassed two other villages of the southwest coast of Emau Island, namely Mangarongo and Wiana, that have also implemented their own locally-managed marine tabu areas (Fig 1). Results will be transferable to other sites with similar management objectives and environmental characteristics.

Field surveys were conducted with focus on harvested invertebrates and fish species inside and outside tabu areas, using robust field techniques allowing simple estimates of abundances and sizes. Data were analysed while working on the site, so as to provide simplified guidelines for the community.

This final report presents the results of monitoring with focus on target fish & invertebrate species, as well as final recommendations for optimizing the community surveys (field tools, transect sizes / numbers, focal species).

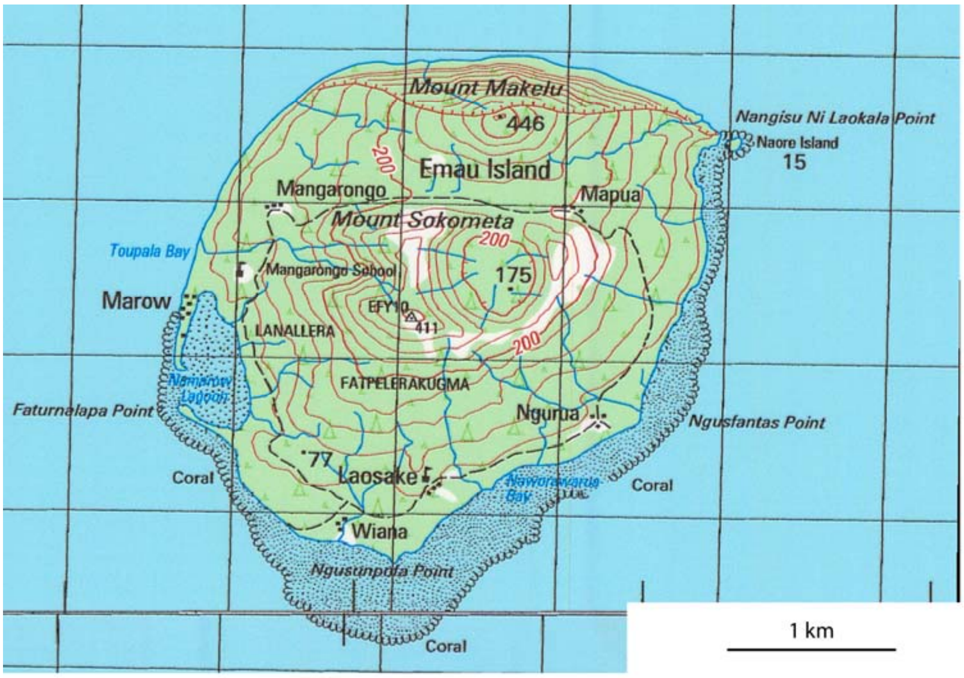


Figure 1. Emau Island, North Efate, Vanuatu.

Two types of tabu areas are located in the survey area (Fig 2). Each village has implemented its own no-take zone (NTZ) where all species (invertebrates and fish) are protected:

- Marow NTZ (2004): 0.06 km²
- Mangarongo NTZ (2005): 0.05 km²
- Wiana NTZ (2006): 0.12 km²

Moreover, Marow village tabu area extends 0.24 km² southward to preserve trochus and giant clams in an additional 0.30 km² zone.

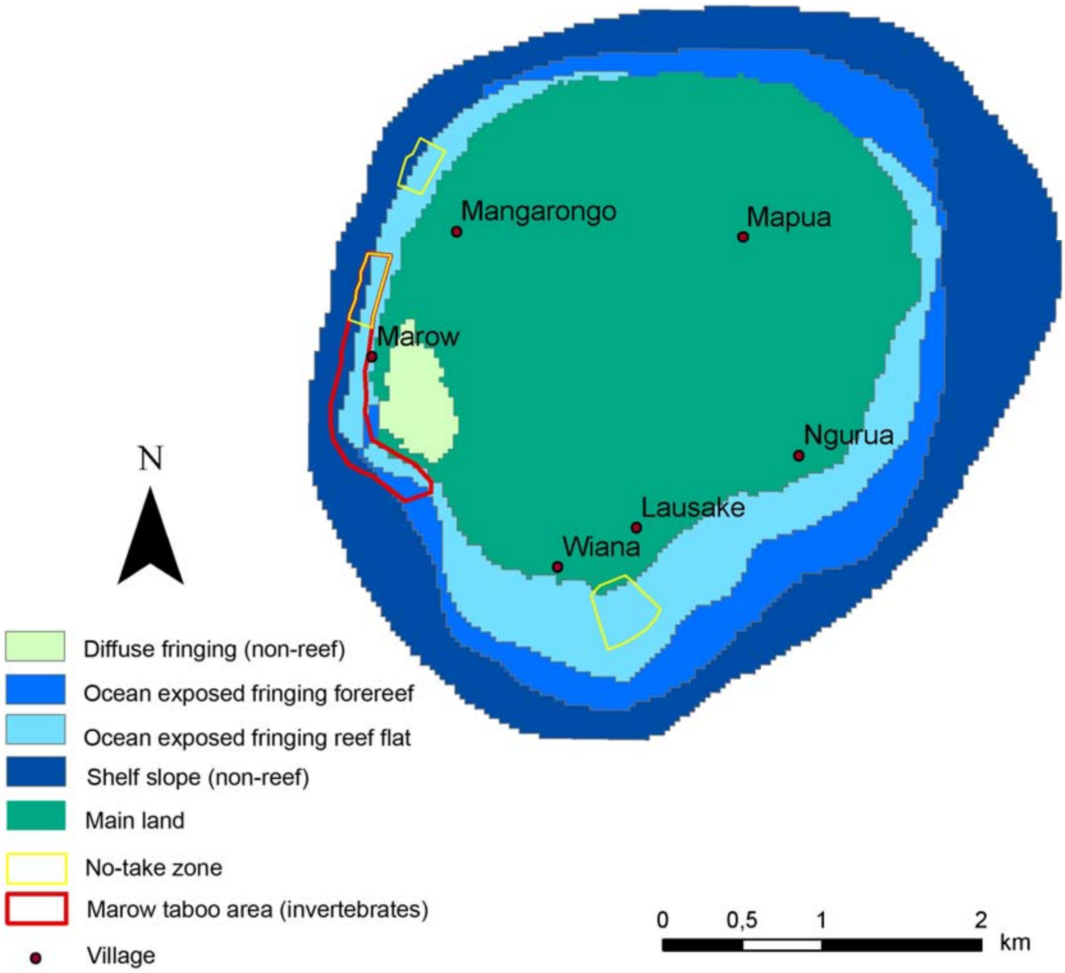


Figure 2. Geomorphologic structures of Emau and location of marine reserves in the survey area. (Geomorphologic data from S. Andrefouët, Millenium Project)

1.2 Monitoring methods

Participative monitoring surveys using underwater visual censuses (UVC) of fish and invertebrates were conducted separately, using simple snorkelling equipment and dedicated field tools. Two local surveyors were involved in both teams (4 villagers: two from Marow, one from Mangarongo and one from Wiana), so as to learn the field protocols.

1.2.1 Fish monitoring

Several fish species are mentioned in the Marow monitoring plan that has been developed since 2006. Seven focal taxa are designated by their Bichlamar names: blue fish, parrot, red mouth, piko, black piko, mustash, and rainbow. We found that local fishers got sometimes confused with this classification. We determined which species these names really refer to according to vernacular and scientific classifications. Eleven vernacular taxa were selected by the local fishers during a group interview according to both identification and use criteria (Table 1 and Annexe 1). They belong to 6 families: Scaridae, Acanthuridae, Lethrinidae, Siganidae, Mullidae, and Chaetodontidae.

Table 1. Focal fish species and size categories

Vernacular name	Bichlamar name	Scientific name	Small/Large threshold (cm) Standard length
Malakesa	Blue fish	Scaridae (terminal phase)	17
Raea	Blue fish	*Scarus microrhinos*	20
Saama	Parrot fish	*Scarus spp.*	19
Ansus	Mustach fish	Mullidae	19
Sfapua	Rainbow	*Acanthurus lineatus*	15
Rourou	Red mouth	*Lethrinus harak*	18
Siko	Red mouth	*Lethrinus miniatus*	18
Tofe	Piko	*Siganus doliatus, Siganus puellus,*	18
Polo	Black piko	*A. striatus* -like Surgeon fish	14
Salla	Black piko	*Acanthurus blochii* (Nega maito), *A. dussumieri* (Saala), *A. nigricans*, *A. nigricauda*	16
Pepe	Butterfly fish	Chaetodontidae	12

These species were recorded by two snorkellers from Marow and Mangarongo. Fishes were counted, using two size categories (small/large). Both local divers defined specific thresholds (Tab 1). Each diver recorded 5 to 6 taxa on both sides of line transects 50 m in length. Transect width was equal to underwater visibility (15 to 20 m). We did not use belt transects because local divers are very likely to return highly imprecise density estimates (given their difficulty to estimate transect width from the surface). UVC were done during high tide and good water conditions. Swim speed was standardised at about 2.4 m/minute (15-20 minutes/transect).

31 transects were located both inside and outside no-take zones at the edge of the fringing reef (Marow, Mangarongo) and on the reef flat (Wiana, where the reef edge is not included in the tabu area and exposed to waves) depending on reef geomorphology (Fig 3). Depth varied accordingly between 1.5 m and 7 m.

Fish abundance was estimated by the number of fish in transect 50 m in length. It was compared between no-take zone and exploited areas, and between sites using Kruskal-Wallis non parametric tests.

Annexe 1. Pictures of the focal fish taxa used in Emau monitoring

1.2.2 Invertebrate monitoring

The surveys initially focused on harvested invertebrate species: trochus shells (*Trochus niloticus*), giant clams (*Tridacna* spp.) and green snail (*Turbo marmoratus*). Given the high densities of poison starfish (*Acanthaster planci*) and holothurians (sea cucumbers) locally observed in the field, they were added to the focal invertebrates list. For the latter, while information was not collected at species levels, it should be noticed that almost all the individuals effectively observed belonged to non harvested species (mostly *Stichopus sp.*).

The surveys occurred in March 2008 at 57 shallow reef stations: 36 inside vs. 21 outside tabu areas (Fig. 3). Depth range was 1–3m, with distance between the stations of approximately 50m. On each station, one randomly selected (50x4m) transect belt was materialized by a 50m color-marked survey tape attached to the substrate. Data was collected by a team of two snorkellers swimming simultaneously along both sides of the transect line, each surveying a 2m-wide corridor.

On the whole, 57 (50 x 4m) belt transects were thus located in the studied area, divided into five zones from North to South, based upon their regulation status (Table 2).

Table 2. Sampled zones in Emau, North Efate.
Code, regulation status and number of invertebrate stations (belt transects).

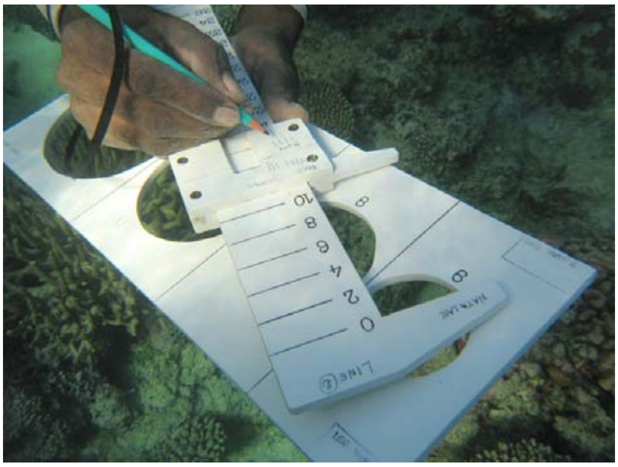
Zone	Status	Number of stations
A	Outside tabu area	3
B	Mangarongo tabu area	7
C	Outside tabu area	10
D	Marow tabu area	29
E	Outside tabu area	8

In each transect side, the snorkeller recorded target species abundance and individual sizes using simple, robust field tools that were specifically developed by IRD team for the operation.

They consisted in two specific PVC measuring devices:

- a calliper used for giant clams, graduated from 0 to 30 cm in 2 cm size classes ;
- a plate with four holes (6 – 8 – 10 – 12 cm in diameter), used to measure trochus shells & green snails.

Invertebrate sizes were recorded by ticking individual marks directly on the PVC devices. Abundance data were derived after the transect field work by simply counting the individual size marks written on the devices.



Picture 1. Underwater PVC field tools developed by IRD team and provided for participative monitoring of invertebrate target species.

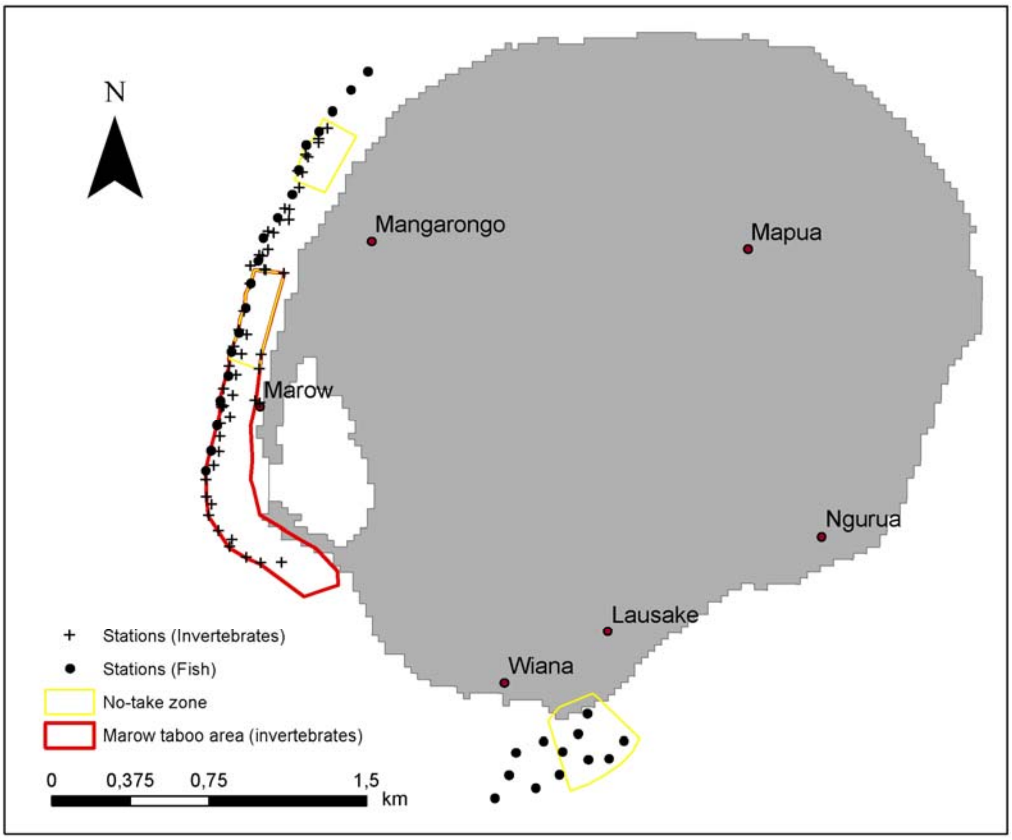


Figure 3. Location of fish and invertebrate transects in Emau Island, North Efate, Vanuatu.

1.2.3 Habitat monitoring

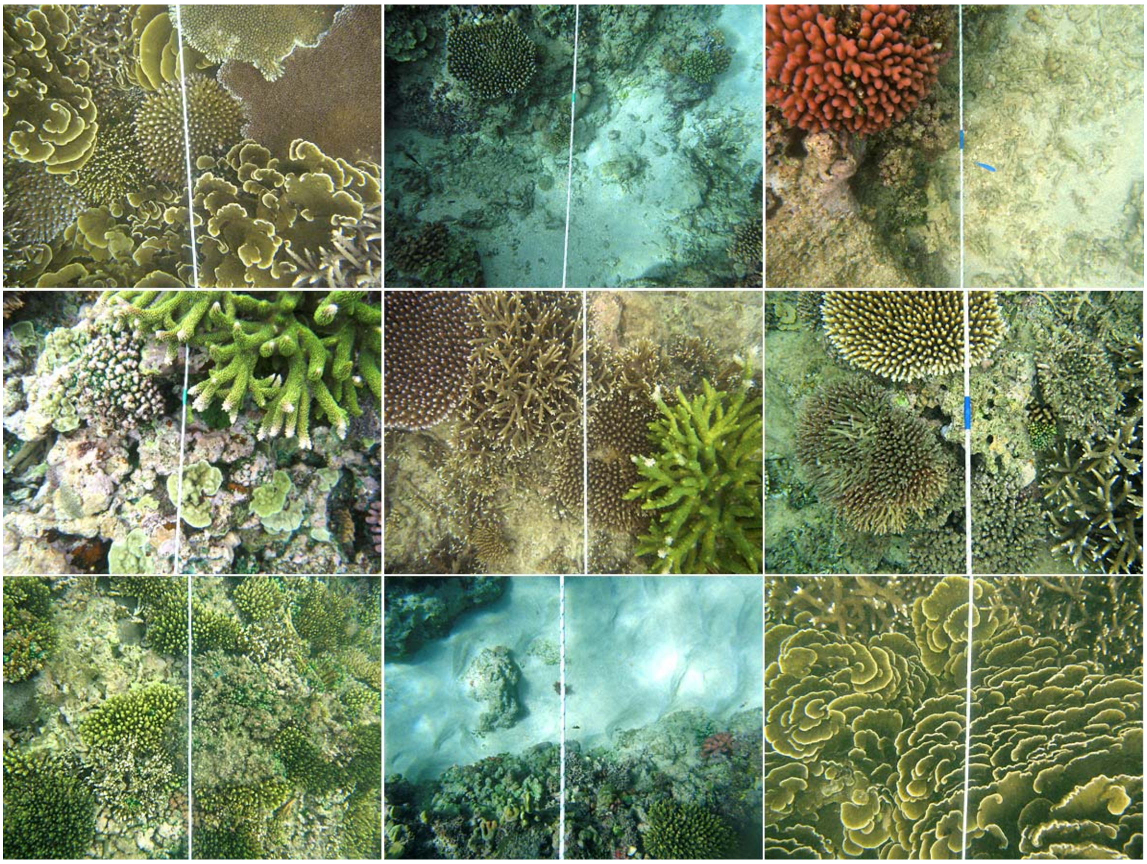
For each station, sediment type and substratum coverage variables were estimated using a photographic method recently developed to provide a "quick and clean" description of contrasted reef habitats (Dumas et al. 2009).

Pictures were taken from the surface along transects using a standard digital 8 Mpixels Canon S80 camera in underwater housing, oriented perpendicular to the substrate (Annexe 2). 25 pictures per transect (i.e. one shot every two meters) were recorded and subsequently imported in an image analysis software including efficient, user-friendly features for the estimation of sediment / substrate cover (CPCe "Coral Point Count with Excel extensions" software, Kohler & Gill 2006). Surface estimates expressed in percent covers were derived from random stratified point count techniques using a 9 points.m^{-2} ratio ensuring reliable habitat profiles with low bias and high precision.

18 local habitat variables were considered, related to sediment type and substratum coverage by large, sessile organisms (Table 3).

Table 3. Habitat variables referring to sediment type, substratum coverage used for habitat characterization in the selected sites

SEDIMENT TYPE	SUBSTRATE COVERAGE
Mud	Branching corals
Sand	Digitate corals
Rubble (1-5 cm)	Tabular corals
Boulders (<100 cm)	Massive corals
Bedrock	Submassive corals
Dead Coral substrate	Foliose corals
	Encrusting corals
	Soft corals (Alcyonarians)
	Fire corals (Milleporidae)
	Seagrass
	Encrusting algae
	Macroalgae



Annexe 2. Picture samples from the surveyed transects, used for habitat monitoring.

II. Survey results

2.1 Fish taxa

2.1.1 Between-site comparisons

Mean total abundances were 78, 93 and 107 fish/transect in Mangarongo, Marow and Wiana respectively (Fig 4) and were not statistically different (p>0.05). The high overall abundance in Wiana reef was due to the significantly higher number of small individuals (Fig 4). In the latter site large individuals represented only 18 % of all recorded fishes whereas these were 46 % and 48 % in Marow and Mangarongo fish communities respectively.

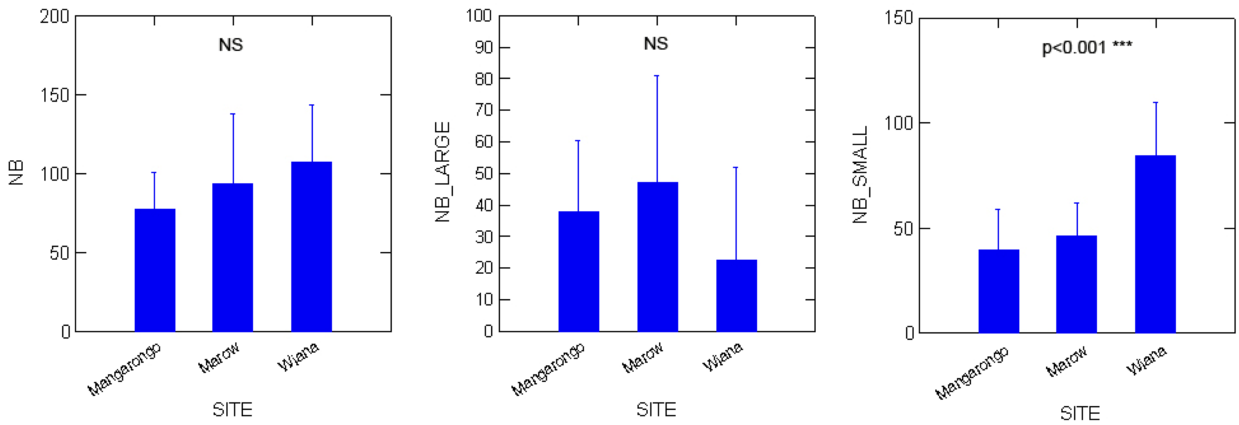


Figure 4. Mean total abundance, and of large and small fish in the three sites, Emau, North Efate.

Due to identification mistakes among Scaridae taxa, *Malakesa*, *Raea* and *Saama* were grouped in a single category (named *Parrot*).

We found that the abundance of the 8 focal taxa was broadly similar in Marow and Mangarongo sites, but that *Sfapua* and *Pollo* were respectively less and more abundant in Wiana than in both other sites (Fig 5). In Wiana *Pollo* constituted 49 % of the observed fish community (only 22 % in Marow and Mangarongo). Small *Tofe* and small *Parrot* were also more abundant in this site (p=0.02 and p=0.002 respectively), where very few large *Parrot* were recorded compared to both other sites (p<0.001).

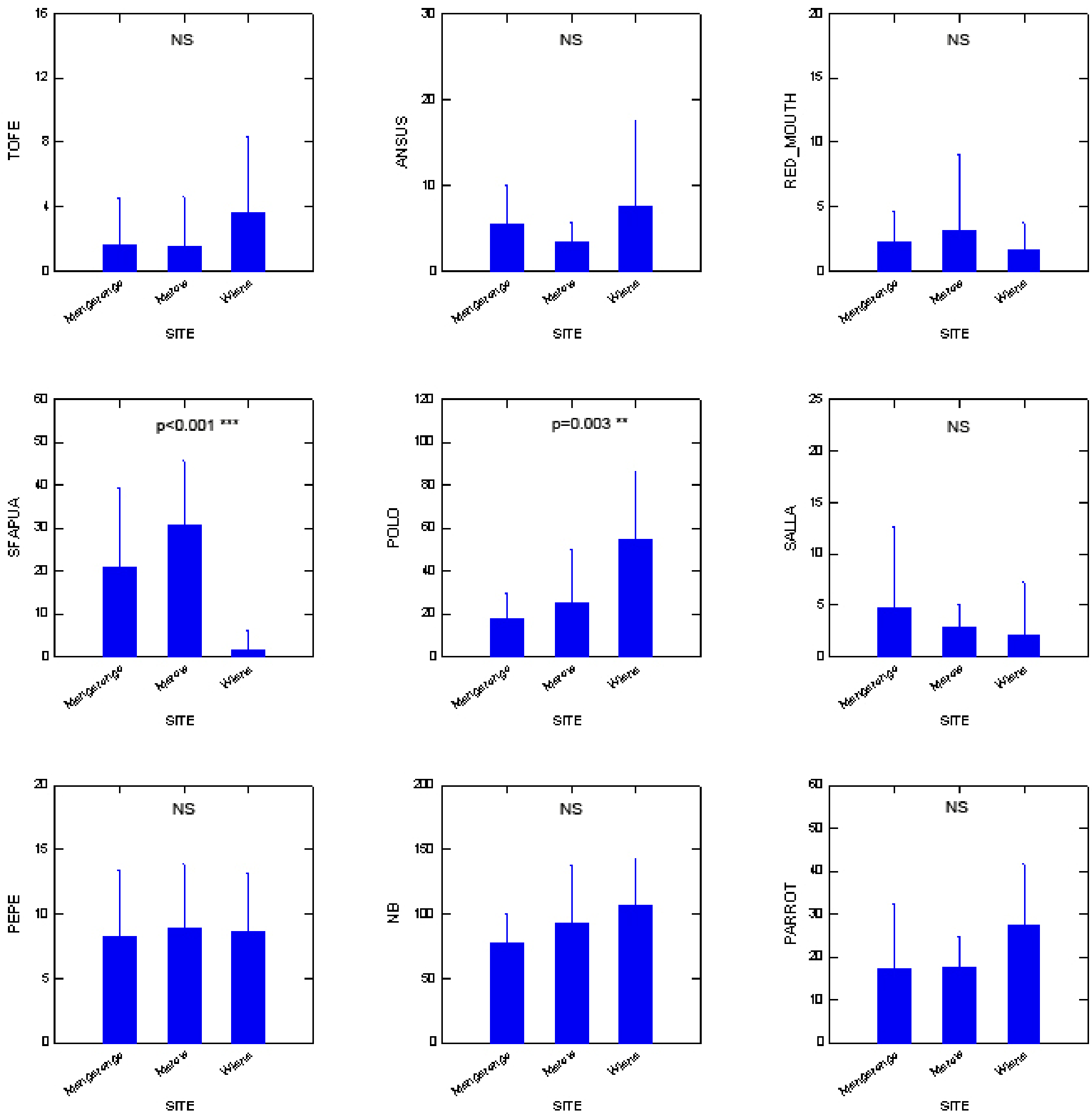


Figure 5. Mean abundance of the 8 fish taxa and overall abundance in the three sites, Emau, North Efate

2.1.2 Between-status comparisons

The effects of no-take zones on fish abundance were investigated pooling UVC data of the 3 study sites. We found no significant difference between open and tabu areas across 7 out of 8 taxa (p>0.05 - Fig 6, 7, 8). The total number of recorded fish was also identical (about 93 fish per transect). *Red-Mouth* was the only taxon that was significantly more abundant in the tabu areas (p=0.03). This difference was mainly observed on small *Red-Mouth* in Wiana reef.

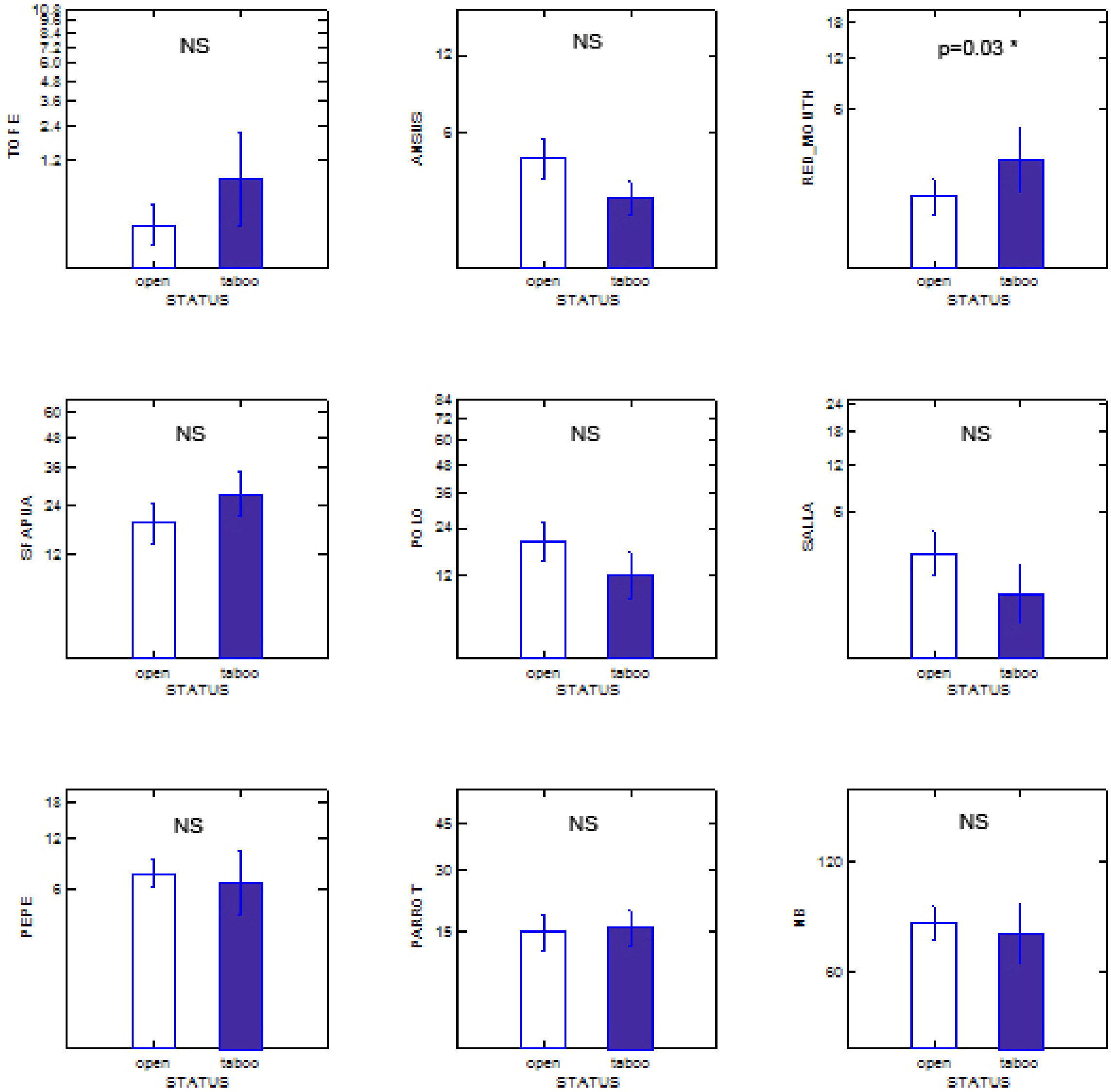


Figure 6. Mean abundance of the 8 fish taxa and overall abundance inside and outside no-take zones, Emau, North Efate.

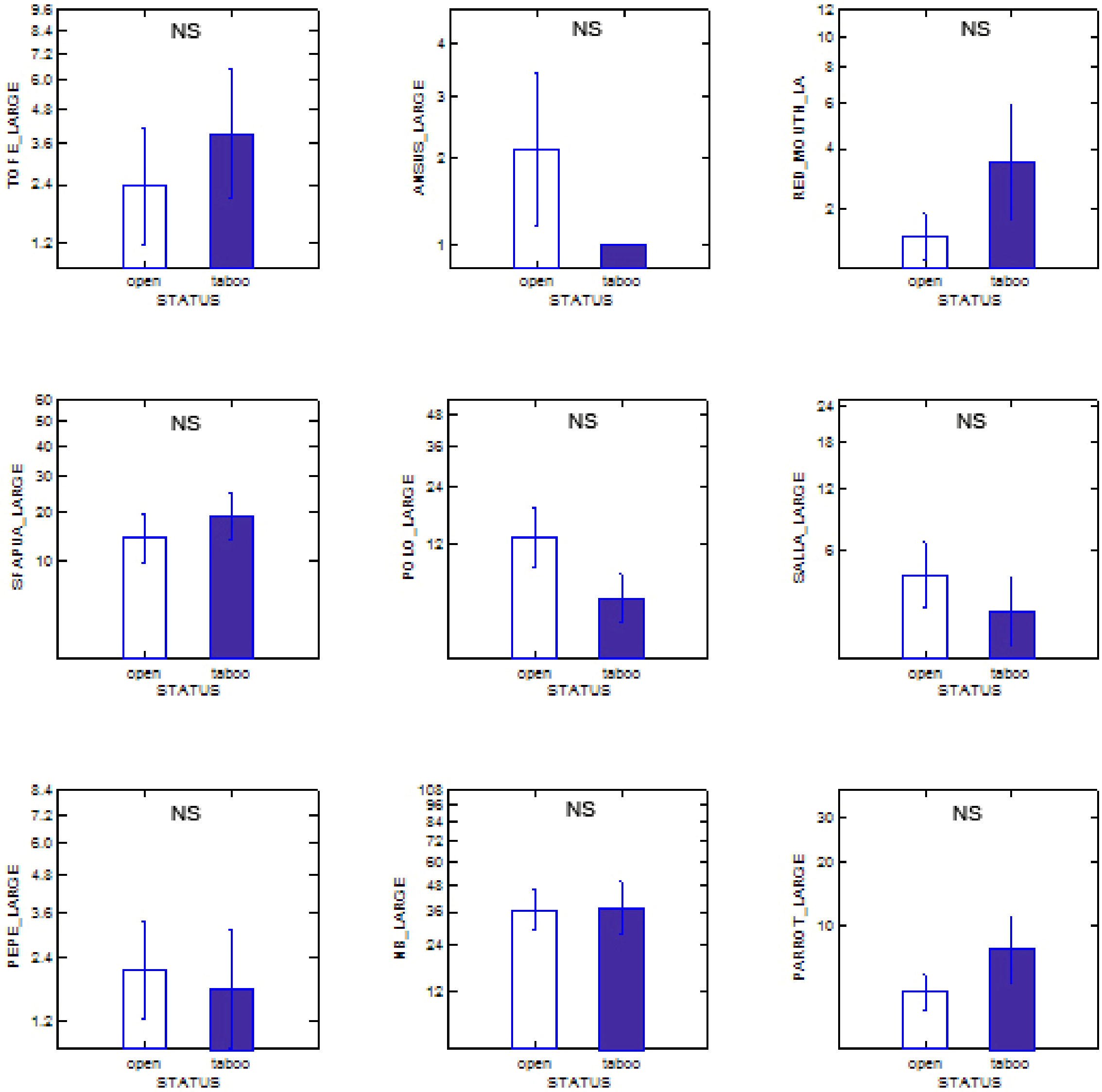


Figure 7. Mean abundance of large individuals of the 8 fish taxa and overall abundance inside and outside no-take zones (Emau Island).

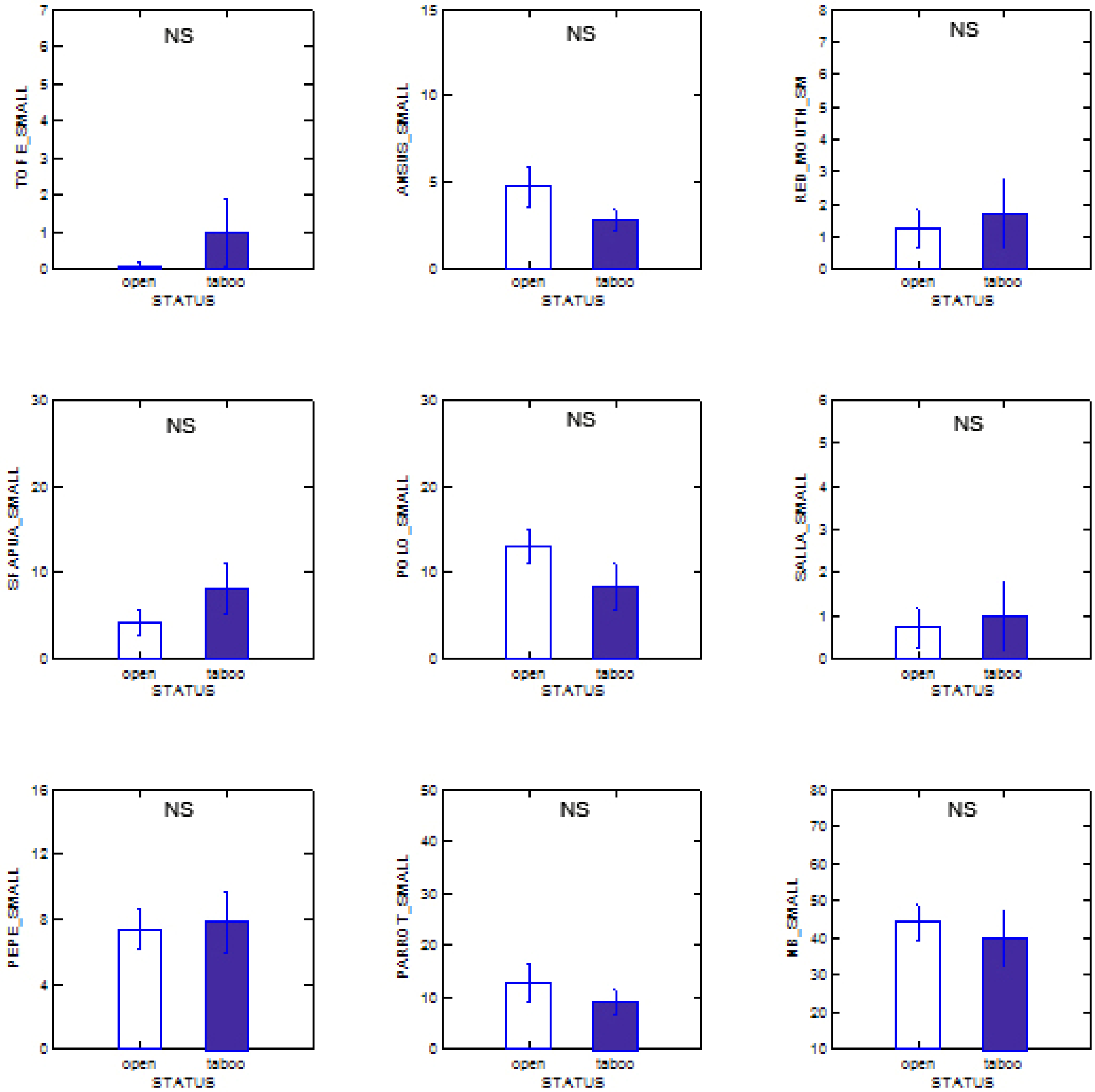


Figure 8. Mean abundance of small individuals of the 8 fish taxa and overall abundance inside and outside no-take zones, Emau, North Efate.

2.2 Invertebrate taxa

In the surveyed areas the mean abundances were generally low for trochus shells and giant clams, with values ranging from 0.8 to 2.7 trochus per transect (i.e. 39 – 134 $indiv.ha^{-1}$) and 0.9 to 2.1 giant clams per transect (i.e. 44 – 104 $indiv.ha^{-1}$). No green snails were found on transects, therefore they were not included in the following tables and figures.

Sea cucumbers had intermediate values (140 – 280 $indiv.ha^{-1}$), while local, high densities highlighted poison starfish outbreak in some areas, with a maximum of 80 individuals observed on a single transect (mean 132 – 1060 $indiv.ha^{-1}$). Spatial (i.e. between-transect and between-zone) variability was high whatever the species considered (Table 4).

Table 4. Abundance of the surveyed invertebrate species inside and outside Tabu areas, Emau, North Efate. Mean number of individuals per transect and per hectare for trochus shells (*Trochus niloticus*), giant clams (*Tridacna* spp.), sea cucumbers & poison starfish (*Acanthaster planci*). Standard deviations between brackets.

	Trochus shell		Giant clams		Sea cucumbers		Poison starfish	
	Per transect	*Per Ha*	Per transect	*Per Ha*	Per transect	*Per Ha*	Per transect	*Per Ha*
Mangarongo Tabu area	1.0 (1.4)	*50.0 (70.7)*	1.1 (1.2)	*57.1 (60.7)*	2.1 (2.8)	*107.1 (139.7)*	1.0 (2.6)	*50.0 (132.3)*
Marow Tabu area	2.7 (3.3)	*134.1 (165.0)*	2.1 (2.9)	*104.5 (143.8)*	3.4 (3.1)	*170.5 (157.1)*	17.7 (21.2)	*884.1 (1060.5)*
Outside Tabu areas	0.8 (0.8)	*38.9 (40.4)*	0.9 (0.8)	*44.4 (37.9)*	2.9 (5.6)	*147.2 (279.4)*	10.8 (11.7)	*541.7 (587.4)*

On the whole, while the data emphasized trends towards slightly higher densities in tabu areas for harvested species (trochus shells / giant clams), no significant differences were detected using formal statistical analyses (Fig. 9). The only exception was for trochus shells, more abundant in Marow tabu area (mean number on individuals per transect : 2.7 / 0.8, p°<°0.05, Mann Whitney U test).

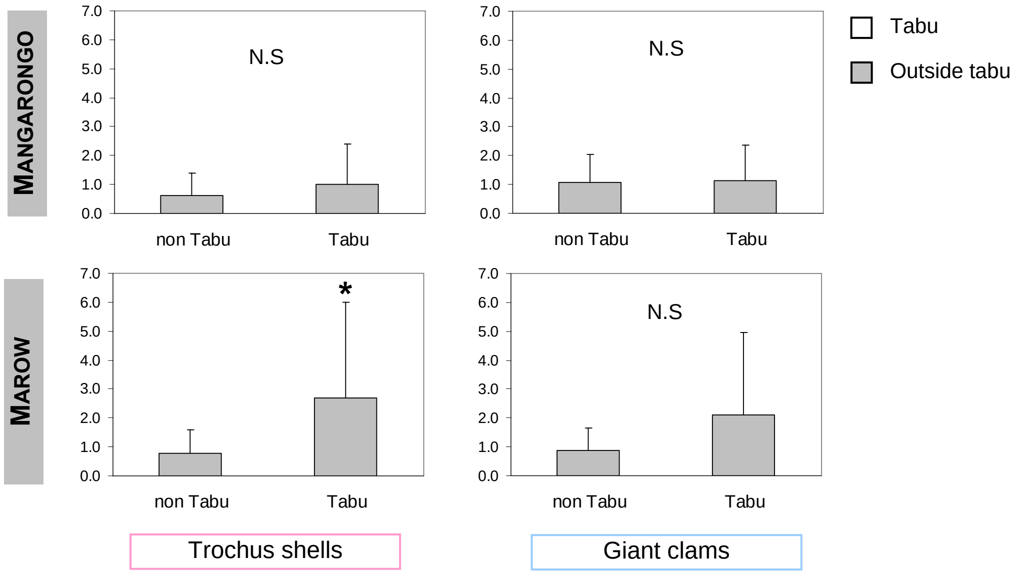


Figure 9. Comparison of invertebrate densities inside vs. outside Tabu areas, Emau, North Efate. Mean number of individuals per transect with associated Mann Whitney U tests (N.S. non significant, *°p< 0.05 ; ** p°<°0.01).

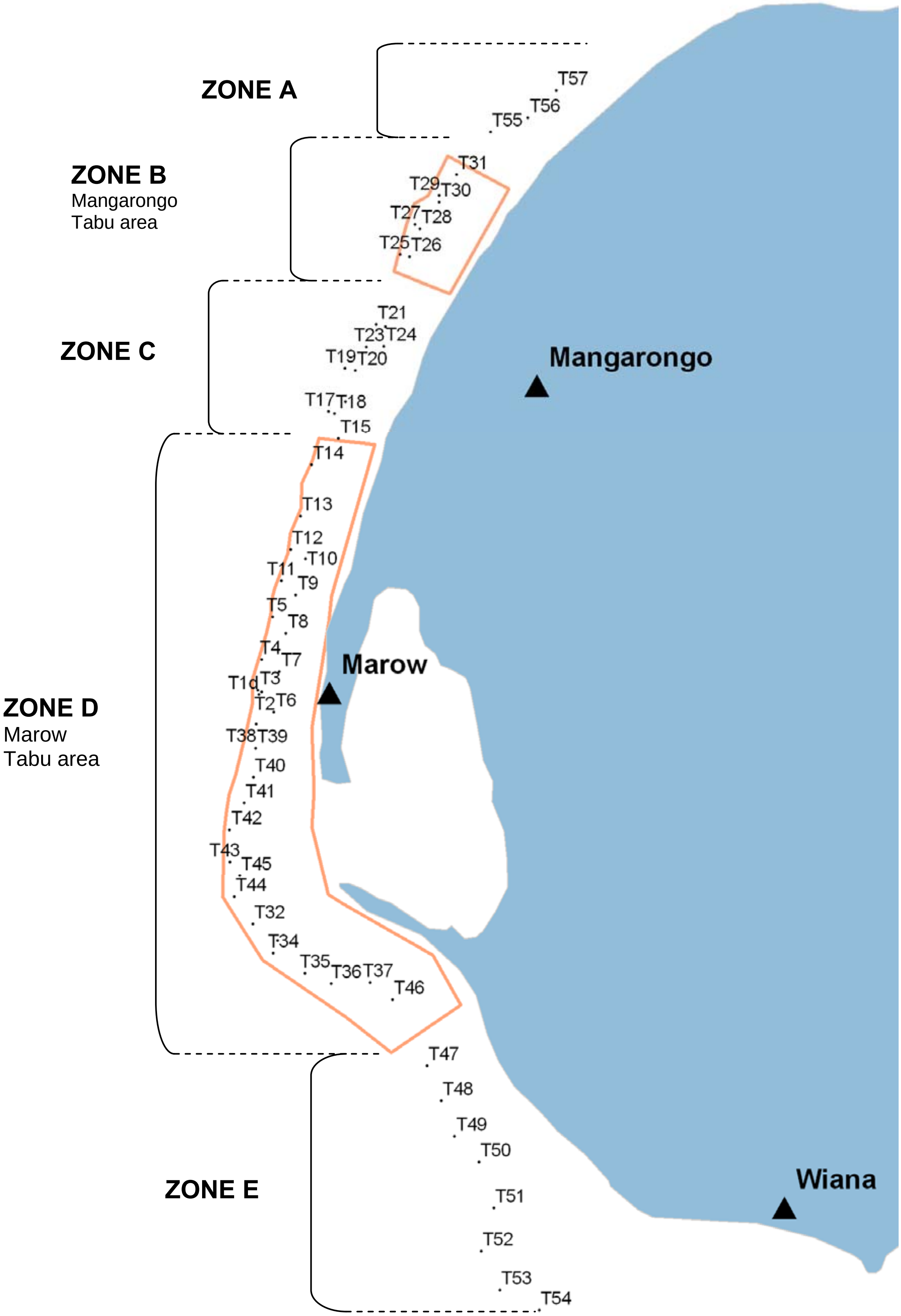


Figure 10. Detailed locations of invertebrate & habitat transects.

Table 5. Raw data for the surveyed invertebrate species inside and outside Tabu areas, Emau, North Efate. Number of individuals per transect.

ZONES A – B – C																				
Transect Name	**T55**	**T56**	**T57**	**T25**	**T26**	**T27**	**T28**	**T29**	**T30**	**T31**	**T15**	**T16**	**T17**	**T18**	**T19**	**T20**	**T21**	**T22**	**T23**	**T24**
Zone	A	A	A	B	B	B	B	B	B	B	C	C	C	C	C	C	C	C	C	C
Status				Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu										
Trochus / transect																				
All	1	0	0	4	0	0	1	1	0	1	0	0	0	2	0	1	1	1	0	2
Size < 6cm	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	1	0	0
Size 6 - 8 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Size 8 - 10 cm	0	0	0	3	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1
Size 10 - 12 cm	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Size > 12cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Giant clams / transect																				
All	0	2	2	2	0	3	0	0	1	2	0	0	2	0	1	1	2	2	2	0
Size < 6cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Size 4 - 6 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Size 6 - 8 cm	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Size 8 - 10 cm	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Size 10 - 12 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Size 12 - 14 cm	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
Size 14 - 16 cm	0	0	1	1	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0
Size 16 - 18 cm	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Size 18 - 20 cm	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
Size 20 - 22 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Size 22 - 24 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Size 24 - 26 cm	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Size 26 - 28 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poison starfish / transect																				
All	2	0	1	7	0	0	0	0	0	0	27	16	8	10	6	2	42	29	7	0
Sea cucumbers / transect																				
All	9	1	2	2	1	1	0	0	3	8	23	3	0	1	8	1	2	2	8	0

ZONE D - North

Transect Name	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14
Zone	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Status	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu
Trochus / transect														
All	2	1	14	3	1	1	0	0	0	0	6	3	0	1
Size < 6cm	0	0	0	0	0	1	0	0	0	0	2	1	0	0
Size 6 - 8 cm	0	0	1	0	0	0	0	0	0	0	1	0	0	1
Size 8 - 10 cm	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Size 10 - 12 cm	1	1	5	1	1	0	0	0	0	0	2	1	0	0
Size > 12cm	0	0	7	2	0	0	0	0	0	0	1	1	0	0
Giant clams / transect														
All	4	6	1	2	4	0	1	1	0	2	1	6	12	2
Size < 6cm	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Size 4 - 6 cm	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Size 6 - 8 cm	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Size 8 - 10 cm	2	1	1	0	1	0	0	0	0	0	0	2	0	0
Size 10 - 12 cm	0	2	0	0	1	0	1	0	0	0	0	0	3	1
Size 12 - 14 cm	1	0	0	0	0	0	0	0	0	0	0	1	2	0
Size 14 - 16 cm	1	2	0	0	0	0	0	0	0	0	0	0	2	1
Size 16 - 18 cm	0	0	0	0	1	0	0	0	0	1	0	2	3	0
Size 18 - 20 cm	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Size 20 - 22 cm	0	1	0	0	0	0	0	0	0	0	1	1	1	0
Size 22 - 24 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Size 24 - 26 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Size 26 - 28 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poison starfish / transect														
All	6	13	4	2	5	9	18	2	6	5	12	2	27	7
Sea cucumbers / transect														
All	3	5	0	0	8	5	4	5	28	61	3	3	9	0

ZONE D - South

Transect Name	T32	T33	T34	T35	T36	T37	T38	T39	T40	T41	T42	T43	T44	T45	T46
Zone	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Status	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu	Tabu
Trochus / transect															
All	1	5	0	0	1	0	0	8	3	2	3	4	0	0	1
Size < 6cm	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0
Size 6 - 8 cm	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Size 8 - 10 cm	0	1	0	0	0	0	0	1	0	0	0	1	0	0	1
Size 10 - 12 cm	1	1	0	0	0	0	0	0	2	2	2	2	0	0	0
Size > 12cm	0	0	0	0	0	0	0	7	0	0	1	1	0	0	0
Giant clams / transect															
All	1	0	0	0	2	1	1	1	0	1	2	0	0	0	0
Size < 6cm	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Size 4 - 6 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Size 6 - 8 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Size 8 - 10 cm	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Size 10 - 12 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Size 12 - 14 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Size 14 - 16 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Size 16 - 18 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Size 18 - 20 cm	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0
Size 20 - 22 cm	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Size 22 - 24 cm	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Size 24 - 26 cm	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Size 26 - 28 cm	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Poison starfish / transect															
All	10	0	65	0	3	10	14	20	47	17	27	80	24	33	4
Sea cucumbers / transect															
All	7	9	4	5	1	8	0	1	0	4	8	2	0	11	3

ZONE E

Transect Name	T47	T48	T49	T50	T51	T52	T53	T54
Zone	E	E	E	E	E	E	E	E
Status								
Trochus / transect								
All	2	1	1	0	2	1	0	0
Size < 6cm	1	0	0	0	0	0	0	0
Size 6 - 8 cm	0	0	1	0	2	1	0	0
Size 8 - 10 cm	0	0	0	0	0	0	0	0
Size 10 - 12 cm	1	1	0	0	0	0	0	0
Size > 12cm	0	0	0	0	0	0	0	0
Giant clams / transect								
All	0	1	1	1	1	1	1	0
Size < 6cm	0	0	0	0	0	0	0	0
Size 4 - 6 cm	0	0	0	0	0	0	0	0
Size 6 - 8 cm	0	0	0	0	0	0	0	0
Size 8 - 10 cm	0	0	0	0	0	0	0	0
Size 10 - 12 cm	0	0	0	0	0	0	0	0
Size 12 - 14 cm	0	0	0	0	0	0	0	0
Size 14 - 16 cm	0	0	0	0	0	0	0	0
Size 16 - 18 cm	0	0	0	0	0	0	0	0
Size 18 - 20 cm	0	0	0	0	0	0	1	0
Size 20 - 22 cm	0	0	1	0	1	0	0	0
Size 22 - 24 cm	0	0	0	0	0	1	0	0
Size 24 - 26 cm	0	1	0	1	0	0	0	0
Size 26 - 28 cm	0	0	0	0	0	0	0	0
Poison starfish / transect								
All	6	10	5	2	1	21	3	0
Sea cucumbers / transect								
All	1	0	0	0	0	1	0	3

Spatial analyses revealed contrasted density patterns at the scale of the 5 surveyed zones (Fig. 11). The highest densities were generally observed in zones C & D, whatever the species considered.

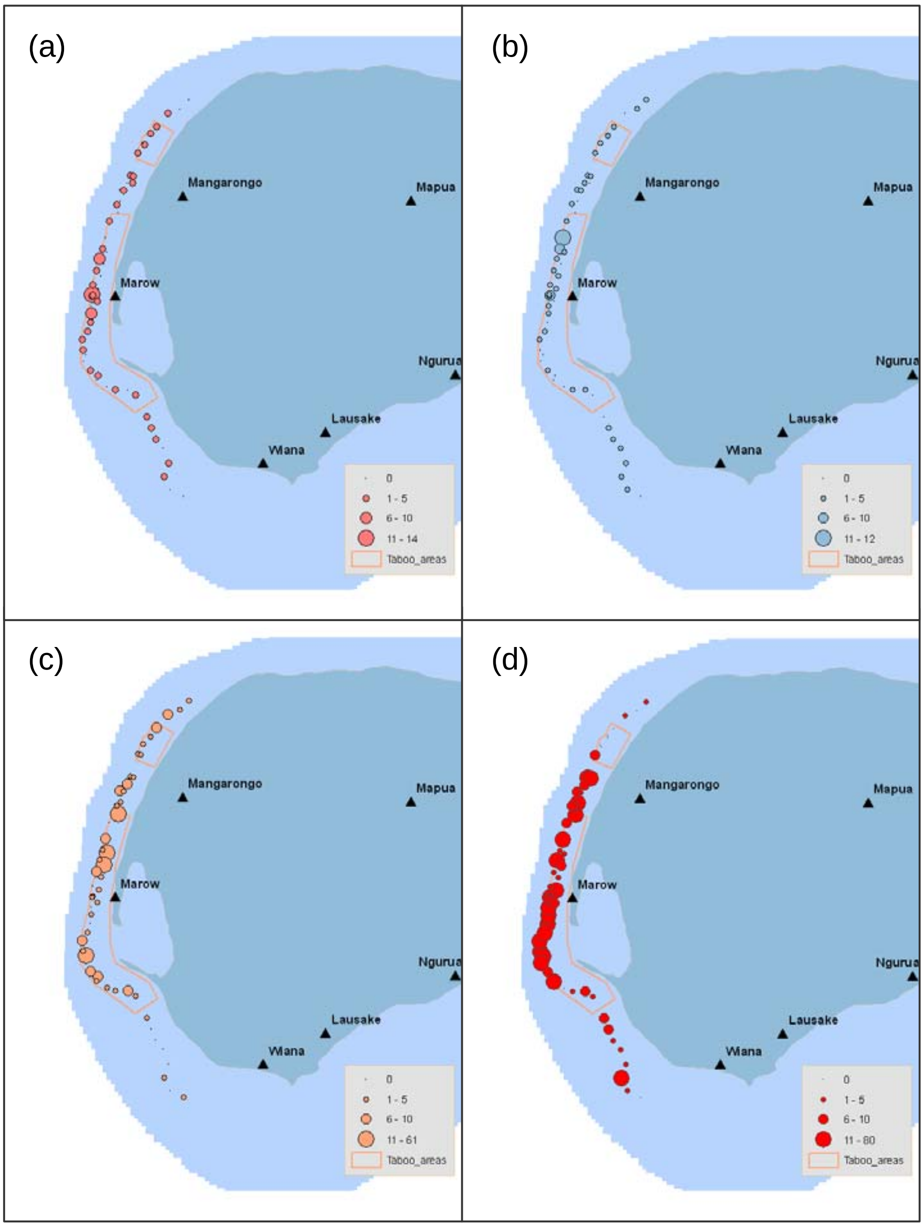


Figure 11. Spatial distribution invertebrate densities inside and outside Tabu areas, Emau, North Efate. Mean number of individuals per transect for (a) trochus shells (*Trochus niloticus*), (b) giant clams (*Tridacna* spp.), (c) sea cucumbers & (d) poison starfish (*Acanthaster planci*).

2.2.1 Invertebrate size distribution

Investigating size distributions for the surveyed species using simple field tools provided valuable additional information, in particular regarding the effects of tabu areas on the invertebrate populations (Fig. 12).

For both Tabu areas (Mangarongo and Marow), significant differences were detected for medium-large trochus shells : individuals with diameter > 8 cm were more abundant in the tabu areas than outside. Differences were more pronounced for Marow, who had larger trochus populations than Mangarongo. No significant differences were detected for smaller individuals (< 8 cm).
For giant clams, statistical analyses emphasized no differences, whatever the size classes considered.

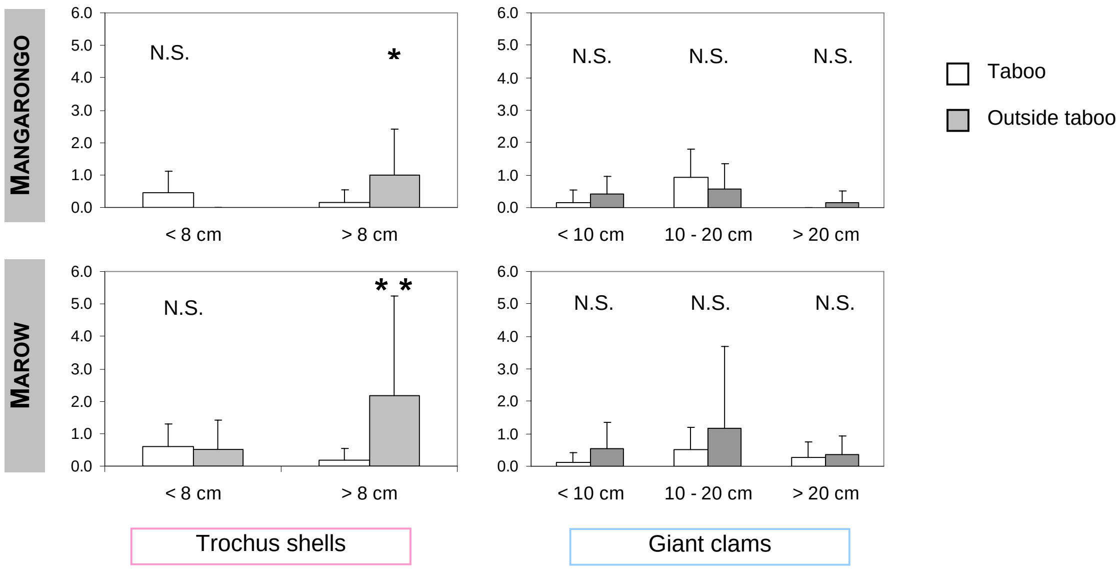


Figure 12. Comparison of invertebrate size structure inside vs. outside Tabu areas, Emau, North Efate. Mean number of individuals per transect for aggregated size classes with associated Mann Whitney U tests (N.S. non significant, * p< 0.05 ; ** p < 0.01).

2.2.2 Stock estimates for invertebrates

Very simple, rough population estimates were calculated for trochus shells, giant clams and poison starfish in the studied zone (Table 6). As detailed habitat maps were not available and given the restricted spatial coverage of this study, we used the following "quick & dirty" approach:

(1) the reef linear distance of each sampled zone (i.e. A, B, C, D, E) was computed using GIS approach ;

(2) for each zone, population estimates were restricted to a 15 m-wide corridor along this linear distance, roughly corresponding to the reef crest habitats were trochus and clams were most abundant.

Table 6. Stock estimates for the surveyed invertebrate species inside and outside Tabu areas, Emau, North Efate. Abundance estimates per zone for trochus shells (*Trochus niloticus*), giant clams (*Tridacna* spp.), sea cucumbers & poison starfish (*Acanthaster planci*).

	Mangarongo Tabu area	**Marow Tabu area**	**Outside Tabu areas**		
			Zone A	Zone C	Zone E
Trochus (all)	26.3 (32.4)	362.0 (219.1)	7.5 (17.3)	23.6 (20.3)	49.2 (38.3)
Trochus > 8 cm	26.3 (32.4)	294.5 (202.4)	7.5 (17.3)	3.4 (7.8)	14.1 (21.2)
Giant clams (all)	30 (27.8)	282.3 (191.0)	30 (34.6)	33.8 (23.2)	42.2 (21.2)
Giant clams > 10 cm	18.8 (17.3)	208.6 (180.6)	30 (34.6)	27.0 (19.4)	42.2 (21.2)
Acanthaster	26.3 (60.5)	2387 (1407)	22.5 (30)	496 (336)	337.5 (313.9)

The results highlighted the critical status of trochus / giant clam populations in the studied area, with estimates of total abundance never beyond some hundreds of individuals, whatever the considered zone (A, B, C, D, E) or species.

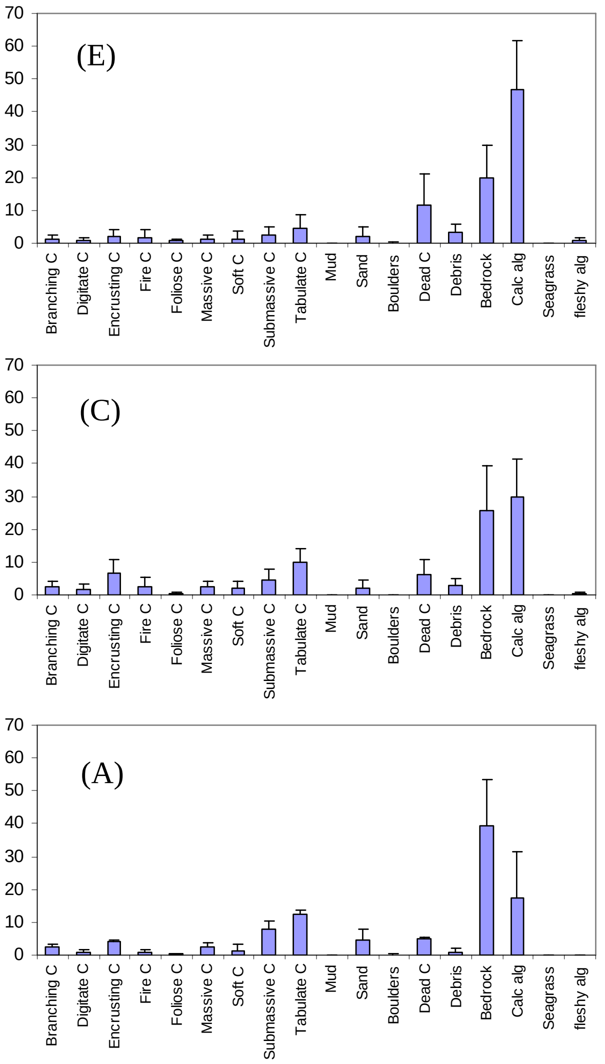
2.3 Habitat

In the sampled zones, the reef habitat was mostly represented by hard, rocky bottoms (20 – 40 %) covered by calcareous algae (17 – 47%). Living coral cover ranged between 16 and 33°%, with a maximum of 50°% in some transects. Percent cover of dead coral was between 3 and 30 % (Table 7).

Table 7. Most represented habitat variables per sampled zone in Emau, North Efate. Mean percent covers (standard deviation between brackets

Zone	Living coral	Dead coral	Bedrock	Calcareous algae
A	32.6 (3.1)	4.9 (0.5)	39.2 (14.2)	17.4 (14.3)
B (Mangarongo Tabu area)	28.4 (9.3)	2.9 (2.2)	35.2 (19.9)	29.8 (15.4)
C	32.7 (10.4)	6.4 (4.3)	25.7 (13.5)	29.9 (11.6)
D (Marow Tabu area)	18.9 (9.9)	29.0 (13.5)	21.1 (8.9)	26.5 (13.9)
E	15.6 (8.5)	11.5 (9.6)	20.1 (9.6)	46.7 (14.9)

Details per zone are provided in Fig. 13 & 14. On the whole, the ratio living coral / dead coral decreased from North to South, with zones D & E characterized by lower living coral / higher dead coral covers.
On the whole, the habitat typology did not highlight marked differences based upon reserve status in Marow or Mangarongo areas. Only a few stations in Marow reserve showed some habitat specificity due to higher dead coral cover (zone D, Southern stations). Multifactorial analyses of similarity (ANOSIM) did not show any significant effect of MPA status neither for Marow nor for Mangarongo tabu areas, suggesting that the protection status was not a major structuring factor for the reef habitats.



↑ **Figure 13.** Habitat description for the 5 surveyed zones in Emau, North Efate. Percent covers for the 18 habitat classes with standard deviations.

Figure 14. Spatial distribution of 4 habitat variables across the studied zones, Emau, North Efate. ⟶

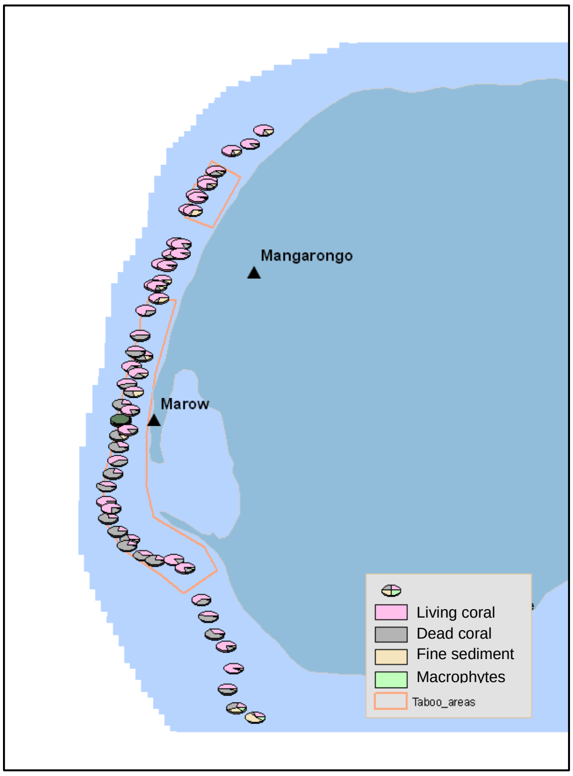


Table 8. Raw data for reef habitat in the surveyed invertebrate stations inside and outside Tabu areas, Emau, North Efate. Percent cover per transect.

ZONES A – B – C																				
TRANSECT NAME	**T15**	**T16**	**T17**	**T18**	**T19**	**T20**	**T21**	**T22**	**T23**	**T24**	**T25**	**T26**	**T27**	**T28**	**T29**	**T30**	**T31**	**T55**	**T56**	**T57**
MAJOR CATEGORIES (%)																				
CORAL	15.11	31.94	29.13	25.89	35.00	42.08	31.58	50.83	23.26	42.41	39.25	24.43	27.64	29.21	39.81	26.17	12.62	31.60	36.13	30.18
FINE SEDIMENT	6.22	3.70	0.00	3.57	0.00	0.99	4.21	0.83	2.79	0.45	0.54	10.41	1.51	0.50	0.00	3.27	1.87	7.36	1.26	5.41
ROCKY SUBSTRATE	78.67	64.35	70.87	68.75	64.44	56.93	64.21	48.33	73.95	57.14	60.22	64.71	70.85	70.30	59.72	70.56	85.05	61.04	62.61	64.41
MACROPHYTES	0.00	0.00	0.00	1.79	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.46	0.00	0.47	0.00	0.00	0.00
DETAILED CATEGORIES (%)																				
CORAL																				
Branching coral	0.44	1.39	1.94	3.57	1.11	5.45	4.21	3.33	0.93	3.13	1.61	2.71	2.51	0.50	2.31	0.47	2.80	2.60	2.94	1.35
Digitate coral	0.89	2.31	0.97	0.45	1.11	1.49	1.05	5.00	0.47	4.02	2.15	1.81	3.02	4.46	5.09	0.00	1.87	0.43	1.68	0.90
Encrusting coral	2.22	5.09	10.19	9.82	15.00	6.44	5.26	2.50	6.51	3.57	17.74	7.69	6.53	7.92	7.41	4.21	2.34	4.33	4.62	3.60
Fire Corals	2.22	0.93	0.49	1.34	1.11	3.47	1.05	9.17	1.40	5.36	0.00	1.36	0.00	0.00	2.78	2.80	0.00	0.00	1.68	0.90
Foliose coral	0.00	0.00	0.00	0.45	0.00	1.49	0.00	0.00	0.93	1.34	1.61	0.00	0.00	0.99	1.39	2.34	0.00	0.00	0.42	0.45
Massive coral	0.44	0.93	1.46	0.89	1.67	0.99	5.26	4.17	2.79	4.46	2.15	1.36	2.01	1.98	2.31	0.47	0.93	3.90	2.10	1.35
Soft coral	0.00	4.17	0.97	0.45	1.11	0.99	0.00	7.50	3.26	0.89	2.15	0.45	0.00	0.50	0.93	3.27	0.93	3.46	0.00	0.00
Submassive coral	5.78	3.70	5.83	1.34	3.33	7.43	2.11	3.33	1.40	11.61	3.23	7.24	7.54	7.92	8.33	7.01	1.87	5.19	8.82	9.91
Tabulate coral	3.11	13.43	7.28	7.59	10.56	14.36	12.63	15.83	5.58	8.04	8.60	1.81	6.03	4.95	9.26	5.61	1.87	11.69	13.87	11.71
FINE SEDIMENT																				
Mud	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand	6.22	3.70	0.00	3.57	0.00	0.99	4.21	0.83	2.79	0.45	0.54	10.41	1.51	0.50	0.00	3.27	1.87	7.36	1.26	5.41
ROCKY SUBSTRATE																				
Boulders	0.00	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.47	0.00	0.43	0.00	0.00
Dead coral	2.22	2.78	8.74	4.46	8.89	1.98	8.42	9.17	14.88	2.23	0.54	2.26	2.01	1.49	2.31	6.07	6.07	4.33	5.04	5.41
Debris	6.22	1.85	1.94	0.00	0.00	4.46	5.26	3.33	1.40	3.13	0.00	0.90	0.50	0.99	0.00	0.00	2.34	0.00	1.26	1.80
Rock/dead coral	48.89	24.54	16.99	19.20	18.33	18.81	41.05	8.33	42.79	17.86	21.51	29.86	43.22	17.33	14.81	51.40	68.22	53.68	25.21	38.74
calc algae	21.33	35.19	42.72	45.09	37.22	31.68	9.47	27.50	14.88	33.93	38.17	31.67	25.13	50.00	42.59	12.62	8.41	2.60	31.09	18.47
MACROPHYTES																				
Seagrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fleshy algae	0.00	0.00	0.00	1.79	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.46	0.00	0.47	0.00	0.00	0.00

ZONE D - North

TRANSECT NAME	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T14
MAJOR CATEGORIES (%)													
CORAL	8.37	9.26	8.37	12.09	25.33	56.02	50.67	16.00	16.96	13.33	27.78	19.64	27.54
FINE SEDIMENT	0.93	1.85	0.00	0.47	0.44	0.00	1.33	7.56	2.23	3.11	0.00	0.00	0.00
ROCKY SUBSTRATE	90.70	88.89	91.16	86.98	73.78	43.98	47.56	76.44	80.36	83.11	70.83	79.46	71.98
MACROPHYTES	0.00	0.00	0.47	0.47	0.44	0.00	0.44	0.00	0.45	0.44	1.39	0.89	0.48
DETAILED CATEGORIES (%)													
CORAL													
Branching coral	4.19	3.24	0.93	0.00	0.44	23.61	31.56	4.00	8.93	0.89	5.09	2.23	1.45
Digitate coral	0.47	0.93	0.47	0.47	0.00	0.93	1.78	2.67	0.45	1.33	0.00	1.34	0.00
Encrusting coral	0.00	0.00	0.00	0.00	5.33	0.00	0.89	1.33	0.89	0.89	7.87	8.04	17.39
Fire Corals	0.47	0.46	2.79	7.91	2.22	0.00	0.44	0.00	0.00	0.44	0.46	0.00	0.00
Foliose coral	0.00	0.00	0.00	0.00	0.00	12.04	6.22	1.33	0.00	0.00	0.00	0.00	0.97
Massive coral	0.47	1.39	0.93	0.93	0.89	0.93	0.00	0.00	0.89	0.89	1.85	2.23	0.48
Soft coral	0.00	0.00	0.47	1.40	2.67	0.00	0.00	0.00	0.00	0.00	1.85	0.89	1.45
Submassive coral	1.40	0.00	0.93	0.93	1.33	3.70	6.22	5.78	4.91	1.33	2.31	0.89	1.93
Tabulate coral	1.40	3.24	1.86	0.47	12.44	14.81	3.56	0.89	0.89	7.56	8.33	4.02	3.86
FINE SEDIMENT													
Mud	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand	0.93	1.85	0.00	0.47	0.44	0.00	1.33	7.56	2.23	3.11	0.00	0.00	0.00
ROCKY SUBSTRATE													
Boulders	0.47	0.46	0.00	0.00	0.00	0.00	0.44	0.44	0.00	0.00	0.00	0.00	0.00
Dead coral	45.58	40.28	31.16	40.47	21.33	10.65	12.00	8.44	6.25	6.22	14.35	19.64	9.18
Debris	3.72	9.72	1.86	1.40	0.89	8.80	8.89	14.67	11.16	11.11	0.00	0.45	0.00
Rock/dead coral	33.49	25.00	40.00	12.09	12.00	12.04	15.11	38.22	41.52	53.33	16.67	15.18	7.25
calc algae	7.44	13.43	18.14	33.02	39.56	12.50	11.11	14.67	21.43	12.44	39.81	44.20	55.56
MACROPHYTES													
Seagrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fleshy algae	0.00	0.00	0.47	0.47	0.44	0.00	0.44	0.00	0.45	0.44	1.39	0.89	0.48

ZONE D - South

TRANSECT NAME	T32	T33	T34	T35	T36	T37	T38	T39	T40	T41	T42	T43	T44	T45	T46	T47
MAJOR CATEGORIES (%)																
CORAL	14.02	19.59	13.33	20.29	12.82	45.92	6.19	16.59	38.86	10.27	20.72	40.09	9.81	31.11	34.72	26.04
FINE SEDIMENT	0.00	4.05	0.67	0.48	1.03	0.00	3.33	0.45	0.00	0.00	0.90	0.43	0.00	0.89	0.00	0.00
ROCKY SUBSTRATE	85.98	76.35	86.00	79.23	86.15	54.08	90.48	81.17	61.14	89.73	77.93	59.48	90.19	68.00	63.19	73.37
MACROPHYTES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.79	0.00	0.00	0.45	0.00	0.00	0.00	2.08	0.59
DETAILED CATEGORIES (%)																
CORAL																
Branching coral	3.74	3.38	1.33	9.18	4.10	14.29	0.00	3.14	2.62	1.79	1.80	7.33	1.87	6.67	4.17	3.55
Digitate coral	0.00	1.35	0.00	0.00	0.51	1.02	0.00	0.00	3.06	0.00	2.25	0.00	0.00	2.22	2.08	0.00
Encrusting coral	0.47	0.00	0.00	0.48	0.51	1.02	0.48	0.45	0.00	0.00	0.00	1.72	0.00	0.00	0.69	1.18
Fire Corals	4.21	8.11	6.67	6.76	7.18	2.04	1.43	2.69	0.00	2.68	0.00	0.00	0.00	0.00	1.39	6.51
Foliose coral	0.00	0.00	0.00	0.00	0.00	1.02	0.00	0.00	0.44	0.00	0.90	0.00	0.00	0.00	1.39	1.18
Massive coral	0.00	0.00	0.00	0.00	0.00	0.51	0.95	0.45	0.87	3.13	0.45	0.43	0.00	0.00	4.17	1.18
Soft coral	2.80	0.00	0.67	0.48	0.51	0.00	0.00	3.14	0.00	0.00	1.80	0.43	0.93	0.00	0.00	0.00
Submassive coral	0.93	1.35	2.00	1.45	0.00	2.04	0.48	2.24	0.44	0.89	0.90	1.29	0.00	0.89	4.86	1.78
Tabulate coral	1.87	5.41	2.67	1.93	0.00	23.98	2.86	4.48	31.44	1.79	12.61	28.88	7.01	21.33	15.97	10.65
FINE SEDIMENT																
Mud	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand	0.00	4.05	0.67	0.48	1.03	0.00	3.33	0.45	0.00	0.00	0.90	0.43	0.00	0.89	0.00	0.00
ROCKY SUBSTRATE																
Boulders	0.00	0.68	0.00	0.00	1.03	0.00	0.95	0.00	0.00	0.89	0.45	0.43	0.00	0.00	0.00	0.00
Dead coral	49.07	42.57	48.67	33.82	42.56	7.14	13.33	38.57	25.33	36.61	24.77	9.48	26.17	8.89	8.33	15.38
Debris	0.93	16.22	2.00	4.83	7.69	4.08	2.86	3.14	0.00	3.13	5.41	0.86	3.74	9.78	2.08	2.96
Rock/dead coral	13.55	14.19	24.00	30.92	22.56	28.57	38.10	10.31	15.72	23.66	28.83	19.40	21.03	30.67	16.67	11.24
calc algae	22.43	2.70	11.33	9.66	12.31	14.29	35.24	29.15	20.09	25.45	18.47	29.31	39.25	18.67	36.11	43.79
MACROPHYTES																
Seagrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fleshy algae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.79	0.00	0.00	0.45	0.00	0.00	0.00	2.08	0.59

ZONE E

TRANSECT NAME	T48	T49	T50	T51	T52	T53	T54
MAJOR CATEGORIES (%)							
CORAL	14.35	14.85	19.90	16.13	25.56	4.87	2.78
FINE SEDIMENT	0.00	0.00	1.46	0.92	2.69	7.08	5.09
ROCKY SUBSTRATE	85.19	84.16	78.64	82.95	71.30	85.40	91.20
MACROPHYTES	0.46	0.99	0.00	0.00	0.45	2.65	0.93
DETAILED CATEGORIES (%)							
CORAL							
Branching coral	0.00	1.98	1.46	0.00	1.79	0.00	0.00
Digitate coral	0.93	0.50	1.94	0.92	1.35	0.88	0.00
Encrusting coral	0.00	0.99	2.43	3.23	7.17	0.44	0.00
Fire Corals	1.39	3.47	2.91	0.00	0.45	0.00	0.00
Foliose coral	0.00	0.99	1.46	1.38	0.45	0.00	0.00
Massive coral	0.46	0.00	0.49	3.69	1.35	1.33	0.93
Soft coral	0.00	0.00	0.00	1.38	7.17	0.00	0.00
Submassive coral	0.93	1.49	8.25	3.69	2.24	0.88	1.39
Tabulate coral	10.65	5.45	0.97	1.84	3.59	1.33	0.46
FINE SEDIMENT							
Mud	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand	0.00	0.00	1.46	0.92	2.69	7.08	5.09
ROCKY SUBSTRATE							
Boulders	0.00	0.00	0.00	0.92	0.45	0.00	0.00
Dead coral	15.74	25.25	4.37	0.46	22.42	7.52	0.46
Debris	0.00	1.49	4.85	2.76	0.90	3.98	8.33
Rock/dead coral	18.06	20.30	40.78	10.14	20.18	15.93	24.07
Calcareous algae	51.39	37.13	28.64	68.66	27.35	57.96	58.33
MACROPHYTES							
Seagrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fleshy algae	0.463	0.99	0	0	0.448	2.655	0.926

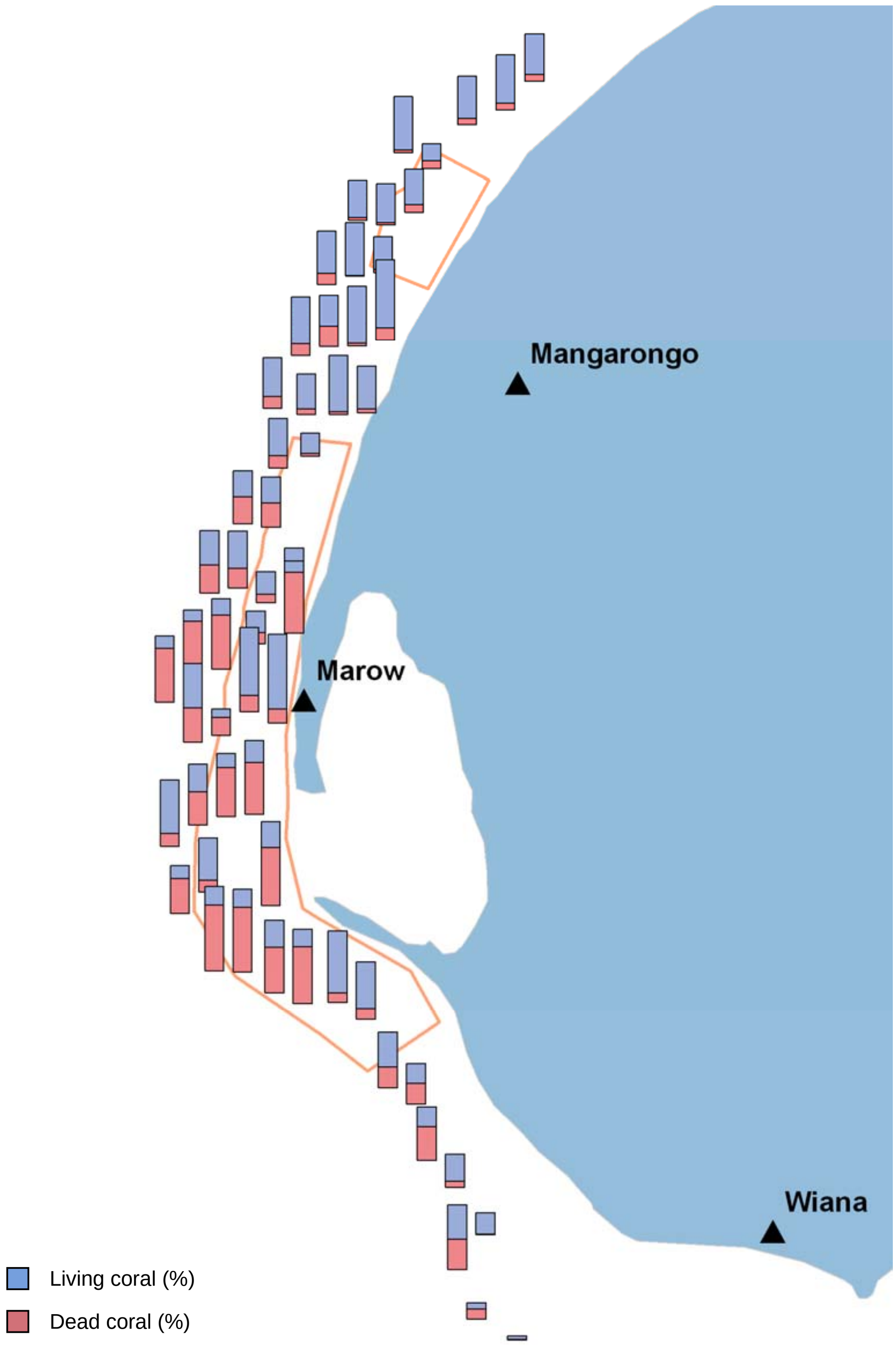


Figure 15. Spatial distribution of coral cover along the surveyed stations in Emau, North Efate. Percent cover per transect for living coral vs. dead coral.

2.4 Interpretation

2.4.1 Fishing status

Our findings on size-based abundances suggest that fish resources have been more exploited in Wiana reef (where about 80 % of fish are composed of small individuals) than in Marow and Mangarongo reefs though the overall abundance of main targeted species does not show any significant difference. The very low abundance of *Sfapua* and the very high abundance of *Pollo* would be mainly attributable to reef geomorphology rather than fishing status. Habitat characteristics should however be described to analyse these results more precisely.

Results of invertebrate surveys highlight that resource species (trochus shells, giant clams) were strongly exploited across the whole area. Low to very low densities were generally observed whatever the zone considered, corresponding to severely depleted invertebrate populations. Despite differences in coral covers and substrate variables across the studied area, statistical analyses (not presented here) suggest that habitat is not a main factor responsible for invertebrate spatial distribution.

2.4.2 Effects of tabu areas on resource abundance

We did not find any impact of tabu areas on the recorded fish taxa in the three study sites (excepted on *Red-Mouth* in Wiana). However few stations were sampled during this survey due to the short length of the village reefs. Our assessment should then be confirmed by temporal replication as part of the local monitoring programmes.

On the other hand, our results provide clear evidence of invertebrate population enhancement in Marow MPA, in particular for trochus that was three times more abundant inside than outside the tabu area. The Marow MPA also harbored large adult individuals (>10 cm in diameter), in contrast with the surrounding reef stations where they were almost absent. However the spatial distribution of trochus alongside Marow reef showed that abundance peaked in front of the village and then strongly decreased towards both edges of the tabu area (Fig. 16).

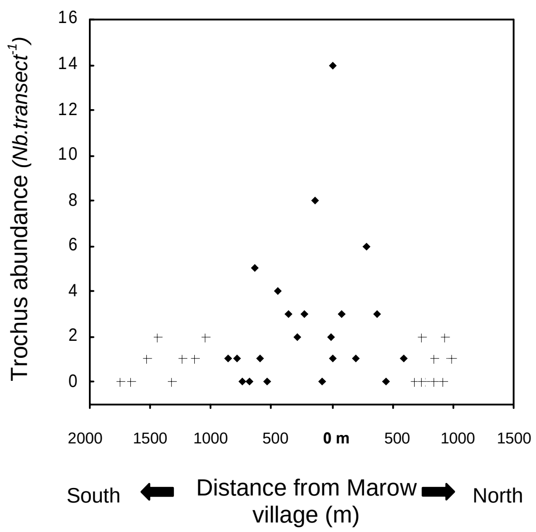


Figure 16. Longitudinal distribution pattern of *Trochus niloticus* along the reef stations of Marow.

These spatial size patterns may actually result from direct human intervention rather than natural biological processes only, through the translocation of individuals from non-protected stations by the fishers themselves. Village-based management practices therefore tend to associate fishery closure and breeding stocks aggregation in a similar way to government-supported restocking actions enforced throughout the country.
Similar trends were observed for giant clams *Tridacna spp*. (almost all individuals observed by the IRD team belonging to *Tridacna maxima*), but with MPA effects slightly below the level of statistical significance. On the contrary, no MPA effects could be discerned in Mangarongo tabu area on the population structure of the surveyed species.
Yet, alternative conclusions arise when considering two separate parts in Marow tabu area, as data highlighted contrasted, lower giant clam densities in the distant, Southern part of the reserve. While the reasons for this remain unclear (effects of poaching ? small-scale habitat factors ?), considering the part of Marow tabu area mostly located in front of the village emphasizes highly significant tabu effects for giant clams (and trochus shells as well).

2.4.3 Importance of resource monitoring

Our data support the conclusions that effect magnitude of Emau tabu areas may be time and size-dependant.
On the one hand, the rapidity of response to protection is in particular mediated by species life-history strategies, with quicker effects expected for fast-growing, early-mature species. In the case of fast-growing trochus, short term stock rebuilding could be expected inside the tabu areas if juvenile growth counterbalances natural mortality. Large, benthic invertebrates do not usually fall into the latter category, therefore requiring more time before significant effects on population structure can be reached. This is the case for slow-growing giant clams, highlighting the importance of framing any ecological assessment of reserve efficiency in a temporal context.

On the other hand, the principle of spillover of mobile species (the migration of adult stock from the marine reserve to the surrounding unprotected waters) may lead to the concentration of fishing effort at the boundary of tabu areas to increase catch. Interactions between closure size and adult mobility have been investigated to provide guidelines for the implementation of marine protected areas. The small surface of such areas in Emau and adult mobility alongside Southwest reef is expected to make such closed zones able to enhance the stocks of low-dispersing or highly territorial species only. Main target species of fish (Lethrinidae, Scaridae, Acanthuridae, among other) may not fall in these categories. The closing of a larger area (for example the area between Marow and Mangarongo no-take zones) may therefore be a practical way to make these tabu more effective.

Monitoring marine resources through periodic surveys is therefore of particular importance inside and at the boundary of Emau tabu areas. Spatial data on fish catch closed to tabu areas may also help to assess the success of these small marine reserves in enhancing invertebrate and fish stocks.

III. Practical recommendations for resource monitoring in Emau island

The surveys were designed to implement easy-to-use techniques for community-based biological monitoring of fish and invertebrate resources in three villages in Emau island.

3.1 Monitoring fish resources

Two local snorkellers have been trained to the technique (cf. section 2.1) We would recommend that each diver focus on half of the height focal taxa on both sides of transects (Table 9).

Table 9. Recommanded focal fish species and size categories

Vernacular name	Bichlamar name	Scientific name	**Small/Large threshold (cm)** Standard length
Saama, Malakesa, Raea	Blue fish, Parrot fish	Scaridae	19
Ansus	Mustach fish	Mullidae	19
Sfapua	Rainbow	*Acanthurus lineatus*	15
Rourou, Siko	Red mouth	*Lethrinus harak, Lethrinus miniatus*	18
Tofe	Piko	*Siganus doliatus, Siganus puellus,*	18
Polo	Black piko	*A. striatus* -like Surgeon fish	14
Salla	Black piko	*Acanthurus blochii* (Nega maito), *A. dussumieri* (Saala), *A. nigricans*, *A. nigricauda*	16
Pepe	Butterfly fish	Chaetodontidae	12

We found that using two size categories was a relevant approach to characterize fishing exploitation, while still being easy to implement after training. Monitoring the abundance of target fish alone would not be efficient enough to detect a significant change in resource status.
Abundance can not be expressed per surface unit (as there is no defined transect width) but the local divers felt comfortable with this simple way to record fish. The interpretation of the results (number of fish per transect) is straightforward.

- **Final recommendations for fish monitoring**

i) Transect length should be (at least) **50m long** to avoid 0 values of abundance. The transect line **should NOT be materialized** on the bottom to avoid fish disturbance before counting. It should be release during the census to measure the 50 m distance.

Transect width should be defined by underwater visibility and exceed 10 m on both sides of the transect. Basically all fish of the focal taxa that are observed are recorded. Diver speed should be fixed (e.g. 15 minutes/transect) even where fish abundance is low.

ii) Fish surveys should be conducted during **high tides**.

iii) Abundance and individual sizes of the target species should be recorded by **2 snorkellers per transect,** each surveying half of the focal taxa on both sides of the transect.

Snorkellers should be trained in fish identification and size estimation before the survey.

3.2 Monitoring invertebrate resources

Two local snorkellers were trained to the monitoring techniques (cf. section 2.2), in particular to the use of simple field measuring tools.

Results highlighted that encompassing invertebrate sizes provided easy-to-collect but valuable information for trochus as well as giant clam populations. This is of particular importance when investigating potential effects of area closures on resource species, which may remain unclear when only abundance/density is recorded., Data on individual sizes must also be collected and combined with density estimates to monitor population growth.

The low densities generally observed confirmed the need to use large transects, in order to collect representative values of trochus and clams abundance. 50 x 4m transects actually constitute a compromise between the surface that is covered and the amount of time needed for data collection. It could be expanded (e.g. 100m x 4m) to better capture the (very low) giant clam densities, but with lower field convenience.

One potential issue arises from the particular spatial distribution observed for trochus alongside Marow reef (Fig. 16). In this context, using random transects in the monitoring program is very likely to yield ambiguous, misleading trends between surveys. The easiest way to overcome this issue is to perform all the surveys using a number of fixed, spatially localized transects.

- **Final recommendations for invertebrate monitoring**

i) Transect size should be (at least) **50m long x 4m wide**, and should be materialized on the bottom to help the snorkellers visualize the transect dimensions.

50 m rope or fishing line can be used for this purpose.

ii) Invertebrate surveys should be conducted at low tide if possible, to allow easier and consistent detection of cryptic individuals (e.g. hidden behind tabular corals, in crevices etc.).

iii) Abundance and individual sizes of the target species should be recorded by **2 snorkellers per transect,** each surveying a 2m-corridor.

The greatest care should be observed by the snorkeling team to respect corridor width, to ensure relevant density calculations.

3.3 Spatial and temporal design of fish and invertebrate monitoring programmes

i) The monitoring scheme should rely on a set of **5-10 fixed stations**, located inside and outside the tabu area **alongside the reef crest**.

Fish and invertebrates transects may be located right on and about 20 m from the reef crest respectively (where both resources concentrate).

Once selected, the stations set should remain the same between surveys to ensure relevant temporal comparisons of abundance and size structure. Permanent signs may be used to mark the station locations on the seashore as well as on the reef crest (Fig. 17).

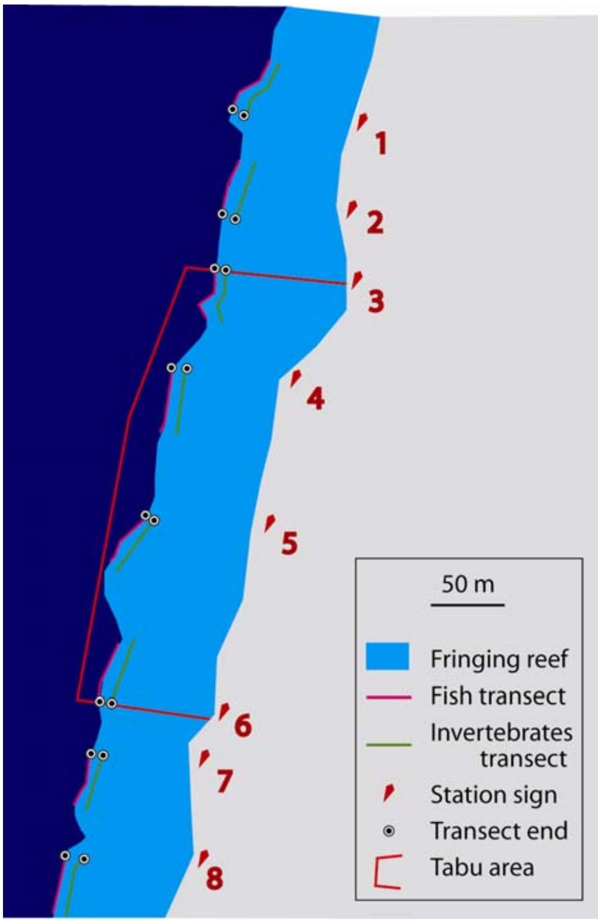


Figure 17. Example of spatial design of the fish and invertebrate monitoring programme inside and outside a theorical tabu area in Emau island.

ii) Monitoring should be performed at least **on a yearly basis**, or every 6 months (if possible) to increase the temporal resolution and the ability to detect trends in resource evolution.

Ideally, surveys would coincide with the contrasted water (warm vs. cold) seasons.

COMPONENT 2A - Project 2A2 - August 2009

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