Monitoring and Baseline Assessment of Marine Protected Areas in the Fish Project Focal Areas:

TAWI-TAWI

Implementation of the

Fisheries Improved for Sustainable Harvest Project

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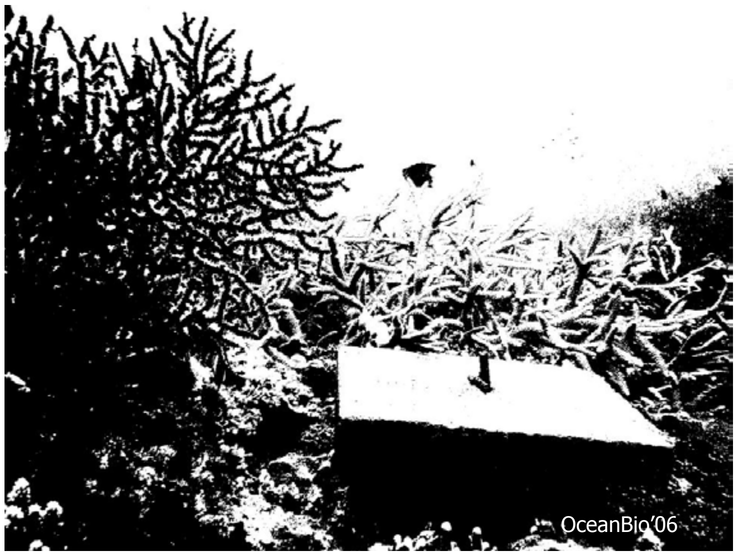

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Introduction

The overexploitation of fisheries resources in the country is a result of several factors. These include their open access nature, unregulated and destructive fishing leading to stock depletion and habitat degradation, the inability of responsible government agencies to effectively enforce fisheries-related laws, and the absence of rational national and local fisheries management policies and plans geared towards sustainable use.

The goal of the Fisheries Improved for Sustainable Harvest (FISH) Project is to conserve biological diversity in at least four important marine ecosystems in the country and to affect a 10% increase in fish stocks by the year 2010. This goal is to be evaluated by the measurement of baseline estimates of quantitative indicators at the start of management interventions (2003-04) and through periodic monitoring for the duration of the project.

This study was conducted to provide the information necessary for deriving indicators in three reef MPA sites first surveyed in 2004, and to establish baseline information for three new MPA sites in the FISH focal area in Tawi-Tawi (Fig. 1). The three new MPA sites included in the project were chosen based on studies conducted in 2004-05 on the distribution of fish eggs and larvae (Campos, 2006; unpublished report) and simulations of their dispersal (Villanoy, 2006; unpublished report).

Objectives

The objectives of the study were to:

1) estimate density, biomass and species composition of reef fish assemblages within and outside of MPA boundaries in the three sites surveyed in 2004;

2) characterize reef habitat conditions by estimating the cover of various benthic life form categories within and outside of MPA boundaries in these sites; and

3) gather the same information as in (1) and (2) for the three new MPA sites in the area.

Materials and methods

Study Area

The location of the six sites surveyed from 17-26 October 2006 are shown in Fig. 1. These include Ubol (Ub), Simunul (S), Tundon (Td), Panglima Sugala (Ps), Ungos-ungos (Ug) and Pababag (P). In each of these sites, ten (10) dives were conducted to gather the information enumerated below. Of these, five (5) were done outside of the MPA boundaries, while the other five (5) were done within the MPA boundaries. In 2004, MPA boundaries were already established for only one (1) of the three (3) surveyed sites, Pababag. Reef surveys that year were thus conducted to characterize the reef habitats in the other two (2) sites, Panglima Sugala and Simunul. The results were then used by another group in 2005 to set MPA boundaries and to collect baseline data from appropriately located dive stations. Hence, except for Pababag, original station locations in 2004 were modified so that there would be equal representation of areas inside and outside of the newly-established MPA boundaries. In addition, three (3) additional sites were surveyed in October 2006. The list of coordinates for each of the 10 stations in each of the 6 sites is shown in Table 1a. Station locations in each of the sites are shown in Figs. 2a-f.

Geographical coordinates of each transect (dive station) were recorded with the use of handheld GPS units. As was done in 2004, fabricated concrete blocks (25cm x 25cm x 4cm) were laid and fixed (via steel rod thru a hole in the center of the concrete block) at 5m intervals along at least one half of the transect line in each of the stations in the three new sites. This was done to ensure that future monitoring would be done in the exact same station. Two years, however, is a relatively long time and many of the blocks in the original stations could not be relocated in the field in 2006. Hence, GPS coordinates served as the primary reference points in the field surveys. Replacement blocks were deployed whenever there were opportunities to do so.

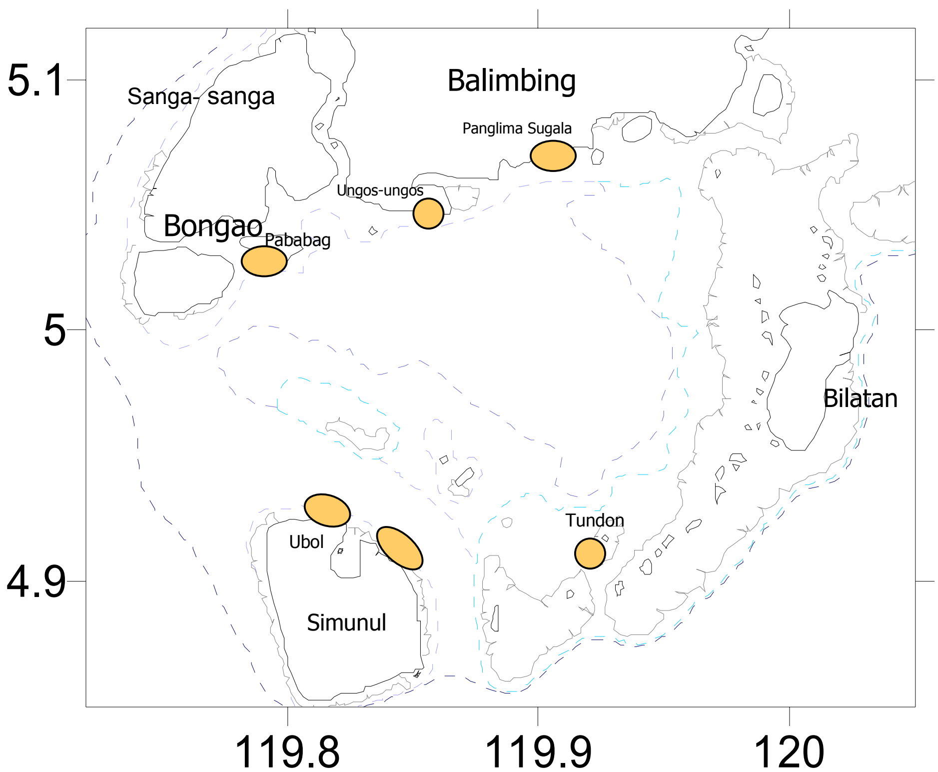


Figure 1. Map showing the location of MPA sites in Tawi-Tawi, October 2006.

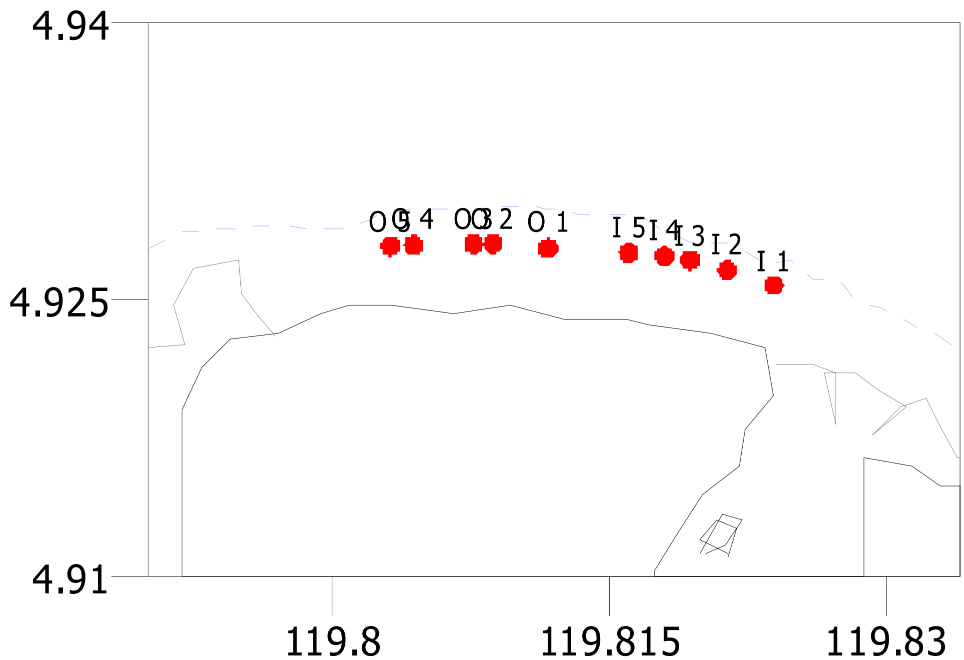


Figure 2a. Map showing location of stations in Ubol MPA surveyed in October 2006.

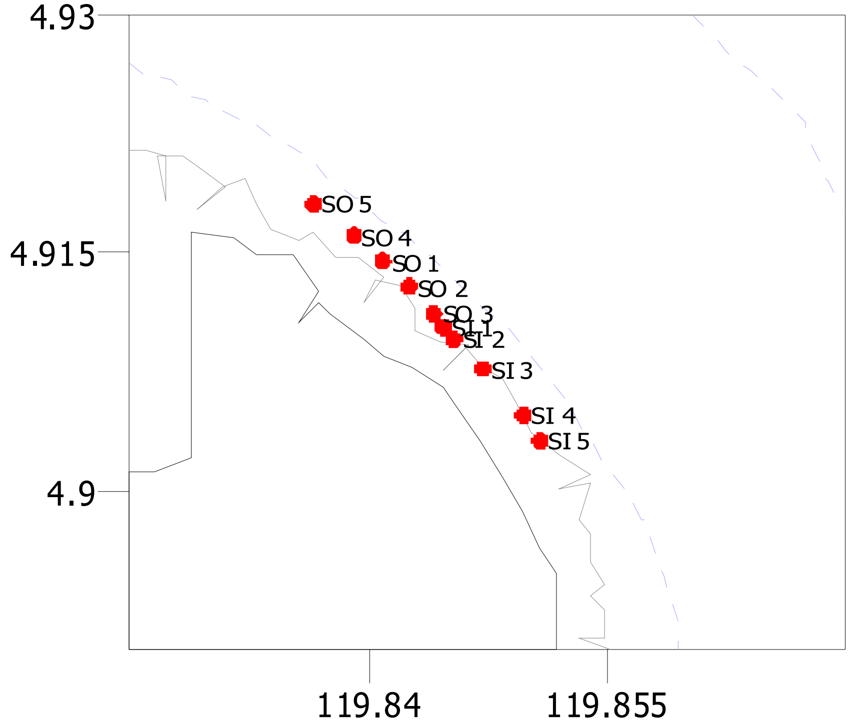


Figure 2b. Map showing location of stations in Simunul MPA surveyed in October 2006.

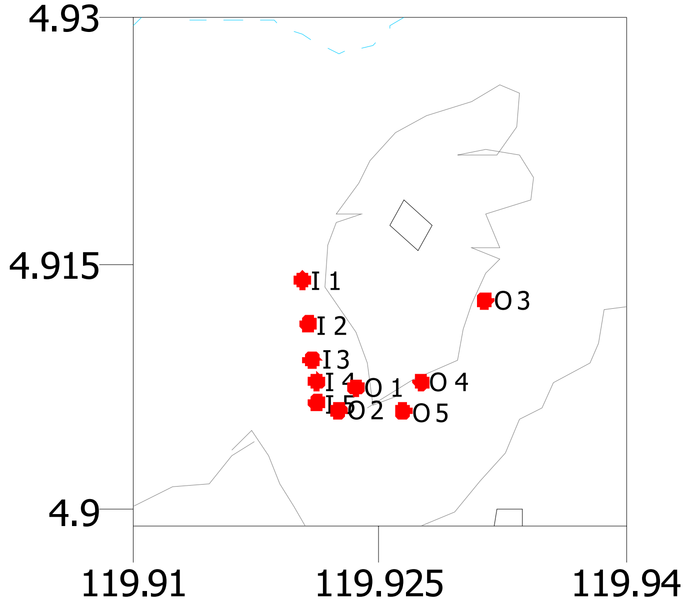


Figure 2c. Map showing location of stations in Tundon MPA surveyed in October 2006.

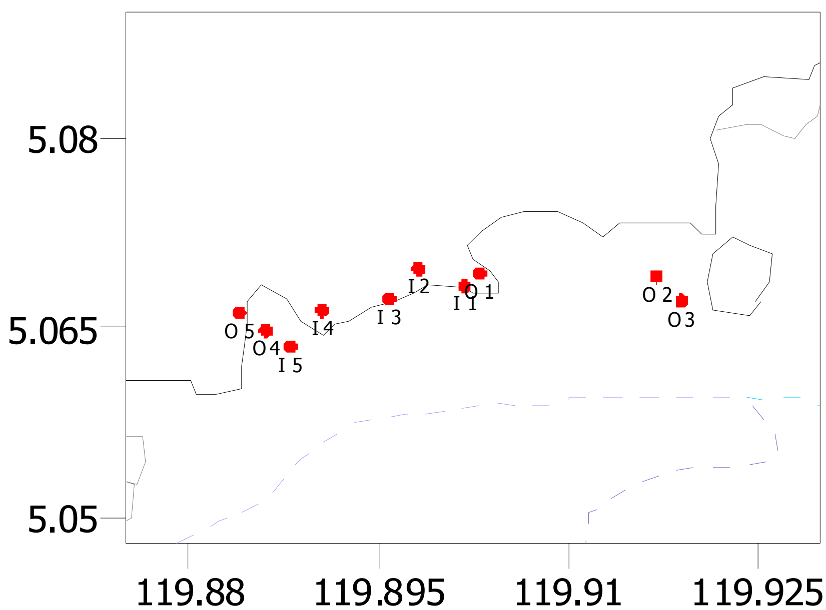


Figure 2d. Map showing location of stations in Panglima Sugala MPA surveyed in October 2006.

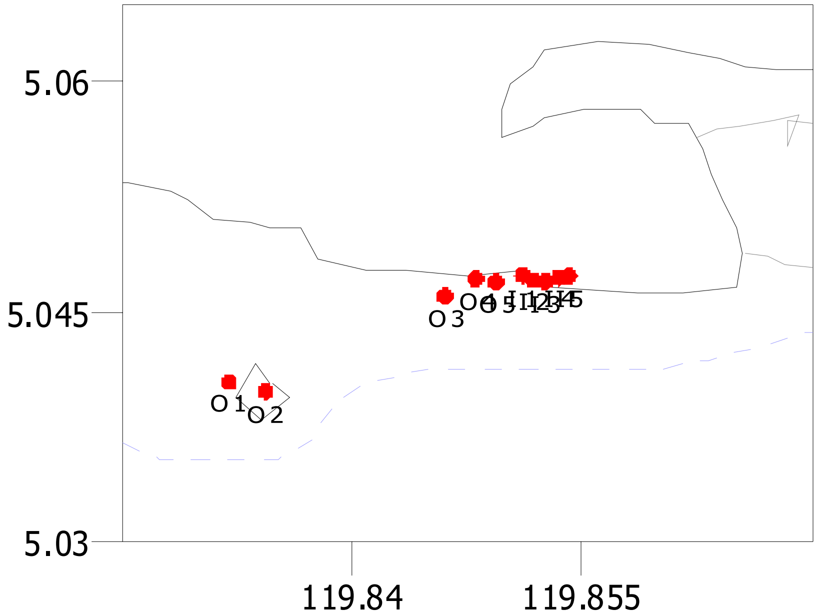


Figure 2e. Map showing location of stations in Ungos-ungos MPA surveyed in October 2006.

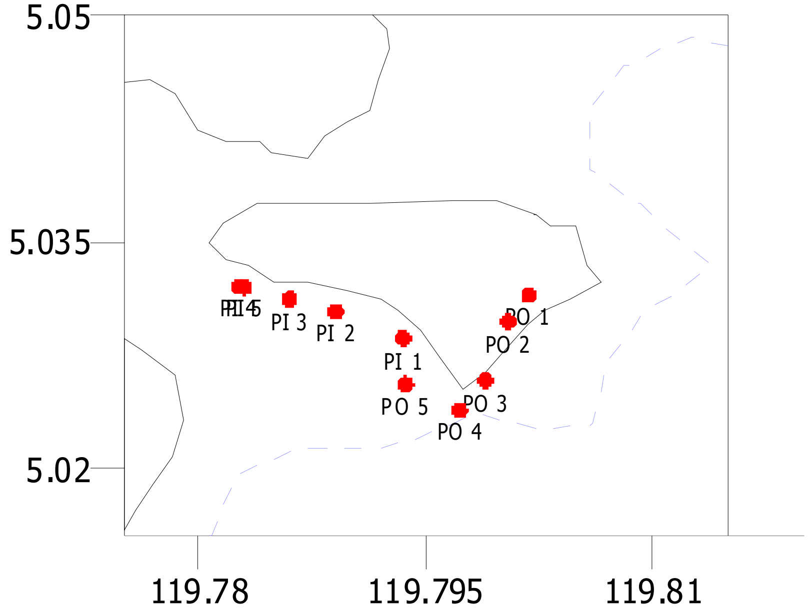


Figure 2f. Map showing location of stations in Pababag MPA surveyed in October 2006.

Table 1a. Coordinates and physical habitat characteristics in each dive station surveyed in October 17-26, 2006 in Tawi-Tawi.

Station	North	East	Slope Depth (ft)	Slope (scaled)	Visibility (m)	Temp (^{0}C)	Mean Rugosity	Physical Relief
Ubol (inside)								
UBI 1	4.92577	119.82391	88	3.0	25	28.0	1.60	423.0
UBI 2	4.92660	119.82140	60	5.5	25	27.5	1.67	551.2
UBI 3	4.92713	119.81937	58	3.0	40	28.0	1.38	240.8
UBI 4	4.92735	119.81799	50	2.5	40	27.0	1.54	193.0
UBI 5	4.92754	119.81605	55	5.0	25	27.5	1.44	395.7
n			5	5	5	5	5	5
mean			62.2	3.8	31.0	27.6	1.5	360.7
sd			14.9	1.4	8.2	0.4	0.1	144.8
Ubol (outside)								
UBO 1	4.92779	119.81167	60	5.0	20	27.5	1.68	503.2
UBO 2	4.92802	119.80868	55	2.5	30	28.0	1.22	168.0
UBO 3	4.92801	119.80764	25	2.5	25	28.0	1.38	86.1
UBO 4	4.92795	119.80438	30	1.5	30	28.0	1.33	60.1
UBO 5	4.92791	119.80312	40	2.5	25	28.0	1.46	146.3
n			5	5	5	5	5	5
mean			42.0	2.8	26.0	27.9	1.4	192.7
sd			15.2	1.3	4.2	0.2	0.2	178.9
Ubol (combined)								
n			10	10	10	10	10	10
mean			52.1	3.3	28.5	27.8	1.5	276.7
sd			17.8	1.4	6.7	0.4	0.2	177.2
Simunul (inside)								
SI 1	4.91030	119.84468	100	5.0	10	27.5	1.47	733.0
SI 2	4.90956	119.84536	60	3.5	10	28.0	1.72	362
SI 3	4.90770	119.84718	100	3.0	10	28.0	1.22	365.1
SI 4	4.90476	119.84973	100	5.5	12.5	27.5	1.62	890.3
SI 5	4.90314	119.85079	60	4.0	15	28.0	1.92	461.0
n			5	5	5	5	5	5
mean			84.0	4.2	11.5	27.8	1.6	562.3
sd			21.9	1.0	2.2	0.3	0.3	237.7
Simunul (outside)								
SO 1	4.91447	119.84087	60	3.0	20	27.5		
SO 2	4.91287	119.84252	60	3.0	20	28.0	1.33	239.4
SO 3	4.91116	119.84408	60	2.5	20	28.0	1.32	197.5
SO 4	4.91608	119.83908	75	5.5	20	27.5	1.43	590.6
SO 5	4.91806	119.83653	75	5.0	25	27.5	1.42	532.0
n			5	5	5	5	4	4
mean			66.0	3.8	21.0	27.7	1.4	389.9
sd			8.2	1.4	2.2	0.3	0.1	200.1
Simunul (combined)								
n			10	10	10	10	9	9
mean			75.0	4.0	16.3	27.8	1.5	485.7
sd			18.3	1.2	5.4	0.3	0.2	227.0

Table 1a. Con't

Station	North	East	Slope Depth (ft)	Slope (scaled)	Visibility (m)	Temp (^0C)	Mean Rugosity	Physical Relief
Tundon (inside)								
TDI 1	4.91404	119.92031		1.0	6.5	28.0	1.21	
TDI 2	4.91136	119.92070	40	1.0	15	29.0	1.62	64.9
TDI 3	4.90920	119.92090	38	1.0	10	29.0	1.54	58.5
TDI 4	4.90786	119.92120	35	2.5	20	27.0	1.64	143.8
TDI 5	4.90656	119.92122		1.0	5.5	28.0	1.32	
n			3	5	5	5	5	3
mean			37.7	1.3	11.4	28.2	1.5	89.1
sd			2.5	0.7	6.1	0.8	0.2	47.5
Tundon (outside)								
TDO 1	4.90749	119.92358	25	2.0	20	27.5	1.10	55
TDO 2	4.90608	119.92249	15	1.0	15	28.0	1.15	17.2
TDO 3	4.91280	119.93141	20	1.0	15	28.0	1.22	24.5
TDO 4	4.90783	119.92758	38	1.0	20	28.0	1.18	44.7
TDO 5	4.90603	119.92642	40	1.0	25	28.0	1.17	46.7
n			5	5	5	5	5	5
mean			27.6	1.2	19.0	27.9	1.2	37.6
sd			11.0	0.4	4.2	0.2	0.0	16.0
Tundon (combined)								
n			8	10	10	10	10	8
mean			31.4	1.3	15.2	28.1	1.3	56.9
sd			9.9	0.5	6.3	0.6	0.2	38.7
Panglima Sugala (inside)								
PSI 1	5.06831	119.90183	60	1.0	10	29.0	1.86	111.4
PSI 2	5.06968	119.89817	60	1.0	10	29.5	2.10	125.9
PSI 3	5.06730	119.89584	25	2.5	15	27.5	1.93	120.7
PSI 4	5.06636	119.89055	30	2.5	15	27.5	2.08	156.1
PSI 5	5.06352	119.88802		1.0	6	28.0	1.04	0.0
n			4	5	5	5	5	5
mean			43.8	1.6	11.2	28.3	1.8	102.8
sd			18.9	0.8	3.8	0.9	0.4	59.9
Panglima Sugala (outside)								
PSO 1	5.06931	119.90298	60	1.0	10	29.0	2.03	121.9
PSO 2	5.06906	119.91699	25	2.5	15	28.0	1.82	113.8
PSO 3	5.06716	119.91898		1.0	7	28.0	1.52	
PSO 4	5.06480	119.88611		1.0	5.5	28.0	1.13	
PSO 5	5.06619	119.88399	60	1.0	8	29.0	1.38	83.0
n			3	5	5	5	5	3
mean			48.3	1.3	9.1	28.4	1.6	106.2
sd			20.2	0.7	3.7	0.5	0.4	20.5
Panglima Sugala (combined)								
n			7	10	10	10	10	8
mean			45.7	1.5	10.2	28.4	1.7	104.1
sd			17.9	0.7	3.7	0.7	0.4	46.6

Table 1a. Con't

Station	North	East	Slope Depth (ft)	Slope (scaled)	Visibility (m)	Temp (^0C)	Mean Rugosity	Physical Relief
Ungos-ungos (inside)								
UGI 1	5.04741	119.85110	20	1	10	27.5	1.24	24.8
UGI 2	5.04706	119.85182	18	1	7	27.0	2.09	37.6
UGI 3	5.04701	119.85257	60	1	25	28.0	1.97	118.3
UGI 4	5.04724	119.85347	60	1		28.0	3.28	196.8
UGI 5	5.04735	119.85412	50	1	15	27.0	1.43	71.6
n			5	5	4	5	5	5
mean			41.6	1.0	14.3	27.5	2.0	89.8
sd			21.0	0.0	7.9	0.5	0.8	69.9
Ungos-ungos (outside)								
UGO 1	5.04044	119.83194	75	1	20	29.0	1.19	89.3
UGO 2	5.03984	119.83435	20	1	8	27.5	1.13	22.6
UGO 3	5.04604	119.84604	20	1	8	27.5	1.38	27.6
UGO 4	5.04716	119.84804	65	1	20	28.0	1.42	92.1
UGO 5	5.04696	119.84936	50	1	20	29.0	1.31	65.4
n			5	5	5	5	5	5
mean			46.0	1.0	15.2	28.2	1.3	59.4
sd			25.3	0.0	6.6	0.8	0.1	33.0
Ungos-ungos (combined)								
n			10	10	9	10	10	10
mean			43.8	1.0	14.8	27.9	1.6	74.6
sd			22.1	0.0	6.7	0.7	0.7	54.0
Pababag (inside)								
PI 1	5.02863	119.79351		1	8	28.0	1.31	
PI 2	5.03038	119.78904	55	1	17.5	28.0	1.45	79.8
PI 3	5.03122	119.78602	25	2	15	27.5	1.47	73.5
PI 4	5.03204	119.78265		2	6	28.0	1.32	
PI 5	5.03202	119.78302	55	2	17.5	28.0	1.40	153.8
n			3	5	5	5	5	3
mean			45.0	1.6	12.8	27.9	1.4	102.4
sd			17.3	0.5	5.4	0.2	0.1	44.7
Pababag (outside)								
PO 1	5.03148	119.80182	50	1.5	15	29.0	1.57	117.8
PO 2	5.02974	119.80045	55	1	15	28.0	0.92	50.5
PO 3	5.02584	119.79893		1	6.5	28.0	1.38	
PO 4	5.02385	119.79723	20	1	10	27.0	1.34	26.8
PO 5	5.02559	119.79367	20	1	10	27.0	1.79	35.9
n			4	5	5	5	5	4
mean			36.3	1.1	11.3	27.8	1.4	57.7
sd			18.9	0.2	3.7	0.8	0.3	41.2
Pababag (combined)								
n			7	10	10	10	10	7
mean			40.0	1.4	12.1	27.9	1.4	76.9
sd			17.3	0.5	4.4	0.6	0.2	45.6

Fish Visual Census

Reef fish assemblages were surveyed using a modification of the standard visual census technique described by English et al. (1994). A 50m transect line was set parallel to depth contours along the reef slope. All fish, including juveniles (FL < 2cm), encountered within 5m of both (slope & crest) sides of the line were identified, counted, and their sizes (fork lengths) estimated to the nearest centimeter. The surface area covered in each fish census (dive) was thus 50m x 5m x 2 = 500m^2.

Macroinvertebrate Survey

Along the same transect, all motile epibenthic macroinvertebrates (e.g.,crustaceans, echinoderms, mollusks), including sessile tunicates and polychaetes, within 1m of both sides of the transect line were identified and counted. The surface area covered for macroinvertebrates was thus 50m x 2m = 100m^2.

Reef Substrate Characterization

Benthic life form cover was determined using the line intercept technique (English et al., 1994), wherein all lifeforms intercepted by the transect line are recorded. The data were then summarized in the following categories: Live hard coral (LHC), live soft coral (LSC), dead coral & coral rubble (Dead), dead coral with algae (DCA), algae on substrate other than dead coral/rubble (Algae), other sessile fauna (Other fauna), and rock/mud/sand/water (Abiotics).

Substrate rugosity was measured by recording the length of the transect line covered by an underlying ~3m segment of chain laid to follow the substrate's (surface) contour. Rugosity measurements were done every 5m, and the rugosity index is computed as the ratio of the length of the chain over the linear distance covered by laying the said chain. In addition, other characteristics such as depth (of transect and of reef bottom, in ft), steepness of slope (degrees), water visibility (m), and general reef typology in each dive station were noted down.

Slope steepness in degrees was further converted to a scale from 1-6, with a 15^o interval between points. A composite factor called "habitat complexity" was computed as the product of rugosity, bottom depth of the reef slope (ft) and slope steepness scale and used to characterize each station.

Density and Biomass

Fish density is reported as individuals per m^2. Fish biomass was derived using size estimates (FL) from the surveys and length-weight conversions of the form $W = aL^b$. The species-specific parameters a & b of such conversions are available from various references. Adjustments for lengths were made whenever available conversions pertained to total or standard lengths. Biomass estimates are presented as g/m^2 (= mt/km^2) and kg/500m^2. Abundance is presented as ind/500m^2. Fish families were also grouped into target, indicator and common fish. Target fish follows the description of English et al. (1994) and includes the families Acanthuridae, Haemulidae, Lethrinidae, Lutjanidae, Serranidae (Epinephelinae + *Diploprion)* and Siganidae. Because of their local commercial importance, information for caesionids, carangids and scarids are also presented separately. Chaetodontidae were used as indicators, while pomacentrids and labrids made up the common fish.

Data Analysis

The Line Intercept Transect (LIT) data was analyzed using indices formulated by various authors. For the Mortality Index, two formulae were used and these were based on Gomez et al. (1994) and by Ben-Tzvi et al. (2004). The recruitment index and the deterioration index were based on Ben-Tzvi et al. (2004). Three more indices (Development Index, Condition Index, and Succession Index (Manthachitra, 1994)) were also computed. In order to avoid the problem of no recruitment/algae/ot/dc/sc in the transects (recruits /algae/ ot/dc/sc = 0), a very small value (0.00012) was used instead. This substituted value is actually 1/5 of the actual lowest value recorded in the focal area during the survey in October 2006. By doing so, it was possible to calculate mean indices for sites where one or more of the transects possess recruits/algae/ot/dc/sc = 0.

The indices and their formulae are described as follows:

Mortality Index 1 (MI; Ben-Tzvi et al., 2004) is estimated as the proportion of dead coral cover from the sum of dead and live coral cover, both hard and soft.

$$MI\ 1 = \frac{DC}{DC + LC}$$

where,

DC = dead coral (includes dead coral with algae)
LC = live coral (hard & soft)

Mortality Index 2 (MI; Gomez et al., 1994) is estimated as the proportion of dead coral cover from the sum of dead and live hard coral cover.

$$MI\ 2 = \frac{DC}{DC + LHC}$$

where,

DC = dead coral (includes dead coral with algae)
LHC = live hard coral

Recruitment Index (RI) is represented by the proportion of small colonies, up to 2.5cm in diameter, from all living corals.

$$RI = \frac{\%\ \text{cover of recruit}}{LC}$$

(using the same abbreviation as for MI)

Deterioration Index (DI) is indicative of the state of "health" of the examined coral reef. The idea is to examine the dynamics of the reef by comparing two of its major processes, the recruitment and the mortality of corals. It is simply the ratio between mortality index and recruitment index. The formula is as follows:

$$DI = \frac{MI\ 1}{RI}$$

where,

MI 1– Mortality Index
RI – Recruitment Index

Development Index (Dev. I) was computed following Manthachitra (1994). This index was used to indicate the degree of coral-reef assemblage development. For the LIT data, live coral, dead coral, algae and other fauna represent the Coral Related Component (CRC), while abiotics (rock, sand, mud or water) represent the Abiotic Related Component (ARC). The formula is as follows:

Dev. I = log (CRC/ARC)

or

Dev. I = log [(LC + DC + Algae + OT) / Abiotics]

where,

LC = percentage area cover of live coral category
DC = percentage area cover of dead coral category
Algae = percentage area cover of algae category
OT = percentage area cover of other fauna category
Abiotics = percentage area cover of abiotics category

However, this index requires that algae and other fauna be included in CRC only when they colonize on a coral component (live or dead). They are excluded from the CRC and are included in the abiotic related component (ARC) when they colonize an abiotic component. For the LIT data, percentage area cover for Algae and OT was divided into Algae/OT CRC and Algae/OT ARC. The formulae are as follows:

Algae/OT ARC = Total Fish Algae/OT x % Abiotics

and

Algae/OT CRC = Total Fish Algae/OT – (Total Fish Algae/OT x % Abiotics)

Condition Index (CI) is used to characterize the condition of the coral assemblage. The formulation of CI is derived from the coral related component (CRC) by using the proportion between live coral and dead coral related component (DRC). The formula is as follows:

CI = log (LC/DRC)

or

CI = log [LC/(DC + Algae + OT)]

(using the same abbreviation as for Dev. I)

Succession Index (SI) is used to indicate the level of succession occurring on the reef. The term "succession" means the sequential changes in the benthic community occurring on dead coral. This index is based on the DRC only. There are three major categories (dead coral, algae, and other fauna) used in the DRC, of which algae and other fauna represent different stages of succession. Hence, the SI can be separated into two minor indices, SI 1 as succession by algae and SI 2 as succession by other fauna. The formulae of both indices are as follows:

$$SI\ 1 = \log [Algae/(DC + OT)]$$

and

$$SI\ 2 = \log [OT/(DC + Algae)]$$

(using the same abbreviation as for Dev. I)

Results and Discussion

Physical reef characteristics

Measurements of physical characteristics of the reef are shown in Table 1a, and average values are summarized in Table 1b. Average temperatures on the reef sites ranged from 27.9 – 28.4 ^{o}C.

In all six sites, water clarity was highest in Ubol, with a range of 26 – 31m while visibility was lowest in Panglima Sugala (mean = 10.2m). On the average, overall visibility in all six sites is comparable with many other reef areas in the country.

Table 1b. Average measurements of physical characteristics inside and outside of MPAs in the six (6) sites surveyed in Tawi-Tawi in October 17-26, 2006.

Reef Site	Depth (ft)	Slope (scaled)	Visibility (m)	Temp (^{o}C)	Mean Rugosity	Physical Relief
Ubol (inside)	62.2	3.8	31	27.6	1.5	360.7
Ubol (outside)	42	2.8	26	27.9	1.4	192.7
Ubol (combined)	52.1	3.3	28.5	27.8	1.5	276.7
Simunul (inside)	84	4.2	11.5	27.8	1.6	562.3
Simunul (outside)	66	3.8	21	27.7	1.4	389.9
Simunul (combined)	75	4	16.3	27.8	1.5	485.7
Tundon (inside)	37.7	1.3	11.4	28.2	1.5	89.1
Tundon (outside)	27.6	1.2	19	27.9	1.2	37.6
Tundon (combined)	31.4	1.3	15.2	28.1	1.3	56.9
Panglima Sugala (inside)	43.8	1.6	11.2	28.3	1.8	102.8
Panglima Sugala (outside)	48.3	1.3	9.1	28.4	1.6	106.2
Panglima Sugala (combined)	45.7	1.45	10.15	28.35	1.7	104.1
Ungos-ungos (inside)	41.6	1	14.3	27.5	2	89.8
Ungos-unogs (outside)	46	1	15.2	28.2	1.3	59.4
Ungos-ungos (combined)	43.8	1	14.8	27.9	1.6	74.6
Pababag (inside)	45	1.6	12.8	27.9	1.4	102.4
Pababag (outside)	36.3	1.1	11.3	27.8	1.4	57.7
Pababag (combined)	40	1.4	12.1	27.9	1.4	76.9

A composite factor called "physical relief" was computed as the product of depth of the slope bottom, reef slope inclination (scaled) and rugosity, and mean values are shown in Table 1b. Overall mean values for rugosity did not vary much across all sites (mean = 1.3 – 1.7) (Fig. 3). Among the factors used to derive physical relief, slope bottom depth has the greatest contribution. Together with a steep slope, a wider (i.e., deeper bottom) reef slope translates to a larger change in habitat conditions per unit distance across the slope, and to a higher habitat diversity per surface of substrate. This is so since the faster change in depth leads to corresponding changes in life forms, hence a wider range of habitats. On average, physical relief was lowest in Tundon (56.9), where slope bottom depth and steepness were also low, while Panglima Sugala, Ungos-ungos and Pababag did not show much higher values. High physical relief was observed in Ubol (276.7) and Simunul (485.7). Small scale habitat complexity, as indicated by rugosity, was similar among all 6 sites (Table 1b). Slope steepness showed the biggest difference in habitat structure among the different sites.

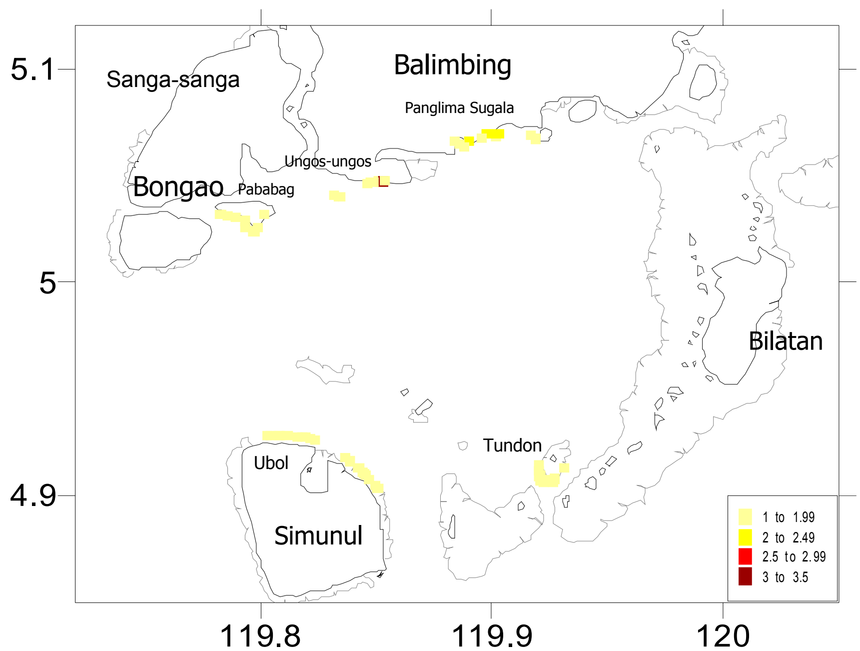


Figure 3. The distribution of rugosity in the study area, Tawi-tawi, in October 2006.

Reef Corals

Live hard coral cover was highest in Panglima Sugala, with an overall mean of 39.3% (Table 2), while the lowest value was observed in Tundon (mean= 12.9%) (Fig. 4). The overall mean live hard coral cover across all 60 stations (29.6%) was low compared to those observed in the other focal areas, although this value is within the range of what is considered as fair reef health. All of the stations in Tundon, however, are considered in poor health (mean LHC = 7.8 – 17.9%).

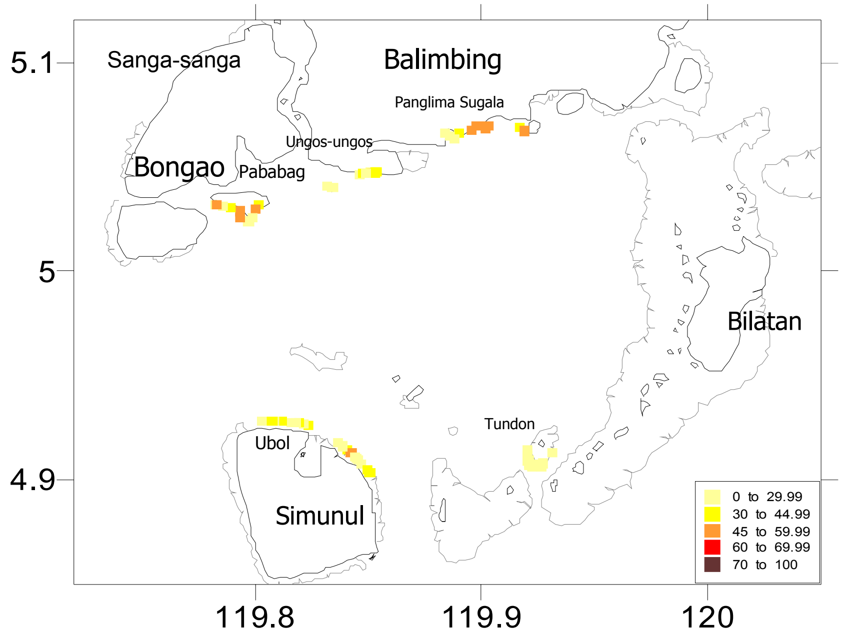


Figure 4. The distribution of live hard coral cover (via LIT) in the study area, Tawi-tawi, in October 2006.

Average dead coral cover (including coral rubble) ranged from 0.3-15.2% across the different sites, with an overall mean value of 7.5% (Table 2). Dead coral with algae (DCA) on the other hand, showed an overall mean of 13.4%. If macroalgal cover (algae only) were included with DCA, the highest observed value would be in Panglima Sugala (Fig. 5).

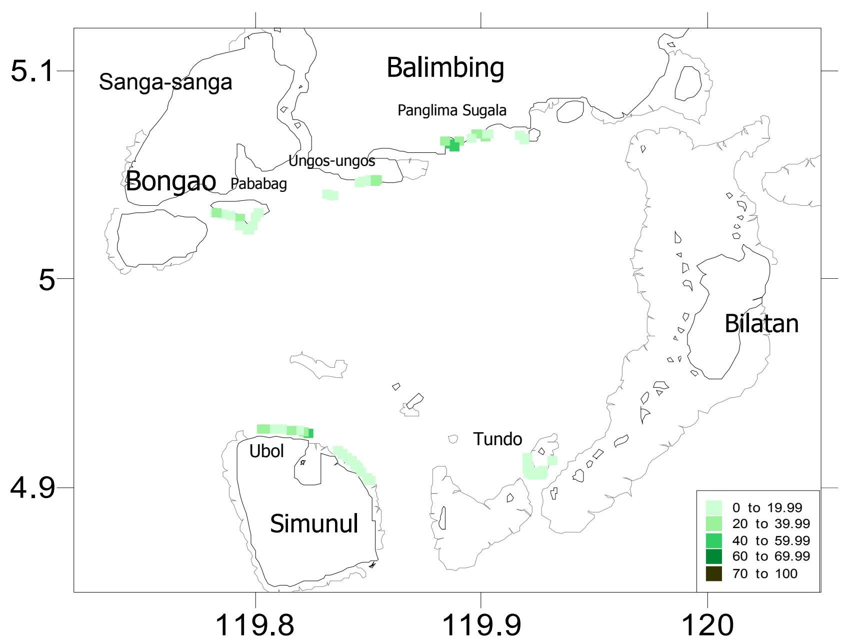


Figure 5. The distribution of total algal cover (including DCA) in the study area, Tawi-tawi, in October 2006.

Table 2. Summary of benthic cover and reef habitat indices for stations inside and outside of MPA boundaries in the six sites surveyed in Tawi-Tawi in October 17-26, 2006. See text for explanations of abbreviations and indices.

	LHC	LSC	Algae	DCA	Dead	Other fauna	Abiot	Mort. 1	Mort. 2	Rec.	Det.	Dev.	Cond.	Succ. 1	Succ. 2
Ubol															
inside	29.9	17.0	0.1	23.6	14.2	3.7	11.4	0.4	0.6	-	-	1.1	0.1	0.13	-1.2
outside	28.8	26.1	1.1	12.1	16.1	3.0	12.7	0.3	0.5	-	-	0.8	0.3	-0.5	-1.5
combined	29.3	21.6	0.6	17.9	15.2	3.4	12.1	0.4	0.5	-	-	1.0	0.2	-0.2	-1.3
Simunul															
inside	26.5	13.6	1.51	3.4	17.4	5.8	31.9	0.3	0.4	-	-	0.3	0.4	-1.06	-1.1
outside	33.1	12.2	0.10	3.4	11.4	8.7	31.2	0.3	0.3	-	-	0.3	0.5	-0.9	-1.2
combined	29.8	12.9	0.81	3.4	14.4	7.2	31.5	0.3	0.4	-	-	0.3	0.4	-1.0	-1.2
Tundon															
inside	17.9	31.4	0.0	2.3	6.2	3.7	38.4	0.1	0.3	0.0005	355.6	0.2	1.30	-1.0	0.04
outside	7.8	24.1	0.09	1.7	6.2	7.7	52.3	0.2	0.3	0.0004	416.8	-0.1	0.91	-0.7	-0.02
combined	12.9	27.8	0.04	2.0	6.2	5.7	45.4	0.1	0.3	0.0004	386.2	0.03	1.10	-0.8	0.01
Panglima Sugala															
inside	41.4	2.2	1.1	31.9	8.9	7.8	6.8	0.5	0.5	0.0008	1376.7	2.0	-0.04	0.3	-0.7
outside	37.3	3.3	0.4	25.4	4.4	8.9	20.2	0.4	0.4	0.0004	1095.4	1.0	0.1	0.4	-0.8
combined	39.3	2.7	0.7	28.7	6.7	8.4	13.5	0.5	0.5	0.0006	1236.1	1.5	0.03	0.4	-0.8
Ungos-ungos															
inside	37.7	4.0	0.012	22.7	0	10.7	24.8	0.4	0.4	-	-	0.4	0.2	0.5	-0.5
outside	21.5	18.4	0.0	8.4	0.52	3.9	47.2	0.2	0.3	-	-	-0.1	0.8	0.3	-0.4
combined	29.6	11.2	0.006	15.6	0.26	7.3	36.0	0.3	0.3	-	-	0.2	0.5	0.4	-0.5
Pababag															
inside	37.4	6.6	0.02	18.5	2.5	4.10	30.9	0.3	0.3	0.0005	822.0	0.5	0.5	0.5	-1.0
outside	36.1	19.7	0.0	7.6	2.3	7.80	26.5	0.1	0.2	0.0002	621.8	0.5	0.8	0.2	-0.6
combined	36.8	13.1	0.01	13.0	2.4	5.95	28.7	0.2	0.3	0.0004	721.9	0.5	0.8	0.2	-0.6
All stns combined	29.6	14.9	0.4	13.4	7.5	6.3	27.9	0.3	0.4	-	-	0.6	0.5	-0.2	-0.7

Coral mortality index was highest in Panglima Sugala and Ubol (Table 2) where dead coral (with and without algae) cover was also highest. Coral recruits, with ≤ 2.5cm colony diameter, were observed only in Tundon, Panglima Sugala and Pababag and represented on average only 0.004% of all living corals in the sites surveyed. This value is about 30X less than what was recorded in Surigao del Sur in the same year, and from 5-8X less than estimates in the Calamianes and Bohol.

The development index is basically a ratio of biotic over abiotic cover, and showed a range of -0.1– 1.5 across the six sites. The lowest value (negative) for this index was observed in Tundon and Ungos-ungos. The condition index, on the other hand, is a measure of the ratio of live coral-related reef assemblages to those related to dead coral (i.e., DCA, abiotics & other fauna). All sites showed low values (< 0) for this index except Tundon (mean = 1.1) where dead coral with algae cover was also lowest (Table 2). Algal succession (Succ 1) was lowest in Simunul, while Succ 2 index was highest (positive value) in Tundon. The comparison of coral population indices in the 6 sites is shown in Figure 6.

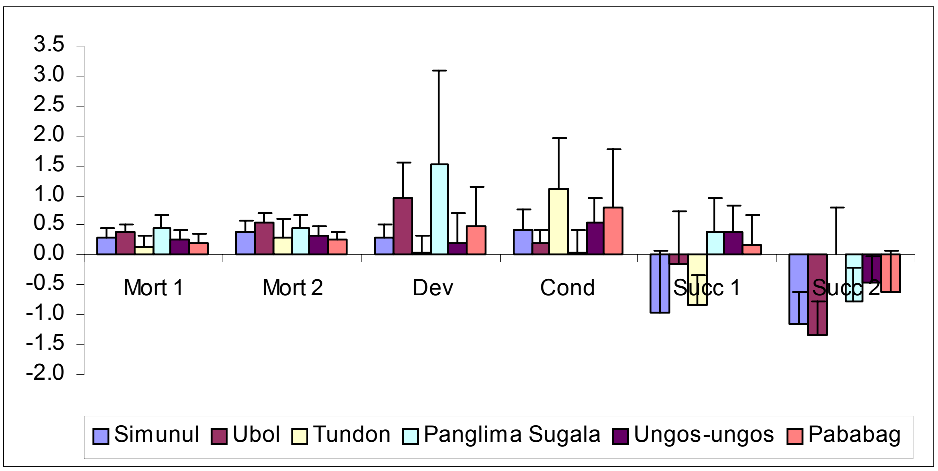


Figure 6. Comparison of coral population indices in the 6 sites in Tawi-Tawi, October 2006. The error bars represent 1 sd from the mean.

Reef associated macroepifauna

The abundances of reef associated macroepifauna in the six sites surveyed are summarized in Table 3. Overall mean abundance was 5193 ind/500m^2. Highest mean abundance was recorded in Simunul (Table 3), while abundance was consistently high in Ubol and Tundon, and consistently moderate in Pababag and Panglima Sugala (Figure 7). Lowest mean abundance was recorded in Ungos-ungos (< 1500 ind/500m^2). About 80% of all macroepifauna recorded was comprised of tunicates and echinoids (sea urchins). The remaining 20% consisted mainly of ophiuroids, bivalves, gastropods and asteroids.

The number of macroepifaunal species recorded in each site (10 stations X 100m^2 surveyed) ranged from 49 in Ubol to 63 in Pababag (Table 4). All in all, a total of 120 species were recorded in all six sites. This is comparable with those recorded in the other focal areas. These were dominated by tunicates, followed by bivalves and gastropods. Giant clams (Tridacnids) showed an overall mean abundance of 3.8 ind/500m^2, ranging from 2 in Simunul, Panglima Sugala and Pababag to 13 in Tundon. A total of two (2) species were recorded from the various sites surveyed.

Table 3. Summary of mean abundance (ind/500m^2) and relative abundance (%) of the various macroepifaunal groups in the 6 sites surveyed, and in all sites combined, in Tawi-Tawi in October 17-26, 2006.

	Ubol		**Simunul**		**Tundon**		**Panglima Sugala**		**Ungos-ungos**		**Pababag**		**All 6 sites**	
Taxa	**Mean Abund**	**%**	**Mean Abund**	**%**	**Mean Abund**	**%**	**Mean Abund**	**%**	**Mean Abund**	**%**	**Mean Abund**	**%**	**Mean Abund**	**%**
Tunicates	3171	44.1	3252	38.0	3840.5	60.8	2707	91.3	442	30.3	3428	73.3	2807	54.05
Scyphozoans	2	0.03	0	0	0	0	0	0	0	0	0	0	0	0.01
Cephalopods	0	0	0	0	0.5	0.008	1	0	0	0	0	0	0	0.003
Bivalves	13	0.2	35	0.4	361.5	5.7	90	3.0	497	34.0	340	7.3	223	4.3
Crustaceans	10	0.1	6	0.1	6.5	0.1	1	0	4.5	0.3	0	0	5	0.1
Tridacnids	3	0.0	2	0	13	0.2	2	0	2.5	0.2	2	0	3.8	0.1
Asteroids	228	3.2	339	4.0	172.5	2.7	11	0.4	114.5	7.8	75	1.6	157	3.02
Holothuroids	44	0.6	5	0.1	0	0	8	0	1	0.1	5	0	10	0.2
Echinoids	2575	35.8	4355	50.9	946	15.0	14	0.5	228	15.6	445	9.5	1427	27.5
Ophiuroids	495	6.9	452	5.3	489.5	7.7	55	1.9	58.5	4.0	208	4.4	293	5.6
Gastropods	598	8.3	55	0.6	389.5	6.2	46	1.6	48	3.3	17	0.4	192	3.7
Nudibranchs	2	0	1	0	0	0	7	0	0	0	3	0	2	0.04
Polychaetes	48	0.7	50	0.6	100.5	1.6	26	0.9	65	4.4	152	3.3	74	1.4
Sum	7189	100	8550	100	6320	100	2965	100	1461	100	4674	100	5193	100

Table 4. Summary of the number of species (in $100m^2$ area surveyed) of the various macro-epifaunal groups in the 6 sites surveyed in Tawi-Tawi in October 17-26, 2006.

Taxa	Ubol	Simunul	Tundon	Panglima Sugala	Ungos-ungos	Pababag	All 6 sites
Tunicates	8	11	12	17	13	14	24
Scyphozoans	1	0	0	0	0	0	1
Cephalopods	0	0	1	1	0	0	1
Bivalves	3	5	16	13	17	17	22
Crustaceans	1	3	5	1	4	0	13
Tridacnids	2	2	2	1	1	1	2
Asteroids	6	9	6	6	6	9	13
Holothuroids	2	2	0	4	2	1	4
Echinoids	6	6	7	4	8	6	9
Ophiuroids	2	2	2	1	4	2	3
Gastropods	12	13	6	5	3	8	18
Nudibranchs	4	1	0	2	0	2	4
Polychaetes	2	2	1	3	2	3	6
Sum	49	56	58	58	60	63	120

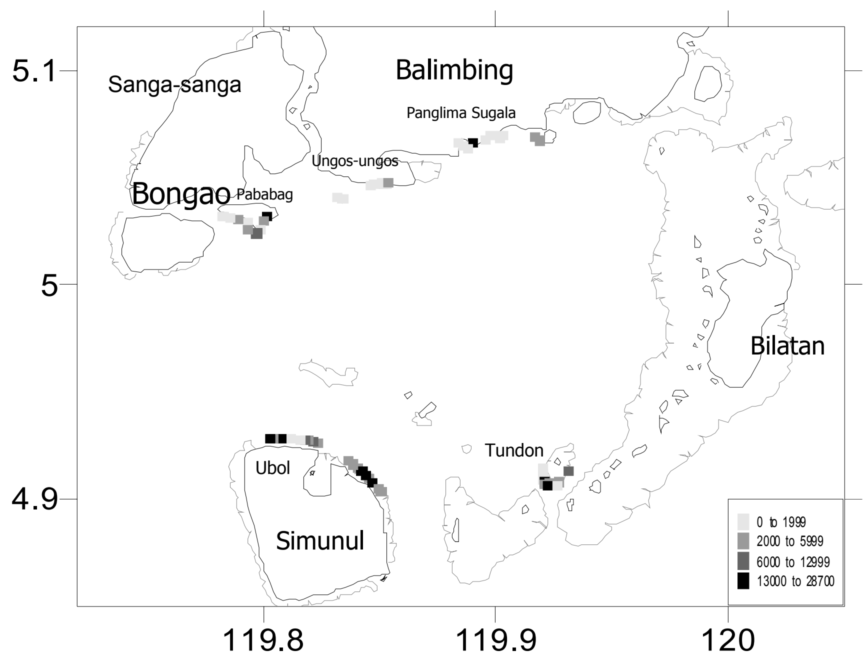


Figure 7. The distribution of macroepifaunal abundance ($ind/500m^2$) in the study area, Tawi-tawi, in October 2006.

Reef fish

Abundance, biomass, density and other characteristics of the assemblages of reef fish in the focal area are summarized in Table 5. Overall mean fish abundance in the six sites ranged from 602 in Tundon to 1411 ind/500m^2 in Ubol. Most of the stations had relatively high concentrations (> 1000 ind/500m^2) except in Tundon where 7 out of 10 stations showed concentrations < 500 ind/500m^2 (Fig. 8). Highest fish abundance (2719 ind/500m^2) was recorded in Panglima Sugala (Table 5). Fish biomass was relatively high in Ubol, Simunul and Tundon (16.8-17.7 kg/500m^2) and lowest in Pababag (6.9 kg/500m^2) (Fig. 9). In all six sites, only Ubol showed consistently high fish abundance and biomass values (Figs. 8 & 9).

Overall mean values for juveniles ranged from 73.5 ind/500m^2 in Simunul to 232.8 ind/500m^2 in Tundon (Table 5). Stations with high juvenile fish abundances were rather patchily distributed in Ungos-ungos and Pababag and in the southern portion of Tundon (Fig. 10). Coral recruit densities were also highest in Tundon and Pababag but there were no recruits found in Ungos-ungos (Table 2). This may be related to simulated water circulation patterns in the area (Villanoy, 2006), which show a general southward drift from Bongao towards the channel east of Simunul Island throughout the year. Under this scenario, water movement would tend to converge in the vicinity of Simunul Channel, physically concentrating particles, including propagules perhaps, in the general vicinity where MPAs in Simunul and Tundon are located (Fig. 1). Dispersal modeling showed that particles from the vicinity of Bongao are moved towards the east then southwards following the northern (inner) contour of the Bilatan Island chain. After leaving via Simunul Channel, particles are then dispersed eastwards again, along the southern (outer) coast of the Bilatan Island chain. Under this scenario, the most likely sources of propagules would include much of the northern coast of Tawi-Tawi Bay, where reef conditions are comparatively better than along the inner coast of the Bilatan Island Chain. This is consistent with live hard coral cover observations in Pababag, Ungos-Ungos and Panglima Sugala, ranging from 29.6-39.3% being about 3X higher than in Tundon (Table 2), which typifies the inner portion of the Bilatan Island Chain.

Mean individual weight of fish is used in this study as an indicator of fish size. This value was highest in Tundon (33.2g/ind) and lowest in Ungos-ungos (7.7g/ind) (Fig. 11). The mean value in Tundon is actually very high compared with the other stations as well as those recorded in other focal areas. In this case, larger fish did not correspond with low juvenile fish abundance since both parameters were found to be highest in Tundon. On the other hand, small average size of fish in Ungos-ungos correspond closely with a preponderance of juveniles as well as small sized fish species. Based on average species composition of fish assemblages in the different sites pomacentrids, together with labrids, comprised 40.6 % of the total weight of all fish recorded in Ungos-ungos, albeit these groups made up 29.8-40% in the other five sites.

Mean species richness in fish ranged from 55 (species/500m^2 surveyed) in Tundon to 71 in Ubol (Fig. 12), but was not distributed similarly to that of live hard coral cover nor to a composite factor called "physical relief" which was derived to include factors that influence habitat complexity in various spatial scales. Although low species count in Tundon corresponded with very low live hard coral cover (12.9%) and physical relief (56.9), this was not found to be generally true with the other sites.

Table 5. Summary of reef fish abundance, biomass and diversity in the six sites surveyed in the Tawi-Tawi in October 17-26, 2006.

Station	no. spp	no. families	abundance (ind/500m²)	biomass (g/m²)	biomass2 (kg/500m²)	density (ind/m²)	mean ind wt (g)	Juv abun (ind/500m²)
Ubol (inside)								
UBI 1	66	14	1316	16.6	8.3	2.6	6.3	106
UBI 2	65	18	649	7.2	3.6	1.3	5.5	93
UBI 3	91	22	1315	32.4	16.2	2.6	12.3	154
UBI 4	53	16	1789	64.2	32.1	3.6	17.9	4
UBI 5	71	21	1644	11.2	5.6	3.3	3.4	226
n	5	5	5	5	5	5	5	5
mean	69.2	18.2	1342.6	26.3	13.2	2.7	9.1	116.6
sd	13.9	3.3	439.5	23.2	11.6	0.9	5.9	81.7
Ubol (outside)								
UBO 1	68	24	535	27.2	13.6	1	25.4	1
UBO 2	72	19	2381	26.7	13.4	5	5.6	154
UBO 3	71	19	1242	86.2	43.1	3	33	106
UBO 4	84	20	1865	40.2	20.1	4	10.8	90
UBO 5	66	23	1373	41.6	20.8	3	15.1	4
n	5	5	5	5	5	5	5	5
mean	72.2	21	1479.2	44.4	22.2	3	18	71
sd	7	2.3	693	24.4	12.2	1.4	11.1	66.8
Ubol (combined)								
n	10	10	10	10	10	10	10	10
mean	70.7	19.6	1410.9	35.3	17.7	2.8	13.5	93.8
sd	10.5	3.1	551.8	24.4	12.2	1.1	9.6	74.4
Simunul (inside)								
SI 1	64	25	666	25.6	12.8	1	19.2	37
SI 2	69	21	1293	39.6	19.8	3	15.3	111
SI 3	54	20	1325	112.7	56.3	3	42.5	5
SI 4	65	21	428	14.4	7.2	1	11.8	24
SI 5	57	18	1632	26.8	13.4	3	8.2	239
n	5	5	5	5	5	5	5	5
mean	61.8	21	1068.8	43.8	21.9	2.2	19.4	83.2
sd	6.1	2.5	501.5	39.5	19.8	0.9	13.6	95.9
Simunul (outside)								
SO 1	75	20	1706	26	13	3.4	7.6	190
SO 2	46	16	2326	55.4	27.7	4.7	11.9	0
SO 3	43	20	399	16.5	8.3	0.8	20.7	14
SO 4	65	22	586	13	6.5	1.2	10.5	73
SO 5	78	24	578	13.3	6.6	1.2	11.5	42
n	5	5	5	5	5	5	5	5
mean	61.4	20.4	1119	24.8	12.4	2.3	12.4	63.8
sd	16.2	3	851	17.9	8.9	1.7	4.9	75.9
Simunul (combined)								
n	10	10	10	10	10	10	10	10
mean	61.6	20.7	1093.9	34.3	17.2	2.2	15.9	73.5
sd	11.5	2.6	659	30.6	15.3	1.3	10.3	82.2

Table 5. Con't

Station	no. spp	no. families	abundance (ind/500m²)	biomass (g/m²)	biomass2 (kg/500m²)	density (ind/m²)	mean ind wt (g)	Juv abun (ind/500m²)
Tundon (inside)								
TDI 1	68	20	458	108.8	54.4	0.9	118.8	120
TDI 2	77	20	920	60.7	30.4	1.8	33.0	66
TDI 3	60	19	490	26.9	13.5	1	27.5	115
TDI 4	52	17	384	59.4	29.7	0.8	77.3	0
TDI 5	84	23	498	29.3	14.7	1.0	29.4	76
n	5	5	5	5	5	5	5	5
mean	68.2	19.8	550.0	57.0	28.5	1.1	57.2	75.4
sd	12.8	2.2	211.7	33.1	16.5	0.4	40.1	48.3
Tundon (outside)								
TDO 1	62	19	1849	12.6	6.3	3.7	3.4	1342
TDO 2	46	17	678	25.4	12.7	1.4	18.7	450
TDO 3	40	13	311	6.1	3.1	0.6	9.9	92
TDO 4	38	16	316	5.1	2.6	0.6	8.1	47
TDO 5	23	10	116	2.2	1.1	0.4	5.8	20
n	5	5	5	5	5	5	5	5
mean	41.8	15	654	10.3	5.1	1.3	9.2	390.2
sd	14.1	3.5	698.2	9.2	4.6	1.4	5.9	559.7
Tundon (combined)								
n	10	10	10	10	10	10	10	10
mean	55	17.4	602	33.7	16.8	1.2	33.2	232.8
sd	18.8	3.7	489.5	33.6	16.8	1	37	409.7
Panglima Sugala (inside)								
PSI 1	83	22	1140	33.5	16.8	2.3	14.7	30
PSI 2	67	18	832	35.5	17.7	1.7	21.3	155
PSI 3	55	15	2267	36.6	18.3	4.5	8.1	114
PSI 4	61	18	2719	65.7	32.8	5.4	12.1	52
PSI 5	63	18	1031	14.8	7.4	2.1	7.2	138
n	5	5	5	5	5	5	5	5
mean	65.8	18.2	1597.8	37.2	18.6	3.2	12.7	97.8
sd	10.5	2.5	840	18.2	9.1	1.7	5.7	54.4
Panglima Sugala (outside)								
PSO 1	55	17	830	9.1	4.6	1.7	5.5	44
PSO 2	51	16	2066	24.3	12.2	4.1	5.9	23
PSO 3	61	17	1023	15.2	7.6	2.0	7.5	163
PSO 4	52	14	914	9.7	4.8	1.8	5.3	162
PSO 5	39	13	524	7.8	3.9	1.0	7.5	111
n	5	5	5	5	5	5	5	5
mean	51.6	15.4	1071.4	13.2	6.6	2.1	6.3	100.6
sd	**8.0**	1.8	586.1	6.8	3.4	1.2	1.1	65.2
Panglima Sugala (combined)								
n	10	10	10	10	10	10	10	10
mean	58.7	16.8	1334.6	25.2	12.6	2.7	9.5	99.2
sd	11.6	2.5	737.1	18.1	9.1	1.5	5.1	56.6

Table 5. Con't

Station	no. spp	no. families	abundance (ind/500m²)	biomass (g/m²)	biomass2 (kg/500m²)	density (ind/m²)	mean ind wt (g)	Juv abun (ind/500m²)
Ungos-ungos (inside)								
UGI 1	57	17	1488	37.9	19.0	3.0	12.7	21
UGI 2	67	17	2590	44.1	22.0	5.2	8.5	55
UGI 3	88	21	1307	22.7	11.4	2.6	8.7	123
UGI 4	92	22	2347	38.9	19.5	4.7	8.3	422
UGI 5	63	19	1440	16.2	8.1	2.9	5.6	191
n	5	5	5	5	5	5	5	5
mean	73.4	19.2	1834.4	32.0	16.0	3.7	8.8	162.4
sd	15.6	2.3	588.9	11.9	5.9	1.2	2.6	159.1
Ungos-ungos (outside)								
UGO 1	69	22	847	8.0	4.0	1.7	4.7	281
UGO 2	56	18	1175	11.5	5.8	2.4	4.9	435
UGO 3	40	11	901	4.8	2.4	1.8	2.6	320
UGO 4	70	23	474	11.2	5.6	0.9	11.8	114
UGO 5	69	20	681	12.3	6.2	1.4	9.1	82
n	5	5	5	5	5	5	5	5
mean	60.8	18.8	815.6	9.6	4.8	1.6	6.6	246.4
sd	13.0	4.8	260.9	3.2	1.6	0.5	3.7	147.3
Ungos-ungos (combined)								
n	10	10	10	10	10	10	10	10
mean	67.1	19.0	1325.0	20.8	10.4	2.7	7.7	204.4
sd	15.1	3.5	687.5	14.4	7.2	1.4	3.2	151.2
Pababag (inside)								
PI 1	82	22	1199	17.1	8.6	2.4	7.1	279
PI 2	64	21	342	9.9	4.9	2.4	4.1	7
PI 3	43	13	650	10.1	5.1	1.3	7.8	54
PI 4	60	16	448	8.6	4.3	0.9	9.6	79
PI 5	79	22	640	13.8	6.9	1.3	10.8	19
n	5	5	5	5	5	5	5	5
mean	65.6	18.8	655.8	11.9	6.0	1.7	7.9	87.6
sd	15.8	4.1	330.5	3.5	1.8	0.7	2.6	110.7
Pababag (outside)								
PO 1	84	20	1456	13.7	6.8	2.9	4.7	197
PO 2	61	19	326	3.5	1.8	0.7	5.4	73
PO 3	55	18	430	11.5	5.7	0.9	13.3	66
PO 4	29	11	353	7.2	3.6	0.7	10.2	4
PO 5	79	20	1703	43.1	21.6	3.4	12.7	454
n	5	5	5	5	5	5	5	5
mean	61.6	17.6	853.6	15.8	7.9	1.7	9.3	158.8
sd	21.9	3.8	669.5	15.8	7.9	1.3	4.0	179.3
Pababag (combined)								
n	10	10	10	10	10	10	10	10
mean	63.6	18.2	754.7	13.9	6.9	1.7	8.6	123.2
sd	18.1	3.8	508.5	11.0	5.5	1.0	3.3	145.4

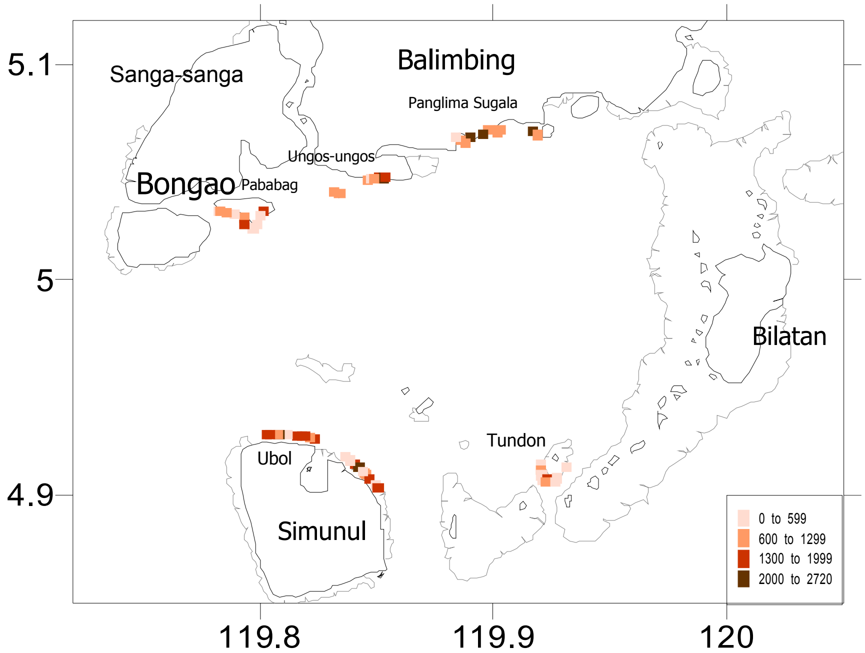


Figure 8. The distribution of fish abundance (ind/500m^2) in the study area, Tawi-tawi in October 2006.

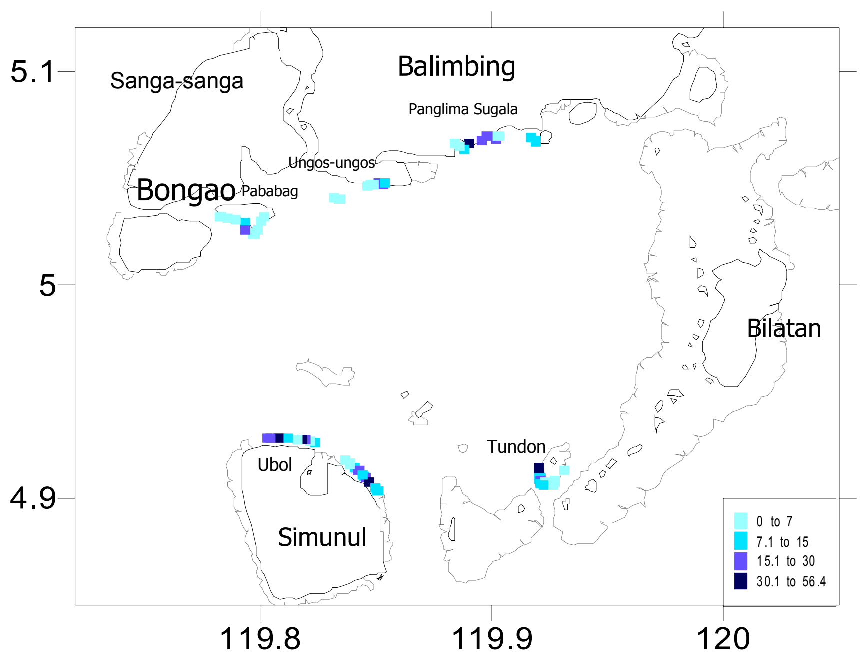


Figure 9. The distribution of fish biomass (kg/500m^2) in the study area, Tawi-tawi, in October 2006.

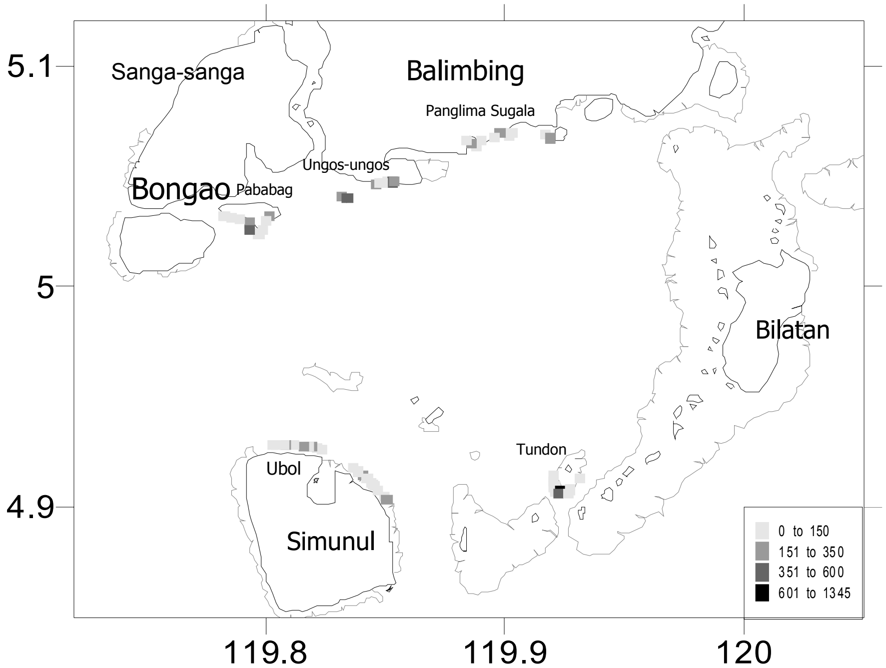


Figure 10. The distribution of juvenile fish (all spp) abundance (ind/500m^2) in the study area, Tawi-tawi, in October 2006.

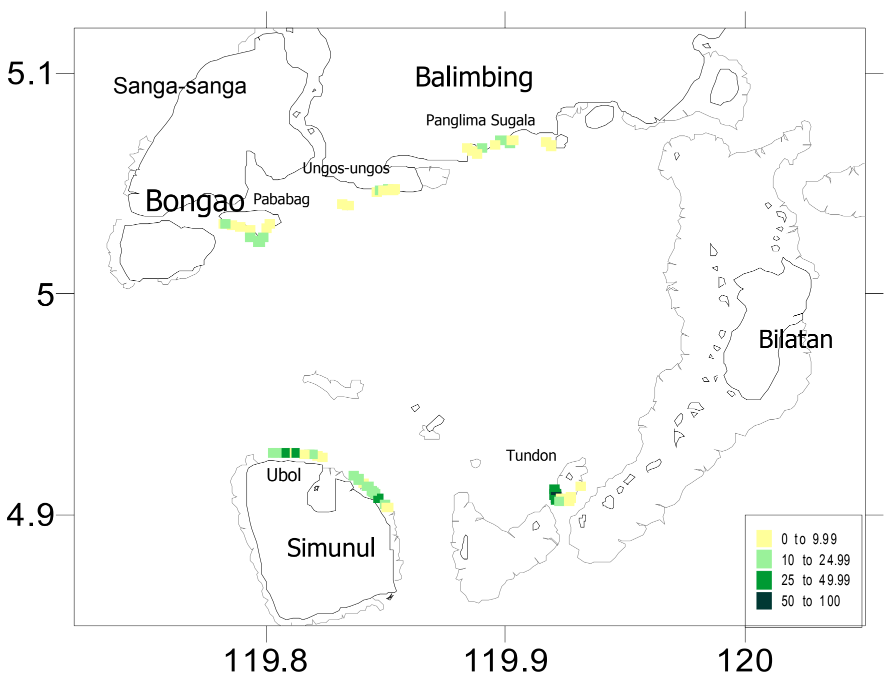


Figure 11. The distribution of ave ind. wt. of fish (g/ind) in the study area, Tawi-tawi, in October 2006.

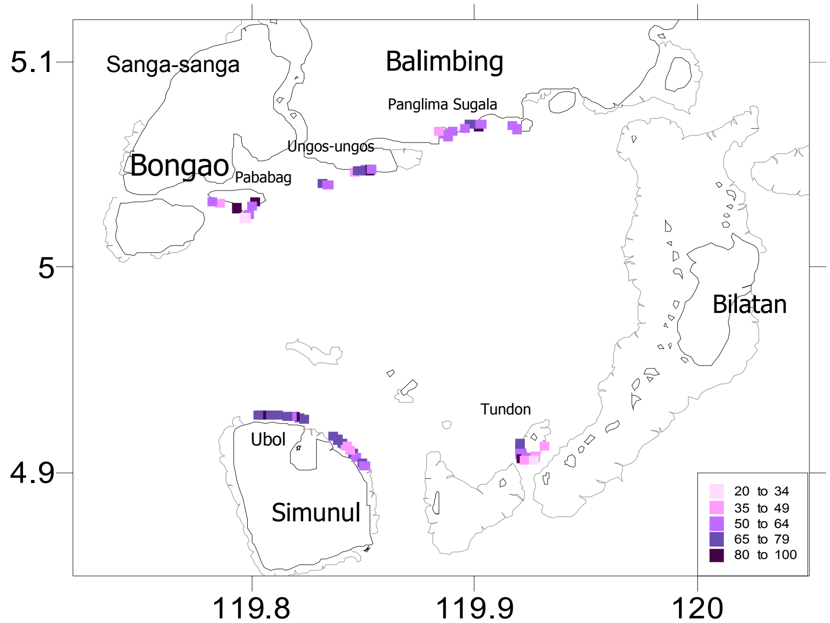


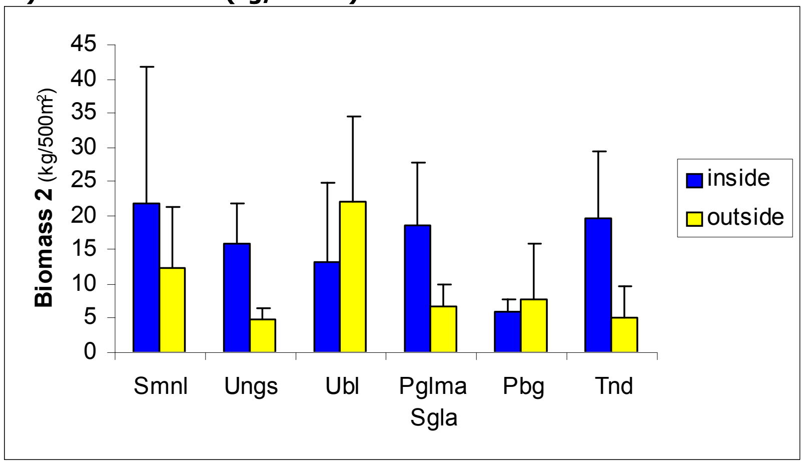
Figure 12. The distribution of species richness (no. of fish species in $250m^2$) in the study area, Tawi-tawi, in October 2006.

Inside-Outside MPA comparisons

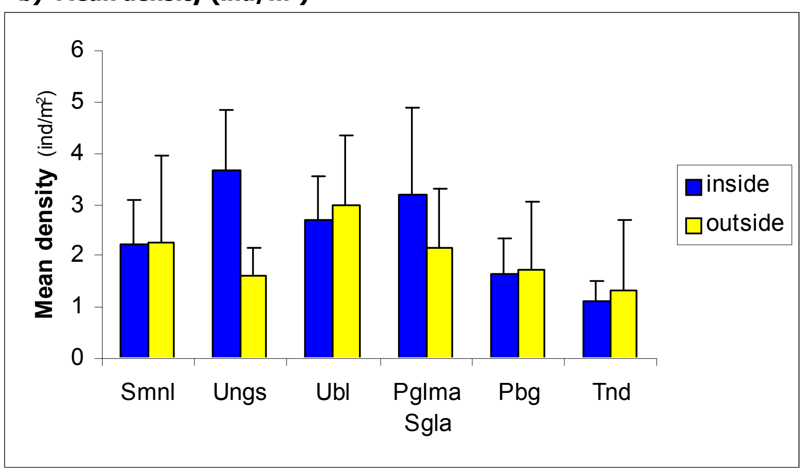
In general, no consistent differences were observed between groups of stations inside and outside of MPAs. For instance, fish biomass and mean density showed higher values inside the MPA boundaries in some sites, but the opposite was true in the others. Two-way ANOVAs were employed to examine the contributions of site and station location (in or out of an MPA) to total variation in fish assemblage parameters. In terms of biomass, Simunul, Ungos-ungos, Panglima Sugala and Tundon showed higher mean values in stations within the MPA boundaries but the opposite was true in the other two sites (Fig. 13a). No recognizable differences in mean density were shown between stations in or out of the MPA boundaries in general (Figs. 13b). Number of species and number of families were generally high and the same in inside and outside stations in all of the six sites (Figs. 13c-d). Differences were shown for mean individual size and juvenile fish abundance, although these were not consistent between stations inside and outside of MPA boundaries nor across all sites (Figs. 13e-f). Generally, the abundance of target and indicator species was higher in stations inside the MPA boundaries but an apparent difference is exhibited when compared across sites as extremely high values were consistently observed in Ubol and Simunul (Figs. 13g-h). The contribution of caesionids and scarids to total weight showed clear differences between stations inside and outside of the MPA boundaries (Fig. 13i-j).

Fig. 13. Comparison of fish parameters measured inside and outside of MPA boundaries in the study area, Danajon Bank, Bohol, in September 2006.

a) Biomass of fish (kg/500m²)



b) Mean density (ind/m²)



c) Mean spp richness (no. of fish species)

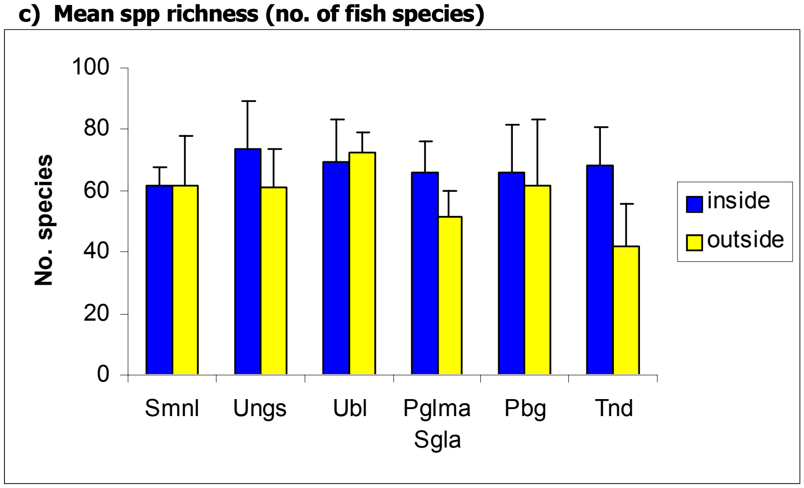
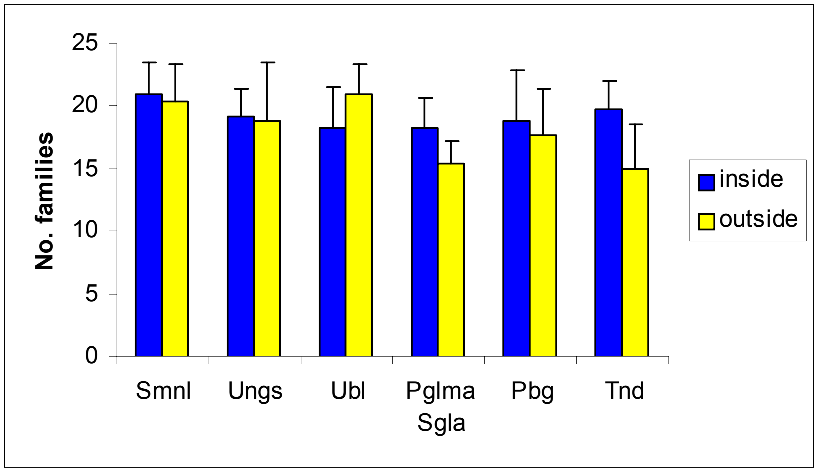
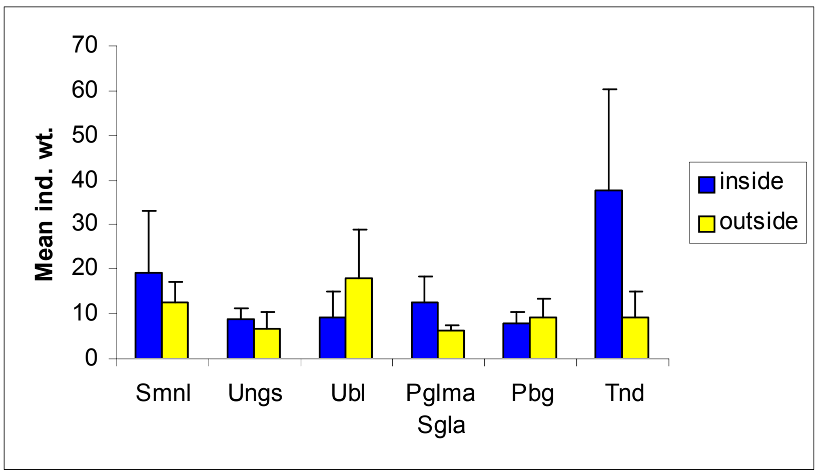


Fig. 13. Continued

d) Mean no. of fish families



e) Mean ind. Wt (g)



f) Juv. Fish abundance (ind/500m^2) (y axis rescaled)

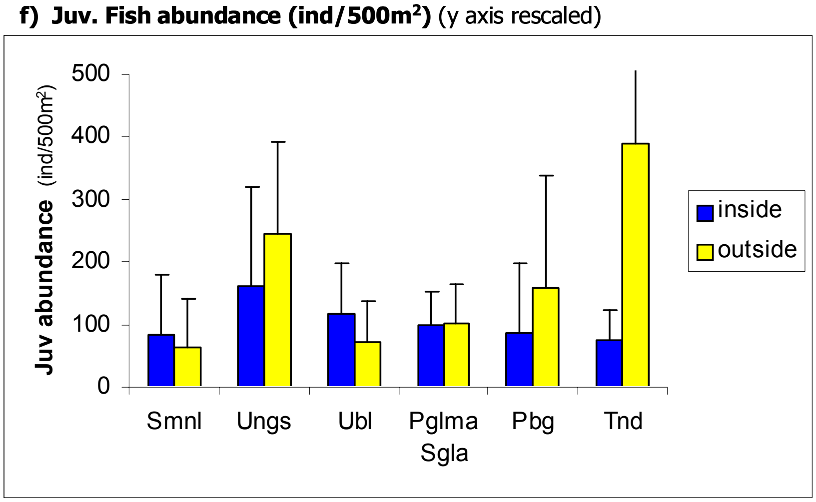
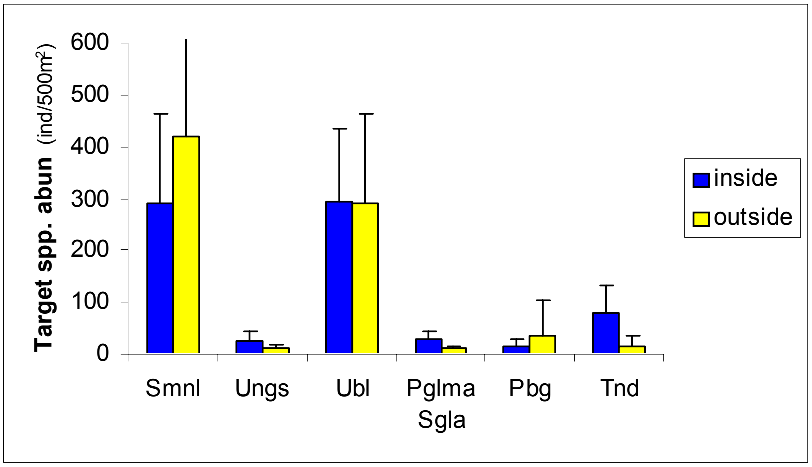
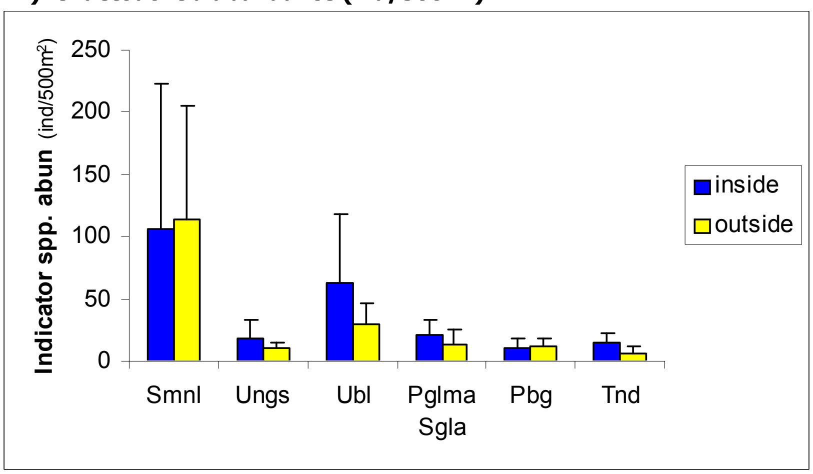


Fig. 13. Continued

g) Target species abundance (ind/500m²) (y axis rescaled)



h) Chaetodontid abundance (ind/500m²)



i) Caesionid abundance (ind/500m²) (y axis rescaled)

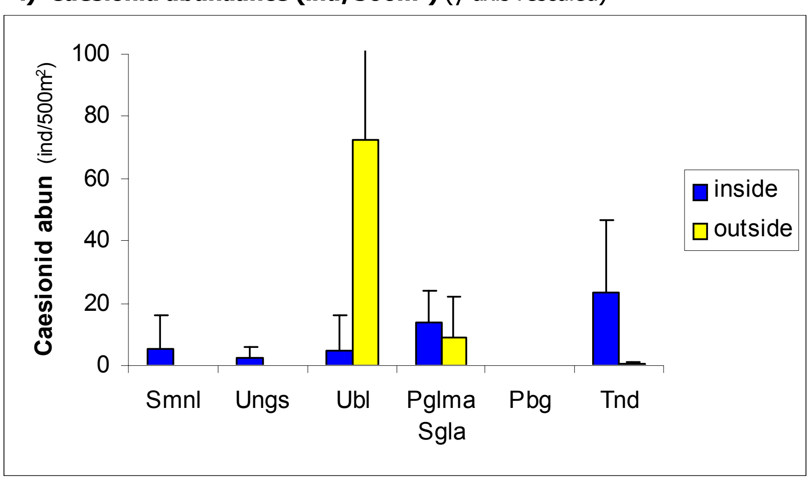
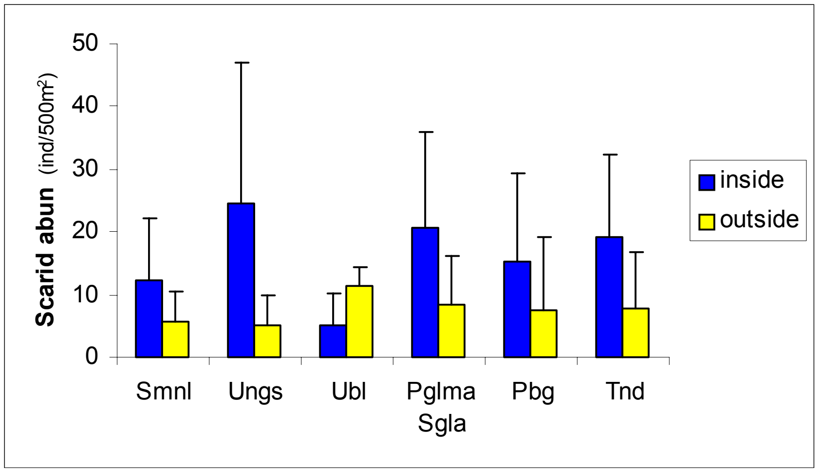


Fig. 13. Continued

j) Scarid abundance (ind/500m²)



Reef fish composition

Target fish abundance was highest in Simunul (mean = 357 ind/500m^2) and Ubol (mean = 292 ind/500m^2), where biomass was also highest (Table 6). Interestingly, physical relief was also very high in these sites compared with the other four. Slope steepness and slope bottom depth seem to have the greatest influence in the abundance of target fish in these MPAs which are also located in the same island and exhibit more or less the same reef characteristics. On the other hand, overall target fish abundance was lowest (mean = 19 ind/500m^2) in Ungos-ungos and Panglima Sugala.

Overall abundance of indicator fish species was also highest in Simunul (mean = 110.6 ind/500m^2) and lowest in Tundon (mean = 10.1 ind/500m^2). Chaetodontids make good indicators of reef health. Since they are corallivores, live hard coral cover must be sufficiently high to support high chaetodontid abundance. The overall mean abundance was about 34.9 ind/500m^2. This is very well above the average value of butterflyfish abundance (~10-11/500m^2) from 52 reef sites in the northern half of the country (Nañola and Aliño, 1999). However, reef health conditions in the focal area are still considered to be within the fair live hard coral cover category (29.6%) in spite of the overall abundance of indicator fish.

Caesionids made up, on average, about 3.1% of total weight of all fish in each of the 60 stations. Caesionid abundance was very low (mean = 0-38.6 ind/500m^2) and patchily distributed in all sites. Among the six sites, mean abundance was highest in Ubol, while caesionids were not observed in Pababag. Although their abundance in Ubol appears to be supported by proximity of the reef slope to deep water, this was not true for Simunul where mean abundance was only 2.6 ind/500m^2.

Average scarid abundances ranged from 5 in Ubol and 24.6 ind/500m^2 in Ungos-ungos (Table 6). Overall mean abundance ranged from 8.2-14.9 ind/500m^2. Reef-associated carangids were encountered only in one or two stations in Ubol, Simunul, Panglima Sugala and Ungos-ungos.

Table 6. Summary of abundance (ind/500m^2) and contributions to total weight of target & indicator fish, and caesionids & scarids in each station surveyed in the six sites in Tawi-Tawi in October 17-26, 2006.

	Target		Indicator		Caesionids		Scarids	
	no	% tot wt	no	% tot wt	no	% tot wt	no	% tot wt
Ubol (inside)								
UBI 1	466	34.8	27	8	0	0	2	0.2
UBI 2	139	19.2	37	6.7	0	0	5	0.7
UBI 3	185	20.4	54	8.7	25	12.1	14	6.5
UBI 4	404	28.7	161	27.1	0	0	2	4.3
UBI 5	281	13.1	38	8.7	0	0	2	0.3
n	5	5	5	5	5	5	5	5
mean	295	23.2	63.4	11.9	5	2.4	5	2.4
sd	139.4	8.5	55.4	8.6	11.2	5.4	5.2	2.9
Ubol (outside)								
UBO 1	44	14.8	59	9.1	94	29.4	8	27.1
UBO 2	274	19.6	20	1.4	50	29.3	14	1.4
UBO 3	219	29.2	26	2.5	207	32.7	9	8.1
UBO 4	470	15.4	27	1.7	0	0	11	8.7
UBO 5	441	20.2	14	2.4	10	1.8	15	8.8
n	5	5	5	5	5	5	5	5
mean	289.6	19.8	29.2	3.4	72.2	18.7	11.4	10.8
sd	173.9	5.8	17.5	3.2	84.0	16.3	3.0	9.6
Ubol (combined)								
n	10	10	10	10	10	10	10	10
mean	292.3	21.5	46.3	7.6	38.6	10.5	8.2	6.6
sd	148.6	7.1	42.7	7.6	66.7	14.3	5.2	8
Simunul (inside)								
SI 1	268	21.4	77	4.8	0	0	2	0.4
SI 2	243	72	54	4	0	0	20	1.8
SI 3	325	35.9	314	8.9	1	0.2	25	3
SI 4	74	30.2	42	13.3	25	10.5	9	2.3
SI 5	551	49	47	5.8	0	0	6	0.8
n	5	5	5	5	5	5	5	5
mean	292.2	41.7	106.8	7.4	5.2	2.1	12.4	1.7
sd	172.2	19.7	116.6	3.8	11.1	4.7	9.7	1.1
Simunul (outside)								
SO 1	536	26.3	79	6.9	0	0	7	2.7
SO 2	1092	31.2	274	22.4	0	0	4	4.4
SO 3	64	8.9	80	10.3	0	0	1	0.1
SO 4	241	38.2	46	5.2	0	0	13	0.1
SO 5	171	34.9	93	10.9	0	0	4	11.9
n	5	5	5	5	5	5	5	5
mean	420.8	27.9	114.4	11.1	0	0	5.8	3.8
sd	414.1	11.5	90.9	6.7	0	0	4.5	4.9
Simunul (combined)								
n	10	10	10	10	10	10	10	10
mean	356.5	34.8	110.6	9.2	2.6	1.1	9.1	2.7
sd	306.6	16.9	98.6	5.5	7.9	3.3	8	3.5

Table 6. Con't

	Target		Indicator		Caesionids		Scarids	
	no	% tot wt	no	% tot wt	no	% tot wt	no	% tot wt
Tundon (inside)								
TDI 1	28	3.8	9	0.7	50	3.7	2	0.4
TDI 2	76	30	14	0.8	46	5.1	36	8.8
TDI 3	119	44.5	8	1.2	5	1	23	14.9
TDI 4	145	58.3	27	4.2	0	0	11	4.8
TDI 5	32	21.4	14	2.7	15	10.5	24	11.0
n	5	5	5	5	5	5	5	5
mean	80	31.6	14.4	1.9	23.2	4	19.2	8
sd	51.9	21	7.6	1.5	23.3	4.2	13.1	5.6
Tundon (outside)								
TDO 1	51	18.5	16	5.6	0	0	22	21.8
TDO 2	11	22.2	6	0.6	0	0	10	5.5
TDO 3	12	18.1	0	0	0	0	6	12.3
TDO 4	5	15.4	7	11.2	0	0	1	4.8
TDO 5	1	8.9	0	0	2	17.7	0	0
n	5	5	5	5	5	5	5	5
mean	16.0	16.6	5.8	3.5	0.4	3.5	7.8	8.9
sd	20.1	4.9	6.6	4.9	0.9	7.9	8.9	8.4
Tundon (combined)								
n	10	10	10	10	10	10	10	10
mean	48	24.1	10.1	2.7	11.8	3.8	13.5	8.4
sd	50.1	16.4	8.1	3.5	19.7	6	12.1	6.8
Panglima Sugala (inside)								
PSI 1	46	30.1	40	3.6	23	6.3	47	22.8
PSI 2	23	51.2	20	3.2	12	0.7	17	8.5
PSI 3	16	5.3	14	4.5	25	2.9	19	5.5
PSI 4	44	42.8	25	4.2	10	2.1	12	2.9
PSI 5	12	10.6	9	5.7	0	0	9	7.1
n	5	5	5	5	5	5	5	5
mean	28.2	28	21.6	4.2	14	2.4	20.8	9.4
sd	15.8	19.9	11.9	1	10.2	2.5	15.2	7.8
Panglima Sugala (outside)								
PSO 1	8	8.9	11	7.2	14	14.1	0	0
PSO 2	5	19.2	17	8.1	30	1.8	13	6.6
PSO 3	12	30.9	32	7.7	0	0	13	14.7
PSO 4	6	3.5	4	0.8	0	0	16	11.9
PSO 5	16	15.2	1	0.7	0	0	0	0
n	5	5	5	5	5	5	5	5
mean	9.4	15.5	13	4.9	8.8	3.2	8.4	6.6
sd	4.6	10.4	12.3	3.8	13.3	6.2	7.8	6.7
Panglima Sugala (combined)								
n	10	10	10	10	10	10	10	10
mean	18.8	21.8	17.3	4.6	11.4	2.8	14.6	8
sd	14.8	16.3	12.3	2.6	11.5	4.4	13.1	7

Table 6. Con't

	Target		Indicator		Caesionids		Scarids	
	no	% tot wt	no	% tot wt	no	% tot wt	no	% tot wt
Ungos-ungos (inside)								
UGI 1	9	9.6	1	0	0	0	0	0
UGI 2	13	3.8	4	1.2	0	0	13	1.6
UGI 3	31	6.3	35	5.8	0	0	15	18.4
UGI 4	35	2.8	26	4	7	0	40	4
UGI 5	45	32.4	24	5.4	5	2.4	55	21
n	5	5	5	5	5	5	5	5
mean	26.6	11	18	3.3	2.4	0.5	24.6	9
sd	15.2	12.2	14.8	2.6	3.4	1.1	22.3	9.9
Ungos-ungos (outside)								
UGO 1	11	12	10	2.8	0	0	4	0.4
UGO 2	10	9.4	18	3.6	0	0	3	8.8
UGO 3	1	0	4	0	0	0	1	0.7
UGO 4	14	14.8	6	2.9	0	0	13	33.9
UGO 5	16	3.7	12	5	0	0	5	0.6
n	5	5	5	5	5	5	5	5
mean	10.4	8.0	10	3.0	0	0	5.2	8.9
sd	5.8	6.1	5.5	1.7	0	0	4.6	14.4
Ungos-ungos (combined)								
n	10	10	10	10	10	10	10	10
mean	18.5	9.5	14.0	3.1	1.2	0.2	14.9	8.9
sd	13.8	9.2	11.3	2.1	2.6	0.8	18.3	11.7
Pababag (inside)								
PI 1	18	16.2	13	5.9	0	0	11	3.9
PI 2	19	22.0	11	3.6	0	0	5	1.3
PI 3	1	0	0	0	0	0	23	4.8
PI 4	3	2.7	6	2.2	0	0	1	1.9
PI 5	34	16.2	21	17.1	0	0	36	12
n	5	5	5	5	5	5	5	5
mean	15.0	11.4	10.2	5.8	0	0	15.2	4.8
sd	13.5	9.5	7.9	6.7	0	0	14.3	4.3
Pababag (outside)								
PO 1	11	5.4	1	1.2	0	0	4	0.6
PO 2	9	6.6	15	7.8	0	0	4	5.3
PO 3	9	13.5	11	5.4	0	0	2	3
PO 4	3	1.6	15	7.5	0	0	0	0
PO 5	156	52.6	15	2	0	0	28	7.9
n	**5**	5	5	5	5	5	5	5
mean	37.6	16	11.4	4.8	0	0	7.6	3.4
sd	66.3	20.9	6.1	3.1	0	0	11.5	3.3
Pababag (combined)								
n	10	10	10	10	10	10	10	10
mean	26.3	13.7	10.8	5.3	0	0	11.4	4.1
sd	46.6	15.5	6.6	4.9	0	0	12.9	3.7

The most common fish species within sites and across all sites are shown in Table 7a. *Cirrhilabrus cyanopleura*, which ranked no. 1 in Ubol and Pababag, also ranked as the top species across all sites. *Plotosus lineatus* and *Pseudanthias squamipinnis* ranked 2nd and 3rd, respectively. On the other hand, the most common fish families within sites and across all sites are shown in Table 7b. Expectedly, Pomacentridae and Labridae were the top two families across all sites as well as within most sites (Table 8). The preponderance of these families is not new in reef fish surveys as these are the most common fish groups observed by reef divers.

Table 7a. List of fish species among the top 10 in at least one of the six sites surveyed in Tawi-Tawi in October 17-26, 2006. The rank abundance of each species in the various sites, as well as their frequency of occurrence within the top 20 species in any of the six sites are shown.

Species	**Panglima**	**Pab**	**Sim**	**Tund**	**Ubol**	**Ungos**	**Freq**
Cirrhilabrus cyanopleura	4	1	4	2	1	16	6
Chromis ternatensis	15	15	15	4	8	5	6
Thalassoma lunare	12	13	11	7	17	15	6
Pomacentrus moluccensis	11	3		17	9	3	5
Dascyllus trimaculatus		11	5	12	6	19	5
Cheilodipterus quinquelineatus	5	4		10		9	4
Amblyglyphidodon curacao	10	9		14		8	4
Chrysiptera rollandi	3	7		18		17	4
Plotosus lineatus	1		8		2		3
Dascyllus aruanus		8		5		1	3
Pomacentrus brachialis			7	6	7		3
Sphaeramia nematoptera	6	16				4	3
Pomacentrus amboinensis		5		15		7	3
Pomacentrus smithi	7	2				18	3
Acanthochromis polyacanthus			10	19	5		3
Amblyglyphidodon leucogaster	13	6				20	3
Ctenochaetus binotatus		19	14	8			3
Chromis viridis				1		2	2
Pseudanthias squamipinnis			1		3		2
Pseudanthias huchtii			2		4		2
Dascyllus reticulatus				3		11	2
Chaetodon kleinii			3		14		2
Archamia zosterophora	9					10	2
Chromis margaritifer			6		15		2
Apogon cyanosoma		10		13			2
Pholidichthys leucotaenia	17				10		2
Chrysiptera parasema	2						1
Hypoatherina barresi						6	1
Pomacentrus alexanderae	8						1
Dascyllus carneus				9			1
Pomacentrus auriventris			9				1
No. species recorded	200	226	213	226	224	223	

Table 7b. List of fish families among the top 10 in at least one of the six sites surveyed in Tawi-Tawi in October 17-26, 2006. The rank abundance of each family in the various sites, as well as their frequency of occurrence within the top 20 families in any of the six sites are shown.

Family	Panglima	Pab	Sim	Tund	Ubol	Ungos	Freq
Pomacentridae	1	1	1	1	1	1	6
Labridae	4	2	3	2	2	4	6
Apogonidae	3	3	10	4	12	2	6
Acanthuridae	10	4	5	3	5	7	6
Chaetodontidae	5	7	4	9	6	6	6
Scaridae	6	6	9	6	11	5	6
Pomacanthidae	15	10	8	16	9	11	6
Zanclidae	11	13	12	12	17	10	6
Serranidae	12		2	8	3	14	5
Nemipteridae	14	12	15	5		8	5
Caesionidae	9		13	7	8	19	5
Tetraodontidae		8	14	13	13	13	5
Pinguipedidae		9	17	10		9	4
Centriscidae	8			18	15	15	4
Holocentridae	16	16		17	10		4
Plotosidae	2		6		4		3
Pholidichthyidae	7				7		2
Carangidae			7			12	2
Gobiidae		5				16	2
Atherinidae						3	1
No. families recorded	33	32	35	34	41	38	

Across all six sites, the 20 most abundant species comprised only 62.8% of all fish recorded. This exemplifies the rather high diversity of fish assemblages in Tawi-Tawi in comparison to those in Bohol or in the Calamianes, where the top 20 species comprised over 70% of all fish recorded. The total number of fish species recorded in Tawi-Tawi ranged from 200-226 in the various sites. This is higher than what were observed in Bohol (118-200) and the Calamianes (165-202), but comparable to records in Surigao del Sur (190-236).

Table 8. Top 20 species and top 10 families of fish based on overall mean abundance across all six sites surveyed in Tawi-Tawi in October 17-26, 2006.

Species	%totno	%totwt	Family	% No	% Wt
Cirrhilabrus cyanopleura	8.2	1.9	Pomacentridae	44.7	19.1
Plotosus lineatus	7.1	1.2	Labridae	14.3	11.7
Pseudanthias squamipinnis	3.9	1.0	Apogonidae	10.1	4.4
Chromis viridis	3.5	0.4	Serranidae	7.9	3.1
Chrysiptera parasema	3.3	0.5	Plotosidae	7.1	1.2
Pseudanthias huchtii	3.3	1.0	Acanthuridae	3.4	18.4
Pomacentrus moluccensis	3.2	1.1	Chaetodontidae	3.2	6.1
Chromis ternatensis	3.2	2.1	Scaridae	1.1	6.5
Dascyllus aruanus	2.9	0.5	Atherinidae	1.1	0.1
Cheilodipterus quinquelineatus	2.8	0.8	Caesionidae	1.0	4.8
Dascyllus trimaculatus	2.7	2.6		93.91	75.3
Pomacentrus brachialis	2.4	1.0			
Sphaeramia nematoptera	2.4	0.4			
Chrysiptera rollandi	2.3	0.2			
Chaetodon kleinii	2.2	2.8			
Pomacentrus amboinensis	2.1	0.1			
Pomacentrus smithi	1.9	0.4			
Thalassoma lunare	1.9	1.9			
Amblyglyphidodon curacao	1.8	0.9			
Acanthochromis polyacanthus	1.7	1.1			
	62.8	22.1			

Fisheries management

Reef fish diversity is relatively high in Tawi-Tawi, particularly at the family level, with 32-41 families recorded per site, as opposed to Surigao del Sur with 32-37 families per site. However, live coral cover is low, particularly along the northern (inner) coast of the Bilatan Island Chain, and juvenile fish abundance and coral recruit frequency are also relatively low. The continued observation of frequent blastfishing in 2006 indicates that much work needs to be done in this focal area before interventions can produce positive results. However, the relatively high overall abundance of target species (mean = 126.7 ind/500m2), representing about ¼ (27.0%) of total fish biomass, is encouraging.

Dispersal models (Villanoy, 2006) and reef habitat conditions show that the northern coastline of Tawi-Tawi Bay likely serves as the major source of juvenile fish and coral recruits for much of the focal area, perhaps even for areas further east. Efforts to strengthen habitat and resource conservation in this vicinity will likely benefit the entire Bay as well as adjacent portions outside of it.

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