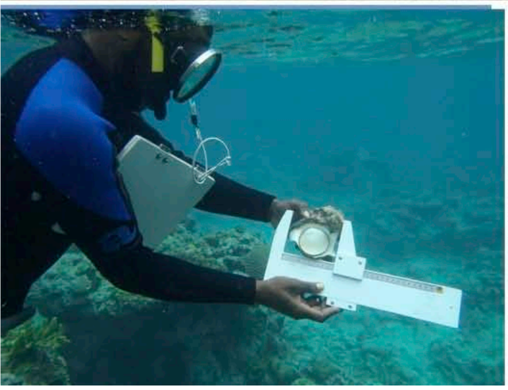
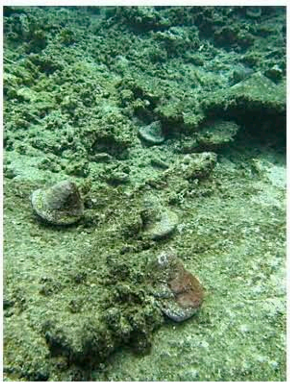
Efficiency of tabu areas in Vanuatu
(EFITAV project)

Final report - December 2012





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Project context

In Vanuatu, fishing for sale and/or subsistence has severely affected the live stocks of reef molluscs, with populations now considered close to collapse in many locations despite the presence of suitable habitats for juveniles and adults (Amos 1995). In this context, Vanuatu has been experiencing since the early 1990s a striking upsurge in small-scale initiatives to protect marine invertebrate resources, in particular trochus (*Trochus niloticus*), giant clams (*Tridacna* spp.), green snail (*Turbo marmoratus*) and sea cucumbers (e.g. Amos 1991, Johannes 1998, Jimmy 1995, Jimmy & Amos 2004). One of the most common actions was the creation of very small, village-based marine reserves (*tabu* areas) with permanent or temporary fishing bans for invertebrate species (Johannes & Hickey 2004). Spread throughout the archipelago, these tabu areas are unparalleled in the temperate zone: they are usually characterized by small sizes (typically 0.1 to 1 km²) and very diverse, village-specific management rules in terms of species, periods, capture method etc.

Community-based management is booming in Melanesia (Fiji, Solomon Islands), Micronesia and Polynesia or the Philippines; yet, theoretical and methodological questions arise concerning the efficiency and potential impact on marine ecosystems (e.g. see McClanahan *et al*. 2006; Cinner *et al*. 2005). In fact, the overall positive perception within the local populations is far from being scientifically confirmed: the few available studies report contrasted effects on marine resources, under the direct influence of the intrinsic characteristics of the tabu areas (in particular size, age, regulation). The results obtained in Emao (North Efate) in 2008 by IRD also suggest the importance of the species' life history traits, in particular those related to the mobility of adults and larvae which may modulate the global efficiency of the abu areas (Dumas et al. 2010).

Based on the existence of an extensive network of tabu areas managed by the local communities, the main objective of the EFITAV project ("Efficiency of tabu areas in Vanuatu") is to assess the capacity of tabu areas to restore and/or to maintain the level of reef resources, in order to provide objective criteria to optimize their effectiveness.

This project was implemented in Vanuatu from September 2011 to August 2012.




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Acknowledgements

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We also extend our warm thanks to the village communities of the study sites for their strong involvement and participation throughout the project, in particular the people from Marow, Takara, Emua, Paonangisu, Mangaliliu and Anelcowat.
This work is dedicated to the people of Vanuatu.

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INFLUENCE OF TABU AREAS ON THE MARINE INVERTEBRATE RESOURCES

EFITAV project

Efficiency of Tabu Areas in Vanuatu

1. OBJECTIVES

The first part of this document presents the results of comparative invertebrate surveys & stock assessment carried out inside vs. outside the tabu areas of several village communities. These evaluations target the main reef species traditionally exploited in Vanuatu for commercial or subsistence purposes, i.e. trochus (*Trochus niloticus*), giant clams (genus *Tridacna* and *Hippopus*) and green snail (*Turbo marmoratus*).

2. MATERIAL & METHODS

The surveys were performed using standardized, UVC-derived methods providing reliable, quantitative data on i) the habitat structure of the reef area studied, ii) the population structure (abundance/density, size distribution) of the target species and iii) statistical estimates of stock abundance and biomass.
The field surveys involved experienced scientists from the IRD and the Department of Fisheries Port Vila, and some local villagers selected for the study needs. The surveys were based upon random stratified sampling, where survey stations inside and outside the tabu areas were randomly generated prior to fieldwork using GIS habitat layers derived from high-resolution satellite imagery. The stations coordinates were then uploaded to portable GPS units before going in the field.

2.1 Invertebrate sampling

In the field, data were collected along standardized transects of 50 x 4m (200 m^2). On each station, one transect belt was laid using a 50m color-marked survey tape attached to the substratum. Data were collected by a pair of two snorkellers or SCUBA divers swimming simultaneously along the two sides of the transect line, each surveying a 2m-wide corridor. All individuals belonging to the target species which were detectable without disturbing the substratum were counted and measured. Individual sizes were recorded using simple, easy-to-use field tools developed for this study and suitable for participative monitoring. They consisted of underwater PVC callipers used to measure shell width (giant clams) or largest basal diameter (trochus / green snails). Measures were recorded to the nearest millimeter.

2.2 Habitat sampling

For each station, sediment type and substratum coverage variables were estimated using a photographic method developed to quickly and quantitatively describe contrasting reef habitats (Dumas et al. 2009). Pictures were taken from the surface along transects using a standard digital 10 Mpixels Canon S90 camera in underwater housing, oriented perpendicular to the substratum; 25 pictures were taken per transect (i.e. one shot every two meters) and subsequently imported into an image analysis software including efficient, user-friendly features for the estimation of sediment / substratum cover (CPCe "Coral Point Count with Excel extensions" software, Kohler & Gill 2006). Surface estimates expressed in percent cover were derived from random stratified point count techniques using a nine points.m^{-2} ratio ensuring reliable habitat profiles with low bias and high precision. Seventeen local habitat variables were considered, related to sediment type and substratum coverage by large, sessile organisms. Percentage cover was then aggregated at the transect level.

The surface of reef areas (inside vs. outside the tabu areas) was estimated using high resolution satellite images, thus allowing the extrapolation of population abundance and biomass across all study areas.

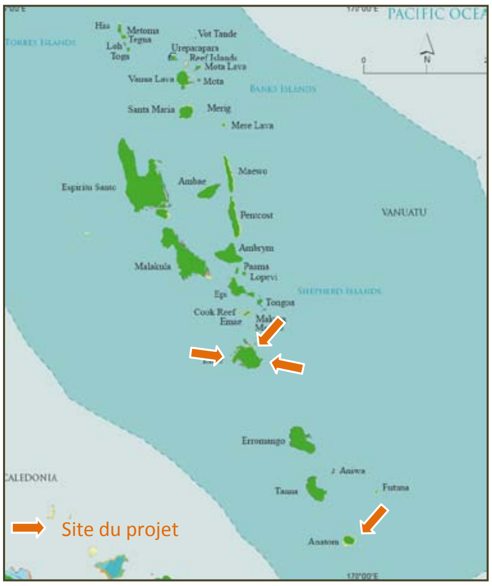


Figure 1. Vanuatu archipelago
(source: Atlas des récifs coralliens du Pacifique).

The study was conducted on four village communities spread over the islands of Efate (Mangaliliu and Takara villages), Emao (Marou village) and Aneityum (Anelcowat village + Mystery Island). Depending on the size of the zones, between 41 and 126 reef stations have been sampled per village, totaling nearly 8 hectares of reef fund fully covered in this project (see Table 1).

A GIS database including all the surveyed transects with the associated results (geographical coordinates, abundance and density per species, percent cover for the 17 habitat variables) was established as an archive, and transferred to the Department of Fisheries Port Vila.

Table 1. Characteristics of the study sites

VILLAGE	INSIDE TABU	OUTSIDE TABU
MAROU (Emao)		
Date of creation of tabu area	2004	
Number of sampled stations	25	22
Total reef surface (hectares) used for stock estimates	15.0	22.1
TAKARA (North Efate)		
Date of creation of tabu area	2008	
Number of sampled stations	16	25
Total reef surface (hectares) used for stock estimates	3.3	29.0
MANGALILIU (West Efate)		
Date of creation of tabu area	1990s	
Number of sampled stations	35	91
Total reef surface (hectares) used for stock estimates	25.5	165.1
ANELCOWAT / MYSTERY ISLAND (Aneityum)		
Date of creation of tabu area	2000	
Number of sampled stations	17 + 39 (1)	24
Total reef surface (hectares) (2)	13.7	18.3

(1) 17 stations inside the mainland tabu area plus 39 additional stations inside the Mystery Island Conservation area. The latter were not considered for stock extrapolations.
(2) Not including Mystery Island Conservation area.

3. RESULTS

3.1 Trochus

Trochus are an important economic resource for the people of Vanuatu, whose exploitation has resulted in a marked reduction in stocks across the archipelago in recent years. Their rapid growth rate (sexual maturity can be reached after 3 years) and the reduced mobility of adults constitute characteristics that can enhance the effectiveness of protective measures such as tabu areas.

3.1.1 Abundance/density/biomass

On the whole, abundance and density data reflect the scarcity of trochus populations in Vanuatu. As an example, even inside the tabu areas, trochus densities are generally 50 to 100 times lower than those observed inside marine reserves with similar habitat in New Caledonia, (data P. Dumas, IRD).

Table 2. Survey results for trochus (*Trochus niloticus)*.

VILLAGE	INSIDE TABU	OUTSIDE TABU
MAROU		
Total number found during the survey	31	8
Mean abundance (trochus per transect)	1.24	0.36
Mean density (trochus per ha)	62.0	18.2
Mean harvestable density (trochus per ha)	42.0	9.1
TAKARA		
Total number found during the survey	29	31
Mean abundance (trochus per transect)	1.81	1.24
Mean density (trochus per ha)	90.6	62.0
Mean harvestable density (trochus per ha)	71.9	26.0
MANGALILIU		
Total number found during the survey	63	41
Mean abundance (trochus per transect)	1.8	0.45
Mean density (trochus per ha)	90.0	22.5
Mean harvestable density (trochus per ha)	67.1	22.5
ANELCOWAT/MYSTERY ISLAND		
Total number found during the survey	463 / 193	55
Mean abundance (trochus per transect)	27.2 / 11.22	1.95
Mean density (trochus per ha)	1 361.8 / 247.4	97.5
Mean harvestable density (trochus per ha)	1 132.4 / 160.2	30.0

The results confirm the positive impacts of tabu areas in aggregating the individuals: in the studied areas, the trochus density increases up to four times inside the tabu areas when compared to adjacent, non-protected sites (see Figure 2 & Table 2). The biomass follows the same trend, in particular for large, harvestable individuals (trochus with basal diameter comprised between 90 and 130 mm) which are found almost only inside the tabu areas.

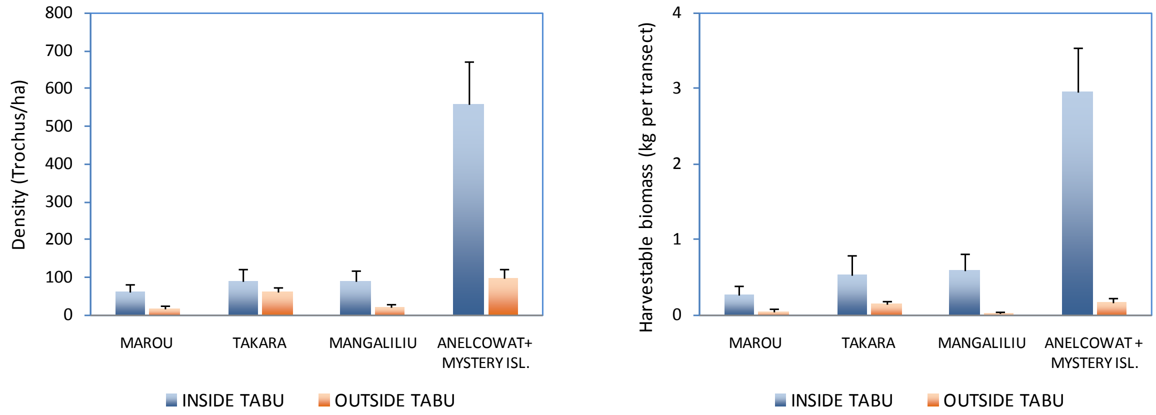


Figure 2. Effects of tabu areas on trochus density (*left*) and harvestable biomass (*right*).
Means ± SE.

Yet, these results must be qualified for various reasons. Firstly, the increase in abundance or density observed within the tabu areas sometimes results from translocation actions carried out by the fishermen themselves. In the latter case, the benefits in terms of density and biomass do not necessarily reflect a recovery of depleted populations through reproduction and recruitment processes, and may be temporary if environmental conditions (including habitat) are not favorable. Second, even if the observed densities are much higher in tabu areas, the small size of these reef areas allows only a limited increase in stock biomass.

3.1.2 Stock extrapolation

Table 3. Stock estimates for trochus (*Trochus niloticus).*
Total extrapolated numbers and biomass per zone with 95% confidence intervals.

VILLAGE	ZONE TABU	ZONE NON TABU
MAROU		
Total number of trochus in the area	935 ± 682	402 ± 310
Total number of harvestable trochus in the area	633 ± 505	201 ± 186
Total biomass (in kg) in the area	402.1 ± 365.24	115.49 ± 100.81
Total harvestable biomass (in kg) in the area	214.14 ± 178.33	63.57 ± 67.15
Conservative estimate – harvestable stock	**35 kg**	**0 kg**
TAKARA		
Total number of trochus in the area	299.1 ± 227.9	1 802 ± 737.7
Total number of harvestable trochus in the area	237.2 ± 192.8	755.6 ± 533.7
Total biomass (in kg) in the area	130.4 ± 102.4	546.3 ± 357.7
Total harvestable biomass (in kg) in the area	90.2 ± 81.4	215.2 ± 123.4
Conservative estimate – harvestable stock	**10 kg**	**100 kg**
MANGALILIU		
Total number of trochus in the area	2304 ± 1574	3719 ± 2354
Total number of harvestable trochus in the area	1719 ± 1268	1089 ± 589
Total biomass (in kg) in the area	1219.6 ± 909.6	894.5 ± 829.9
Total harvestable biomass (in kg) in the area	752.5 ± 586.6	338.9 ± 319.2
Conservative estimate – harvestable stock	**170 kg**	**20 kg**

VILLAGE	ZONE TABU	ZONE NON TABU
ANELCOWAT (1)		
Total number of trochus in the area	18 683 ± 6 915	2 101 ± 990
Total number of harvestable trochus in the area	15 536 ± 6 405	688 ± 472
Total biomass (in kg) in the area	5 960 ± 1 812	535 ± 553
Total harvestable biomass (in kg) in the area	5 018 ± 1 616	191 ± 144
Conservative estimate – harvestable stock	**3 403 kg**	**47 kg**

(1) Because of harsh weather conditions, only a few stations were surveyed for Mystery Island protected area. Thus, extrapolations were calculated only for the Anelcowat area.

Because of the densities observed, the estimated stocks are generally low in all the studied areas. Order of magnitude is a few hundred kg per area (cf. Table 3). At this stage and given the high statistical variability associated with the results, conservative estimates of the stocks harvestable under the Vanuatu fishing regulation (trochus with basal diameter comprised between 90 and 130 mm) are particularly low: 35 kg inside the tabu area of Marow (Emao), 60 kg in Takara (mostly outside the tabu area) and 190 kg in the large reef area of Mangaliliu.

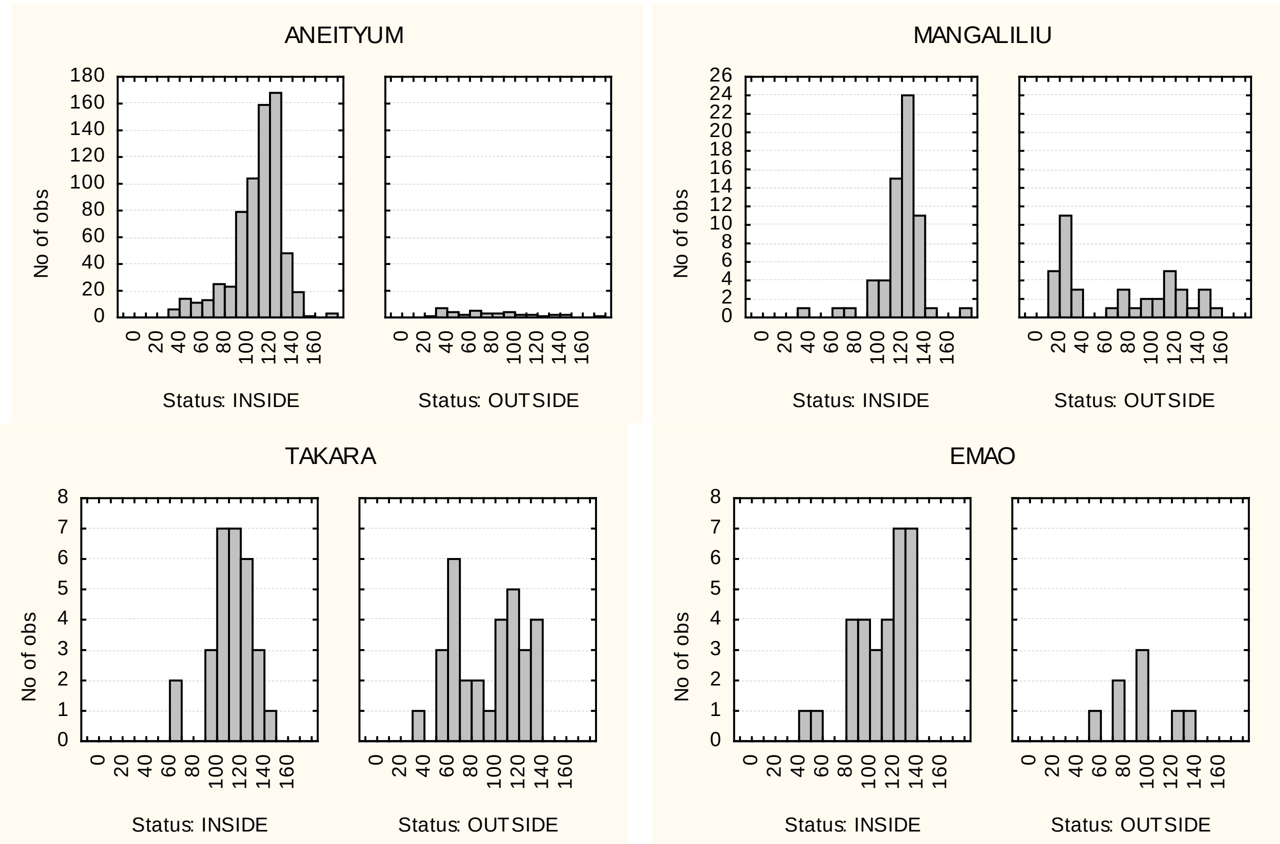


Figure 3. Size structure of trochus populations in the study areas.
Size-frequency histograms (basal diameter in mm) with 10 mm intervals

While limited harvest is possible in some areas, the size structures emphasize low levels of natural recruitment for trochus (Fig. 3). Except in Aneityum (both inside and outside the tabu area) and Mangaliliu (mostly outside the tabu area), young trochus are rarely found and population are mostly composed of old, mature individuals.

Since recruitment is strongly density-dependent for this species, keeping high densities of spawning adults inside particular areas is crucial. With the depletion of trochus populations elsewhere, tabu areas constitute the last reservoirs of bloodstock in Vanuatu. They are likely to play a major role in the recovery of trochus resource at larger scale through the production of larvae. Depending on temperature conditions, trochus larvae usually have a swimming period of 5-7 days before settling on the substrate. While positive effects in terms of recruitment may not be visible yet locally (as larvae can swim long distances during their dispersal phase), benefits are likely to extend well beyond the tabu areas. This is a crucial contribution to the natural restocking of trochus at the scale of Efate Island and Shefa Province.

3.2 Green snails

For green snail (*Turbo marmoratus*), the very low density values found on sites formerly known for their wealth emphasizes the severe population collapse of this heavily targeted species (cf. Table 4).

Table 4. Survey results for green snail (*Turbo marmoratus)*.

VILLAGE	INSIDE TABU	OUTSIDE TABU
MAROU		
Total number found during the survey	0	0
Mean abundance (Green snails per transect)	0	0
Mean density (Green snails per ha)	0	0
TAKARA		
Total number found during the survey	3	1
Mean abundance (Green snails per transect)	0.19	0.04
Mean density (Green snails per ha)	9.38	2.00
MANGALILIU		
Total number found during the survey	15	11
Mean abundance (Green snails per transect)	0.43	0.12
Mean density (Green snails per ha)	21.42	6.00
ANELCOWAT/MYSTERY ISLAND		
Total number found during the survey	50 / 10	1
Mean abundance (Green snails per transect)	2.94 / 0.26	0.04
Mean density (Green snails per ha)	147.1 / 12.8	2.0

Tabu areas clearly constitute “sanctuaries” for green snails, whose densities are almost negligible in the unprotected reefs of the study area.

Despite significantly higher populations inside protected areas, these measures are likely to be insufficient for green snails, as the density of breeding adults may have fallen below the threshold ensuring effective recruitment within the populations. This was apparently the case everywhere, except in the sites of Anelcowat and Mangaliliu. Yet, in the latter case a significant part of the population may be composed of individuals restocked from Aneityum in the 2000s. Some young green snails were found in Aneityum and Mangaliliu, but in very low abundance (Fig. 5).

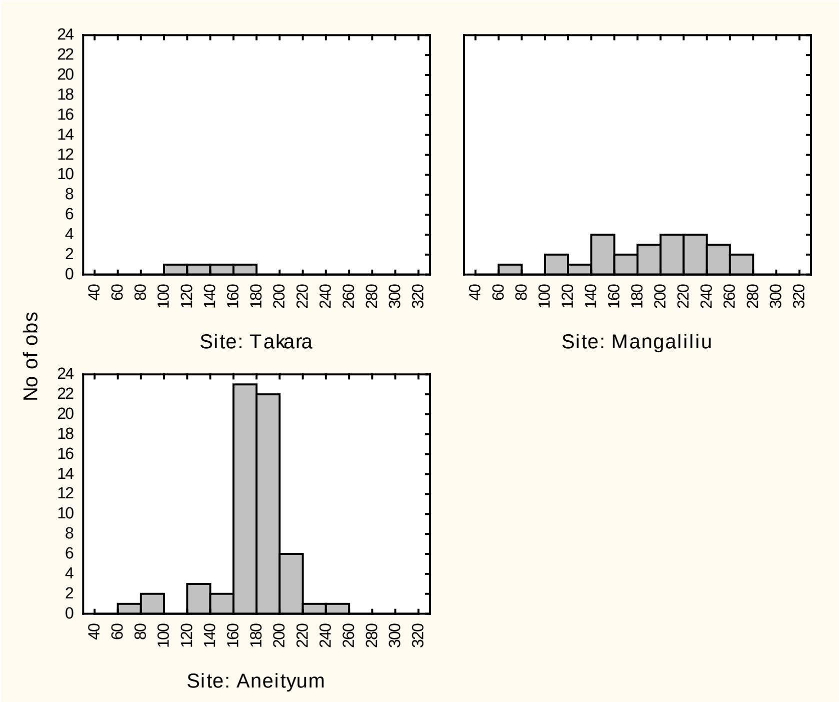


Figure 5. Size structure of green snail populations in the study areas.
Size-frequency histograms (basal diameter in mm) with 20 mm intervals

3.3 Giant clams

Positive effects of tabu areas in terms of abundance/density are also visible for giant clams of the genus *Tridacna*, locally exploited for local consumption. The densities of the two major species found in the area (*Tridacna maxima* and *Tridacna crocea*) significantly increased by a factor of 1-3 in tabu areas (Fig. 6). The ubiquist species *T. maxima* was generally dominant, except in the Mangaliliu area where very high populations of *T. crocea* were locally found (conservative estimate of stock above 30 000 individuals for the whole area).

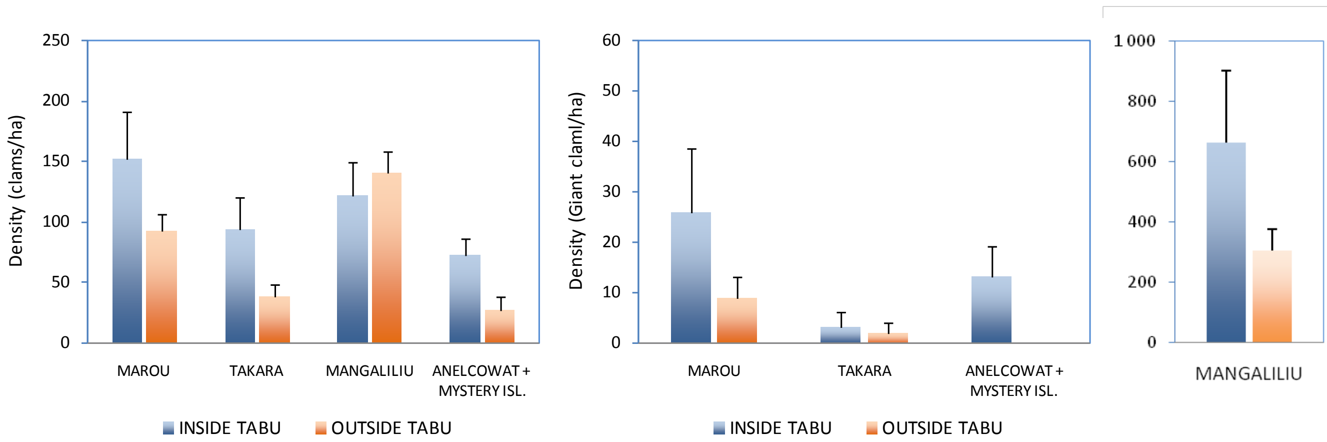


Figure 6. Effects of tabu areas on the density of giant clams.
A. *Tridacna maxima*; **B.** *Tridacna crocea* (Means ± SE).

The other species (*Tridacna derasa, Tridacna squamosa, Hippopus hippopus*) were found in very low abundances in the area.

Tables 5 & 6. Survey results & extrapolation for the giant clams *Tridacna maxima* and *Tridacna crocea*.

Tridacna maxima	INSIDE TABU	OUTSIDE TABU
MAROU		
Total number found during the survey	76	41
Mean abundance (giant clams per transect)	3.04	1.86
Mean density (giant clams per ha)	152.0	93.18
Total number of giant clams in the area	**2 292 ± 1208**	**2 059 ± 622**
TAKARA		
Total number found during the survey	30	19
Mean abundance (giant clams per transect)	1.88	0.76
Mean density (giant clams per ha)	93.8	38.0
Total number of giant clams in the area	**309 ± 175**	**1 104 ± 588**
MANGALILIU		
Total number found during the survey	85	257
Mean abundance (giant clams per transect)	2.43	2.82
Mean density (giant clams per ha)	121.4	141.2
Total number of giant clams in the area	**3 109 ± 1 459**	**23 314 ± 5 892**
ANELCOWAT/MYSTERY ISLAND		
Total number found during the survey	12 / 70	17
Mean abundance (giant clams per transect)	0.71 / 1.75	0.74
Mean density (giant clams per ha)	35.29 / 87.5	36.96
Total number of giant clams in the area (*)	**484 ± 348**	**678 ± 425**

Tridacna crocea	INSIDE TABU	OUTSIDE TABU
MAROU		
Total number found during the survey	13	4
Mean abundance (giant clams per transect)	0.52	0.18
Mean density (giant clams per ha)	26.00	9.09
Total number of giant clams in the area	**392 ± 381**	**201 ± 186**
TAKARA		
Total number found during the survey	1	1
Mean abundance (giant clams per transect)	0.06	0.04
Mean density (giant clams per ha)	3.13	2.00
Total number of giant clams in the area	**10 ± 21**	**58 ± 116**
MANGALILIU		
Total number found during the survey	465	553
Mean abundance (giant clams per transect)	13.23	6.08
Mean density (giant clams per ha)	664.29	303.85
Total number of giant clams in the area	**17 000 ± 12 247**	**50 165 ± 23 917**
ANELCOWAT/MYSTERY ISLAND		
Total number found during the survey	0 / 16	0
Mean abundance (giant clams per transect)	0 / 0.41	0
Mean density (giant clams per ha)	0 / 20.51	27.5
Total number of giant clams in the area (*)	-	-

(*) for the Anelcowat area (not including Mystery Island).

4. CONCLUSION

Ecological effects of tabu areas in Vanuatu

Community-based marine resource management may thus now be more widespread in Oceania than in any other tropical region in the world. Tabu areas are examples of simple, widespread tools used for the management of marine resources in Vanuatu. Firmly rooted in the practices of village communities, they contribute to the local restoration of populations of traditionally harvested species through a combination of natural processes (reproduction, recruitment) and human actions (protection from fishing, broodstock aggregation). Abundance, density and biomass of trochus, green snails and giant clams thus showed clear, significant increases inside the tabu areas when compared to the adjacent, unprotected reef areas.

Counterbalancing the effects of overfishing: challenges & issues

Despite these positive trends, effectiveness in the long term depends on the ability of tabu areas to support significant population increases at larger scales, i.e. beyond the physical limits of the tabu areas. The importance of gregarious behaviour for optimal reproduction and/or larval settlement is increasingly recognized for marine invertebrates including trochus, green snails and clams. Since recruitment appears to be strongly density-dependent for these species, increasing their density inside the tabu areas (including through active translocation/aggregation by the local communities) will enhance the spawning success inside the tabu areas. While the results may not be visible in the short term, as larvae can swim long distances during their dispersal phase, benefits are likely to extend well beyond the tabu areas.

Yet, restoring sufficient densities of spawning biomass to counterbalance the effects of global overfishing is a challenge, given the limited extension of tabu areas at country scale. Even with the support of these informal, village-based management practices, self-replenishment at larger scales remains uncertain for green snails and trochus, as evidenced by the low levels of recruitments observed during this study. For slow-growing giant clams, the rate of natural recruitment is generally low and erratic, with alternating irregular "good" or "bad" years. Despite the evidence of intermediate to high fishing pressure on giant clams (e.g. in the Mangaliliu area), large, healthy populations could still be found, counterbalancing the risks of short-term population decline at least for the two major species (*Tridacna maxima* and *Tridacna crocea*). On the other hand, and while this may be partly explained by contrasted habitat preferences, low populations were found for larger target species (*Tridacna derasa, Tridacna squamosa, Hippopus hippopus*) For green snail *Turbo marmoratus*, the surveys emphasized severe population collapse, thus challenging the effectiveness of the conservative measures currently in place. The species is the subject of a national moratorium of 20 years since 2009, but extremely low densities of breeding adults and juveniles suggest that only emergency actions such as translocation or reseeding would likely stop the local extinction of the species (the phenomenon of the "Allee effect").

Finally, the protection effects within the tabu areas are usually temporary: for trochus, a few years before temporary or permanent reopening of the fishing. Information available from other sites suggests that uncontrolled harvest can quickly lead to a severe resource collapse –even if the trochus fishery is reopened for a very short period of time (e.g. a few days). Accumulating high densities of spawning adults to enhance recruitment should be the major goal of tabu areas: these should be considered as "broodstock sanctuarys" where fishing should be avoided as long as population will not have significantly replenished, with strong evidence of natural recruitment.

For open areas, results emphasize strong depletion in all the project sites –and probably at larger, country scale. In Efate and most likely in other islands, the most efficient way to speed up the process of natural recovery would be to fully stop trochus harvest.

As for green snails, the Fisheries Department should be particularly must be particularly vigilant about the risks of local extinction. Short openings may be eventually allowed for particular sites after stock assessment, using proper management and restrictions (e.g. quotas, cf. methodology proposed for sea cucumbers) to avoid uncontrolled harvest that could ruin the ongoing efforts to restore trochus resource in Vanuatu.

5. FINAL RECOMMENDATIONS for trochus

In the present state, trochus populations
CANNOT BE HARVESTED without serious risks

TABU AREAS should be considered as **SANCTUARYS** for broodstock.

- They constitute the last places in Vanuatu where adult density may be sufficient for successful reproduction & recruitment.

- Broodstock aggregation will increase the chance of producing larvae. But recruitment may NOT be enhanced locally if tabu areas they are too small or unsuitable for recruitment.

- Replenishment at significant scale can only be expected through a network of large tabu areas.

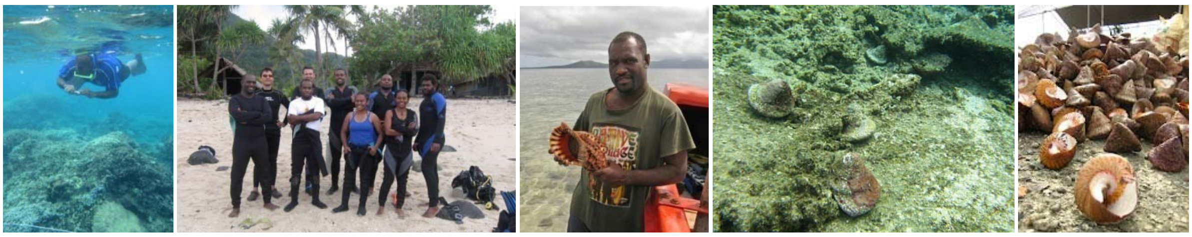
- Increasing their sizes and numbers will enhance the process of natural recovery.

OPEN AREAS are still severely depleted

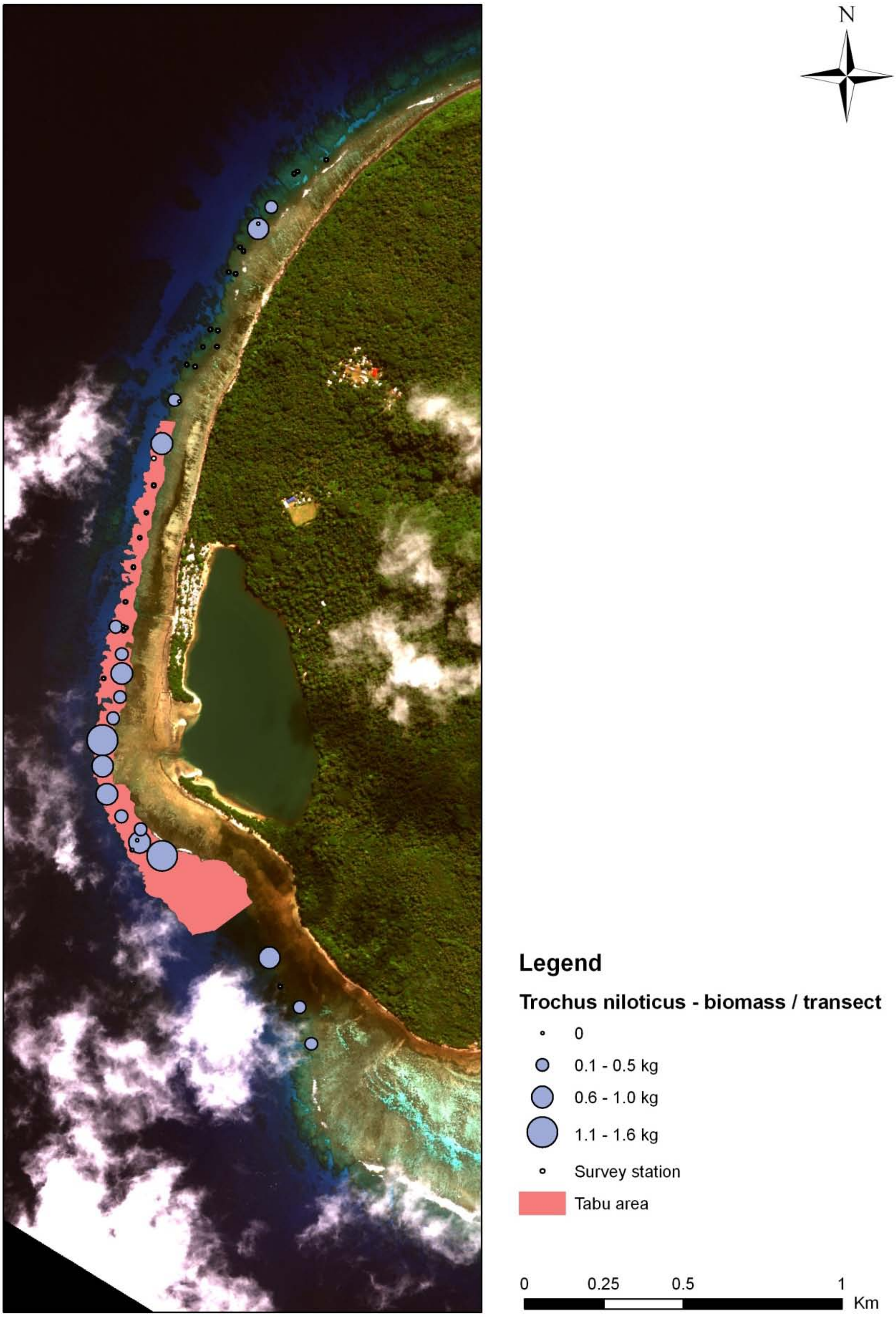
- In Efate and most likely in other islands, the most efficient way to speed up the process of natural recovery would be to fully stop trochus harvest.

- Other studies (GESTRAD) show that local communities may be ready to accept a ban on trochus.

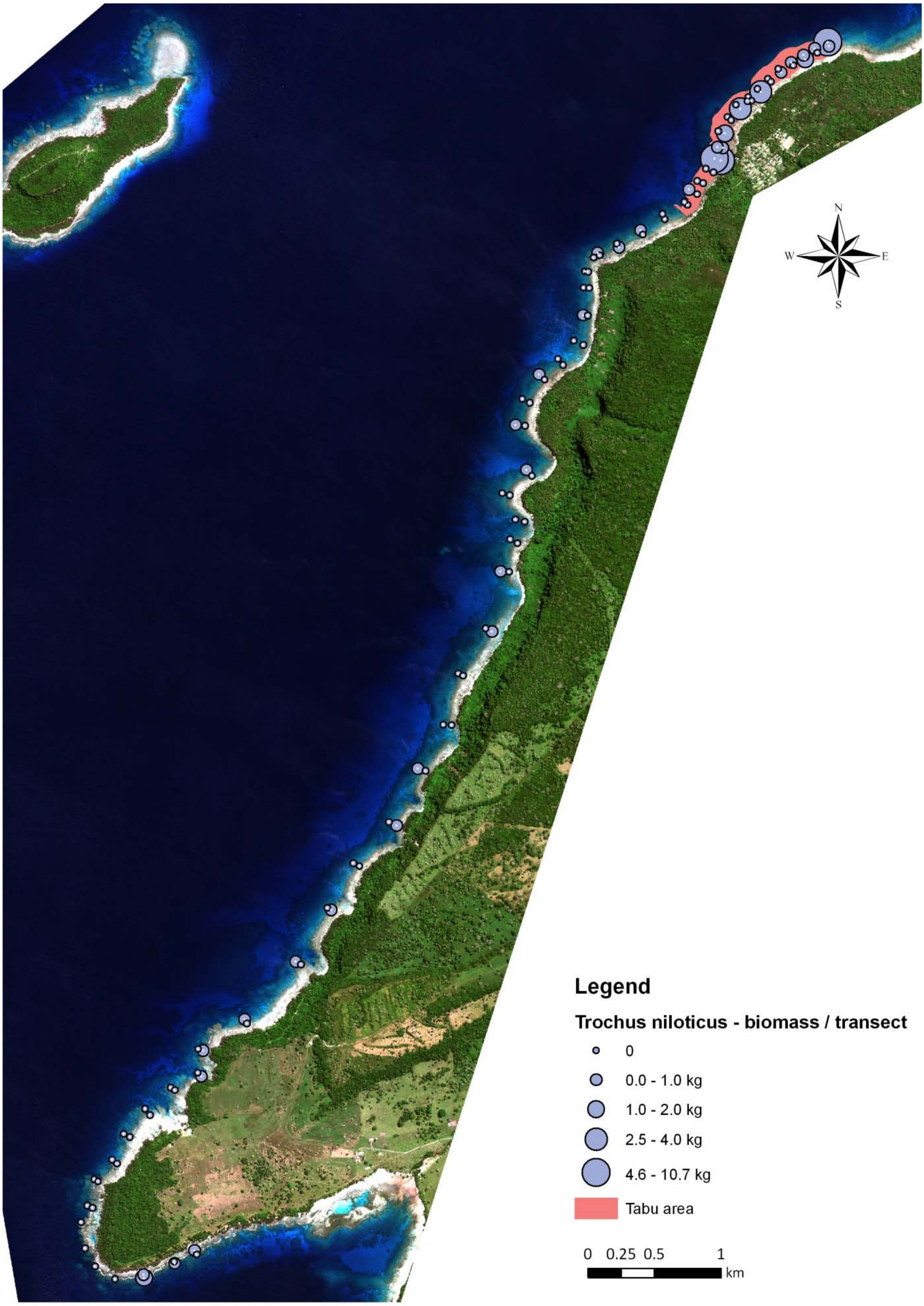
- Harvest may be allowed for particular sites after stock assessment, using proper management methodology (e.g. fishing quotas *–cf. methodology proposed for sea cucumbers).*



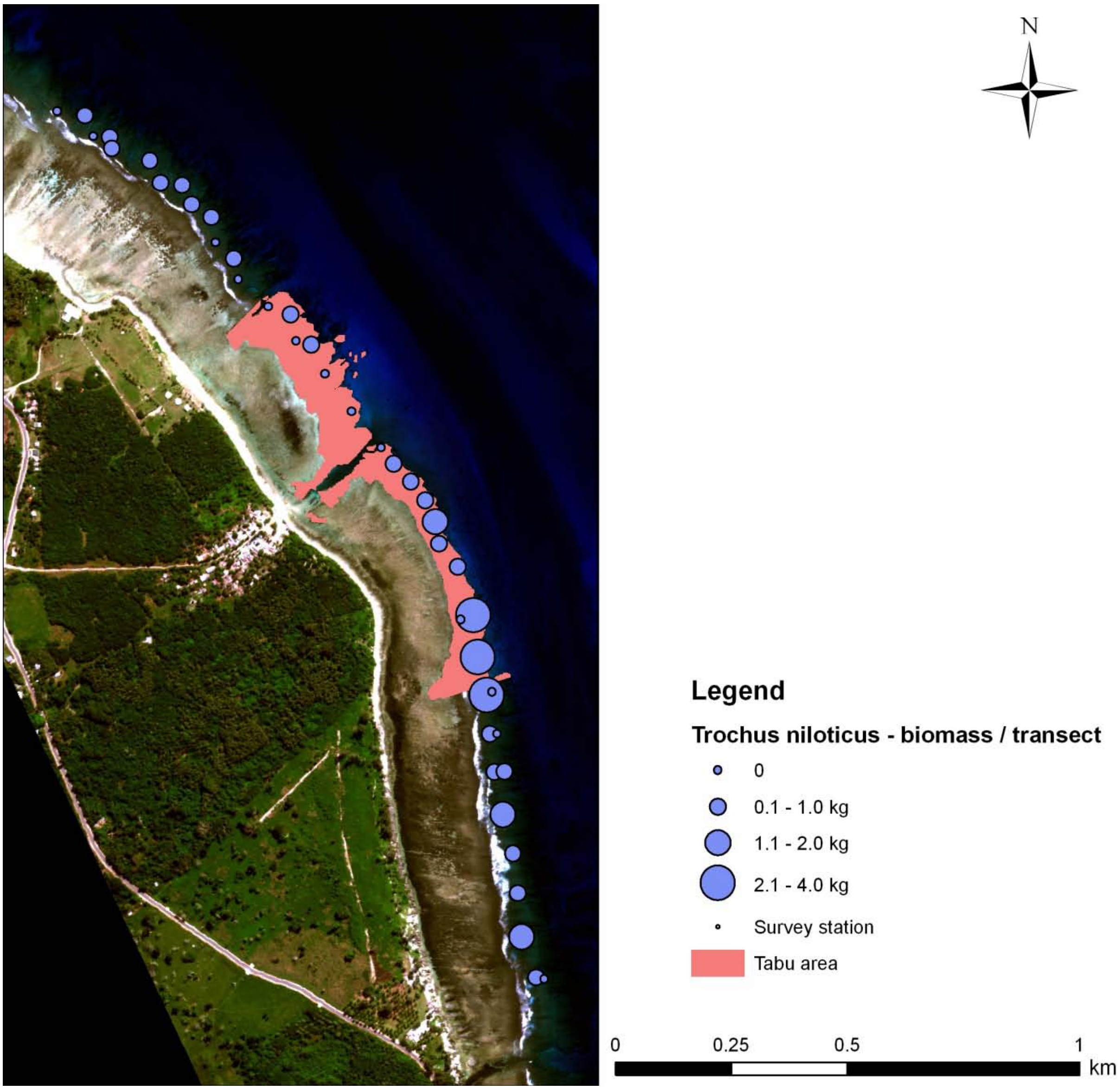
MAP 1. Spatial distribution of Trochus niloticus biomass, Marow area (West Emao).



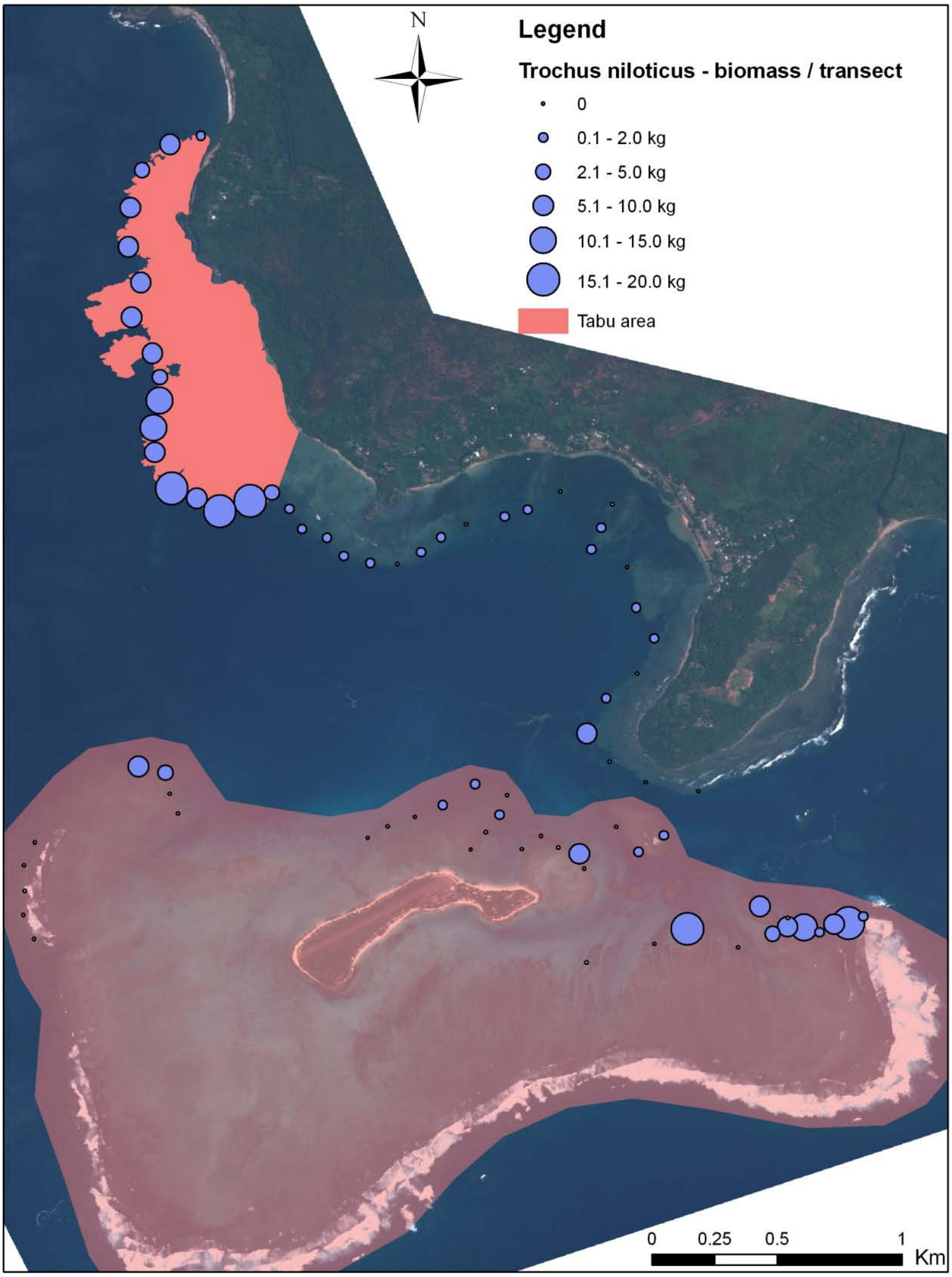
MAP 2. Spatial distribution of Trochus niloticus biomass, Mangaliliu area (North-West Efate).



MAP 3. Spatial distribution of *Trochus niloticus* biomass, Takara area (North-East Efate).

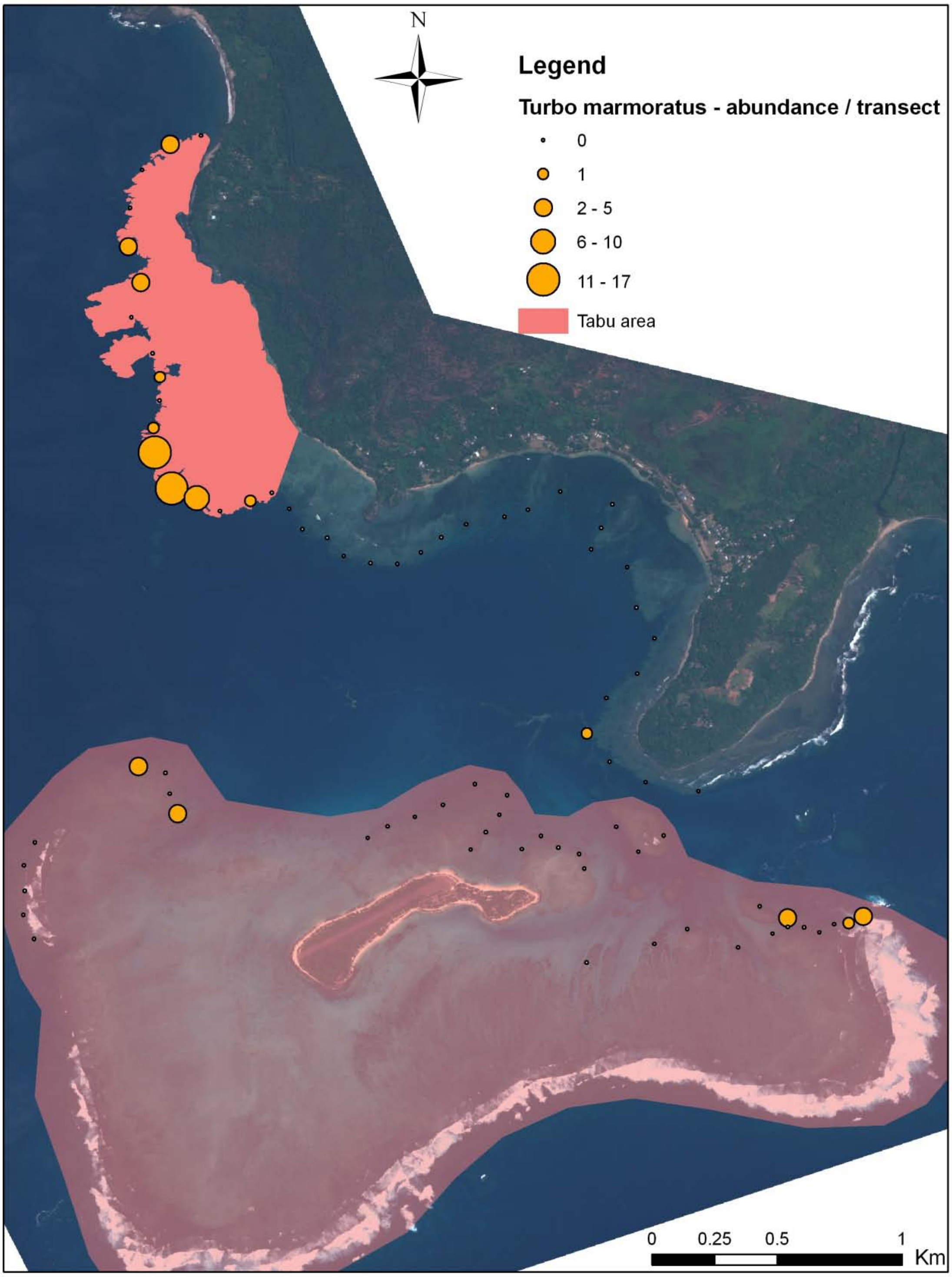


MAP 4. Spatial distribution of *Trochus niloticus* biomass, Anelcowat / Mystery Island area.

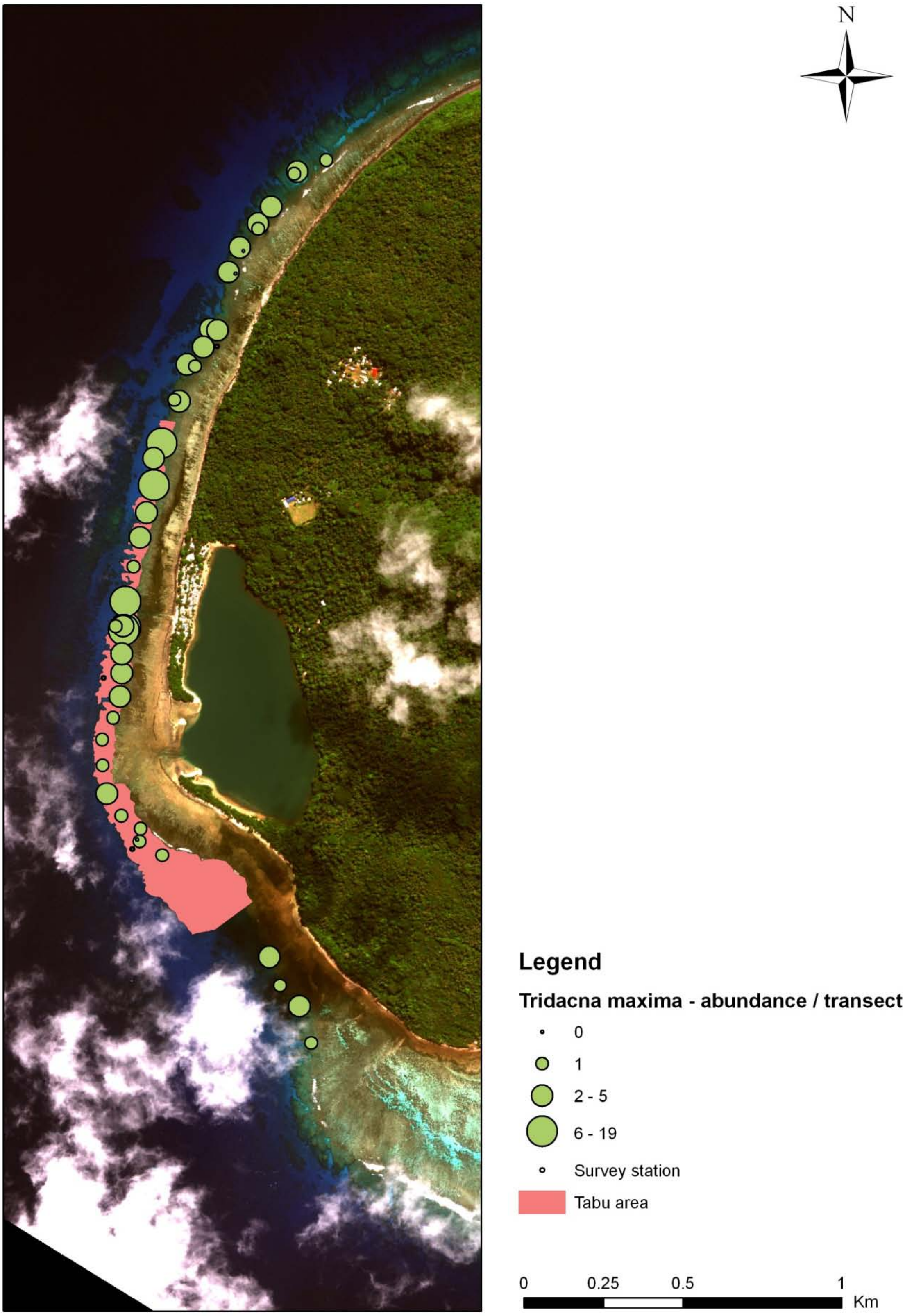


MAP 5. Spatial distribution of *Turbo marmoratus* abundance, Mangaliliu area (North-West Efate).

MAP 6. Spatial distribution of *Turbo marmoratus* abundance, Anelcowat / Mystery Island area

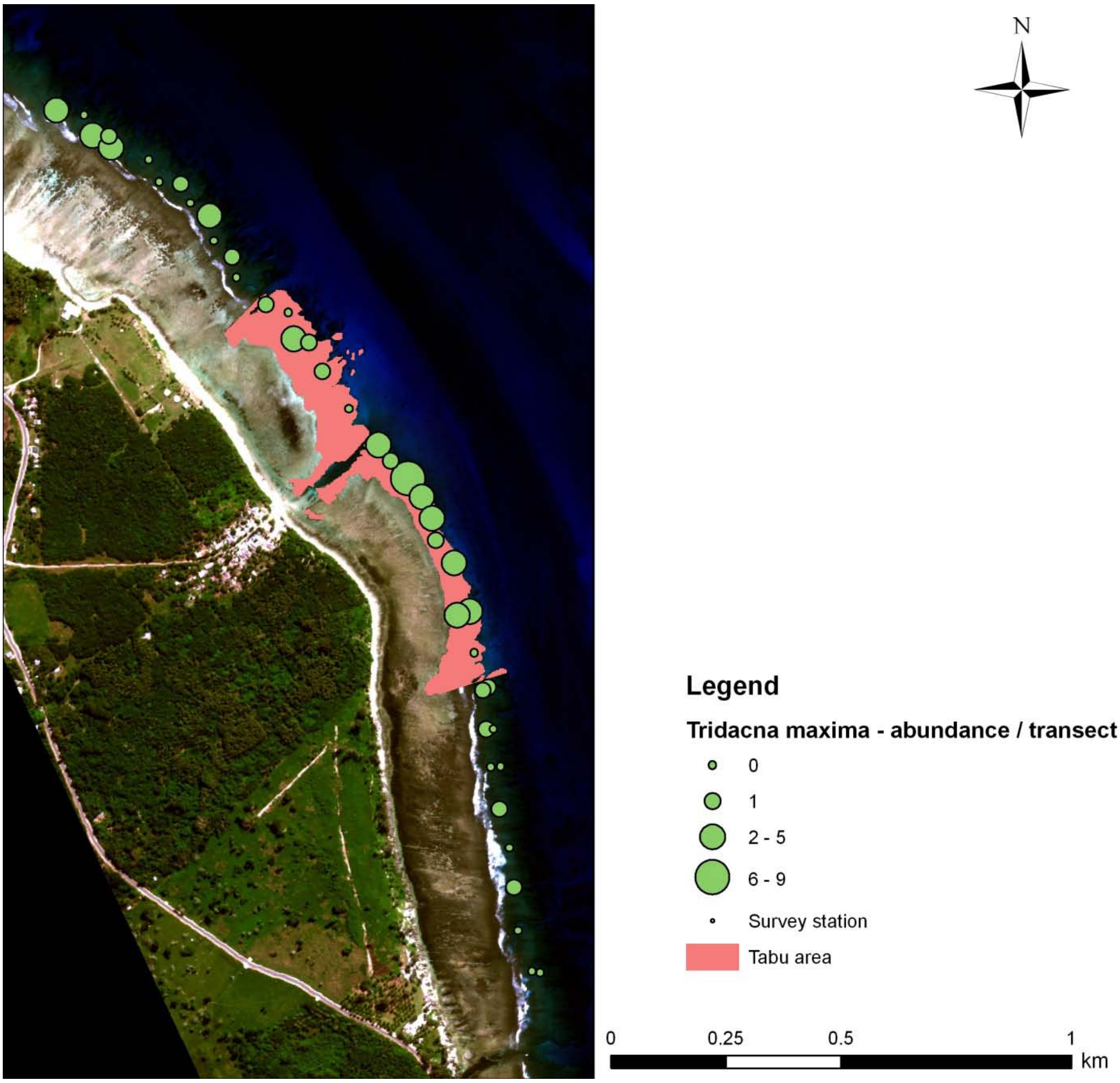


MAP 7. Spatial distribution of *Tridacna maxima* abundance, Marow area (West Emao).

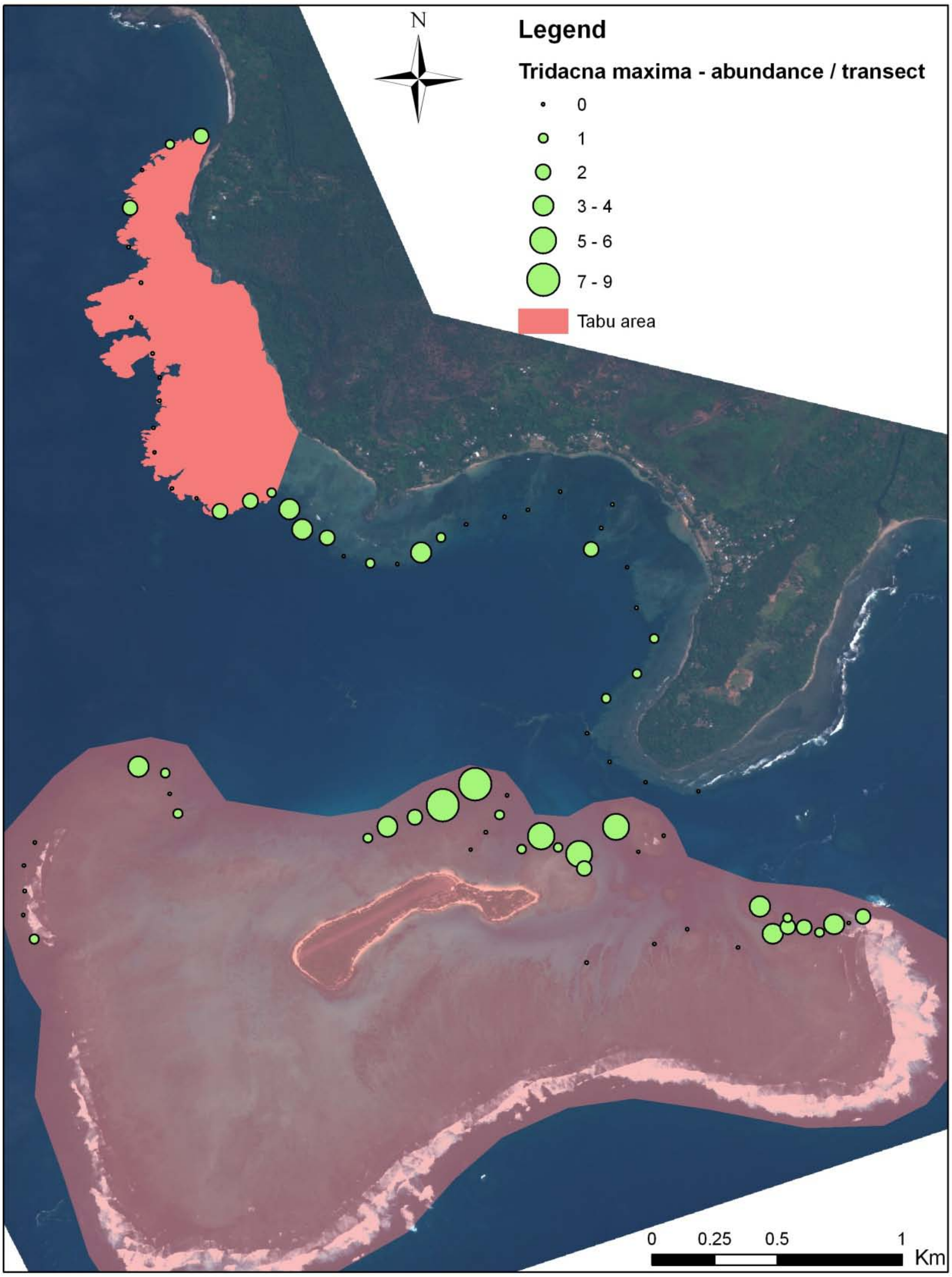


MAP 8. Spatial distribution of *Tridacna maxima* abundance, Mangaliliu area (North-West Efate).

MAP 9. Spatial distribution of *Tridacna maxima* abundance, Takara area (North-East Efate).



MAP 10. Spatial distribution of *Tridacna maxima* abundance, Anelcowat / Mystery Island area



Effects of the movements of *Lethrinus harak* (Thumbprint Emperor, Redmaot) on the effectiveness of community-based management using acoustic telemetry

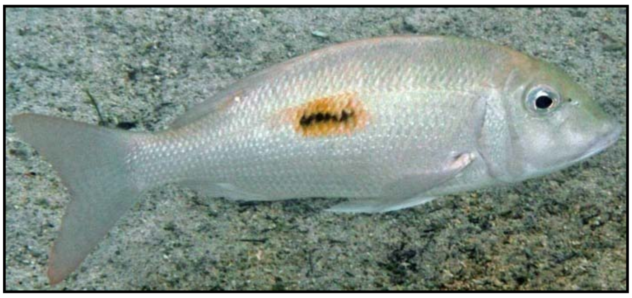
EFITAV project

Efficiency of Tabu Areas in Vanuatu

1. Objectives

Given the small size of the tabu areas in Vanuatu (<1 to 0.1 km²), their ability to effectively protect resources depends partly on the dispersal capacity of target species (reef fish and invertebrates). Highly mobile species will thus tend to get lower protection than highly sedentary species, that would be more effectively protected including within small reserves. Thanks to the recent development of acoustic telemetry, it is now possible to estimate the movement capabilities of fish in their environment.

In the EFITAV project three communities in Efate Island (Emua, Paonangisu, Takara) were selected to conduct an study of the displacement of reef fish adults. An acoustic array has been deployed along 11 km of this coastal area to study the movements and dispersal scales of the Thumbprint Emperor (Redmaot) Lethrinus harak, a common species targeted by fishermen in the area.



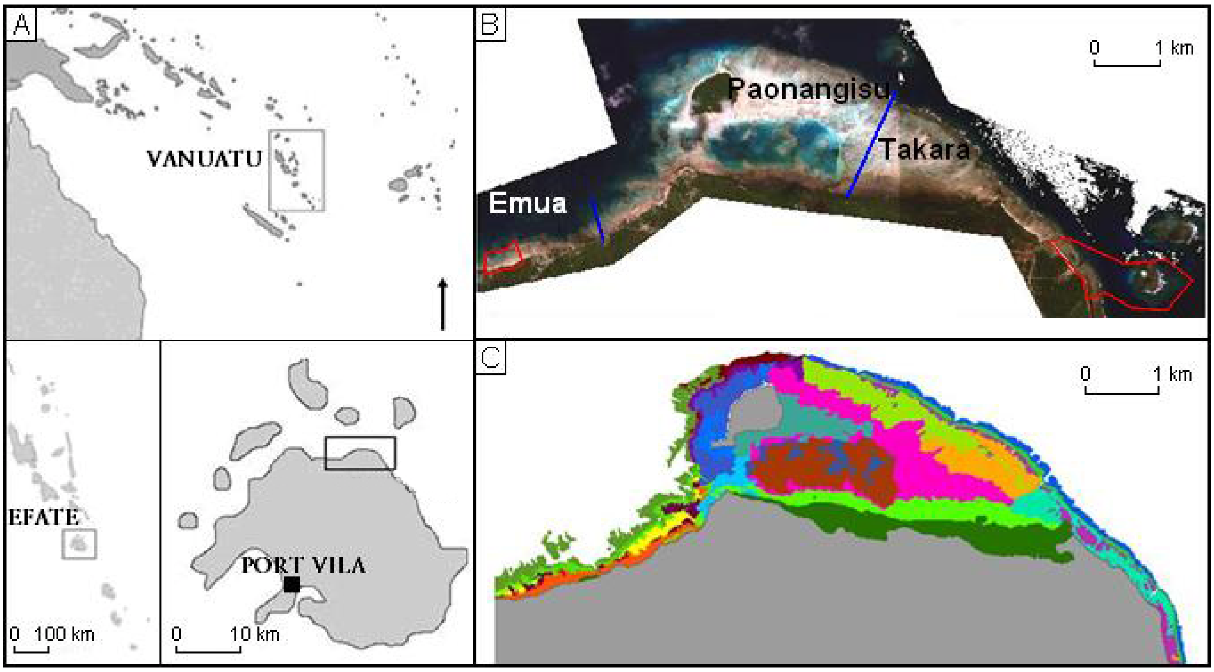
Thumbprint Emperor (Redmaot) *Lethrinus harak*

2. Study sites & Methods

A total of 38 fish, from 16.2 to 32 cm fork length, were fitted with acoustic tags between May and August 2011 in seven sites (Figure 5).

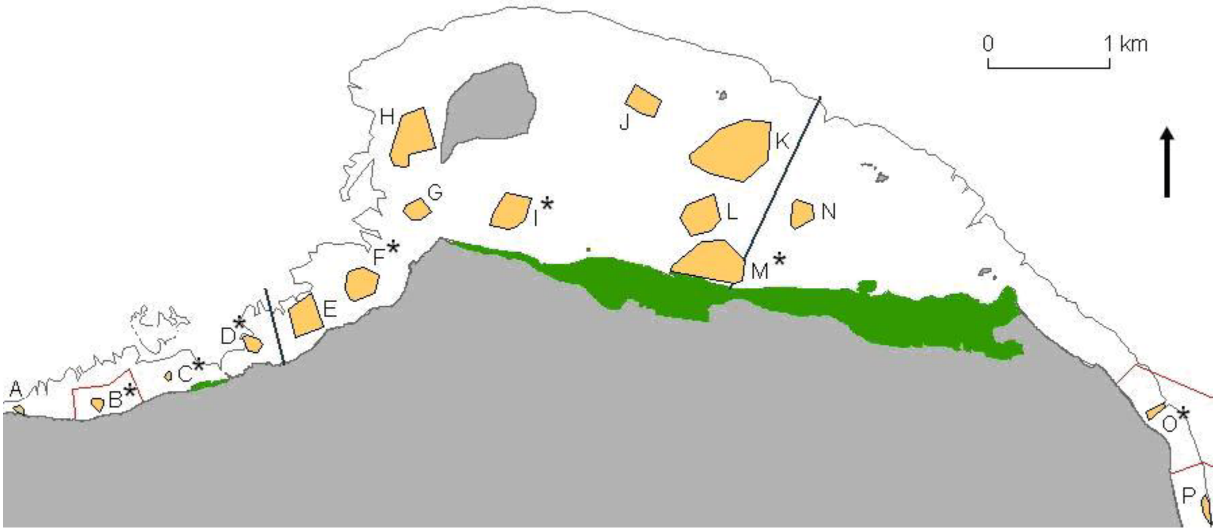
After being caught by line or seine net without injury; the fish were placed in a container where they were anesthetized with clove oil (0.2 ml.L-1). Once asleep, a VEMVO V8-L transmitter was placed in the peritoneal cavity of the fish using surgery. These tags (battery life of about 200 days) randomly emit signals every 90s ± 40s the first 60 days and 240s ± 70s the following days. After closing the incision, the fish were placed in a cage, away from predators, for at least two hours while the effects of the anesthesia wear off. To reduce the stress of capture and handle the fish is as little as possible, all fish were released the same day if possible, or the following morning after capture, in the area of capture.

A network of 16 omnidirectional hydrophones VR2-W VEMCO was installed in the study area. The hydrophones are located between 1.5 and 5 m depth in the three villages in MPAs and unprotected areas and diverse habitats (reef, bowls, lagoon). Where a trade mark issues in the detection range of the hydrophone, it records the identification number of the mark and the date and time of detection. To prevent the movement of the hydrophone linked to the tides and currents, thereby ensuring quality detection constant, the hydrophones are mounted on the substrate.



Study area. Blue lines (B): village boundaries. Red lines (B): tabu areas. C: habitat map derived from photo-interpretation of a high resolution Worldview 2 satellite image.

Data recorded by the hydrophones were downloaded using the VUE software by bluetooth transmission. This operation was performed at sea once a month from June 2011 to April 2012.



Array of 16 acoustic hydrophones (A to P) deployed in the study area. Orange areas: detection area of each hydrophone. Green areas: mangroves. Black line: 10 m depth reef contour. *: tagging sites.

3. Results

3.1. Redmaot exhibited site fidelity

Out of the 38 tagged fish, eight (21.1%) were never detected after release and 30 (78.9%) were detected at least once in the study area between April 2011 and February 2012. The following analysis was focused only on the 30 individuals detected at least once.

The real detection period of these 30 individuals spanned from 1 to 187 days (median: 64 days) and greater than or equal to 10 days for 80% of them.

Their total detection period ranged from 1 to 229 days (median 153 days) and was greater than 60 days 80% of these individuals.

Fish movements were classified into eleven classes according to their detection patterns (in hours) by the 16 hydrophones. These classes can be separated into two groups based on the real detection period. The first group consists of five classes and is composed of nine individuals (30%), including five mature fish (≥ 24 cm), that were rarely detected.

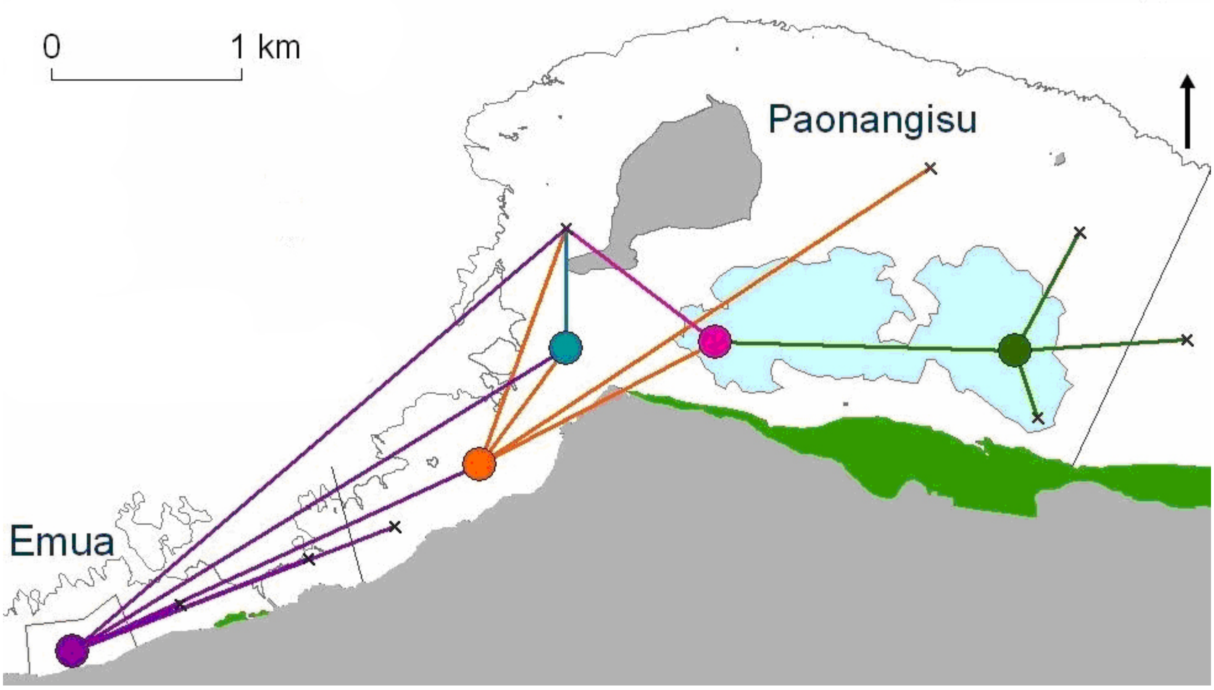
The second group consists of six classes, contains 21 individuals in total (70%), including 17 mature fish. **All individuals detected over 80 hours exhibited high site tenacity**. They were indeed detected during more than 89% of the detection period on a single hydrophone. This type of behavior is common among reef fish, such as Lethrinidae. The day / night activity differed among individuals and over the study area, suggesting that Redmaot may exhibit site fidelity for different activities (ex. feeding area, shelter).

The six classes were composed of one to five individuals. Individuals of the same class have not all been released in the same place and therefore have been caught outside their fidelity zones. The existence of these fidelity zones (centered on a single hydrophone) specific to each class, in the three villages, both in MPAs and in unprotected areas, and in different habitats (reef, pools, lagoon), reveals that **1) there was no home range relocation over the study period and that 2) population of Redmaot was spatially segmented over the study area.**

It is likely that fish from group 1 also present site fidelity and that their site fidelity was located outside the acoustic array that therefore recorded few of their movements).

3.2. How did Redmaot use their home range ?

The extent of the estimated home range of Redmaot varied between 0.1 and 2.5 km for 81.3% of individuals in the survey area, and can reach 3.5 km. This estimate, which directly depends on the location of hydrophones, may however underestimate the real home range of the fish. Within their home range, individuals can travel a minimum of 0.2 to 25.9 km per month (0.9 to 9 km per month for 68.8% of them) at a maximum speed of 1.7 km per hour. Our data on the home range and movement of Redmaot are of the same order of magnitude as those calculated for other reef fish.



Movements of Redmaot Lethrinus harak that were recorded by acoustic telemetry. Circles: observed fidelity sites (core areas) of 1 to 5 tagged fish. Colour lines figure out the minimum distance between fidelity sites and associated excursion site(s). EMUA MPA is also shown.

A maximum of six trips per month by individual was recorded outside fidelity sites. These excursions, which seem not linked to either the tide or day / night hours, are probably not related to the spawning of the species as they occurred throughout the year. They may correspond to exploratory movements as some hydrophones were visited only once. They may also be linked to feeding behavior.

Even if individuals were regularly detected within their fidelity site (more than one out of two days for 71.4% of them), it seems that they do not spend most of their time within this site (less than 16% the total detection period for 76.2% of individuals). Only two fish from Emua MPA were detected more than 68% of their total detection period (in hours) within their fidelity site. **Fidelity sites correspond to "core areas" of the fish home range**. The existence of "core areas" of small size has been observed for many reef fish species and shows **a non-uniform use of the fish home range**.

4. Conclusion

Redmaot home range extends over 1 to 2 km for most individuals and determines the effectiveness of tabu areas. Fish frequently move out of their fidelity site up to several km away. This suggests that if MPAs are much smaller than the fish home range, fish would be vulnerable to fishing. For example, Emua MPA does not effectively protect Redmaot.

Long-distance movements of Redmaot from Emua MPA demonstrate **the continuity of home range along the fringing reef**, across MPA and village boundaries. Redmaot populations that exhibited site tenacity in Emua and Paonangisu therefore seem strongly connected, suggesting to coordinate fisheries management between these two villages. More broadly, **results suggest to define consistent fishing restrictions among neighbor villages to take into account the spatial scale of fish movements**.

Lastly, in order to assess more precisely the effectiveness of community-based multispecies fisheries management and that of MPAs in particular, the movements of other target reef fish species should be investigated.





TRAININGS & TRANSFER OF KNOWLEDGE

EFITAV project

Efficiency of Tabu Areas in Vanuatu

1. Objectives

Improving VFD capacities through scientific collaborations. The Vanuatu Fisheries Department (VFD) is mandated to manage and develop the coastal and offshore fisheries. VFD has engaged in surveys of coastal resources, to provide the Department's policy makers with information on fish and invertebrate stocks. Along with regional partners, VFD implements programs and projects to address issues regarding coastal commercial species, notably reef fish and invertebrate species (giant clams, sea cucumbers, green snails, trochus etc.).

One of the objectives of the project was to strengthen the capacities of VFD in terms of underwater observation methods, stock assessments and GIS (Geographic Information Systems). As part of the EFITAV project, two complementary trainings were conducted at VFD office in Port-Vila in 2011 and 2012, in order to significantly improve the capacities of VFD to collect and analyse biological data on reef habitats and invertebrate resources.

2. Training Workshop 1: "Monitoring reef habitats and invertebrate resources" (21-29 November & 5-9 December 2011).

This training introduced validated, advanced methods for conducting habitat and invertebrate stock assessment. Until recently, resource assessments were carried out by VFD utilising standard SPC / reef-check derived techniques to report on average abundance/density of the main target species. The new methods would report on abundance, density and biomass along with quantitative habitat description. The methods would also provide straightforward estimation on the harvestable stock per species using basic statistical functions through simple, easy-to-use worksheets provided in Excel and/or Access format.

The training was organized in two parts that consisted in: 1) a theoretical training and fieldwork, and 2) two case studies that involved data collection and the use of application softwares to enter and process daily collected data. A competency test was conducted at the end of the workshop to assess the knowledge gained by workshop attendees.

Table 1. Attendees to the 1st training, VFD, Port-Vila (2011).

Andrew William	Aquaculture officer South, Fisheries Department
Betsy Charlie	Project officer, Fisheries Department
George Amos	Fisheries Development officer SANMA, Fisheries Department
Lucy Joy	Senior data officer, Fisheries Department
Rocky Kaku	Project officer, Fisheries Department
Jeremie Kaltavara	Senior Fisheries biologist, Fisheries Department
Jayven Ham	Fisheries biologist, Fisheries Department
Petro George	Environment officer, Wan Smol Bag
Pascal Dumas	Senior Researcher, IRD
Marc Léopold	Research Engineer, IRD
Christophe Peignon	Technician, IRD

2.1 Topics

The training covered 4 main topics:

- Field survey for stock assessment of Trochus and other invertebrates.
- A "quick and clean" photographic method for describing/mapping habitats.
- Basic statistics on quantitative surveys using simple random sampling.
- GPS and related software basics.

A user guide for the 4 tutorials was written by the trainers and given to each participant:
Dumas P., Léopold M. (November 2011). Monitoring habitats and invertebrate resources. 19 p.

The IRD training/assessment has been a new experience to the trainees as it enables an individual to be able to estimate stock abundance, density and biomass via a simple but accurate technique. The training was a stepping stone for the Fisheries Department as it was well in depth and provided accurate estimations in actual figures. The trainings were coordinated by IRD experts whom were able to deliver the course contents with a knowledgeable but informal manner both in theory and fieldwork.

Training workshop 1 - Schedule:

Monday 21st November
- General briefing and basic theory, Fisheries Department
- Trip to first case study site (Marou village, Emao)

Tuesday 22nd to Thursday 24th November
- Fieldwork in Emao island: habitat & stock assessment inside vs. outside the Tabu areas of Marou and Mangarongo villages
- Data management & pre-analysis

Friday 25th November
- Presentation of the results to the community
- Comparison with results from IRD 2008 survey

Monday 28th November
- Habitat description using photographic methods: theory & tools
- Data management and analysis (habitat data)

Tuesday 29th November
- Basic statistics for stock assessment: theory & tools
- Data management and analysis
- Closing ceremony

Monday 5th to Friday 09th December
- Second case studies (Takara village, North Efate) by VFD/WSB team with minimal supervision from the IRD team.

3. Training Workshop 2: "Handling spatial data using Quantum GIS software" (16-20 April 2012).

This second training aimed to make VFD staff familiar with the use of GIS. GIS tools are indeed critical for VFD for a number of common issues, such as designing the spatial sampling of biological surveys and mapping VFD data on coastal fisheries. Quantum GIS software are selected as it is currently one of the best free and user-friendly GIS software. The training was conducted together with SPC as part of the SciCoFish project.

7 officers from Vanuatu Fisheries Department (VFD) and one officer from the Department of Environment attended the training (Table 5) that was held on 16-20 April 2012 in VFD conference room, Port-Vila.

Table 2. Attendees to the 2nd training, VFD, Port-Vila, 2012.

Betsy Charlie	Project officer, Fisheries Department
Kalna ARTHUR	Project officer, Management division, Fisheries Department
Lucy Joy	Senior data officer, Fisheries Department
Rocky Kaku	Project officer, Fisheries Department
Jeremie Kaltavara	Senior fisheries biologist, Fisheries Department
Jayven Ham	Fisheries biologist, Fisheries Department
Graham Nimoho	Manager, Development division, Fisheries Department
Vatumaraca Molisa,	Marine biologist, Department of Environment
Pascal Dumas	Senior Researcher, IRD
Marc Léopold	Research Engineer, IRD
Franck Magron	Research Engineer, SPC

3.1 Topics

The training aimed to give the trainees the following capacities:

- To understand the baseline theoretical foundation of GIS and the scope of map products delivered by Quantum GIS software
- To handle spatial data from different sources (GPS, pre-available GIS layers, new entities from scratch) and of different kind (vector and raster data, point/areas, etc.)
- To create thematic maps for survey planning, data analysis, and project/survey reporting.

Quantum GIS (or QGIS) 1.7.4 software was selected as it is one of the best free and user-friendly GIS softwares. This ensures that further development of QGIS will be available for VFD for free, and that GIS functions would be more easily acquired by the trainees. Given most trainees had not used GIS before, more sophisticated free softwares (such as GvSIG) were not an optimal choice.

The training was composed of 4 intensive one-day tutorials. Each tutorial was conducted such as to train the participants to some specific GIS tools following a step-by-step approach, thus giving more time to practice. **Real data from several invertebrate surveys available through the EFITAV and BICHLAMA projects were used, so as to make the work more realistic.**

The basic GIS tools included in the training had been previously selected by IRD based on current VFD projects and on the most important needs. This was to ensure that the training would effectively be useful for VFD common activities. Sophisticated GIS analyses were deliberately skipped at this stage as they would rather be included in a next advanced training.

A user guide with the 4 tutorials was written by the trainers and given to each participant:
Dumas P., Léopold M., Magron F. (April 2012). Handling spatial data using QGIS. 45 p.

Schedule:
Monday 16th April
General briefing and basic theory, Fisheries Department.
Installation of QGIS software on individual PCs

Tuesday 17th April
Tutorial 1: QGIS Basics (projections, raster/vector data, thematic analyses).

Wed. 18th April
Tutorial 2: Mapping survey data (invertebrates & habitat)
Field trip

Thursday 19th April
Tutorial 3: Dealing with points and sampling designs.

Friday 20th April
Tutorial 4: Dealing with polygons and surfaces
Closing ceremony.

QGIS prove to be a relevant alternative to commercial GIS systems such as MapInfo or ArcGIS. Despite good overall performances and a user-friendly interface, some limitations arose that caused problems to both trainers and trainees. Some additional QGIS plugins proved to be very useful and efficient (Table Manager to delete columns in an existing vector layer), OpenLayers Plugin (to download and display Google Map satellite image as backdrop), and ProfileFromLine (to create sample points at set distances along a path). The software GMapCatcher was also useful to import available GoogleEarth raster images to QGIS.

The training required a high level of concentration from the trainees during the whole step-by-step learning phases. A strong commitment of all the trainee was observed throughout the week: the participation and the motivation were high during the four days, suggesting that the training effectively addressed an important gap in VFD and ED officers' capacities.
While the training could be done in two days, a lot of practice was necessary to overcome practical difficulties and to ensure that skills have been effectively acquired.