Broad-scale assessment of the status of coastal finfish in North Efate, Vanuatu

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Coasts | Climate | Oceans

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Introduction

Coastal fisheries in Vanuatu support important finfish catches for local subsistence and income generation, representing a critical source of protein for ni-Vanuatu people (Friedman et al., 2008; Bell et al., 2011b). Despite the importance of high-valued oceanic tuna fisheries, inshore fisheries in Vanuatu contribute approximately 95% of the overall value of all fisheries to the national GDP (MSGS, 2015). Recent projections identify Vanuatu as one of the PICTs at highest risk to future shortfalls in coastal marine resources to support food security, primarily due to increasing populations and the implications for increased levels of harvesting (Bell et al., 20011b). The island of Efate, with the capital of Port Vila in the southwest, has the highest density population of all Vanuatu's extensive island system. Although North Efate is a rural region with a reliance on fisheries catches primarily for subsistence and local use, communities have reported that coastal reef fish populations have declined dramatically in recent years (RESCCUE community meetings). However, the status of local coastal finfish stocks has generally not been well established. Further, despite the use of tabu areas (marine protected areas), some localised fisheries management plans and some national fisheries regulations aimed at managing invertebrate fisheries, there is effectively no management of coastal finfish resources in North Efate (MSGS, 2015).

Although there has been some work done in North Efate on assessing marine resources, it is generally fragmented in time and space and therefore resource status remains undefined. This is understandable given the difficulty in assessing marine resource status generally, and establishing a baseline of finfish stock status in the region will directly inform communities and government of coastal fisheries management needs. The Vanuatu Fisheries Department (VFD) have recognized this as a need and have longer term goals of establishing a baseline of finfish stock across Vanuatu. Therefore, after consultation with VFD, we conducted finfish surveys at broad spatial scales across North Efate to provide a preliminary assessment of their status in terms of current fishing levels. This will assist in guiding national priorities as well as guiding future fisheries development and management planning of the region.

Methods

Field methods

We conducted underwater visual surveys (UVS) of coastal finfish at broad spatial scales of North Efate to provide preliminary estimates of relative abundance and biomass of key species. After consultation with VFD we agreed on the UVS method adopted by the Secretariat of the Pacific Community (SPC) PROCFish project (Friedman et al., 2008). This method is the distance-sampling underwater visual census (D-UVC) technique described by Labrosse et al. (2002) (Figure 1). The technique involves two divers on SCUBA[1] swimming a 50 m transect measured by one diver laying out the tape as the divers swam along the bottom. Divers recorded on a data sheet fish species name where possible (otherwise Family name), the number sighted, the fishes length and the distance from the transect line. Data were recorded for a selection of key fish families based on their fishery importance and as indicators of coral reef health (Chaetodontidae: Butterflyfishes) (Table 1).

[1] Site RESC01 was surveyed on snorkel due to the very shallow depth.

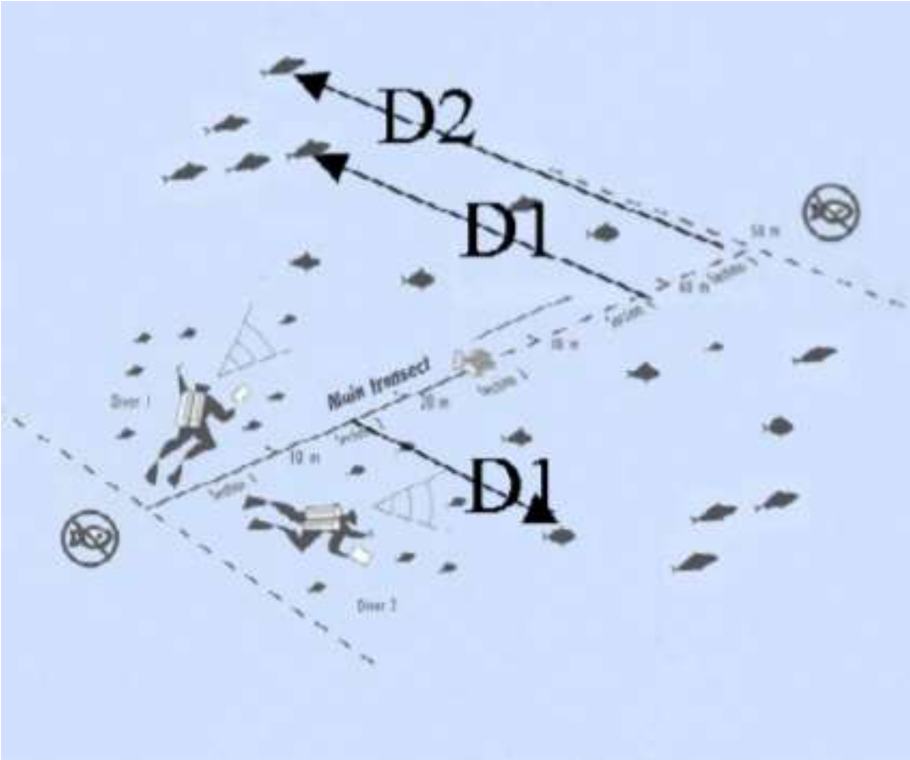

Figure 1. Diagrammatic representation of the distance-sampling underwater visual census (D-UVC) technique used during these surveys (Source: Friedman et al., 2008).

Table 1. Key fish families and their common names recorded during underwater visual surveys based on their local fishery importance and as coral reef health indicators.

Family	**Common name**
Acanthuridae	Surgeonfish
Balistidae	Triggerfish
Chaetodontidae	Butterflyfish
Holocentridae	Squirrelfish/Soldierfish
Lethrinidae	Emperors
Lutjanidae	Snappers
Kyphosidae	Sea chubs
Mullidae	Goatfish
Scaridae	Parrotfish
Serranidae	Groupers
Siganidae	Rabbitfish
Zanclidae	Moorish idol

Field sites

Finfish surveys were conducted from 10 – 15 May, 2016. Survey sites were chosen to coincide with sites already surveyed by the RESCCUE project benthic team and, otherwise were haphazardly chosen to spread effort across the North Efate region (Figure 2). At each site divers randomly chose a swimming direction perpendicular to the reef slope. Three transects were conducted at each site with divers ensuring that there was at least 100 m between transects to minimize the possibility of recounting fish. A total of 10 sites were surveyed for a total of 30 transects ranging in depth from 2 – 12 m (Table 2).

Table 2. Summary of the field survey sites. Three transects were conducted at each site.

Site #	Name	Date	Lat	Long	Depth (m)
RESC15	East Nguna Sth	10/05/16	17° 28.232’ S	168° 23.261’ E	6-8
RESC16	East Nguna Nth	10/05/16	17° 27.648’ S	168° 22.835’ E	5-8
RESC17	Emao Island	10/05/16	17° 28.484’ S	168° 28.402’ E	5-8
RESC18	Paonangisu outer	11/05/16	17° 30.688’ S	168° 25.145’ E	2-10
RESC19	West Nguna	11/05/16	17° 28.574’ S	168° 21.039’ E	5-7
RESC9	West Paonangisu	12/05/16	17° 31.640’ S	168° 23.864’ E	4-6
RESC8	Siviri village	12/05/16	17° 31.323’ S	168° 19.679’ E	4-6
RESC3	Moso Island Nth	14/05/16	17° 32.519’ S	168° 16.212’ E	7-12
RESC4	Moso Island Sth	14/05/16	17° 33.304’ S	168° 14.187’ E	4-7
RESC1	Port Havannah	15/05/16	17° 35.567’ S	168° 14.603’ E	3-4

Figure 2. Map of North Efate showing the finfish survey sites indicated by the red dots. Full names and co-ordinates of the sites are given in Table 2.

Data analyses

Regional groupings

For the purposes of analysis, as well as providing more robust estimates, site data were grouped into broad-scale geographical regions. The basis for these groupings was to include adjacent sites that have a high likelihood of connectivity (with the exception of Emao Island) and also corresponded to regions of existing community networks (Nguna-Pele and Tasivanua) (Table 3).

Parameters

From the raw data collected during the surveys three main parameters were generated for each family in each of the three broad-scale regions. The three key parameters analysed were: i) relative abundance using density estimates (number of fish per unit area; fish/1,000 m^2), ii) biomass (weight of fish per unit area; g/m^2), and iii) mean fish size (cm, fork length (FL)). Finfish data were only analysed at the family level as not all observations could be consistently recorded to the species level. Where data were sufficient for individual species, size distributions were generated.

Table 3. Regional groupings of sites for data analysis.

Broad-scale region	Site #	Site name	Community network
Port Havannah	RESC01	Port Havannah	TasiVanua
	RESC03	Moso Island Nth	
	RESC04	Moso Island Sth	
Undine Bay	RESC08	Siviri village	TasiVanua
	RESC09	West Paonangisu	
	RESC18	Paonangisu outer	
North Efate Islands	RESC15	East Nguna Sth	Nguna-Pele
	RESC16	East Nguna Nth	
	RESC17	Emao Island	
	RESC19	West Nguna	

Results

Finfish population parameters

Density

Across all three regions the most abundant families tended to be Surgeonfish (local name Strong skin) and Parrotfish (local name Blu fis), however the relative densities among regions varied. In Undine Bay the density of Surgeonfish was approximately 4x and 2.5x that found in Port Havannah and North Efate Islands respectively (Figure 3). Parrotfish were most abundant in the Port Havannah and Undine Bay regions where densities were approximately 3x that of North Efate Islands. Moorish idol were notably more abundant in Port Havannah than other regions, and in the North Efate Islands region Goatfish were more abundant than parrotfish. The least abundant families generally across the three regions were Sea chubs, Grouper (local name Los), Squirrelfish/Soldierfish, Emperors and Rabbitfish (local name Pico) (Figure 3). There were no Rabbitfish sighted at any of the four sites within the North Efate Islands region.

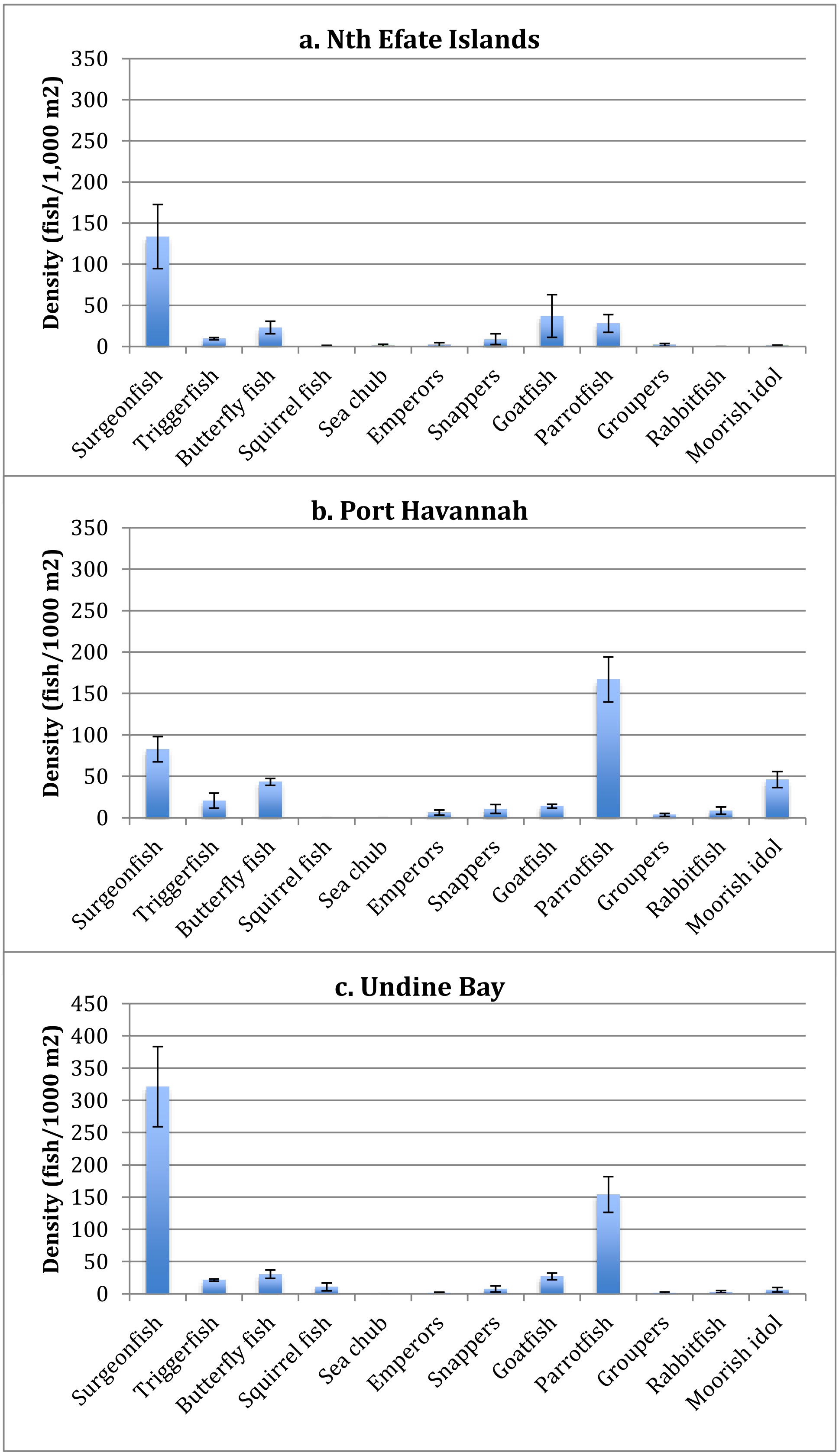

Figure 3. Densities (+/- SE) for the 12 finfish families surveyed for the three broad-scale regions (density is number of fish/1,000 m^2).

Within regions there was also significant variation in the relative density of the different families surveyed. The North Efate Islands region had the lowest overall fish density of all the regions. This was driven mainly by the very low fish densities found in the East Nguna North and West Nguna sites, which had the lowest fish densities of all the 10 sites surveyed (Appendix A).

At the West Nguna site the triggerfish were surprisingly the most dominant family, however all families were in very low abundance at this site. The East Nguna North site, as well as having the 2nd lowest density of all sites overall, was also the least diverse in terms of the survey target species with only 6 of the 12 families present. All other sites had at least 9 of the 12 families present (Appendix A). Surgeonfish were the dominant family in the North Efate Islands region due to relatively high densities in East Nguna South and Emao Island. Sea chubs densities were very low and were only found in the North Efate Islands region, possibly due to their preference for high-energy reef zones.

In Undine Bay Surgeonfish were consistently the most abundant family, followed by Parrotfish (Figure 3; Appendix A). Parrotfish abundance was relatively consistent among the 3 sites, however for surgeonfish the density at the Paunangisu outer reef site was approximately 4x that of the other two sites in this region (Appendix A).

In the Port Havannah region parrotfish was consistently the most abundant family at all three sites. Surgeonfish were the second most abundant family, however with densities among the lowest of all sites surveyed. Butterflyfish were the most abundant in the Port Havannah region and this was consistent among three sites in the region. Moorish idol were also the most abundant in the Port Havannah region however this was due to a single site (Moso Island North) where density was 5x that of the other two sites. Notably, higher trophic level families (Grouper, Snappers (local name Siko), Emperors) were in very low abundance across all the surveyed sites.

Biomass and mean size

Trends in biomass among the broad-scale regions were similar to density with the lowest overall biomass in the North Efate Islands region and the highest in the Undine Bay region. In Port Havannah the parrotfish biomass was approximately 4x that of Surgeonfish (Figure 4). Surgeonfish biomass varied among the three regions with the highest in Undine Bay which was 2x and 4x that of Nth Efate Islands and Port Havannah respectively (Figure 4). Biomass of all other families were relatively low and in Port Havannah the Moorish idol biomass, remarkably, was similar to Surgeonfish, again due to their high density in Moso Island North.

In the North Efate Islands region, although the overall densities were similarly low for the East Nguna North and West Nguna sites, the overall biomass at West Nguna was half that of East Nguna North due to smaller fish on average.

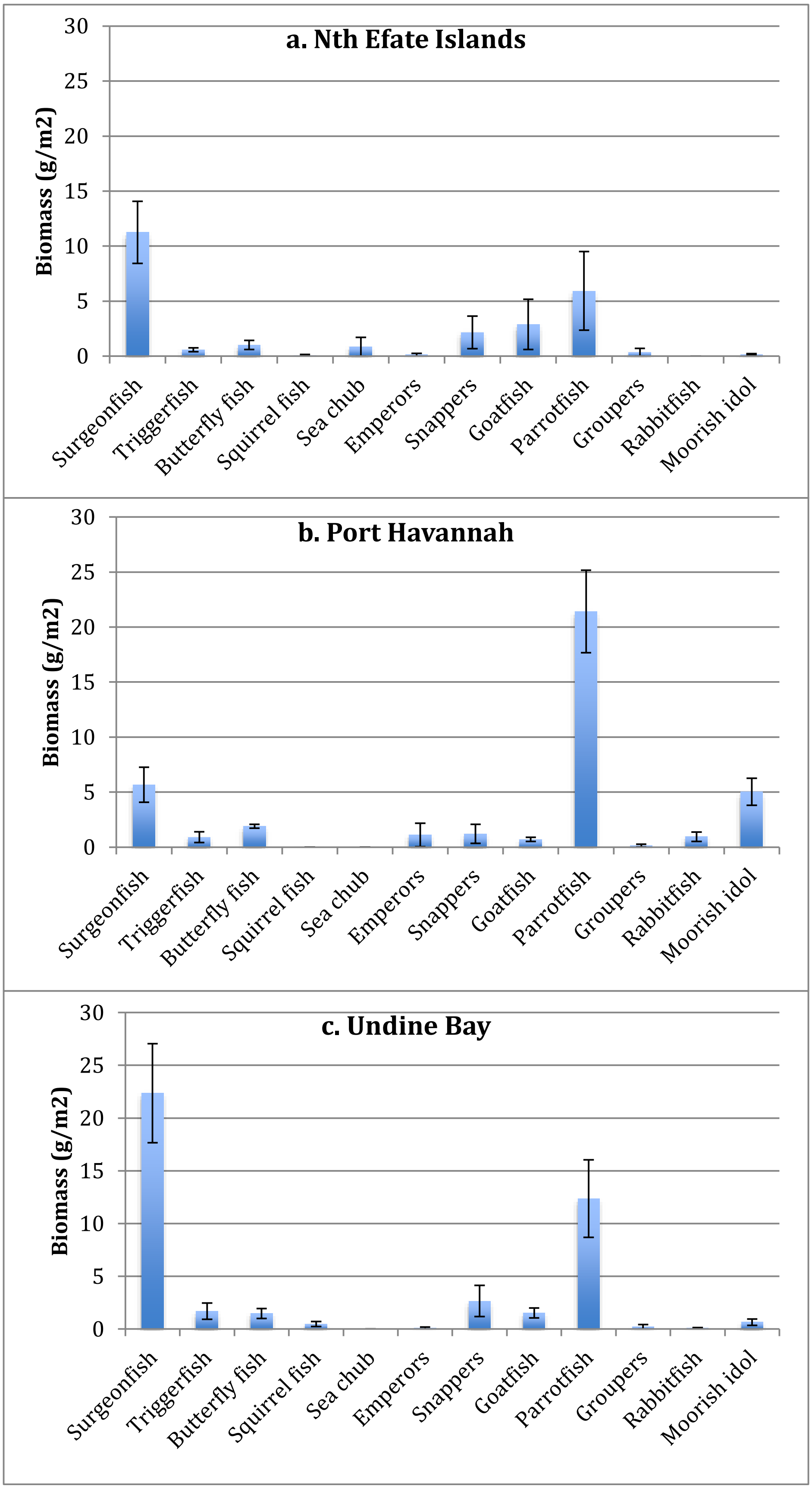

Figure 4. Biomass (+/- SE) for the 12 finfish families surveyed for the three broad-scale regions (biomass is grams of fish/m^2).

The site with the highest biomass of Surgeonfish was the Paonangisu outer reef site due to the much higher density on the reef crest in particular. The Port Havannah site in the Port Havannah region, and the West Nguna site in the North Efate Islands region, each had densities and biomass considerably lower than all other sites. Biomass of Parrotfish was generally consistently with the highest in the Undine Bay and Port Havannah regions. In the North Efate Islands region the Parrotfish biomass tended be relatively low at all sites except for the East Nguna North site where, despite very low density, the biomass was similar to sites in other regions. This was due to Parrotfish at this site having the largest mean size than all other sites (~24 cm FL vs 19 cm FL next largest).

The mean sizes for each family was generally similar for all regions, however was considerably smaller for Grouper in the Port Havannah region compared to the other two regions. Serranid numbers overall, however, were very low. The size distribution of the snapper *Lutjanus gibbus* showed a narrow range of sizes probably due to their schooling behavior which is often size based, however there were very few large fish observed (Figure 5). For the two most common Scarids, *Chlorurus bleekeri* and *C. sordidus*, there was a lack of large fish above the size at maturity (Figures 6 & 7). For the most dominant Acanthurid, *Ctenochaetus striatus*, there were a significant proportion likely to be mature however there were very few larger than 20 cm even though they are reported to attain a much larger size (Figure 8).

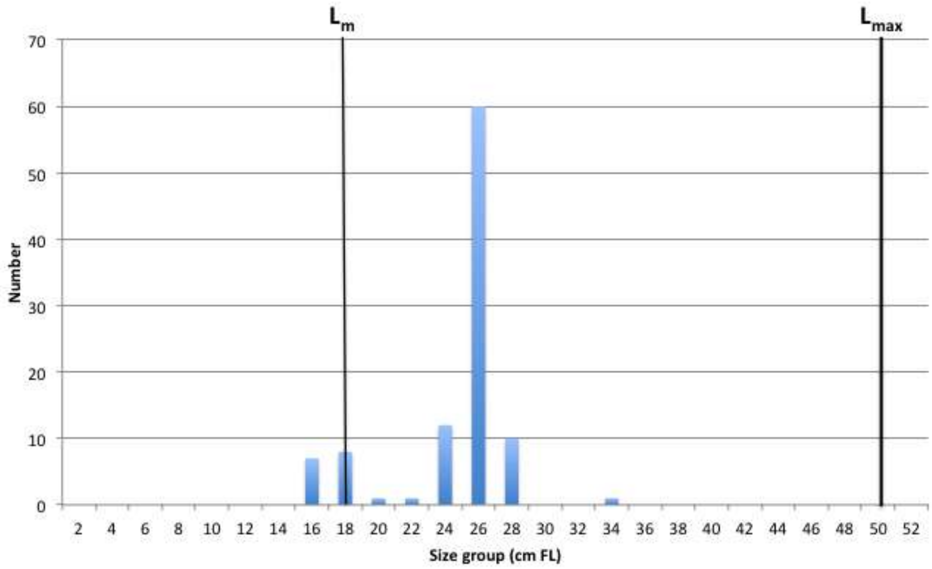

Figure 5. Size distribution of *Lutjanus gibbus* observed across all sites and all surveys. L_m shows the size at maturity and L_{max} shows the reported maximum size.

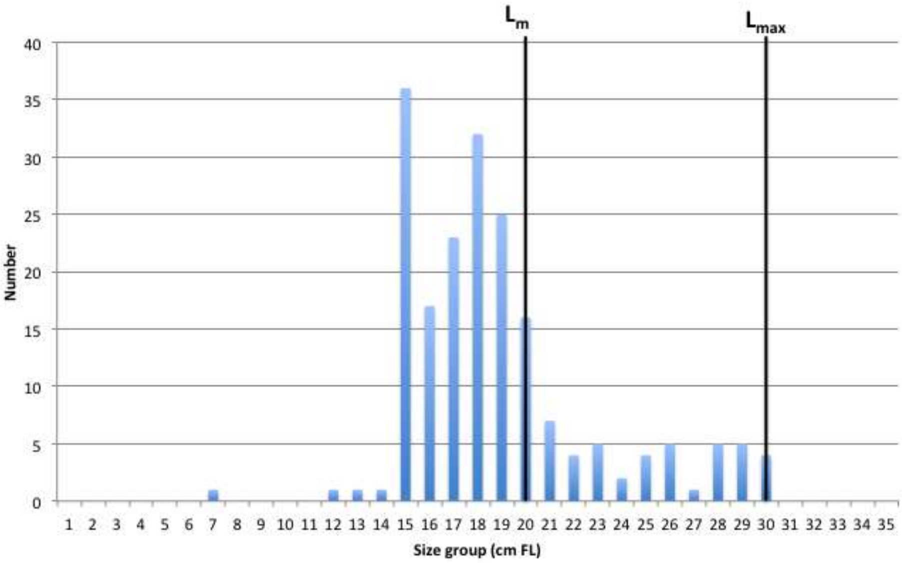

Figure 6. Size distribution of *Chlorurus bleekeri* observed across all sites and all surveys. L_m shows the size at maturity and L_{max} shows the reported maximum size.

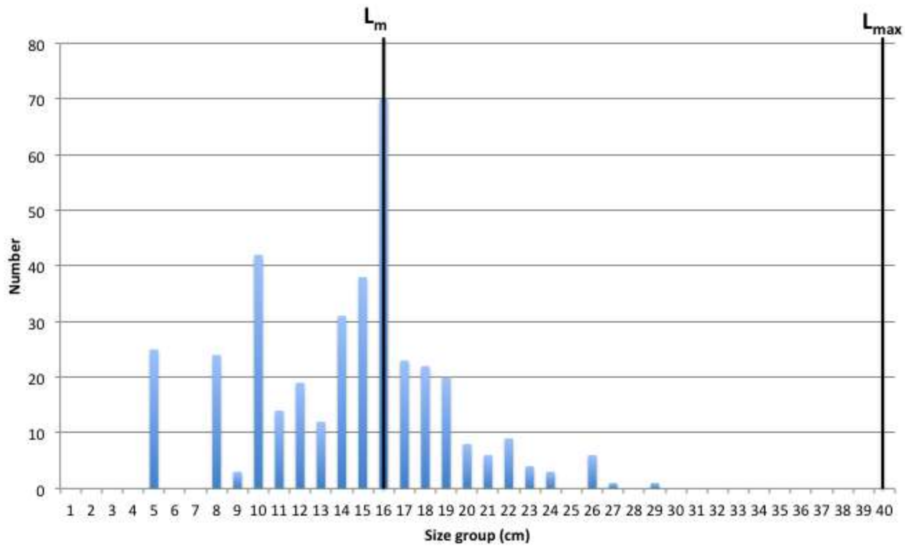

Figure 7. Size distribution of *Chlorurus sordidus* observed across all sites and all surveys. L_m shows the size at maturity and L_{max} shows the reported maximum size.

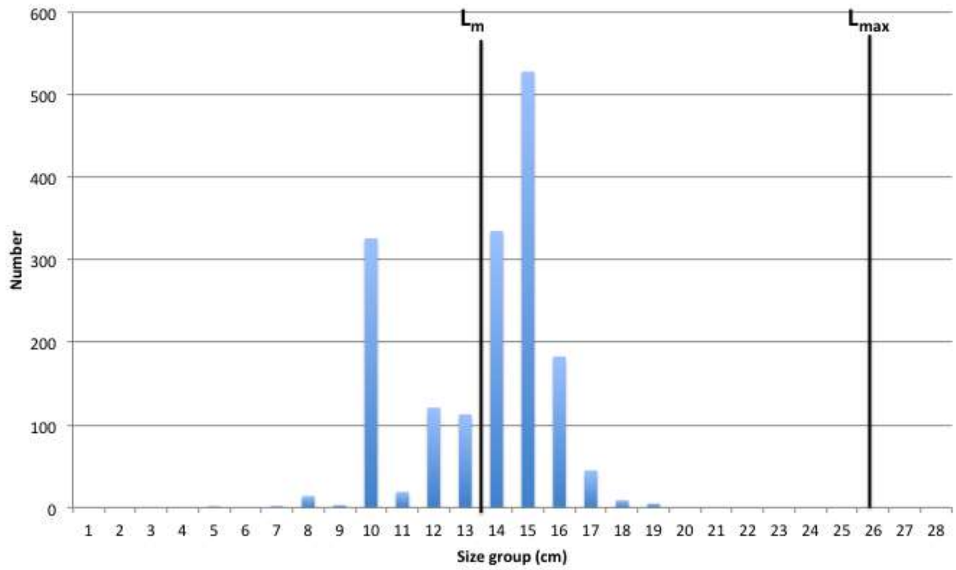

Figure 8. Size distribution of *Ctenochaetus striatus* observed across all sites and all surveys. L_m shows the size at maturity and L_{max} shows the reported maximum size.

Table 4. A compilation of density and biomass estimates from comparable studies in Vanuatu and other regions of the Pacific. Where possible, the status of stocks in the respective studies are also indicated.

Country/ region	Location	Target group	Mean density (fish/1,000 m^2)	Mean biomass (g/m^2)	Notes about status	Reference
Vanuatu, North Efate	***Nth Efate Islands***	Surgeonfish	133	11		This study
		Parrotfish	28	6		
		Snappers	9	2		
		Rabbitfish	0	0		
		Grouper	2	<1		
	Port Havannah	Surgeonfish	83	6		
		Parrotfish	167	21		
		Snappers	11	1		
		Rabbitfish	9	1		
		Grouper	3	<1		
	Undine Bay	Surgeonfish	321	22		
		Parrotfish	154	12		
		Snappers	7	3		
		Rabbitfish	3	<1		
		Grouper	1	<1		
Vanuatu, Efate	Paonangisu sheltered coastal reef	Overall	440	68	Possibly overfished. Confounded by naturally poor habitat	Friedman et al., 2008
	Paonangisu intermediate reef		670	80		
	Paonangisu back reef		340	41		
	Paonangisu outer reef		650	175		
	Paonangisu outer reef	Surgeonfish	~320	~95		
		Parrotfish	~71	~24		
		Snappers	~39	~20		

		Rabbitfish	~1	< 1		
		Grouper	~1	~2		
	Paonangisu all habitats	Surgeonfish	~115	~19		
		Parrotfish	~89	~13		
		Snappers	~26	~8		
		Rabbitfish	~25	~3		
		Grouper	< 1	< 1		
	Moso Island sheltered	Overall	420	76	Local fishing pressure is considered low, given relatively low population and the dominant role of agriculture. Surveys however, noted impacts of fishing, particularly on parrotfish stocks	
		Surgeonfish	~82	~14		
		Parrotfish	~107	~27		
		Snappers	~18	~3		
		Rabbitfish	~27	~8		
		Grouper	~4	< 1		
Vanuatu, Malekula	Uri & Uripiv Islands	Overall	670	210	Local fishing pressure assessed as moderate-high, despite the relatively small local population, low per capita consumption of fresh fish, and strong local management (Uri). Fishing impacts assessed as below average for Vanuatu (PROCFish sites)	
		Surgeonfish	~158	~32		
		Parrotfish	~96	~30		
		Snappers	~63	~32		
		Rabbitfish	~13	~6		
		Grouper	~2	< 1		
PNG	Ahus, Manus Islands	Surgeonfish	~80 - 270	~7 - 28	Only the outer reef location data are presented (which tends to be the highest density zone). The range represents different estimates	Moore et al., 2015
		Parrotfish	~20 - 80	~1 - 7		
		Snappers	~10	~1		
		Rabbitfish	~5	~1		
		Grouper	~5	< 1		

	Andra, Manus Islands	Surgeonfish	~120 - 170		among years (2012 & 2014). No indication of stock status is given except conclusions suggest at least fully fished stocks	
		Parrotfish	~60 - 120			
		Snappers	~3			
		Rabbitfish	~1			
		Grouper	~1			
Australia	GBR, exposed outer reef	Parrotfish	306	92	Virtually unfished; Mean size 15.0 cm FL (*cf*. 14 – 18 cm FL this study)	Gust et al., 2001
	GBR, mid-shelf and sheltered reefs	Parrotfish	76	31	Virtually unfished; 20.8 – 22.1 cm FL	

Discussion

The dominance of Surgeonfish and Parrotfish in the finfish counts across all the sites is common for coral reefs and to be expected given their trophic role as herbivores. Their high relative abundance gave reliable numbers to compare among regions and sites for these two fish families and the notable observation was the high level of variability. This is likely to be due to habitat variability, which was relatively high. In fact the Undine Bay region, which had the highest herbivore density overall, was also found to have the highest cover of macro-algae from the benthic surveys. However, even considering habitat variation, the scarid densities in the North Efate Islands region, particularly at the Nguna sites, were extremely low when compared with densities of other regions in this study (Figure 3; Appendix A). Also, even in sites with relatively healthy habitat (high diversity, structure, coral cover) the density of Parrotfish was very low. They were also significantly lower than other regions in the Pacific thought to be already overfished (Table 4). Further, compared with densities on virtually unfished scarid populations, populations on Nguna Island for example, may be approximately less than 10% of their potential population size. This estimate does not take into account habitat variation although all habitats surveyed tended to be relatively sheltered reef slopes. These data suggest that scarids may be overfished across North Efate with possible localised depletions.

Acanthurid counts were also variable and relatively similar to previous surveys done in Vanuatu and other parts of the Pacific (Figure 3; Table 4). There were two sites, however, where densities were extremely low (52 fish per 1,000 m^2, Port Havannah; 28 fish per 1,000 m^2, West Nguna), which may reflect localised overfishing, although habitat differences is likely to be a contributing factor.

Monitoring of reefs open and closed to fishing on the Great Barrier Reef, where fishing of herbivore species (comprised almost entirely of Surgeonfish, Parrotfish, Rabbitfish) is virtually non-existent, found that total herbivore density was in the range of approximately 150 and 600 fish per 1,000 m^2 with an average close to 400 fish per 1,000 m^2 approximately (Sweatman et al., 2015). In the current study densities of the three main herbivore family groups among all sites tended to be consistently below 400 fish per to 1,000 m^2 although at one site (Paonangisu outer reef) it was over 700 fish per 1,000 m^2. This may be an outlier simply due to habitat differences with it being the only outer reef site while others were sheltered or semi-exposed reef slopes. This comparison suggests that, based on density at least, herbivore numbers in North Efate are relatively healthy. However, at one North Efate Islands site the total density for the three key herbivore families was only ~50 fish per 1,000 m^2, suggesting possible localized high fishing pressure on these fish. These observations are again likely to be influenced by habitat variation however the mean size of the scarids overall were assessed as small compared to other similar regions with correspondingly low levels of biomass. Also, Rabbitfish were in very low numbers and completely absent from the North Efate Islands region. These species are herbivores that are generally common on coral reefs and also known to be targeted by local fisheries. To be totally absent from a total of 12 transects conducted suggests they may be overfished in this region.

Other species groups were in relatively low abundance, which is again to be expected, however there are some notable observations that may be of concern. Piscivores are an important functional group on coral reefs and the two major families surveyed here (Snappers and Grouper) were found to be in very low abundance. Although Serranid densities were similar to previous surveys in the region, it is likely that this species group was already overfished at the time of these surveys (2003; Friedman et al, 2008, Table 4) since groupers have always been a highly prized targeted species across their range and are also easily targeted. Lutjanid densities in the current study were all considerably lower than previous surveys, which suggest population declines for this species group over the past 13 years (Table 4). This would need to be verified with further surveys and species-specific analyses.

The most dominant Acanthurid was *Ctenochaetus striatus* representing nearly 60% of the total observed. Scarids were the most diverse group with 20 different species observed, however two species made up approximately 63 % of the total observed (*Chlororurus sordidus* and *C. bleekeri*). Although there was only a very small total number of Serranids observed they were predominantly (66%) very small *Cephalopholis* species. There were eleven species of Snappers observed although approximately half of these were *Lutjanus gibbus*. Notably, not a single shark was sighted during all the finfish surveys, nor during any of the benthic surveys conducted during this project.

Surgeonfish and Parrotfish, due to their numerical dominance, represent the species groups with the highest biomass across North Efate and regional patterns reflect those of density. Although there was regional variability, overall Acanthurid and Scarid mean biomass was similar despite Acanthurids being far denser. This was due to the higher mean size of Scarids.

Compared to unfished areas on the GBR, the mean size of Scarids in the present study was considerably lower (~16 cm FL this study compared to 21-22 cm FL). Although this may reflect regional differences it is also likely to be due to the effects of fishing. *Ctenochaetus striatus* is reported to be very small on average throughout their range with an average size of 15 cm TL. At all sites in our surveys the average size was similar at 13.47 cm FL (~15 cm TL). *C. striatus* are a fast growing and relatively early maturing species meaning they are relatively less vulnerable to fishing compared to other species. Despite this there were very few fish larger than 20 cm (Figure 8).

Influence of local management

There is currently effectively no management of coastal finfish populations in North Efate. There are local management plans, however these appear to be not well developed, poorly implemented or not implemented at all. Further, most do not address finfish explicitly. Communities in Vanuatu have traditionally used tabu areas for local management for many years. Many communities in North Efate currently have local tabu (no fishing) areas but this study did not conduct finfish surveys inside and outside tabu areas to assess their effectiveness because it was likely that any differences (or otherwise) would be confounded by the fact that almost all tabu areas in the region had recently been opened up by local chiefs as a strategy to improve access to marine resources for food in the aftermath of Cyclone Pam (March, 2015). Many of these tabu areas were still open at the time of the surveys, 14 months after the cyclone.

The use of closed fishing areas as a fisheries management tool has received increasing research attention in the past 30 years. The principle behind closed areas benefiting fisheries is based on two major outcomes: i) the recruitment effect, and ii) the spillover effect (Russ, 2002; Figure 9). The success of tabu areas in benefiting fisheries is dependent on a number of factors. Critically a measure of success relies on clear identification of the purpose of the closed area. For example, tabu areas can be used for the protection of habitats, or to conserve finfish or invertebrate species, or a combination of these. The success of tabu areas can only be measured if what tabu areas are intended to achieve is clearly articulated.

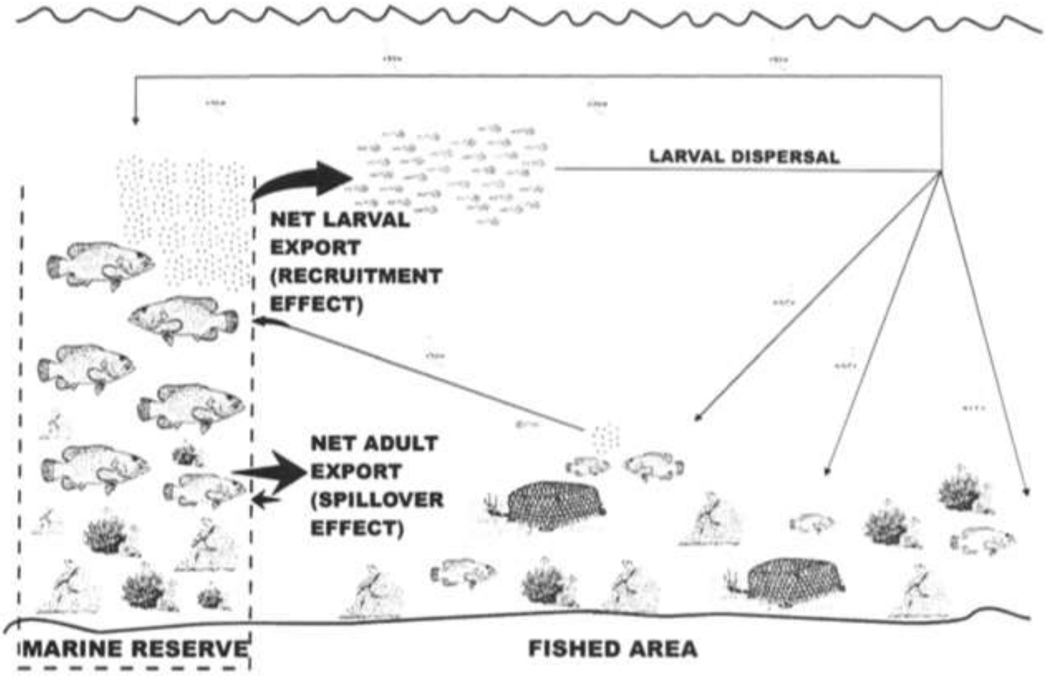

Figure 9. Schematic showing of the principles of tabu areas (marine reserves) in benefiting fisheries through recruitment and spillover effects. (Source: Russ, 2002).

Other factors are also important in determining the success of tabu areas including position, size and governance (Russ, 2002). Position may be important depending on the objectives due to inherent variability in habitat and particular preferences of different organisms. The maximum benefits of tabu areas are also only likely to be realised in the long term if the area is closed permanently since even re-opening a tabu area for a single day can significantly deplete resources. Therefore, adequate enforcement is also important in ensuring the integrity of tabu areas as a successful management measure. Size of the tabu are is important because of the different spatial scales that species require to complete their life cycles. For example, low mobility invertebrate species tend to require smaller areas of protection for populations to successfully rebuild, while larger more mobile fish species will require larger areas to successfully conserve populations (Figure 10; Green et al. 2014).

In North Efate tabu areas vary in size and area and are generally located adjacent to local villages. Their governance also varies with some intended as permanent closures, while others are semi-permanent closures that are opened periodically for special events or traditional reasons (Bartlett, 2009). Almost all tabu areas in North Efate were opened to fishing after Cyclone Pam in March 2015 as a strategy to help relieve food shortages and other hardships faced by communities, and in August 2016 many of these tabu areas remained open to fishing. Therefore, any benefit of these tabu areas, although variable, would have eroded since being re-opened in March 2015.

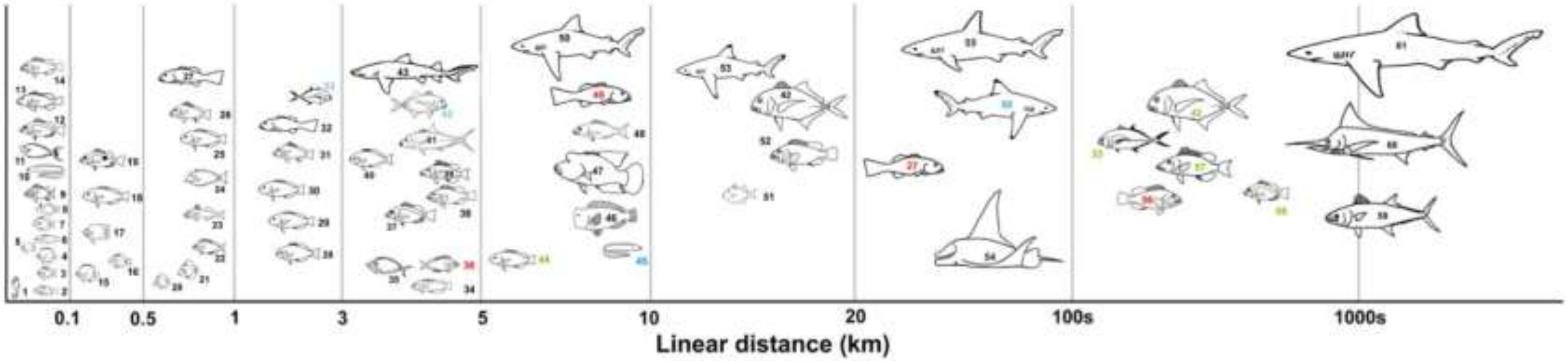

Fig. 1. Linear scale of movement of coral reef and coastal pelagic fish species (modified from Maypa, 2012). Number colours are: black (daily movements: home ranges, territories and core areas of use); blue (ontogenetic shifts); red (spawning migrations); and green (long-term movements of undetermined cause). 1, Seahorses (*Hippocampus* spp.); 2, anemonefishes (*Amphiprion* spp.); 3, most damselfishes (e.g. *Dascyllus* spp.); 4, most butterflyfishes (*Chaetodon* spp.); 5, some angelfishes (e.g. *Centropyge* spp.); 6, some wrasses (e.g. *Halichoeres garnoti*); 7, some surgeonfishes (e.g. *Acanthurus lineatus*); 8, orangespotted filefish (*Cantherhines pullus*); 9, some soldierfishes/squirrelfishes (*Holocentrus* spp./*Myripristis* spp.); 10, moray eels (*Gymnothorax spp.*); 11, bignose unicornfish (e.g. *Naso vlamingii*); 12, some snappers (e.g. *Lutjanus carponotatus*); 13, some groupers (most *Cephalopholis* spp.); 14, some groupers (*Ephinephelus* spp.); 15, some butterflyfishes (e.g. *C. striatus*); 16, some surgeonfishes (e.g. *A. coeruleus* and *Ctenochaetus striatus*); 17, some angelfishes (*Holocanthus/Pomacanthus* spp.); 18, some parrotfishes (some *Scarus/Sparisoma* spp.); 19, some snappers (e.g. *L. ehrenbergii*); 20, yellow tang (*Zebrasoma flavescens*); 21, twotone tang (*Z. scopas*); 22, some rabbitfishes (e.g. *Siganus lineatus*); 23, goatfishes; 24, bluespine unicornfish (*N. unicornis*); 25, some parrotfishes (e.g. *Scarus rivulatus*); 26, some grunts (e.g. *Haemulon sciurus*); 27, squaretail coralgrouper (*Plectropomus areolatus*); 28, Bermuda sea chub (*Kyphosus sectatrix*); 29, some parrotfishes (*Chlorurus* spp.); 30, ember parrotfish (*S. rubroviolaceus*); 31, goldspotted sweetlip (*Plectorhinchus flavomaculatus*); 32, some groupers (e.g. *P. leopardus*); 33, bigeye trevally (*Caranx sexfasciatus*); 34, some wrasses (e.g. *Coris aygula*); 35, some surgeon/unicornfishes (e.g. *A. blochii* and *N. lituratus*); 36, shoemaker spinefoot (*S. sutor*); 37, red snapper (*L. campechanus*); 38, some groupers (e.g. *C. sonnerati* and *E. coicoides*); 39, some emperors (e.g. *Lethrinus nebulosus*); 40, silver drummer (*Kyphosus sydneyanus*); 41, kingfishes (*Seriola* spp.); 42, giant trevally (*C. ignobilis*); 43, lemon sharks (*Negaprion* spp.); 44, blue-barred parrotfish (*S. ghobban*); 45, Indonesian shortfin eel (*Anguilla bicolor bicolor*); 46, bumphead parrotfish (*Bolbometopon muricatum*); 47, humphead wrasse (*Cheilinus undulatus*); 48, green jobfish (*Aprion virescens*); 49, leopard coralgrouper (*P. leopardus*); 50, whitetip reef shark (*Triaenodon obesus*) and nurse shark (*Ginglymostoma cirratum*); 51, grey triggerfish (*Balistes capriscus*); 52, gag grouper (*Mycteroperca microlepis*); 53, blacktip reef shark (*Carcharhinus melanopterus*); 54, manta rays (*Manta* spp.); 55, Galapagos shark (*C. galapagensis*); 56, Nassau grouper (*E. striatus*); 57, trumpet emperor (*L. miniatus*); 58, mangrove red snapper (*L. argentimaculatus*); 59, tuna; 60, marlin/swordfish; 61, tiger shark (*Galeocerdo cuvier*). Most illustrations were modified from Randall, Allen & Steene (1997), *B. muricatum* was modified from Gladstone (1986) and some were drawn by A.P. Maypa. Table 1 provides specific values and additional species.

Figure 10. Linear estimates of movement rates for different species types as an indicator of relative tabu area size for effective protection for fisheries benefits. Original figure legend is included for reader reference to species information. Source: Green et al., 2014.

Also, given that tabu areas are implemented at the village level, most are small in area and tend to cover the narrow fringing reef area along the coast (see Figure 2 in the action plan). The effective length of these tabu areas ranges from 250 m for Tanoliu to 2360 m for Natapau (Table 5). Therefore, based on Figure 10, the effectiveness of these tabu areas based on size alone will be limited to invertebrates and only some species of coastal finfish. A study in North Efate in 2011-12 concluded that tabu areas in the region were effective at providing sanctuary for trochus, however were not effective in protecting the roving emperor species, *Lethrinus harak* (Dumas et al., 2012).

Table 5. Lengths of the current tabu areas across North Efate.

Network	Village	Length of current marine protected area (m)
Tasi-Vanua network	Epao	740
	Ekipe	1340
	Takara	1350
	Port Havannah	1720
	Paonangisu	0
	Emua	0
	Tasariki	1990
	Sunai	1660
	Tanoliu	250
	Ulei	480
	Saama	680
	Siviri	780
	Mangaliliu	1300
	Natapau	2360
	Wiana (joins up to Laosakay)	510
	Marou (not including lagoon)	600
	Laosakay (joins up to Wiana)	430
Nguna-Pele Network	Worearu	460
	Piliura (joins up to worasiviu)	560
	Worasiviu (joins up to Piliura)	580
	Laounamoa	590
	Woralaapa (joins up to Nakapa)	180
	Nakapa (joins up to Woralaapa)	370
	Taloa	510
	Utanlangi	700
	Mere	670
	Unakapu	440

The use of tabu areas to provide fisheries benefits in North Efate would ideally target not only invertebrates, which are important for food and incomes, but also coastal finfish species that are a very important subsistence commodity in the region, especially as overfishing is evident. Although for some communities there are management plans for local tabu areas (but see above), the inclusion of an objective of the tabu area is unclear but reported to be not well documented. This is a community decision and in the future, agreement and articulation of the purpose of tabu areas will assist in choosing appropriate locations, sizes and governance frameworks. If developed and implemented appropriately tabu areas have the potential to assist in ensuring sustainable coastal fisheries in the future for North Efate. However, given the evidence that overfishing is likely to be occurring, achieving sustainability will require complementary fisheries management measures.

Main conclusions

- The generally productive life cycle characteristics of herbivore species make them less vulnerable to overexploitation, however there are several indications that this important species group may be overfished in some areas.
- Total herbivore abundance, and in particular scarids, in the North Efate region is particularly low. Also, the mean size of scarids compared to unfished populations in other regions is small.
- Piscivores are in very low abundance, biomass and their mean sizes are relatively low suggesting these species groups may be overfished. There is evidence of declines in lutjanid populations in recent years, likely due to fishing pressure, and serranid numbers are particularly low with most species being very small grouper species.
- Sharks were completely absent from all surveys. These are top order predators that play an important ecological role and usually have a visual presence on healthy coral reefs.
- These results show indications of overfishing occurring in the North Efate region, however further surveys and species-specific analyses are recommended. Collection and analysis of species-specific catch data would also help to inform the status of coastal reef fish populations.
- There is clear evidence of overfishing of certain species groups in North Efate and this will only be rectified with the introduction of appropriate management measures and significant resourcing of relevant education and awareness raising will be critical to their successful implementation.
- The current design, size and use of the majority of tabu areas in North Efate are highly unlikely to provide ongoing benefits to fisheries and communities. However, they have the potential to assist in rebuilding fisheries populations if used in conjunction with other fisheries management measures.

Recommendations

- <u>Capacity building</u> in local resource management planning and development is required at both community and government levels to empower the urgent need for management of coastal fisheries resources. This should include <u>support in the development</u> of coastal fisheries (invertebrates and finfish) management plans and their implementation.
- Education and awareness raising, particularly at the community level, will be critical for the successful implementation of coastal resource management. An <u>education and awareness raising strategy</u> should be developed to support resource management initiatives that is to be adequately resourced, and should be targeted and appropriate to the audience. This will be key to communities fully understanding the need for management and to the support and respect of management measures and processes.
- A community-based <u>review of local tabu areas</u> is needed to assist communities to use tabu areas effectively for future marine resource conservation and fisheries management. This has been partially achieved by the RESCCUE marine team however now requires further consultation to ensure the use of tabu areas in the future maximize their benefits to communities.
- In collaboration with communities, alternative sources of fish for food for local communities (e.g. tilapia grow-out tanks, near shore FADs, etc.) should be explored, to help take pressure off coastal fisheries and as incentives to maximize the adoption and uptake of management.

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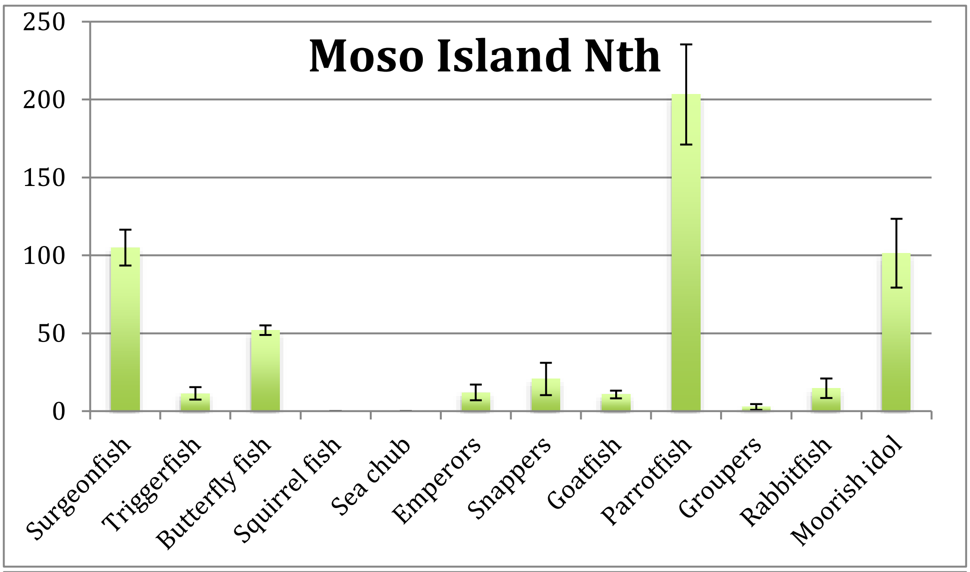
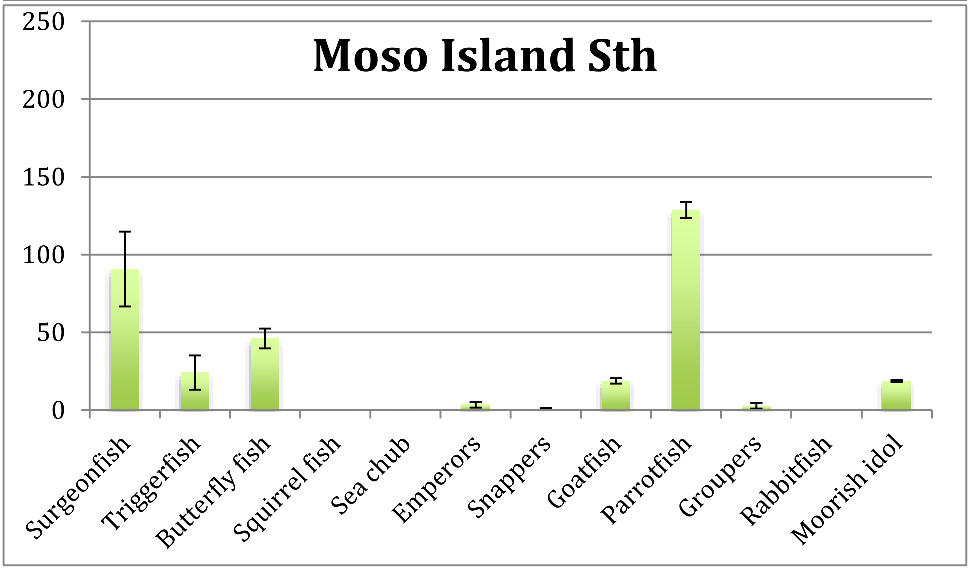
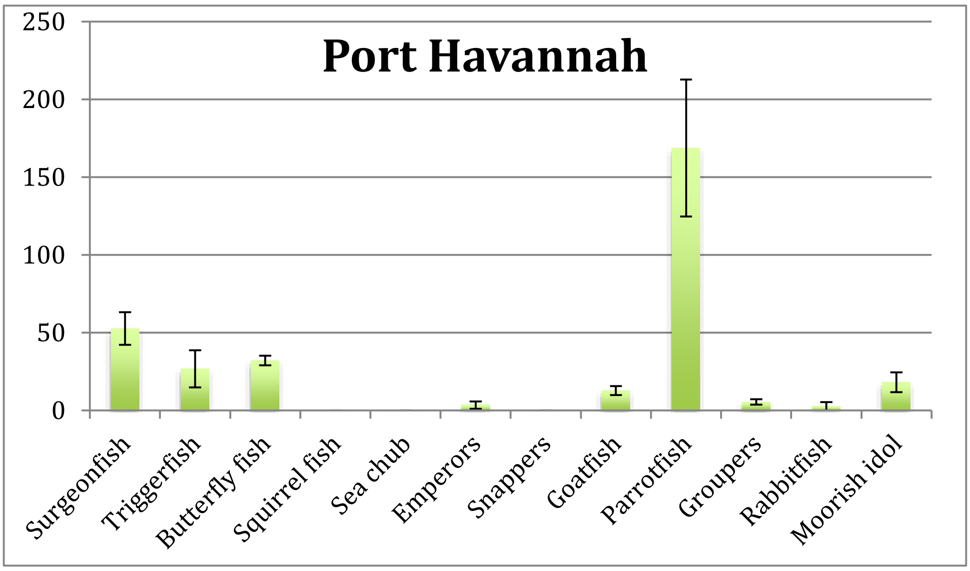
Appendix A

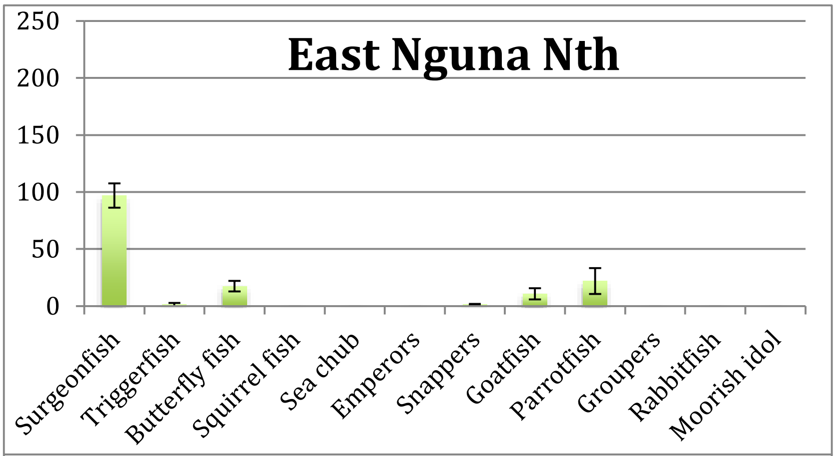
PORT HAVANNAH REGION

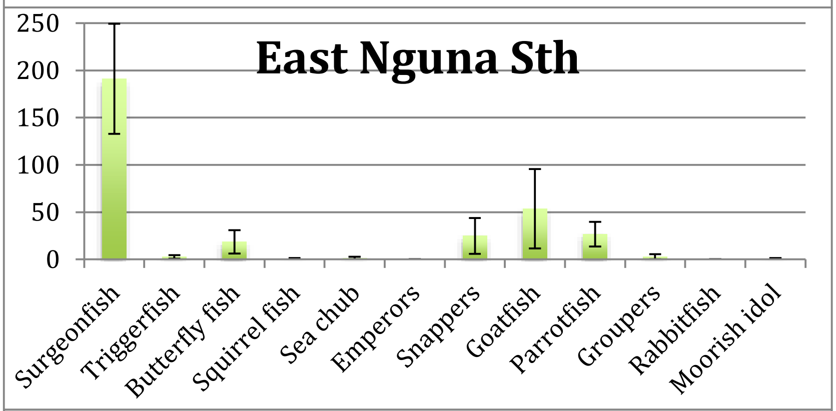


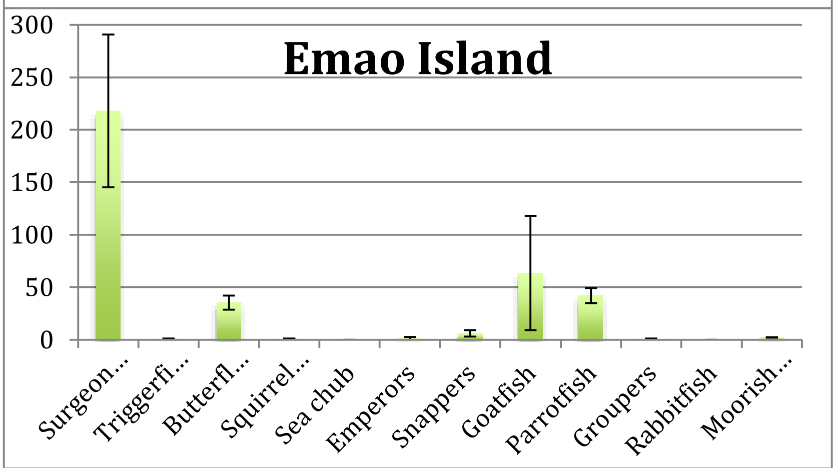


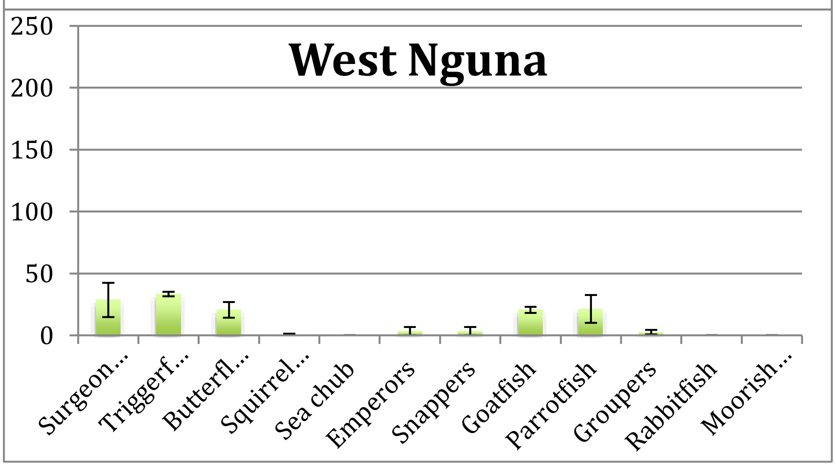


NORTH EFATE ISLANDS REGION









UNDINE BAY REGION