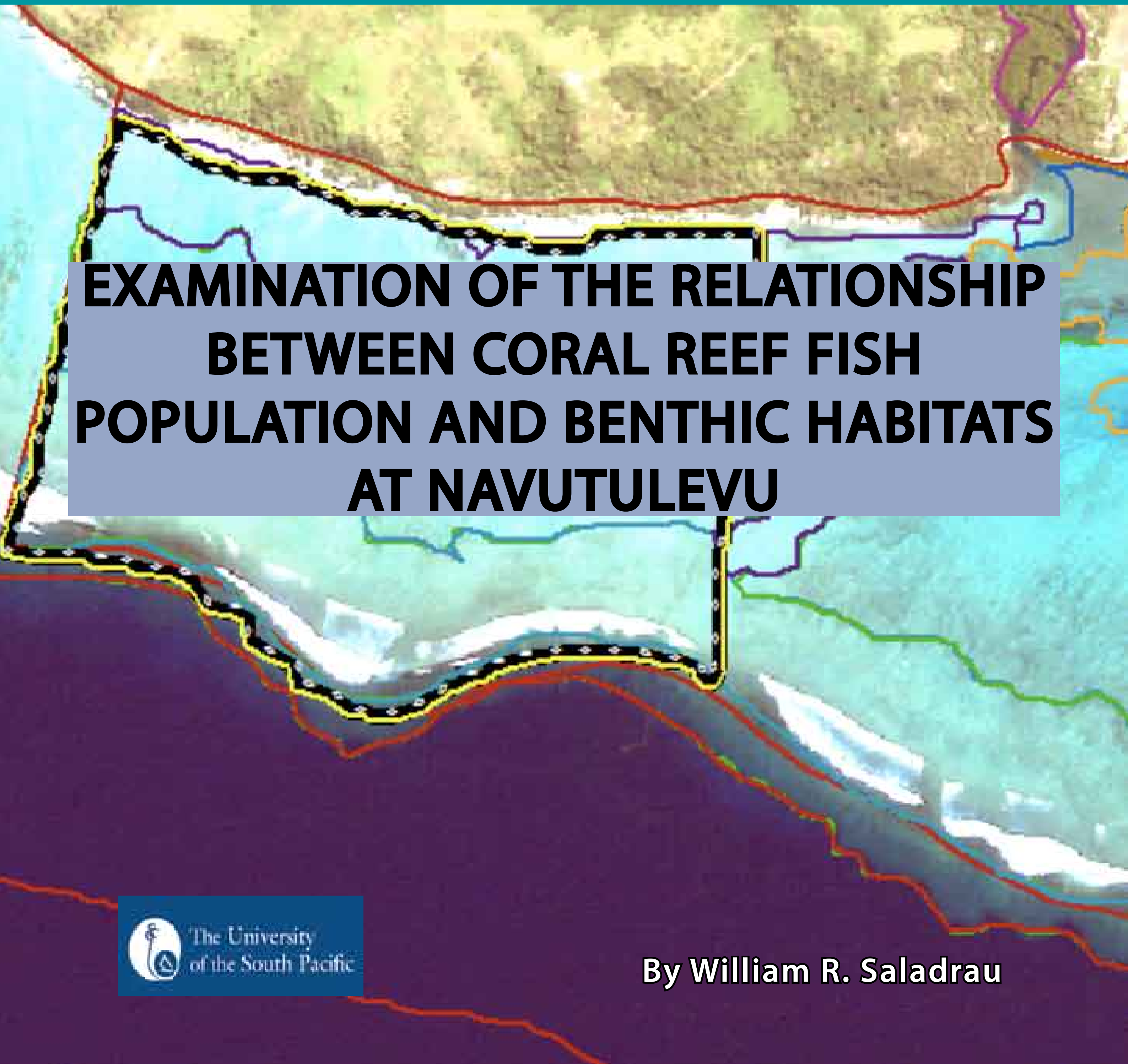
Coral Reef InitiativeS for the Pacific
Initiatives Corail pour le Pacifique

COMPONENT 2A - Project 2A2

Knowledge, monitoring, management and beneficial use of coral reef ecosystems

April 2008

TECHNICAL REPORT



EXAMINATION OF THE RELATIONSHIP BETWEEN CORAL REEF FISH POPULATION AND BENTHIC HABITATS AT NAVUTULEVU

The University of the South Pacific

By William R. Saladrau

CRISP

Coral Reef InitiativeS for the Pacific
Initiatives Corail pour le Pacifique

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

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

The CRISP Programme comprises three major components, which are:

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

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

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

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COMPONENT2A

Knowledge, monitoring and management of coral reef ecosytems

PROJECT 2A-1 :
Postlarvae (fish and crustacean) capture and culture for aquarium trade and restoking

PROJECT 2A-2:
Improvement of knowledge and capacity for a better management of reef ecosystems

PROJECT 2A-3 :
Synopsis and extension work on indicators for monitoring the health of coral ecosystems and developing a remote sensing tool

PROJECT 2A-4 :
Testing of novel information feedback methods for local communitis and users of reef and lagoon resources

PROJECT 2A-5 :
Specific studies on i) the effects on the increase in atmospheric CO_2 on the health of coral formation and ii) the development of eco-tourism

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Introduction

Fishes are the most widely exploited resource on tropical reefs and sustain numerous fisheries of socio-economic importance (Jennings and Polunin, 1996). This led to the survey of the Qoliqoli area of Navutulevu, Serua, to assess coral reef fish population in the different benthic habitats that exist within the inshore area. The coastal communities along coral coast in which Navutulevu is a part off, considers these coastal resources as off fundamental importance. Much of these communities' nutrition, welfare, culture, employment, and recreation involve the usage, consumption or selling of these resources.
Generally, more than 50 % of communities in the Pacific depend on the ocean for protein source and livelihood and in addition the ocean is part of their Heritage and Identity (Tawake, 2004).

In recent years, increasing awareness by conservation organizations and the general public of the potential value of Biodiversity and the accelerated decline in species richness has sparked a renewed interest in better understanding our biological heritage (Allison *et al* 1995).The need for the survey of this inshore area arose from a conversation with one of their Qoliqoli committee member requesting biological survey to be undertaken in their Qoliqoli and data obtained would be baseline information for Navutulevu inshore area.

It was then decided that UVC (Underwater Visual Census) be conducted at the different habitat types that are present in the inshore area. Scientific biological survey is one of the best way of quantifying (assessing) the status of resources (Coral reefs, Seagrass and Soft-bottom/Hard bottom habitats) in a Qoliqoli (inshore customary fishing ground) area (English 1997). The UVC method that will be used in this research is described (English 1997) as repeatable and relatively inexpensive, and describe a minimum standard which will provide baseline data that can be expanded to suit more specifics needs of sampling.

Benthic habitat characterizes the inshore area and it would very interesting to know the fish abundance in these various habitat zones. In addition to this a better understanding of association between species and habitat variables is critical for effective fisheries management (Reynolds 2002). On the other hand common approaches to identifying habitat associations in marine systems can be misleading because of spurious relationships, seasonal environmental changes or migration (Walters and Collic 1988). Despite this setback it is still important to determine the major fish nursery areas in order to be able to assess the relative importance of different habitat type (Smalley et al 1980)

For continued harvesting of fish populations, it is necessary to not overexploit the resources and to preserve the nursery areas (Smalley et al 1980). The community also has a MPA (Marine Protected Area) which was set up 4 years ago (2003) and survey will also look into its success or problems.

2. Background

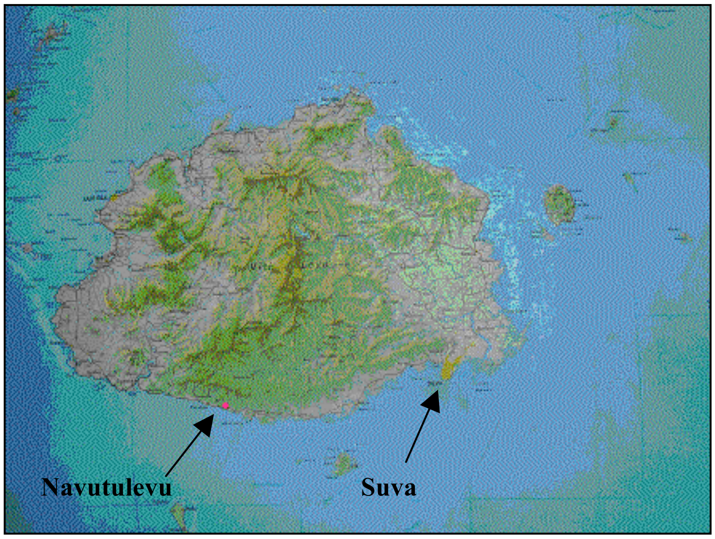


Figure 1. Map of Viti Levu

The village of Navutulevu lies along the Coral Coast stretch of Viti Levu and is the last village in the Province of Serua but geographically it is the first village along the coral coast line of village. The village consists of about 64 households and a total of 350 people reside in the village. Most villagers are either subsistence farmers or fisherman/fisherwomen and very few work in resorts and hotels in the Coral Coast area. The total Qoliqoli area as enlisted under the Native Fisheries Commission is approximately 4.5 km^2 which supports the daily subsistence of the 64 households. Generally the fisherfolks of this area are subsistence fishers and excess catch are shared with other households.

Navutulevu is about 80 - 90 km to Suva and transportation takes about 2 hours by bus and 1 hour to 45 minutes by car, taxi and mini-vans.

3. Objectives and Hypothesis

3.1 Objectives

The main objective of this research project was to:

- Assess the relationship between coral reef fish populations and benthic habitats and to:
- Compare relationship between coral reef fish in MPA area and control area.

3.1.1Specific Objectives

Since the survey focused on various habitats in the Qoliqoli of Navutulevu (based on community-based habitat maps), therefore the specific objectives of the research are:

- To find out the density of each fish species in each habitat type and extrapolate these results to get a density of fish species in the Navutulevu Qoliqoli area
- To calculate fish abundance of each species and total fish abundance in each habitat area and also fish abundance the total Qoliqoli area
- Calculate Biomass of each fish species and total fish biomass for different habitat types and also for the whole Qoliqoli area
- Length/ frequency curve of each fish species in each inshore habitat.
- Compare analyzed results obtained from habitats in the MPA area to similar habitats in the non-MPA area.

3.2 Hypothesis

The hypotheses that will be proven in this research are:

1. Live hard coral-rich habitats are where most fish can be recorded thus will have a greater fish density, biomass and fish abundance compared to other habitat types

2. Fish sizes recorded in the MPA area are much bigger to fish sizes in non MPA areas

3. Habitats in the MPA area will have a greater fish density, biomass, abundance when compared with the similar habitat type in the control areas (non MPA area).

4. Method

The methodology employed to undertake this project involved four major categories. These categories were:

1. Creating a Habitat map

2. Determining Transect location and coordinates

3. UVC survey activity

4. Compilation and analyzing of survey data

4.1. Habitat map construction

This involved defining different habitat boundaries in the inshore area of Navutulevu. Five major categories were thought of as the best way of defining the different habitat that can be found in an inshore area. These major categories were then further sub-divided to best describe the general classification. This can be described by the table below.

Table 1 Classification of Benthic Habitats

Habitats: Level One	Level two	Description
1. Mangrove	-Coastal	Mangroves that grow along coastal edges
	-Riverine	Mangroves that grow along river to estuary
2. Deep Water	-Lagoon	Deep water / blue holes in inshore area
3. Bare Substrate	-Sand	Bare Sand
	-Mud	Mudflats
	-Rubble/rock	Rock or Rubble area
4. Sea grass	-Dense	Dense seagrass area
	-Patchy	Patchy Seagrass area
5.Hard Substrate	-Hard Coral	Dominant Hard coral area
	-Soft Coral	Area with dominant Soft Coral
	-Macro Algae	Area with dominant Macro Algal growth Eg. Sargassum, padina, seaweeds

These categories were taken down to the village (Navutulevu) with little brochures containing images of the various habitat types (level two). The older fishermen and women, who have a lot of traditional knowledge regarding their I Qoliqoli, mapped out the boundaries of habitat types that exist in their inshore area. These boundaries were drawn on an A2 size print-out satellite image of the Navutulevu Qoliqoli area. The community demarcated boundaries of habitat types are then traced using ArcGIS software to incorporate it into the computer to produce a habitat map of Navutulevu.

Both raw (community-based habitat demarcations) and completed images (habitat map) are shown below

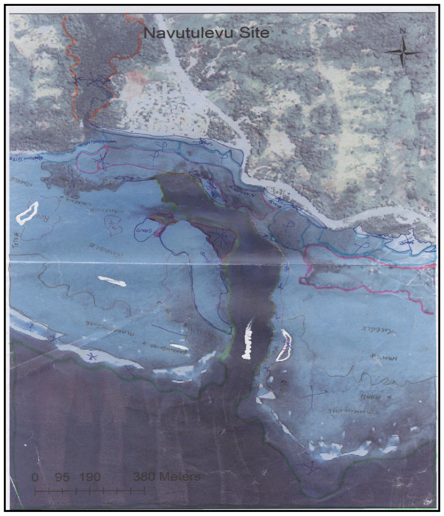


Figure 2. Raw image of Navutulevu

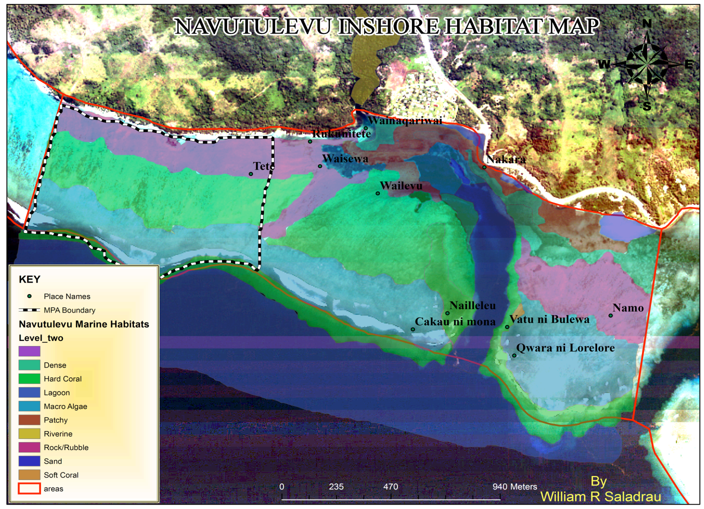


Figure 3. Digitized Habitat Image of Navutulevu

The inshore area of Navutulevu contained these following habitat types, Dense Seagrass, Patchy Seagrass, Lagoon, Sand, Rock/Rubble, Hard Coral, Macro Algae and Soft Coral.

4.2. Determining Transect location and coordinates

Eight (8) out of the 11 level two categories were present in the Navutulevu inshore area. It was decided that in-order to have a good representation of the data to be collected, six belt transects were laid in each habitat type.

These transects were randomly selected by Hawths' tool ((WEBLINK) in ArcGIS) together with its coordinates. These coordinates were then downloaded onto a portable GPS (Global Positioning System) as waypoints. When in the field conducting survey, the GPS was used to identify position of next transect to be surveyed. This was done by scrolling through the desired waypoint (coordinates).

Shown below is map of the various transects in each habitat, this image was laminated to be used as field guide when doing the actual survey.

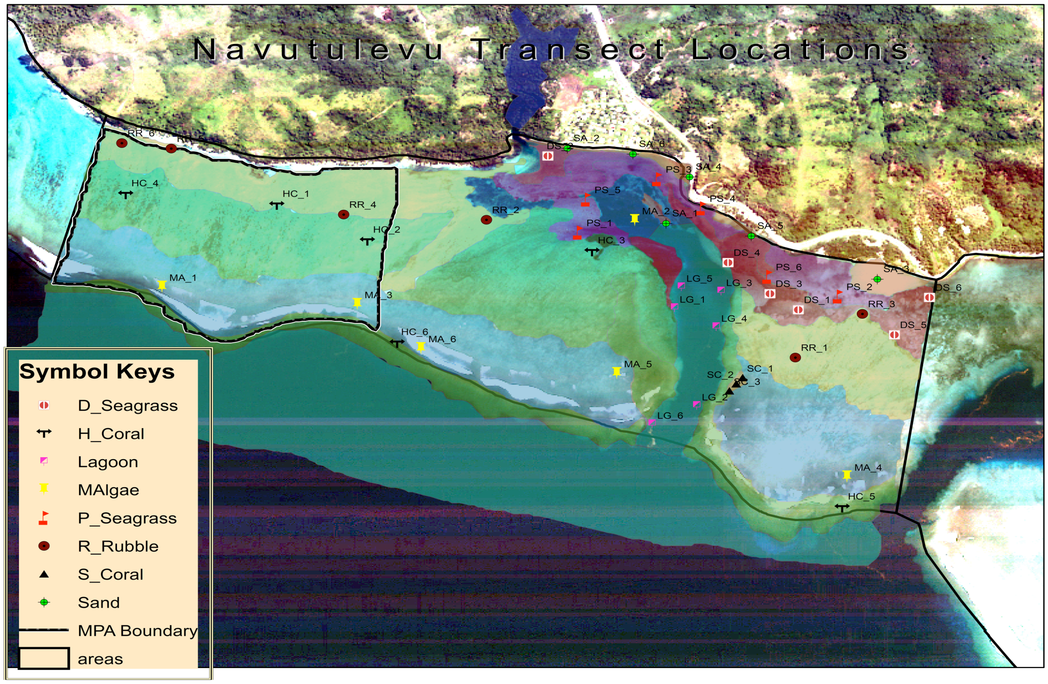


Figure 4. Transect location map

4.3. Underwater Visual Census

The UVC method employs divers to count individual fish and estimate their total lengths in order to determine the standing stock and population size structure of specific species (*English 1997*).

UVC procedures that will be used in this research were fully adopted from the "Survey Manual for Tropical Marine Resources" edited by "S. English", "C. Wilkonson" and "V. baker".

The UVC was undertaken through snorkeling and each belt transect was limited to 20m in length. All dive time had a minimum time of 30 minutes and were undertaken during high tide (+/- 1 hour).

During the survey, fish identification was confined to important fish food species listed out in the "Food Fishes OF Fiji" chart of the Fisheries Division. These are *Plectropomus sp*., *Epinephelus sp*., *Lutjanus sp*. and *Lethrinus sp*, *Caranx sp*. and *Carrangoides sp*., *Scarus sp*., *Acanthurusm sp*., *Naso sp*., *Sphyraena sp*., *Mugil sp*. and *Valamugil sp*., *Siganus sp*. and *Perupenius sp*...

4.4 Compilation and analyzing of survey data

All data collected from the UVC survey were transcribed from the underwater paper onto A4 size paper. Compiled data were then entered onto Excel spreadsheet where manual analyzing was done. Data were grouped into six transects per habitat and analyzed into species type per transect, then density was calculated per transect then total density per habitat.

Density = *n/y*

where n *a* = number of fish (individuals) of species *a*
and *y* = census area

Biomass was then calculated using the *length and weight relationship* formula;

Wt = aLb

Where wt = weight (g)

L = fish length

a and b are constants (Samoilys 1997) a = 1.54 x 10^{-2} and b = 3.043

Fish abundance of each species were also analyzed and also presented as part of the result. The fish abundance in the MPA were also analyzed and compared with similar habitat type in the Non-MPA area.
Analyzed data of fish density and biomass were then entered onto ArcGIS software where it was then projected onto the habitat map of Navutulevu. This could have been done with the rest of the results however it requires more time to input data onto GIS software.

5. Results

5.1. Fish Abundance

A total of 45 belt transects were laid and surveyed in the Qoliqoli of Navutulevu apart from the proposed number of 48.

Table 2 Habitat types and no. of Transect

Habitat type (Code)	Dense Seagrass (DS)	Patchy Seagrass (PS)	Lagoon (LG)	Hard Coral (HC)	Soft Coral (SC)	Macro Algae (MA)	Sand (SA)	Rock/ Rubble (RR)	Total
Trans No.	6	6	6	6	3	6	6	6	**45**

The soft coral habitat area were too small to have 6 transects carried out in its vicinity therefore number of transects in this area were reduced to only three.

From the 45 transects that were surveyed a total of 2,759 number of fish were encountered and recorded, this were the food-fish species that are normally consumed or sold.

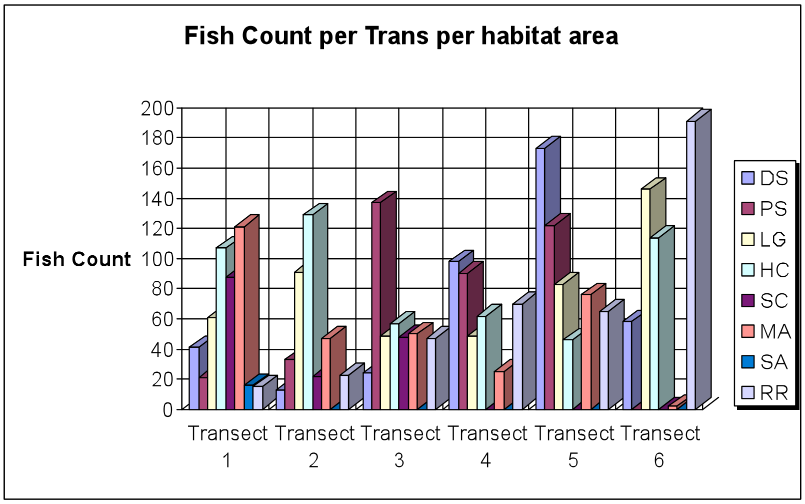
The table shows number of fish count in each transects in the various habitat types.

Table 3 Summary of fish count in each habitat

Transects / Habitats	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5	Transect 6	**Total**
DS	41	13	24	98	173	58	**407**
PS	21	33	137	90	122	0	**403**
LG	61	91	49	49	83	146	**479**
HC	107	129	57	62	46	114	**515**
SC	88	22	48	-	-	-	**158**
MA	121	47	50	25	76	2	**321**
SA	16	0	0	0	0	0	**16**
RR	15	23	47	70	65	191	**411**
Total	**470**	**358**	**412**	**394**	**565**	**511**	**2759**

The graph shows the total number of fish count in each transects in the various habitat types refer to the table above for value of each transect points.

Graph 1 Total fish count summary in each transect per habitat



This graph shows a lot of fluctuations where different habitats (DS, PS, LG, HC, SC, MA, SA, RR) dominate in fish abundant in each transect from 1-6. Some fish families have low population in the earlier transect and tend to dominate in the last transects, others started off with a high count and later dropped whilst some remain constant throughout. Individual species such as *C. trilobatus*, *E. merra* are the ones with constant appearance during the survey however species such as *Scarus sp., Acanthrus sp. Siganus sp.* which are normally found in groups tend to fluctuate depending on the habitat and water depths.

5.2. Fish Density

It was decided that presentation of fish density be generalized into families and not individual species as proposed. This is because there were quite a big number of species recorded during the survey and squeezing this huge amount of data on limited space would be very untidy and loose the interest of the data and importantly would require a long time for report to be completed as time is restricted in this exercise due educational purposes.

As the result, in every habitat the individual species recorded were grouped into the same families and density was taken for each family in individual transects, within a habitat. It was decided that density be calculated as per $1000m^2$ and not per habitat, to standardize the results and make it more logical to compare between densities of different habitats

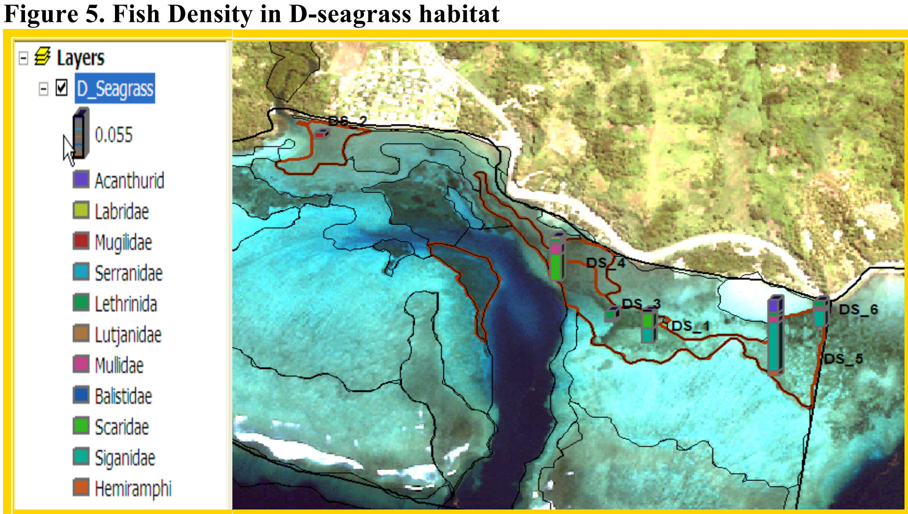
The fish density for fish families in each habitat are as such:

5.2.1Dense Seagrass habitat

Dense seagrass had a total area of 123491.6m^2 when calculated, and this habitat recorded a total 407 fishes in six transects, 12 food-fish species within its boundary which was categorized into 11 fish families.

Fish Density chart (Dense Seagrass) per 1000m^2

Figure 5. Fish Density in D-seagrass habitat



The area of Dense Seagrass is the being highlighted in dark orange and the position of the stacked bars is the exact position of where the survey transects were carried out. The stacked bars show the proportion of each fish family in each transect. However labels were not possible therefore the table below shows value for each fish family per transect in dense seagrass habitat area.

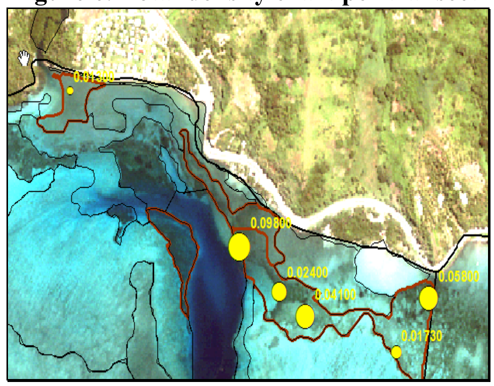
Table 4 Fish Density values in each transect

	Trans 1	Trans 2	Trans 3	Trans 4	Trans 5	Trans 6
Acanthuridae	0.002				0.03	
Labridae				0.006		
Mugilidae		0.012				
Serranidae	0.002			0.001		
Lethrinidae			0.019	0.006	0.009	0.015
Lutjanidae		0.001		0.003		0.001
Mullidae	0.004			0.023	0.013	0.007
Balistidae			0.001			
Scaridae				0.059		
Siganidae	0.033		0.004		0.11	0.035
Hemiramphidae					0.011	

The table above shows the values of food-fish density as displayed in the satellite image of Navutulevu. There were 11 families recorded in this Habitat.
Total of fish density of each family in dense seagrass habitat area is shown in the next graph while in the other image shows total fish density per transect in Dense Seagrass habitat

Graph 2 Fish Density of each family in D-seagrass

Figure 6. Total density chart per transect



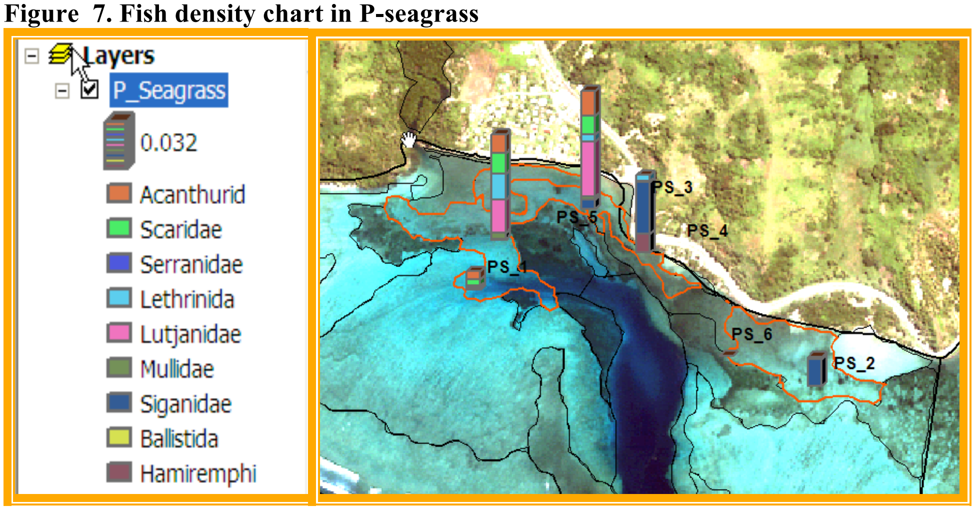
From the first graph we can clearly point out that Siganidae (Rabbitfishes) has the most density then the rest of the other fish families while in the next image we can identify transect where most fish was counted by identifying the larger circle.

<u>5.2.2 Patchy Seagrass Habitat</u>

Patchy Seagrass area had a total area of 132,414.0 m^2 in the Navutulevu Qoliqoli area, and this survey recorded a total of 30 fish species within its boundary, and a total of 403 fishes were counted. However when classified into families, the total fish was grouped into 9 families.

Fish Density Chart (per 1000 m^2) in Patchy Seagrass.

Figure 7. Fish density chart in P-seagrass



The table below represents densities values of the different families recorded during the survey and as shown in the diagram above.

Table 5 Fish FamilyvDensity values per transect

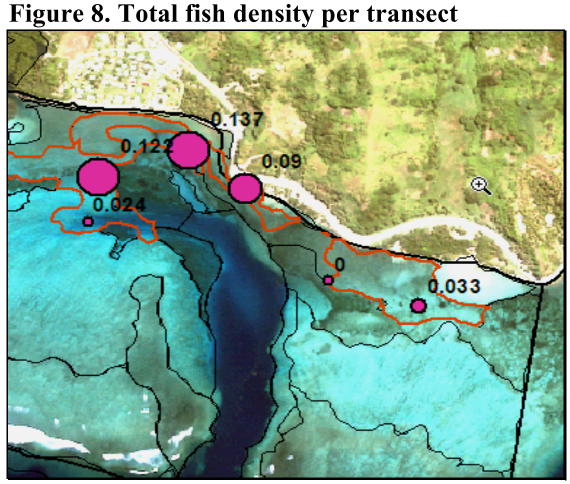
Fish Dense- Family/1000	PS 1	PS 2	PS 3	PS 4	PS 5	PS 6
Acanthuridae	0.009		0.029		0.021	0
Scaridae	0.008		0.022		0.024	0
Serrenidae		0.002				0
Lethrinidae	0.001		0.008	0.007	0.03	0
Lutjanidae	0.001		0.064	0.001	0.039	0
Mullidae			0.003		0.007	0
Siganidae		0.031	0.011	0.06		0
Balistidae	0.002				0.001	0
Hamiremphidae				0.022		0

The diagram shows fish-family density in the patchy seagrass area which is being highlighted. The position of the stacked bars portrays the exact transect location in the field where the survey was carried out. We can interpret from this image that Lutjanidae (Snappers/ *Lutjanus sp*.), Siganidae (Rabbitfishes/ *siganus sp*.) dominate this habitat (patchy seagrass) and a followed by Scaridae (*Scarus sp*.) and Lethrinidae (Emperor/ *Lethrinus sp.*) and Acanthuridae (Acanthurus sp. / Surgeonfish)

There were no fish recorded in transect PS 6 therefore the column is filled with zero, whilst other fish are distributed evenly amongst the rest of the transects indicating that this particular habitat had a lot of fish even though there were only 8 families recorded in the patchy seagrass.

Graph 3 Total Density of fish family

Figure 8. Total fish density per transect



The two diagrams above refer to analysis of density in two perspectives. The graph on the left refers to total density of each fish family in the patchy area whilst the second diagram reflects on total fish density per transect in patchy seagrass area.

5.2.3 Lagoon Habitat

The lagoon habitat had a total area of 1, 404, 099 m^2 and this included the area from the mouth of Navutulevu passage to the inside of the lagoon as highlighted in the diagram. The deep water area beyond the outer reef is classified as high seas and is beyond the Qoliqoli boundary. The survey recorded a total of 479 numbers of fishes, 37 types of different species, and 12 families.

Fish Density Chart (per 1000 m^2) in Lagoon habitat

Figure 9. Fish Density in Lagoon habitat

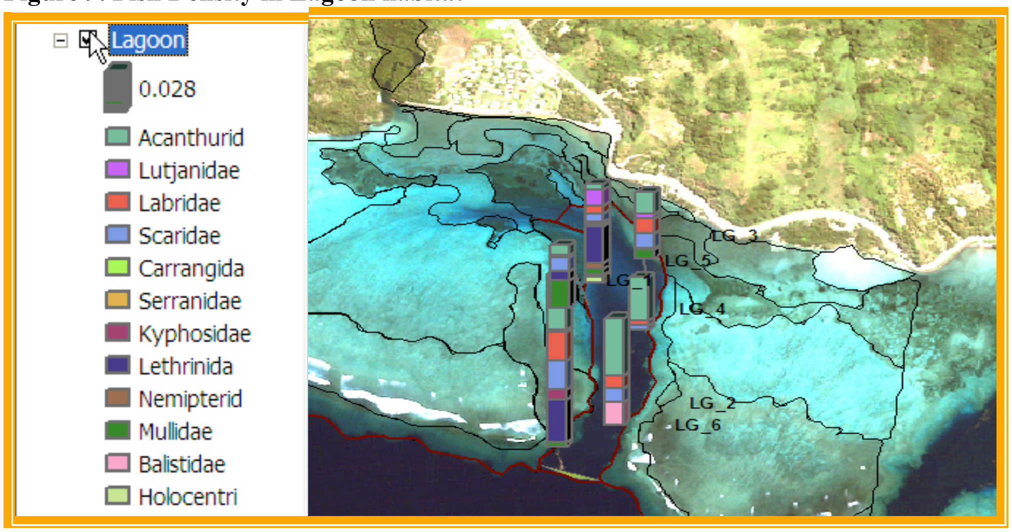


Table 6 Fish density in Lagoon area

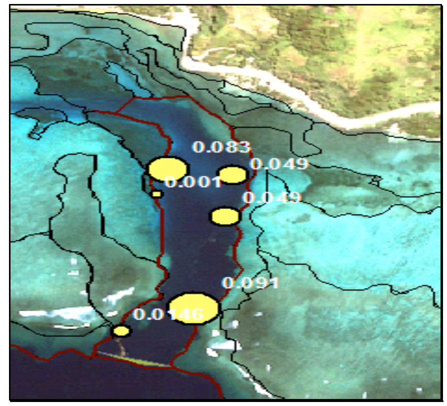
Fish Dense- Family/1000	LG 1	LG 2	LG 3	LG 4	LG 5	LG 6
Acanthuridae	0.01	0.056	0.021	0.043	0.006	0.055
Lutjanidae	0.001		0.004		0.015	0.002
Labridae	0.001			0.001		
Scaridae	0.014	0.013	0.015	0.004	0.008	0.028
Carangidae					0.002	
Serranidae					0.002	
Kyphosidae						0.01
Lethrinidae	0.009				0.036	0.042
Mullidae	0.026		0.008	0.001	0.006	0.004
Balistidae		0.022			0.002	
Holocentridae						0.005
Nemipteridae			0.001		0.006	

The lagoon is different from both seagrass habitats because it recorded a greater number of fish count and also a greater number of species. Acanthuridae (Surgeonfishes), Lethrinidae (Emperors) and Scaridae (Parotfishes) dominate this habitat followed by Mullidae (Goatfishes) and Lutjanidae (Snappers). Other families were recorded only once or twice during the six transects laid.

Density of each family in habitat and total fish density per transect in Lagoon habitat area.

Graph 4 Total of Family density

Figure 10. Total Density per Transect



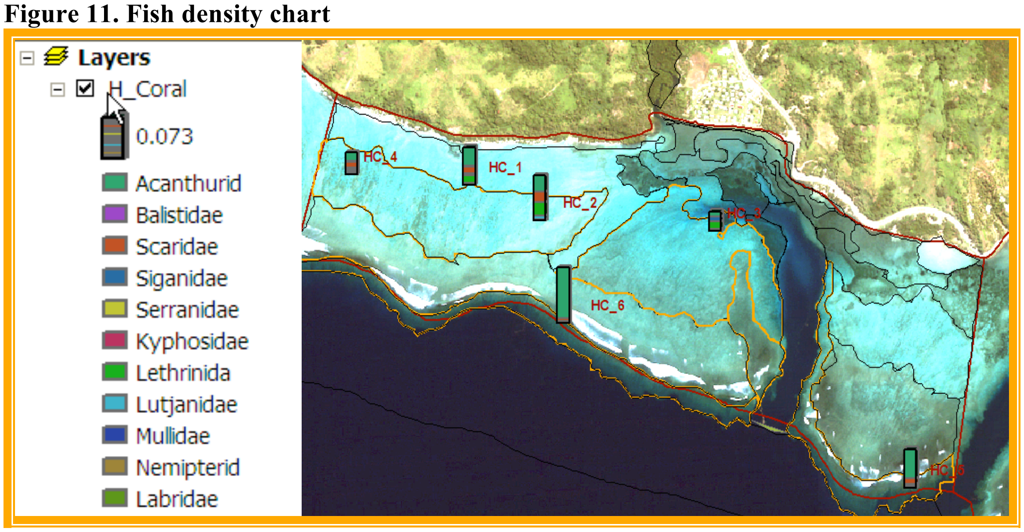
The first graph showing individual densities of each family where Acanthuridae (Surgeonfish), Scaridae (Parrotfishes) and Lethrinidae (Emperor) dominating this habitat. The second image showing total fish density per transect in the Lagoon habitat.

5.2.4 Hard Coral Habitat

The Hard Coral habitat recorded a total fish count of 515 fish with 43 different types of species, however when grouped into different families there were 12 different families. Hard Coral habitat covered a total area of 801,650.8 m^2 in the Navutulevu Qoliqoli area.

Fish Density Chart (per 1000 m^2) in Hard Coral Habitat

Figure 11. Fish density chart



Refer to table below for values of each density.

Table 7 Fish density table

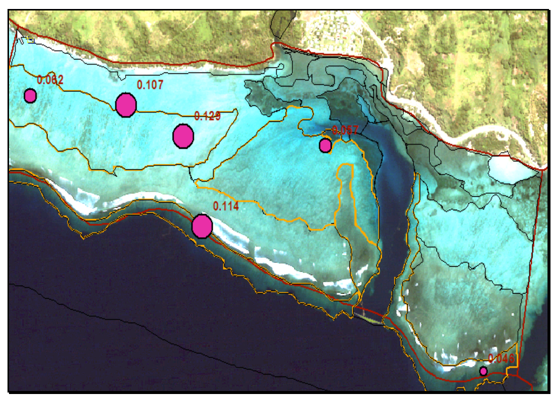
Fish Dense- Family/1000	HC_1	HC_2	HC_3	HC_4	HC_5	HC_6
Acanthuridae	0.054	0.046	0.016	0.025	0.019	0.101
Balistidae	0.002			0.002		
Labridae			0.002	0.004	0.001	0.002
Scaridae	0.02	0.03		0.016	0.015	0.008
Siganidae			0.012	0.004	0.001	0.003
Serranidae	0.004	0.001		0.003		
Kyphosidae					0.006	
Lethrinidae	0.021	0.039	0.022	0.003		
Lutjanidae		0.009		0.002	0.002	
Mullidae	0.006	0.003	0.005	0.003	0.001	
Nemipteridae		0.001			0.001	

Acanthuridae (Surgeonfish), Scaridae (Parrotfish) and Lethrinidae (Emperor) has dominated this habitat once again followed by Lutjanidae (Snappers) and Mullidae (Goatfish). The other families are contributing to some extent but there occurrence is less.

Density of each family in Hard Coral Habitat and total fish density per transect in Hard Coral habitat area

Graph 5 Fish Density per family

Figure 12. Fish densities per transect



Dominance of Acanthuridae, Scaridae, Lethridae shows the difference in benthic habitat type. However total fish density per transect revealed that the two transects in the inshore area have more densities then the ntwo transects on the outer reef edge.

<u>5.2.5 Soft Coral</u>

Compared to the rest of the Habitat types, soft coral was the least habitat area in the Navutulevu Qoliqoli area. The area of soft coral was approximately 2390 m^2 which was the smallest area of the eight habitat type. A total number of 158 fish was recorded with 18 different types of species, and 6 families when classification was generalized to families.

Fish Density Chart (per 1000 m^2) in Soft Coral Habitat

Figure 13. Fish Density in Soft Coral

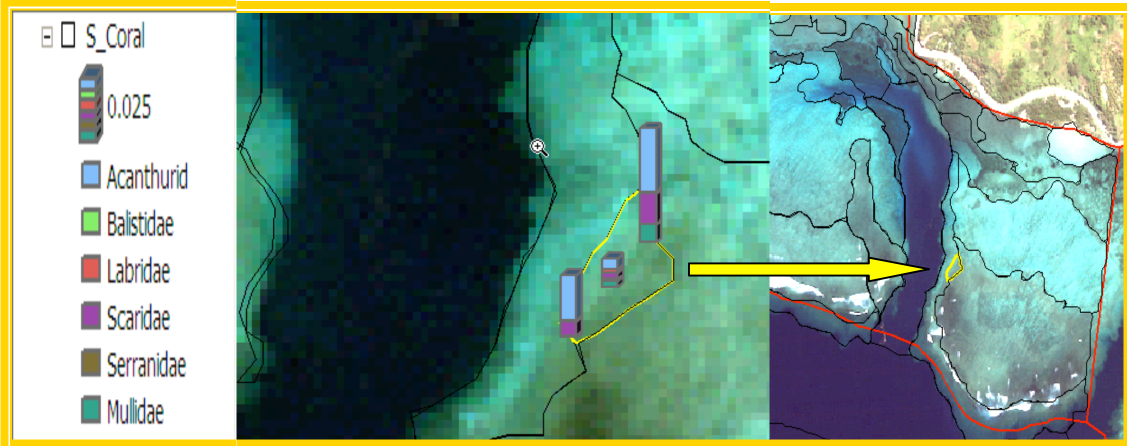


Table 8 Fish Density values in Soft Coral

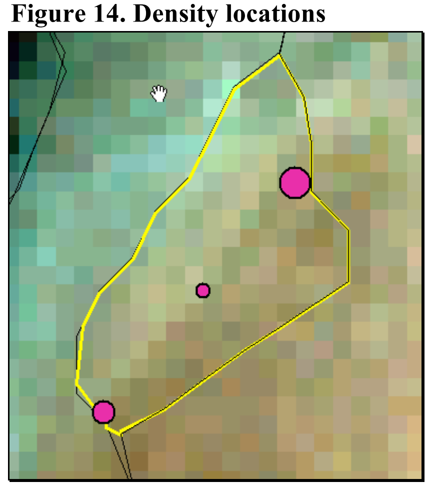
Fish Dense- Family/1000	SC 1	SC 2	SC 3
Acanthuridae	0.049	0.008	0.035
Balistidae			0.001
Labridae	0.001	0.003	
Scaridae	0.024	0.005	0.011
Serrenidae		0.001	
Mullidae	0.014	0.005	0.001

Soft coral habitat was dominated by Acanthuridae and Scaridae whilst the other families recorded a low population, such as Labridae (*C. trilobatus*) and Serreanidae (*E. merra)* and Balistidae (*R. aculeatus*, *B. undulates*) which has a normal trend of 1 or 2 per transect.

Density of each family in Soft Coral Habitat and total fish density per transect in Soft Coral habitat area

Graph 6 Total fish density

Figure 14. Density locations

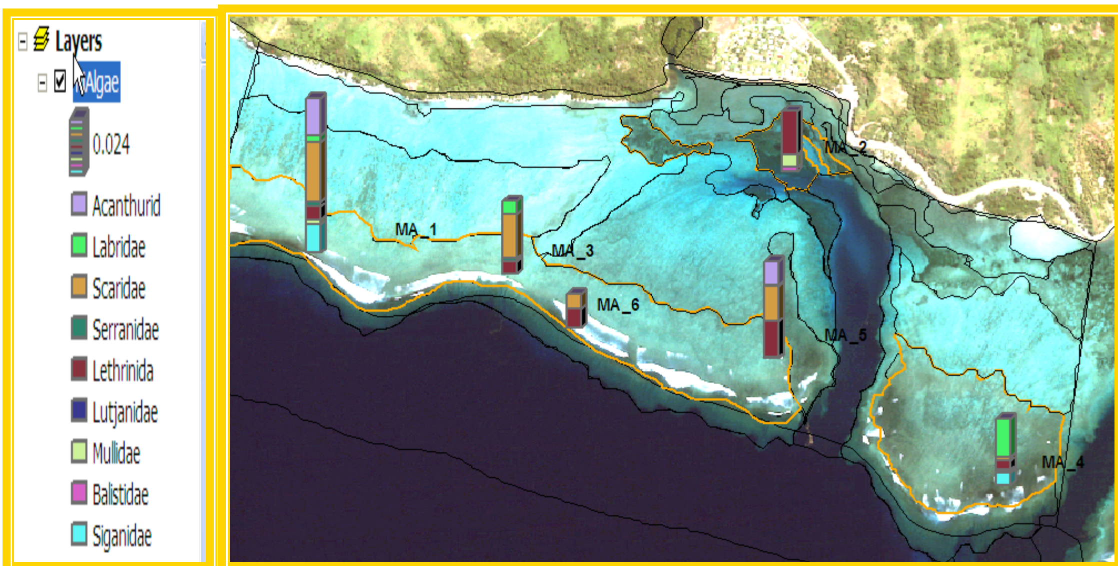


The graph clearly showing the dominant family and the less dominat ones. Eventhough this habitat recorded a low number of fish; the total fish count was 153.

5.2.6. Macro Algae Habitat

Macro algae are one of the largest habitat areas in the Navutulevu Qoliqoli boundary and its area covers approximately 639,604.4 m^2. Being one of the largest habitat type, survey recorded a total of 321 fish count with 22 different type of species and 9 families.

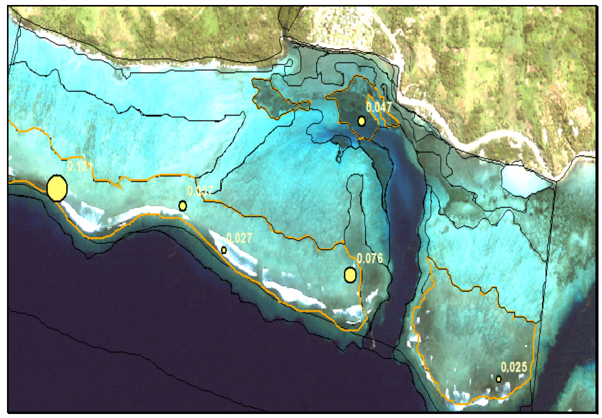
Fish Density Chart (per 1000 m^2) in Soft Coral Habitat



Fish Dense- Family/1000	MA 1	MA 2	MA 3	MA 4	MA 5	MA 6
Acanthuridae	0.029				0.018	
Labridae	0.005		0.01	0.003	0.001	
Scaridae	0.047		0.035	0.003	0.028	0.012
Serrenidae	0.004		0.002			
Lethrinidae	0.01	0.034	0.01	0.007	0.028	0.015
Lutjanidae					0.001	
Mullidae	0.004	0.01		0.001		
Balistidae		0.003		0.001		
Siganidae	0.022			0.01		

The above table contains values of each Density as shown in Fish Density Chart in Macro Algae habitat. The Density has been standardized to $1000m^2$ so that all the density results are presented on the same level and not according to different habitat type as proposed.

Density of each family in Macro Algae Habitat and total fish density per transect in Macro Algae habitat area

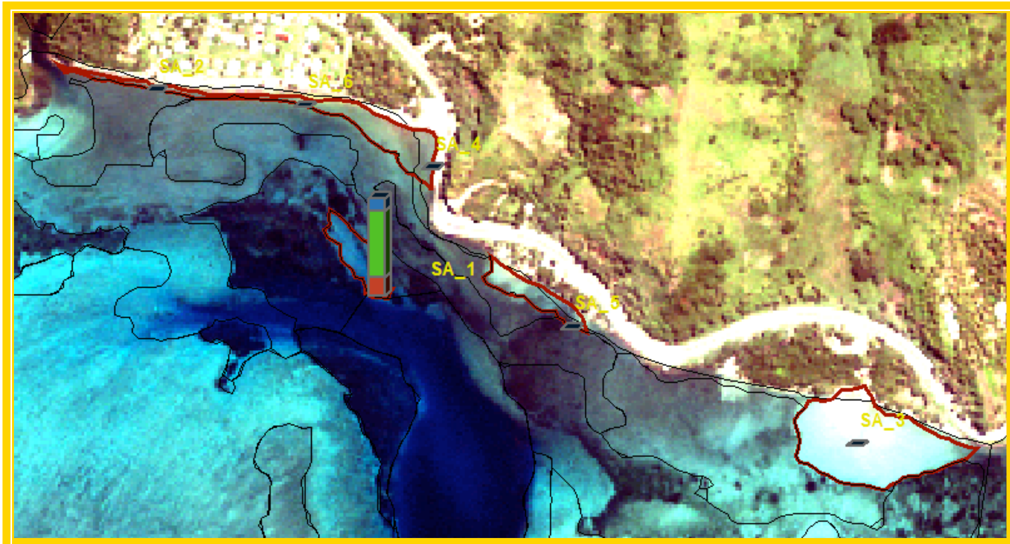


The graph clearly indicating Dominant fish families (Scaridae and Lethrinidae) on the top followed Acnthuridae and Siganidae at the middle then the low density families (Labridae, Serranidae, Mullidae and Balistidae). Whilst on the other diagram, showing the most densely populated transect.

5.2.7. Sand Habitat

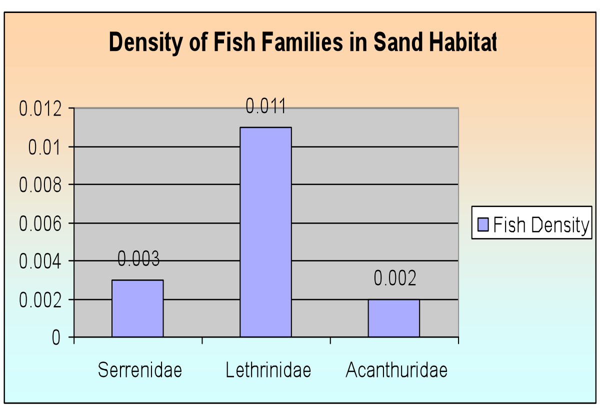
Sand habitat recorded the lowest fish count and density compared to the rest of the habitat types. Total number of fish recorded in Sand habitat was 16, 4 species types and three families. All the fish were encountered in the first transect and the remaining transect contained no fish.

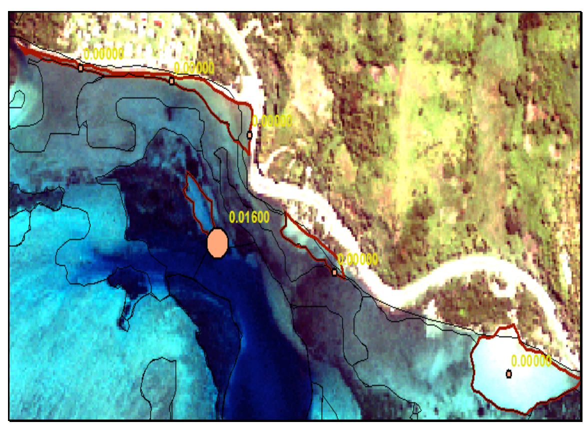
Fish Density Chart (per 1000 m^2) in Soft Coral Habitat



Fish Dense-Family/1000	SA_1	SA_2	SA_3	SA_4	SA_5	SA_6
Serrenidae	0.003	0	0	0	0	0
Lethrinidae	0.011	0	0	0	0	0
Acanthuridae	0.002	0	0	0	0	0

Density of each family in Sand Habitat and total fish density per transect in Sand habitat area

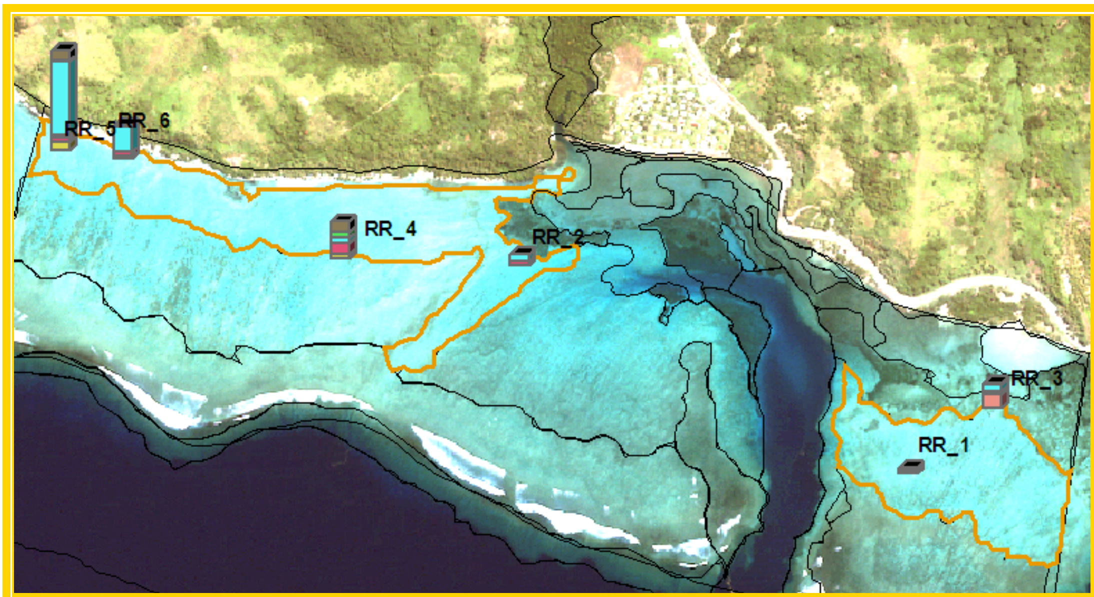




Lethrinidae seemed to be dominating in this type of habitat followed Serranidae then finally Acanthridae. Generally Sand are habitat to totally different types of fish, and very few fish inhibits this area except for feeding purposes. This could explain for why this fish families were encountered in this area.

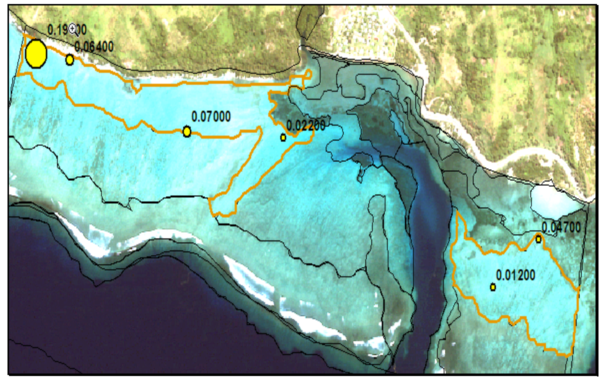
5.2.8. Rock/Rubble Habitat

Rock/Rubble habitat area is quite an extensive one compared to the rest and covers a n area of approximately 370, 946 m^2. A total of 411 number fish were recorded with 20 different species, under 10 different families.



Fish Dense- Family/1000	RR1	RR 2	RR 3	RR 4	RR 5	RR 6
Acanthuridae				0.02	0.001	0.02
Carangidae					0.002	
Labridae			0.002	0.012		0.001
Scaridae	0.004	0.013	0.013	0.01	0.05	0.142
Serranidae	0.002		0.001			0.006
Lethrinidae	0.001	0.009	0.002	0.021	0.008	0.006
Mullidae	0.001		0.003	0.007	0.002	0.016
Balistidae			0.001			
Pomacanthidae					0.001	
Signidae	0.004		0.025			

There was more fish density on the far left corner the inshore area dominated by fish family Scaridae (Parrrotfish) whilst RR_4 is made of several fish families at lesser density.



This habitat (Sand) is dominated by Scaridae (Parrotfishes) followed by Acanthuridae and Lethrinidae in the middle whilst the low density families include Carangidae, Labridae, Serranidae, Mullidae, Balistidae and Signidae.

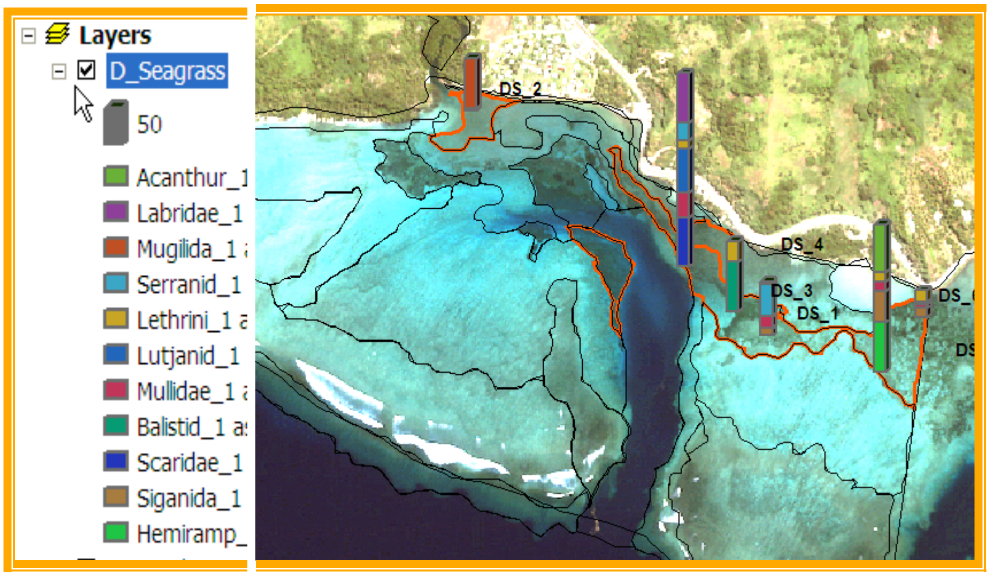
5.3 Biomass

The Biomass was calculated separately for individual species but later had to be grouped into families per transect in every habitat using (g) per transect area. The reason for doing this is because the number of fish is to great and analyzing results species-wise will take a long time, which would delay the submission of report.

The Biomass of different fish families in each habitat are as follows;

5.3.1 **Dense Seagrass Habitat**

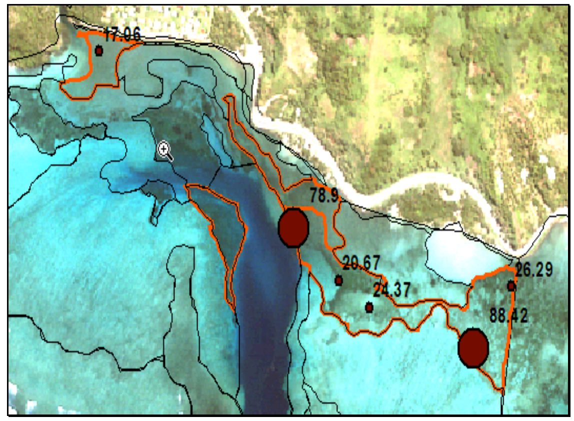
Map of fish biomass composition per individual transects in Dense Seagrass habitat



Biomass (g)	DS 1	DS 2	DS 3	DS 4	DS 5	DS 6
Acanthuridae	0.75				16.87	
Labridae				4.12		
Mugillidae		16.87				
Serranidae	1.31			0.7		
Lethrinidae			19.45	8.06	8.9	10.6
Lutjanidae		0.19		3.37		0.23
Mullidae	12.75			26.24	9.89	3.94
Balistidae			0.47			
Scaridae				36.41		
Siganidae	9.56		0.75		39.36	11.48
Hemiramphidae					13.4	

The diagram shows that no certain family dominated throughout all the rest of the transects, for e.g. in transect 2 Mugillidae (Rabbitfish) dominated but became lesser in other transects. Most greater biomass were found in Transect 4 where most of the families were recorded and the least in trans. 5 at the far right corner of the Qoliqoli area.

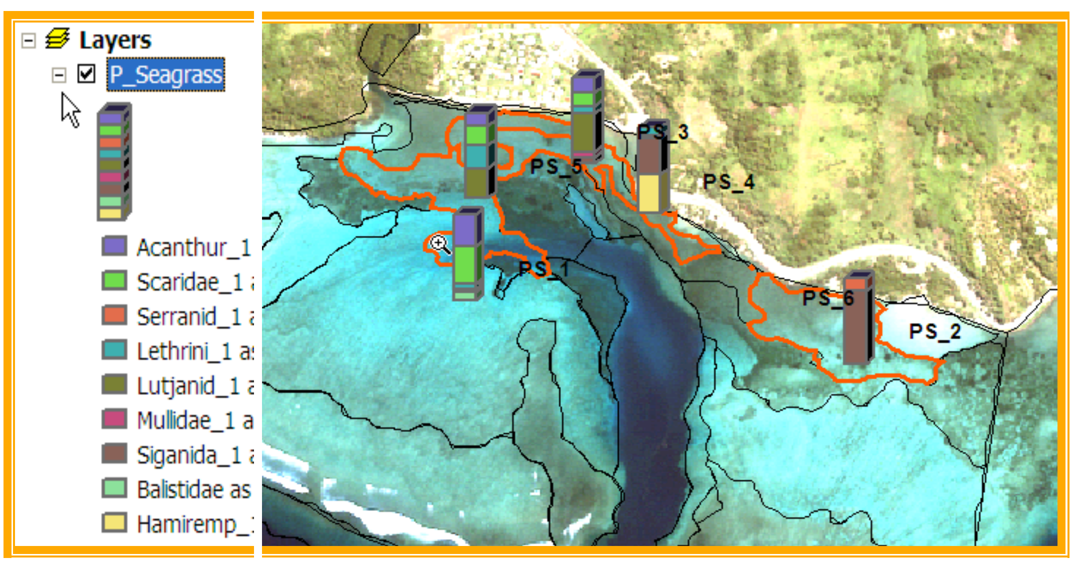
The following diagrams respectively depicts biomass of individual families in dense seagrass habitat and the following image shows which transect recorded the highest biomass in dense seagrass habitat



From the graph three families had higher biomass recorded, this were Siganidae, Mullidae and Lethrinidae. Scaridae came in the middle whilst the rest recorded a low biomass. Compared to its density Siganidae had the greatest density in this habitat (Dense Seagrass). The data range was manually classified (5 classes) by ArcGIS and came out with the following on the second image where two transect showed a higher amount of biomass then the rest. Density of Lethrinidae and Mullidae was not high therefore we can assume that sizes were big which is why there biomass was among the dominant families in Dense seagrass

5.3.2 Patchy Seagrass Habitat

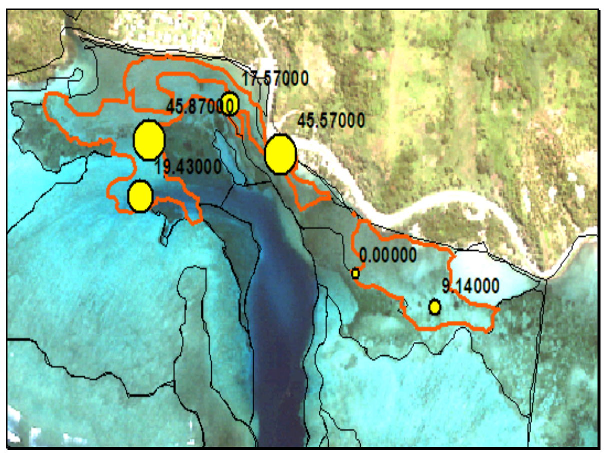
Map of fish biomass composition per individual transects in Dense Seagrass habitat



Biomass (g)	PS 1	PS 2	PS 3	PS 4	PS 5	PS 6
Acanthuridae	7.22		3.09		24.09	0
Scaridae	8.52		2.71		36.83	0
Serranidae		1.41				0
Lethrinidae	1.12		1.64	4.59	41.61	0
Lutjanidae	0.7		7.78	0.98	54.07	0
Mullidae			1.08		7.73	0
Siganidae		7.73	1.27	19.68		0
Ballistidae	1.87				0.56	0
Hamiremphidae				20.62		0

The diagram shows that there were more fish families recorded in this habitat and their biomass in individual transects are more evenly distributed unlike Dense seagrass where a single fish family can dominate a certain transect. Transect PS 6 did not record any fish.

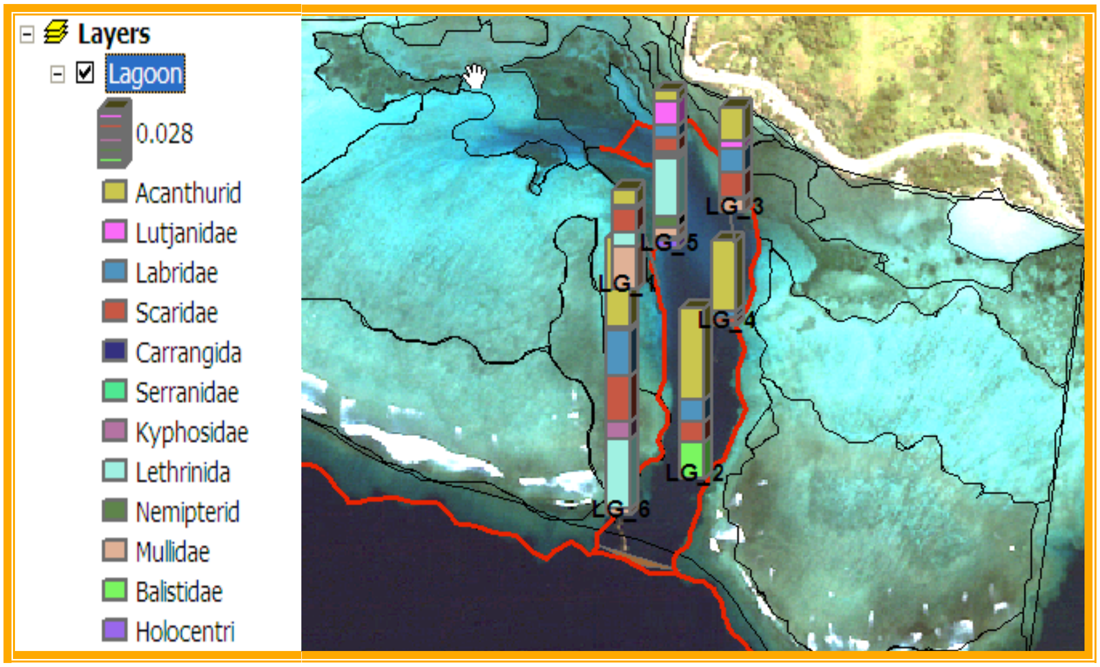
The following diagram respectively depicts biomass of individual families in Patchy seagrass habitat and the following image shows which transect recorded the highest biomass in Patchy seagrass habitat.



The two families with dominant biomass was Lutjanidae and Lethrinidae followed by scaridae, Acanthuridae, Siganidae. Some families which fail to attain higher density are making up through their bigger lengths that result in greater biomass. In the second image there were two transects which recorded greater transect. When compared to its density component they also had the same size.

5.3.3. Lagoon Habitat

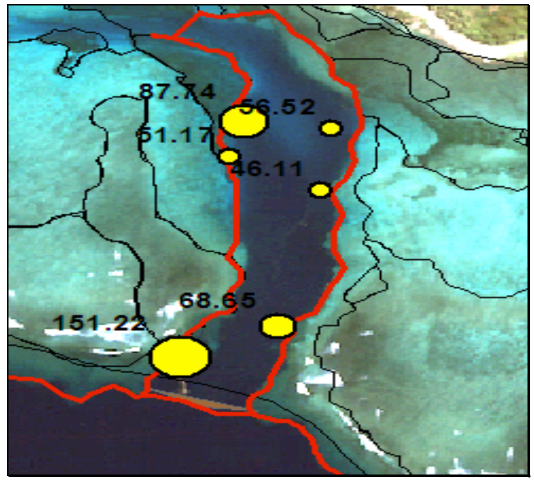
Map of fish biomass composition per individual transects in Lagoon habitat



Acanthuridae	8.43	50.94	12.89	41.71	7.73	48.97
Lutjanidae	0.66		4.83		9.37	2.81
Labridae	0.56			0.7		
Scaridae	12.37	15.65	28.73	2.95	9.37	36.88
Carangidae					2.81	
Serranidae					1.14	
Kyphosidae						16.4
Lethrinidae	6.89				37.3	41.94
Mullidae	22.26		8.95	0.75	7.97	4.22
Balistidae		2.06			1.41	
Holocentridae					5.86	
Nemipteridae			1.12		4.78	

All transects in Lagoon area indicated that it contained great abundance of fish and this could be seen in their Biomasses and its composition (different families) in each transect. From the above diagram we can infer that there could be more fish in a transect or just larger sized fish which leads to greater biomass.

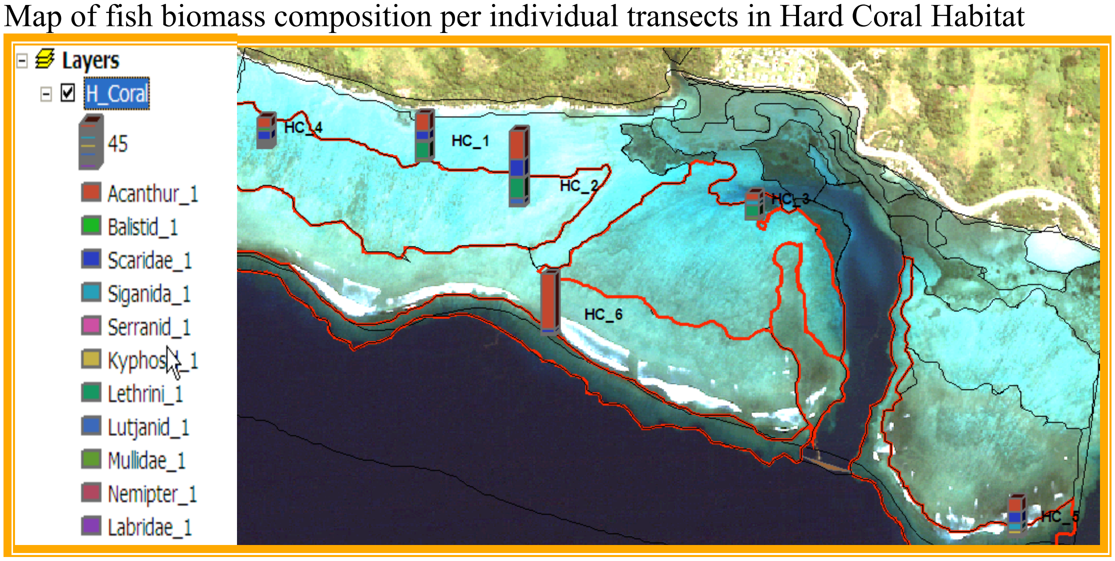
The following diagram respectively depicts biomass of individual families in Lagoon habitat and the following image shows which transect recorded the highest biomass in Lagoon habitat.



From the first graph two families stood out as the greatest biomass in Lagoon area i.e Acanthuridae followed by Scaridae, Lethrinidae and Mullidae were in the middle while the rest recorded a low density. Figure indicated that lagoon habitat has clearly surpassed both former habitats on fish biomass. The middle values in this case are in line with the top biomass values in the first two habitats. Whilst the second picture indicate where the top biomass values were recorded from.

5.3.4. Hard Coral Habitat

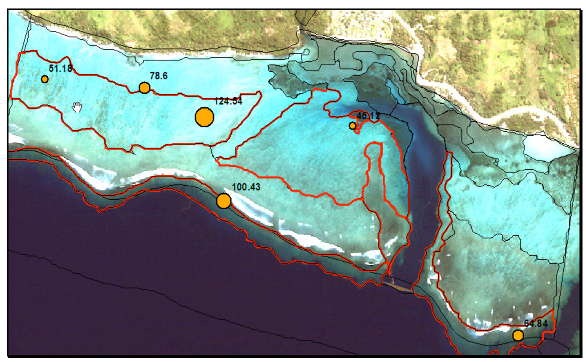
Map of fish biomass composition per individual transects in Hard Coral Habitat



Biomass (g)	HC_1	HC_2	HC_3	HC_4	HC_5	HC_6
Acanthuridae	27.47	46.25	13.31	17.34	21.46	89.65
Balistidae	0.66			4.41		
Labridae			1.12	2.62	0.8	1.17
Scaridae	15.79	29.34		15.09	19.87	7.5
Siganidae			8.2	2.44	10.94	2.11
Serranidae	2.44	0.93		1.78		
Kyphosidae					0.006	
Lethrinidae	27.46	34.81	18.74	3.37	7.03	
Lutjanidae		8.95		1.69	2.06	
Mullidae	4.78	3.14	3.75	2.44	1.5	
Nemipteridae		1.12			1.17	

The Hard Coral Habitat seemed to be dominated by Acanthuridae in terms of Biomass. The biomass values topped all the other families in 5 transects and came second in the other one. The composition of fish in a transect is well composed where all have biomasses in each transect indicating the fish are well spread throughout this habitat even though transects could be more then 100ms' apart.

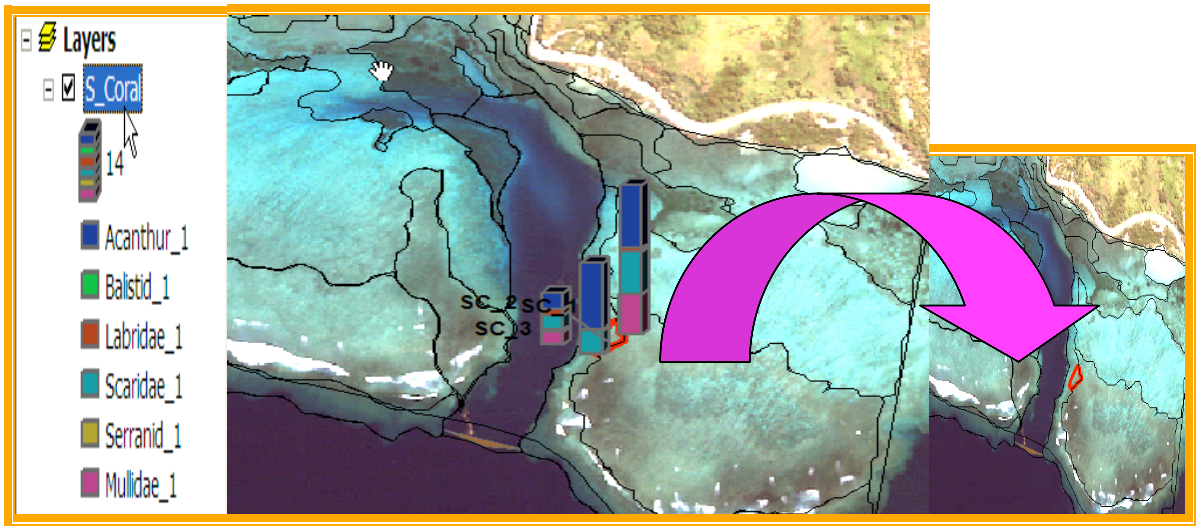
The following diagram respectively depicts biomass of individual families in Hard Coral habitat and the following image shows which transect recorded the highest biomass in Hard Coral habitat.



Acanthuridae has th greaest biomass at 215g while followed by Scaridae and Lethrinidae having values 88g and 91g respectively. The rest of the families have huge differences and are well below the two middle values. Their values of families such as Siganidae (23,8), Lutjanidae (12.7) and Mullidae (15.6) are quite reasonable but due to the large values of the three top families they have been considered to be very insignificant.

5.3.5. Soft Coral

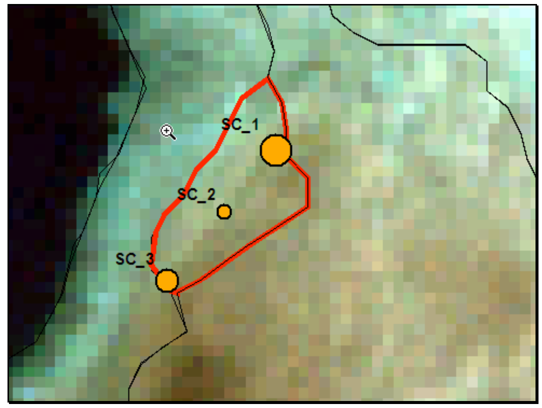
Map of fish biomass composition per individual transects in Soft Coral Habitat



Biomass (g)	SC 1	SC 2	SC 3
Acanthuridae	25.77	6.37	27.09
Balistidae			0.66
Labridae	1.41	2.67	
Scaridae	17.1	5,76	8.81
Serrenidae		0.98	
Mullidae	16.4	4.78	0.8

The Soft Coral Habitat contains the least area compared to other habitat types in the Qoliqoli Navutulevu. The area's biomass is dominated by Acanthuridae (Surgeonfish), Mullidae (Goatfishes) and Scaridae (Parrotfish) even though other fish families are alos present such as Labridae (Wrasse), Serranidae (Honeycomb Grouper) and Balistidae (Triggerfish).

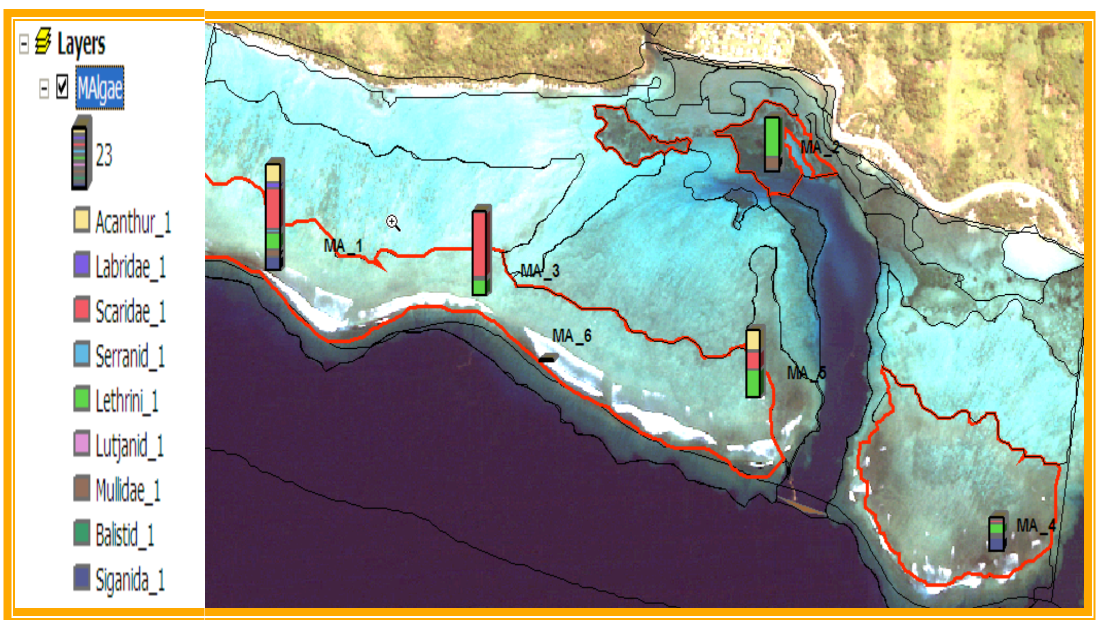
The following diagram respectively depicts biomass of individual families in Soft Coral habitat and the following image shows which transect recorded the highest biomass in Soft Coral habitat.



Acanthuridae (Surgeonfishes) can be concluded to be abundant in this small habitat area as it dominated both biomass and density. Other families following are Scaridae and Mullidae, whilst the low biomass families are Balistidae, Serranidae and Labridae. Transect Sc_1 recorded the most biomass of fish families out of the three transects laid in this habitat.

5.3.6. Macro Algae

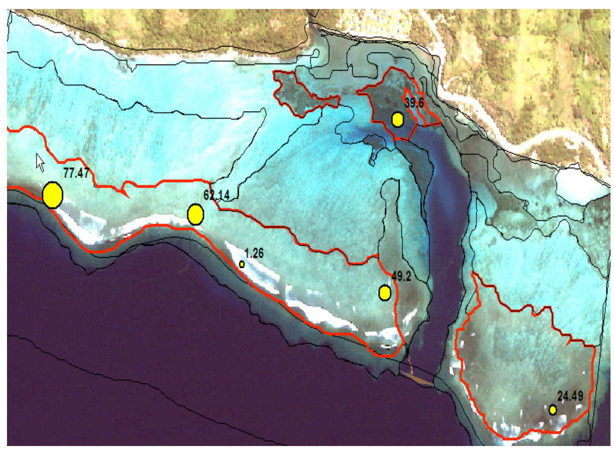
Map of fish biomass composition per individual transects in Macro Algae Habitat



Fish Biomass (g)	MA 1	MA 2	MA 3	MA 4	MA 5	MA 6
Acanthuridae	12.93				14.86	
Labridae	4.64		1.41	2.01	0.56	
Scaridae	30		46.86	2.72	13.17	0.56
Serrenidae	2.81		1.87			
Lethrinidae	11.86	28.4	12	8	20	0.7
Lutjanidae					0.61	
Mullidae	5.06	9.23		1.22		
Balistidae		1.97		1.17		
Siganidae	10.12			9.37		

The transects are spread across the Qoliqoli and in different regions, we can see that Transects on the same reef flat have similar fish as shown on the biomass graph of the three transects. The other two transects displayed a different composition of fish and thus biomass. Biomass for Transects for 1,3 & 5 are dominated by Scaridae followed by Acanthuridae. The rest of the other families have their biomass below 10g.

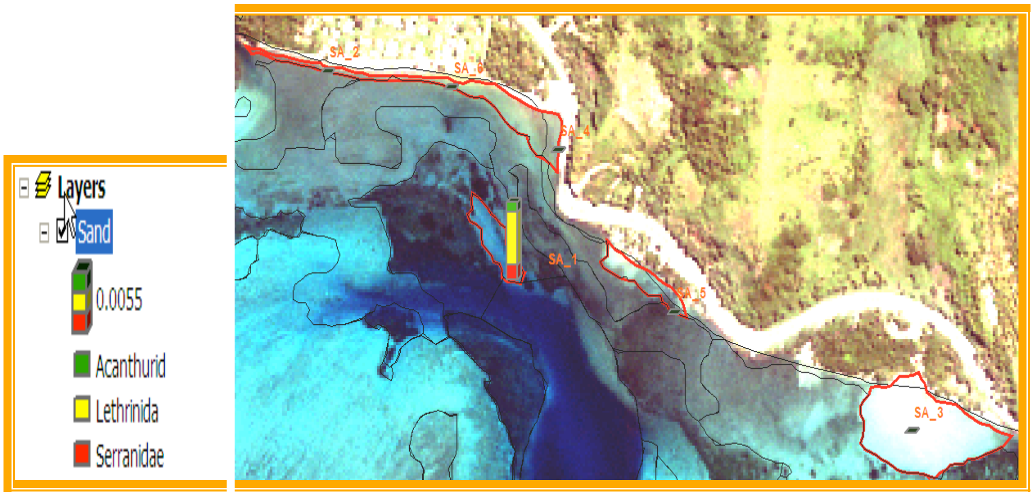
The following diagram respectively depicts biomass of individual families in Macro Algae habitat and the following image shows which transect recorded the highest biomass in Macro Algae habitat.



From the graph, Scaridae and Lethrinidae recorded 93.31g and 80.96g as biomass values respectively while the rest were well below 30g. Scaridae dominated in the Biomass as well as density whilst Lethrinidae had average density but dominated in its biomass. This is an indication that sizes of fish family Lethrinidae in this Habitat are bigger thus their weights are heavy.

5.3.7. Sand Habitat

Map of fish biomass composition per individual transects in Sand Habitat



Fish Biomass (g)	SA_1	SA_2	SA_3	SA_4	SA_5	SA_6
Serrenidae	2.76	0	0	0	0	0
Lethrinidae	14.11	0	0	0	0	0
Acanthuridae	2.34	0	0	0	0	0

All fish recorded were encountered in Transect SA_1, there were no fish recorded during the rest of the transects.

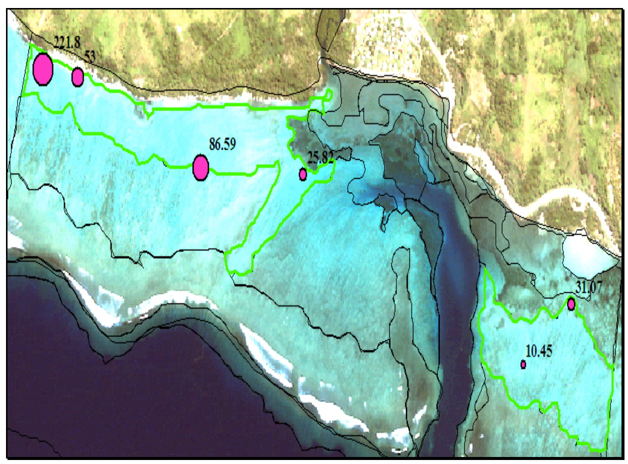
5.3.8. Rock/Rubble Habitat

Map of fish biomass composition per individual transects in Rock/Rubble Habitat

Fish Biomass (g)	RR1	RR 2	RR 3	RR 4	RR 5	RR 6
Acanthuridae				24.13	1.36	18.7
Carangidae					2.62	
Labridae			1.69	10.68		0.56
Scaridae	3.56	12.32	9.14	14.06	37.21	170.3
Serranidae	1.78		0.84			4.78
Lethrinidae	1.41	12.23	2.25	29.52	8.76	7.73
Mullidae	0.89	1.27	1.97	8.2	2.11	19.73
Balistidae			0.89			
Pomacanthidae					0.94	

Only one side of the Rock/Rubble habitat recorded most fish as evident in the diagram above. The density on the right hand side of the Qoliqoli recorded low fish densities and biomass as revealed by the data. Scaridae being the dominant fish family half the number of transects surveyed.

The following diagram respectively depicts biomass of individual families in Rocky/Rubble habitat and the following image shows which transect recorded the highest biomass in Rocky/Rubble habitat.



The graph indicates that Biomass of Scaridae dominates and contributes to the total biomass of the Rock/Rubble habitat followed by Lethrinidae, Acanthuridae and later Mullidae. The rest of the families come in below 12g. On the other diagram the biggest biomass recorded in this habitat exists on one corner of the inshore area whilst the half recorded low biomasses.

5.4. Comparison between MPA and NON-MPA area

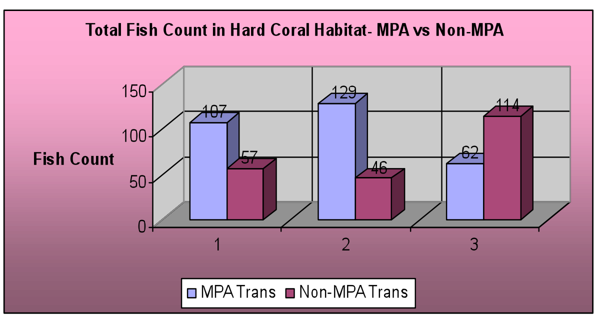
In comparing status of reef fish in MPA area and Non-MPA area, transects within the MPA area were selected to be used to compare with same habitat transects out of the MPA area. Given below are the list of transects in different habitats that will be used in analyzing the status of Fish food species in MPA and Non-MPA area.

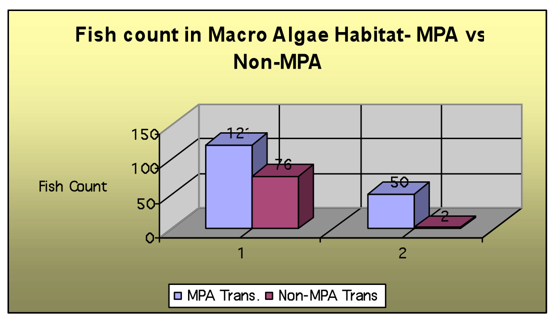
Transects

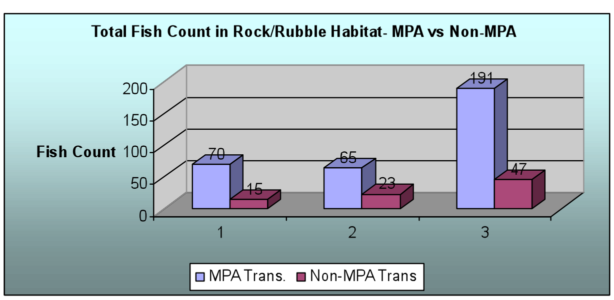
No.	MPA	Non-MPA
1	HC_1	HC_3
2	HC_2	HC_5
3	HC_4	HC_6
4	MA_1	MA_6
5	MA_3	MA_5
6	RR_4	RR_1
7	RR_5	RR_2
8	RR_6	RR_3

5.4.1. Total Fish Count- MPA vs. Non-MPA

One way of checking for the success of an MPA is to compare it with a Non-MPA area but on similar habitat type. The above transects on different habitat type that exist in MPA were used in comparison with transects on Non-MPA area but same habitat type. Fish counts in the two contrasting categories were the first indication to be tested and results are as follows:
5.4.1.1 Fish count in Hard Coral Habitat







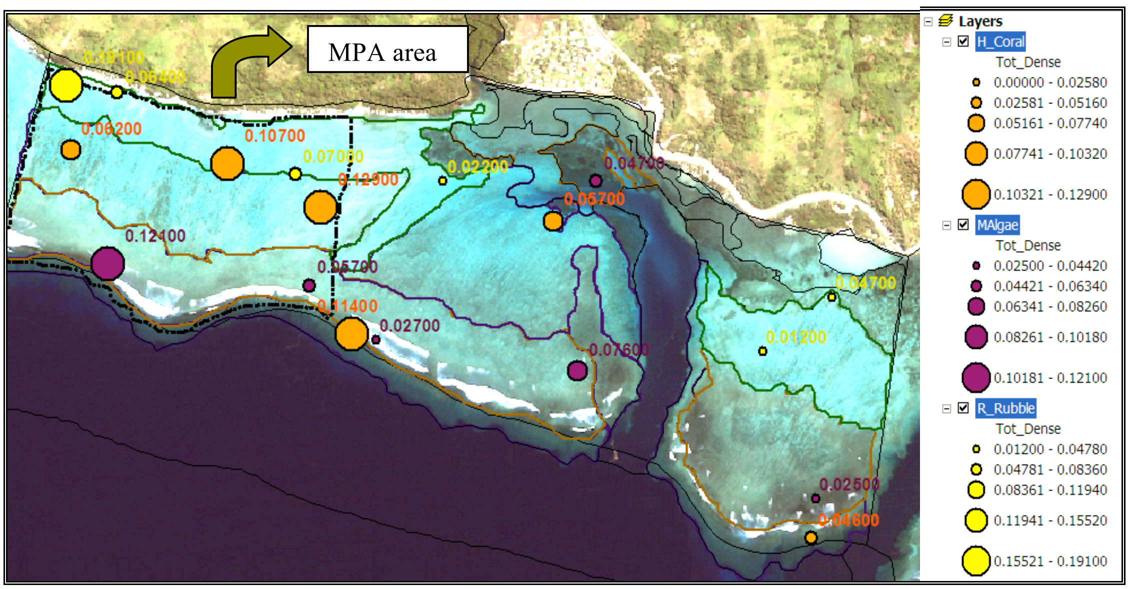
5.4.2. Total Fish Density –MPA vs. Non-MPA

The graph identifies the difference where in Hard Coral Habitat MPA area recorded a total of 289 fish while Non-MPA recorded a total of 217, the Macro Algae habitat recorded a total of 171 fish count in MPA area while Non-MPA area recorded a total of 78 fish and Rock/Rubble habitat recorded a total of 326 fish counted in the MPA zone and 85 fish counted in the Non-MPA zone.

5.4.2. Total Fish Density –MPA vs. Non-MPA

The density between MPA and Non-MPA was analyzed using ArcGIS as previously done before to show the differences in densities between the two zones mentioned above.

Total of Fish Density in each Transect for the three Habitats



In this case the ArcGIS reads all the data from different habitats and classifies them into equal intervals, the number of interval can be changed but for this exercise it has been classed into 5 categories. The software automatically assigns each data entered into their various categories according to their values and adjusts its circle accordingly.

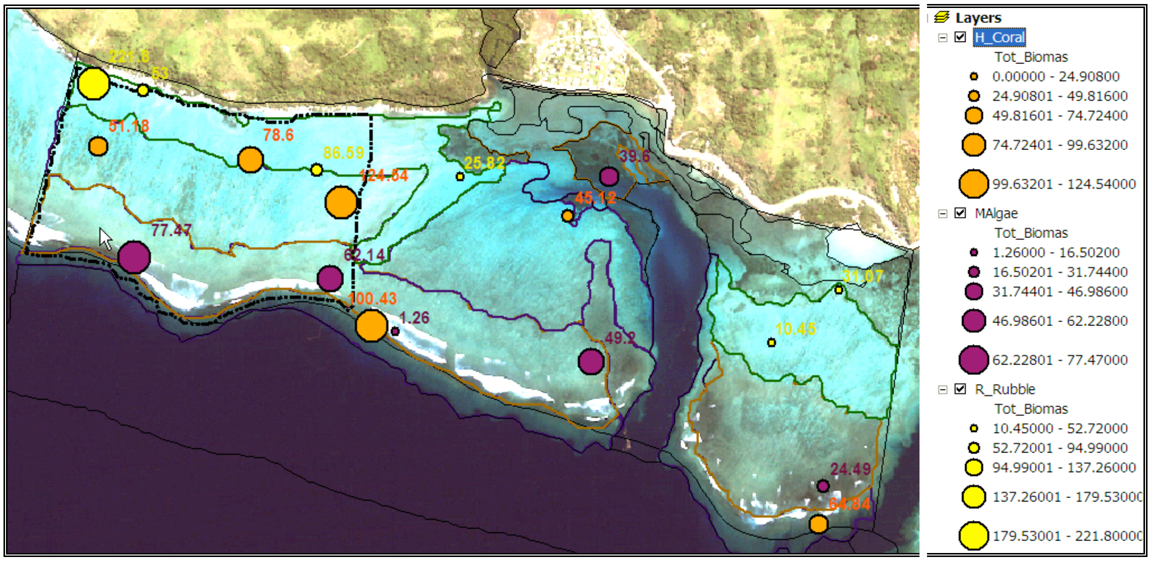
The diagram shows the three habitats and there transects which are located in the MPA and also out of the MPA. The MPA is situated on the top left of the Qoliqoli area, enclosed by a dashed-dotted black line and the rest is the open area.

The circle indicates the total density of fish in each transect and the greater the circle the greater the value of densities and likewise the other way around for the smaller dots. The three different colors are for the three habitat types which are found in the MPA zone.

The MPA zones are dominated by Acanthuridae and Scaridae families in the Hard Coral Habitats and in the Rock/Rubble habitat, Scaridae was found to be dominant. However the Macro Algae habitat was dominated by Scaridae and Lethrinidae.

5.4.3. Total Fish Biomass-MPA vs. Non-MPA

The Biomass of fish between MPA and Non-MPA was also analyzed through the ArcGIS software.



The diagram clearly shows the biomass values of each transect in MPA and Non-MPA area. It is also interesting to note that some good biomass values were also recorded outside the MPA. This is evident in Rock/Rubble and also Hard Coral habitat where some large circles are found out of the MPA.

Fish Families with dominating Biomasses are Acanthuridae, Scaridae and Lethrinidae and followed by Mullidae, Lutjanidae and Siganidae.

After analyzing this data we can argue that MPA is a success and has shown signs of improvement when compared to control sites i.e. outside of MPA area.

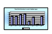
6. Discussion.

A total of 2,759 fish were encountered and recorded after the UVC survey of 45 Belt transects in 8 different benthic habitat types, this had an average of 345 fish per habitat or 61 fish per transect. However this amount cannot be accepted as there were few transects which recorded fish count of twice the average amount. The highest fish encountered in a transect was 191 this was recorded in Rock/Rubble Trans.6 whilst the lowest to be recorded was 16 from Sand Trans 1. There were six transects (DS, PS, LA, HC, MA &RR) which had their highest transect recording well above 100.

6.1. Density

Total fish densities for each habitat per 1000m² are as such:

Habitat	DS	PS	LA	HC	SC	MA	SA	RR	Total
	0.407	0.403	0.479	0.515	0.158	0.353	0.016	0.406	2.737



Hard Coral Benthic Habitat had the highest fish density recorded in all its' transects and lowest being Sand habitat having recorded 0.016 total density. The coral reefs are habitats to a lot of reef fish and good feeding grounds thus a lot of fish count was anticipated before starting of the survey. Acanthuridae, Scaridae and Lethrinidae are the types of fish that dominates this habitat.

Sand habitat is a totally different habitat from the rest as nothing was recorded in it this could be due to heavy sedimentation from the river situated beside the village and also very few of the fish food fish species wonder into sand area for food.

Lagoon also recorded the second highest fish density, due to fresh current flushing into the short inner lagoon area from the reef passage which attracts lots of fish for feeding purposes and also provides good habitat. This habitat not only had a lot of fish but bigger fish sizes

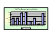
were also noted. Once again Acanthuridae, Scaridae and Lethrinidae are majority of the fish types that can be encountered in this habitat.
The seagrass (Dense and Patchy) habitats are habitats where certain types of fish are confined to this habitat only. These are Siganus spinus, Parupenius indicus whose density are quite high only in seagrass habitats. Fish sizes range from 5cm – 20cm.

Rock/Rubble and Macro Algae Habitats also recorded a moderate populations and fish types recorded in this area are similar to Hard Coral and Lagoon habitat fish types.

6.2. Biomass

Total Biomass recorded in each habitat types are:

Habitat	DS	PS	LG	HC	SC	MA	SA	RR	Total
(g)	255.67	256.9	461.41	464.706	112.84	254.11	19.21	428.73	2,253.58



The graph for biomass of each habitat shows that Hard Coral habitat had the most biomass with 464.76g and Lagoon coming close on 461.41. The two fish families dominated in density and also biomass. This is because large sized fish was recorded in this two habitat types. Size estimates common in Lagoon ranged from 20cm – 30cm and some exceeding the 30cm mark such as *Parupenius barberinus, Lethrinus harak, Naso unicornis, chlororurus microhinos and chlorurus sordidus.*

6.3. MPA vs Non-MPA

Numerous studies have reported higher abundances and larger sizes of fish inside no-take reserves relative to outside while others have reported increase in the abundance and size of fish in an area following its designation as a no-take zone (Scrooter et al 2001). The overall count of number of fish recorded in MPA was 786 and 380 recorded in Non-MPA zone. This has indicated that fish abundance is more in the MPA area relative to Non-MPA area.

ArcGIS analysis of total fish densities and biomass clearly indicated that MPA area was more relative to the open area (Non-MPA).

Fish Density of transects in MPA were compared to transects out of the M PA yet same habitat.

All three types of habitat display similar trends showing transects in MPA zones have a greater densities relative to their counterparts in Non-MPA area.
The Biomass graph also displayed the same results showing more biomass values with transects in MPA zones to Non-MPA zones.

7. Conclusion

To conclude the data that were gathered from this research were very useful and sufficient to make an assessment of the relationship between coral reef fish and various benthic habitats in the Navutulevu inshore area. Analysis of densities and biomass of different transects and habitat types were able to define which habitat has a lot of fish and which doesn't have fish.

From the three hypotheses that were put forward during the proposal, only two were being answered from the analysis of the result. Hypothesis 1 stated that Live hard coral-rich habitats are where most fish can be found thus will have a greater density, biomass and fish abundance. Analysed results proved this hypothesis to be true as most fish abundance, density and biomass were recorded in Hard Coral Habitat. However Lagoon habitat records came second and there was not much difference in results so we can also state that Lagoon contains more fish and thus has greater density, biomass and fish abundance.

Hypothesis three states that Habitats in MPA area will have a greater fish density, biomass and abundance relative to its similar habitats in Non-MPA zones. This hypothesis was also proved correct as results showed that transects in MPA area recorded more fish density, abundance and biomass. However there were few transects in the Non-MPA zones which matched or even surpass results in the MPA area. This could be due to its distance from the community making it very hard to accessed by fishing.

The fish sizes were not being analyzed due to huge amount of data available and analyzing would take a lot of time which is not possible. However if there were time extensions then length would have been analyzed to support or disapprove hypothesis statement 2.

One point of recommendation is that more studies is needed to gauge the effects of fishing pressure on the fish population closer and away from the village and benthic coverage of the transects that were surveyed.

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