An underwater visual census survey of the marine aquarium fish resources of Funafuti Atoll, Tuvalu

By

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BY

Acronyms

SPC	Secretariat of the Pacific Community
ADB	Asian Development Bank
WB	World Bank
SPREP	South Pacific Regional Environment Programme
RFID	Reef Fisheries Integrated Database

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Executive Summary

The international aquarium (freshwater and marine) industry is a multi-billion dollar business with a current annual worldwide wholesale trade value estimated at about US$900 million and a retail trade value of about US$3,000 million

The Pacific nations' role in the international marine aquarium trade has significantly grown over the past decade with continued expansion expected. It is currently the only reef fishery that is proving to be commercially viable in providing a successful ongoing income earning industry and a provider of employment within the region, especially those land impoverished small island states, through direct village-based employment, income generation and export earnings.

Tuvalu is one of the new countries showing an interest in the marine aquarium trade and in 2004 officially requested the Secretariat of the Pacific Community (SPC) for assistance to look into this.

In response to the request, in early 2005, SPC conducted a survey of Funafuti Atoll's marine aquarium resources to assess the presence and abundance of potential species. Such survey will provide the first basis of looking at the feasibility of setting up operations.

Funafuti Atoll is the capital of Tuvalu. It is the largest atoll in the country and has a population of about 4492 (Census 2002), the highest in the country. It is also the main port and therefore is the gateway for international travel and trade. Air Fiji provides two weekly flights between Nausori and Funafuti.

Management of marine resources has followed on from the British colonial administration, giving free access to all marine resources and total management responsibility to the Government. More recently several legal instruments have given more power to the island communities to manage their own resources. All resource management decisions regarding the entire coastal zone/area of each island falls under the Island Council and the *Falekaupule* and therefore considerations of these authorities is important in any future efforts to develop exploitation of marine resources.

In addition to assessing the marine aquarium trade resources of Funafuti, the identification of awareness needs about the marine aquarium trade among the local community was also conducted and 4 local fisheries officers (divers) were trained in the resource survey method to give the Fisheries Department the capacity to be able to conduct other resource appraisals, including monitoring of the resources in the future.

The **distance-sampling underwater visual census (D-UVC)** method was used to assess marine aquarium trade finfish resources in Funafuti Atoll. This is the method that SPC has developed and used to assess reef fisheries resources in the Pacific region.

All fish species with potential for the marine aquarium trade are assessed using Pacific export records as the basis, which reports up to 150 fish species from 20 families.

The bottom substrate was also surveyed using a medium scale approach (MSA), which was also developed by SPC as part of the fisheries resources D-UVC method.

The results of the survey showed a total of 74 species from 12 families with potential for the marine aquarium trade. 58 species from 11 families were reported in the lagoon reef areas and 59 species from 11 families were reported from the outer reefs.

On the outer reefs, the family Pomacentridae (damselfishes) was the most common with *Pomacentrus vaiuli* being the most abundant species with an average density of 48 individuals per 1000 m^2 of reef. Other significant Pomacentrid species included *Pomacentrus pavo*, *Chromis iomelas*, *Chromis margaritifer,* and *Plectroglyphidodon johnstonianus*. Among the Pomacanthids (angelfishes), *Centropyge flavissimus* and *C. loriculus* were the most common.

On the lagoon reefs, again the Pomacentrids were dominant but with *Chrysiptera cyanea* being the most abundant species with an average density of 166 individuals per 1000 m^2 of reef. *Pomacentrus pavo* was also very common with an average density of 117 individuals per 1000 m^2 of reef. Looking at other family groups, the most common Chaetodontid (butterflyfish) in the lagoon was *Chaetodon trifascialis* and the most common Pomacanthid (angelfish) was *Centropyge flavissimus*.

Looking at the observed sizes of the fish species, generally on average the fish seen in Funafuti were 50% or less of the known maximum sizes. This was observed on average in both lagoon and outer reef habitats. Given that these fish species have not been exploited previously then this could be a natural phenomenon but more detailed aging work will be needed to verify this.

Using the mean densities of the different species from the survey, and the total area of lagoon and outer reefs, it was possible to get an estimate of the stock of each fish species in the two different reef habitats.

Generally, there is an adequate stock of fish species with potential for export in the marine aquarium trade in Funafuti. Even by just taking 10 of the more popular

species and with the provision of setting 10% of the stock estimates to be available for export, this would still support some small operations.

Even though the resource might be available, this does not mean that a marine aquarium trade would be automatically feasible to develop. An important area that needs to be considered carefully before deciding on this is the basic infrastructure required to support this export industry. The most obvious factor is the availability of airline connections from Funafuti to the market, including air cargo space available per flight, air freight rates, the number of transits and interflight connection delays.

Should the Tuvalu Government choose to go ahead with the development of the marine aquarium trade in Funafuti then it is very important that a management plan is developed and put in place. The management plan should take into account all the administrative bodies that have some relation and legal authority to all or any part of the coastal marine ecosystem and should also include details of management measures such as regulations, license conditions and fees, a monitoring program, an effective enforcement mechanism and a sustainable source of finance to support all these management activities.

Live coral coverage was 43% in the outer reefs and 33% in the lagoon reefs which is fairly good. Very little evidence (less than 0.5%).of coral bleaching was observed on all reefs.

Basically this report is just to give the status of the resources in terms of presence and abundance of important marine aquarium fish species and with some guidelines on how this trade should be developed based on other known successful experiences from elsewhere.

The successful development of a marine aquarium trade would need a lot more consideration than just the availability of the resource and some commitment from the government in terms of supporting the next required steps. SPC is able to provide further advice if required but first of all the Tuvalu government will need to decide whether they want to move on or not and if so then to further request SPC assistance.

1. Introduction

1.1 Background to the study

At the beginning of 2004, an official request to SPC was received from the Tuvalu Ministry of Natural Resources and Lands through the Tuvalu Ministry of Foreign Affairs. The initial request was to assess the abundance of the live reef food fish resources in all of the Tuvalu atolls and evaluate the feasibility of starting live reef food fish trade operations in Tuvalu. Due to the lack of funding it was not possible to respond to Tuvalu's request immediately and therefore the assistance was delayed until funds become available.

In early 2005, funds from the SPC Fisheries Minor Projects were made available to do the work. After some extensive discussion between the SPC and the Tuvalu Fisheries Department and initial consideration and comparison of problems and difficulties in live reef food fish trade operations and marine aquarium trade operations, it was agreed that the work should look at the marine aquarium fish trade resources first. In addition, instead of conducting the survey of all atolls of Tuvalu, it was more realistic and fundable to assess one or two atolls first and train a team of local fisheries officers on the survey method to be used, to give them the technical capacity to conduct underwater fish surveys and to extend the survey to the other islands of Tuvalu. After consideration of the logistics, it was decided appropriate to conduct the survey in Funafuti atoll and to train the fisheries officers on the UVC method at the same time.

The present report presents results of a baseline survey of the marine aquarium resources of Funafuti conducted in 2005 by SPC in association with the Tuvalu Fisheries Department. The survey focused mainly on finfish resources and did not take into account the invertebrate resources. Some observations were made on bottom habitat making it possible to give a general description of the status of the live coral coverage.

1.2 The Marine Aquarium Trade

The international aquarium (freshwater and marine) industry is a multi-billion dollar business with a current annual worldwide wholesale trade value estimated at about US$900 million and a retail trade value of about US$3,000 million (Forum Secretariat, 1999 & Holthus, 2001).

The market for the aquarium trade is dominated by the Unites States, with an estimated 60 percent of the demand. Western Europe (Germany, France and the United Kingdom), Japan, Taiwan and Australia constitute the remaining 40 percent of the market (Holthus, 2001). A greater majority of the aquarium fish species being traded are freshwater species, however marine tropical species are considered more prestigious and therefore are valued higher.

The Pacific nations' role in the international marine aquarium trade has significantly grown over the past decade with continued expansion expected. It is currently the only reef fishery that is proving to be commercially viable in providing a successful ongoing income earning industry and a provider of employment within the region. It is also seen as an industry that is making good use of fisheries resource, given the fact that the species being traded are not food fish species and therefore would not be normally utilized otherwise.

The marine aquarium organisms being traded consist of fish species and invertebrates, live rock, and live corals, with most of these coming mainly from the tropics. Subsequently, the marine aquarium industry provides a valuable economic opportunity for Pacific island communities especially in those land resources-impoverished small island states, through direct village-based employment, income generation and export earnings.

Regional estimates indicate that over 150 species of marine aquarium fish are traded by the industry with an estimated annual number of over 400,000 individuals. The export of marine aquarium fish species from the Pacific is dominated by the Republic of Kiribati which constitutes about 49 percent. The annual live rock exports for the region are estimated at 700,000 metric tonnes for 2003 with 95 percent of this originating from Fiji.

The SPC member countries that are currently involved in the marine aquarium industry include: Fiji, Tonga, Vanuatu, Solomon Islands, Cook Islands, Marshall Islands (RMI), Palau, American Samoa, Kiribati, New Caledonia and French Polynesia. A few more Pacific countries like Tuvalu are seriously considering starting marine aquarium trade operations. This includes Nauru, PNG, FSM and Samoa. In order for these operations to be sustainable, it is vitally important to have realistic and effective management and monitoring regimes for this trade. A baseline assessment of the resource forms one of the first important steps in developing such a fishery and its management plan. It is therefore our hope that the results of this study would be useful in providing this required baseline which would be useful also for future reference.

2. The country of Tuvalu

2.1 General Geography

Tuvalu is one of the smallest island nations in the Pacific region and lies west of the international dateline and 1000 km north of Fiji in the central Pacific just below the equator (Tuvalu Fact File 1997-1998). This tiny island nation is comprised of nine very low lying coralline islands scattered over a wide space of ocean. The islands highest point above sea level is about 3 m. The very sandy and porous soil is not fertile and hence agricultural opportunities are limited. The marine resources therefore form an important source of protein and provides the basis of the mostly subsistence livelihood for the people (see next section).

The total population for Tuvalu is less than 10,000 people with an annual growth rate of 0.5% (Government of Tuvalu, 2002). 47% of this population resides on Fogafale, the main island of the country's capital atoll, Funafuti, giving a population density of about 1,610 people per square kilometers which is one of the highest population densities in the region.

The primary source of cash income is through government employment which is especially very significant in Funafuti, the capital atoll, where the government headquarters are based. Remittances from relatives living and working abroad including seafarers also provide an important income support to families and contribution to the economy of the country. Business opportunities exist but are limited to local scale and include: sale of fish or marine produce, handicraft production and small retail shops. Export opportunities have been limited by the lack of good transportation links to overseas markets.

2.2 The Coastal Fisheries of Tuvalu

Fisheries related activities in the country are very limited and fishing is mainly for local consumption. Reef fishing is the most common fishing activity which accounts to more than 75% of fishing households. This is due to the accessibility of reef fishing areas and the ease of efforts to catch some of these reef fish. Various fishing methods and gears are used for catching fish in the reef areas. Common fishing methods include hand-lining, trolling, gill netting, scoop-net fishing, rod fishing and spearfishing. The use of traditional fishing gears is considered outdated and the use of modern fishing gears is now much more preferred. Some of the currently known main uses of coastal reef resources include:

Source of food for households

The marine reef resources provide the main source of food and especially protein for more than 50% of the households in Tuvalu. This dependence is apparently higher in the outer islands (59% - 95% of households) compared to Funafuti (just over 50% of the households).

Special food items for social events

Shellfish stocks are not usually subsistence food. However, they are particularly important food during festive seasons and for special occasions such as weddings, funerals, birthday parties and government occasions.

Shellfish for handicrafts

While larger shells are collected for food, the cowries and other small species are collected especially for the ornamental industry and for making handicraft. In the 2002 census, 137 women were reported as being economically active in the production and selling of handicrafts. These handicrafts are targeted at tourists and visitors. The very small number of tourists that usually visit Tuvalu puts a

limit on this income earning activity. There is also a concern about the sustainability of the collection of shellfish for this use.

Small scale commercial fishing

Small scale commercial fishing operations are a common feature on the islands of Tuvalu. This is more attractive in Funafuti with the bigger local demand compared to the outer islands.

Very little is known about the status of the reef fish stocks in Tuvalu. However there is a general belief among residents that fish stocks are already in decline especially in reef areas adjacent to villages with the increasing human population perhaps as the main contributing factor to the problem. Given the significant importance of coastal fisheries resources, the need for proper assessment to develop practical management guidelines for the resource should be given high priority.

2.3 Management Framework

Tuvalu has a nationwide open access system of resource ownership. Traditionally, the Government has the power to control the overall fisheries. This power is vested in the Minister responsible for Fisheries (Fisheries Ordinance 1990). Basically, the State owns everything up to, and including, the coastal highest water mark and includes both all marine living resources (fish and invertebrates) as well as non-living resources (minerals, sand, gravel, rubble, rock etc.) below and above the seabed.

Regulations pertaining to matters related to the marine sector include the Fisheries Act, the Local Government Act, and the Maritime Act which to date have been ineffective in managing the marine resources, due to the lack of resources in terms of capital and manpower. More recently several legal instruments have given more power to the island communities to manage their own resources. The 1997 *Falekaupule* Act, the Marine Resources Conservation Area Act and the 2006 Marine Resources Act all give significant recognition to the coastal fisheries resources and provide a stronger legal framework for its management by the communities.

Nowadays, all resource management decisions regarding the entire coastal zone/area of each island fall under the Island Council and the *Falekaupule*.

The Island Council is a body made up of members selected by and representing the island communities, and is empowered by the national government as the administrative authority with the legal power and responsibility for the management of the coastal area in line with the welfare of the people. The Island Council makes and administers by-laws and levy rates, and can also refer major legal or administrative matters to the national government for advice or for finalising decisions where decisions are hard to be made.

The *Falekaupule* (assembly of elders) is comprised of all men in a community over the age of 50 years old who regularly meet to discuss issues pertaining to the welfare of the people. Under the *Falekaupule Act*, they have the power to control and regulate fisheries activities within their area of jurisdiction (12 miles off from shore). They are the body that endorses any by-laws or resolutions proposed by the Island Council as stated under the *1997 Falekaupule Act*, "…no Town Council resolutions and by-laws can be passed without the consent of the *Falekaupule* (Government of Tuvalu, 1995)…" but by-laws agreed upon by the *Falekaupule* during their meetings (*fono*) can be immediately implemented and enacted with the application of penalties on perpetrators, without the need of gazetting. The new by-laws, after being legally scrutinized and if proven to possess merits in the national interest, will be formulated into a bill which is submitted for debate in parliament. If the bill is passed in parliament, it is then gazetted and comes into force.

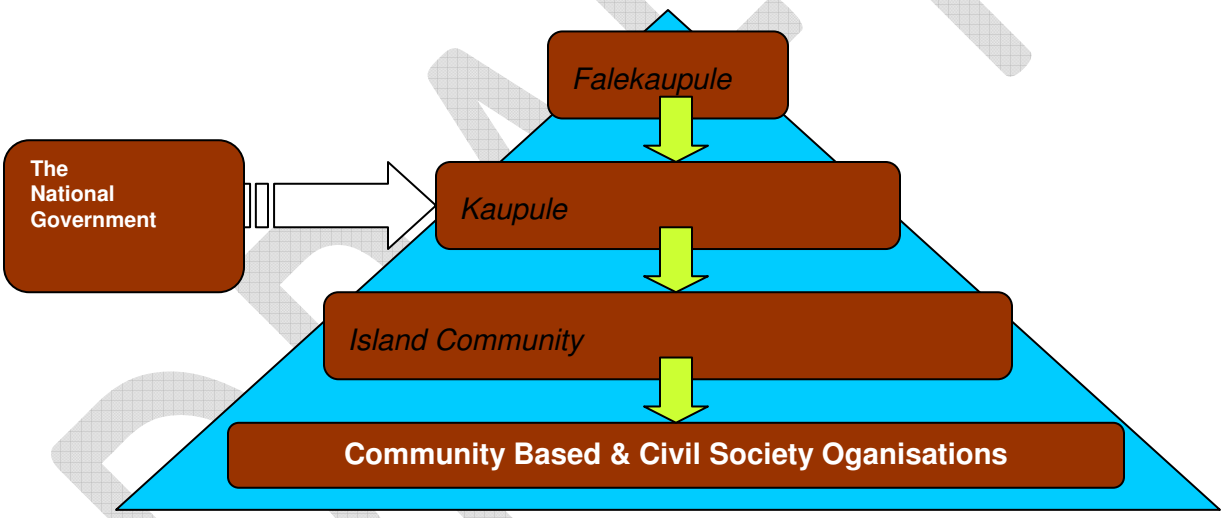

Figure 1. Structure of Community Governance. The Falekaupule is the product of the fusion of the traditional leadership and the introduced governing system and it functions as the decision making body on the island. The Kaupule is the executive arm of the Falekaupule. The central Government links directly to the Kaupule. (Adopted from Tuvalu NAPA Document).

3. Study Site

3.1 Funafuti Atoll

General

Funafuti Atoll is the capital of Tuvalu. It is the largest atoll in the country and has a population of about 3962 which is the highest population in the country (see also Section 2.1). Funafuti is also the main port and therefore is the gateway for international travel and trade. Air Fiji provides two weekly flights between Nausori and Funafuti. International shipping services for passengers and cargo are

provided regularly by the government-owned vessel as well as by private overseas shipping companies. An inter-island government-run ferry service provides the only transportation link with the outer islands. Even as the main port, and with more economic opportunities compared to the rest of the atolls in Tuvalu, Funafuti currently still lacks any ongoing activities for foreign trade**.**

Topography

The atoll is only between 3-5 m above sea level but with quite a large reef and lagoon areas (the largest for the country). The atoll is made up of a series of submerged reef encircling a lagoon of about 205 km^2 and 40-50 m deep. Mclean & Hosking (1991) described the reef platform of 37 km^2, to consist of bare reef flats (92 %), vegetated islets (7 %) and adjacent beaches (1 %). The eastern side of the atoll is comprised of well vegetated islets and is where the population of the atoll is concentrated. On the western side of the atoll is a barrier reef consisting of a few very small islets, traversed by deep passages, where the GEF-funded national marine conservation area, established in 1996, is located. The deepest passage is located on the south-east part of the atoll which is the only one through which the big ships such as tourist cruise liners can pass and enter into the lagoon. All the other numerous passages are only deep enough for any other smaller ships (passenger, cargo and fishing) to pass through, especially during high tides.

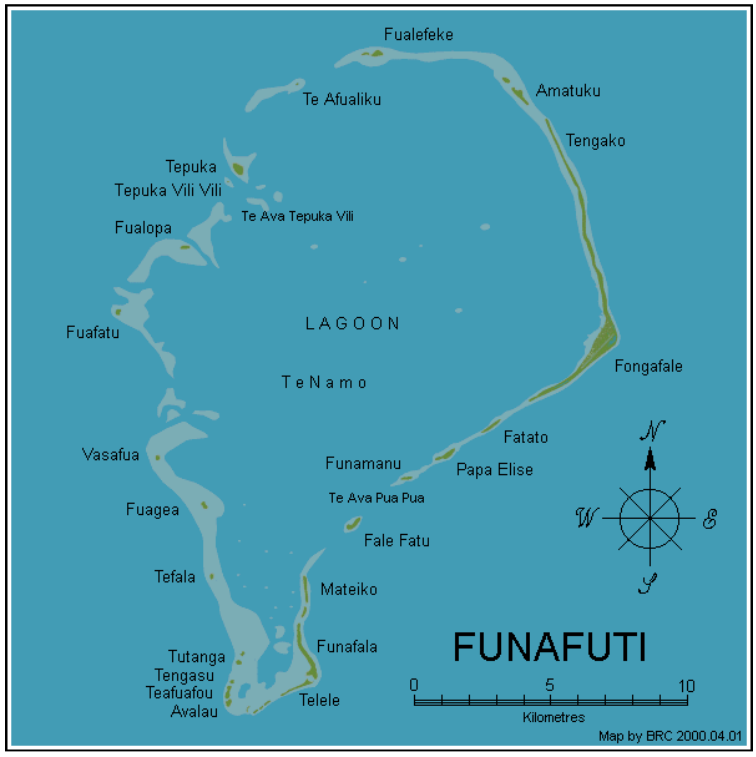

Figure 2. Map of Funafuti Atoll with its numerous islets and reef passages

Fishing Activities

There are currently no formal commercial fishing and fisheries related operations on Funafuti. The National Fishing Corporation of Tuvalu (Naficot) once tried a deep bottom and outer reef fishing operation exporting to buyers in Fiji. The operation was stopped because fish stocks were too low to meet the demand and to make it economically sustainable. Also, there have been several small-beche-de-mer operations on the island some years back. The entrepreneurs hired local divers, and, using hookah gears, engaged in the collection of high valued white-teat fish. The stocks were too low to sustain operations and this, along with the big drop in market prices of beche-de-mer, the operations had to close down.

In Funafuti, the demand for fish is high. To meet this local demand there are a number of small scale local commercial fishing activities which undertake a mixture of ocean fishing for tuna and reef fishing using mostly outboard powered boats. A high percentage of households in Funafuti still consume fish that they catch themselves. Most of this fishing is done by men but women and children are quite often engaged in shallow water fishing and also in reef gleaning activities to collect invertebrates such *Anadara* species, turbo and ornamental seashells. The seashells are sold to the ornamental seashell trade which is the biggest employer of women on Funafuti and the whole country.

Fish Consumption

On Funafuti, the average estimated per capita daily consumption of fish seemed to have dropped in recent years from 0.9 kg per head per day reported by Sauni, 1997 (34% coverage) to 0.4 kg per head per day in 2005 (5% coverage, SPC, 2005). It is not known if the cause of the drop is due to less fish being available or to the increased preference of the local people for imported sources of protein.

3.2 Marine Resource Management

As described in Section 2.3 above, like the rest of all the atolls in Tuvalu, the management of marine resources in Funafuti is controlled and administered under the powers of the *Falekaupule* and the Island Council through by-laws. These new endorsed by-laws become as effective as any already existing fisheries regulations established under the Fisheries Ordinance. The number of existing related by-laws and fisheries regulations for Funafuti includes:

- the ban of catching *Selar crumenophthalmus* (salala) fish (bye-law)
- restriction of gillnet mesh-sizes (by-law)
- indiscriminate harvesting of giant clams and beche-de-mer in certain reef areas (by-law)
- prohibition of the use of hookah and scuba gears for any form of fishing (fisheries regulation)
- use of dynamite and any form of fish poisons (fisheries regulation)

Under the new Marine Resources Area Conservation Act, the Funafuti Conservation Area was established in 1996. This is the only legal localized tapu area in the country, covering approximately 33 square kilometers of protected marine area which is a third of the entire Funafuti atoll, and includes six small motus and about 20 percent of the total coral reef area of Funafuti lagoon. All animals and plants in this area both on land and in the sea are protected. The excavation of beach sand and gravels from this protected area is also prohibited.

In the present exercise, the importance of this existing legal framework is recognized and any future efforts to develop and manage the marine aquarium resources should consider and respect these legal instruments to avoid any potential management conflicts in the future.

4. Objectives

The primary purpose of the study was to conduct an assessment of the marine aquarium fish resources of Funafuti, i.e. to find out what species exist and if they are in good enough numbers to support a marine aquarium fish trade.

The secondary aim is to collect the relevant information needed for a first and quick assessment of the economical viability and feasibility of setting up a marine aquarium trade in Funafuti. An assessment of the level of awareness about the marine aquarium fish trade among the local community was also conducted in order to identify the kind of information that is needed to improve basic understanding about the trade, which would be valuable in the future should the Government of Tuvalu choose to start a marine aquarium trade.

Most of the Pacific countries do not have local expertise to conduct resources surveys so, as a side objective of this study, a training component was included to address this issue and train at least 4 local divers, preferably from the Fisheries Department, on the underwater visual census method that SPC have been using in their reef fisheries resources assessment work. With this building of local technical capacity to do surveys, it is then expected that the surveys can be extended to the other atolls in Tuvalu and, over the long term, if marine aquarium trade operations do start, then the Fisheries Department would have the capacity to monitor the trade.

5. Methodology

5.1 Underwater visual census

The **distance-sampling underwater visual census (D-UVC)** method (Kulbicki and Sarramegna 1999, Kulbicki *et al.* 2000) was used to assess the marine aquarium trade finfish resources in Funafuti Atoll. The D-UVC is fully described in Labrosse *et al.* (2002). The transect consists of a 50 m line, represented on the seafloor by an underwater tape (Fig. 2). Briefly, the method consists of recording

the species name, abundance, body length and the distance to the transect line for each fish or group of fish observed. Normally, for safety reasons, two divers are required to conduct a survey, each diver counting fish on a different side of the transect line. Mathematical models are then used to estimate fish density (number of fish per unit area) and biomass (weight of fish per unit area) from the counts.

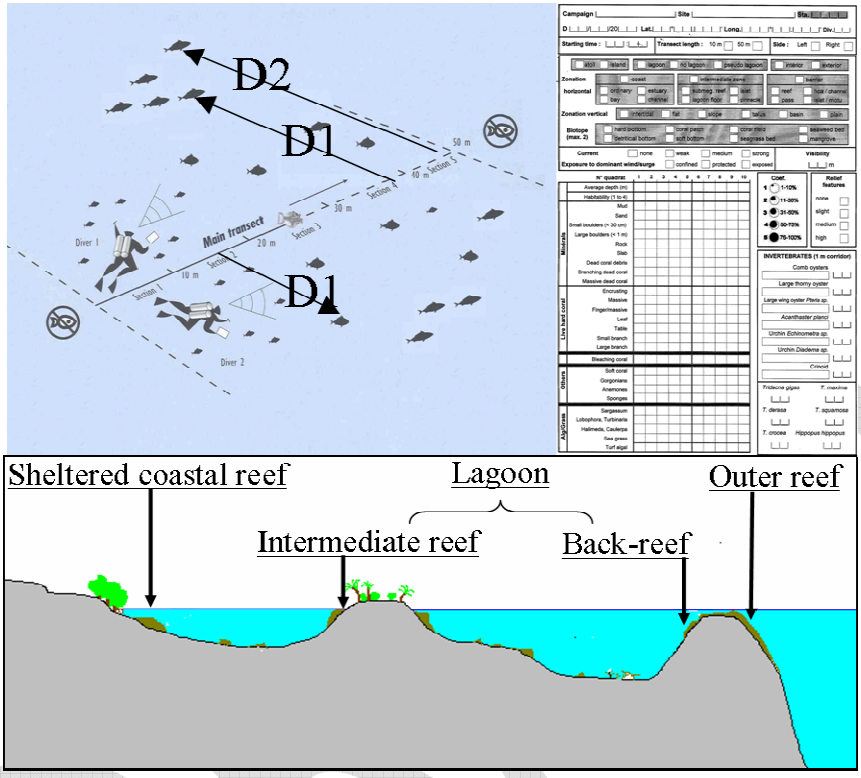

Figure 3. Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC). Each diver recorded number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper.

5.2 Species Selection

Only reef fish of interest to the marine aquarium trade were surveyed. Since Tuvalu does not have a marine aquarium trade yet and therefore there was no existing list of local species of interest, a preliminary list of species was obtained from the export invoices of nearby pacific countries of the most commonly exported species. There are about 150 fish species from 20 families that are commonly exported from the Pacific countries. These are listed in Table 1 below.

5.3 Substrate

Having some idea of the bottom substrate where the fish were counted is important in order to be able to explain some of the environmental factors that may influence the local abundance and distributions of fish species. A modified version of the **medium scale approach** (MSA) similar to that developed and

described by Clua *et al*. (2006) was used to record substrate characteristics along transects where finfish were counted. Briefly, the method consists of recording depth, habitat complexity, and 23 substrate parameters within ten 5x5 m quadrats located on each side of a 50-m transect, for a total of 20 quadrats per transect (Fig. 2). The transect's habitat characteristics are then calculated by averaging substrate records over the 20 quadrats.

Table 1 List of species with potential for the marine aquarium trade

Family	Selected species
Acanthuridae (surgeonfishes)	*Acanthurus achilles, A. dussumieri, A. guttatus, A. lineatus, A. maculiceps, A. mata, A. nigricans, A. nigrofuscus, A. nigroris, A. olivaceus, A. pyroferus,* all species of genus *Ctenochaetus* and *Zebrasoma*
Balistidae (triggerfishes)	*Abalistes stellatus, Balistapus undulates, Balistoides conspicillum,* all species of genus *Melichthys*, *Rhinecanthus* and *Sufflamen*
Blenniidae (blennies)	All species
Callionymidae (dragonets)	All species
Chaetodontidae (butterflyfishes)	All species
Cirrhitidae (hawkfishes)	All species
Ephippidae (batfishes)	All species
Gobiidae (gobies)	All species
Labridae (wrasses)	All species of genus *Anampses, Bodianus, Choerodon, Cirrhilabrus, Coris, Halichoeres, Hemigymnus, Hologymnosus, Iniistius, Labroides, Labropsis, Macropharyngodon, Oxycheilinus, Pseudocheilinus, Pseudojuloides, Stethojulis, Thalassoma, Wetmorella, Epibulus insidiator, Gomphosus varius, Labrichthys unilineatus* and *Novaculichthys taeniourus*
Microdesmidae (wormfishes and dartfishes)	All species
Monacanthidae (filefishes)	All species
Mullidae (goatfishes)	Juveniles of genus *Parupeneus*
Ostraciidae (trunkfishes)	All species
Pomacanthidae (angelfishes)	All species
Pomacentridae (damselfishes)	All species
Pseudochromidae (dottybacks)	All species
Ptereleotridae (dartfishes)	All species
Scorpaenidae (scorpionfishes)	All species of genus *Pterois*
Serranidae (groupers, fairy basslets and anthias)	All species of genus *Luzonichthys*, *Pseudanthias,* Juveniles of genus *Variola and Cephalopholis*
Tetraodontidae (puffers)	All species
Zanclidae (moorish idol)	All species

5.4 Parameters of interest

Fish resources

In this report, the interest is to note the occurrence of the fish species that has potential for the marine aquarium trade and to get an idea of how much of these species are available. The following parameters are therefore noted:

- **biodiversity —** the number of families, genera and species observed and counted in D-UVC transects;
- **density** (fish per m^2) — estimated from fish abundance in D-UVC;

- **size** (cm fork length) — direct estimated record of fish size by D-UVC;
- **community structure —** density and size compared among families;
- **stock size estimates —** number of individuals per species estimated in potentially known habitable reef areas.

The parameter **size ratio** (%) — the ratio between fish size and maximum reported size of the species – could be used as an indicator for over fishing of a species. This ratio can range from nearly zero when fish are very small (usually the case when the bigger size fish have been removed by fishing) to nearly one when fish has reached the greatest size reported for the species (unfished population). The calculation of this parameter uses maximum reported size from referenced sources for each species stored in the RFID database. This parameter is not considered in this report but could be a useful one to consider in future monitoring surveys.

Substrates

The bottom substrates are assessed at all sites in terms of several crucial substrate parameters. These are obtained by grouping 23 primary substrate parameters recorded by divers into 6 groups:

- **depth** (m);
- **soft bottom** (% cover) — sum of substrate components **(1). mud** (sediment particles < 0.1 mm) and **(2). sand and gravel** (0.1 mm < hard particles < 30 mm);
- **rubble and boulders** (% cover) — sum of substrate components **(3). dead coral debris** (carbonated structures of heterogeneous sizes, broken and removed from their original locations), **(4). small boulders** (diameter < 30 cm) and **(5). large boulders** (diameter < 1 m);
- **hard bottom** (% cover) — sum of substrate components **(6). slab and pavement** (flat hard substratum with no relief), rock (massive minerals) and eroded dead coral (carbonated edifices that have lost their coral colony shape), **(7). dead coral** (dead carbonated edifices that are still in place and retain a general coral shape) and **(8). bleaching coral**;
- **live coral** (% cover) — sum of substrate components **(9). encrusting live coral**, **(10). massive and sub-massive live corals**, **(11). digitate live coral**, **(12). branching live coral**, **(13). foliose live coral**, **(14). tabulate live coral** and **(15). Millepora spp**.; and
- **soft coral** (% cover) — substrate component **(16). soft coral**.

5.5 Survey Design

Coral reef ecosystems are complex and diverse. The NASA Millennium Coral Reef Mapping Project (http://imars.marine.usf.edu/corals/index.html) has

identified and classified coral reefs of the world in about 1000 categories.[1] These very detailed categories can be used directly to try to explain the status of living resources or be lumped into more general categories to fit a study's particular needs. For the needs of the present marine aquarium finfish resource assessment, reef types using the Millennium Project classification were grouped into two main categories: – lagoon reefs, which includes the sheltered coastal reefs, the intermediate reefs and the back reefs, and the outer reefs (Fig. 2). A definition of the reef types is given below.

- **lagoon reef —** three sub categories
  - **sheltered coastal reef —** reef that fringes the land but is located inside a lagoon or a pseudo-lagoon;
  - **intermediate reef (**patch reef that is located inside a lagoon or a pseudo-lagoon) and
  - **back reef (**inner/lagoon side of outer reef); and
- **outer reef —** ocean side of fringing or barrier reefs.

Fish and associated habitat parameters are recorded along 30 transects for the whole atoll, with a balanced design of 15 transects on the lagoon reefs and 15 transects on the outer reefs. The exact position of transects are determined in advance using satellite imagery, and actual positions are also marked using a handheld Garmin GPS (Global Positioning System) 72, to maximize accuracy and to allow repeatability for monitoring purposes.

5.6 Scaling

Maps from the Millennium Project allow the calculation of reef areas in the study site, and those areas can be used to scale (using weighted averages) the resource assessment at any spatial level. Technically, the weight given to each transect corresponds to the ratio between the area of the reef structure on which the transect was conducted (e.g. the area of sheltered coastal reef) and the product of the total area of reef present (i.e. the area of sheltered coastal reef + the area of intermediate reef, etc.) and the total number of transects performed on the reef structure on which the transect was done.

[1] Thanks to a collaboration with Dr Serge Andrefouet, IRD-Coreus Noumea and leader of the Millenium Project, our study benefited in real time from the outputs of the ongoing Millenium Project.

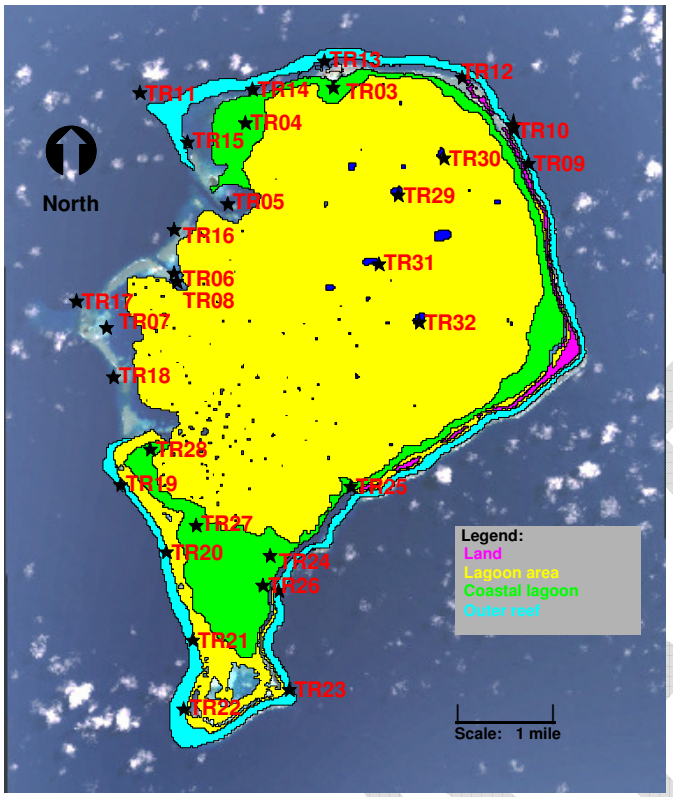

Figure 4. Location of sampling stations on Funafuti Atoll

5.7 Training of local Fisheries Officers

One of the main aims of the SPC Regional Live Reef Fish Trade (LRFT) Initiative is to try and address the problem of lack of technical capacity in the Pacific Island member countries and territories to monitor and manage live reef fisheries both for the Live Reef Food Fish (LRFF) and the aquarium trade (AT). The approach taken by the Initiative is to use the country field surveys to train local fisheries officers in the survey methods. A one week hands-on training is usually conducted before the survey is done. The trained local fisheries officers are then given the opportunity to participate and apply their newly acquired field survey skills in the actual survey under the guidance of the SPC Live Reef Fisheries Scientist.

Following the in-country survey, one of the trained local officers is given the opportunity to go to the SPC headquarters and learn on how to process the survey data using the SPC Reef Fisheries Observatory Interactive Database (RFID). The data processing component also includes the analysis of the data, interpretation and writing up the results into a technical report. For most countries where a live reef fish trade already exists (LRFF or AT), this would also include the drafting up of a management plan and a monitoring program for the particular fisheries.

From this capacity building program, it is expected that the trained local fisheries officers would be able to carry out any required future assessment surveys in new proposed sites and to conduct the monitoring of any ongoing live reef fish activities.

The present technical report is the result of a survey conducted in Funafuti using this approach.

6. Results

6.1 Species Numbers and Abundance

For the whole Funafuti survey, a total of 74 species from 12 families which have potential for the marine aquarium trade were recorded. 58 species from 11 families were reported in the lagoon reef areas and 59 species from 11 families were reported from the outer reefs. A complete list of species is appended but the number of species recorded by family is given in Table 2 below.

It should be noted here that the number of species recorded does not reflect species biodiversity but rather the number of species seen with potential for the marine aquarium trade.

Table 2 Fish families and numbers of species recorded in the survey

FISH FAMILY:	No. of Species	
	Lagoon Reefs	Outer Reefs
Acanthuridae	4	3
Balistidae	2	3
Blennidae	1	0
Chaetodontidae	15	19
Cirrhitidae	1	1
Gobiidae	1	1
Labridae	16	15
Microdesmidae	0	2
Mullidae	1	1
Pomacanthidae	4	4
Pomacentridae	12	9
Zanclidae	1	1

The density of all the different species that were censured in the survey are given in Appendix II. In terms of abundance, the family Pomacentridae (damselfishes) was very well represented on the outer reefs with *Pomacentrus vaiuli* being the

most abundant species with an average density of 48 individuals/1000 m^2 of reef. The other Pomacentrids with significant densities includes *Pomacentrus pavo* (38 inds/1000 m^2), *Chromis iomelas* (23), *Chromis margaritifer* (22) and *Plectroglyphidodon johnstonianus* (15). Among the Pomacanthids (angelfishes), two species were quite common; *Centropyge flavissimus* with an average density of 17 inds/1000 m^2 of reef and *C. loriculus* with an average density of 8 inds/1000 m^2 of reef.

On the lagoon reefs, again the Pomacentrids were very well represented but this time with *Chrysiptera cyanea* being the most abundant species with an average density of 166 inds/1000 m^2 of reef. *Pomacentrus pavo* was also very common with an average density of 117 inds/1000 m^2 of reef. The most common Chaetodon (butterflyfish) in the lagoon was *Chaetodon trifascialis* with an average density of 19 inds/1000 m^2 of reef. The most common Pomacanthid (angelfish) was *Centropyge flavissimus* with an average density of 15 inds/1000 m^2 of reef.

6.2 Species Size Distributions

Given that neither maximum size estimates specific for fish species of Funafuti or Tuvalu, nor size estimates from previous surveys are available, it was only possible to compare the fish sizes of fish surveyed with maximum size estimates of the fish species obtained from Fishbase 2004. It should be noted here that these maximum size estimates might be very different from the real maximum sizes of fish species in Tuvalu and therefore should be treated with caution.

The mean sizes of fish species in the survey and associated size ratios i.e. ratio of mean size to known maximum size, are tabulated in Appendix III. Looking at the mean sizes of fish on the outer reefs of Funafuti, only 19% of the fish species were larger than 50% of known maximum size. In the lagoon, however, a lot more of the fish species recorded (i.e. 32%) were larger than 50% of the known maximum size.

From this it will seem that most of the fish species in Tuvalu are generally much smaller in size than the same species from other areas as reported in the literature. In exploited fisheries situations, this would have been normally associated to over fishing of the adult populations. However, given that these particular species have not been exploited then this is very unlikely. Another possible explanation might have to do with differences in habitat preference between size groups (Helfman, 1978; Wener and Gilliam, 1984; Jones, 1988) or just that fish in Tuvalu might be naturally smaller on average than those from other places. All of these however would need to be verified further with more work.

6.3 Stock Estimates

Using the mean densities of the different species from the survey, it was possible to get an estimate of the stock of each fish species in the two different reef habitats, the lagoon reefs and the outer reefs, by simply multiplying the density of each fish species for each habitat per 1000 m^2 by the total area of lagoon reefs and outer reefs respectively, as in Equation 1 below.

Species Density x Reef Area = Species Stock ……Equation 1

(**species density** is the density of a species obtained from the UVC survey conducted in a particular reef habitat and **reef area** is the estimated total area of that particular reef habitat calculated using the reef classification and area estimates of Dr. Serge Andrefouet from the Millennium Project).

The calculated stock estimates of each species in the different habitats are given in Appendix IIA and the total combined stock estimate for the surveyed species for Funafuti are given in Appendix IIB. From these tabulated stock estimates, it can be seen that among the species in the lagoon *Chrysiptera cyanea* was the most abundant, with an estimated lagoon stock of about 8.1 million individuals. On the outer fringing reef, the *Pomacentrus vaiuli* was the most abundant, with a stock estimate of 1.2 million individuals.

It should be stressed here that these calculated estimates of the stock of the different species are first one-off estimates and assumes that fish are distributed homogeneously and at the moment will not take into account for any temporal and spatial variations in distributions. The calculated stock estimates will be reviewed and improved through further repeated surveys.

In grouping the fish species into families, the stock estimates by fish family is given in Table 3 below.

From Table 3 below, it is clear that the four most abundant groups includes Pomacentrids with a total stock of about 24 million individuals, the most dominant group, followed by Chaetodontids with 2.5 million, Pomacanthids with 2.2 million and then Labridae with 1.9 million. Considering the general biology of these family groups, being generally short lived, fast growing and therefore being quick to mature, and including their reproductive strategies, being all year spawners or daily spawners (as in the case of the Pomacanthids), with strong social and territorial behaviour in spawning and in looking after their demersal eggs, these are expected to favour successful recruitment and good support to the high densities observed.

Table 3 Stock estimate by Family Group of Tuvalu Fish in the combined reef habitat

Family	Nos. Species	Stock Estimate	StdErr_ Stock
Acanthuridae	4	568,680	330,857
Balistidae	4	141,360	87,892
Blenniidae	1	111,067	79,366

Chaetodontidae	21	2,451,440	960,941
Cirrhitidae	1	67,253	51,902
Gobiidae	1	59,120	47,279
Labridae	20	1,929,267	1,134,216
Microdesmidae	1	34,267	27,898
Mullidae	1	154,013	108,141
Pomacanthidae	5	2,204,493	772,692
Pomacentridae	13	23,998,943	14,042,804
Zanclidae	1	57,293	27,892
Total	**73**		

Table 4 below gives stock estimates of the 10 most valuable species for the marine aquarium trade. The most valuable among the 10 species, *Pomacanthus imperator,* has the smallest standing stock of about 3,400 individuals. *Centropyge loriculus* and *C. flavissimus,* which are two species with very high demands, seemed to have good stocks (235,000 individuals and 1.2 million individuals respectively). *Pomacentrus vaiuli,* with its very high abundance of 3.3 million individuals, could also become an important species. Given the lack of information for giving estimates of sustainable yields, as a rule of thumb 10% of the calculated stock estimates per year is considered conservative enough as a start to allow the different fish species to be exploited in a sustainable manner. It should be noted however, that, this first approximation should be refined through a monitoring program every year.

Table 4 Estimated Stocks of 10 important marine aquarium trade species

Species	Stock Estimates	StdErr_ Stock	10% of Stock
Pomacanthus imperator	3,427	3,427	343
Centropyge loriculus	235,480	83,484	23,548
Centropyge flavissimus	1,177,200	303,229	117,720
Labroides bicolor	450,800	229,890	45,080
Nemateleotris magnifica	30,840	24,471	3,084
Ctenochaetus strigosus	396,253	182,765	39,625
Gomphosus varius	231,640	102,644	23,164
Pomacentrus vaiuli	3,278,533	1,144,037	327,853
Plagiotremus laudandus	111,067	79,366	11,107
Thalassoma lunare	225,560	135,070	22,556

6.4 Substrate and Habitat

General description

The bottom substrate of Funafuti Atoll has been described in other studies (Kaly, 1997). The assessment methods used in these studies were quite different and therefore, although they could be used as indicators of the general status of coral reefs, they would not provide a good basis for a detailed comparison. Similarly,

just previous to this study, another study was conducted by the EU funded SPC PROCFish project which utilizes a similar medium scale approach but using a different habitat survey form and slightly different classification. The present survey records bottom substrate using a landscape method which was developed by the SPC Reef Fisheries Observatory (Vigliola, unpublished). The method, basically assess the bottom substrate in 3 layers. The data from these two recent surveys should provide similar results at the lower classification levels and are more than likely to yield slightly different results at the higher levels of habitat classification.

The results of the present survey are tabulated in Table 5 below. A total of 15 transects were assessed in both lagoon reef sites and outer reef sites. On each transect, ten 5 m x 5 m quadrats were considered, thus covering 250 m^2 of reef area. This gives a total area of 3750 m^2 each for the lagoon reef areas and the outer reef areas which corresponds to 0.0096% of the total lagoon reef habitat and 0.0146% of the total outer reef habitats respectively.

Table 5 Percentage cover of bottom substrates on Funafuti reefs

Transect/Habitat Details	Lagoon reefs[2]	Outer reef	All reefs
Number of transects	15	15	30
Total habitat area (km^2)	39	25.7	64.7
Depth (m)	8 (3-14)	10 (3-20)	
Soft bottom (% cover)	37.23 ± 2.96	3.86 ± 0.59	
Hard bottom (% cover)	62.77 ± 2.96	96.14 ± 0.59	
Rubble & boulders (% cover)	12.99 ± 4.11	6.11 ± 2.90	
Soft coral (% cover)	0.43 ± 0.32	1.69 ± 1.62	
Dead Coral (% cover)	15.56 ± 4.74	23.18 ± 5.45	
Live coral (% cover)	32.46 ± 6.80	43.19 ± 6.01	
Bleaching coral	0.47 ± 0.26	0.26 ± 0.14	

[2] includes coastal sheltered reefs and back reefs

As given in Table 5, in the reef areas of the lagoon there is on average about 37% soft substrate (silt and sand) with the rest being hard substrates (hard corals, slabs, rocks, rubble and boulders). On the outer reefs, there is much lesser soft substrate (average of about 4%) with a predominant hard substrate (average 96%). In the lagoon, much of the hard substrate was comprised of abiotic substrates (51.5%, see Appendix V) whereas on the outer reefs this was comprised mostly of hard corals (66.6%, see Appendix V).

Live Coral Cover

Looking at the status of corals in Funafuti, the live coral cover was higher on the outer reefs (43%) than the lagoon reefs (33%). Dead standing intact corals were also more common in the outer reefs (23%) compared to the lagoon reefs (16%). Very little signs of bleaching were seen i.e. less than 0.5% in both habitats.

Figure 5 below shows the different proportions of live coral types in the outer reefs and the lagoon reefs. The lagoon is comprised mainly of branching corals, some tabulate corals and sub-massive corals. On the outer reef the branching corals are also dominant but there are more tabulate and encrusting corals. Compared to the lagoon reefs, the outer reefs seemed to host a lot more massive, digitate and foliose corals.

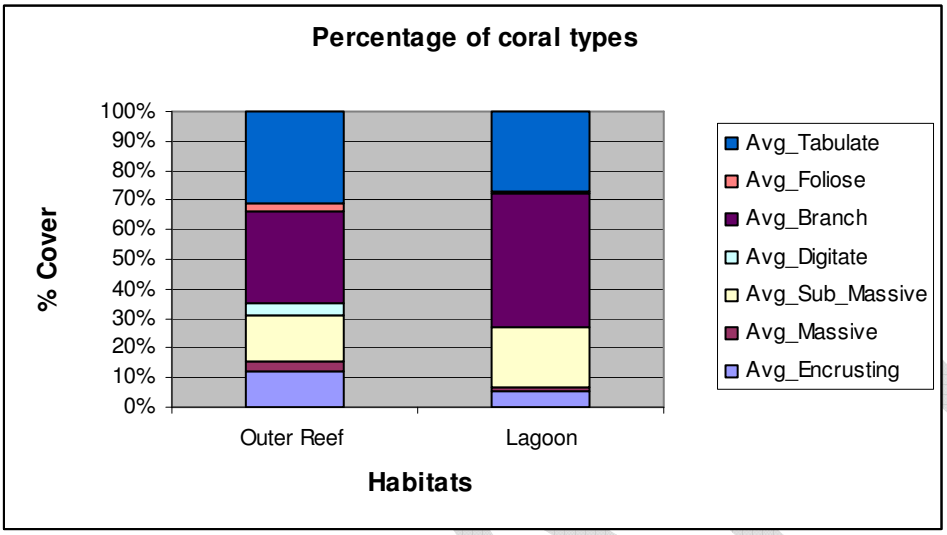

Figure 5 Composition of live coral types in the two habitats

Other Observations

The percentage cover of other substrate types is tabulated in Appendix V. In looking at the non-coralline bottom substrates, macro-algae seemed to be more prominent in the lagoon compared to the reefs. This is especially true with the calcareous algae (*Halimeda sp.*). No seagrass were seen in any of the survey sites, neither in the lagoon nor in the outer reefs.

The presence of soft corals was very low in both habitats, with the lagoon having an average cover of 0.43% and the outer reefs an average of 1.69%. Sponges were similarly low in occurrence but were more common in the lagoon (3.70%) than the outer reefs (1.76%).

7. Discussions and Recommendations

7.1 Potential of the Fish Resources for the Marine aquarium Trade

The results of the survey seemed to indicate that in Funafuti, there are at least 74 species that have potential for the marine aquarium trade. Given that no marine aquarium trade operations have existed there in the past, then the stock estimate from the survey provides a first baseline of the standing stock of the different species. The stocks of some of these species especially, *Pomacentrus vaiuli* and

Chrysiptera cyanea of the family Pomacentrids, are very abundant. The Chaetodontids, the Pomacanthids and the Labrids are also quite abundant.

In considering the stocks of the 10 most valuable species among the species recorded in the survey, it is clear that these selected species can support some marine aquarium trade operations, even if only 10% of the stocks was allowed to be harvested every year. It is however important to note here that should the Tuvalu government decide to go ahead and develop the marine aquarium trade industry in Funafuti, then the suggested 10% harvestable stock should only be used as a basis to have a limit on the exploitation of the resource and a proper monitoring program to monitor catch per unit effort and to collect biological information should also be initiated. The 10% harvestable stock should also be spread out over the year to dilute fishing pressure on the resources. Moreover, a limit should be set on the number of exporting companies. These should all be part of a management policy and plan which is necessary before operations are allowed to start.

7.2 The Management Framework

Should the Tuvalu Government choose to go ahead with the development of the marine aquarium trade in Funafuti, then it is very important that management plan is developed and put in place. The management plan should take into account all the administrative bodies that have some relation and legal authority to all or any part of the coastal marine ecosystem. Evidently, the Fisheries Department, the Environment Division, the Island Council, and the Falekaupule working closely with the Attorney General's Office would be no doubt form the core group for a marine aquarium trade management and coordinating committee. In the development of such a management plan, it is always advisable to consult with the community to ensure that any concerns are considered which will minimize the possibilities of future conflicts developing once the marine aquarium trade starts.

As part of the management plan, there would also be a need to develop management measures in the form of regulations, license conditions and fees, a monitoring program, an effective enforcement mechanism and a sustainable source of finance to support all these management activities.

7.3 The Infrastructure

Even though the resource might be available, this does not mean that a marine aquarium trade will be feasible to develop. An important area that needs to be carefully considered before deciding on this is the basic infrastructure required to support this export industry. The most obvious factor is the availability of airline connections from Funafuti to the market, including air cargo space available per flight, air freight rates, the number of transits and connecting times between flights.

The availability of oxygen and packing materials and good source of electricity for land facilities, including costs of these items, are also important considerations. For the collection of marine organisms, one would need certified divers, good diving gears, good source of air (compressors). All these would need to be consistently available on the island and be in accordance with the required safety and maintenance standards.

7.4 Future Requirements

The development of a successful marine aquarium trade industry would need good consideration of the important factors and issues required to support such an industry to make it economically feasible and sustainable. Advice and assistance on undertaking such a venture can be provided through the SPC Live Reef Fisheries Trade Initiative but would need to be formally requested through the formal channel (Ministry of Foreign Affairs) if the Tuvalu Government wishes to pursue this further.

The following steps provide a general guideline as to the kind of activities that will still be required before full operations can start.

1. The Tuvalu Government reviews this report and decides if it wants to go ahead with developing a marine aquarium trade or not.
2. If yes, then a formal request to SPC should be submitted indicating this interest and the commitment to develop this industry.
3. A pilot study will be undertaken to assess the economic feasibility of such a trade, which would include the whole process involved in such an operation, from the catching of the fish right to the receipt of payment from the overseas buyers. The study will look at both the economic and the operational side to see the problems that would be encountered in the whole process as well as the quality of the product when its gets to the buyer. This study will also provide further information for making the final decision if it will be worth getting into the trade, as well as information on areas which can be improved to make operations more effective, including location of market.
4. If the pilot study is a success, then a management plan and monitoring program would need to be developed through a consultative process and the management framework will be put in place.
5. Whilst the management plan is being developed, training can start for fish catching, handling, husbandry procedures and packing for export.
6. Once the management plan and monitoring program is completed and endorsed, then the operations can start. It is advisable that for the first year only 2 marine aquarium trade licenses are awarded and that these be monitored carefully. From the data collected from the monitoring, the number of licenses to be awarded can then be refined.

7. SPC will monitor the implementation of the management plan and the new operations for the first year and will provide technical assistance and advice when required.

8. Conclusions

The result of the survey indicates that a number of some important marine aquarium trade species are present on Funafuti reefs. The abundance of these species is adequate enough to set up a marine aquarium trade in Funafuti Atoll. Five to ten of the most valuable species reported in the survey as listed in Table 4 would even be enough to support a small operation.

Even with this potential of the resources, there are a lot of other considerations that the Tuvalu Government would need to look at before making any decisions for operations to start. These considerations include logistical problems as well as doing a cost/benefit analysis of having the trade.

If the Tuvalu Government decides to go ahead then it is very important to have a properly designed plan to develop the trade. This should include two important things to be taken up as the next immediate steps. These are:

1. A pilot study market trial to look at the economic feasibility of starting up operations in Funafuti including the economics of exporting marine aquarium trade products from Funafuti and at the same time
2. The development of a practical management framework, including a management plan with regulations and a monitoring program, is necessary before starting up operations.

Assistance to develop the industry, including the training of locals on collection and handling procedures for the marine aquarium trade, can be provided with assistance from the SPC LRFT Initiative but a formal request would be required from the Tuvalu Government to SPC through the proper channels.

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Appendices

Appendix I: List of fish species surveyed and habitat location

FAMILY/ Species surveyed	Outer Reef	Lagoon Reef
Acanthuridae		
Acanthurus nigricans		x
Acanthurus pyroferus	x	x
Ctenochaetus strigosus	x	x
Zebrasoma scopas	x	x
Balistidae		
Balistapus undulatus	x	x
Melichthys vidua	x	
Rhinecanthus aculeatus		x
Sufflamen bursa	x	
Blenniidae		
Plagiotremus laudandus		x
Chaetodontidae		
Chaetodon auriga		x
Chaetodon citrinellus	x	x
Chaetodon ephippium	x	x
Chaetodon lineolatus	x	x
Chaetodon lunula	x	x
Chaetodon lunulatus	x	x
Chaetodon melannotus	x	
Chaetodon meyeri	x	
Chaetodon ornatissimus	x	x
Chaetodon pelewensis	x	x
Chaetodon rafflesii	x	x
Chaetodon reticulates	x	x
Chaetodon semeion	x	
Chaetodon trifascialis	x	x
Chaetodon ulietensis	x	x
Chaetodon unimaculatus	x	
Chaetodon vagabundus		x
Forcipiger flavissimus	x	x
Hemitaurichthys polylepis	x	
Heniochus acuminatus	x	
Heniochus chrysostomus	x	x
Cirrhitidae		
Paracirrhites arcatus	x	x
Gobiidae		
Valenciennea strigata	x	x
Labridae		
Anampses meleagrides	x	
Anampses twistii	x	x
Coris aygula	x	
Coris gaimard	x	
Epibulus insidiator		x
Gomphosus varius	x	x
Halichoeres hortulanus	x	x
Halichoeres margaritaceus	x	x
Halichoeres melanurus	x	x
Halichoeres trimaculatus		x
Labroides bicolor	x	x
Labroides dimidiatus	x	x
Labropsis sp.		x
Macropharyngodon meleagris		x
Stethojulis bandanensis	x	x

Stethojulis strigiventer	x	x
Thalassoma hardwicke		x
Thalassoma lunare	x	x
Thalassoma purpureum	x	x
Thalassoma quinquevittatum	x	
Microdesmidae		
Nemateleotris magnifica	x	
Ptereleotris evides	x	
Mullidae		
Parupeneus multifasciatus	x	x
Pomacanthidae		
Centropyge bicolor		x
Centropyge flavissimus	x	x
Centropyge loriculus	x	x
Pomacanthus imperator	x	
Pygoplites diacanthus	x	x
Pomacentridae		
Amphiprion chrysopterus		x
Chromis iomelas	x	x
Chromis margaritifer	x	x
Chromis sp.	x	
Chromis ternatensis		x
Chromis viridis		x
Chrysiptera cyanea	x	x
Dascyllus aruanus	x	x
Dascyllus reticulatus		x
Plectroglyphidodon johnstonianus	x	x
Pomacentrus bankanensis	x	x
Pomacentrus pavo	x	x
Pomacentrus vaiuli	x	x
Zanclidae		
Zanclus cornutus	x	x

Appendix IIA: Density and Stock Estimates of species surveyed by habitat

Habitat	Family	Species	Density / m^2	Density /1000 m^2	StdErr Density	Stock Estimate	10% of Stock
Outer Fringing Reef	Acanthuridae	*Acanthurus pyroferus*	0.00187	1.86667	0.00149	47973	4797
Outer Fringing Reef	Acanthuridae	*Ctenochaetus strigosus*	0.00627	6.26667	0.00189	161053	16105
Outer Fringing Reef	Acanthuridae	*Zebrasoma scopas*	0.00027	0.26667	0.00018	6853	685
Outer Fringing Reef	Balistidae	*Balistapus undulatus*	0.00253	2.53333	0.00104	65107	6511
Outer Fringing Reef	Balistidae	*Melichthys vidua*	0.00053	0.53333	0.00031	13707	1371
Outer Fringing Reef	Balistidae	*Sufflamen bursa*	0.00040	0.40000	0.00029	10280	1028
Outer Fringing Reef	Chaetodontidae	*Chaetodon citrinellus*	0.00040	0.40000	0.00029	10280	1028
Outer Fringing Reef	Chaetodontidae	*Chaetodon ephippium*	0.00133	1.33333	0.00061	34267	3427
Outer Fringing Reef	Chaetodontidae	*Chaetodon lineolatus*	0.00093	0.93333	0.00058	23987	2399
Outer Fringing Reef	Chaetodontidae	*Chaetodon lunula*	0.00160	1.60000	0.00049	41120	4112
Outer Fringing Reef	Chaetodontidae	*Chaetodon lunulatus*	0.00053	0.53333	0.00053	13707	1371
Outer Fringing Reef	Chaetodontidae	*Chaetodon melannotus*	0.00027	0.26667	0.00027	6853	685
Outer Fringing Reef	Chaetodontidae	*Chaetodon meyeri*	0.00013	0.13333	0.00013	3427	343
Outer Fringing Reef	Chaetodontidae	*Chaetodon ornatissimus*	0.00080	0.80000	0.00058	20560	2056
Outer Fringing Reef	Chaetodontidae	*Chaetodon pelewensis*	0.00307	3.06667	0.00114	78813	7881
Outer Fringing Reef	Chaetodontidae	*Chaetodon rafflesii*	0.00320	3.20000	0.00099	82240	8224
Outer Fringing Reef	Chaetodontidae	*Chaetodon reticulatus*	0.00707	7.06667	0.00279	181613	18161
Outer Fringing Reef	Chaetodontidae	*Chaetodon semeion*	0.00013	0.13333	0.00013	3427	343
Outer Fringing Reef	Chaetodontidae	*Chaetodon trifascialis*	0.00747	7.46667	0.00196	191893	19189
Outer Fringing Reef	Chaetodontidae	*Chaetodon ulietensis*	0.00107	1.06667	0.00051	27413	2741
Outer Fringing Reef	Chaetodontidae	*Chaetodon unimaculatus*	0.00027	0.26667	0.00027	6853	685
Outer Fringing Reef	Chaetodontidae	*Forcipiger flavissimus*	0.00120	1.20000	0.00070	30840	3084
Outer Fringing Reef	Chaetodontidae	*Hemitaurichthys polylepis*	0.00360	3.60000	0.00252	92520	9252
Outer Fringing Reef	Chaetodontidae	*Heniochus acuminatus*	0.00013	0.13333	0.00013	3427	343
Outer Fringing Reef	Chaetodontidae	*Heniochus chrysostomus*	0.00067	0.66667	0.00067	17133	1713
Outer Fringing Reef	Cirrhitidae	*Paracirrhites arcatus*	0.00160	1.60000	0.00133	41120	4112
Outer Fringing Reef	Gobiidae	*Valenciennea strigata*	0.00027	0.26667	0.00027	6853	685
Outer Fringing Reef	Labridae	*Anampses meleagrides*	0.00013	0.13333	0.00013	3427	343
Outer Fringing Reef	Labridae	*Anampses twistii*	0.00013	0.13333	0.00013	3427	343

Outer Fringing Reef	Labridae	*Coris aygula*	0.00027	0.26667	0.00027	6853	685
Outer Fringing Reef	Labridae	*Coris gaimard*	0.00027	0.26667	0.00027	6853	685
Outer Fringing Reef	Labridae	*Gomphosus varius*	0.00520	5.20000	0.00246	133640	13364
Outer Fringing Reef	Labridae	*Halichoeres hortulanus*	0.00280	2.80000	0.00125	71960	7196
Outer Fringing Reef	Labridae	*Halichoeres margaritaceus*	0.00280	2.80000	0.00131	71960	7196
Outer Fringing Reef	Labridae	*Halichoeres melanurus*	0.00013	0.13333	0.00013	3427	343
Outer Fringing Reef	Labridae	*Labroides bicolor*	0.00040	0.40000	0.00021	10280	1028
Outer Fringing Reef	Labridae	*Labroides dimidiatus*	0.00347	3.46667	0.00124	89093	8909
Outer Fringing Reef	Labridae	*Stethojulis bandanensis*	0.00053	0.53333	0.00024	13707	1371
Outer Fringing Reef	Labridae	*Stethojulis strigiventer*	0.00093	0.93333	0.00064	23987	2399
Outer Fringing Reef	Labridae	*Thalassoma lunare*	0.00013	0.13333	0.00013	3427	343
Outer Fringing Reef	Labridae	*Thalassoma purpureum*	0.00280	2.80000	0.00158	71960	7196
Outer Fringing Reef	Labridae	*Thalassoma quinquevittatum*	0.00067	0.66667	0.00054	17133	1713
Outer Fringing Reef	Microdesmidae	*Nemateleotris magnifica*	0.00120	1.20000	0.00095	30840	3084
Outer Fringing Reef	Microdesmidae	*Ptereleotris evides*	0.00013	0.13333	0.00013	3427	343
Outer Fringing Reef	Mullidae	*Parupeneus multifasciatus*	0.00040	0.40000	0.00029	10280	1028
Outer Fringing Reef	Pomacanthidae	*Centropyge flavissimus*	0.01733	17.33333	0.00408	445467	44547
Outer Fringing Reef	Pomacanthidae	*Centropyge loriculus*	0.00840	8.40000	0.00249	215880	21588
Outer Fringing Reef	Pomacanthidae	*Pomacanthus imperator*	0.00013	0.13333	0.00013	3427	343
Outer Fringing Reef	Pomacanthidae	*Pygoplites diacanthus*	0.00093	0.93333	0.00043	23987	2399
Outer Fringing Reef	Pomacentridae	*Chromis iomelas*	0.02280	22.80000	0.00913	585960	58596
Outer Fringing Reef	Pomacentridae	*Chromis margaritifer*	0.02222	22.22222	0.00899	571111	57111
Outer Fringing Reef	Pomacentridae	*Chromis sp.*	0.00067	0.66667	0.00067	17133	1713
Outer Fringing Reef	Pomacentridae	*Chrysiptera cyanea*	0.00960	9.60000	0.00960	246720	24672
Outer Fringing Reef	Pomacentridae	*Dascyllus aruanus*	0.00400	4.00000	0.00345	102800	10280
Outer Fringing Reef	Pomacentridae	*Plectroglyphidodon johnstonianus*	0.01440	14.40000	0.00981	370080	37008
Outer Fringing Reef	Pomacentridae	*Pomacentrus bankanensis*	0.00360	3.60000	0.00243	92520	9252
Outer Fringing Reef	Pomacentridae	*Pomacentrus pavo*	0.03773	37.73333	0.02343	969747	96975
Outer Fringing Reef	Pomacentridae	*Pomacentrus vaiuli*	0.04800	48.00000	0.02115	1233600	123360
Outer Fringing Reef	Zanclidae	*Zanclus cornutus*	0.00147	1.46667	0.00053	37693	3769
Lagoon Reef	Acanthuridae	*Acanthurus nigricans*	0.00080	0.80000	0.00067	39200	3920
Lagoon Reef	Acanthuridae	*Acanthurus pyroferus*	0.00067	0.66667	0.00054	32667	3267
Lagoon Reef	Acanthuridae	*Ctenochaetus strigosus*	0.00480	4.80000	0.00274	235200	23520

Lagoon Reef	Acanthuridae	*Zebrasoma scopas*	0.00093	0.93333	0.00093	45733	4573
Lagoon Reef	Balistidae	*Balistapus undulatus*	0.00093	0.93333	0.00080	45733	4573
Lagoon Reef	Balistidae	*Rhinecanthus aculeatus*	0.00013	0.13333	0.00013	6533	653
Lagoon Reef	Blenniidae	*Plagiotremus laudandus*	0.00227	2.26667	0.00162	111067	11107
Lagoon Reef	Chaetodontidae	*Chaetodon auriga*	0.00133	1.33333	0.00054	65333	6533
Lagoon Reef	Chaetodontidae	*Chaetodon citrinellus*	0.00187	1.86667	0.00077	91467	9147
Lagoon Reef	Chaetodontidae	*Chaetodon ephippium*	0.00213	2.13333	0.00093	104533	10453
Lagoon Reef	Chaetodontidae	*Chaetodon lineolatus*	0.00093	0.93333	0.00064	45733	4573
Lagoon Reef	Chaetodontidae	*Chaetodon lunula*	0.00040	0.40000	0.00029	19600	1960
Lagoon Reef	Chaetodontidae	*Chaetodon lunulatus*	0.00027	0.26667	0.00027	13067	1307
Lagoon Reef	Chaetodontidae	*Chaetodon ornatissimus*	0.00040	0.40000	0.00029	19600	1960
Lagoon Reef	Chaetodontidae	*Chaetodon pelewensis*	0.00013	0.13333	0.00013	6533	653
Lagoon Reef	Chaetodontidae	*Chaetodon rafflesii*	0.00200	2.00000	0.00085	98000	9800
Lagoon Reef	Chaetodontidae	*Chaetodon reticulatus*	0.00187	1.86667	0.00093	91467	9147
Lagoon Reef	Chaetodontidae	*Chaetodon trifascialis*	0.01853	18.53333	0.00421	908133	90813
Lagoon Reef	Chaetodontidae	*Chaetodon ulietensis*	0.00067	0.66667	0.00067	32667	3267
Lagoon Reef	Chaetodontidae	*Chaetodon vagabundus*	0.00107	1.06667	0.00061	52267	5227
Lagoon Reef	Chaetodontidae	*Forcipiger flavissimus*	0.00027	0.26667	0.00018	13067	1307
Lagoon Reef	Chaetodontidae	*Heniochus chrysostomus*	0.00040	0.40000	0.00029	19600	1960
Lagoon Reef	Cirrhitidae	*Paracirrhites arcatus*	0.00053	0.53333	0.00036	26133	2613
Lagoon Reef	Gobiidae	*Valenciennea strigata*	0.00107	1.06667	0.00083	52267	5227
Lagoon Reef	Labridae	*Anampses twistii*	0.00013	0.13333	0.00013	6533	653
Lagoon Reef	Labridae	*Epibulus insidiator*	0.00013	0.13333	0.00013	6533	653
Lagoon Reef	Labridae	*Gomphosus varius*	0.00200	2.00000	0.00080	98000	9800
Lagoon Reef	Labridae	*Halichoeres hortulanus*	0.00280	2.80000	0.00143	137200	13720
Lagoon Reef	Labridae	*Halichoeres margaritaceus*	0.00013	0.13333	0.00013	6533	653
Lagoon Reef	Labridae	*Halichoeres melanurus*	0.00027	0.26667	0.00027	13067	1307
Lagoon Reef	Labridae	*Halichoeres trimaculatus*	0.00827	8.26667	0.00785	405067	40507
Lagoon Reef	Labridae	*Labroides bicolor*	0.00187	1.86667	0.00072	91467	9147
Lagoon Reef	Labridae	*Labroides dimidiatus*	0.00440	4.40000	0.00094	215600	21560
Lagoon Reef	Labridae	*Labropsis sp.*	0.00013	0.13333	0.00013	6533	653
Lagoon Reef	Labridae	*Macropharyngodon meleagris*	0.00013	0.13333	0.00013	6533	653
Lagoon Reef	Labridae	*Stethojulis bandanensis*	0.00120	1.20000	0.00061	58800	5880

Lagoon Reef	Labridae	*Stethojulis strigiventer*	0.00107	1.06667	0.00051	52267	5227
Lagoon Reef	Labridae	*Thalassoma hardwicke*	0.00080	0.80000	0.00047	39200	3920
Lagoon Reef	Labridae	*Thalassoma lunare*	0.00453	4.53333	0.00269	222133	22213
Lagoon Reef	Labridae	*Thalassoma purpureum*	0.00067	0.66667	0.00067	32667	3267
Lagoon Reef	Mullidae	*Parupeneus multifasciatus*	0.00293	2.93333	0.00206	143733	14373
Lagoon Reef	Pomacanthidae	*Centropyge bicolor*	0.00920	9.20000	0.00469	450800	45080
Lagoon Reef	Pomacanthidae	*Centropyge flavissimus*	0.01493	14.93333	0.00405	731733	73173
Lagoon Reef	Pomacanthidae	*Centropyge loriculus*	0.00040	0.40000	0.00040	19600	1960
Lagoon Reef	Pomacanthidae	*Pygoplites diacanthus*	0.00640	6.40000	0.00289	313600	31360
Lagoon Reef	Pomacentridae	*Amphiprion chrysopterus*	0.00040	0.40000	0.00040	19600	1960
Lagoon Reef	Pomacentridae	*Chromis iomelas*	0.00133	1.33333	0.00108	65333	6533
Lagoon Reef	Pomacentridae	*Chromis margaritifer*	0.00053	0.53333	0.00041	26133	2613
Lagoon Reef	Pomacentridae	*Chromis ternatensis*	0.01867	18.66667	0.01867	914667	91467
Lagoon Reef	Pomacentridae	*Chromis viridis*	0.05333	53.33333	0.02487	2613333	261333
Lagoon Reef	Pomacentridae	*Chrysiptera cyanea*	0.16560	165.59680	0.10812	8114243	811424
Lagoon Reef	Pomacentridae	*Dascyllus aruanus*	0.00227	2.26667	0.00105	111067	11107
Lagoon Reef	Pomacentridae	*Dascyllus reticulatus*	0.00027	0.26667	0.00027	13067	1307
Lagoon Reef	Pomacentridae	*Plectroglyphidodon johnstonianus*	0.00080	0.80000	0.00055	39200	3920
Lagoon Reef	Pomacentridae	*Pomacentrus bankanensis*	0.00213	2.13333	0.00213	104533	10453
Lagoon Reef	Pomacentridae	*Pomacentrus pavo*	0.11721	117.20740	0.07029	5743163	574316
Lagoon Reef	Pomacentridae	*Pomacentrus vaiuli*	0.04173	41.73333	0.01226	2044933	204493
Lagoon Reef	Zanclidae	*Zanclus cornutus*	0.00040	0.40000	0.00029	19600	1960

Appendix IIB: Total Stock Estimates for each species for Funafuti Atoll

Family	Species	Total stock	10% Total Stock
Acanthuridae	*Acanthurus nigricans*	39200	3920
Acanthuridae	*Acanthurus pyroferus*	80640	8064
Acanthuridae	*Ctenochaetus strigosus*	396253	39625
Acanthuridae	*Zebrasoma scopas*	52587	5259
Balistidae	*Balistapus undulatus*	110840	11084
Balistidae	*Melichthys vidua*	13707	1371
Balistidae	*Rhinecanthus aculeatus*	6533	653
Balistidae	*Sufflamen bursa*	10280	1028
Blenniidae	*Plagiotremus laudandus*	111067	11107
Chaetodontidae	*Chaetodon auriga*	65333	6533
Chaetodontidae	*Chaetodon citrinellus*	101747	10175
Chaetodontidae	*Chaetodon ephippium*	138800	13880
Chaetodontidae	*Chaetodon lineolatus*	69720	6972
Chaetodontidae	*Chaetodon lunula*	60720	6072
Chaetodontidae	*Chaetodon lunulatus*	26773	2677
Chaetodontidae	*Chaetodon melannotus*	6853	685
Chaetodontidae	*Chaetodon meyeri*	3427	343
Chaetodontidae	*Chaetodon ornatissimus*	40160	4016
Chaetodontidae	*Chaetodon pelewensis*	85347	8535
Chaetodontidae	*Chaetodon rafflesii*	180240	18024
Chaetodontidae	*Chaetodon reticulatus*	273080	27308
Chaetodontidae	*Chaetodon semeion*	3427	343
Chaetodontidae	*Chaetodon trifascialis*	1100027	110003
Chaetodontidae	*Chaetodon ulietensis*	60080	6008
Chaetodontidae	*Chaetodon unimaculatus*	6853	685
Chaetodontidae	*Chaetodon vagabundus*	52267	5227
Chaetodontidae	*Forcipiger flavissimus*	43907	4391
Chaetodontidae	*Hemitaurichthys polylepis*	92520	9252
Chaetodontidae	*Heniochus acuminatus*	3427	343

Cirrhitidae	*Heniochus chrysostomus*	36733	3673
Gobiidae	*Paracirrhites arcatus*	67253	6725
Labridae	*Valenciennea strigata*	59120	5912
Labridae	*Anampses meleagrides*	3427	343
Labridae	*Anampses twistii*	9960	996
Labridae	*Coris aygula*	6853	685
Labridae	*Coris gaimard*	6853	685
Labridae	*Epibulus insidiator*	6533	653
Labridae	*Gomphosus varius*	231640	23164
Labridae	*Halichoeres hortulanus*	209160	20916
Labridae	*Halichoeres margaritaceus*	78493	7849
Labridae	*Halichoeres melanurus*	16493	1649
Labridae	*Halichoeres trimaculatus*	405067	40507
Labridae	*Labroides bicolor*	101747	10175
Labridae	*Labroides dimidiatus*	304693	30469
Labridae	*Labropsis sp.*	6533	653
Labridae	*Stethojulis bandanensis*	72507	7251
Labridae	*Stethojulis strigiventer*	76253	7625
Labridae	*Thalassoma hardwicke*	39200	3920
Labridae	*Thalassoma lunare*	225560	22556
Labridae	*Thalassoma purpureum*	104627	10463
Labridae	*Thalassoma quinquevittatum*	17133	1713
Microdesmidae	*Nemateleotris magnifica*	30840	3084
Microdesmidae	*Ptereleotris evides*	3427	343
Mullidae	*Parupeneus multifasciatus*	154013	15401
Pomacanthidae	*Centropyge bicolor*	450800	89627
Pomacanthidae	*Centropyge flavissimus*	1177200	94761
Pomacanthidae	*Centropyge loriculus*	235480	2303
Pomacanthidae	*Pomacanthus imperator*	3427	2399
Pomacanthidae	*Pygoplites diacanthus*	337587	89956
Pomacentridae	*Amphiprion chrysopterus*	19600	59071
Pomacentridae	*Chromis iomelas*	651293	8247
Pomacentridae	*Chromis margaritifer*	597244	27285

Pomacentridae	*Chromis sp.*	17133	10280
Pomacentridae	*Chromis ternatensis*	914667	128475
Pomacentridae	*Chromis viridis*	2613333	270585
Pomacentridae	*Chrysiptera cyanea*	8360963	908399
Pomacentridae	*Dascyllus aruanus*	213867	134467
Pomacentridae	*Dascyllus reticulatus*	13067	1307
Pomacentridae	*Plectroglyphidodon johnstonianus*	409280	7689
Pomacentridae	*Pomacentrus bankanensis*	197053	10453
Pomacentridae	*Pomacentrus pavo*	6712909	574316
Pomacentridae	*Pomacentrus vaiuli*	3278533	204493
Zanclidae	*Zanclus cornutus*	57293	1960

Appendix III: Species Mean Sizes and calculated Size Ratio to known maximum length (where available)

Habitat	Species	Mean Size (cm)	Std.Err_ MeanSize	Size Ratio	Std.Err_ SizeRatio
Outer Reefs	*Acanthurus pyroferus*	3.64	1.29	0.15	0.05
Outer Reefs	*Ctenochaetus strigosus*	2.06	0.32	0.11	0.02
Outer Reefs	*Zebrasoma scopas*	4.50	3.18	0.23	0.16
Outer Reefs	*Balistapus undulatus*	7.58	1.52	0.25	0.05
Outer Reefs	*Melichthys vidua*	9.50	3.88	0.27	0.11
Outer Reefs	*Sufflamen bursa*	9.00	4.50	0.38	0.19
Outer Reefs	*Chaetodon citrinellus*	4.00	2.00	0.31	0.15
Outer Reefs	*Chaetodon ephippium*	7.50	2.50	0.33	0.11
Outer Reefs	*Chaetodon lineolatus*	9.71	4.34	0.32	0.14
Outer Reefs	*Chaetodon lunula*	8.17	2.58	0.41	0.13
Outer Reefs	*Chaetodon lunulatus*	8.00	5.66	0.53	0.38
Outer Reefs	*Chaetodon melannotus*	5.00	5.00	0.33	0.33
Outer Reefs	*Chaetodon meyeri*	11.00	7.78	0.61	0.43
Outer Reefs	*Chaetodon ornatissimus*	11.67	5.83	0.61	0.31
Outer Reefs	*Chaetodon pelewensis*	5.74	1.43	0.46	0.11
Outer Reefs	*Chaetodon rafflesii*	7.46	1.56	0.50	0.10
Outer Reefs	*Chaetodon reticulatus*	6.66	1.05	0.42	0.07
Outer Reefs	*Chaetodon semeion*	18.00	12.73	0.78	0.55
Outer Reefs	*Chaetodon trifascialis*	7.57	0.94	0.42	0.05
Outer Reefs	*Chaetodon ulietensis*	7.75	3.16	0.52	0.21
Outer Reefs	*Chaetodon unimaculatus*	4.00	4.00	0.20	0.20
Outer Reefs	*Forcipiger flavissimus*	9.56	3.61	0.43	0.16
Outer Reefs	*Hemitaurichthys polylepis*	8.78	2.53	0.49	0.14
Outer Reefs	*Heniochus acuminatus*	20.00	20.00	0.80	0.80
Outer Reefs	*Heniochus chrysostomus*	3.00	3.00	0.19	0.19
Outer Reefs	*Paracirrhites arcatus*	4.75	1.50		
Outer Reefs	*Valenciennea strigata*	2.00	2.00		
Outer Reefs	*Anampses meleagrides*	6.00	4.24	0.27	0.19
Outer Reefs	*Anampses twistii*	8.00	8.00		
Outer Reefs	*Coris aygula*	7.00	4.04	0.07	0.04

Outer Reefs	*Coris gaimard*	7.50	3.75	0.19	0.09
Outer Reefs	*Gomphosus varius*	5.72	0.98	0.20	0.04
Outer Reefs	*Halichoeres hortulanus*	7.48	1.72	0.28	0.06
Outer Reefs	*Halichoeres margaritaceus*	5.76	1.44		
Outer Reefs	*Halichoeres melanurus*	5.00	5.00		
Outer Reefs	*Labroides bicolor*	5.33	2.67		
Outer Reefs	*Labroides dimidiatus*	4.00	0.89		
Outer Reefs	*Stethojulis bandanensis*	5.00	2.50		
Outer Reefs	*Stethojulis strigiventer*	5.71	2.56		
Outer Reefs	*Thalassoma lunare*	4.00	4.00		
Outer Reefs	*Thalassoma purpureum*	6.90	1.73		
Outer Reefs	*Thalassoma quinquevittatum*	5.80	2.90		
Outer Reefs	*Nemateleotris magnifica*	5.56	2.48		
Outer Reefs	*Ptereleotris evides*	6.00	6.00		
Outer Reefs	*Parupeneus multifasciatus*	5.00	2.89	0.17	0.10
Outer Reefs	*Centropyge flavissimus*	4.24	0.32	0.30	0.02
Outer Reefs	*Centropyge loriculus*	3.86	0.50	0.39	0.05
Outer Reefs	*Pomacanthus imperator*	10.00	10.00	0.26	0.26
Outer Reefs	*Pygoplites diacanthus*	9.57	3.91	0.37	0.15
Outer Reefs	*Chromis iomelas*	2.98	0.49		
Outer Reefs	*Chromis margaritifer*	2.77	0.51		
Outer Reefs	*Chromis sp.*	3.40	1.96		
Outer Reefs	*Chrysiptera cyanea*	2.00	1.00		
Outer Reefs	*Dascyllus aruanus*	2.43	0.81		
Outer Reefs	*Plectroglyphidodon johnstonianus*	4.58	0.72		
Outer Reefs	*Pomacentrus bankanensis*	2.48	0.83		
Outer Reefs	*Pomacentrus pavo*	2.27	0.44		
Outer Reefs	*Pomacentrus vaiuli*	2.65	0.36		
Outer Reefs	*Zanclus cornutus*	10.27	2.75	0.64	0.17
Lagoon Reefs	*Acanthurus nigricans*	3.83	2.21	0.18	0.10
Lagoon Reefs	*Acanthurus pyroferus*	8.60	4.97	0.34	0.20
Lagoon Reefs	*Ctenochaetus strigosus*	2.94	0.52	0.16	0.03
Lagoon Reefs	*Zebrasoma scopas*	6.00	4.24	0.30	0.21

Lagoon Reefs	*Balistapus undulatus*	7.29	2.75	0.24	0.09
Lagoon Reefs	*Rhinecanthus aculeatus*				
Lagoon Reefs	*Plagiotremus laudandus*	5.65	2.53		
Lagoon Reefs	*Chaetodon auriga*	11.60	3.87	0.58	0.19
Lagoon Reefs	*Chaetodon citrinellus*	7.14	2.53	0.55	0.19
Lagoon Reefs	*Chaetodon ephippium*	9.63	2.57	0.42	0.11
Lagoon Reefs	*Chaetodon lineolatus*	10.14	5.86	0.34	0.20
Lagoon Reefs	*Chaetodon lunula*	14.00	8.08	0.70	0.40
Lagoon Reefs	*Chaetodon lunulatus*	8.00	8.00	0.53	0.53
Lagoon Reefs	*Chaetodon ornatissimus*	8.00	5.66	0.42	0.30
Lagoon Reefs	*Chaetodon pelewensis*	5.00	5.00	0.40	0.40
Lagoon Reefs	*Chaetodon rafflesii*	8.67	2.61	0.58	0.17
Lagoon Reefs	*Chaetodon reticulatus*	8.71	2.76	0.54	0.17
Lagoon Reefs	*Chaetodon trifascialis*	8.42	0.79	0.47	0.04
Lagoon Reefs	*Chaetodon ulietensis*	10.80	6.24	0.72	0.42
Lagoon Reefs	*Chaetodon vagabundus*	9.25	4.14	0.40	0.18
Lagoon Reefs	*Forcipiger flavissimus*	6.00	3.46	0.27	0.16
Lagoon Reefs	*Heniochus chrysostomus*	14.00	8.08	0.88	0.51
Lagoon Reefs	*Paracirrhites arcatus*	4.25	2.45		
Lagoon Reefs	*Valenciennea strigata*	4.88	2.18		
Lagoon Reefs	*Anampses twistii*	6.00	6.00		
Lagoon Reefs	*Epibulus insidiator*	24.00	16.97	0.69	0.48
Lagoon Reefs	*Gomphosus varius*	7.53	2.09	0.27	0.07
Lagoon Reefs	*Halichoeres hortulanus*	6.33	1.45	0.23	0.05
Lagoon Reefs	*Halichoeres margaritaceus*	6.00	6.00		
Lagoon Reefs	*Halichoeres melanurus*	5.00	3.54		
Lagoon Reefs	*Halichoeres trimaculatus*	5.87	1.20		
Lagoon Reefs	*Labroides bicolor*	5.21	1.35		
Lagoon Reefs	*Labroides dimidiatus*	4.15	0.85		
Lagoon Reefs	*Labropsis sp.*	5.00	5.00		
Lagoon Reefs	*Macropharyngodon meleagris*	3.00	3.00		
Lagoon Reefs	*Stethojulis bandanensis*	5.00	2.04		
Lagoon Reefs	*Stethojulis strigiventer*	5.13	2.29		

Lagoon Reefs	*Thalassoma hardwicke*	4.83	2.42		
Lagoon Reefs	*Thalassoma lunare*	5.79	1.37		
Lagoon Reefs	*Thalassoma purpureum*	5.20	2.60		
Lagoon Reefs	*Parupeneus multifasciatus*	6.95	2.20	0.23	0.07
Lagoon Reefs	*Centropyge bicolor*	5.10	0.76	0.34	0.05
Lagoon Reefs	*Centropyge flavissimus*	4.32	0.44	0.31	0.03
Lagoon Reefs	*Centropyge loriculus*	4.33	3.06	0.43	0.31
Lagoon Reefs	*Pygoplites diacanthus*	11.33	1.75	0.44	0.07
Lagoon Reefs	*Amphiprion chrysopterus*	3.33	1.92		
Lagoon Reefs	*Chromis iomelas*	2.80	1.62		
Lagoon Reefs	*Chromis margaritifer*	3.50	2.02		
Lagoon Reefs	*Chromis ternatensis*	4.14	2.39		
Lagoon Reefs	*Chromis viridis*	1.67	0.42		
Lagoon Reefs	*Chrysiptera cyanea*	2.45	0.40		
Lagoon Reefs	*Dascyllus aruanus*	1.88	0.71		
Lagoon Reefs	*Dascyllus reticulatus*	4.00	4.00		
Lagoon Reefs	*Plectroglyphidodon johnstonianus*	4.83	2.42		
Lagoon Reefs	*Pomacentrus bankanensis*	5.31	1.77		
Lagoon Reefs	*Pomacentrus pavo*	2.66	0.38		
Lagoon Reefs	*Pomacentrus vaiuli*	2.85	0.28		
Lagoon Reefs	*Zanclus cornutus*	12.67	6.33	0.79	0.40

Appendix IV: List of Funafuti transect stations and positions

Country	Site	Stn_Name	Habitat	Latitude	Longitude
Tuvalu	Funafuti Aquarium	TR09	coastal.back	8°27'28.3788" S	179°11'07.1988" E
Tuvalu	Funafuti Aquarium	TR10	coastal.back	8°26'50.7012" S	179°10'47.9388" E
Tuvalu	Funafuti Aquarium	TR11	coastal.back	8°26'05.1612" S	179°03'19.9188" E
Tuvalu	Funafuti Aquarium	TR12	coastal.back	8°25'39.0612" S	179°09'40.2588" E
Tuvalu	Funafuti Aquarium	TR13	coastal.back	8°25'26.8788" S	179°07'02.82" E
Tuvalu	Funafuti Aquarium	TR14	coastal.back	8°26'00.1212" S	179°05'34.3788" E
Tuvalu	Funafuti Aquarium	TR15	coastal.back	8°27'01.7388" S	179°04'17.22" E
Tuvalu	Funafuti Aquarium	TR16	coastal.back	8°28'29.82" S	179°40'04.08" E
Tuvalu	Funafuti Aquarium	TR17	coastal.back	8°30'11.0412" S	179°02'04.3188" E
Tuvalu	Funafuti Aquarium	TR18	coastal.back	8°31'40.1988" S	179°02'47.6988" E
Tuvalu	Funafuti Aquarium	TR19	coastal.back	8°33'47.0988" S	179°02'57.5988" E
Tuvalu	Funafuti Aquarium	TR20	coastal.back	8°35'07.8612" S	179°03'51.48" E
Tuvalu	Funafuti Aquarium	TR21	coastal.back	8°36'52.92" S	179°04'24.3588" E
Tuvalu	Funafuti Aquarium	TR22	coastal.back	8°38'12.66" S	179°04'13.26" E
Tuvalu	Funafuti Aquarium	TR23	coastal.back	8°37'51.24" S	179°06'18.7812" E
Tuvalu	Funafuti Aquarium	TR03	lagoon.lagoon	8°25'57.4212" S	179°07'12.18" E
Tuvalu	Funafuti Aquarium	TR04	lagoon.lagoon	8°26'40.1388" S	179°05'26.4012" E
Tuvalu	Funafuti Aquarium	TR05	lagoon.lagoon	8°28'14.8188" S	179°05'05.1612" E
Tuvalu	Funafuti Aquarium	TR06	lagoon.lagoon	8°29'47.5188" S	179°04'03.9" E
Tuvalu	Funafuti Aquarium	TR07	lagoon.lagoon	8°30'42.2388" S E	179°02'39.4188"
Tuvalu	Funafuti Aquarium	TR08	lagoon.lagoon	8°29'47.5188" S	179°04'03.9" E
Tuvalu	Funafuti Aquarium	TR24	lagoon.lagoon	8°35'54.24" S	179°06'07.6788" E
Tuvalu	Funafuti Aquarium	TR25	lagoon.lagoon	8°33'50.8212" S E	179°07'32.7"
Tuvalu	Funafuti Aquarium	TR26	lagoon.lagoon	8°35'48.2388" S	179°05'47.4" E
Tuvalu	Funafuti Aquarium	TR27	lagoon.lagoon	8°34'35.4612" S	179°04'27.1812" E
Tuvalu	Funafuti Aquarium	TR28	lagoon.lagoon	8°33'06.48" S	179°03'31.68" E
Tuvalu	Funafuti Aquarium	TR29	lagoon.lagoon	8°28'06.1212" S	179°08'29.58" E
Tuvalu	Funafuti Aquarium	TR30	lagoon.lagoon	8°27'22.14" S	179°09'26.1" E
Tuvalu	Funafuti Aquarium	TR31	lagoon.lagoon	8°29'26.2212" S	179°08'06.36" E
Tuvalu	Funafuti Aquarium	TR32	lagoon.lagoon	8°30'35.9388" S	179°08'55.7412" E

Appendix V: Average bottom features for the two different habitats

Habitat	Lagoon	Std. Error	Outer Reef	Std. Error
Depth_Transect	7.83 m	± 0.44	9.65 m	± 0.53
Depth_Crest	4.53 m		4.60 m	
Depth_Floor	14.33 m		16.07 m	
Line_Of_Sight_Visibility	20.60 m	± 1.90	22.41m	± 1.91
Topography	1.8	± 0.24	2.27	± 0.21
Complexity	2.27	± 0.23	2.8	± 0.14
Hard_Substrate	62.77	± 8.93	96.14	± 1.78
Soft_Substrate	37.23	± 8.93	3.86	± 1.78
Abiotic	51.51	± 6.94	33.37	± 7.46
Hard_Corals	48.49	± 6.94	66.63	± 7.46
Slab	12.57	± 4.41	23.45	± 7.64
Silt	2.07	± 1.12	0.13	± 0.09
Mud	0.00	± 0.00	0.00	± 0.00
Sand	20.75	± 5.91	0.89	± 0.46
Rubbles	5.77	± 1.88	3.11	± 1.18
Small_Boulders	4.87	± 1.58	1.21	± 0.64
Large_Boulders	2.36	± 0.95	1.79	± 1.09
Rock	3.12	± 1.30	2.79	± 1.15
Live_Coral	32.46	± 6.80	43.20	± 6.01
Bleaching_Coral	15.57	± 4.74	23.18	± 5.45
Dead_Coral_In_Place	0.47	± 0.26	0.26	± 0.14
Encrusting	2.47	± 0.63	8.30	± 2.18
Massive	0.84	± 0.33	1.85	± 0.82
Sub_Massive	9.65	± 3.74	10.77	± 3.67
Digitate	0.23	± 0.17	2.52	± 0.96
Branch	22.03	± 5.46	20.69	± 6.13
Foliose	0.08	± 0.08	1.69	± 0.59
Tabulate	13.19	± 2.64	20.82	± 5.87
Sponges	3.70	± 3.49	1.76	± 1.76
Soft_Coral	0.43	± 0.32	1.69	± 1.62
Macro_Algae	9.72	± 3.45	9.67	± 3.28
Turf	7.07	± 3.44	2.79	± 0.82
Calcareous_Algae	18.91	± 5.97	10.83	± 4.16
Encrusting_Algae	2.25	± 1.31	13.01	± 4.45
Seagrass	0.00	± 0.00	0.00	± 0.00
Silt_Covering_Coral	1.23	± 0.42	0.37	± 0.21
Cyanophycae	0.00	± 0.00	0.37	± 0.25

NOTE:
Complexity and Topography are graded from 1 (least) to 5 (most)
All Substrate descriptions are average % occurrence