INSTITUTE OF APPLIED SCIENCES

THE UNIVERSITY OF THE SOUTH PACIFIC

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IAS TECHNICAL REPORT NUMBER: 2003/04

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June, 2003

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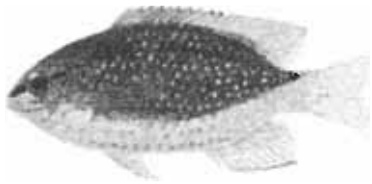
Effects of Collection on Ornamental Reef Fish Populations in Fiji



A Pilot Study of Fish Populations in Collection and Non-collection Areas September - November 2002

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Effects of Collection on Ornamental Reef Fish Populations in Fiji

A Pilot Study of Fish Populations in Collection and Non-collection Areas
September - November 2002

Summary

A three-month pilot study of ornamental fish species collected by Walt Smith International Ltd in Fiji was carried out in order to examine the effects of fish collection pressures on the reef populations. A method and species list for underwater visual survey was purpose-designed and tested.

A comparison was made of:

- Sites where fish were routinely collected
- Neighbouring sites subject to similar stresses but where fish were not collected
- Physically similar sites remote from the collection zone
- Physically dissimilar sites remote from the collection zone

Fish populations on Collection sites were found to be lower than in Non-collected areas, indicating that collection pressures may be affecting populations of certain species. Improvements to the survey technique to improve statistical significance are recommended.

A revised survey technique is suggested by which fish on geographically remote and physically dissimilar reefs across the country could be compared to the family level.

A list of 10-15 key species identified as relevant to each area could be used as a reasonable basis for future specific area monitoring.

It is recommended that closure of a collection site and subsequent re-surveying be used to determine the amount of recovery time needed for populations of key species to return to levels found at nearby Non-collected sites. This would be important in the formation of a management plan based on site rotation.

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Photos by Helen Sykes except where indicated.

Tables:

Introduction

The global trade in ornamental marine organisms for aquarium use is a growing one. Many countries with extensive coral reef systems are exporting corals, fish and other organisms to developed nations for hobby and public aquariums.

Figure 1 Marine Aquarium Council map of chief exporters and importers of Marine Organisms, 2002. (MAC website)

The major Importing Countries are primarily the USA, Japan and Europe (Blue),

The largest Exporting Countries are primarily Indonesia and Asia (Dark Orange)

The large Exporting Countries are primarily Australia, Brazil, Florida USA, Hawai'i and Fiji (Pink)

The medium to small Exporting Countries are primarily Africa, the Middle East, Central and South America, and other South Pacific Island Nations (Pale Orange)

While this trade is commonly associated in many people's minds with the Philippines and Indonesia, it is growing in the South Pacific, and Fiji is one of the larger exporters in the region, along with Hawai'i. Ornamental Reef Fish for retail to the Aquarium Trade overseas have been collected from Fiji's reefs for over 15 years (Lovell 2001).

Figure 2. Map of exporting nations in the South Pacific. (MAC website)

Collection licenses in Fiji have been based on fishing permission from the local landowners and Fiji's government Fisheries Authority. The limits on amounts of organisms collected or exported have been determined by demand and airline freight availability. Until recently, there have been no studies done to establish the effect of such collection on Fiji's reef populations, or the sustainable limits of such collection. Records of catch and sales have been the only measure of populations.

There are now serious concerns about the health of the world's coral reefs, and the pressures being exerted on them (Wilkinson 2000). One of these pressures is the collection of organisms for the Aquarium trade, which is coming under scrutiny. (Birkeland 2001, Lieberman et al 2001, McManus 2001, Moore et al 2001, Spruill et al 2001). CITES (the Convention on the International Trade in Endangered Species of Wild Flora and Fauna) is coming into play to control the amount of hard corals that can be exported from a signatory country. CITES does not currently cover any reef fish.

The Marine Aquarium Council (MAC) is working on voluntary certification to encourage the use of sustainable collection procedures and to minimise wasteful practices. Aquarium trading companies in Fiji are currently working towards MAC certification, and the Department of Fisheries is considering making MAC certification a requirement for collection licenses. (MAC website and quarterly newsletter)

A study and management plan for corals and invertebrate animals is being carried out by Ed Lovell on reefs harvested by Walt Smith International. (Lovell 2002)

This study is a first look at the effects of collection on the populations of collected fish species on reef areas where regular collection takes place, and a test of effective survey methods.

Acknowledgements

An initial small-scale survey was commissioned by Walt Smith International, one of the largest Aquarium collection agencies in Fiji.

A larger survey was made possible by the presence of two undergraduate students from Holland, Kristiaan Kats and Raymond Derksen. They spent 3 months as volunteers collecting data under the supervision of Helen Sykes of Resort Support, a private consultancy firm, and Professor Bill Aalbersberg of the University of the South Pacific.

These surveys were supported in the form of accommodation, food, and diving facilities, without any monetary compensation, by the following organisations, to whom we extend our thanks:

- Jean Micheal Cousteau Fiji Islands Resort and L'Aventure Cousteau Diving
- Wananavu Beach Resort and Crystal Divers
- Beachcomber Island Resort and Subsurface Fiji
- Castaway Resort and Coral Cay Conservation
- Walt Smith International Ltd

Invaluable advice and assistance with statistical analysis was provided by Lynette Kumar of the Institute of Marine Sciences, and Ron Vave of the Institute of Applied Sciences, at the University of the South Pacific.

Methods

The surveyors went to four regions of Fiji over a period of three months. Three were resort areas where they went out on regular dive excursions. In the region used for fish collection, they went out on regular fish collection trips, and on non-collection days they were taken to reefs used for coral collection, farming, and live rock culture, where fish were not collected. At the fish collection sites, fishing took place at the same time as surveys, but in different areas of the reef. During the period of the study, the surveyors also observed the regular collection methods used by the fish harvesters at Walt Smith International Ltd.

Collection methods

Between 2 and 4 collectors usually collected fish 2-3 days a week on SCUBA or Snorkel, usually no deeper than 5M. Divers made two 2-hour collection dives a day. They usually were told by the warehouse which species to target each day, but would collect others which were regularly demanded.

Fish were collected using one of two methods depending on habitat. Hand nets were used to collect small fish that live close to the sea bed, and larger nets weighted at the bottom with floats at the top to trap fish that swim more actively. In both cases fish were chased into the nets using hands or sticks. These methods are not unduly destructive, although there is quite a high level of hand contact on living coral.

Poisons and blasting are not in use, and the hand collection, when carefully done, did not appear to cause undue environmental damage or death of fish.

Photos of fish collection by Walt Smith International collectors in Lautoka Waters.

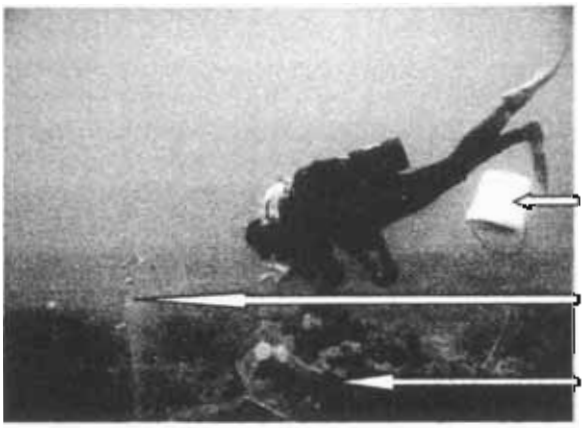


Figure 3 SCUBA diver fully equipped for fish collection.

Bucket for fish storage and acclimatisation after collection.

Float net for collection of free-swimming species

Handnet and pots for collection of rubble dwelling species

Figure 4 Collector using hand net

This method is used for the majority of fish collected.
Collector lays handnet against sea bed and uses hand or stick to chase fish into net. Usually only one fish at a time is caught this way.

Figure 5 Collector using float net
(From *Philippines*, photo by Gary Brasch, MAC brochure)
Collector herds fish into semicircular net laid between coral heads. Several free-swimming fish at a time are caught this way.

Figure 6 Fish caught by nets are placed into small pots.

The fish remain in these pots (with holes in the sides for water circulation) inside the nets to prevent escape while the collectors continue to fish.

Figure 7 Underwater storage during collection
Fish are transferred to a bucket with a mesh top and a zip closure to prevent escape while collection continues. They remain in the bucket to acclimatise until the boat leaves.

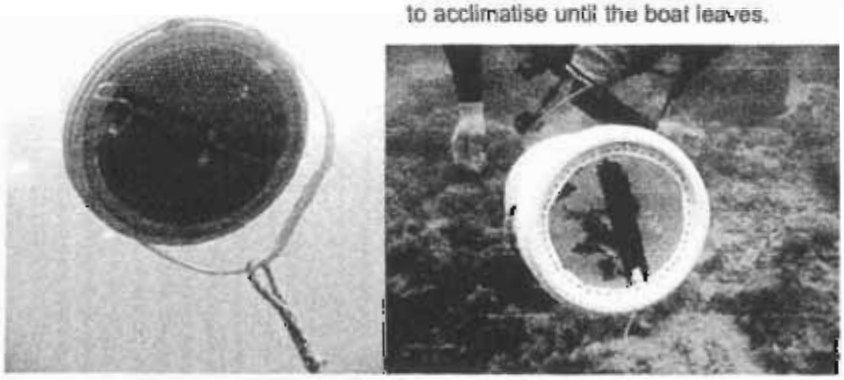


Figure 8 Newly caught fish in tank

The fish are slowly raised to the surface to allow decompression, and poured into tanks on the boat for transport back to the warehouse.

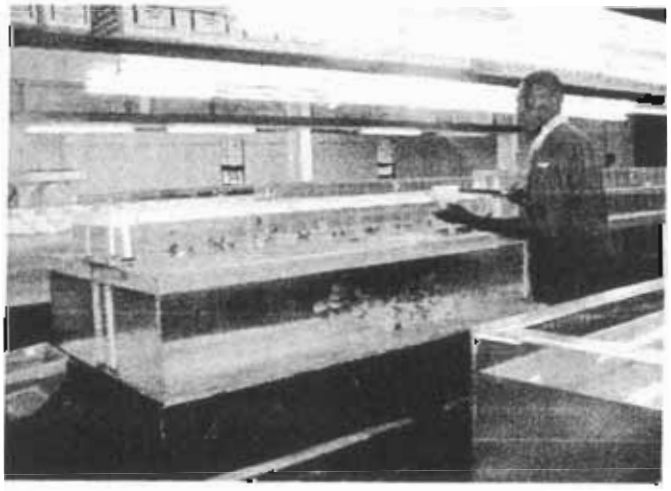


Figure 9 Tanks at the warehouse

Back in Lautoka, the fish are placed into holding tanks until shipment.

At this point the catch is recorded and logged, and the collectors are paid per fish.

Collection records

Walt Smith International compiled collection and sales figures for the year to date. Collection figures are kept in a daily log as each collector brings in fish. The surveyors also kept records of fish taken during the days they were on the boats.

Underwater Visual Survey

The main effort was directed to performing underwater censuses of fish populations along measured and timed transects on reefs where fish were regularly collected (Collection sites), and reef where fish collection was not done (Non-collection sites).

Surveyors used SCUBA equipment and a list of species based on the most commonly collected species. Fish identification guides for use underwater were developed based on this species list. (Mohajerani et al 2001) The basic method was a modified version of MACTRAQ. (Hodgson 2001) Reef Check surveys were used to characterise each reef area. (Hodgson 2002)

Figure 10
Survey team with slates and fish identification guides.

Figure 11
Surveyor recording population along transect line

Figure 12
Surveyor with survey tape

As the majority of fish collection takes place at shallow depths (less than 6M) surveys were done between 3 and 5M on most sites. If the site was deeper than that, surveys were done at convenient depths and this fact was recorded.

Surveyors were students from a course in Aquatic Ecotechnology from Hogeschool Zeeland course, who were in Fiji for 3 months. They were trained in Reef Check techniques by Helen Sykes (Fiji Reef Check co-coordinator).

A laminated sheet with pictures of the species selected for survey was prepared for assistance with underwater identification, using illustrations taken from the Reef Fishes of the World guide, with the kind permission of the author, Ewald Lieske. Assessing fish sizes and numbers in a moving school was practiced using the holding tanks at Walt Smith International.

After 3 weeks practice surveys and with the assistance of the underwater sheet, the surveyors were making identifications with confidence and accuracy. They then spent 3 weeks moving around resorts honing their skills and making small-scale surveys, before doing 4 weeks of solid surveying at the collection areas, on which the main part of this study is based.

Reef Check characterisation:

GPS coordinates and reef name were recorded.
Site Description was made - depth, visibility, current, reef type, temperature, compass direction, assessment of impacts.
Four replicate Reef Check Transects were recorded for each site -

- 20m point transect for Benthic cover,
- 20 x 5 m belt transect for selected invertebrates,
- 20 x 5 x 5 m 3-D corridor belt transect for selected fish species.

Survey of Ornamental Fish Species:

20 x 5 x 5 m belt transects were surveyed. The initial transect was done along a laid 20m tape, and timed. Subsequent surveys at that site on that day were carried out as timed swims of the same duration, usually 10-15 minutes. (Bohnsack 1995, Cheal and Thompson 1997, Hodgson et al, Smith et al 1999)

The surveyor swam slowly along the transect, stopping at regular intervals to count fish and allow cryptic species to come out of hiding. Size and abundance of each species on the survey were recorded. The number of transects was determined by the accessibility of the site.

If fish collection was going on during the survey time, the survey was done in an area away from where the collectors were working. If the site had just been harvested prior to the survey time, it was recorded in the site description.

When collection had been taking place, the fish species, numbers, and sizes of catch were recorded.

Table 1. Fish species surveyed.

This list was based upon the list Walt Smith International gives to its collectors. While other species were occasionally collected, this list represents the commonest species that are taken from the reefs in the Lautoka area. Butterflyfish were excluded from this survey for two reasons:

- They are not regularly collected, only when a specific order is made
- They are covered as a group in the Reef Check survey

(* R = Rakiraki, Crystal Divers and Wananavu Beach Resort; M = Mamanucas, Coral Cay Conservation, Subsurface Fiji and Beachcomber Island Resort; S = Savusavu, Jean Michel Cousteau Fiji Islands Resort;
L = Lautoka, Walt Smith International Ltd.)

Family	Species			Actually found on surveys*
	Scientific name	Divers' common name	Aquarists' common name	
Angelfish	*Centropyge bicolor*	Bicolour angel	Bicolor angel	R, M, S
	Centropyge bispinosus	2-Spine angel	Coral beauty	R, M, S
	Centropyge flavissimus	Lemon peel angel	Lemon peel	R, M, S
	Pomacanthus imperator	Emperor angel	Imperator angel	M, L
	Pomacanthus semicirculatus	Semicircle angel	Koran angel	
Butterflyfish	*Heniochus acuminatus*	Longfin banner	B/W heniochus	R, M, L
	Heniochus chrysostomus	Pennant banner	Feather fin heniochus	R, M, L
	Heniochus varius	Humphead banner	Brown heniochus	R, M, S, L
Surgeonfish	*Zebrasoma veliferum*	Sailfin tang	Sailfin tang	R, S, L
	Acanthurus pyroferus	Mimic surgeon	Mimic tang	
	Ctenochaetus strigosus	Goldring bristletooth	False mimic tang	R, M, S, L
Rabbitfish	*Siganus doliatus*	Pencil-streaked rabbit	Blue & goldline rabbitfish	M, S, L
	Siganus uspi	Uspi rabbit	Fiji foxface	R, M, S, L
Damselfish	*Amphiprion chrysopterus*	Orange fin anemonefish	Blue line clown	R, M, S, L
	Amphiprion perideraion	Pink anemonefish	Pink skunk clown	R, S, L
	Amphiprion frenatus	Tomato anemonefish	Tomato clown	R, M, S, L
	Dascyllus sp.	Asst. damselfish	Asst. damsel	
	Chrysiptera taupou	South seas devil	Fiji devil	R, M, S,L
	Dascyllus aruanus	Humbug dascyllus	Three-stripe damsel	S
	Dascyllus melanurus	Black-tailed dascyllus	Four-stripe damsel	
	Amblyglyphidodon leucogaster	White belly damsel	Goldfin damsel	R, M, S, L
	Pomacentrus molucccensis	Lemon damsel	Gold dusky damsel	
	Chromis viridis	Blue-green chromis	Green chromis	R, M, S, L
	Pomacentrus bankanensis	Speckled damsel	Flame damsel	R, L
	Amblyglyphidodon curacao	Staghorn damsel	Green damsel	M, S, L
	Dascyllus trimaculatus	3-Spot dascyllus	Domino damsel	
	Pomacentrus caeruleus	Caerulean damsel	Fiji electric damsel	R, M, S, L
	Amblyglyphidodon aureus	Golden damsel	Giant golden damsel	R, M, L
	Chrysiptera talboti	Talbot's demoiselle	Fiji yellow head damsel	R, M, S, L

Dottybacks	*Pseudochromis novaehollandiae*	Multicoloured dottyback	Red & green dottyback	
	Pseudochromis porphyreus	Magenta dottyback	Magenta dottyback	
Sandperch	*Parapercis nebulosa*	Nebulous sandperch	Bar faced weever	M, S
Anthias	*Serranocirrhitus latus*	Hawkfish anthias	Flathead bass	
Wrasse	*Coris gaimard*	Yellow tail coris	Red coris (Juv.)	S
	Coris aygula	Clown coris	Twinspot wrasse	
	Pseuduocheilinus hexataenia	6-Line wrasse	Hexitania wrasse	S, M, L
	Macropharyngodon meleagris	Leopard wrasse	Leopard wrasse	S, L
	Novaculichthys taeniourus	Rockmover wrasse	Dragon wrasse	L
	Thalassoma hardwicke	6-Bar wrasse	Hardwicki wrasse	R, M, S, L
	Thalassoma lunare	Moon / crescent wrasse	Lunare wrasse	R, M, S, L
	Cheilinus species	Floral wrasse	Leaf wrasse	R, M, S, L
	Thalassoma jansenii	Jansen's wrasse	Jansen's wrasse	R, S, L
	Stethojulis bandanensis	Red shoulder wrasse	Neon wrasse	R, S, L
	Epibulus insidiator	Slingjaw wrasse	Sling jaw wrasse	R, M, S, L
	Halichoeres melanurus	Pinstriped wrasse	Orangeline wrasse	R, M, S, L
	Halichoeres nebulosus	Nebulous wrasse	Nebulous wrasse	M, S, L
	Hemigymnus melapterus	Blackedge thicklip wrasse	Half & half wrasse	M, S, L
	Oxycheilinus diagrammus	Bandcheek wrasse	Bandcheek wrasse	S
Parrotfish	*Cetoscarus bicolor*	Bicolour parrot	Bicolour parrot	R, M, S, L
Goatfish	*Parupeneus barberinoides*	Half and half goat	Bicolour goat	M, S, L
Jacks or Trevallies	*Gnathanodon speciosus*	Golden trevally	Pilot fish	
Triggerfish	*Rhinecanthus aculeatus*	Picassofish	Humuhumu trigger	M, L
Bream	*Scolopsis bilineatus*	2-Line spinecheek	Yellow scolopsus	R, M, S, L
	Scolopsis frenatus	Bridled spinecheek	Purple scolopsus	
Cardinalfish	*Apogon lyanusoma*	Blackstripe cardinal	Orange line cardinal	R, M, S, L
	Sphaeramia nematoptera	Pajama cardinal	Apogon cardinal	L
Pufferfish	*Canthigaster solandri*	Spotted toby	Orange tail Fiji puffer	M, L
	Arothron meppa	Map puffer	Honey comb puffer	S
	Arothron nigropunctatus	Blackspotted puffer	Dogface puffer	R, M, S, L
	Diodon histrix	Porcupinefish	Dalmation puffer	M
Lionfish	*Pterois volitans*	Turkey lionfish	Volitan lion	
	Pterois radiata	Clearfin lionfish	Radiata lion	M, S
	Dendrochirus zebra	Zebra lionfish	Dwarf lion	

Blennies	*Salarias fasciatus*	Jewelled blenny	Algae blenny	M, S, L
	Meiacanthus ovalauensis	Yellow poisonfang blenny	Fiji canary	R, M, S, L
	Plagiotremus flavus	Poisonfang blenny mimic	Fiji canary	R, M, S, L
	Astrosalarias fuscus	Highfin blenny	Black blenny	R, M, S, L
	Ecsenius oculus	Ocular blenny	Eyelash blenny	
	Ecsenius bicolor	Bicolour blenny	Bicolor blenny	R, M, S, L
Gobies	*Amblygobius sphynx*	Sphynx goby	Zebra goby	M, S, L
	Gobiodon citrinus	Citron goby	Clown goby	
	Ambleyeleotris wheeleri	Wheeler prawn goby	Wheeler prawn goby	
	Amblygobius rainfordi	Old glory goby	Rainford goby	M, S, L
	Amblygobi sp.	Assorted goby spp.	Assorted goby spp.	
	Valenciennea strigata	Bluestreak goby	Gold head sleeper	
	Valenciennea longipinnis	Longfinned goby	Tiger sleeper	S
	Valenciennea sexguttata	6-Spot goby	Blue dot sleeper	S, L
	Nemateleotris helfrichi	Helfrich's dartfish	Helfrichi firefish	S
	Amblygobius phalaena	Brownbarred goby	Dragon goby	S, L
	Ambleyeleotris steinitzi	Steinitz' prawn goby	Orange bar goby	M, S, L

Not all of these species were found during the surveys, or collected during the year.

A "commonness index" was prepared by allocating each species an index number relating to the amount of fish that were seen during surveys.
1 = highest number seen during surveys, 2 = next highest etc.

A "collection index" was prepared by allocating each species an index number relating to the amount of fish that had been collected over the year 2002 (January to October). 1 = highest number collected, 2 = next highest etc. Collection witnessed by surveyors was examined in the same way, and found to reflect a similar collection index rating.

From this, 14 "Key Species" of fish were selected for in-detail analysis:

- 11 were selected because they ranked highly as most commonly seen during the surveys, and were also the most collected or Fiji endemics.
- 3 anemone fish species were selected because they are of sedentary habitat and vulnerable to over collection.

Table 2 Commonness and Collection Indices and Key Species identified.

Species Scientific name	Common-ness on transect index*	Collection index by witnessed collection	Collection index by warehouse records	Identified as Key Species
Chrysiptera taupou	1	1	1	†
Pomacentrus caeruleus	6		10	
Chrysiptera talboti	4	5	6	†
Pomacentrus bankanensis	7		34	
Amblyglyphidodon aureus	30		38	
Amblyglyphidodon leucogaster	11		31	
Chromis viridis	2		8	†
Amblyglyphidodon curacao	3		25	†

Chromis viridis	2		8	†
Amblyglyphidodon curacao	3		25	†
Dascyllus sp.	–		27	
Novaculichthys taeniourus	48		46	
Chellinus species	22		33	
Hemigymnus melapterus	13		46	
Thalassoma hardwicke	37		46	
Pseuduocheilinus hexataenia	9		46	
Thalassoma jansenii	43		46	
Macropharyngodon meleagris	47		46	
Thalassoma lunare	20		46	
Halichoeres nebulosus	19		27	
Stethojulis bandanensis	38		46	
Halichoeres melanurus	5	6	21	†
Epibulus insidiator	36		46	
Ecsenius bicolor	24		11	
Astrosalarias fuscus	18		19	
Meiacanthus ovalauensis	8	2	2	†
Salarias fasciatus	14	12	9	
Siganus doliatus	12	7	5	†
Siganus uspi	16	12	7	†
Gnathanodon speciosus	–		9	
Parapercis nebulosa	–		26	
Scolopsis bilineatus	10		23	
Valenciennea sexguttata	32	9	13	
Valenciennea longipinnis	–		18	
Valenciennea strigata	–		38	
Amblygobius phalaena	28		24	
Amblyeleotris steinitzi	26		37	
Amblygobius rainfordi	16	4	4	†
Amblygobius sphynx	38		29	
Amblygobi sp.	–		43	
Gobiodon citrinus	–	10	16	
Amblyeleotris wheeleri	–		44	
Ctenochaetus strigosus	15		46	
Zebrasoma veliferum	21		17	
Heniochus acuminatus	33		41	
Heniochus varius	30		46	
Heniochus chrysostomus	35		41	
Sphaeramia nematoptera	23		22	
Apogon lyanusoma	38		15	
Arothron nigropunctatus	38		31	
Arothron mappa	–		36	
Diodon histrix	–		35	
Canthigaster solandri	24	3	3	†
Parupeneus barberinoides	27	11	14	
Amphiprion chrysopterus	43		44	†
Amphiprion perideraion	43		38	†
Amphiprion frenatus	33	14	12	†
Rhinecanthus aculeatus	28	8	20	†
Pomacanthus semicirculatus	42		46	
Cetoscarus bicolor	43		46	

(* – = Collected but not seen during surveys)

Figure 13 . 14 Key species - illustrations courtesy of Ewald Lieske

South Seas Devil
Fiji Devil
Chrysiptera taupou

Talbot's Demoiselle
Fiji Yellowhead
Chrysiptera talboti

Blue-Green Chromis
Green Chromis
Chromis viridis

Staghorn Damsel
Green Damsel
Amblyglyphidodon curacao

Orange Fin Anemonefish
Blue Line Clown
Amphiprion chrysopterus

Tomato Anemonefish
Tomato Clown
Amphiprion frenatus

Pink Anemonefish
Pink Skunk Clown
Amphiprion perideraion

Yellow Poison Fang Blenny
Fiji Canary (and Mimic)
Meiacanthus ovaleuensis
or Plagiotremus flavus

Old Glory
Rainford's Goby
Amblygobius rainfordi

Orangeline wrasse
Pinstripe wrass
Halichoeres melanurus

Spotted Toby
Orangetail Puffer
Canthigaster solandri

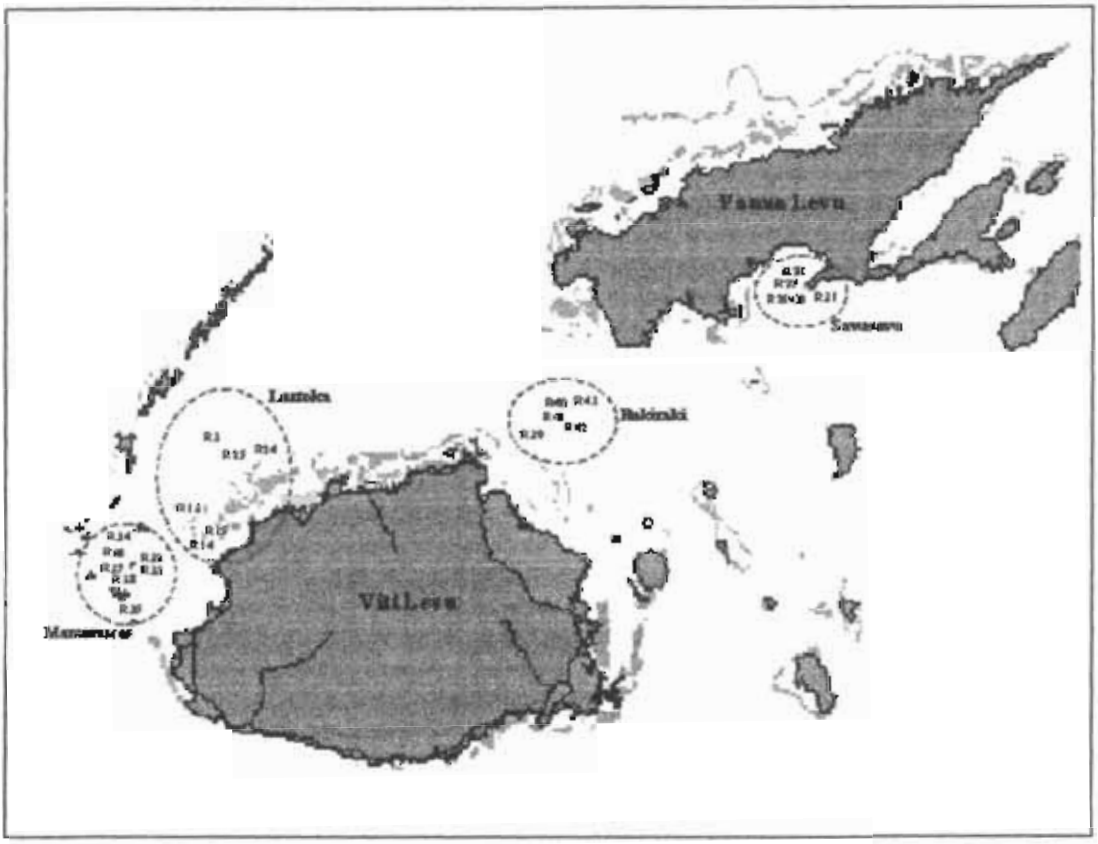
Pencil-Scrawled Rabbit
Blue & Gold Line Rabbit
Siganus doliatus

Uspi Rabbit
Fiji Foxface
Siganus uspi

Picassofish
Humuhumu Trigger
Rhinecanthus aculeatus

Site Selection

Figure 14 Map showing the four survey regions used.



In three regions the major reef users were tourism concerns. These were the subject of small surveys designed to examine the populations at sites regularly visited by tourist divers. Such sites are subject to a similar amount and type of human (i.e. diving) disturbance as the collection sites, but there is no regular removal of fish or corals.

Of these three regions, one definitely has no collection for the Aquarium trade (Savusavu), one is in an area where it is thought that occasional irregular collection may take place (Rakiraki), and the other is in an area that has specifically disallowed collection, but where unauthorised collection sometimes occurs (Mamanucas).

The main survey was carried out in the collection grounds of Walt Smith International, in a large area of patch reefs north of Lautoka. Regular collection sites were surveyed, and sites in a "Buffer zone" nearby where reefs were of a similar physical type, and subject to similar stresses, but no fish collection was being carried out.

Coral harvesting is carried out in all areas studied. Some of the "buffer zone" sites are the sites of coral and live rock culturing.

Figure 15 Map showing zones of Fiji used for collection of Marine Species for Aquarium and related trades (Lovell 2001).

Collection of Marine Species of various types is carried out along most areas of the coastline of the main island of Viti Levu. Different organisms are collected in different areas depending on reef type.

Figure 16 Boundaries of the collection areas of Walt Smith International, showing the areas of each Qoliqoli (traditional fishing ground ownership) involved, according to the Native Lands and Fishery Commission (Lovell 2001)

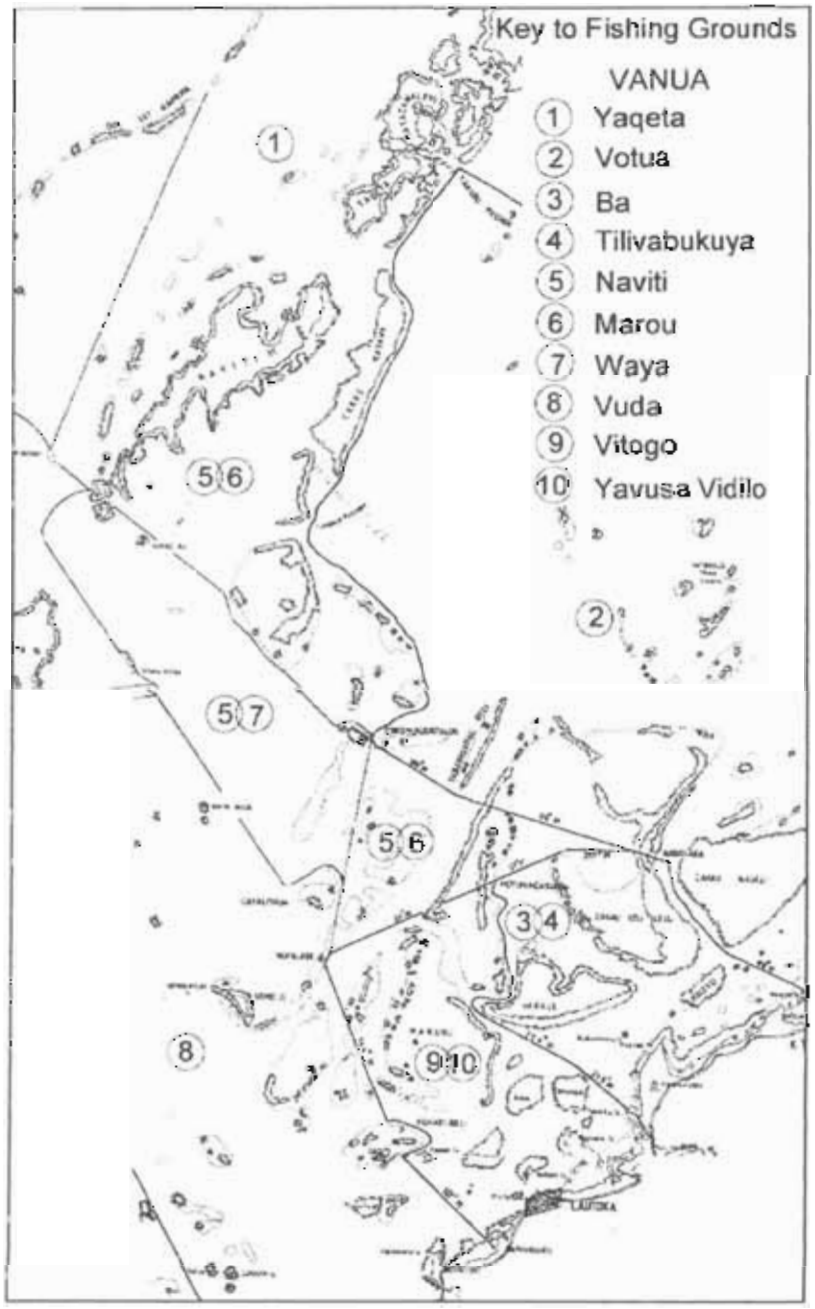


Figure 17 Landsat Satellite photo showing survey reefs in Lautoka area (Lovell 2001)

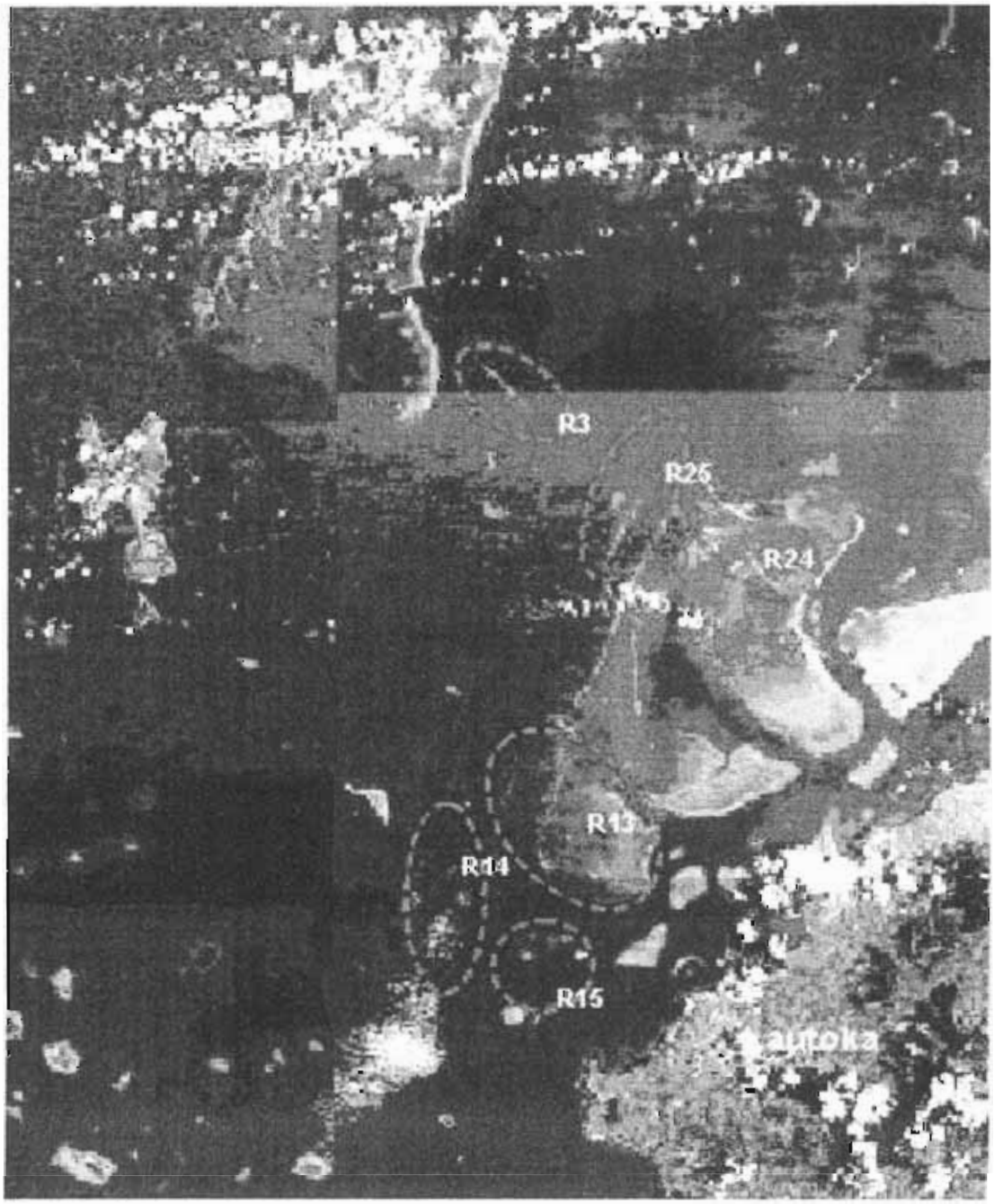


Figure 18 Map showing survey reefs in Lautoka area (Lovell 2002)

The numbering system used is a continuation of that used in the study of corals and benthic cover by Ed Lovell (Lovell 2002). Where reefs included in that study were used for fish surveys, the same numbers were used. Where reefs not included in the Lovell survey were visited, the reef numbers continued on from his system. Therefore, if this report is read alongside the Lovell report (Lovell 2002), the reef numbers will coincide.

Table 3 Locations of survey sites

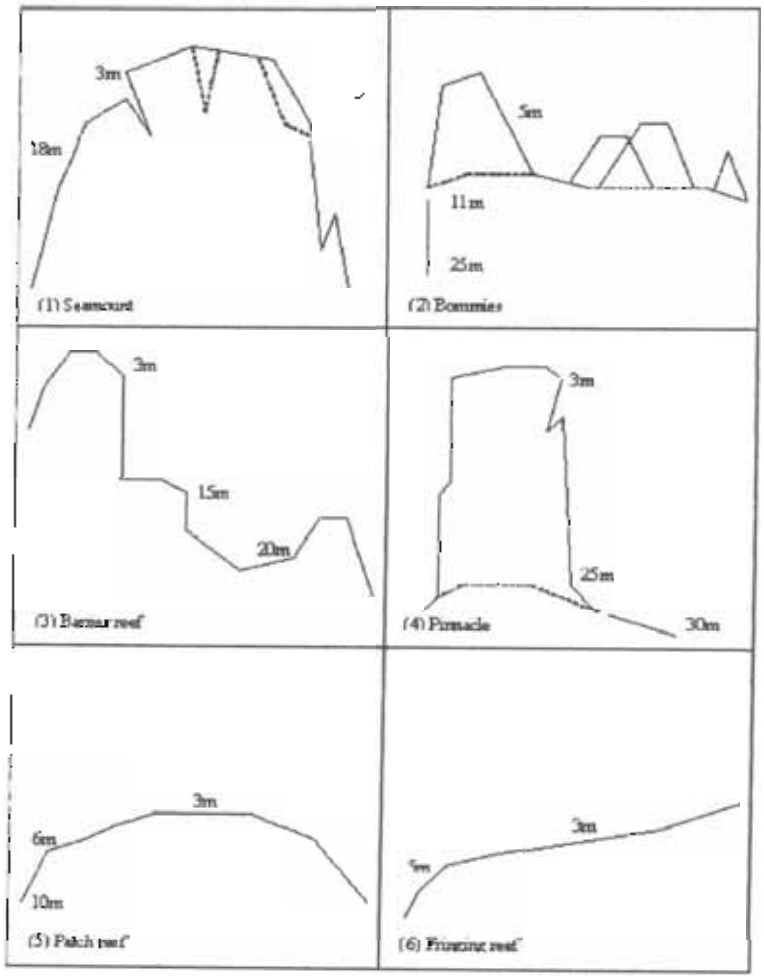
Reef no.	Region	Reef name	Latitude	Longitude	Reef type	Fish coll. yes/no
R3	Lautoka	Naitovalase Reef	17° 16.52' S	177° 21.15' E	Line reef with some reef patches	No
R13	Lautoka	Nakubu Reef	17° 31.00' S	177° 21.50' E	Patch reef	No
R14	Lautoka	Vunaqiliqili Reef	17° 35.22' S	177° 21.02' E	Line reef and patch reef	No
R15	Lautoka	Savala Reef	17° 34.81' S	177° 22.65' E	Fringing reef, and reef flats	Yes
R24	Lautoka	Cakauniciva Reef	17° 20.35' S	177° 28.15' E	Patch reef	Yes
R25	Lautoka	Ovulavula Reef	17° 20.80' S	177° 24.15' E	Line reef and patch reef	No
R27	Savusavu	Alice Reef	16° 48.92' S	179° 15.51' E	Patch reef	No
R28	Savusavu	Cousteau Jetty Reef	16° 48.74' S	179° 17.21' E	Fringing reef	No
R29	Savusavu	Golden Nuggets Reef (shallow)	16° 49.20' S	179° 18.51' E	Bommie	No
R30	Savusavu	Golden Nuggets Reef (snorkelspot)	16° 49.20' S	179° 18.51' E	Bommie	No
R31	Savusavu	Shark Alley Reef	16° 49.54' S	179° 18.44' E	Barrier reef	No
R32	Mamanucas	Jacky's Reef	17° 39.05' S	177° 15.06' E	Fringing reef	No
R33	Mamanucas	Jimmy's Reef	17° 39.30' S	177° 15.15' E	Fringing reef	No
R34	Mamanucas	Pleasure Point Reef	17° 38.10' S	177° 10.20' E	Patch reef	No
R35	Mamanucas	Plantation Pinnacles	17° 46.07' S	177° 12.15' E	Bommie	Yes
R36	Mamanucas	Angel's Reef	17° 39.40' S	177° 08.33' E	Patch reef	No
R37	Mamanucas	Castaway Pinnacles	17° 43.66' S	177° 06.53' E	Bommie	No
R38	Mamanucas	M+M Reef	17° 44.25' S	177° 08.28' E	Patch reef	No
R39	Rakiraki	Wailu Express Reef	17° 18.24' S	178° 26.87' E	Patch reef	Unknown
R40	Rakiraki	G-6 Reef	17° 16.98' S	178° 28.27' E	Bommie	Unknown
R41	Rakiraki	Mellow Yellow Reef	17° 16.92' S	178° 27.74' E	Bommie	Unknown
R42	Rakiraki	Purple Haze Reef	17° 16.78' S	178° 27.67' E	Bommie	Unknown
R43	Rakiraki	Black Magic Mountain Reef	17° 16.86' S	178° 27.50' E	Bommie	Unknown
R44	Rakiraki	Garden of Eden Reef	17° 16.92' S	178° 27.74' E	Patch reef	Unknown
R45	Rakiraki	Instant Replay Reef	17° 17.03' S	178° 27.44' E	Bommie	Unknown

Within the Lautoka region, six sites were visited and surveyed for ornamental fish populations. These sites were determined by the regular fish collection schedule, and so represent the areas most regularly collected. On days when collection was not taking place, the surveyors were taken to close-by sites where fish were not collected, but where other stress factors were similar to the fish collection sites, i.e., regular dives were made to collect corals or live rock from culture sites and farms, so that the fish populations were regularly disturbed by divers, but not removed.

Reef Characteristics

There was a large variety of reef types in the smaller resort surveys, and a greater homogeneity of reef types in the main survey of the Lautoka reefs. The types of reefs were split into 6 main descriptive groups

Figure 19 Reef types



Where possible, surveys were carried out on shallow reef flats and slopes that best matched the areas where the majority of ornamental fish were collected. Where site limitations disallowed this, surveys were carried out on the most representative zone of the reef.

The reefs were split into three main zones:
"Shallow"; the reef flat and gradual slope between 0 and 6m depth,
"Mid-reef"; the reef slope between 6 and 14m depth, and
"Deep Reef", the reef slope below 14m.

Figure 20 Survey zones on the Lautoka reefs.

The Lautoka reefs were mostly shallow patch and line reefs. The majority of surveys were carried out in the Shallow reef top area, and a few on the Mid-reef slope.

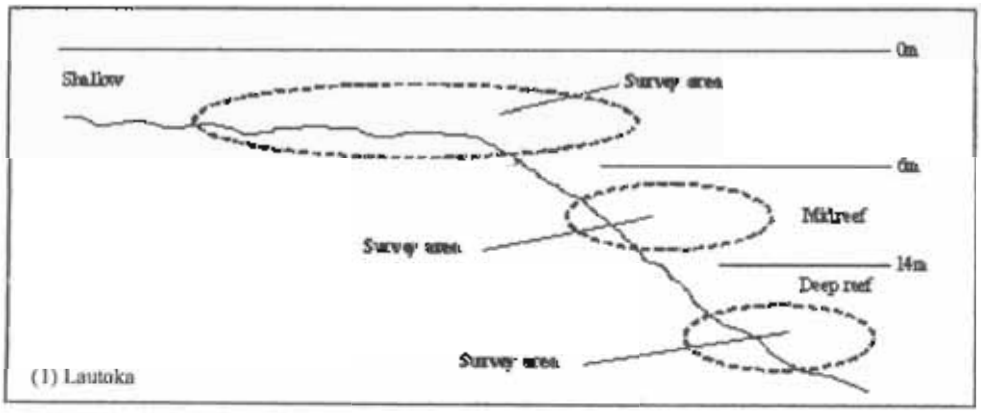


Figure 21 Survey zones on the Mamanuca reefs.

Most of these reefs were patch reefs or bommies. Most surveys were carried out on the Shallow reef which was very similar to the Lautoka areas. Where surge or depth made shallow surveys impossible, the Midreef was used.

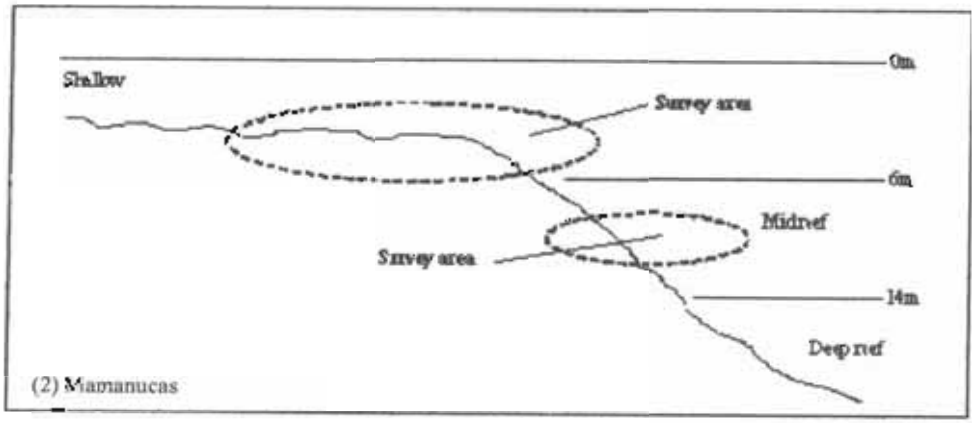


Figure 22 Survey zones on the Savusavu reefs.

Most of the sites surveyed were Shallow reef, either on the top of the reef, or the Shallow reef slope between bommies.

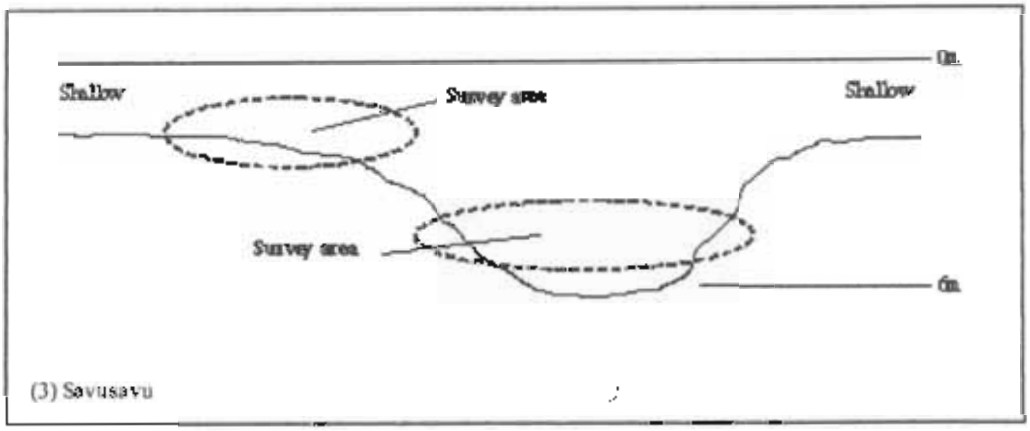
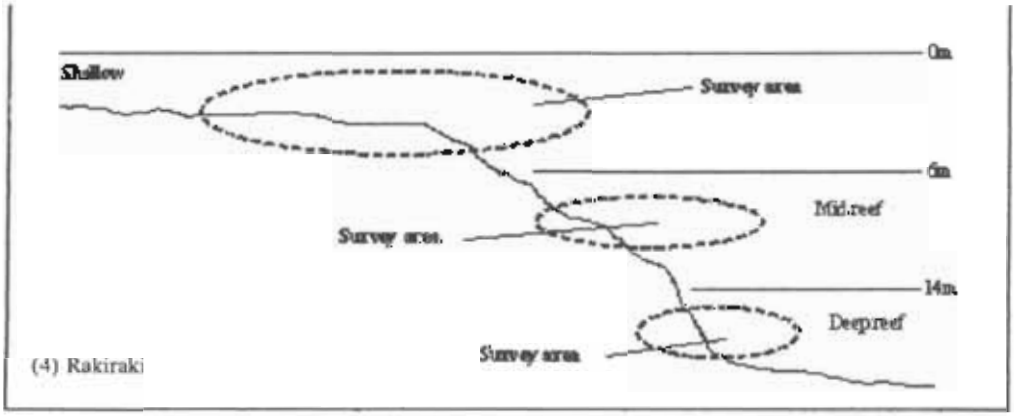
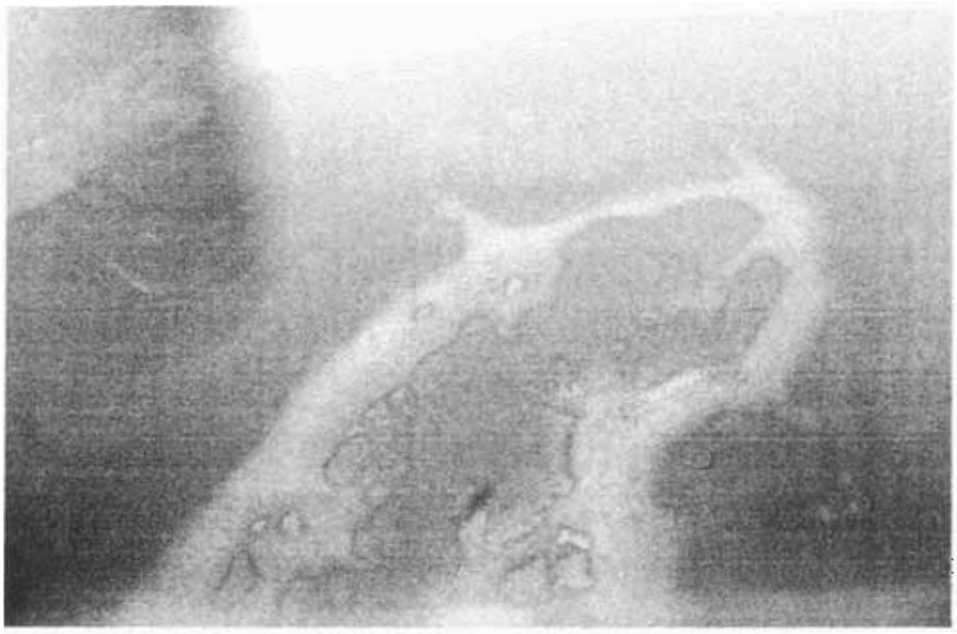


Figure 23 Survey zones on the Rakiraki reefs.

These reefs were further offshore than others surveyed, and in general were large bommies or seamounts on an outer barrier reef. They were mostly deeper than the other sites, and surveys were divided amongst Shallow, Midreef and Deep Reef zones.



Figures 24 and 25 Aerial photos of typical reefs between Lautoka and Vomo Island.



Site description of reefs in the Lautoka area

Six sites were surveyed, four of these were regularly visited, two were less accessible. While all six are included in the general results, only four were used for specific data analysis. Sites excluded from analysis were Naitovolase and Ovulavula.

Fish Collection sites:

Savala Reef (R15) (Fish Collection)
This reef is the only fringing reef surveyed in the Lautoka area. The reef is used for coral harvesting and fish collection regularly. The surveys took place on the shallow part of the reef on two different sites. The sites are similar to each other in regard to the depth and reef structure.

Cakaunicva Reef (R24) (Fish Collection)
This line reef is divided in two reef areas. Both are regularly used for coral harvesting and fish collection. The reef is similar in all zones with the exception of the weather side of both line reefs. On these sides reef patches are located.
The surveys were all carried out on the lee side of the reefs.

Fish Non-collection Sites used in data analysis:

Nakubu Reef (R13) (Fish Non-collection)
R13 is a large reef used for coral harvesting, coral farming and in certain areas for fish collection. The reef is similar in all reef zones. In contrast to the coral harvesting the fish collection takes only place at the Lautoka side (eastern side) of the reef. The coral farm is located in the western part of R13.
All the surveys were carried out near the coral farm away from the fish collection area in the shallow parts and mid reef zones.

Vunaqilqili Reef (R14) (Fish Non-collection)
This reef is outside the collection area of Wall Smith International Ltd. and is used as a site for coral farming. Material for the establishment of the farm has come from the reef area. This area is also the field venue for the live rock mariculture.
The reef consists of elongate reefs and interspersed reef patches.
All the surveys were carried out on the shallow zones near the coral farm and around the reef patches used for live rock culture.

Fish Non-collection sites not used in data analysis:

Naitovolase Reef (R3) (Fish Non-collection)
This small line reef is regularly used for collection of colony rock. The reef is quite hererogeneous in all zones. Shallow parts are alternated with deeper reef zones. Small coral heads are located on both sides of the major reef zone.
Surveys were carried out on the lee side of the reef, on the deeper zone as well as the shallow parts.

Ovulavula Reef (R25) (Fish Non-collection)
This small line reef is used regularly for coral harvesting. There is one steep side facing the prevailing currents and a gentler lee slope. Almost all the coral harvesting takes place at the lee side of the reef and on the shallow flat. All the surveys were carried out on the shallow parts of the lee side.

Surveys were made over a 3 month period September to November 2002. Three weeks of practice surveys at Lautoka were not included in the data. Resort surveys were carried out in September and the main surveys at Lautoka were done over 4 weeks October - November.

Table 4. Date and details of resort surveys

Reef number	Area	Date	Depth (m)	Reef zone	Number of transects
R27	Savusavu	09-Sep-02	6	Shallow	5
R28	Savusavu	10-Sep-02	2	Shallow	4
R29	Savusavu	10-Sep-02	8	Mid reef	2
R30	Savusavu	11Sep-02	6	Shallow	4
R31	Savusavu	12-Sep-02	8	Mid reef	4
Total transects in the Savusavu area					19
R32	Mamanucas	15-Sep-02	7	Mid reef	4
R33	Mamanucas	15-Sep-02	8	Mid reef	4
R34	Mamanucas	16-Sep-02	7	Mid reef	4
R35	Mamanucas	17-Sep-02	6	Shallow	2
R36	Mamanucas	17Sep-02	3	Shallow	4
R37	Mamanucas	20-Sep-02	7	Mid reef	4
R38	Mamanucas	20-Sep-02	9	Mid reef	4
Total transects in the Mamanuca area					26
R39	Rakiraki	23-Sep-02	6	Shallow	4
R40	Rakiraki	24-Sep-02	9	Mid reef	2
R41	Rakiraki	24-Sep-02	7	Mid reef	2
R42	Rakiraki	24-Sep-02	6	Shallow	4
R43	Rakiraki	25-Sep-02	14	Deep Reef	2
R44	Rakiraki	25-Sep-02	6	Shallow	2
R45	Rakiraki	25-Sep-02	8	Mid reef	2
Total transects in the Rakiraki area					18

Table 5 Dates and details of collection area surveys

Reef number	Date	Depth (m)	Reef zone	Number of transects
R13	15-Oct-02	4	Shallow	4
	22-Oct-02	3	Shallow	5
	29-Oct-02	4	Shallow	8
	01-Nov-02	3	Shallow	4
	01-Nov-02	6	Shallow	4
Total transects at a depth ≤ 6 meter				25
R14	17-Oct-02	3	Shallow	8
	28-Oct-02	4	Shallow	12
	28-Oct-02	6	Shallow	4
	30-Oct-02	4	Shallow	8
	31-Oct-02	4	Shallow	8
	31-Oct-02	6	Shallow	4
Total transects at a depth ≤ 6 meter				44
R15	23-Oct-02	3	Shallow	7
	06-Nov-02	2	Shallow	12
	07-Nov-02	2	Shallow	8
	07-Nov-02	3	Shallow	4
Total transects at a depth ≤ 6 meter				31
R24	14-Oct-02	3	Shallow	7
	25-Oct-02	2	Shallow	8
	25-Oct-02	4	Shallow	8
	05-Nov-02	2	Shallow	8
Total transects at a depth ≤ 6 meter				31
R25	16-Oct-02	4	Shallow	5
Total transects at a depth ≤ 6 meter				5
R26	21-Oct-02	15	Deep reef	6
	04-Nov-02	2	Shallow	7
	04-Nov-02	4	Shallow	1
	04-Nov-02	5	Shallow	8
Total transects at a depth ≤ 6 meter				16

Statistical analysis

Reef Check characterisations and basic fish population data are presented as averages of four transects for each site.

Resort Sites data are also presented as averages without further data analysis due to small sample size and large variation in site characteristics.

The Lautoka area was surveyed much more extensively than the Resort sites. A total of 158 transects were sampled. Some of these were excluded from statistical analysis because of site variation or in the interests of pairing surveys of compared sites. A total of 84 transects were used for all Lautoka results and analysis.

Table 6 Details of number of transects on sites used or excluded from analysis

Transects indicated as used in analysis were used for all graphs and analyses for the Lautoka Area.

6 Sites over Lautoka Area								
	4 Non-Collection sites					2 Collection sites		
Site	Naitovalase R3	Vunaqilliqili R14	Ovaluvalu R25	Nakubu R13		Savala R15	Cakaulidva R24	Total
# Transects	22	44	5	25		31	31	158
Reef zone	6 Deep 8 Middle depth 8 Shallow reef	All Shallow reef	All Shallow reef	4 Mid reef	21 Shallow reef	All Shallow reef	All Shallow reef	
Notes on transects selected for statistical analysis	Whole site excluded due to physical remoteness from rest of sites, and small number of shallow sites	23 transects randomly excluded to match R13 numbers	Whole site excluded due to physical remoteness and small sample number	4 sites excluded due to depth	All 21 used for analysis	10 transects randomly excluded to match R13 numbers	10 transects randomly excluded to match R13 numbers	
Transects used in analysis	-	21	-	-	21	21	21	84

The data generated by the surveys were tested with SPSS and PRIMER.

SPSS

In SPSS al the data are analysed via univariate statistics (ANOVA) (Dytham 1999) .
The normal distribution is tested with the Kolmogorov-Smirnov Test (K-S) and the homogeneity with the Levene's Test for Homogeneity of Variances.

Analysis of Variance was not found to be the most useful method of analysis.

Therefore analysis using PRIMER was used to test the data.

PRIMER

(Plymouth Routines in Multivariate Ecological Research)

PRIMER software was specifically developed for the analysis of non-parametric data in community structure ecological studies. It consists of a range of univariate, graphical and multivariate routines for analysing matrices of species by sample abundances. The methods make few, if any, assumptions about the form of the data and concentrate on techniques that are straightforward to understand and explain.

In PRIMER the MDS (Multi Dimensional Scan) plot and SIMPER procedure were used to test the similarity and dissimilarity between the collection and non-collection data.

Collection records

Numbers of each species collected over the year 2002, up to October 2002, were recorded from the warehouse collectors' logs, and any collection witnessed by the surveyors during their work was recorded.

The top 4 most collected species were the same over the entire year as was witnessed in the 5 collection days.

The other fish varied slightly in collection "rank", but overall, the fish most seen to be collected in the time surveyors witnessed collection was accurately reflected in the warehouse annual records.

Table 7 Collection and sales of the "Top Ten" most collected fish Jan - Oct 2002.

Collection Rank		Scientific name	Divers' Common name	Aquarists' Common name
Warehouse Records	Witnessed			
1	1	*Chrysiptera taupou*	South Seas Devil	Fiji Devil
2	2	*Meiacanthus ovaleuensis*	Yellow Poison Fang Blenny	Fiji Canary
3	3	*Canthigaster solandri*	Spotted Toby	Fiji Orangetail Puffer
4	4	*Amblygobius rainfordi*	Old Glory	Rainford's Goby
5	7	*Siganus doliatus*	Pencil-Scrawled Rabbit	Blue & Gold Line Rabbit
6	5	*Chrysiptera talboti*	Talbot's Demoiselle	Fiji Yellowhead
7		*Siganus uspi*	Uspi Rabbit	Fiji Foxface
8		*Chromis viridis*	Blue-Green Chromis	Green Chromis
9		*Salarias fasciatus*	Jewelled blenny	Algae blenny
10		*Pomacentrus caeruleus*	Caerulean damsel	Fiji electric damsel

Figure 26 Collection and sales of the "Top Ten" most collected fish Jan - Oct 2002. (from Warehouse records)

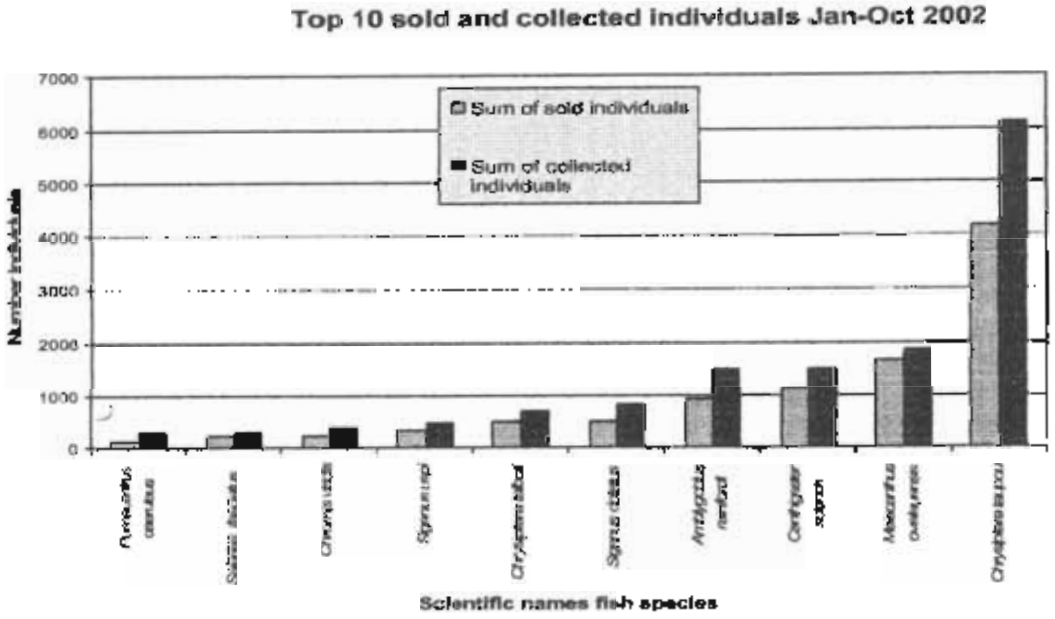
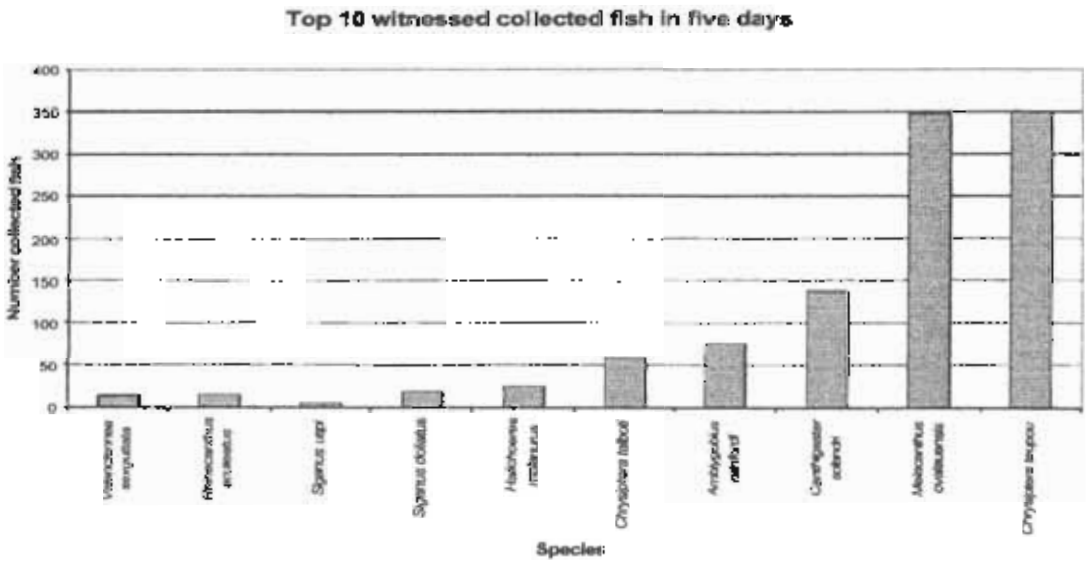


Figure 27 "Top Ten" fish collected as witnessed by surveyors Oct/Nov 2002



Underwater Visual Survey

Reef Check Site Characterisation

Figure 28. Percentage Benthic Cover at each site

Other Sponge Sand Rubble Fleshy Seaweed Recently Killed Coral Rock Soft Coral Hard Coral	**Reef Check Categories:** "Recently Killed Coral" — Coral dead less than 12 months "Rock" — Coral dead for over a year, pieces over 15cm "Rubble" — Pieces 0.5-15cm "Sand" — Grains under 0.5cm

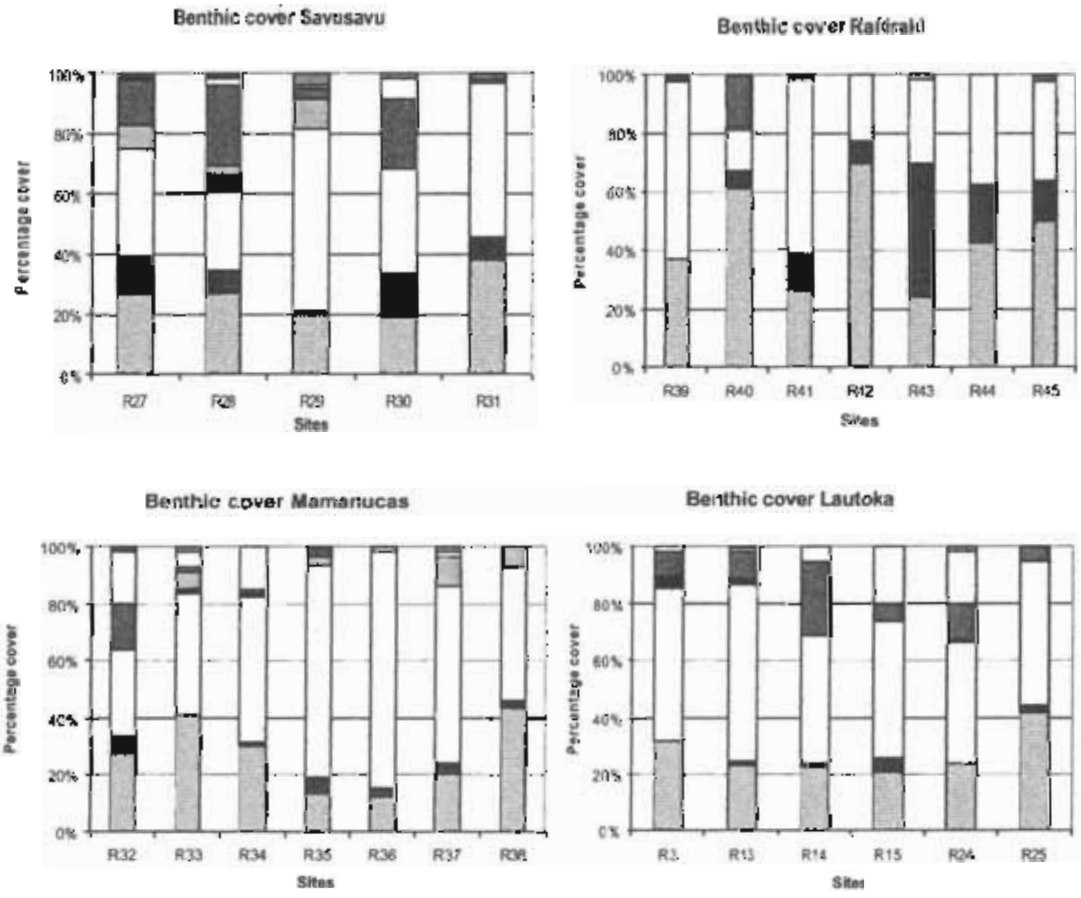


Figure 29 Average numbers of Standard Invertebrates at each site (scale 1-40).

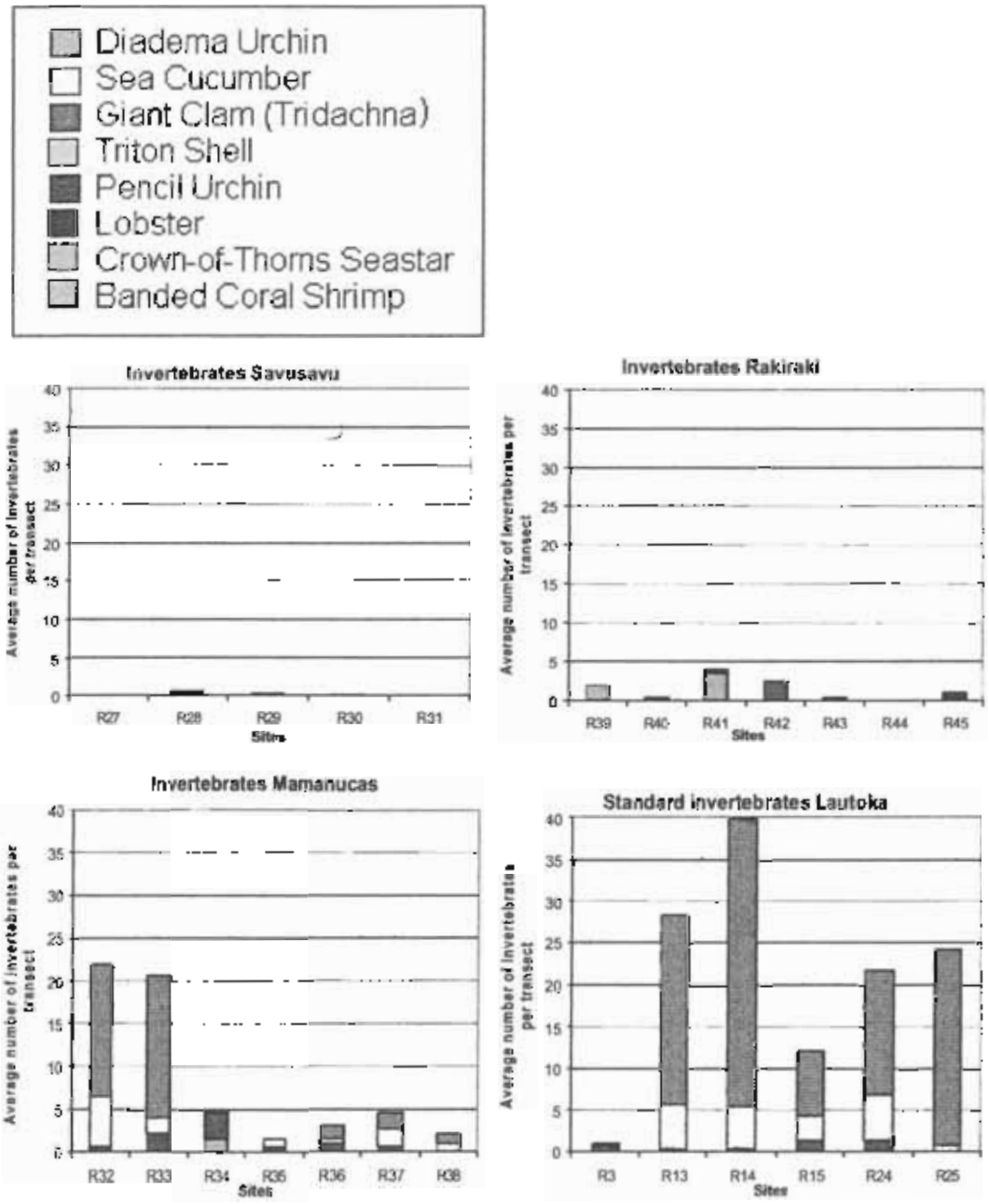
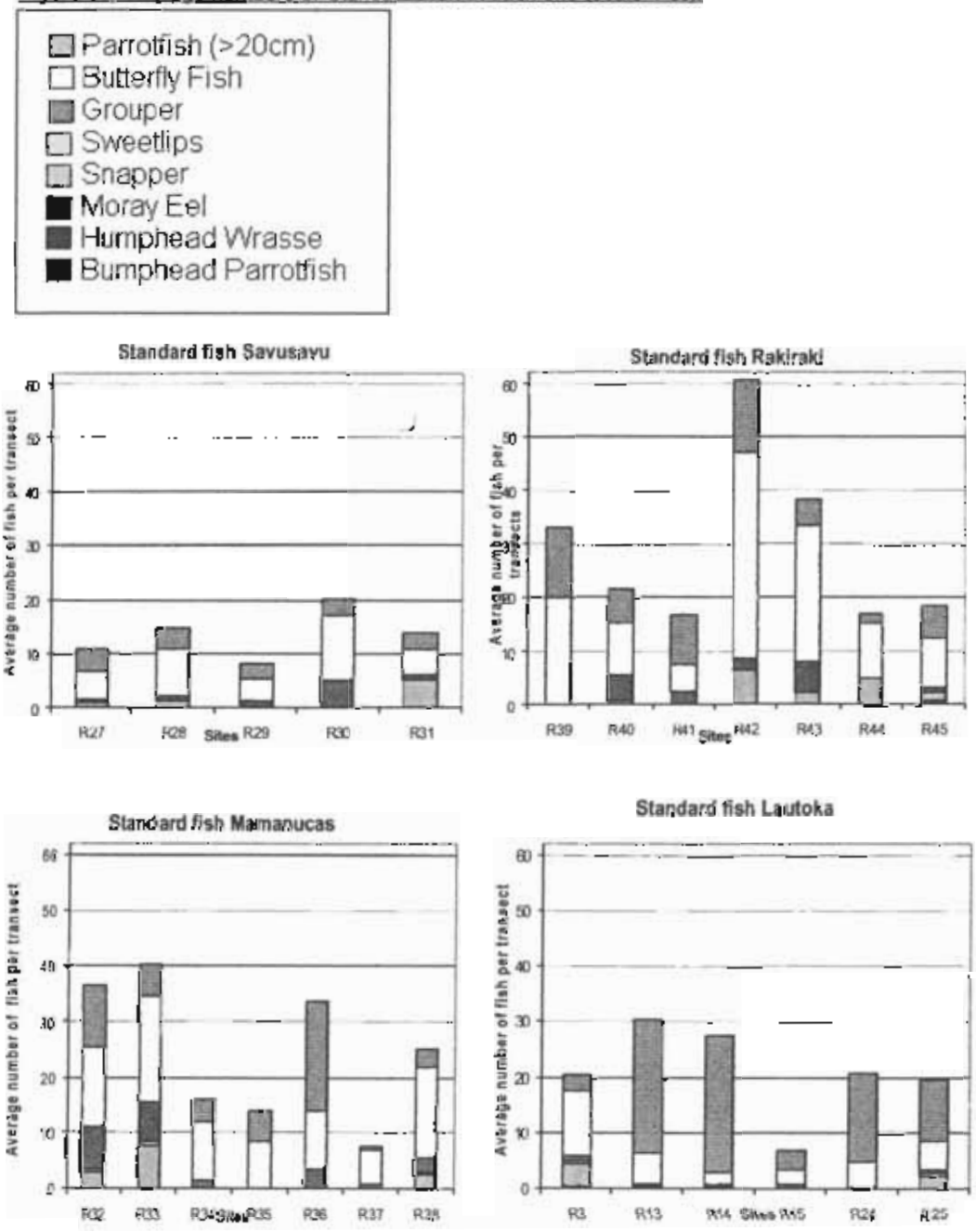


Figure 30: Average numbers of Standard Fish at each site (scale 1-60).



Survey of Ornamental Fish Species:

Surveys of Ornamental fish were analysed at three levels for each region:
A) Totals of all fish surveyed
B) Fish grouped into families
C) Key species

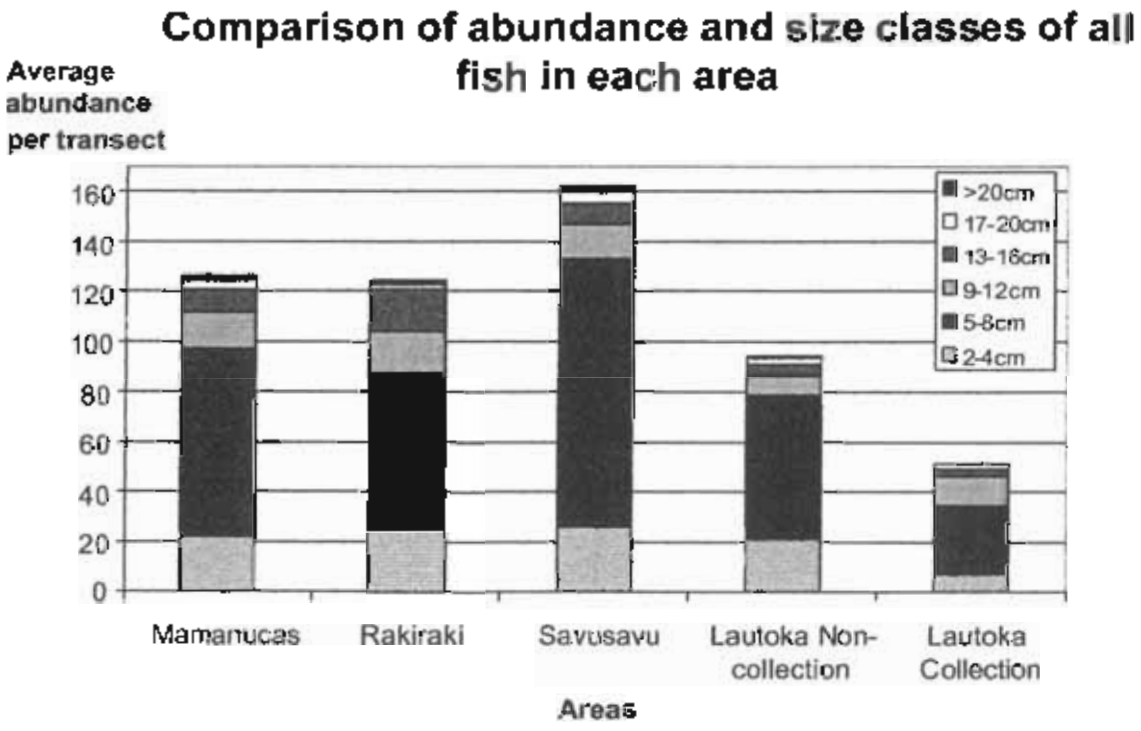
Note – as previously discussed, sample size in the resort regions was less than at the Lautoka sites. Because of this, and the high site variation in the resort sites, Standard Deviation was not calculated or used in these graphs.

Table 8 Number of transects included from each region
(Resort regions had lower numbers of transects than the Lautoka areas)

Resort regions			Lautoka region	
Mamanucas	Rakiraki	Savusavu	Non-collection	Collection
26	19	18	42	42

A) All fish surveyed grouped per region.

Figure 31: Average numbers and size classes of all fish surveyed in each region.



B) *Fish grouped into families per region*

Figures used are averages of all transects at all sites in each area. Two sets of graphs are presented – one set with all families, and the second set with damsel fish excluded. This was done because the large numbers of damsel fish dominated the graph so much that other families could not be examined using the same scale.

Figure 32: Comparison of family abundance in all regions

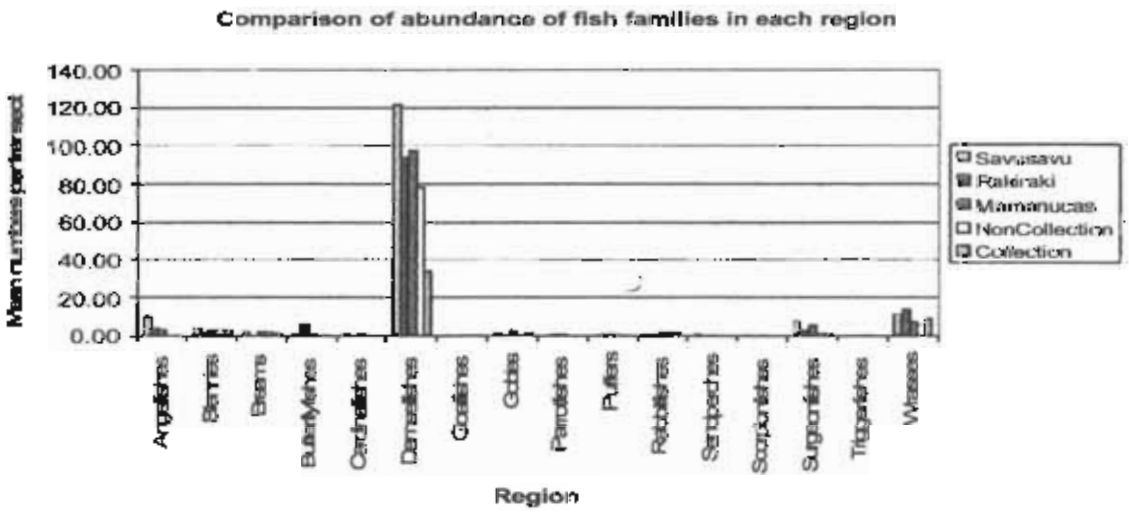
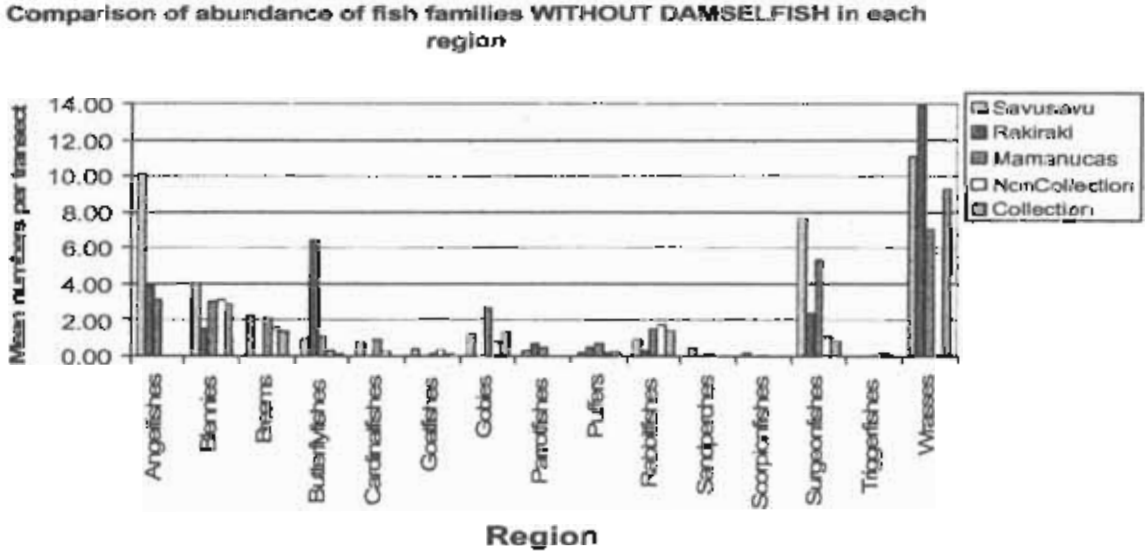


Figure 33: Comparison of family abundance without damselfish, to show other fish species in all regions.



C) *Key Species per region*

For the following graphs the Key Species are referred to by the Aquarists' common name for simplicity and ease of distinction.

Table 9: Scientific and Common names of Key Species.

Scientific name	Divers' Common name	Aquarists' Common name	Notes
DAMSELFISH			
Amphiprion chrysopterus	Orange Fin Anemonefish	Blue Line Clown	Analysed as one group "Anemonefish"
Amphiprion frenatus	Tomato Anemonefish	Tomato Clown	
Amphiprion perideraion	Pink Anemonefish	Pink Skunk Clown	
Chrysiptera taupou	South Seas Devil	Fiji Devil	
Chrysiptera talboti	Talbot's Demoiselle	Fiji Yellowhead	
Chromis viridis	Blue-Green Chromis	Green Chromis	
Amblyglyphidodon curacao	Staghorn Damsel	Green Damsel	
OTHER SMALL SPECIES			
Meiacanthus ovalauensis	Yellow Poison Fang Blenny	Fiji Canary	Analysed as one species "Fiji Canary"
Plagiotremus flavus	Yellow Fang Blenny Mimic		
Amblygobius rainfordi	Old Glory	Rainford's Goby	
Halichoeres melanurus	Pinstripe wrasse	Orangeline wrasse	
Canthigaster solandri	Spotted Toby	Fiji Orangetail Puffer	
LARGER SPECIES			
Siganus uspi	Uspi Rabbit	Fiji Foxface	
Siganus doliatus	Pencil-Scrawled Rabbit	Blue & Gold Line Rabbit	
Rhinecanthus aculeatus	Picassofish	Humuhumu Trigger	

Figures are presented as average numbers counted on all transects. On surveys of the three resort regions, sample size was small, and site variation high, so no statistical analysis beyond calculation of means was done. Lautoka surveys were more numerous and more evenly matched. Standard Deviation and Standard Error for these sites are shown here.

Table 10: Means, Standard Deviation and Standard Error for Key Species counted on the Lautoka Non-Collection and Collection sites

		Means of 42 transects									
		Non-collection					Collection				
		2-4cm	5-8cm	9-12cm	13-16cm	17-20cm	2-4cm	5-8cm	9-12cm	13-16cm	17-20cm
Anemone fish	Mean	0.02	0.05				0.02	0.05			
	Stdev	0.15	0.22				0.15	0.31			
	St Err	0.02	0.03				0.02	0.05			
Fiji Devil	Mean	11.19	13.90				4.81	11.49			
	Stdev	9.70	9.81				4.02	6.49			
	St Err	1.50	1.51				0.62	1.00			
Yellowhead damsel	Mean	1.93	7.81				0.21	1.98			
	Stdev	3.80	10.20				0.68	4.42			
	St Err	0.59	1.57				0.11	0.68			
Green chromis	Mean	5.55	14.93				0.33	2.00			
	Stdev	8.96	13.24				1.57	5.46			
	St Err	1.38	2.04				0.24	0.84			
Green damsel	Mean	0.26	5.62	2.64			1.98	9.05	1.74		
	Stdev	0.77	12.05	4.18			4.65	11.44	3.74		
	St Err	0.12	1.86	0.64			0.72	1.77	0.58		
Rainfords goby	Mean		0.24	0.17				0.26	0.36		
	Stdev		0.69	0.58				0.70	0.82		
	St Err		0.11	0.09				0.11	0.13		
Fiji Canary	Mean		0.02	1.29				0.02	1.38		
	Stdev		0.15	1.42				0.15	1.34		
	St Err		0.02	0.22				0.02	0.21		
Orangetail Puffer	Mean		0.02	0.17				0.14	0.10		
	Stdev		0.15	0.54				0.47	0.43		
	St Err		0.02	0.08				0.07	0.07		
Orangelina wrasse	Mean		0.79	1.95	0.69			0.19	4.10	0.76	
	Stdev		2.10	1.79	1.20			0.77	4.21	1.16	
	St Err		0.32	0.28	0.19			0.12	0.65	0.18	
Fiji foxface rabbit	Mean				0.07	0.38				0.02	0.14
	Stdev				0.26	0.82				0.15	0.68
	St Err				0.04	0.13				0.02	0.11
Bluelined Rabbit	Mean				0.69	0.62			0.19	0.83	0.26
	Stdev				1.32	1.27			0.86	1.53	0.91
	St Err				0.20	0.20			0.13	0.24	0.14
Humuhumu trigger	Mean			0.02	0.12	0.10				0.02	0.02
	Stdev			0.15	0.33	0.30				0.15	0.15
	St Err			0.02	0.05	0.05				0.02	0.02

Figure 34. Comparison of Key Species shown by Region and Size Class

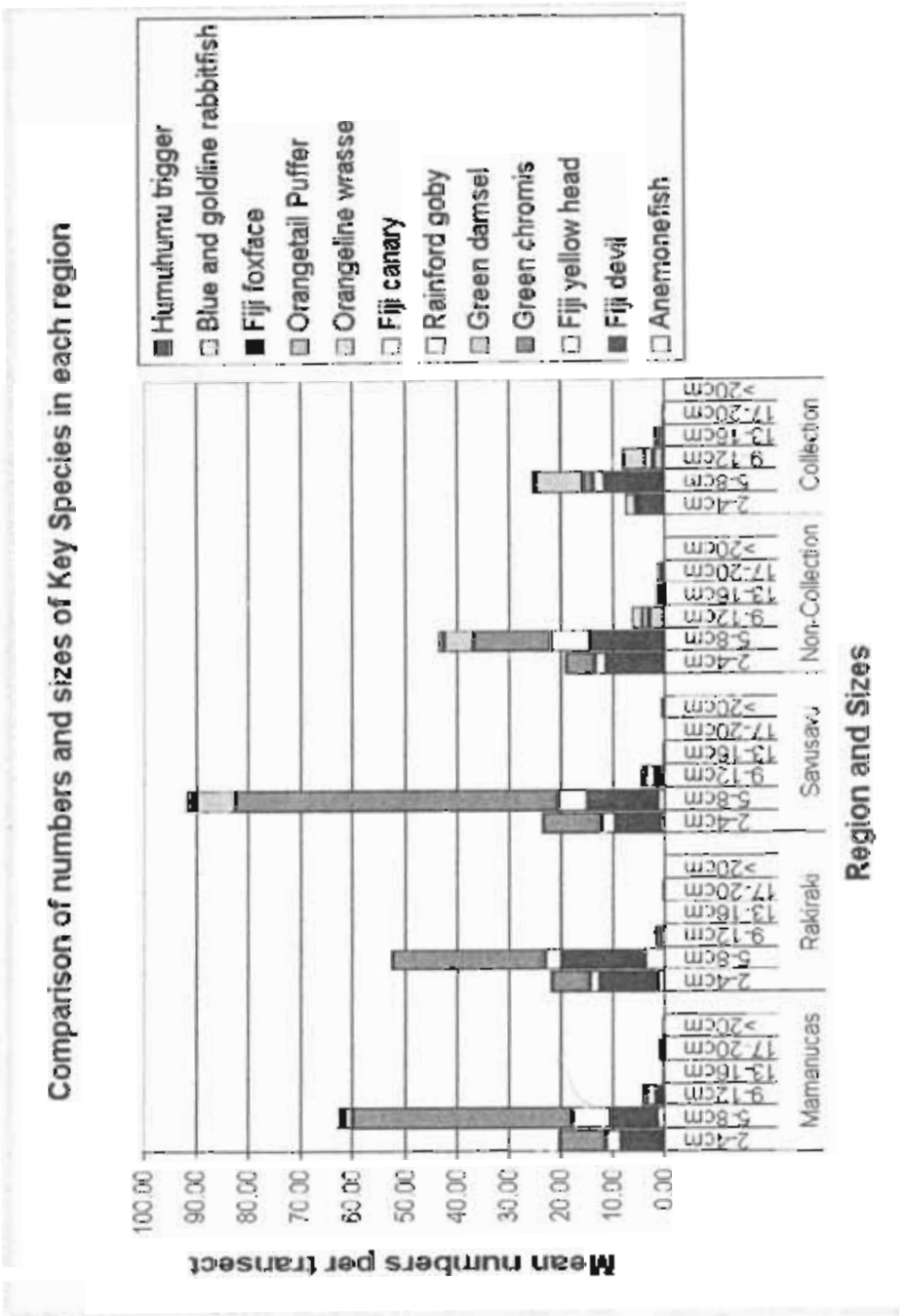
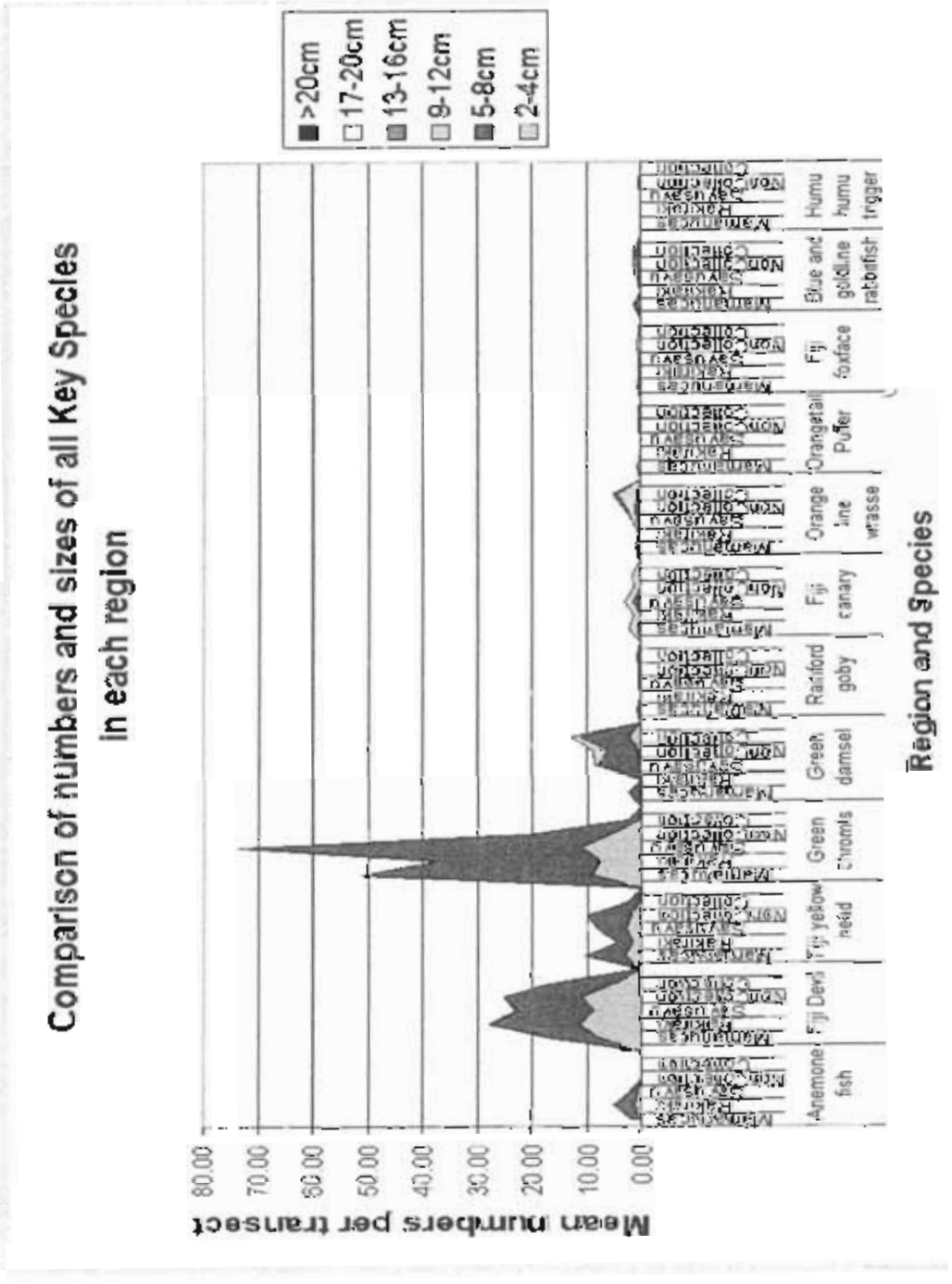


Figure 35 Comparison of Key Species shown by Region and Species



The previous graph demonstrates the relative numbers and sizes of each species. Damselfish dominated the numbers of key species seen during surveys by a factor of 10.

Due to this scale difference, the same information is presented here in three separate bar charts to enable examination of the details of size and abundance of key species in each region.

Note differences in scale between groups –

- Damselfish 0 – 80
- Other small species 0 – 6
- Larger species 0 – 1.4

Figure 36. Damselfish

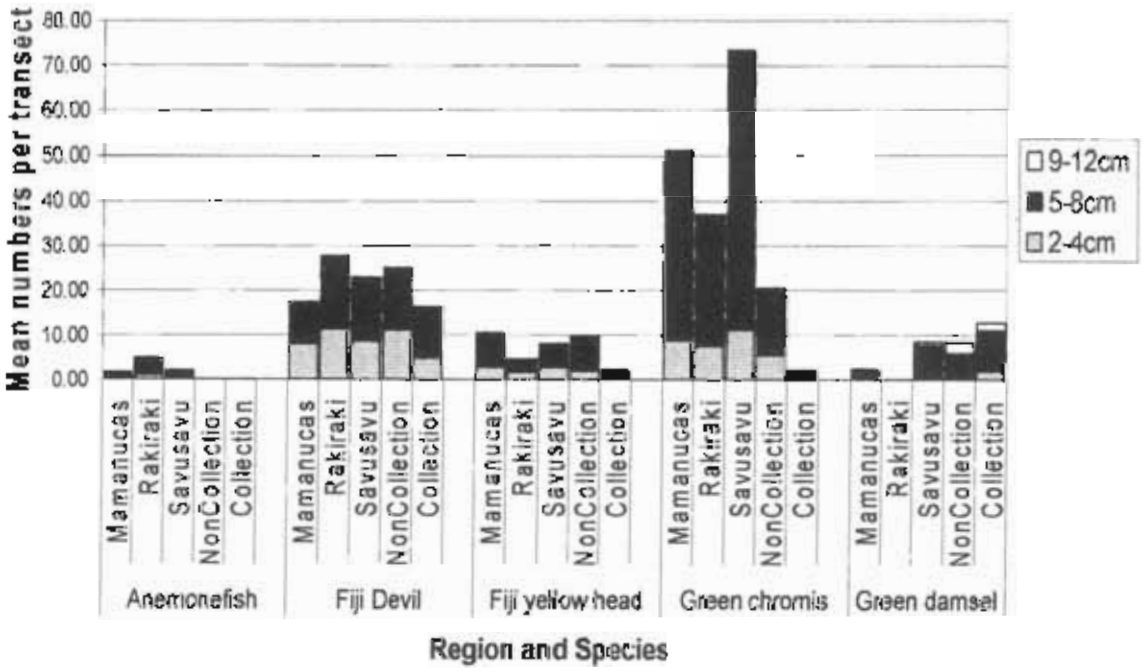


Figure 37: Other small species.

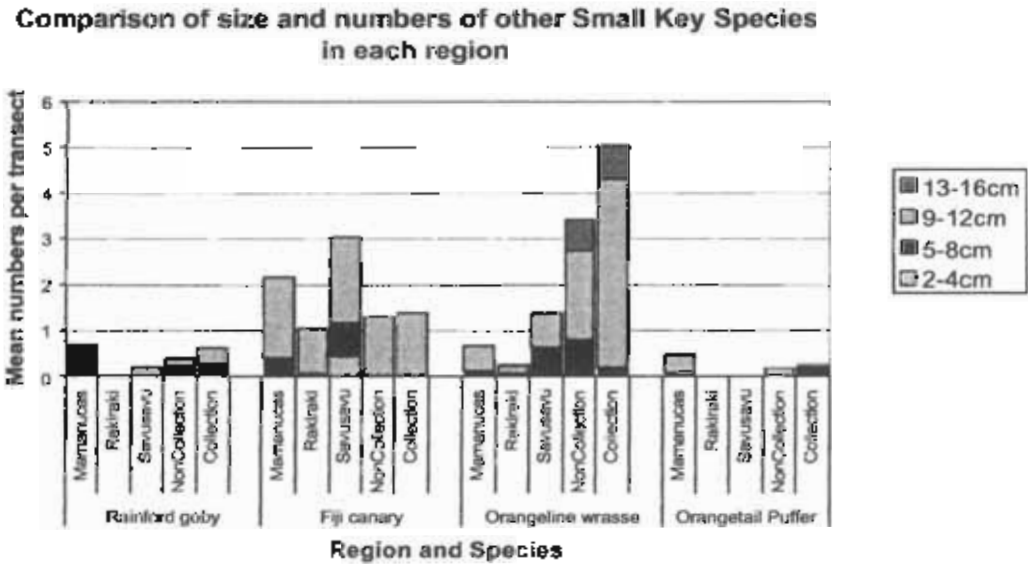
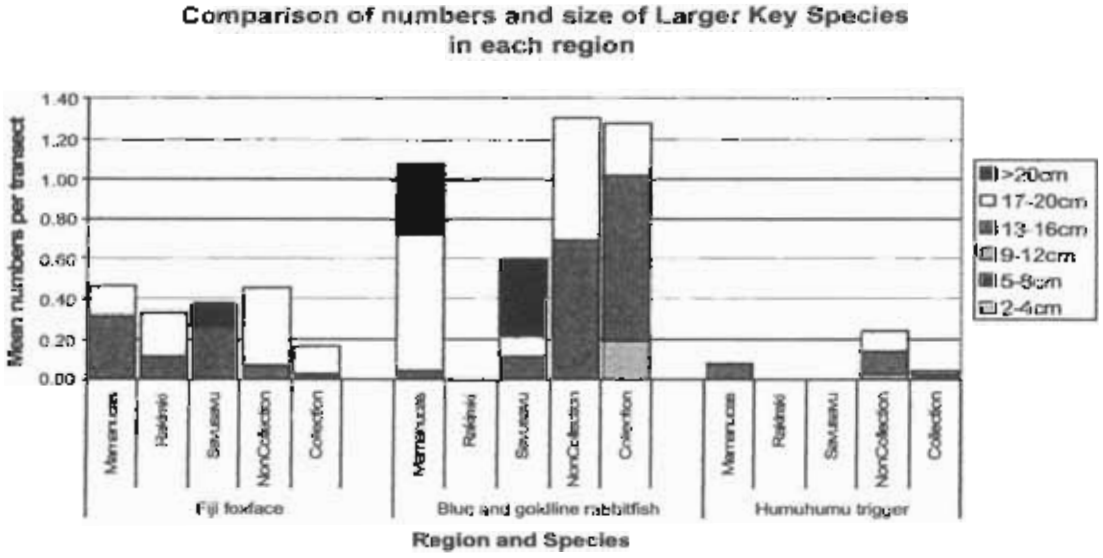


Figure 38 Other larger species



Statistical Analysis

Results: SPSS

The results of the Kolmogorov-Smirnov Test (K-S) showed a non-normality for most of the data. The Analysis of Variance (ANOVA) was quite robust - in other words, the outcome and interpretation are not affected by the non-normality of the data (Underwood, 2001).

The Levene's Test for Homogeneity of Variances also showed no significant result for most of the data. Transformation of the data by square-root and log did not give a significant result. For heterogeneous experiments the recommendation was to do the analysis of variances anyway (Underwood, 2001).

Analysis of variance showed no significant difference between the Collection and Non-collection areas, considering the total abundance, families and key species. Only the Gobies and a few key species (*Chromis viridis and Siganus uspi)* had a $p<0.005$ or $0.05 = 95\%$, indicating a significant difference in the abundance between the two areas. Analysis of Variance also showed no significant difference between the fish size classes for each key species, except the *Chromis viridis*.

This lack of statistical significance is attributed to the small sample size obtained for many of the species under investigation. It has been stated (Hodgson 2001) that for statistical analysis, 200 individuals of each species under survey should be counted.

It should be noted that even in a total of 84 surveys done in the Lautoka area, only 6 species attained the desired sample size of 200 individuals counted. In many other cases, less than 20 fish were recorded. (See following table).

In the light of this sampling difficulty, ANOVA was not considered the best way to analyse this data, and Primer MDS was used.

Table 11. Sample numbers of all fish obtained on non-collection and collection sites. In 84 transects, only the last 6 reached the desired total of 200 individuals.

Scientific name	Non-collection	Collection
Cetoscarus bicolor	1	0
Amphiprion chrysopterus	1	0
Macropharyngodon meleagris	1	0
Epibulus insidiator	1	0
Pomacanthus semicirculatus	1	1
Heniochus varius	0	3
Thalassoma jansenii	3	0
Stethojulis bandanensis	3	0
Arothron nigropunctatus	2	2
Heniochus chrysostomus	4	1
Amblyglyphidodon aureus	5	0
Amphiprion frenatus	2	4
Amblygobius sphynx	5	1
Amblygobius phalaena	1	9
Heniochus acuminatus	12	0
Rhinecanthus aculeatus	10	2
Sphaeramia nematoptera	12	0
Valenciennea sexguttata	0	15
Amblyeleotris steinitzi	11	5
Canthigaster solandri	8	10
Ecsenius bicolor	16	3
Parupeneus barberinoides	14	5
Cheilinus species	11	10
Zebrasoma veliferum	13	12
Siganus uspi	20	7
Halichoeres nebulosus	24	12
Amblygobius rainfordi	17	26
Astrosalarias fuscus	34	14
Ctenochaetus strigosus	33	24
Hemigymnus melapterus	31	36
Amblyglyphidodon leucogaster	68	4
Salarias fasciatus	26	46
Siganus doliatus	55	54
Melacanthus ovalaviensis	55	59
Scolopsis bilineatus	66	59
Pseudocheilinus hexataenia	21	114
Pomacentrus bankanensis	147	39
Pomacentrus caeruleus	311	0 (src) **
Halichoeres melanurus	145	218
Chrysiptera talboti	426	92
Amblyglyphidodon curacao	358	541
Chromis viridis	904	103
Chrysiptera taupou	1064	640
Total	3942	2171

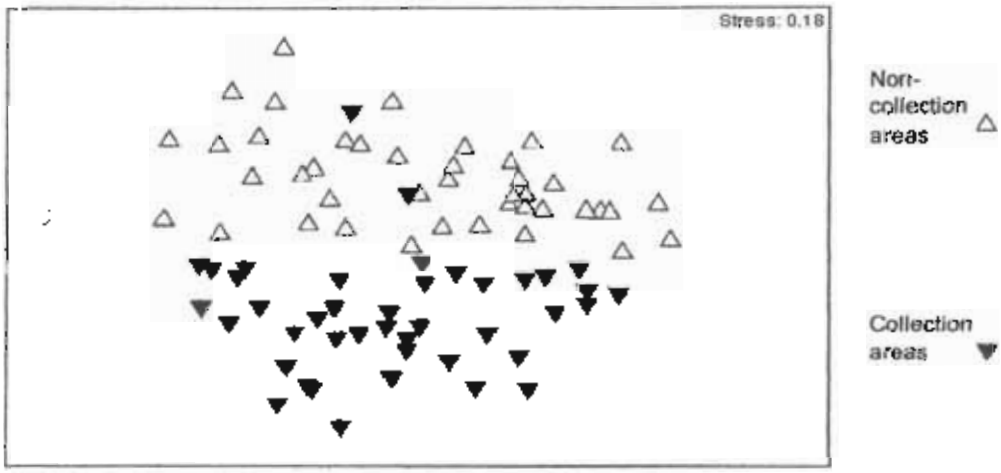
(** Note: The score of 0 for Pomacentrus caeruleus on the Collection sites was a true observation.)

Results: Primer

Each point represents data from one survey. Grey points are from Non-collection sites, Black points from Collection sites.

The "Stress" figure in the top right of each plot indicates the level of disturbance from normal community spread. The higher the stress factor, the more deviation from the expected norm, and the higher the indication that there is a disturbing element present.

Figure 39: MDS plot comparison of total abundance of all species between Collection and Non-collection regions



Each point represents total fish abundance data from one survey.

There is a clear indication that the two types of sites are grouped, rather than randomly mixed. This grouping, and the high stress factor (0.18), show a dissimilarity in total fish abundance between Collection and Non-Collection sites.

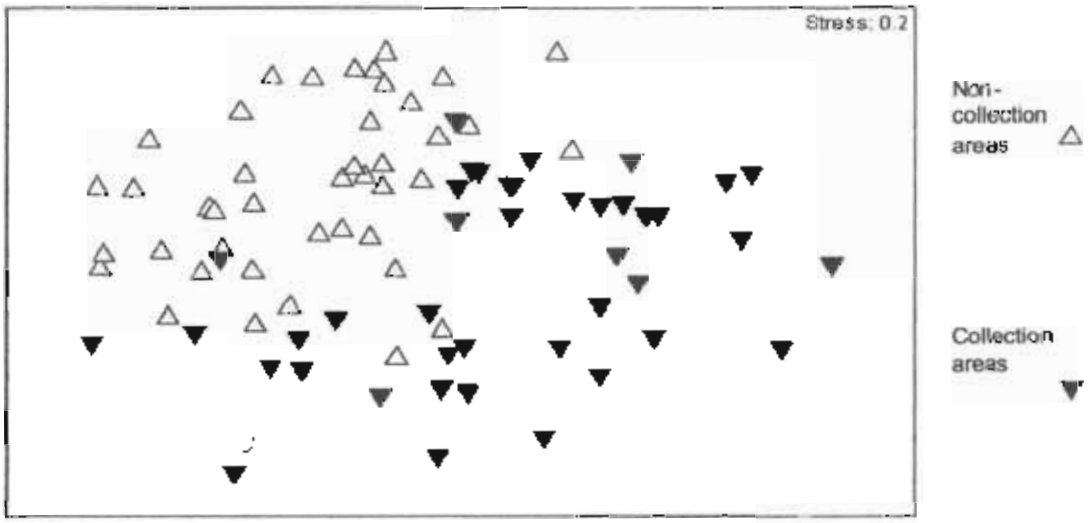
From the same data, the SIMPER procedure provided a list of species that had the highest average dissimilarity between sites.

Table 12: Result of the SIMPER procedure on total fish abundance.

Scientific name	Average abundance non-collection area	Average abundance collection area	Average dissimilarity between collection and non-collection area (%)
Chromis viridis	21.52	2.45	14.27
Chrysiptera taupou	25.33	15.24	11.96
Ambliglyphidodon curacao	8.52	12.88	9.23
Chrysiptera talboti	10.14	2.19	6.84
Pomacentrus caeruleus	5.93	0.00	3.72

These 5 species showed the greatest differences between Collection and Non-collection sites. They are all damselfish.

Figure 40: MDS plot comparison of families between Collection and Non-collection regions.



Each point represents family abundance data from one survey.
There is again an indication that the two types of sites are grouped, rather than randomly mixed. This grouping, and the high stress factor (0.2), show a dissimilarity between Collection and Non-Collection sites for families of fish.

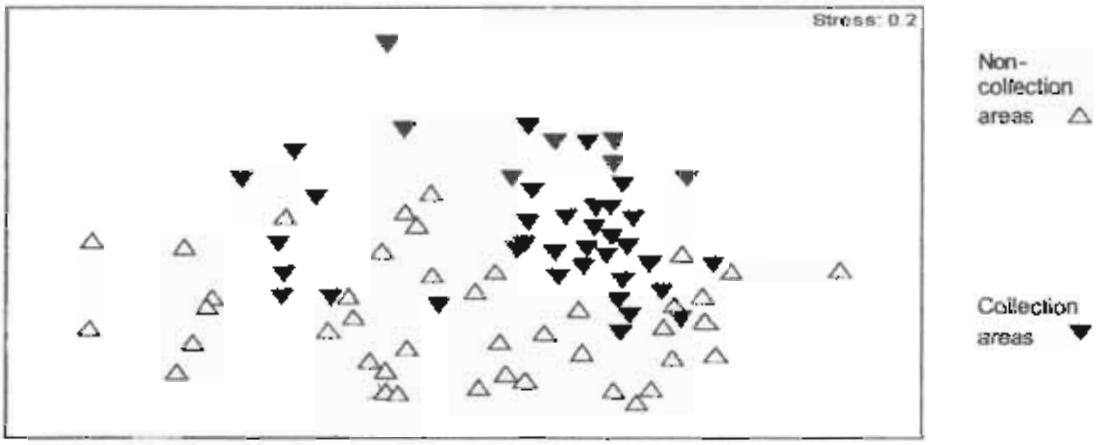
From the same data, the SIMPER procedure provided a list of families that had the highest average dissimilarity between sites.

Table 13: Result of the SIMPER procedure.

Families	Average abundance non-collection area	Average abundance collection area	Average dissimilarity between collection and non-collection area (%)
Damselfishes	78.17	33.79	10.76
Wrasses	5.71	9.29	4.01
Rabbitfishes	1.79	1.45	3.35
Breams	1.57	1.40	3.17
Gobies	0.81	1.33	2.76

In the SIMPER print-out the Damselfishes, Wrasses, Rabbitfishes, Breams and Gobies are mainly responsible for this dissimilarity.

Figure 41: MDS plot of comparison of key species between Collection and Non-collection regions.



Each point represents the abundance of the twelve key species from one survey.

Although there appears to be some grouping of the types of sites, it is not as clearly defined as in the two previous plots. The Collection areas are more tightly grouped than the Non-collection, suggesting that the abundance of the key species was more similar over them than over the Non-collection sites, which show a wider spread of points.

The stress factor remains high (0.2), showing a dissimilarity in key species between Collection and Non-collection sites, and again indicating that there has been a disturbing factor introduced.

From the same data, the Simper procedure provided a list of the particular key species that had the highest average dissimilarity between sites.

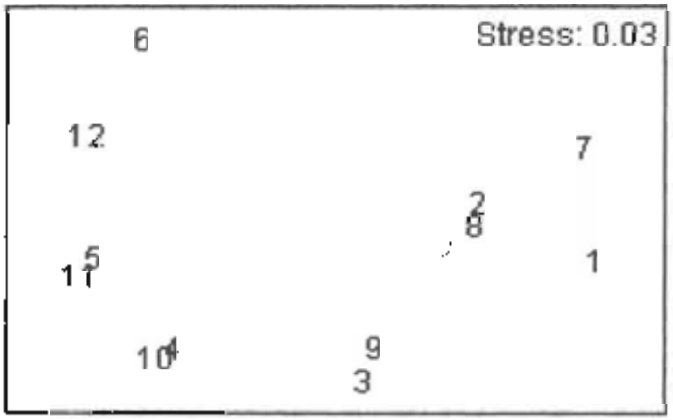
Table 14: Result of the SIMPER procedure.

Scientific name	Average abundance non-collection area	Average abundance collection area	Average dissimilarity between collection and non-collection area (%)
Chrysiptera taupou	25.33	15.24	23.21
Chrysiptera talboti	10.14	2.19	15.11
Halichoeres melanures	3.40	5.19	5.97
Siganus doliatus	1.31	1.29	2.75

The SIMPER procedure shows the particular key species that had the greatest difference between Collection and Non-collection sites. Other species showed very small differences.

Figure 42: Comparison between fish size classes in Non-collection and Collection regions

Numbered points show specific fish size classes (see key). The same fish size classes from both areas are paired (e.g. 1 and 7, 2 and 8, 3 and 9, etc.). The closer the paired points are together, the more similarity there is between the types of sites.



Fish size classes in the Non-collection area

1. 2-4 cm
2. 5-8 cm
3. 9-12cm
4. 13-16cm
5. 17-20cm
6. >20cm

Fish size classes in the Collection area

7. 2-4cm
8. 5-8cm
9. 9-12cm
10. 13-16cm
11. 17-20cm
12. >20cm

Most size classes were similarly abundant on both types of sites.

Only the largest and smallest fish (classes 1 / 7 and 6 / 12) showed any dissimilarity.

For other size classes, the pairs are almost similar with regard to each other.

This signifies a dissimilarity in the smallest and largest groups between the Collection and Non-collection areas.

Fish collection methods

In general, the hand-collection methods being used are the least destructive available. Cyanide or blast fishing is not in use. When hand-collection methods are used by conscientious collectors, very little damage is sustained to the fish or to the surrounding environment. There can be post-collection death in the holding tanks, which is not covered in this text, as it appears to be more due to tank design and length of time before shipping than to collection methods.

Fish collection amounts

As the collectors get paid by the fish brought in, their log is always up to date, and appears to be an accurate and reliable indicator of the fish being removed from the reef. The collections witnessed during survey days reflected the yearly records kept by the collection firm.

Collection was very much dominated by a few species, with very small numbers of others being taken. Of the 78 species on the original survey list, only 48 were seen during surveys, and 51 appeared in the yearly collection records. Fiji endemics and variants are the largest group of species collected, as obviously there is a demand for fish that cannot be found elsewhere. Most of the heavily collected species are from the damsel and goby/blenny families, plus two rabbitfish and one small puffer. Damselfish in particular make up a huge proportion of all fish collected.

Underwater Visual Survey

With adequate training, and in-water identification guides, volunteer surveyors can make accurate evaluations of a limited target species. (Several volunteer programmes already exist in Fiji, including Reef Check, Coral Cay Conservation and Greenforce, also see Darwell at al 1996). In this case, the surveyors had specially designed underwater identification guides to the specific species under survey, and three weeks' training surveying before undertaking data collection. This was found to be adequate to ensure positive identification of a limited number of species.

Reef Check site characterisation:

Substrate definitions used were as per the Reef Check methodology:

- *Recently Killed Coral* = Coral dead for less than 12 months (good skeletal definition still exists)
- *Rock* = Coral dead over 12 months (Lack of skeletal definition although shape may still be clearly visible) or solid substrate over 15cm in size
- *Rubble* = Pieces of rock, or coral dead for over 12 months between 0.5 to 15cm in size.

Therefore, a site with a large proportion of rock or rubble may actually have a large proportion of dead coral which was, for example, killed in the mass bleaching event of 2000.

The benthic (sea bed) cover of most sites was dominated by rock - probably corals that died in the 2000 bleaching. 10-40% of Fiji's corals died during this event (Cumming 2000).

The Savusavu, Mamanuca and Lautoka sites all had around 20% Live Hard Coral, while the Rakiraki sites had an average of 40% of Live Hard Coral. Soft Coral was also more prevalent in the Rakiraki sites, and did not make up a large proportion of the other regions. This reflects the difference between the Rakiraki sites which are in deeper water in the Vatu-i-Ra passage, and other regions where sites are closer to shore and in shallower water. Most branching corals were small re-growing colonies, and so did not make up a high proportion of the sea bed, although they appeared to be in good health.

The Mamanuca sites had the largest proportion of fleshy seaweed, reflecting high nutrient levels in the water. The neighbouring Lautoka sites did not show the same amount of algal cover.

The populations of standard fish species of all regions were dominated by butterflyfish and parrotfish. No sites had significant populations of larger food fish such as snapper or sweetlips. A few small grouper were seen at some sites. All regions therefore appear to be subject to similar fishing pressures, probably subsistence and perhaps small commercial operations.

Within regions there were a few site variations that bear discussion.

Savusavu sites were generally low in the fish populations being recorded (although they are the highest in Aquarium fish species as discussed later). This is probably due to local subsistence fishing.

In Rakiraki sites R42 and R43 were very high in butterflyfish, and this relates well to the high live coral populations of these sites (many butterflyfish species feed on coral polyps).

In the Mamanucas, sites R32 and R33 are reefs off the shore at Beachcomber Island Resort, where a small no-fishing reserve and regular fish feeding may have resulted in the larger amounts of snapper and grouper.

In the Lautoka region, sites R15 and R24 are regular Aquarium Fish Collection sites. R15 has lower overall fish populations than the other sites. As the Reef Check species are not those collected by the Aquarium trade, this may reflect either habitat change, or other fishing practices concentrating on this reef.

The populations of standard invertebrates in all regions were dominated by Diadema (black spiky) Sea Urchins, and Sea Cucumbers (mostly of the species *Holothuria atra* or *H. edulis*, locally known as Loli or Pinkfish and of low commercial value). A few small Giant Clams (*Tridachna species*) were seen. There were very few Crown of Thorns Sea Stars (*Acanthaster planci*) seen in any region.

Savusavu and Rakiraki were lowest in invertebrate populations, which may be due to site type in Rakiraki and fishing pressures in Savusavu.

The Mamanuca sites showed similar low populations except at the two sites near Beachcomber which were in the no-fishing protected area, and so less affected by reef walking and fishing.

In contrast, the Lautoka sites were much richer in invertebrate life, especially Diadema urchins, and had quite a few small *Tridachna* giant clams which were not seen at all in other regions. Also seen, but not recorded, was a surprisingly high populations of *Linkai laevigata* blue sea stars at the same sites.

Overall, the Lautoka sites are not significantly dissimilar to the other sites examined, and are most closely comparable to the Mamanuca sites, with the exception of the higher algal cover seen in the Mamanucas.

Survey of Ornamental Fish Species:

Sample size

The reefs are dominated by a small number of fish species, while others occur quite rarely. This made it difficult to obtain large sample numbers for many species. It has been suggested (Hodgson 2001) that surveys should be done until at least 200 of each species are counted.

The total fish counted during 42 transects on Non-collection sites and 42 surveys on Collection sites in the Lautoka region are shown in Table 11. From this table it can be seen that only 6 of the survey species reached the suggested minimum number of 200 in the survey time available. It would take considerably more surveys to reach the minimum sample size for many of the species under survey.

Out of the 6 species that reached satisfactory numbers for analysis, 5 had been identified as key species for survey; 9 other key species did not reach adequate numbers in over 80 transects. Consequently although these data showed certain trends, the small sample size for many species made the data difficult to analyse with Analysis of Variance, and this limitation of the pilot study is recognised.

Total fish

Comparison of the abundance of ornamental fish species in all regions showed a distinctly smaller amount of fish in the Lautoka Collection zone than in any of the four other regions where fish were not being collected.

This was particularly true of the smaller size groups, which are the most collected. The size class 2-4cm was much less abundant in the Collection sites than any of the others.

The statistical analysis by Primer MDS plot of these data showed a distinct dissimilarity in total fish numbers and size between Lautoka Non-Collection and Collection areas.

Savusavu, the region with the lowest populations of Reef Check standard fish species, had the highest population of small marine ornamental species, indicating that local subsistence fishing does not adversely affect the species which are collected for the Aquarium trade, and may actually help increase their populations by removing predatory animals.

It is suggested that there is an overall deleterious effect of collection on some targeted fish populations and size. Further study and data collection would be required to firmly establish this.

Family groupings

When the fish were grouped into families, it could be clearly seen that the populations were heavily dominated by damselfish. This is also reflected in the species most collected. Many of the species that are collected most by the aquarium fishermen are the most common on the shallow reef.

There was a clear indication that damselfish were less numerous on the Lautoka Collection sites than in any of the other regions where fish were not routinely collected. Figure 4 shows that the Lautoka Non-Collection zones, and the three other regions examined, all had at least twice as many damselfish as the Collection sites.

Other species were less affected by collection: wrasse were actually more plentiful in the Lautoka Collection zone than elsewhere, while other species did not show an appreciable difference. This may be due to lower sample numbers, as previously discussed.

Primer statistical analysis showed a dissimilarity between Lautoka Non-Collection and Collection sites, but not such a distinct one as was seen with the total fish numbers. There is a suggestion that some families may be affected by collection, and the SIMPER procedure identifies the damselfish family as being the most affected.

Key Species

When the 12 Key Species (counting the three Anemonefish species as one group) were examined, similar patterns could be seen.

Figure 34 compares the Key Species by region and size class, and Figure 35 by region and species. These graphs clearly indicate that two of the damselfish species in the size range 2-4 and 5-8cm are most affected by collection.

Other species are hard to evaluate from these graphs because of the dominance of these two species. The following three bar charts, Figures 36, 37 and 38, show the same data at different scales to compensate for the domination of the damsel fish species.

From figure 36, it can be seen that the two damselfish species which appear to be significantly lower in abundance in the Collection zones are the **Green Chromis** *(Chromis viridis)* which is very much less abundant in the Collection zones than elsewhere and the **Fiji Yellowhead Damsel** *(Chrysiptera talboti)*, which is slightly less common in the Collection zones. Table 12, the SIMPER analysis of the total fish data, also identifies these as two of the species which show significant dissimilarities between the Lautoka Collection and Non-Collection sites.

However, as can be seen in Figures 34 and 36, the Green Chromis also varies considerably between regions without Collection pressures, and this may be due to the abundance of suitable habitat. Green Chromis are found mostly within branching corals, and are less common on low relief rubble areas, whereas the Fiji Yellowhead is a rubble-dweller and appears to have suitable habitat at most sites investigated. Both the Lautoka Collection and Non-Collection sites were lower in Green Chromis than the resort sites, and the Collection site was much lower than the Non-Collection, but this may relate to the coral collection practices in the area rather than fish collection pressures.

A further study relating abundance to prevalent coral types would be necessary to establish whether this difference is a direct result of fish collection, or of lack of branching coral habitat in the collection zones.

The other three damselfish species, the Anemonefish *(Amphiprion spp)*, the Green Damsel *(Amblyglyphidodon curacao)*, and the Fiji Devil *(Chrysiptera taupou)*, which is by far the most collected of all the species) do not appear to be significantly different in the Lautoka Collection zone than in any of the Non-Collection regions.

When other Key Species are examined (Figures 37 and 38) the only one that appears to have been lowered by collection is the Fiji Foxface *(Siganus uspi)*, an endemic rabbitfish. The other species do not show any consistent pattern of lower numbers in the Collection zones.

The statistical analysis showed no definite dissimilarity between Lautoka Collection and Non-Collection zones for the Key Species, and the differences between regions becomes less distinct at this level of analysis.

Figure 42 shows that where there are differences between the Lautoka Collection and Non-Collection regions, they are most significant in the size classes 2-4cm and over 20cm.

Methodology

- Reef Check was found to be a simple and effective way of making site characterizations which were comparable between regions.
- The underwater visual survey of ornamental fish species proved to be viable but time consuming. It would probably take at least 6 months of constant surveying the Collection/Non-Collection regions to get statistically significant data for most species under investigation.
- It is indicated that a list of 10-15 key species could be identified for the region. This species list needs to be designed for local applications, as many of the fish most collected are local variants or endemics. Survey of only these species would be less time-consuming, and just as significant.
- Future work towards management plans will require many more surveys to be done, and should concentrate on the key species until samples of at least 200 are reached.
- Student volunteers studying marine sciences were used to perform most of these surveys. They were highly educated but initially inexperienced in underwater survey techniques. They quickly achieved a high level of proficiency, due largely to the development of underwater fish identification guides, which indicates that the use of non-specialists to monitor a concise species list can be extremely useful. It is emphasised that these surveyors spent 3 months doing nothing but this survey, and that data from the first 3 weeks were regarded as practice data and not used.
- Sites that were disparate geographically and physically were still comparable at the level and size of total ornamental fish population and abundance of families. However, individual species cannot be compared between sites very different from each other due to variations in habitat type.
- A survey could be designed to count all ornamental fish to family level and size class that would be useful all over the country, while a more detailed key species survey would be needed to establish the effects of collection inside and bordering collection zones.

Site Character

- There was quite a lot of variation between types of reef surveyed at the resorts, while the Lautoka sites were selected to be more homogenous. Of the four regions, the Mamanuca reefs were much more similar to those in Lautoka area than the reefs at Savusavu or Rakiraki, although the Mamanucas had a much higher amount of algal cover than the Lautoka sites.

Ornamental Fish Survey

- Size and abundance of fish surveyed were seen to be slightly lower in the Lautoka Collection zone than in the Lautoka Non-Collection Zone, and than in any of the other regions examined, and it was smaller fish that were most affected.
- Of the 12 Key Species examined, two species of damselfish showed a direct reduction in numbers in the Collection zones under study, the rest of the Key Species did not appear to be significantly affected.
- The most frequently collected fish are damselfish and a few locally endemic species. Most of the species being collected are locally abundant, and their populations do not appear to be being immediately reduced.
- As local variants and endemics are under much greater collection pressures than fish common elsewhere, these need to be investigated carefully to establish population regeneration times, and would be suitable candidates for quota control.
- Although this work did not specifically study collection of fish from static and limited habitats such as anemones, or habitats where collection entails coral breakage, it is felt that these practices are most likely to be unsustainable, and should probably be avoided where possible. Further work should be done on these species.
- It would make sense to close a Collection zone and establish how long it takes for population levels to return to those found on the Non-Collection sites. This could form the basis of a management plan utilising site rotation to maintain species levels.
- This survey provided a valuable baseline set of figures. Walt Smith International intends to fund future surveys to establish whether populations continue to change or remain stable on the two types of site.
- Sustainable harvesting of marine ornamentals is possible in theory, but requires a considerable input of resources to establish and maintain. Collection firms should to be encouraged to set up population monitoring and management plans for sustainable use of the marine resource. Marine Aquarium Council (MAC) Certification is one way to do this. Walt Smith International is committing resources to assess and monitor the reef populations over a long term period, and is zoning collection areas to reduce the impact of collection. This practice should be continued and promoted.

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