Government of Kiribati

Onotoa

Fish Resource Assessment Survey

Using the Underwater Visual Census Technique

Compiled by Taratau Kirata

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Fisheries Division
Ministry of Natural Resource Development

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The Ag. Chief Fisheries Officer Johnny Kirata in providing a fruitful briefing before the survey team left.

Background Information:

Onotoa has a population of 1918 in the 1995 census. It is located in the southern Kiribati group at Latitudes 1° 47' S to 1° 57' S and Longitudes 175° 31' E to 175° 38' E. The island has a land area of 15.62 sq. Kms, reef area of 21.56-sq. Kms and lagoon area of 75.38 sq. Kms. It has a Fishing Household in 1999 of 402 houses with annual catch in 1998 of 385.50 kg.

Onotoa is one of the four islands namely Butaritari, Nonouti and TabNorth that the Live Reef Trade Fish export took place. The fishing activity only concentrated on two villages Buariki and Temao. This is because the fish cages were located near these villages. The fishermen had difficulty in transporting their catch by using their small canoes from villages that were extreme in distance from the fish cages. If they had motorboats, it would be easier, similar to what is provided by China Star the company that operated on Butaritari, transporting of fish would be easier.

1. Introduction:

On Friday the 26 May 2000, a team of three personnel from the Marine Resource Assessment and Monitoring Unit and two from the Engineering Unit visited Onotoa on the RS Tebenebene; the team spent ten days on the island. This team conducted an Underwater Visual Census (UVC) survey on the island's reef. The team was also despatched to determine the distribution, trend and abundance of groupers on the coastal reef of Onotoa. This would help determine the impact of commercial fishing on populations of groupers, wrasses and emperors on the island. However, since the Live Reef Trade fishing activity stopped operating in February 1999 this survey could be treated as a resource assessment of the forenamed finfish species.

Coral reefs are amazing living creatures with ecosystems that support a diverse marine life. The ecosystem has great importance to the subsistence and artisanal fisheries of Kiribati. In recognition of this, coral reefs have to be well managed not only for its present role but also for its further roles. Appropriate coral reef management plans should be devised and made sure that the strategies are put into practise. The main objectives of these management plans are to conserve reef resources. These resources are susceptible to extinction or drop to dangerous numbers and would not be sustainable. It is believed that humans increase exponentially where as this is not the case with coral reef resources. Much of these living resources are not enduring as was once said, but instead decline in numbers as we interfere or disrupt their habitats because of our own advantage. Recent studies on groupers in the Indian, Caribbean and Palau results shows that they are prone to over-exploitation by extensive fishing activities, in particular if caught or targeted during their spawning aggregation runs. This is also the case in Kiribati (Awira 1999).

2. Materials and methods:

The method used in this survey was out lined in the manual: Manual for assessing Fish Stocks on Pacific Coral Reefs. Edited by Melita Samoilys (ACIAR).
The fish species and their scientific names were cross referenced by using photographs in the book: A practical guide to the identification of the coral reefs fishes of the tropical central pacific and western pacific.

The survey included an informal interview with local fishermen, to collect relevant information on the potential sites for the trade where these fish species would be abundant. The spawning seasons, spawning aggregating grounds, fishing seasons and fishing activities were questions asked. As for ciguatera fish poisoning, because it is a drawback to the industry it was carefully made sure that they do point out the sites that were believed to be toxic
There were six stations with four replicates, two deep and two shallow dives in every station: in total 24 transects. The sites selected at each station were the ones that would give the most representative of the whole coral reef of the island. Five stations were located on the outer reef of the island's barrier reef, the sixth located in the lagoon area of the atoll so a general comparison could be made with the outer reef. There was also a control site located on the reef south of Karururangana Reef. This site is referred to as the control site (Station 3) because fishers do not frequently visit it. The handling

6 Details of control site ...
... sampling sites

fishing methods for reef fishes is not commonly practised within this area because it has been known to harbour dangerous shark's ie. Great white shark, Tiger shark, and Mako shark. If fishing trips were conducted around the area, it is usually trolling for oceanic or pelagic fishes. The trips that are made have to take place early in the morning until just before mid day. This is because locally it is believed that these dangerous sharks are asleep early in the morning until midday when they become awake and start the day's hunting. This was observed to have some truth as Tiger shark, Mako shark and Grey reef shark were observed sleeping during the survey at one of our site. The observation of Tiger shark (*Galeocerdo curvier*) etc. shark sleeping is contrary with outdated scientific literature. It says sharks other than the Nurse shark (*Nebrius concolor*) do not sleep in a motionless manner or else they will suffocate (Johnson Seeto pers comm.) Johnson, 1978, supports this recent discovery. During the survey at this site, it was observed that sharks are also asleep just the way the other finfish do. The sharks are asleep lying on sandy bottom, which were at depths of about 30 metres.

2.1 Fish count and length estimation.

Fish (target species) within the 5m on both sides of the 50m transect were counted. If the species are high in a particular area, the length is averaged for all of these fish species. When encountering individual fishes the length is estimated. The dives had a deep and shallow dive so a wider depth range is covered.

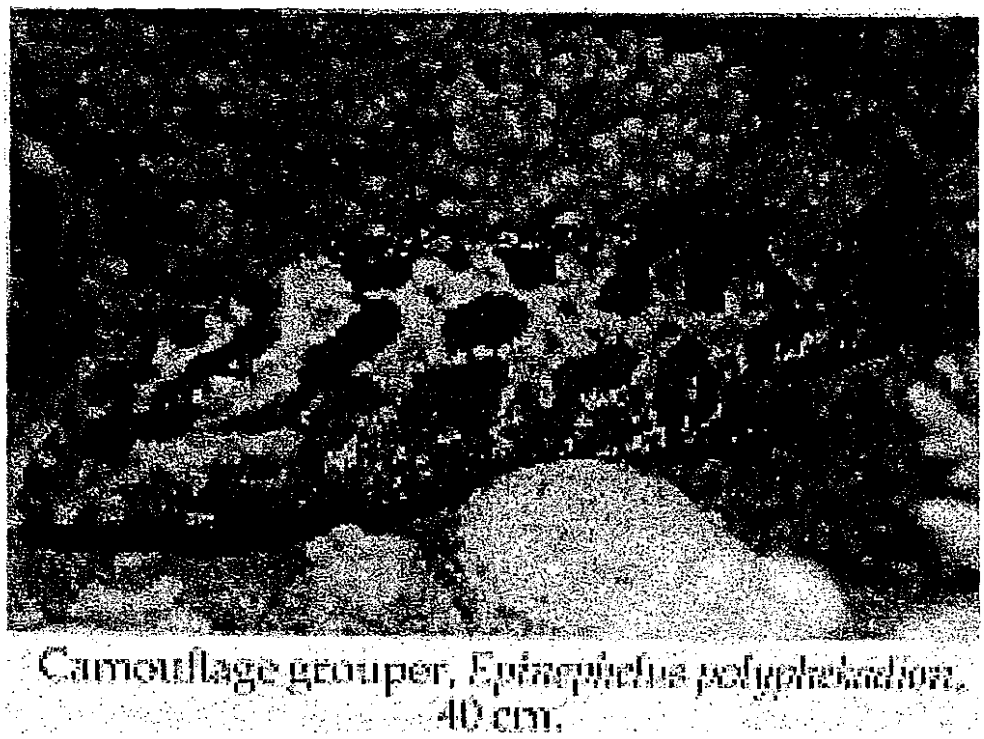
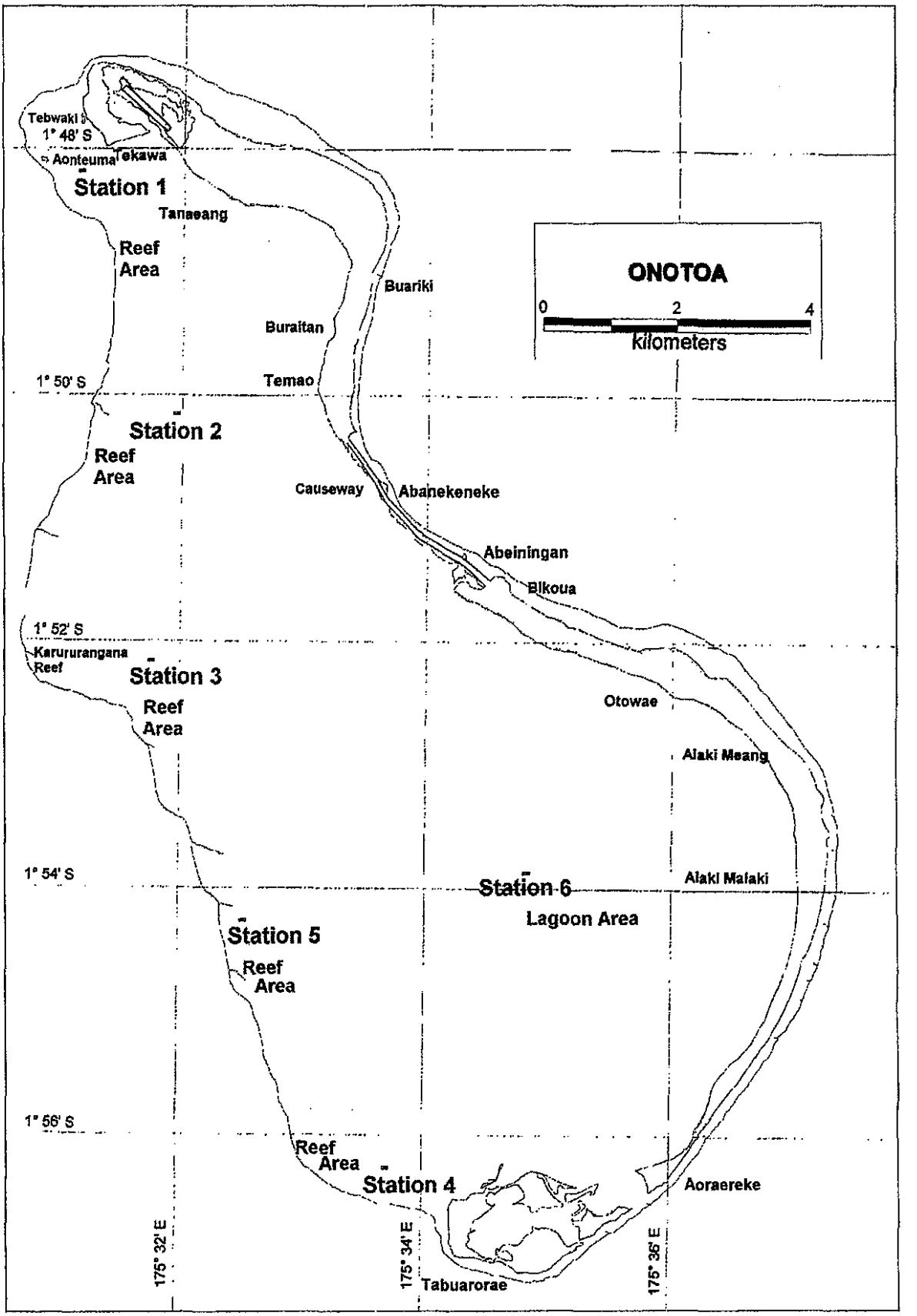


Fig. 2.1 Grouper from the family Serranidae (**Uati**) commonly found on corals reefs of Kiribati.

An example of how easy it is not to be aware of the presence of this grouper as it camouflages with the coral reef. As already mentioned, this plus other factors contributes to underestimating the resource.

3. Survey Stations:



Map of Onotoa permission from Lands Office.

4. Ciguatera Survey:

Algae were collected using SCUBA driving at sites where fish counting were carried out. This algae species have been believed to be the most likely settling medium in the Gilberts' Group: McCarthy and Tebano (1983) of the toxic dinoflagellate: *Gambierdiscus toxicus, Prorocentrum lima, Prorocentrum concave, Ostreopsis lentircularis* and *Ostreopsis siamensis*. Yasumato et al (1977). These algae include green algae *Halimeda* spp. and filamentous red algae species as being evident with ciguatera outbreak cases on other infected outer islands ie Kuria: Kirata, (1999). The results are presented in **Appendix 5.**

4.1 Ciguatera interview:

From the interviews, the fishers were consistent with the fact that they have not heard about ciguatera for a very long time, maybe nearly ten years now. It was true that it was common in the 1980s but it slowly got better, one or two cases in a year until it got all right. Aram Keati the islands FA mentioned that during his 5 years working there he has never had any reported case of ciguatera. *Halimeda* results from previously toxic areas, around site 1 collected during the survey, supported this report on ciguatera. It revealed that very few toxic dinoflagellates believed to cause ciguatera on other islands were present.

5. Results:

In this survey, the target species were quite a few; this is a bargain between the number of species to be counted during the survey and the accuracy of the estimated biomass. This is important as a much more diverse species is being surveyed and so more information is available for the island's fishery resource. Although the results are not extra accurate in comparison with fewer species say ten or slightly more the information is satisfactory for management strategies. It is most applicable where the cost of conducting such surveys is very expensive.

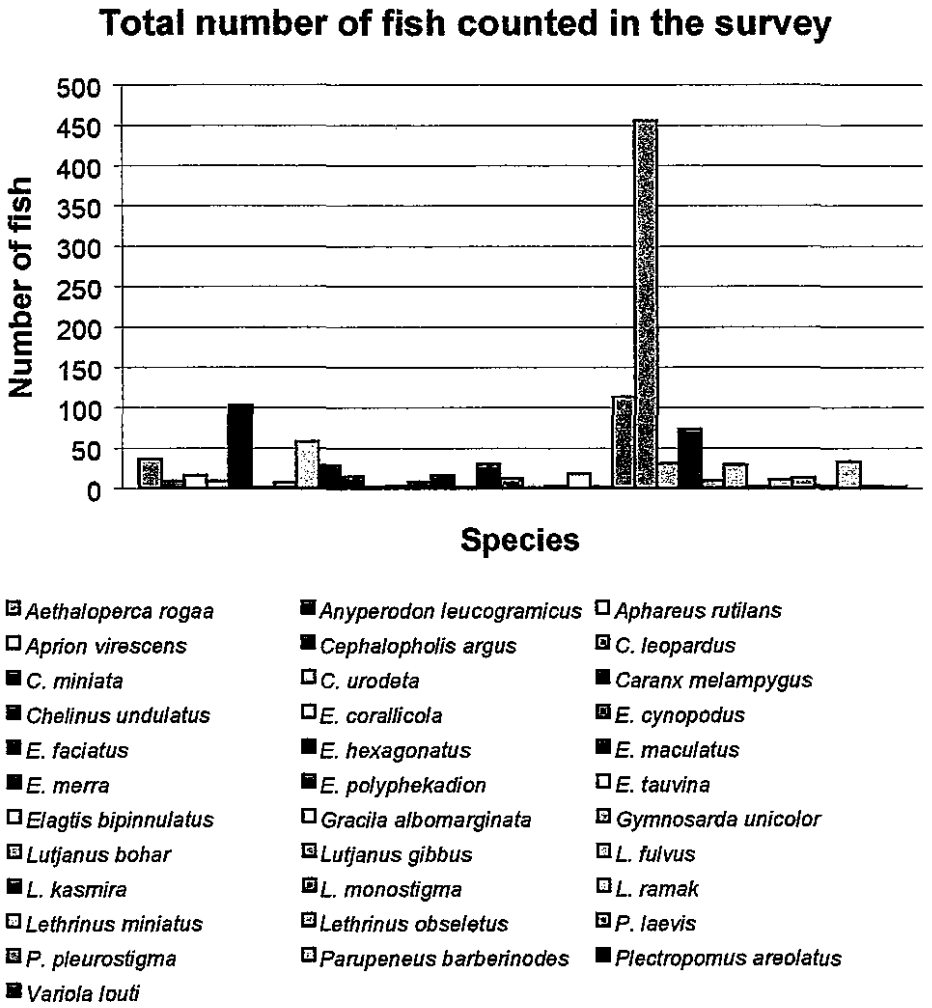
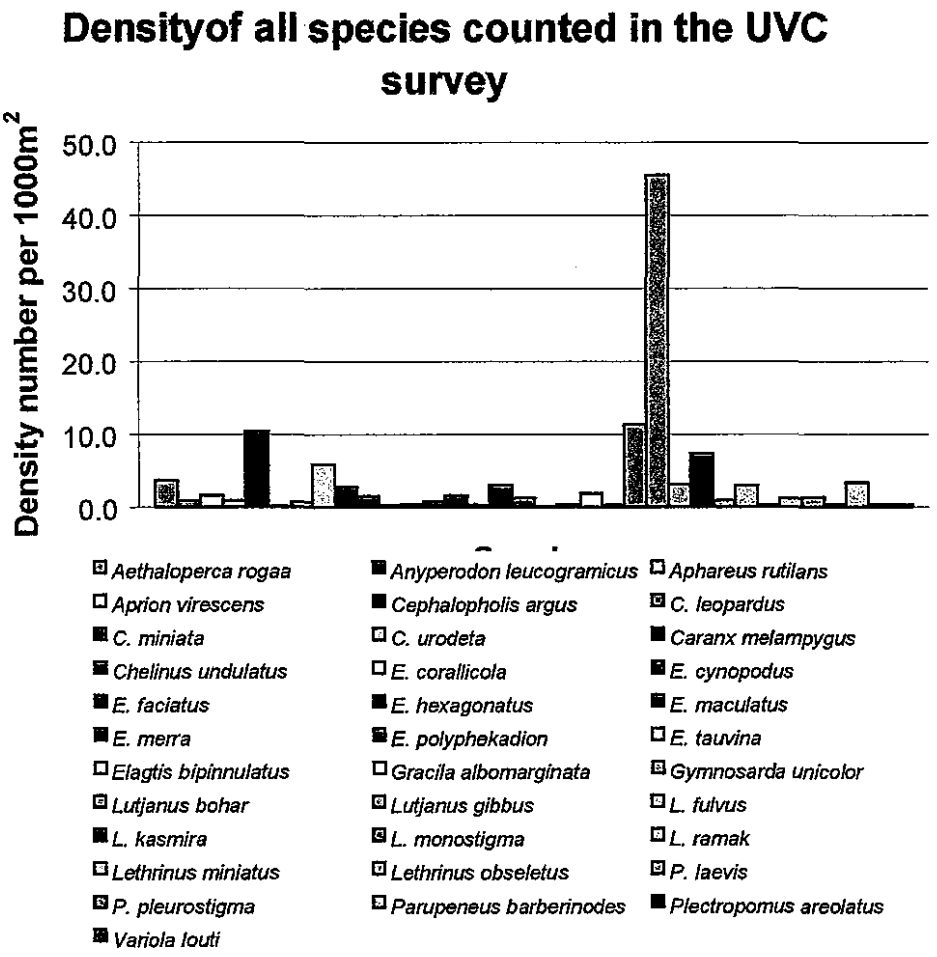


Fig. 5.1 Graph showing number of species and count number.

The graph shows that the highest numbers of target species over 50 are *Lutjanus gibbus, Lutjanus bohar, Cephalopholis argus, Lutjanus kasmira* and *Cephalopholis urodeta. Lutjanus gibbus* had the highest; nevertheless, the fish are juveniles found abundant at site 6 as seen from the survey data.



5.1 Stock Estimation:

It is always a good assumption when overestimating densities; are more accurate as there would be always a portion likely to be missed by divers. Overestimating can be detected or otherwise measured for its accurateness. The stock estimation that were able to be calculated in this report used the weight length relationship available from Melita et al 95 figures from the Fiji-Papua New Guinea survey. This is because the database for length-weight relationship for Kiribati is not yet available. So the estimated stock could be either overestimated or underestimated. However, from local experience this could be underestimated as reef fish in this part of the pacific region seemly grow at fast rates, an area where it could further be researched.

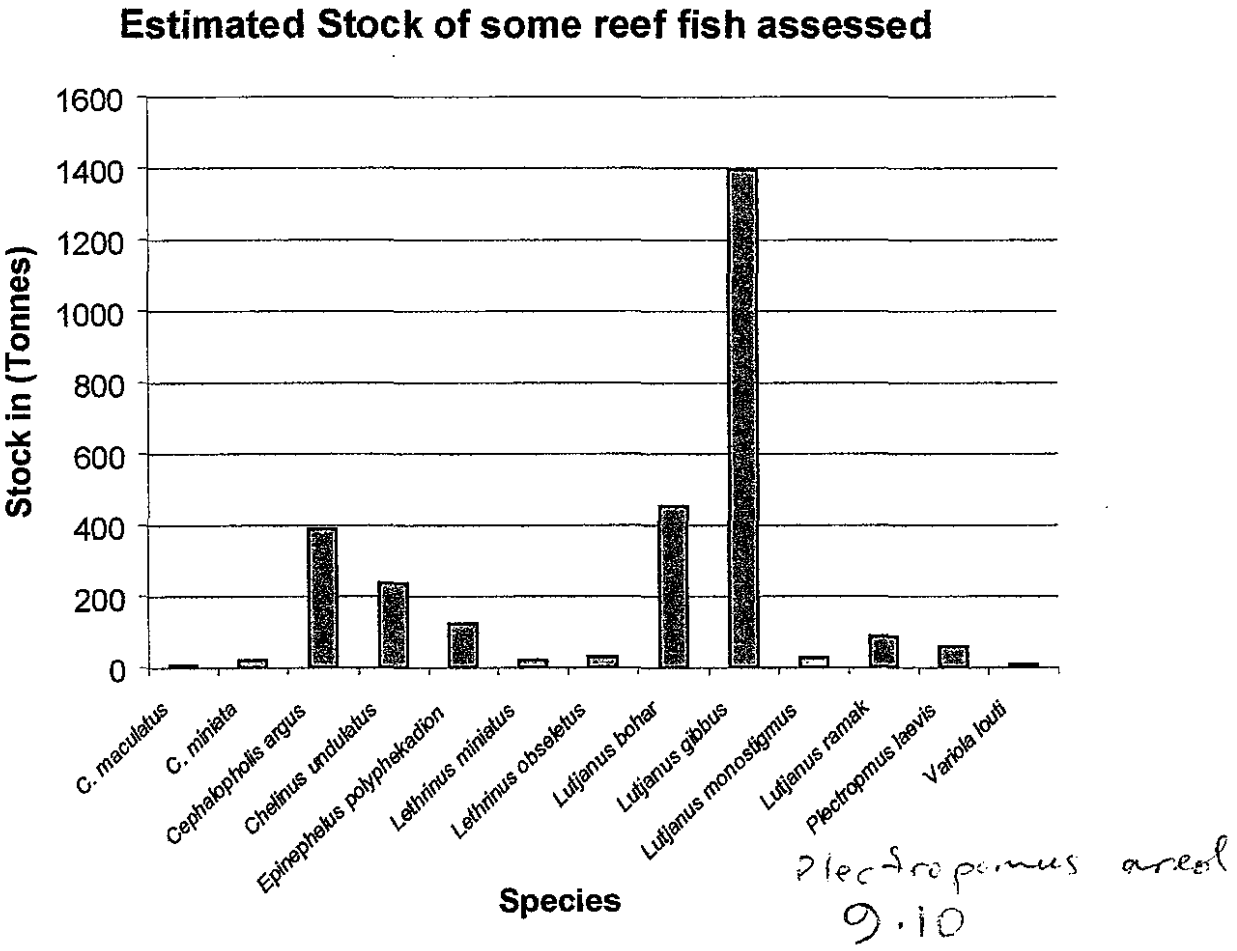


Fig. 5.2 Graph showing estimated stock of some species counted on during the UVC survey.

Mean Species Table

Site number	Average no. of shallow species	Average no. of deep species	Average site species
1	10	12	11
2	10	11	10
3	6	14	10
4	9	10	10
5	8	9	8
6	5	5	5

Table: 5.1 Table showing mean species at surveyed stations

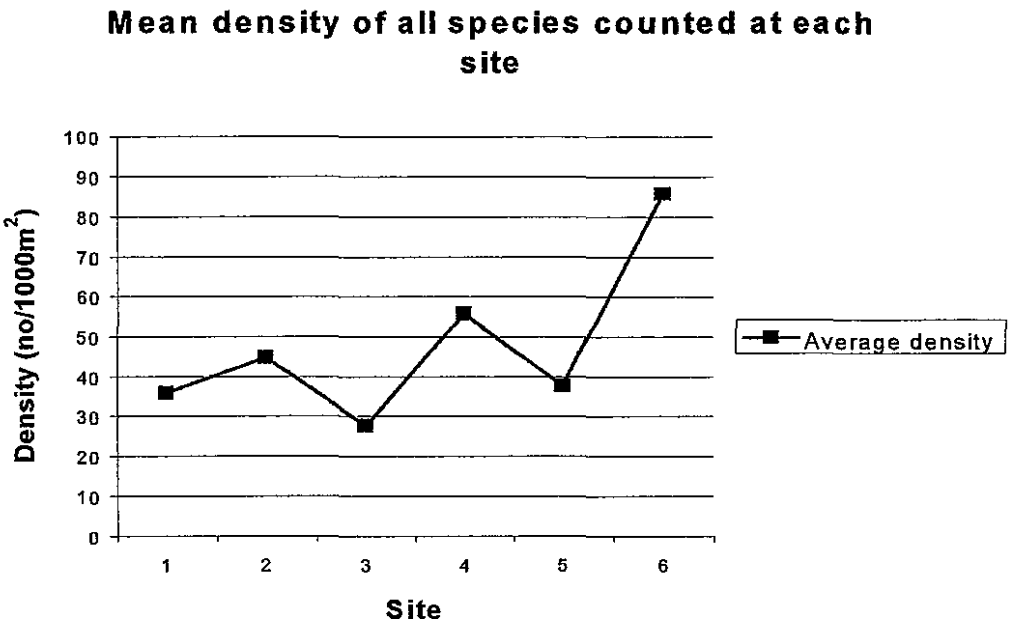
The table shows that the highest species diversity is at site one. However, site 3 had the highest with its deep species of fourteen. This is because site 3 was the site, which was not commonly visited by fishermen, and if visited it is for a limited fishing time (morning til mid-day). Site 6 is located in the lagoon and has the lowest number of our target species. The list of the target species is listed in Appendix 1. The deep dives conducted at each site had most of the target species. This gives us the general picture that the target species were mostly abundant at slightly greater depths 20-27 metres. In comparing, the outer reef with the lagoon area there were also noticeable difference. Results show that there was much higher species diversity on the outer reef than the lagoon area. However, there were higher numbers of juvenile *Lutjanus bohar* as to the outer reef area. The nursery area therefore is located at lagoon habitats.

5.3 Mean Densities of Surveyed Species:

Mean Density Table of sites

Site number	Mean density no/1000m^2 for all species counted
1	36
2	45
3	28
4	56
5	38
6	86

Table: 5.2 Table showing mean densities for each site surveyed.



As can be seen from the graph, site 6 has the highest mean density of the six sites surveyed. This site was located in the lagoon. For the biomass, it is different.

6. Discussion:

The general view of the Onotoa survey is a little different from the other UVC surveys that have been conducted on the other islands. This is because the survey observed a more diverse serranidae family group on the outer reef slope. Slightly higher abundance of *Chelinus undulatus* (humphead wrasse) and grouper species *Plectropomus areolatus* and *Cephalopholis argus* were found. This could be inferred from good fisheries management to their reef resource. A good example here is Tamana and Arorae, the southern most tips of the southern group where fishing are not done on Sundays and certain types of fishing methods and equipment are not permitted. Although this may not be commonly and strictly practised nowadays it is good management ie. Mechanised motorboats not used in any fishery. Another reason may be owing to biased data collection compared to the other surveys. However, errors due to biased data collection were minimised by having the same counters throughout the whole of the six stations surveyed. The counters were also the same ones who conducted similar surveys on the other islands. Therefore, it would be accurate to neglect this assumption.

The Live Reef Trade Fish that began trading these finfish species ceased operation not that it had no more of these grouper species. As it seems by the survey the resource; the numbers were decreasing and so they voluntarily decrease their fishing pressure. Maybe the local people were worried, as it had become apparent to them that the numbers were diminishing dramatically. An accurate or reliable estimate of the maximum sustainable yield of the resource has to be worked out if the fishery has to be properly managed. It is not possible to obtain such information from the available data, however it is most probable to be much less than the estimated biomass.

The salinity of Onotoa Island is quite consistent throughout the outer reef at the sites that were surveyed. It falls between 35 ‰ and 35.5 ‰. The lagoon area was slightly higher 36 ‰. This is usual considering the fact that it is relatively small in size 75.38 sq. km. These salinity measures are normal thought, when compared with the open sea salinity of 37 ‰. Enclosed area for example could fluctuate around this open sea salinity depending on the amount of precipitation within that region.

6.1 Lagoon area:

Lagoon areas have a coral reef patchy characteristic with many areas having sandy seabeds, but does not harbour the target species. These areas are known not to be good places for all species of the family Serranidae, in particular the Labridae which are not found there and are one of the highly priced fish species in this fish trade. Fish count results from this area confirms the assumption. The survey was extensively carried out on the reef area, it is believed to have a diverse Serranidae species and high abundance - thus proved from other previous surveys (Awira, 1999). Results that were conducted on the lagoon area shows that it was true however red snappers (*Lutjanus gibbus*) juveniles were present in high numbers. This suggests that the site could be the rearing place for this species.

7. Conclusion:

Although from the survey it is quite clear that the island's reef resource is not in a dangerous situation, it can not be taken for granted the still abundant of these reef resources are of no problem. One can say that we Pacific Islanders are fortunate for these given marine resources that are being sought at very high prices from many countries, in these instance the Chinese people and that we should make us of it. We should also bear in mind our role as the individual owners of these resources to properly manage and conserve them not only for economic benefits but also for our future generations. Hear it could be concluded that more work is to be done in order to be sure of the dynamic standing of these reef fish. However, this survey presents itself an overall view that the kind of operation that took place there could be beneficial to both the locals and the country from foreign earings getting into the country. This is because there are no indisputable damages to the marine resource or the marine environment in general. As already mentioned it could only be possible if proper management plans are put in place and the locals are well aware of them. Onotoa has the potential of the Live Reef Fish Trade returning. This is because ciguatera survey conducted on the island it reveals that the dinoflagellates proved to be responsible for ciguatera are present but not exceedingly abundant, plus the additional fact that there are no reported cases of fish poisoning there. This was the principal reason for the withdrawal of the companies (China Star Enterprises and Marine Product Kiribati) which ventured this business here in Kiribati.

Recommendations:

The survey forms a preliminary baseline for coral reef fish (studied here are the most important local species). Although the survey is preliminary, it is very important as it acts as a snapshot view of Onotoa's marine resource assessment. It has been recommended previously from similar surveys like this, that a Marine Protected Area is most relevant to be set-up in areas where these groupers aggregate. Here it is also very much supported and hoped that it is enacted in the very near future, as the longer the delay is the seriousness the problem becomes.

The duration of the last commercial fishing activity to the time of the survey is over one year. After this survey, it could be concluded that if there were an impact to these resources, the effect might have recovered. It is recommended that if the Live Reef Fish Trade were to be operative again, it would be good management if operative for 1 year and ceased the next year and start again the following year. The years where it is closed the operators could move to an island where it was closed the previous year. This then could be operational all throughout the year and each year taking alternate years within islands. Although it has been proved that fish stocks would not completely recover after one year, at least it will lessen the fishing pressure as seen during the survey.

While it is common practise by the locals to only go out fishing early in the morning until midday, is likewise good management strategy. This is because fish are harvested at specified periods ie. Morning to midday and so they are landed in restricted quantities. This should be encouraged, but for a different perspective. These sharks have a very good purpose for them to be present ecologically in their natural habitat; and be achieved by not harvesting it unrestrainable ie. For the shark fin trade. This is a multimillion-dollar industry, however it is considered unsustainable at this stage.

It is recommended that since the Live Reef Fish industry is new it is appropriate that it is monitored carefully. Since the industry has ceased operating now, this would be practicable in future, as the industry would return if proper arrangements were made and their current suppliers elsewhere are depleted. Careful monitoring of these coral reef fish resources would help prevent the resources from being depleted at an early stage, as the resources are vulnerable to overexploitation. Beside that, the local population is dependent on for their subsistence fishery.

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Appendix 1

Site **1A** Lat: S 1° 49.217' Depth:11.5m
Date:29/5/00 Long: E 175° 30.033' Vis:10m
Coral cover: 35% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
Aethaloperca rogaa	3	27	6	NA
Cephalopholis argus	7	29	14	5.70
Epinephelus polyphekadion	3	37	6	5.91
E. merra	4	16	8	NA
Lutjanus bohar	1	15	2	0.12
L. gibbus	11	26	22	8.43
L. fulvus	4	25	8	2.81
L. monostigmus	1	29	2	0.96
Plectropomus laevis	2	33	4	1.74
Chelinus undulatus	1	73	2	12.34

Site **1B** Lat: S 1° 49.833' Depth:18-20m
Date:30/5/00 Long: E 175° 30.950' Vis:12m
Coral cover: 30% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
Aethaloperca rogaa	1	23	2	NA
Aprion virescens	1	43	2	NA
Cephalopholis argus	3	33	6	3.61
C. leopardus	1	13	2	NA
C. urodeta	4	17	8	NA
Epinephelus polyphekadion	1	36	2	1.82
Gracila albomarginata	2	23	4	NA
Lutjanus bohar	3	41	6	7.77
L. gibbus	7	35	14	13.08

Site **1C** Lat: S 1°49.983' Depth:20-22m
Date:30/5/00 Long: E 175° 30.833' Vis:15m
Coral cover: 40% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
Anyperodon leucogrammicus	1	20	2	0.23
Aprion virescens	1	25	2	NA
Cephalopholis argus	5	25	10	2.60
C. urodeta	7	19	14	NA
Chelinus undulatus	1	45	2	2.75
Epinephelus faciatus	5	14	10	NA
E. hexagonatus	3	21	6	NA
E. maculatus	1	18	2	0.22
E. merra	1	20	2	NA
Gracila albomarginata	5	17	10	NA
Lutjanus bohar	3	18	6	0.65
L. gibbus	25	20	50	8.73
L. fulvus	4	25	8	2.80
P. areolatus	2	28	4	1.05
Parupeneus pleurostigma	3	16	6	NA
Variola louti	1	12	2	0.13

Site **1D** Lat: S 1° 49.017' Depth:
Date:30/6/00 Long: E 175° 30.779' Vis: 15m
Coral cover: 40% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
Aethaloperca rogaa	2	23	4	NA
Caranx melamygus	2	36	4	NA
Cephalopholis argus	6	18	12	1.16
C. urodeta	7	12	14	NA
Epinephelus fasciatus	1	14	2	NA
Gracila albomarginata	1	25	2	NA
Lutjanus bohar	3	14	6	0.30
Parupeneus barberinoides	2	14	4	NA
Plectropomus laevis	1	27	2	0.47

Site **2A** Lat:S 1° 51.412' Depth:23m
Date:31/5/00 Long:E 175° 30.911' Vis:20m
Coral cover: 80% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
Aethaloperca rogaa	11	22	22	NA
Aprion virescens	1	45	2	NA
Cephalopholis argus	10	29	20	8.14
C. urodeta	2	17	4	NA
Epinephelus hexagonatus	2	17	4	NA
E. merra	1	13	2	NA
Gracila albomarginata	1	27	2	NA
Lutjanus bohar	8	20	16	2.37
L. fulvus	1	28	2	0.98
L. kasmira	18	15	36	4.55
L. ramak	1	18	2	0.20
Parupeneus barberinodes	22	22	44	NA

Site **2B** Lat: S 1° 51.595 Depth:25m
Date:31/5/00 Long: E 175° 30.834' Vis:20m
Coral cover: 75% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
A. rogaa	1	18	2	NA
Chephalopholis argus	8	33	16	9.63
Caranx melampygus	1	30	2	NA
Chelinus undulatus	3	45	3	4.13
L. bohar	30	48	60	124.98
L. gibbus	5	25	10	3.41
L. kasmira	3	14	6	0.36
L. monostigmus	4	27	8	3.14
Plectropomus areolatus	1	80	2	13.30

Site **2C** Lat: S 1° 51.865 Depth: 8m
Date:31/5/00 Long: E 175° 30.828' Vis: 20m
Coral cover: 75% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
Anyperodon leucogrammicus	1	21	2	0.34
C. argus	4	19	8	0.91
C. melampygus	2	23	2	NA
C. urodeta	1	18	2	NA
E. hexagonatus	1	17	2	NA
E. merra	2	15	4	NA
L. bohar	2	25	4	1.16
Lethrinus miniatus	1	52	2	5.84

Site **2D** Lat: S 1° 52.023' Depth:9m
Date:31/5/00 Long:E 175° 30.802' Vis:20m
Coral cover: 40% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
A. leucogrammicus	1	33	2	1.34
A. rogaa	3	22	6	NA
C. argus	3	30	6	2.71
C. undulatus	1	42	2	2.22
C. urodeta	3	12	6	NA
E. hexagonatus	1	22	1	NA
E. merra	2	18	4	NA
Lethrinus ramak	11	23	22	4.72
L. gibbus	4	32	8	5.71
P. barberinoides	2	27	4	NA

Site **3A** Lat: S 1°52.549' Depth:25m
Date:1/6/00 Long:E 175° 30.377' Vis:23m
Coral cover: 50% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
Anyperodon leucogrammicus	5	29	10	4.55
Aethaloperca rogaa	2	22	4	NA
Cephalopholis argus	1	26	2	0.59
C. melampygus	1	26	2	NA
C. undulatus	3	41	6	6.19
C. urodeta	4	16	8	NA
E. corallicola	1	29	2	NA
E. hexagonatus	2	27	4	NA
E. miniatus	3	17	6	NA
E. polyphekadion	1	50	2	4.75
Gracila albomarginata	2	19	4	NA
L. bohar	5	22	10	1.98
L. gibbus	3	33	6	4.70
L. kasmira	9	15	18	1.33
L. ramak	2	27	4	1.40
P. barberinoides	1	18	2	NA

Site **3B** Lat: S 1° 53.067' Depth: 22 - 35m
Date:1/6/00 Long:E 175° 30.215' Vis:25m
Coral cover: 10 - 20% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
Aethaloperca rogaa	3	29	6	NA
Apiron virescens	1	22	2	NA
Caranx melampygus	1	27	2	NA
Cephalopholis urodeta	2	14	4	NA
Epinephelus corallicola	1	20	2	NA
E. cynopodus	2	32	4	NA
E. hexagonatus	3	31	6	NA
E. miniatus	2	23	4	NA
E. polyphekadion	1	25	2	0.63
Gymnosarda unicolor	2	27	4	NA
Plectropomus areolatus	1	62	2	6.07
Variola louti	1	38	2	4.25

Site **3C** Lat: S 1° 53.243' Depth:11 -12.5m
Date:1/6/00 Long: E 175° 30.405' Vis:25m
Coral cover: 30% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
A. rogaa	2	31	4	NA
A. virescens	2	26	4	NA
Cephalopholis argus	6	26	12	3.51
Chelinus undulatus	4	67	8	37.82
C. urodeta	2	11	4	NA
Epinephelus miniatus	2	22	4	NA
Gracila albomarginata	2	17	4	NA
L.utjanus bohar	3	20	6	0.89
Lethrinus miniatus	1	21	2	0.41
V.louti	2	26	4	2.69

Sea: Calm

Site **3D** Lat: S 1° 53.316' Depth:7m
Date: 1/6/00 Long:E 175° 30.656' Vis:25m
Coral cover: 40% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
C. argus	10	40	20	21.52
C. urodeta	11	14	22	NA

Site **4A** Lat: S 1° 57. 350' Depth:22m
Date:2/6/00 Long: E 175° 33. 923' Vis:25m
Coral cover: 20% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
Aprion virescens	1	40	2	NA
C. argus	2	33	4	2.41
E. cynopodus	1	36	2	NA
E. polyphekadion	2	53	4	11.27
G. albomarginata	1	31	2	NA
L. fulvus	3	20	6	1.09
L. gibbus	22	21	44	8.90

cont. for site **4A**

L. kasmira	4	19	8	1.19
L. monostigmus	4	26	8	2.82
L. ramak	20	15	40	2.34
P. barberinodes	1	22	2	NA
P. laevis	3	41	6	5.10

Site **4B** Lat: S 1° 57. 083' Depth:18m
Date: 2/6/00 Long: E 175° 33. 905' Vis: 25m
Coral cover: 40% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
C. argus	1	24	2	0.46
C. urodeta	1	14	2	NA
E. hexagonatus	1	18	2	NA
E. polyphekadion	4	46	8	14.90
G. albomarginata	3	21	6	NA
L. fulvus	6	20	12	2.19
L. kasmira	29	15	58	4.44
P. laevis	7	40	14	11.03

Site:**4C** Lat: S 1° 56. 744' Depth:11 - 12m
Date:2/6/00 Long: E 175° 33.894' Vis: 25m
Coral cover: 20% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
A. rogaa	1	30	2	NA
C. argus	3	24	6	1.38
C. urodeta	3	16	6	NA
E. merra	5	17	10	NA
L. bohar	4	17	8	0.73
L. fulvus	6	18	12	1.60
L. gibbus	15	26	30	10.93
L. ramak	1	20	2	0.28

Site:**4D** Lat: S 1° 56.427' Depth:15m
Date:2/6/00 Long: E 175° 33.767' Vis: 25m
Coral cover: 30% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
A. rogaa	2	32	4	NA
Aphareus rutilans	1	35	2	NA
C. argus	2	33	4	2.41
C. urodeta	4	33	8	NA
G. albomarginata	1	35	2	NA
L. fulvus	2	21	4	0.84
L. gibbus	49	22	98	22.78
L. kasmira	6	14	12	0.78
L. ramak	3	18	6	0.61
P. barberinoides	5	16	10	NA

Site **5A** Lat: S 1° 54.331' Depth:23m
Date:3/6/00 Long: E 175° 32.779' Vis: 25m
Coral cover: 50% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
A. rogaa	1	31	2	NA
A. virescens	1	45	2	NA
C. argus	8	25	16	4.16
E. merra	1	13	2	NA
E. tauvina	1	39	2	NA
Elagatis bipinnulatus	1	42	2	NA
L. bohar	3	31	6	3.34
L. fulvus	1	23	2	0.55
L. gibbus	2	38	4	4.78
Lethrinus ramak	1	31	2	1.06
V. louti	1	41	2	5.36

Site **5B** Lat: S 1° 54.498' Depth:18m
Date:3/6/00 Long: E 175° 32.606' Vis: 25m
Coral cover: 30% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
A. rogaa	2	33	4	NA
A. virescens	1	43	2	NA
C. argus	6	33	12	7.22
E. hexagonatus	1	39	2	NA
E. maculatus	1	31	2	1.07
L. bohar	2	19	4	0.51

Site **5C** Lat: S 1° 54.176' Depth:11m
Date:3/6/00 Long: E 175° 32.374' Vis: 25m
Coral cover: 35% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
A. rutilans	14	29	28	NA
C. argus	5	25	10	2.60
C. urodeta	6	17	12	NA
E. fascitus	1	22	2	NA
P. barberinodes	1	35	2	NA
P. bifasciatus	1	22	2	NA

Site **5D** Lat: S 1° 53.799' Depth: 10 - 11m
Date:3/6/00 Long: E 175° 32.083' Vis: 25m
Coral cover: 80% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
A. rogaa	1	27	2	NA
Aphareus rutilans	1	38	2	NA
C. melampygus	20	61	40	NA
C. argus	13	32	26	14.25
C. undulatus	2	61	4	14.14
C. urodeta	1	20	2	NA
L. bohar	50	59	100	388.37

Cont. site **5D**

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
L. gibbus	1	36	2	2.03
P. barberinoides	1	34	2	NA
P. bifasciatus	1	22	2	NA

Site **6A** Lat: S 1° 53.867' Depth:15m Temp:29°C
Date:5/6/00 Long: E 175° 34.750' Vis:<5m
Coral cover:35% Area covered: 500m^2

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
C. melampygus	3	52	6	NA
E. merra	1	20	2	NA
L. gibbus	267	13	534	25.66
L. ramak	2	15	4	0.23
L. monostigmus	2	17	4	0.42

Site **6B** Lat: S 1° 54.017' Depth:13m Temp:29°C
Date:5/6/00 Long: E 175° 34.850' Vis:<5m
Coral cover:15% Area covered: 500m^2
Salinity: 35 parts per thousand

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
E. hexagonatus	2	19	4	NA
E. merra	5	15	10	NA
L. fulvus	4	14	8	0.51
L. gibbus	33	13	66	3.17

Site **6C** Lat: S 1° 54.015' Depth:8m Temp:29.5 °C
Date:5/6/00 Long: E 175° 34.100' Vis:<5m
Coral cover:5 - 7% Area covered: 500m^2
Salinity: 35 parts per thousand

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
E. merra	5	12	10	NA
L. gibbus	5	17	10	1.02
L. kasmira	2	14	4	0.24
L. ramak	1	10	2	0.03

Site **6D** Lat: S 1° 54.900' Depth:7m Temp:29.5 °C
Date:5/6/00 Long: E 175° 31.183' Vis:<5m
Coral cover:15 % Area covered: 500m^2
Salinity: 35 parts per thousand

Scientific Name	Number	Ave. length	Density no/1000m^2	Biomass kg/1000m^2
E. hexagonatus	2	12	4	NA
E. merra	3	12	6	NA
L. gibbus	11	16	22	1.99
P. barberinus	3	15	6	NA

Appendix 2. Local names

Scientific name	Local name
Aethaloperca rogaa	Utun te Kuau
Anyperodon leucogramicus	Utun te Kuau
Aphareus rutilans	Bukinrin
Aprion virescens	Awai
Cephalopholis argus	Nimanang
C. leopardus	Utun te Kuau
Caranx melampygus	Rereba
C. urodeta	Nimako
Chelinus undulatus	Karon
Epinephelus corallicola	Utun te Kuau
E. cynopodus	Baru
E. faciatus	Utun te Kuau
E. hexagonatus	Utun te Kuau
E. maculatus	Kuaubanni
E. merra	Kuau
E. miniata	Utun te Kuau
E. polyphekadion	Uati
E. tauvina	Utun te Kuau
Elagatis bipinnulatus	Kama
Gracila albomarginata	Utun te Kuau
Gymnosarda unicolor	Buari
Lutjanus bohar	Ingo
L. gibbus	Ikanibong
L. fulvus	Bawe
L. kasmira	Takabe
L. monostigma	Bawaeina
L. ramak	Okaoka
Lethrinus obsoletus	OKaoKa
Lethrinus miniatus	Ikamatoa
Plectropomus areolatus	Utun te Kuau
P. laevis	Utun te Kuau
Parupeneus barberinodes	Utun te Maebo
P. pleurostigma	Utun te Maebo
Variola louti	Bukitakeiau (Utun te Kuau)

Number of Target species counted in the survey:

L. gibbus	455
Lutjanus bohar	113
Cephalopholis argus	103
L. kasmira	73
C. urodeta	58
Aethaloperca rogaa	36
Parupeneus barberinodes	33
L. fulvus	31
E. merra	30
L. ramak	29
Caranx melampygus	28
Gracila albomarginata	18
Aphareus rutilans	16
E. hexagonatus	16
Chelinus undulatus	15
P. laevis	13
E. polyphekadion	12
L. obseletus	11
Anyperodon leucogramicus	9
Aprion virescens	9
L. monostigma	9
E. faciatus	8
E. miniata	7
E. cynopodus	3
Elagtis bipinnulatus	3
Plectropomus areolatus	3
P. pleurostigma	3
Epinephelus corallicola	2
E. maculatus	2
Gymnosarda unicolor	2
Lethrinus miniatus	2
Variola louti	2
C. leopardus	1
E. tauvina	1

Appendix 3

	Site 1				Site 2				Site 3				Site 4				Site 5				Site 6				Total
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	
Aethaloperca rogaa	3	1		2	11	1		3	2	3	2				1	2	1	2		2					36
Anyperodon leucogramicus			1		1		1	1	5																9
Aphareus rutilans																1			14	1					16
Aprion virescens		1	1		1					1	2		1				1	1							9
Cephalopholis argus	7	3	5	6	10	8	4	3	1		6	10	2	1	3	2	8	6	5	13					103
C. leopardus		1																							1
C. melampygus						1	2		1	1										20	3				28
C. urodeta		4	7	7	2		1	3	4	2	2	11		1	3	4			6	1					58
Chelinus undulatus	1		1			3		1	3		4									2					15
Epinephelus corallicola									1	1															2
E. cynopodus										2			1												3
E. faciatus			5	1															1	1					8
E. hexagonatus			3		2		1	1	2	3				1				1						2	16
E. maculatus			1															1							2
E. merra	4		1		1		2	2							5		1				1	5	5	3	30
E. miniata									3	2	2														7
E. polyphekadion	3	1							1	1			2	4											12
E. tauvina																	1								1
Elagtis bipinnulatus																	1		1	1					3
Gracila albomarginata		2	5	1	1				2		2		1	3		1									18
Gymnosarda unicolor										2															2
Lutjanus bohar	1	3	3	1	8	30	2		5		3				4		1	2		50					113
L. fulvus	4				1								3	6	6	2	1					4	4		31
L. kasmira					18	3			9	1			4	29	1	6							2		73
L. monostigma	1					4							4												9
L. ramak					1			11	2	1			20			3	1						1		40
L. gibbus	11	7	25			5		4	3				22		15	49	1			1	267	33	1	11	455
Lethrinus miniatus							1				1														2
Plectropomus areolatus			2			1																			3
P. laevis	2			1									3	7											13
P. pleurostigma			3																						3
Parupeneus barberinodes				2	22			2	1				1						1	1				3	33
Variola louti			1														1								2
Total for each replicate	37	23	64	21	79	56	14	31	45	20	24	21	64	52	38	70	18	13	28	93	271	42	13	19	1156
Total number of fish counted				**145**				**180**				**110**				**224**				**152**				**345**	
Mean no of fish counted				**36.3**				**45.0**				**27.5**				**56.0**				**38.0**				**86.3**	

Appendix 4. Total Area Covered in the survey:

	Site 1				Site 2				Site 3				Site 4				Site 5				Site 6				Total
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	
Area covered	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	**12000** m^2 = 12.0sq.km

Notes:

1. Outer reef dive area covered was 10 sq. km (46.38% of the total reef area which is 21sq.km)
2. Lagoon dive area covered was 2 sq. km (2.65% of the total lagoon area which 72.38sq. Km).
3. A total of 12 sq. Km of area covered in the dive.

Appendix 5 Dinoflagellate Count of Different Algae

Date	Site	Wt (g)	Species algae	Spp. Dinoflagellate	C1	C2	C3	Ave.
29/5/00	1A	650	*Galaxaura* spp.	*Gambierdiscus toxicus*	0	0	0	0
				Ostreopsis lenticularis	1	0	0	0
				O.siamensis	1	0	0	0
				Prorocentrum lima	8	12	4	8
				P.concavum	2	1	0	1
30/5/00	1C	600	*Halimeda* spp.	*Gambierdiscus toxicus*	0	0	0	0
				Ostreopsis lenticularis	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	1	0	0	0.333
				P.concavum	0	0	0	0
30/5/00	1D	450	*Halimeda* spp.	*Gambierdiscus toxicus*	1	3	1	1.6
				Ostreopsis lenticularis	0	0	0	0
				O.siamensis	0	0	2	0.667
				Prorocentrum lima	0	0	3	1
				P.concavum	2	6	7	5
31/5/00	2A	400	*Halimeda* spp.	*Gambierdiscus toxicus*	0	0	0	0
				Ostreopsis lenticularis	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	0	1	0	0.333
				P.concavum	0	0	0	0
31/5/00	2B	400	N/*Halimeda*	*Gambierdiscus toxicus*	0	0	0	0
				Ostreopsis lenticularis	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	3	0	0	1
				P.concavum	0	0	0	0
31/5/00	2C	400	N/*Halimeda*	*Gambierdiscus toxicus*	0	0	0	0
				Ostreopsis lenticularis	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	0	1	1	0.6667
				P.concavum	0	0	0	0
31/5/00	2D	400	N/*Halimeda*	*Gambierdiscus toxicus*	0	0	1	0.333
				Ostreopsis lenticularis	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	0	0	1	0.333
				P.concavum	1	0	0	0.333

Date	Site	Wt (g)	Species algae	Spp. Dinoflagellate	C1	C2	C3	Ave.
6/01/00	3C	250	N/*Halimeda*	*Gambierdiscus toxicus*	0	0	0	0
				Ostreopsis lenticularis	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	0	0	0	0
				P.concavum	0	0	0	0
6/02/00	4A	100	N/*Halimeda*	*Gambierdiscus toxicus*	0	0	2	0.667
				Ostreopsis lenticularis	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	0	1	0	0.333
				P.concavum	0	0	1	0.333
6/02/00	4A	500	Filamentous	*Gambierdiscus toxicus*	0	0	1	0.333
			Halimeda	*Ostreopsis lenticularis*	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	0	0	0	0
				P.concavum	0	0	0	0
6/02/00	4B	300	Filamentous	*Gambierdiscus toxicus*	0	1	0	0.333
			Halimeda	*Ostreopsis lenticularis*	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	0	0	0	0
				P.concavum	1	0	0	0.333
6/02/00	4B	490	N/*Halimeda*	*Gambierdiscus toxicus*	0	1	1	0.667
				Ostreopsis lenticularis	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	0	0	0	0
				P.concavum	0	2	0	0.667
6/02/00	4C	300	N/*Halimeda*	*Gambierdiscus toxicus*	0	0	0	0
				Ostreopsis lenticularis	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	0	0	0	0
				P.concavum	1	0	0	0.333
6/02/00	4C	300	Filamentous	*Gambierdiscus toxicus*	0	0	1	0.333
			Halimeda	*Ostreopsis lenticularis*	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	2	0	0	0.667
				P.concavum	0	0	0	0
6/02/00	4D	300	N/*Halimeda*	*Gambierdiscus toxicus*	0	0	0	0
				Ostreopsis lenticularis	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	0	0	0	0
				P.concavum	1	0	0	0.333

Date	Site	Wt (g)	Species algae	Spp. Dinoflagellate	C1	C2	C3	Ave.
6/02/00	4D	225	Filamentous	*Gambierdiscus toxicus*	0	1	0	0.333
			Halimeda	*Ostreopsis lenticularis*	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	1	0	0	0.333
				P.concavum	0	0	0	0
6/03/00	5A	300	N/*Halimeda*	*Gambierdiscus toxicus*	0	0	0	0
				Ostreopsis lenticularis	0	0	0	0
				O.siamensis	0	1	2	1
				Prorocentrum lima	0	1	0	0.333
				P.concavum	0	0	1	0.333
6/03/00	5A	200	Filamentous	*Gambierdiscus toxicus*	0	0	0	0
			Halimeda	*Ostreopsis lenticularis*	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	1	0	0	0.333
				P.concavum	0	0	0	0
6/03/00	5B	180	N/*Halimeda*	*Gambierdiscus toxicus*	0	0	0	0
				Ostreopsis lenticularis	0	0	0	0
				O.siamensis	0	0	1	0.333
				Prorocentrum lima	0	2	1	1
				P.concavum	0	0	0	0
6/03/00	5B	100	Filamentous	*Gambierdiscus toxicus*	0	0	0	0
			Halimeda	*Ostreopsis lenticularis*	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	0	0	0	0
				P.concavum	0	0	0	0
6/03/00	5D	150	Filamentous	*Gambierdiscus toxicus*	0	0	0	0
			Halimeda	*Ostreopsis lenticularis*	0	0	0	0
				O.siamensis	0	0	0	0
				Prorocentrum lima	0	1	0	0.333
				P.concavum	1	0	0	0.333

Notes.

Area covered in survey is very high 18% is reasonable

2-5 Kg/1000m^2 density for non-fished area is not applicable.