The United Nations University
FISHERIES TRAINING PROGRAMME

P.O. Box 1390, Skulagata 4
120 Reykjavik, Iceland

Final Project 2005

AN APPRAISAL OF ARTISANAL AND SUBSISTENCE FISHERIES MONITORING IN THE FIJI ISLANDS

Warsha Singh
Department of Fisheries
Ministry of Fisheries & Forestry
Fiji Islands
ws_24_fj@yahoo.com, wsingh@mff.net

Supervisors
Dr. Einar Hjörleifsson, einarhj@hafro.is
Dr. Lorna Taylor, lorna@hafro.is

ABSTRACT

In view of strengthening the current artisanal and subsistence catch sampling an appraisal of the two monitoring programmes of Fiji Fisheries Department was carried out. An overview of the artisanal fishery sampling programme and its related strengths, weaknesses, opportunities and threats revealed a major limitation of the Department not having the capacity to follow the current sampling regime. Thus statistical analysis was carried out to determine if this sampling regime organised by month, which necessitates sampling each day from Monday to Saturday was warranted. Survey data from markets Lautoka, Ba, and Nadi for the period April to August 2005 were analysed as an indicator. Analysis of the variations in total landed catch weights (by performing analysis of variance) and associated species composition (by applying hierarchical cluster analysis) between the markets, days and months, indicated that the sampling strategy is not warranted. Sampling can be organised by season since there were no significant variations in catch landings and species composition between the months April and –August, which indicate a season. Saturday and Monday are exceptional days in the fishery. Saturday has the highest landed catch and species composition and Monday the lowest. Tuesday, Wednesday and Thursday are similar with a slight increase in landed catch and species assemblage as the week progresses. Equal sampling for all days is not warranted but sampling on Saturdays and Mondays is important. Subsistence catch (tonnes) for the seven communities namely Namatakula, Komave, Taqage, Lami, Suvavou, Vugalei and Nasavusavu tikina were evaluated using the socio-economic household survey data. Bootstrapping was done to obtain a standard deviation for the estimated catch and a CV for the sampling. Some suggestions were provided for strengthening the survey as this is an on-going programme and in future the samples can be utilised in estimating the total subsistence catch for Fiji.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Fisheries in Fiji

Fiji is an archipelagic state situated in the South Pacific region comprising 322 islands with a total land area of 18,272 km^2, a coastline of 5,010 km and a surrounding EEZ of about 1.3 million km^2 (Oliver *et. al* 2005). The group includes two large high islands, several medium-sized high islands, numerous small islands and atolls. Most of the islands are surrounded by fringing and barrier coral reefs occupying an area of 10,000 km^2. Much of Fiji's coastal waters occur off the main islands of Viti Levu and Vanua Levu and the islands of the Mamanuca and Yasawa groups. The population of Fiji as of December 2004 was 840,201 (Fiji Islands Bureau of Statistics (FIBOS) 2006).

Figure 1: Map of Fiji (FVB 2005).

Most Fijians are maritime people with ongoing fishing traditions (Veitayaki 2005) and fisheries have been part of their lives throughout their history. The industry makes up a significant part of the economy of the nation, contributing approximately US$54 million towards the annual revenue earnings or approximately 2.5% of the Gross Domestic Product and employs a labour force of approximately 1% (ADB 2005). The Department of Fisheries under the Ministry of Fisheries and Forestry is mandated to ensure sustainable development and management of the fisheries resources. The sector is sub-divided into industrial fishery (offshore and inshore), artisanal and subsistence fishery. The total catch from the Fiji waters was estimated at 44,000 tonnes in 2004 (DOF 2004). The offshore industry is dominated by tuna export, which is the major revenue earner of the sector and comprises 27% of the catch. The inshore industrial sector, which constitutes 5% of the total catch deals with export of reef fish (live and frozen), beche-de-mer, trochus, and marine aquarium fishery[1]. The remaining 68% is domestic catch by the local fishermen and collectively forms the artisanal and

[1] The marine aquarium fishery comprises of corals, coral base rocks, aquarium fish and ornamental invertebrates.

subsistence fishery. These sectors are a complex group of diverse fisheries systems and community organisations exploiting a great number of species. The fishery is highly flexible, adjusting modes of production, distribution and social organisation to changing social and economic circumstances (FAO 1999). The per capita comsuption of fish for the country is higher than the world average and stands at 44 kg per year (ADB 2005).

1.2 Resources exploited by artisanal and subsistence sectors

In the Pacific Islands region the definition of artisanal and subsistence fishery is usually vague. Every Pacific Islander is a potential fisherman, and the distinction between commercial, recreational and subsistence fishing is blurred, making it difficult to estimate production and effort in these separate sectors (Dalzell and Adams 1996). However, in this study artisanal fishery refers to small-scale commercial fishing, where the catch is retailed in the local market and the subsistence fishery refers to the catch for home consumption, which is not caught specifically for marketing. Both artisanal and subsistence fishers target the same fishing grounds. The fishing zones exploited by the local fishermen are the inland river systems, mangroves, estuaries, lagoons, shorelines, fore-reef, reef-flats and outer slopes of the reefs to abyssal depths and deeper waters beyond the outer reef.

The archipelagic and inshore waters of Fiji are rich in marine biodiversity. "Research has recorded close to 300 species of corals, 475 species of molluscs and almost 2000 fish species, although the actual number of species of fish and coral is likely to be much greater. Fiji's coral reefs are thus rightfully recognised as being world class in ecological significance" (WWF 2003). The most commonly targeted food finfish are *Lethrinidae, Serranidae, Carangidae, Lutjanidae, Mugilidae, Scrombidae, Scaridae and Sphyraenidae.* Various invertebrates are also fished on a large scale. These mainly include bivalve molluscs, sea cucumbers, crustaceans mainly crab, prawns, lobsters and octopus.

The coastal waters (shorelines, lagoons and reefs) are the most heavily targeted for food supply. Among the finfish, the reef fisheries comprise approximately 60% of the artisanal catch. The estuaries, lagoons and river fisheries collectively form 20% of the catch and the remaining 20% is comprised of pelagic species as apparent from the time-series of artisanal catch statistics available from the Fisheries Department of Fiji.

Artisanal and subsistence fishers practice similar fishing methods, predominantly hand-lining and gill-netting. Other methods of fishing include the use of fish traps (both traditional and modern traps), fish fences, seine nets, hand nets, fish drives, spears, use of poisonous plants (such as *derris* roots), line trawling, reef gleaning and skin diving (especially for collecting shellfish and sea cucumber). Women carry out reef gleaning during low tide. Women gleaning on reefs target shellfish, sea cucumbers, octopus, worms, sea urchins, eels and small fish. Men dominate hand-line fishing, skin diving and spear fishing (Vuki *et al.* 2000).

The coastal zone is divided into 410 fishing grounds traditionally known as '*I Qoliqolis´*. The coastal and foreshore resources are managed under dual ownership. The state owns the land beneath the sea and the marine biodiversity, while Fijian tribal units own the right to fish the marine biodiversity. These tribal rights are exercised in the coastal zone but not in the deeper waters beyond the reef (Richards *et al.* 1998).

Artisanal fishers consist of commercial licensed fishermen, which also include subsidised fishermen under the small-scale skipjack tuna fishery, small-scale deep-water snapper fishery, and since 2003 the Rural Fisheries Service Centre[2] development. Village fisherwomen are also included in this category as they sell invertebrates at the local market.

The District Administration is responsible for deciding, in consultation with customary fishing rights owners and the Fisheries Department, which commercial (licensed) fishermen shall be allowed to fish in the customary areas. The Fisheries Department is responsible for providing advice on the fisheries resources to customary fishing rights owners and issuing fishing licenses to commercial fishermen (Richards *et al*. 1998). This rule does not apply beyond the outer reef. Therefore the Department issues two types of licenses: Inside Demarcated Areas (IDA) and Outside Demarcated Areas (ODA). Licenses and registrations are issued on a calendar year basis. Landings from the artisanal fishery in 2004 were approximately 11,000 tonnes with a market value of US$26 million as estimated by the Fisheries Department, with 1185 licensed fishermen and 840 registered vessels in operation. The number of fisherwomen in operation is not available.

A large number of stocks are exploited for subsistence purposes. Fiji is a small island state and the majority of the population is still confined to rural areas. There are over 800 villages in Fiji and the customary marine owners rely heavily on the reefs for subsistence, livelihood and a source of income. As such, landings occur throughout the coastal areas of the country, roughly in proportion to the distribution of the population (FAO 2002). The Department estimated a total removal of 18,800 tonnes by the subsistence fishery in 2004.

1.3 Resource status and management

Observations have been made by fishers that the stocks of reef fish have been declining in recent years. A World Bank comparative survey in 1998-99 of coastal communities in the Pacific, which included six Fijian communities, indicated that the communities were generally pessimistic about their resources and only 10% perceived an increasing CPUE over the previous decade (Muller *et al.* 2000). The study recommended a reduction in fishing effort and effective co-management between coastal communities and external partners. A number of other studies carried out by Fong (1994), Jennings and Polunin (1995) and Vuki *et al.* (2000) and recent studies carried out by the University of the South Pacific (USP) and other non-governmental organisations (NGOs) such as World Wildlife Fund for Nature (WWF), also state that the biodiversity of the coral reefs of Fiji are under threat mainly from over-fishing, unsustainable fishing practices, and land-pollution and agricultural run-offs and climate change (WWF 2005a). The Fisheries Department made a rough estimate of 70 *qoliqolis´* being over-exploited, around 250 fully developed and the remaining 90 *qoliqolis´* could sustain more fishing pressure. These estimates give some initial guide as to the variability of fishing pressure across *qoliqolis´* (ADB 2005).

[2] Rural Fisheries Service Centres are establishments in remote villages and consist of an ice plant, fish storage facilities, slipway, jetty, fish grading/ processing facilities, collection vessels, pick-up trucks and office facilities. The establishment of these centres is a policy directive of the Government to bridge the economic gap and enable the resource owners to fully benefit from the resources from their fishing grounds.

Importance of resource management and conservation has been realised and substantial work is being done by the NGOs and the Fisheries Department in rapid assessment of the stock status of most of the coastal zones. WWF in collaboration with other NGOs is taking an eco-regional approach to marine conservation (WWF 2005b). The set-up of marine protected areas has been realised as an excellent means of protecting biological diversity (WWF 2005b). The Fiji Locally Managed Marine Areas Network in collaboration with WWF and the Fisheries Department are establishing marine reserves in many villages around Fiji where stock abundance is decreasing. Training and awareness is conducted at the village level to educate the communities about their resource management and conservation. A lot of villages have become members of this network, which assists them in setting up closed areas in their fishing grounds (DOF 2004).

The most significant traditional management practise still followed in Fiji is the customary marine tenure system. Traditional fishing area rights are defined and owned by *vanua* or *tikina* (social units that include a number of villages in a district), which regulate their use and exploitation. People are expected to use their own allocations, and those seeking to use grounds belonging to others are expected to get permission from the owners. From time to time fishing ground owners may declare a portion of their grounds out of bounds, known as "tabu" areas to preserve the resources (Veitayaki 2005).

1.4 Purpose of the study

Sound fisheries management requires reliable multiple surveys on the resources, fleets, landings, fishing effort, fishery costs and earnings and other related data (Tsimenidias *et al*. 1993). What the management system is lacking is an effective monitoring programme to capture the entire domestic catch (artisanal and subsistence) and associated fishing effort.

The Fisheries Department is the responsible agency for collecting the national statistics on fish catch and effort and has an artisanal fishery monitoring programme in place. The present objective of the programme is to provide annual estimates of the total artisanal catch and its market value, of all species, which are targeted by the fishery. The data are collected from the market outlets where the fish are landed for sales. However, the current Department's artisanal fishery monitoring programme strategy is demanding relative to the present manpower and financial resources and is not adhered to in practise. Consequently, the data collection system has in practice developed in an improvised ad hoc manner over the years. A thorough review of the sampling strategy is thus required and this study is the first step towards such a review.

Lack of resources has also restricted the Department from monitoring the subsistence fishery for the past 26 years. The subsistence fishery estimates reported by the Department are based on a survey carried out by the Fisheries Division in 1979. That survey covered only Viti Levu and was based on the ability of a single respondent in each village to recall landings over the previous 12 months (Gillet and Lightfoot 2002). The estimates from the sampled population were then extrapolated to the whole of the Fiji Islands giving an estimated total removal of 14,000 tonnes in 1979. Since then 200 tonnes have been added every year to provide an estimate of subsistence catch over the years giving a current estimate of 18,800 tonnes for the year 2005. The 200 tonnes is accounting for population growth as proposed by the study.

However, the recent fishing behaviour and actual landed catch from this sector is presently unknown.

Monitoring of the subsistence fishery thus commenced in 2002 as socio-economic household questionnaire surveys of the rural communities. Approximately 50 villages have been surveyed in the past two years. The data obtained from the socio-economic surveys so far have not been analysed. In the present study an attempt will be made to evaluate the socio-economic data to obtain subsistence catch estimates for the seven interviewed communities.

This study attempts to address the critical issue of lack of appropriate fisheries data for proper resource management of the coastal and the outer reef fishery. Artisanal and subsistence fisheries target the same stock and the same fishing locations. Both fisheries are considered simultaneously in this study. In order to ensure proper resource management, data from both these sectors are required. According to the DOF (2004) statistics, the artisanal fishery forms 25% and the subsistence fishery forms 43% of the total catch from Fiji waters. The two fisheries have separate monitoring programmes and therefore are considered separately in this study. Thus this study has two main components with respective major objectives, which were executed as the specific objectives outlined below:

1.4.1 Strengthen the artisanal fishery monitoring programme:

- To provide a detailed description of the current sampling scheme and identify the potential strengths, weaknesses, opportunities and threats.
- To examine if the current sampling regime organised by month, which necessitates sampling each day Monday through Saturday is warranted.
- To examine if there are differences in the amount of catch among the different sampling sites within a region.
- To suggest some improvements to the sampling scheme based on the analysis.

1.4.2 Strengthen the subsistence fishery monitoring programme:

- To evaluate the catch from subsistence fisheries from the data that has been collected so far and is practically available (for seven villages) through processing the socio-economic survey data.
- To suggest some improvements to the current sampling scheme.

A general idea was to identify and learn the appropriate techniques that can be used for analysing the existing data and that can be applied to future analysis.

2 REVIEW OF THE ARTISANAL FISHERY SAMPLING PROGRAMME

2.1 Overview

A summary was prepared of the current status of the artisanal fishery monitoring programme of the Fiji Fisheries Department.

The information regarding the programme was acquired from the Department's annual reports, quarterly statistics reports, raw data records from municipal market sampling, and personal communication with senior employees.

2.1.1 Present sampling regime

The sampling system has been in practice by the Fisheries Department since the late 1970's. At present the inshore statistics section under the Management Services unit of the Department is administering the artisanal fishery survey programme. The section employs one fisheries officer that oversees the programme and is subordinated by one project assistant and three data collectors. The main objective of this programme, as stated earlier, is to estimate the total artisanal catch and the market value of all species, which are targeted by the fishery.

The data collection system involves sampling the market outlets where the catch is retailed. The sampling frame, which includes the two main islands Viti Levu and Vanua Levu, is stratified into three groups according to geographical location. Viti Levu is divided into western and central divisions and Vanua Levu is the northern division. The groups are further divided into municipal markets and other outlets, which comprises of hotels, restaurants, butchers, fish shops, and roadsides.

In the eastern division, which comprises of the smaller outer islands, there are no public market places and most of the catch is considered for subsistence consumption. There are, however, some minor sales of fish within the division but this is not monitored by the Department.

One data collector is based in the western area (Lautoka office), one in the northern area (Labasa office) and one in the central area (Wainibokasi office). They are responsible for sampling all the municipal markets and other outlets in their respective divisions. The project assistant is responsible for entering all the raw data into a computerised system. A database in Microsoft Access was set-up in mid 2003 for the sole purpose of storing data. All the raw data from the data collection forms (both municipal and other outlets) since mid-2003 has been entered. The fisheries officer is responsible for producing the quarterly and annual statistics reports, information dissemination and other policy and planning matters of the section. All data analysis is performed in an Excel spreadsheet (DOF 2003).

<u>Municipal market sampling</u>

There are nineteen public fish marketing places, which need to be sampled. Eight of the survey sites are located in the central, six in the western and five in the northern division. Of

these, nine are municipal markets managed by market masters with six based in the western and three in the central division. The municipal markets in the northern area were destroyed in a cyclone that struck the Fiji Islands in January 2003. These markets are under repair. In the interim period, catch is being sold along the roadsides adjacent to where the markets were based.

The survey design involves sampling each municipal market once per month for each weekday, Monday through Saturday. A collection plan is drawn out in each division by the data collector and his immediate supervisor. During the survey data is recorded on a standard form which captures information on the sampling location (name of market place), name of recorder, date/day, time of survey, species, total weight of a particular species, total number of a particular species, average length by species, selling price/kg by species and fishing locations. This form is included as Appendix 1a of this report.

For sampling the data collectors use a weighing scale (spring balance) and a measuring tape. All the catch present in the market is sampled. Actual weights of the fish are taken. Where a variety of species are bundled together, the weights per fish of all different species are estimated. Some of the fish are measured and an average length is recorded. Lengths of the fish are not easily obtained, as the market vendors are not always cooperative.

A figure for total catch landed in the market in a month is obtained by the market masters. The market masters record the total volume of fish, which enters the market daily for the purpose of collecting market fees for the utilisation of the facilities. This information is easily obtained only in the western area and recently from the Laqere market in the central area.

Other outlets sampling

Monthly figures are also collected from outlets other than the municipal markets that receive their supply of seafood directly from the fisherman. A standard data request form has been designed by the section and is either hand delivered or faxed to the various major outlets in the different divisions on a monthly basis to obtain monthly weight of fish retailed by the outlet with a species breakdown. This form is included in Appendix 1b of this report. However, only approximately 30% of the outlets are responsive towards the request.

A survey done in the central division by the section in late 2004 revealed that almost all the hotels, restaurants and butchers buy their fish from the three major fish shops in the vicinity. Therefore the section is changing the practise to collecting data from these fish shops only on a monthly basis. In the northern area also the fish shops receive the bulk of the catch and retail it to smaller businesses therefore the data has been collected from the fish shops since mid 2005. However there are some other businesses that receive the catch directly from fishermen (pers. comm.).

Limitations

In practice, the Department is not able to carry out the survey as per the sampling strategy. This is mainly attributed to lack of operating resources and some administration issues. Lack of transportation is a major impediment. The data collection section does not have an official

vehicle and in most cases samplers do not have access to other official vehicles. This restricts movement between sampling areas especially to the stations based outside of the main district (where the office is based). Data collectors have attempted to use public transport. However, the section doesn't have sufficient budget allocation to reimburse claims for transportation expenses.

The data collectors are recruited on an annual contract basis with standard working hours of 0800 to 1630 from Monday to Friday. Under the General Orders of civil service an officer is entitled to meal allowance for working on weekends (pers. comm.). Due to lack budget allocation for allowances, the data collectors are not compensated for their effort when they work on weekends. Therefore data collectors are not deployed on weekends when the section is taut on budget.

Catch details from late December and January are mostly not available because the contract of employment of the samplers expires in the middle of December and is not renewed until early February.

Sampling details for 2004 and 2005

The actual sampling of the municipal markets carried out by the Department in the western and central divisions in 2004 and 2005 is summarised in Tables 1-4. The figures represent the number of times each market was surveyed in the corresponding month. As stated earlier, the strategy requires each market to be sampled six times a month. The underlined numbers indicate places that were sampled six or more times in a month and yet were not able to cover Monday through Saturday. The sign '-' indicates missing information. This information could not be obtained for the purposes of this study.

The information from these two areas is being used as an indication of poor sampling practises according to the standards of the sampling strategy. A similar tendency is noticed in sampling from the northern area and roadsides.

Data storage and processing

For municipal markets, the total catch is extrapolated on a quarterly basis since there are not enough samples available for each market in a month. A raising factor (Rf) is applied to the sampled catch to obtain a total catch for the whole quarter for each market. The raising factor is:

Rf = Total number of days of fish sales in a quarter / number of days sampled.

Total catch is raised by species for each marketing area. For markets that are not sampled at all, data from the previous years is used to make estimates, taking seasonality into consideration.

A general assumption is made for the other outlets, that outlets of similar sizes sell the same amount of fish. Knowledge of the number and size of outlets is utilised and the total estimate of the amount of seafood retailed through these outlets is based on the available samples.

This data analysis system has been in place since 2003. Overall the data analysis has not been systematic over the years and has been changing under different management.

Catch estimates

The total catch from the artisanal fishery sector and its retail through the municipal markets and other outlets has been fairly consistent over the years. A substantial increase was reported in 2004, however, with a total catch of 10,969 tonnes. The catch comprised of 3997.51 tonnes of fish and 4450.27 tonnes of invertebrates. 53.3% of the catch was retailed through the municipal markets and the remaining 46.7% was retailed through other outlets. This shows a shift from the previous trend of majority of the catch being retailed through the other outlets. Overall the reported landed catch increased by 82% in 2004 with a substantial increase in the municipal markets.

The proportional landed catch in the major areas is delineated in Figure. The highest proportion of catch was recorded in the western area followed by the central, then the northern area. Most of the catch from the northern area is transported to the central area and sold.

The proportions are based on the 2004 figures. The proportion of landed catch between areas has been similar for the past few years, except a much higher amount of landed catch was reported in 2004.

The substantial increase in the catch in 2004 could be attributed to the establishment of rural fisheries service centres. Two of these centres, in Wainikoro and Vanuabalavu, were in full operation. Also, in 2004 a full-time data collector was based in the northern division. This area was lacking sampling in the previous years and the catch estimates were being based on the previous year's data. Whether this increase was due to increased sampling intensity or increase in catch, or a combination of the two, needs to be verified by the Department.

Information dissemination

The data on total catch given by species is presented in the Fisheries Department's Annual Report every year. Copies of the Annual Report are disseminated to other fisheries agencies. Total catch figures are also submitted to the Bureau of Statistics, National Planning Office and the Reserve Bank of Fiji on a quarterly basis as per requirement. Data is also given to other fisheries agencies upon request.

2.2 SWOT analysis

A SWOT analysis technique was applied to review the sampling system. SWOT analysis is a tool for auditing an organisation and its environment. It is the first stage of planning and helps to focus on key issues. SWOT stands for Strengths, Weaknesses, Opportunities, and Threats. Strengths and weaknesses are internal factors. Opportunities and threats are external factors (Marketing Teacher 2000). SWOT analysis can be very subjective and is only used as a guide in this study.

Artisanal fishery sampling programme SWOT

Strengths
• Proper sampling (as per strategy) can give very reliable estimates of total catch as it incorporates frequent sampling of all the major marketing places. • Provides good estimates of the existing market prices. • Provides a complete species breakdown and corresponding catch in volume. • The monthly figures obtained from market masters on catch brought into the municipal markets can be used for verification of the estimated catch from the samples.
Weaknesses
• Demands excessive sampling effort as frequency of sampling is high relative to available resources and requires recording catch for all species. • Not able to account for catch bypassing the market outlets. • No system to detect catch landed by unlicensed fishers. This would result in an unreliable estimate of effort in relation to the total catch from the fishery. • Data collection deals with middlemen and is therefore not able to get precise information on fishing grounds. • Not able to get all the necessary information as the middlemen/ market vendors are not very cooperative at times. • Not able to estimate catch by area from the data available. • Not appropriate for recording information on length-frequency of species. • Data analysis is not systemised and based on ad hoc estimates for areas that are not sampled. <u>Departments constraints and weaknesses in relation to the survey programme</u> • Lack of manpower to carry out sampling on the required scale. • Lack of transportation. • Lack of funds to compensate the data collectors for their extra working hours • No proper data recording system until mid 2003. • No raw data is available for years earlier than 2002 as there was no proper filing system.
Opportunities
• Sampling design can be modified to be more efficient. • The data collectors' contracts of employment can be modified to suit their job description.
Threats
• The sampling programme is not focused on resource management and conservation (the current surveying system focuses on total catch and associated economic return) • Ad hoc manner of data analysis could have resulted in discrepancies in estimates of catch over the years. • The Fisheries Department is continuing to invest in a programme that is not efficient enough in terms of managing the fishery.

2.3 Analysis of total catch variations

2.3.1 Methodology

An analysis of variance was performed to determine any significant variation in the total catch landed among different:

- Days of the week (Monday - Saturday)
- Markets
- Months

Data

Data sets from the municipal market sampling of finfish for markets Lautoka, Ba and Nadi were analysed. This was from the period when the sampling strategy was followed which is April – July 2005 indicated in bold in Table 1.
. The data comprised total catch by market, month and day. Each market had six samples per month, which were samples from Monday to Saturday. Log-transformed data was used to obtain a normal distribution with equal variance.

Analysis of variance (ANOVA)

Analysis of variance, often abbreviated with the acronym ANOVA is a broad class of techniques for identifying and measuring the various sources of variation within a collection of data (Kachigan 1991). It is a flexible technique that allows making comparisons between any numbers of sample means, all in a single test. The potential sources being tested are sometimes referred to as "treatments" or "factors." The model assumptions are:

1. The observations in each cell constitute an independent random sample of size *n* and from a population with mean $\mu_{ij.}$
2. Each population represented by the cell samples is normal and has the same variance σ^2.

The Model hypotheses are:

1 H_0: $\mu_1 = \mu_2 = \ldots = \mu_k$
2. H_a: at least one pair of μ's is not equal.

Difference in the mean of the samples gives rise to two sources of variability referred to as Total Sum of Squares [SS_{Total}] which is partitioned into variability due to differences among treatments [SS_{Treat}] and variability within treatments [SS_{Error}] (Glover and Mitchell 2003). The analyses of the sums of squares are converted to variances by dividing the degrees of freedom in order to apply the F-test to compare them. $F = s_1^2 / s_2^2$ (between sample variance/ within sample variance). The F ratio is the statistic used for testing the difference among two or more sample means (Kachigan 1991). If the F ratio is 1 then H_0 is true and the hypothesis is rejected with F ratio > 1. P gives the level of significance of the variability. The one-way ANOVA is performed where a single input factor is varied at different settings or levels. Two-way ANOVA allows estimating the effects of two independent variables on a dependent variable (Fowler *et al.* 1998).

The factors tested were the landed catch weight (amount of catch retailed) among; markets Lautoka, Ba and Nadi (specified as L, B & N respectively in the results), months April – August and days of the week Monday-Saturday.

The test was carried out to examine any significant variability in the landed catch weight in-between markets, in-between different days of the week for all markets combined and within each market, and in-between months. A two-factor model with interaction was applied to compare markets, days and months. A one-way ANOVA was used to determine the variability of the landed catch among the days within each market.

A Tukey multiple comparison test was undertaken to determine between which treatment levels (markets and days in this case) the actual differences lay.

2.4 Analysis of catch composition

2.4.1 Methodology

A cluster analysis was performed to obtain the hierarchical cluster of species assemblage according to the markets, days and months to determine if species assemblage varied by these factors.

Data

A group of eighteen major fish species, that generally form >75% of the catch in each of the three markets from the western area, was analysed to observe any significant difference in species assemblage among markets, days and months. The group of species comprised of the following with the respective codes as used in the analysis; *Lethrinus elongates* [LEL], *Sphyraena qenie* [SPQ], *Lethrinus nebulosus*[LNB], *Caranx sp*.[CRS], *Scarrus ghoban*[SCG], *Restrelliger brachysoma*[REB], *Lethrinus harak* [LHK], *Valamugil seheli*[VLS], *Plectropomus sp*., [PLS], *Cephalopholis argus*, [CPA], *Lutjanus argentimacalatus* [LJA], *Lethrinus mahsena* [LMS], *Siganus sp*.[SGS], *Epinephilus focus* [EPF], *Lethrinus xanthochilus*[LXA], *Acanthurus mata*[ACM], *Liza melinoptera* [LZM], *Euthynnus affinis*[[EUF]. Table 13 in Appendix 2b outlines the list of species with common names and Fijian names. The total weights of species by market, day and month were utilised. The data were scaled to 0 mean and 1 variance.

Hierarchical cluster analysis

Cluster analysis aims to find natural groupings such that samples within a group are more similar to each other, generally than samples in different groups. Cluster analysis of species similarity can be used to define species assemblage i.e. groups of species that tend to co-occur in a parallel manner across sites (Clarke and Warwick 2001). In a hierarchical classification the data are not partitioned into classes in one step. They are separated into a few broad classes each of which is further sub-divided into smaller classes, and each of these further partitioned and so on until terminal classes are generated which are not further sub-divided (Everett 1980). Similarity between the clusters diminishes moving from lower levels to upper levels.

A chi-square χ^2 test was performed to determine the independence of the markets, days and months between the clusters. A χ^2 is a convenient way of telling how far the results differed from what was expected:

$$\chi^2 = \sum \frac{(\text{Expected} - \text{Observed})^2}{\text{Expected}}$$

The test results with larger values of χ^2 and very low values of p indicate that the expected values differ from the observed values. This test was performed on the identified clusters to examine distribution of the markets and the days among the clusters.

An analysis of variance was performed to study the link between the groups in the cluster analysis in terms of the total landed catch weight and number of species in the corresponding samples. A two-factor model with interaction was applied to determine the variability of the total landed catch weight, and total number of species between the clusters.

The R software was used to carry out all the analysis. The scripts are included in Appendix 5.

2.5 Results

2.5.1 Analysis of total catch variations

The box-and-whisker plots in Figure 4 shows the log-transformed data on which the test was performed to see the differences between the landed catch weight among the markets, days and months.

The results given by the two-factor model with interaction for factors market and day are outlined in Figure 5. The difference in the landed catch weight among the markets Lautoka, Ba and Nadi were statistically significant (F= 23.449, df: 2, $P < 0.05$). The Tukey test indicated that Lautoka market receives more catch than Ba and Nadi markets. Nadi and Ba markets are not significantly different. The difference between days was also significant (F = 48.132, df: 5, $P < 0.05$). Overall between all markets Saturday is significantly different from the rest of the days with the highest landed catch weight. Monday is also different but it is less significant than Saturday and shows the lowest landed catch weight. Tuesdays - Fridays are not significantly different. This is also indicated in Figure 2ii. Appendix 2a, Figure 13 demonstrates the Tukey test results.

An interaction effect exists between the markets and the days (F = 3.221, df: 10, $P < 0.05$).

No significant difference existed in the amount of catch retailed amongst the months April – August (F = 0.96, df: 5 $P > 0.05$). Figure 2iii illustrates this. A Tukey test result in Figure 13 iii in Appendix 2a confirms this.

Since there was an interaction between the markets and days, the difference between days within each market was tested using the simple model.. Within Lautoka market, the difference in the catch retailed between the days of the week was statistically significant (F = 38.878, df: 1, $P < 0.05$). The Tukey test indicates that Saturday is significantly different.

There are no significant differences between Monday and Friday in the amount of catch retailed. For Ba market there is a significant difference between days (F = 12.418, df: 1, P < 0.05). Monday is exceptionally different in this case. The rest of the days show no significant difference. In Nadi market a similar observation of statistical difference is made (F = 4.984, df: 1, P < 0.05), and Saturday is significantly different. The Tukey test results in Appendix 2 demonstrate these differences.

2.5.2 Analysis of catch composition

The result of hierarchical clustering is represented by a tree diagram or dendrogram, with the x-axis representing the full set of samples and the y-axis defining similarity levels at which two samples or groups are considered to have fused (Clarke and Warkick 2001).

The dendrogram was split at 70% level of similarity to generate four clusters. Figure 6 shows clustering labelled by markets, Figure 7 shows clustering labelled by days and Figure 8 shows clustering labelled by months.

A chi-square χ^2 test of the distribution of markets, days and months in the clusters indicated that the allocation of markets to the clusters was very different (χ^2 = 41.73, p=2.08e-07) and days was different but less so (χ^2 = 36.01, p=1.07e-03). This signifies that there is variability in species assemblage among markets and days. Months are not significant and are evenly distributed among the clusters (χ^2 = 3.814, p=0.98).

The details of the markets and days present in each cluster are given in Figure 9. Weekdays of Nadi and Ba markets are grouped together in cluster 1. There is no Lautoka market, and no Saturdays in this cluster. Cluster 2 has mostly end of the week of Ba market grouped with weekdays of Nadi market and Mondays and Tuesdays of Lautoka market. No Mondays for Ba market are present in this cluster. When cluster 3 is split further, Lautoka and Ba markets are separate except for one observation. Lautoka is clustered with some Nadi market in clusters 3 and 4 with no Ba market. Cluster 3 has Saturdays of Nadi market grouped with Fridays and Saturdays and some weekdays of Lautoka market. Cluster 4 has weekdays of Lautoka market combined with Wednesday, Friday and Saturday of Nadi market. This indicates that Nadi and Lautoka markets are similar in terms of species assemblage on some days.

The group of species present in each cluster is delineated in Figure 9, which was obtained by summing up all the samples in the clusters.

There is not much diversity of species in Ba and Nadi markets during the week as shown in cluster 1. The catch is dominated by *Restrelliger brachysoma* (Chub mackerel). Catch in Ba market towards the end of the week is more diverse in species compared to the weekdays as illustrated in cluster 2 and has four predominant species *Restrelliger brachysoma*, *Sphyraena qenie* (Barracuda), *Lethrinus elongates* (Long-Nosed Emperor), *Caranx sp* (Trevally). This is similar to Lautoka market early in the week. High amounts of *Restrelliger brachysoma* are landed in Ba market.

Species diversity in catch is high in Lautoka market throughout the week as illustrated in cluster 3 and 4. Catch in Nadi market is occasionally similar to Lautoka market as indicted in cluster 3 and 2. In cluster 2 early week of Lautoka market is grouped with weekdays of Nadi and in cluster 3 Saturday of Nadi market is grouped with Friday and Saturday of Lautoka market.

The highest diversity of species is found on Saturdays is in Lautoka. The predominant species are *Lethrinus elongates, Sphyraena qenie, Caranx sp*. Catch in the weekdays is dominated by *Restrelliger brachysoma, Lethrinus elongates, Caranx sp*. *Restrelliger brachysoma* and is relatively low on Saturdays. In general, for Lautoka market *Lethrinus elongates* and *Caranx sp*. seem to be significant in the landed catch.

The box-and-whisker plots in Figure 10 show the log-transformed data on which ANOVA was performed to determine the difference between the total landed catch weight and total number of species between the groups. There were significant differences between the total landed catch weight ($F = 38.493$, df: 3, $P < 0.05$) and total number of species landed ($F = 48.644$, df: 3, $P < 0.05$) between the groups. The total landed catch weight is strongly correlated (Figrue 11) to the number of species being landed with a correlation factor of 0.93. The landed catch is highest on Saturdays with the highest number of species (Figure 10iii, 10iv).

A pattern in the fishery is noticed where, with an increase in the total landed catch; an increased number of species are recorded. This is illustrated in Appendix 2c, Appendix 2c: Relationship between the total landed catch weight and total number of species

which shows how the proportion of the species decreases with increasing landed catch for 18 major fish species. Because of the presence of many species in the samples, the proportion of a particular species is low. Even though the catch of a particular species is high in Lautoka market in comparison to Nadi and Ba markets the proportion of the species to total landed catch weight is lower than the other two markets.

2.6 Discussion

Despite having a sampling programme for the artisanal fishery, the Fisheries Department is unable to follow and fulfil the requirements of the sampling strategy. This is due to the constraints arising from lack of operating resources such as funding and manpower. This has greatly hindered the survey programme over the years. It is evident from Tables 1 – 4 that the official sampling program requiring six samples per month in each stratum (market site, month) is not followed. The main reason is that the Department simply lacks the capacity to follow this programme. For example, one data collector is responsible for the western division. This division has six municipal markets and a substantial amount of fish sales along the roadsides. The requirement of sampling each municipal market and roadside six times in a month makes 42 working days in a month by simple multiplication. This is clearly not in the capacity of one individual. The central and northern areas also have one data collector each so this problem is prevalent in all three main divisions. In the west the main branch of the Department is based in Lautoka district. The data collector when unable to travel out of the station ends up surveying the Lautoka market and as a result this market is the most frequently sampled. In the central division the data collector is based in the Wainibokasi office. Laqere market is in the vicinity and hence is the most frequently sampled in that region. Many a times the data collectors have to adjust their monthly collection plan according to the availability of transport. This disrupts the plan and results in repetition of days being sampled, as indicated by the underlined figures in Tables 1 – 4. This sampling programme is thus too ambitious for the Department with the present state of manpower and financial resources.

The current sampling strategy of the artisanal fishery is discussed in the sub-sections below with suggestions for improvements in relation to the findings of the present analysis and in relation to other reviews.

2.6.1 Suggested improvements

Sampling of the municipal markets

The analysis of catch variations and associated species assemblage from Lautoka, Ba and Nadi markets in 2005 show that there is no significant difference between the months of April through August, which would represent one season. Based on this, the current monthly sampling stratification is not warranted. It is thus suggested from this analysis that sampling should be stratified by fishing season. This is a preliminary analysis performed on an available sub-set of data but further analysis based on samples from all the divisions and including more than one year should be performed to verify this conclusion.

The bulk of the catch goes into Lautoka market as it is close to the main fishing port and has a larger market with higher demand for fish. Ba and Nadi markets receive lower catches as these are small areas and do not have any major fish landing sites. In principle one would obtain the most precise estimate of the overall mean volume of catch that goes through the markets by allocating the samples among different markets proportional to the standard deviation of the daily catch estimates within each market. Since the CV among the three market sites studied here is roughly equal (**Error! Reference source not**

found.), the sampling allocation would effectively be proportional to the volume of the fish that goes through each market (FAO 1998). The current sampling strategy of equal sampling frequency among the different markets should thus be revised accordingly.

Two factors need to be taken into account when considering the sampling regime. These are the total volume of catch that goes through the markets and the associated species composition.

Comparison between markets indicates that Lautoka and Ba markets are considerably different both in landed catch weight and species assemblage. The species assemblage in Ba market towards the end of the week is somewhat similar to Lautoka market early in the week. Nadi market is intermediate between Lautoka and Ba. It is similar to Ba market in the amount of catch being landed but more like Lautoka market in terms of species assemblage. Because of these differences each market needs to be sampled.

When considering the days, Saturday is an exceptional day in all markets. In Lautoka and Nadi markets high amounts of catch are being landed with a wider variety of species. In Ba market the landed catch weight is not significantly different from weekdays (Tuesday through Friday) though the catch composition is unlike any other days. As such Saturday sampling would be deemed necessary in all the three markets.

Monday is also different, but not as much as Saturday. Low amounts of catch are being landed. In terms of species composition Monday is most similar to Tuesday. Thus Monday can also be considered as an exceptional day.

The species composition from Tuesday through Friday is similar within each market, except there is a trend of increase in landed catch weight. However the differences in weights are not statistically significant. Therefore these days would be considered similar.

In the cluster analysis, mostly days closer together get clustered together. This would indicate that the species composition gradually increases as the week progresses with more catch being landed.

Thus equal sampling of Monday through Saturday is not warranted. This analysis would indicate the Saturday and Monday sampling is necessary and a random selection can be made on the other days.

Generally, between and within all three markets the landed catch increases as the week progresses. Four major species dominate the catch, *Lethrinus elongates* (Long-nosed emperor), *Restrelliger brachysoma* (Chub mackerel), *Sphyraena qenie* (Barracuda) and *Caranx sp.* (Trevally).

The actual sampling allocation within each division could be based on analysis presented here but as mentioned earlier further analysis would be required to draw some firm overall conclusions about the sampling due to the complex nature of the fishery. The general idea would be to draw out a common sampling strategy for all markets once further analysis on other areas has been preformed.

Since the Department is facing manpower shortage in data collection independent information that is already recorded on the fishery should be utilised wherever possible. In Fiji the market masters of the municipal markets weigh all the fish that comes into the market everyday for sales and this information is recorded manually in their registers. The information on the monthly catch from some markets is currently collected by the Department. It is suggested that the Department should put greater emphasis on obtaining such data on a more systematic basis from all the markets and at the highest resolution possible. At a minimum the daily catch that goes through the market should be collected and stored. A similar technique can be applied to the rural fisheries services centres, where fish is mainly landed by the village fishermen and the market manager records the weight of the total landed catch in the market. These estimates would serve the purpose of independent estimates of total catch. If they are judged to be accurate estimates of total catch, the focus of the market surveys by the Department could, as already suggested by Cook (1986), be shifted from obtaining information of total catch of all the different species towards focusing on getting more accurate estimates of the proportion of different species. Such a shift in the sampling design may free up time for the data collector, enabling him/her to visit more markets each day or to obtain more detailed information on the size composition of selected species.

Cook (1986) also suggested a further simplification, which would reduce the number of species being sampled. He reasons that most of the species have very low catches and the justification for sampling these is questionable on the basis that many of the species volumes are low, and since this survey doesn't allow estimation of catch by area, the data are of limited use for stock assessment and fishery regulation. "In the tropics it is not possible to carry out fish stock assessments for all commercially important living stocks. Most tropical fisheries involve a large number of species. There is no available manpower or funds which would allow for all species to be recorded. Even if the stock concept was replaced by the management units, there are still too many units to assess all of them. Therefore, the solution is to prepare a list of important species representative of the sample and classify the remaining as "Others" (FAO 2000). The Department could consider this approach to sampling. The list of the important species could either be drawn out according to their commercial importance or by their importance in terms of abundance in the catch (weight in the catch) or by ecological significance, which would consider species in the different trophic levels.

It should be noted that the above suggestions are only applicable to the landed catch of fish species. The invertebrates are mostly sold by village women in the municipal markets but outside of the "fish market" area. Therefore this catch brought into the market is not recorded by the market masters (pers. comm.). The invertebrates are laid on plastic on the floor and sold. Therefore the sampling programme would require sampling the invertebrates for the weights, together with species breakdown and price, akin to the present system. There are other non-municipal market areas, which have considerable sales. These include roadsides and areas such as Nabukulou Creek, the marketing areas in Vanua Levu (after the destruction of municipal market facilities by the cyclone) and Lautoka Fishing Port on Sundays. For these areas the present system of obtaining total catch by each species still applies.

Sampling of other outlets

The present system intends a complete survey of all the other outlets. A complete survey is feasible for major outlets such as the fish shops in the central and northern divisions that provide landed catch weight to the Department on a monthly basis. In the central area this information from the fish shops gives 98% of the total landed catch that flows through all the outlets because most of the smaller outlets in this area buy their fish from the major fish as determined by the survey carried out by the Department in 2004. A similar survey should be carried out in the western area and for the smaller outlets in the northern area. A complete sampling would be essential initially and then Cook's suggestion of applying a 25% stratification of the outlets sampled could be considered. The department should continue using their standard request forms and try to build a friendlier and transparent relationship with the businesses to ease the inflow of information. A verification of the catch retailed through the other outlets seems essential as a lot of the estimates in most of the areas are being based on previous surveys carried out some years ago.

Fishing patterns

A pattern in the fishery is noticed in the current analysis of market samples. The landed catch increases as the week goes by but at the same time the diversity of the species increases. The actual cause for this trend needs to be determined. It is known that the demand for fish is higher on weekends (pers. comm.). The increasing diversity of the species may also be related to demand. It would be informative to find out if this pattern can be directly related to the behaviour of the fleets, the types of gear used and/or the location of the fishery as the week progresses. The pattern may arise due to such changes but may also be an artefact due to less market demand for fish variety during the week. The fishermen, may for example, give away the species of lesser commercial value in the earlier part of the week because using market facilities requires paying fees according to the weight being sold. It is suggested that the Department should make a specific investigation related to the above pattern with the specific objective of aiding in designing an appropriate sampling strategy.

Catch estimates

A huge increase in catch landings is reported in 2004 compared with estimates from previous years. It is not clear if this anomaly is due to an increase in fishing effort, increase in biomass or change in sampling methods by the Department. It is known that a lot of agricultural native land leases in the northern area, especially in Macuata Province, were not renewed in 2004. Therefore households that were involved in farming previously have started venturing into fishing as their source of livelihood (pers. comm.). This may in part explain the increase in landed catch in 2004. It is however unlikely that the almost doubling in catches can be attributed to this factor alone. There have been indications that the Fisheries Department is underestimating the artisanal fishery catch (Rawlinson *et al.* 1994, Gillet and Lightfoot 2002). The reported catch landings estimates in 2004 may thus be more reflective of the true annual removal by the artisanal fishery. There is however no information provided in the Department report for 2004 as to a major change in sampling and data processing so this anomaly in catch estimates is suspect and needs to be verified.

Collection of effort data

Catch and effort are the two fundamental data required for monitoring the development of the fisheries and are often used in assessment and management (FAO 1999). CPUE (catch per unit effort), also called catch rate, is frequently the single most useful indicator for long-term monitoring of a fishery. Declines in CPUE may mean that the fish population cannot support the level of harvesting and increases in CPUE may mean that a fish stock is recovering and can sustain more fishing effort (FAO 2000).

In the present state, only information documented on the effort in the artisanal fishery is the number of licensed fishers and boats in operation. However more details on the effort applied to a fishery are required for management of any fishery. An ideal opportunity for collecting this information at a minimal cost would be from the existing fishing license questionnaires that every licensee is required to fill during license application. The license form inquires about the fishers' personal details, fishing grounds, number of fishing trips, hours/trip, method of fishing, place of landing, volume of catch/trip, main species caught, place of retail, revenue generated, and a general question about the status of the stock in the fishers view.

In practice, information on personal details and authorised fishing area is recorded for each fisherman and the essential information related to fishing effort is not available. Nonetheless, the importance of this information has been recognised and all extension and licensing officers have been requested by the statistics unit to resume the practice of recording all this information as of 2005 (pers. comm.)

It is strongly recommended that this practice be established on a systematic long-term basis. A questionnaire requires the respondents to fill out the form themselves; this would require high level of literacy therefore questionnaire should be prepared using the major language of the target group (FAO 1999). Translating the questionnaires, which are in English, into Fijian and Hindi would greatly ease the process as also recommended by Cook (1986). Currently the licensing officers need to assist the fishermen in filling out the forms due to low literacy rates of the majority of the fishermen. With vernacular language the fishermen will require minimum assistance in filling out all the requested information. A revision of some of the questions could also be considered. The licensing officers could educate the fishers about the use and importance of fishery data so that they are more cooperative and this could also reduce some subjectivity in the information provided.

Under the Fisheries Act the village fisherwomen are required to obtain a fishing license from the Fisheries Department to operate. However, a fee is not levied for this license as the women utilise their own fishing grounds. Only a letter of consent is required from the chief of the village to obtain a license. This provision under the act should be fully utilised. Issuing licenses to the fisherwomen would keep track of the effort applied to the fishery.

2.7 Conclusion

Fisheries information cycles require continuous and circular reappraisal. Setting up a data collection system and then operating it without continuous feedback and possible revision may waste resources either on unreliable estimates or on over-sampled variables (Evans and

Grainger 2002). The current sampling regime of the Department has been in place for approximately 30 years and is in need of an appraisal to increase reliability in the fisheries statistics, and for a better informed management system.

The Department should consider addressing the shortcomings in the sampling and re-examining the scope of the survey. It is important simultaneously to consider the survey requirements taking into consideration the manpower and financial constraints. Setting up a data collection programme follows from defining objectives, identifying data needs through to working out how the data should be collected, stored and analysed. In designing the programme, all options should be carefully considered. The strategy will be strongly influenced by the budget and personnel available (FAO 1999).

In view of the above, it is statistically indicated that the current sampling strategy organised by month is not warranted. Sampling could be organised by season. Equal weighting of the weekdays Monday through Saturday is also not warranted for the three studied markets. Similar studies can be carried for others areas in order to revise the sampling regime.

From this analysis it could be said that sampling allocation would be proportional to the volume of catch that is retailed through each market, considering the assemblage of species.

However, should the objective be modified to sample a group of important species instead, a similar analysis would be applied by species to determine the amount of each species that goes through each market. Sampling would then be based on the proportion of the species catch weight that is landed in each market.

The main objective of the market sampling needs to be defined clearly. The level of accuracy of the sampling needs to be decided upon in relation to the available manpower and resources. The sampling regime would then be designed accordingly.

A thorough survey of the other outlets needs to be carried out in the western and northern divisions to determine their source of fish supply. An initial complete survey of the outlets would be necessary and then 25% stratification of outlets sampled can be applied.

Collection of effort data is deemed necessary, as it is fundamental for fisheries management.

3 EVALUATION OF THE SUBSISTENCE FISHERY

The socio-economic household questionnaire survey for the subsistence fishery is incorporated in the Marine resource inventory survey of the Fisheries Department. Apart from the household questionnaire survey the methodology incorporates Underwater Visual Census Surveys (UVC) and creel surveys at some landing sites in the village to sample the actual catch by species for weight, length, number and information on catch/unit effort, fishing methods and gender of fishers.

This survey was initiated with the objective to survey all the 410 *qoliqolis*. This was set as a policy directive by the Government in place of a directive under which the total ownership of

the customary fishing rights areas would be given to the indigenous communities. The resource surveys of the fishing rights areas have to be undertaken to determine the status of each *qoliqoli*.

The main objective of the surveys is to identify the biodiversity and determine the resource status of the fishing areas through gathering base-line biological, ecological and socio-economic data. The study information will be utilised to draw out the Inshore Marine Resources Profiles for each fishing ground and the Department will work with the local indigenous communities adapting a community participatory approach to formulate a Fisheries Management and Conservation Plan.

Each fishing area is targeted only once and the aim is to survey all the villages (DOF 2002). Each *qoliqoli* has many villages and this task appears unfeasible with this strategy.

For the 50 communities surveyed so far, UVC data is analysed to obtain the biomass of different species in all the survey areas (DOF 2005). As mentioned earlier the socio-economic data have not been processed to date and are being analysed for seven communities in this report.

3.1 Methodology

3.1.1 Study site

Household survey information from nine communities was processed. This included eight villages namely: Namatakula, Navola, Taqage, Komave, Lami, Delainavesi, Suvavou, Vugalei and one tikina, Nasavusavu.

Namatakula, Navola, Komave and Taqage are rural settlements situated adjacently along the Coral Coast in Sigatoka on the main island of Viti Levu marked as 1 on Figure 12. This part of the island is surrounded by fringing reefs. Navola is a small village beside Namatakula and is considered part of the Namatakula community in the household census survey conducted by the Fiji Bureau of Statistics. These settlements come under the Nadroga/Navosa province.

Lami, Delainavesi and Suvavou are located on the flank of Suva Harbour on the main island of Viti Levu marked as 2 on Figure 12. Lami is an urban settlement and Delainavesi is situated within Lami. The harbour is protected by the Suva Barrier Reef. Suvavou is an urban village located beside Lami. These settlements are part of Rewa province.

Vugalei is a small rural village located in Labasa Tikina. Nasavusavu tikina is a combination of rural and urban settlements based on the coast marked as 3 on Figure 12. It comprises of the following 21 villages: Drekeniwai, Dromuninku, Korolevu, Koronatoga, Korosi, Leya, Nacavanadi, Nagigi, Naidi, Nasinu, Navakaka, Naweni, Savudrodro, Tabia, Tacilevu, Viani, Vivili, Waivula, Waivunia, Nacekoro, Yaroi and remaining urban area (FIBOS 1996). These two tikina are part of Cakaudrove province located in Vanua Levu.

3.1.2 Socio-economic survey

The socio-economic survey involves questionnaire interviews of randomly selected households in a community. This survey is part of the Department's Marine Resource Inventory Survey as described in the introduction. These study areas were surveyed during the period 2003 – 2004. The interviews were conducted by Fisheries Department staff. For random selection, the households of the whole community are categorised into groups of five based on area. From each group, three households are chosen at random. However in some surveys this strategy was not followed and very few samples were taken. For Nasavusavu tikina random samples were taken from 12 villages including some urban area.

The questionnaire used in this survey was obtained from the study done by Rawlinson in 1993 and is included herein as Appendix 3. A senior member of the household was interviewed and the information gathered includes fisher and community attributes, such as age, education, household size, assets, occupation, dependence on fishery resources, frequency of fishing trips, trip duration, fishing methods, fishing area, catch per trip with species composition, and fish consumption rates. Each community was surveyed once during the period of survey. The number of households surveyed in each community is given in Table 12.

3.1.3 Catch evaluation

All raw data from the household survey questionnaires was entered in a spreadsheet. Catch per trip per household and number of fishing trips per household were utilised to evaluate the subsistence fisheries yield for all communities.

The following catch details for fish were recorded: average weight (grams)/fish, numbers of fish and maximum and minimum lengths. For invertebrates total weights (grams) were recorded. The following discrepancies were identified in the record of catch details, in some questionnaires, during analysis:

i. Weights were missing for some species (including fish and invertebrates)
ii. All weights were missing and only numbers were recorded.
iii. All numbers were missing and only weights were recorded.
iv. Total weights of fish were recorded instead of average weights, with no information on the number of fish.
v. The number of trips was not recorded.

As such, 22 out of 161 households were deleted for all communities combined. These comprised records that didn't have numbers of fish, had total weights with no numbers, and did not state the number of fishing trips.

Weights of some species for some of the households were still missing. Therefore average weights were obtained from the available data and applied for missing information for both fish and invertebrates. This assumption was made for 11 households for which some weights were missing and 20 households for which all the weights were missing.

The catch per trip was recorded under one of the following categories in the questionnaires: 3-7 times/ week, 1-2 times / week, > once a month, < once a month. These categories were converted into values for the purpose of analysis. This technique was taken from Rawlinson (1993) as an equivalent questionnaire is being analysed. The factors used by the 1993 survey were 3, 1.5, 0.5 and 0.25 for the four categories respectively. The same factors were used except for the first category 3-7 times/ week. The factor used in this study was 3.5 because it was known from the survey that, when marked under the category 3-7 times / week, fishing is actually carried out 3-4 times in a week by the majority of the households.

For each household total catch/ year (C_H) was calculated:

$$C_H = C_t * N_t * 52$$

where,
C_t: Catch/ trip
N_t: value for the number of fishing trips/ week
52 represents the number of weeks in a year.

The total catch was calculated by species.

Assuming that the survey is a true sample representative of the population (as it includes fishing and non-fishing households) a deterministic total catch per community (C_{com}) was obtained:

$$C_{com} = \sum C_H * Rf$$

where Rf is a raising factor calculated by the total number of households in a community divided by the number of households sampled.

For Nasavusavu Tikina the samples were not truly representative of the proportion of non-fishing households. In Nasavusavu Tikina 70% of the households are based in the coastal area and 30% of the households are in the urban area. Therefore an assumption was made that 70% of the households are frequent fishers.

The total number of households per community was obtained from the 1996 household census conducted by the Fiji Bureau of Statistics. These were the most recent figures available, as the next census will be conducted in end of 2006.

It was known that in Namatakula 67% of the households were surveyed therefore the total number of households in the community was calculated based on this information. For Vugalei village the households' samples are greater than the actual number of households present in the village according to the 1996 census. No auxiliary information for Vugalei village was available therefore a raising factor of 1 was used. For the rest of the communities the 1996 census figures were used. During analysis, Navola samples were added to Namatakula samples and Delainavesi samples were added to Lami samples. This was done because under the national census, Navola is counted as part of Namatakula, and Delainavesi as part of Lami. As such, catch by subsistence fishery was evaluated for seven communities.

Bootstrap was used to estimate the variance by re-sampling the data on annual catch per household. Bootstrap re-sampling is a general form of re-sampling in that it is re-sampling with replacement to produce samples of size n (Haddon 2001). Re-sampling generates a unique sampling distribution based on the actual data at hand using experimental rather than analytic methods. Unlike approximation with generic distribution tables, re-sampling yields unbiased estimates because it is based on unbiased samples of all possible outcomes in the data being studied (Garson 2006). Bootstrap becomes most useful where the sampled population cannot be represented by a normal distribution and especially where the underlying distribution is unknown (Haddon 2001). The annual catch per household in all the villages is not normally distributed. Therefore, re-sampling technique was applied and 1000 re-samples from the original data were generated. The bootstrap estimates of total catch were normally distributed. The re-samples were raised and mean and standard deviation were obtained. A coefficient of variation (CV) was also calculated. The coefficient of variation provides a relative measure of data dispersion compared to the mean: CV = standard deviation / mean for the normal distribution (Barringer 1999). This was done for all communities except Komave because sufficient samples were not available. The non-parametric catch estimates with standard deviation from bootstrap are presented. It should be noted that the uncertainty estimate is only taking into account the uncertainty associated with sampling. The uncertainty related to the raising factors has not been accounted for.

An attempt was made to estimate the total removal by the subsistence fishery from all the coastal rural communities in Fiji, based on these samples. Estimates are attempted for coastal communities only as the samples are from coastal areas and assumed to be representative of all the coastal areas. An overall average catch/ household (C_{av}) was calculated:

$$C_{av} = \sum C_{com} \; / \; \sum TH$$

where
$\sum C_{com}$: Total catch for all communities surveyed combined
$\sum TH$: Total number of households for all communities combined.

3.2 Results

The estimates for the removal by subsistence fishery for all the communities are delineated in Table 12. Only Vugalei shows a CV greater than 30%.

The majority of the households interviewed in all villages are involved in fishing 1 – 2 times per week with an exception of Namatakula community where a significant number of households (33%) go fishing 3 – 4 times per week.

Approximately 32% of the community in Lami is not involved in fishing and 13% fish less frequently than 1 – 2 times per week.

Only a few households per community own a boat. Fishing is mainly carried out along the shoreline and on the fringing reef where fishers mostly wade into the water and fish.

On average, the amount of time spent fishing is 1 – 4 hours with an exception to Lami and Suvavou where considerable number of fishers are out at sea for 4 – 12 hours.

In most villages both males and females are equally involved in fishing except Lami and Nasavusavu area where the proportion of male fishers to female fishers is 2:1.

The predominant gears used are hand line and spear except in Vugalei where gillnets are used as frequently and in Lami and Suvavou where spear seems to be of less importance. These are based on the number of reported cases. The ranking of the gear usage was not available. The major habitats targeted by all communities are shoreline and lagoons (shallow and deepwater). Some people from Lami and Suvavou village also fish on the reef. Hardly any fishing occurs on the reefs of the Coral Coast adjacent to Namatakula.

All the communities consume fish 1 – 3 times per week except Lami where 40% of the households consume fish once a week only and for some households fish is part of the diet 4 – 6 times per week. All communities also consume canned fish apart from consuming their fresh catch.

All the coral coast villages show similar fishing behaviour and consumption rates. Komave area had three samples only therefore the inferences made from this sample will need validation.

For Nasavusavu tikina the information on the fishing methods, the gear types used, fishing area, trip duration, and consumption of fish was not available from the questionnaires. For interested readers some details by community are provided in Appendix 4a.

Generally within a community, the number of fishing trips per week does not affect the amount caught. Households that go fishing 1 – 2 times per week catch approximately the same amount per trip as those that fish 3 – 4 times per week with the exception of some outliers (Appendix 4b, Figure 19). The correlation factor is 0.22. The trip duration also does not affect the catch size with the correlation factor of 0.2. The distribution of annual catch, number of fishing trips and trip duration by household is illustrated in Figures 16, 17 and 18 in Appendix 4b respectively for all the communities.

The highest diversity of species caught is in Namatakula followed by Nasavusavu tikina. Komave and Vugalei villagers do not catch a lot of species. Lami, Suvavou and Taqage are intermediate. Three main species are landed in all areas, *Lethrinus mahsena* (yellow-tailed emperor), *Cephalopholis argus* (rockcod) *and Lethrinus harak* (thumbprint emperor). *Scarrus sp*. (parrot fish) are caught is high amounts in all the areas except Suvavou and Vugalei where there were no reported cases.

In Komave, Lami, Suvavou and Vugalei not much invertebrates are landed. Despite a turtle moratorium in place, turtles are being landed in Namatakula and Nasavusavu.

An estimate of catch (tonnes) by species according to community is provided in Appendix 4c, Table 14.

Some commercial (licensed) fishers are also present in these villages. The details per community are given in Appendix 4a. The catches landed by these fishers are not available from this survey.

4 DISCUSSION

There is a lot of variability in the catch sizes between the different households in the studied communities. The high values obtained for the CV indicate the dispersion of the actual catches of the households from the mean catch. This is generally expected in all these communities where all households are not involved in fishing on the same scale. A further confirmation to this variability is that a lot of fish is also sold within the villages among households, as reported in most of the questionnaires. This indicates that households that don't go fishing so often buy the catch from the frequent fishers. However, these sales are regarded as subsistence fishery as they are small-scale sales on the village level.

Coastal communities concentrate their fishing effort in areas adjacent to their villages (Rawlinson *et al.* 2004. All the studied communities mainly target the shoreline and the lagoon for food security. Fiji has an extensive and high diversity of coral reef habitats. These inshore reefs support major subsistence and moderate commercial fisheries (Vuki 2000). This dependency has led to over-exploitation of the coastal zones in many fishing grounds as studies indicate. Most of the families in all communities do not own a boat, which also leads to the shorelines and lagoons being heavily targeted for fishing.

The Coral Coast area has a higher average catch in comparison to the other two areas, indicating that the people in this area are more actively involved in fishing in comparison to the people living along Suva Harbour and in the two areas surveyed on Vanua Levu. Based on the coast, the villagers heavily rely on fish as their main source of protein and livelihood. The reef adjacent to the Namatakula village was in a deteriorating state and therefore a marine protected area has been established on the reef. The villagers in Navola do not have permission to fish on the reefs adjacent to their village as the area belongs to the Komave tikina.

WWF based in Fiji together with Fisheries Department is currently carrying out awareness programmes on the turtle moratorium in some of the villages in Fiji, especially places where people are still catching turtles.

The information gathered by household surveys can be very subjective. Such information is also subject to various kinds of "memory error" and a tendency to misreport on the part of the respondent (FAO 2000). As such these estimates need to be verified. Previous surveys done of this nature also have a parallel independent survey, which is used for the verification of the household questionnaire survey information.

Rawlinson *et al.* (1994) carried out a socio-economic survey of artisanal and subsistence fishery for Viti Levu. In this survey, a creel survey was also carried out in three villages that were interviewed for verification of the information obtained by the respondents. Kuster *et al.* (2005) carried out a questionnaire survey on the island of Ono-i-Lau. In this study the verification process involved taking a sub-sample of the population and monitoring their fish consumption daily for two weeks.

Rawlinson *et al.* (1994) recommended that future surveys must employ the composite approach using questionnaire, creel and fish consumption surveys simultaneously in order to

get an accurate assessment of the fisheries and the creel surveys should be undertaken at different times of the year to take into account any seasonal effects on catch. The overall survey planning should place more emphasis on the creel survey and utilise this data for verification. At present the creel survey in most of the villages is not carried out as anticipated because of some administration constraints (pers. comm.). These issues should be addressed during the planning stage of the survey. Nonetheless, verification of these estimates is necessary.

The importance attached to socio-economic information on the fisheries sector has greatly increased for several years (Sabatella and Franquesa 2004). Without subsistence fisheries, individual pacific island countries would have to import an estimated US$3 to 8 million a year in substitute foods (Gillet and Lightfoot 2002).

A lot of rural areas in Fiji are heavily dependent on the marine resources as their main source of livelihood. This household survey information could prove to be of immense value. The two surveys UVC and household survey of the marine resource inventory survey greatly complement each other. The UVC data are used to estimate the biomass of the marine diversity in each of these fishing areas through underwater visual surveys. With this information on fish abundance in an area and the total removal from the same area would simply indicate whether the fishing practices are sustainable. One of the major objectives of the Marine resource inventory survey is to ensure sustainable management of the marine resources (DOF 2005).

4.1.1 Suggested improvements

Survey design, planning and sample selection

A detailed design and planning of the survey including implementation scheduling, training, equipment, logistics, co-ordination, and monitoring should be ensured prior to the survey. A survey design should be realistic and have outlined achievable tasks, which can be accomplished (FAO 1985).

The Department mostly encounters budgetary constraints. In resource limited situations few samples can be taken provided that the samples sizes are representative. Good accuracy levels can be achieved at relatively small size, provided that the samples are representative (FAO 2000). However it must be ensured that enough samples are taken at random. In some of the villages such as Komave and Taqage very few samples were taken during the survey.

It should be ensured that the sample obtained should be truly representative of the community being studied and not be biased in its selection. A true sample will be an indication of the number of fishing and non-fishing households and commercial operators. None of the samples from any communities included licensed households, even though all the studied communities have licensed fishermen. This indicates selection bias as one part of the target population is not in the sampled population (Lohr 1999).

A post-stratification approach can also be applied for sampling where the households within a community can be divided into frequent fishing, non-frequent fishing, and licensed households for instance and random samples taken from each strata.

Data recording system

Weaknesses were identified in the data recording system as outlined in the methodology section above. Samples that have missing information are a loss therefore consistency in the data recording system needs to be ensured. It is natural that some households will have problems in remembering their catch amounts and species composition. Therefore if it is realised during the survey that one sample is not fully representative, it should be discarded and a replacement sample taken. However, care must be taken that this strategy does not create a bias in the sampling. For example, discarding households that cannot remember their catch because they are infrequent fishers might result in only frequently fishing households being sampled.

The design of the questionnaire used allows ranking of the fishing areas and fishing methods. However information is not being recorded according to rank. Recording information in this manner would be recommended as this information would be useful for examining the catch composition. Some details on the number of gear used per household would also be useful.

Other qualitative information such as the number of fishers per household operating at one time could also be collected.

The questionnaires used in surveying Nasavusavu tikina had missing questions on fishing area and fishing methods. In order to achieve consistency in the survey a cross-examination of all the questionnaires should be carried out after the survey to ensure all information has been recorded in the proper manner.

Training of data recorders

“The backbone of a fishery survey is the field team of data recorders and their supervisors who form the primary interface between fishers and fisheries management” (FAO 2000). It is important that the data recorders should have a good understanding of the purpose and the utility of the survey. To ensure this, thorough training and re-training is required. Workshops and training courses concerning aspects of data recording would ensure positive contributions to survey planning and the revision of the survey design (FAO 2000). Currently the data recorders participate in meetings with USP and other NGOs regarding similar work-related issues. The survey team should be actively involved in such relevant trainings and workshops.

Supplementary information

For determining the stock status and sustainability of fishing habits, the total removal from a fishing ground needs to be determined. Apart from determining the total removal from subsistence fishers, the removal from commercial operators also needs to be known. Therefore it is necessary to sample some of the households that operate on a commercial

scale. Catch information of other licensed fishermen who are not residents of the village but have a permit to fish in the area would also be necessary.

Effectiveness of the field operations will directly affect the quality of the collected data. The quality of the data will affect its utility and statistical reliability. Poor data quality, even assuming sample predictability from stratification, cam limit any sample's value (Evans and Grainger. 2002). Therefore, during survey design it is better to establish accuracy indicators so that sample sizes can guarantee an acceptable level of reliability for the estimated data population parameters (FAO 1985).

The socio-economic survey is an ongoing programme and the effectiveness and the dependability of the statistics gathered should be ensured. The efficiency of the programme will be a direct function of ascertaining long-term sustainable use of the resources.

The ADB (2005) sector review expresses the concern that the marine resource inventory survey is too comprehensive and recommends that the survey needs to be more focused on the collection of information relevant to management needs. It was also recommended to focus on the *qoliqolis´* most at threat and/or which have the highest environmental values. This could greatly increase the effectiveness of the survey/management plan development process in managing risks associated with over-exploitation.

The unfeasibility of the survey strategy has been realised by the Department and a change in the scheme is being proposed. The Department will focus on sample surveys rather than complete survey of all the areas and will work in collaboration with NGOs and the USP to ensure that the objectives are attained within a realistic time frame.

An attempt was made to estimate the total removal by the subsistence fishery from all the coastal rural communities in Fiji, based on these samples. An estimate was made for coastal communities only as the samples were from coastal areas and assumed to be representative of all the coastal areas. An overall average catch/ household was calculated:

$$C_{av} = \sum C_{com} \; / \; \sum TH$$

where,
$\sum C_{com}$: Total catch for all communities surveyed combined
$\sum TH$: Total number of households for all communities combined.

The total catch for all coastal villages was obtained:

$$C_{Total} = C_{av} \; * \; H_{Total}$$

where,
H_{Total}: Total number of coastal village households in Fiji.

The total number of households were approximated from the population and household census and some additional qualitative information provided by FIBOS.

Some broad assumptions were made to calculate the number of rural coastal villages by province.

The order of the catch estimate obtained was slightly lower than the current estimate of the Department. However these assumptions and estimates were only based on the catch from these seven coastal communities. None of the samples were representative of the inland village households.

Fiji has over 800 rural communities.

This analysis can be regarded as a first step towards revising the current total subsistence catch estimate. Once additional samples are available from the socio-economic survey, provided they are truly representative of coastal, inland and outer island villages, the above technique can be applied to raise the estimate.

The communities can be divided into groups according to the geographical area. Average catch can be obtained for each group and the estimates raised by group using the above approach.

FIBOS will be conducting a population and household census in the end of 2006. An official arrangement can be made between DOF and FIBOS to also classify the villages as coastal or inland to ensure the reliability of the available statistics.

4.2 Conclusion

The socio-economic household questionnaire survey is an ongoing programme for evaluating the level of subsistence fishery in different communities throughout Fiji. The subsistence fishery is a major part of the lives of the village people and sustainable management of the fishery is necessary to safeguard the resources and in turn the livelihood of the people benefiting from it.

Some weaknesses were identified in the survey programme and recommendations were proposed for strengthening the survey.

Subsistence catches for seven communities were calculated. From the analysed samples some general fishing behaviour was identified between communities. All the communities across the island practice similar fishing methods. The two major fishing methods used were hand-lines and spears. Gill nets are also important in Vugalei village in the north. Subsistence fishery catch estimates indicate that the Namatakula community is heavily dependent upon fishing and catch a much wider variety of species than other communities. Lami is an urban community and therefore shows different fishing habits.

Similar analytical techniques can be applied to the samples from the other communities. Eventually samples, which are representative of all the rural communities involved in subsistence fishing, can be utilised in raising the subsistence fishery estimates for Fiji.

In order to develop an effective fisheries management and conservation plan for each fishing ground as directed by the Government, information from both subsistence and artisanal fisheries exploitation is required for each location.

5 TABLES

Table 1: Frequency of market sampling by month for artisanal catch in the western division in 2004.

	Sigatoka	Nadi	Lautoka	Ba	Tavua	Rakiraki
Jan	0	0	*7*	0	0	0
Feb	0	0	5	0	0	0
Mar	0	0	*13*	0	0	0
Apr	0	4	7	3	1	2
May	0	4	4	3	2	0
Jun	0	0	0	0	0	0
Jul	0	6	7	4	3	1
Aug	0	5	6	4	5	1
Sep	0	3	3	4	5	1
Oct	1	6	6	6	5	1
Nov	0	5	5	*6*	5	1
Dec	0	0	0	0	0	0

Table 2: Frequency of market sampling by month for artisanal catch in the western division in 2004.

Month	Sigatoka	Nadi	Lautoka	Ba	Tavua	Rakiraki
Jan	0	0	0	0	0	0
Feb	0	1	3	1	1	0
Mar	0	3	5	2	1	1
Apr	1	**6**	**6**	**6**	4	0
May	1	**5**	**6**	**6**	*6*	2
Jun	1	**5**	**5**	**6**	4	2
Jul	0	**5**	**6**	***7***	3	1
Aug	1	**6**	**6**	**6**	5	3
Sep	0	3	9	3	5	2
Oct	0	4	4	5	1	0
Nov	0	-	-	-	-	-
Dec	0	-	-	-	-	-

Table 3: Frequency of market sampling by month for artisanal catch in the central division in 2004.

	Navua	Korovou	Laqere	Nausori	Suva	Raiwaqa	Lami	Nabukulou Creek
Jan	0	4	4	4	0	0	0	0
Feb	0	0	0	0	1	0	0	1
Mar	0	0	5	0	*8*	0	0	*8*
Apr	0	6	9	5	10	0	0	0
May	0	2	8	3	9	0	0	0
Jun	0	0	0	0	2	0	0	0
Jul	0	6	6	6	*8*	0	0	*9*
Aug	0	5	5	7	3	0	0	2
Sep	0	4	14	5	2	0	0	2
Oct	0	0	18	3	0	0	0	0
Nov	0	3	22	5	0	0	0	0
Dec	0	0	0	0	0	0	0	0

Table 4: Frequency of market sampling by month for artisanal catch in the central division in 2004.

	Navua	Korovou	Laqere	Nausori	Suva	Raiwaqa	Lami	Nabukulou Creek
Jan	0	0	20	4	-	0	0	-
Feb	0	0	*11*	8	-	0	0	-
Mar	0	0	4	3	-	0	0	-
Apr	0	0	8	8	-	0	0	-
May	0	0	4	4	-	0	0	-
Jun	0	0	4	4	-	0	0	-
Jul	0	0	0	1	-	0	0	-
Aug	0	0	3	3	-	0	0	-
Sep	0	0	0	0	-	0	0	-
Oct	0	0	-	-	-	0	0	-
Nov	0	0	-	-	-	0	0	-
Dec	0	0	-	-	-	0	0	-

NB: Raiwaqa and Nabukulou creek are part of Suva but have separate market sites.

Table 5: The proportion of artisanal catch retailed through the major marketing sites in the central, western and northern divisions.

Central		**Western**		**Northern**	
Markets	**0.163**	**Markets**	**0.223**	**Markets**	**0.147**
Navua	0.006	Lautoka	0.120	Labasa	0.059
Lami	0.005	Ba	0.038	Savusavu	0.032
Raiwaqa	0.009	Tavua	0.015	Nabouwalu	0.023
Suva	0.096	Rakiraki	0.009	Seqaqa	0.018
Nausori	0.016	Nadi	0.028	Wainikoro	0.015
Laqere	0.025	Sigatoka	0.013		
Korovou	0.006				
Other Outlets	**0.202**	**Other Outlets**	**0.168**	**Other Outlets**	**0.095**
Total	**0.365**	Total	**0.392**	Total	**0.243**

Table 6: ANOVA two-factor model with interaction results for landed catch weight between, markets Lautoka, Ba & Nadi and days (Monday –Saturday) [DayN].

	Df	Sum Sq	Mean Sq	F Value	Pr(>F)
Market	2	36.567	7.319	23.449	1.537e-13 ***
factor(DayN)	5	30.048	15.024	48.132	1.101e-13 ***
factor(DayN):Market	10	10.053	10.053	3.221	0.001946 **
Residuals	83	20.913	0.312		

* indicates the level of significance of interaction

Table 7: ANOVA two-factor model with interaction results for landed catch weight between markets Lautoka, Ba and Nadi and months April to August 2005.

	Df	Sum Sq	Mean Sq	F Value	Pr(>F)
Market	2	30.3	15.15	17.093	9.014e-07 ***
factor(MonthN)	4	1.574	0.393	0.444	7.76E-01
Market:factor(MonthN)	8	3.698	0.462	0.5215	8.36E-01
Residuals	70	62.04	0.886		

Table 8: ANOVA one-factor model results for landed catch weight within markets Lautoka, Ba and Nadi.

	Df	**Sum Sq**	**Mean Sq**	**F Value**	**Pr(>F)**
Market L					
factor(DayN)	5	9.866	1.973	11.794	9.836e-06 ***
Residuals	23	3.848	0.167		
Market B					
factor(DayN)	5	16.083	3.216	5.978	0.001104 **
Residuals	23	12.375	0.538		
Market N					
factor(DayN)	5	20.448	4.089	18.314	5.046e-07 ***
Residuals	21	4.689	0.223		

Table 9: Allocation of markets and days to the four identified clusters.

	Mon	Tues	Wed	Thurs	Fri	Sat
Cluster 1						
Ba	3	2	4	2	2	0
Lautoka	0	0	0	0	0	0
Nadi	0	2	0	2	1	0
Cluster 2						
Ba	0	3	1	2	3	5
Lautoka	5	2	0	0	0	0
Nadi	3	2	4	2	3	0
Cluster 3						
Ba	0	0	0	0	0	0
Lautoka	0	1	1	0	4	5
Nadi	0	0	0	1	0	4
Cluster 4						
Ba	0	0	0	0	0	0
Lautoka	0	1	4	5	1	0
Nadi	0	0	1	0	1	1

Table 10: ANOVA two-factor model results for total landed catch weight (TTW) and total number of landed species (TN) between the four identified clusters.

Response: log(TTW)	Df	Sum Sq	Mean Sq	F value	Pr(>F)
factor(gp)	3	47.917	15.972	75.359	2.2e-16 ***
log(TN)	1	16.413	16.413	77.436	3.579e-13 ***
factor(gp):log(TN)	3	0.472	0.157	0.742	0.5304
Residuals	75	15.896	0.212		

Table 11: Bootstrap estimates for total landed mean catch (kg) per day and standard deviation for markets, Lautoka, Nadi and Ba and the coefficient of variation of sampling.

Market	n	Mean	sd	CV
Lautoka	29	1130.35	149.44	13.22
Ba	29	335.08	50.91	15.19
Nadi	27	460.36	97.1	21.09

Table 12: Subsistence catch evaluation by community.

Village	**TH**	**TP**	**HS**	**PS**	**FM**	**FH**	**AvC**	**C_{com} [t]**	**CV**
Namatakula	61	241	46	196	2.27 ± 0.48	0.98	2.46	151.06 ± 26.59	17.06
Komave	27	164	3	15	2.00 ± 0.29	1.00	0.74	19.89	-
Taqage	32	199	6	41	2.00 ± 0.26	1.00	0.97	30.85 ± 7.35	23.84
Lami	226	1,599	38	65	2.30 ± 0.30	0.68	0.24	24.54 ± 7.06	28.79
Suvavou	102	619	10	113	1.08 ± 0.19	1.00	0.19	43.51 ± 8.91	2.82
Vugalei	5	25	7	43	1.57 ± 0.20	1.00	0.97	1.82 ± 0.78	42.78
Nasavusavu	1892	10025	29	148	1.86 ± 0.28	0.93	0.58	1095.89 ± 246.91	22.53

Key:

TH: Total number of households in the community
TP: Total population of the community
HS: Number of households surveyed
PS: Population surveyed
FM: Mean number of fishers per household with standard error
FH: Proportion of fishing households
AvC: Average catch per household in the community
C_{com} [t]: Total catch (tonnes) and standard deviation by community
CV: Coefficient of variation of the survey

6 FIGURES

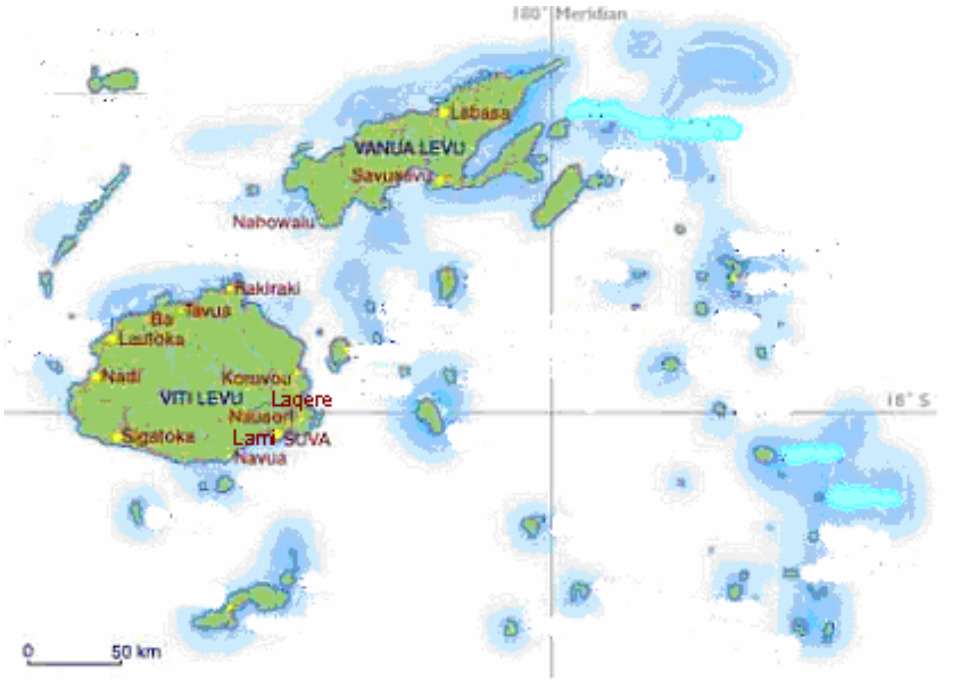

Figure 2: Map of Viti Levu and Vanua Levu showing the market sampling sites.

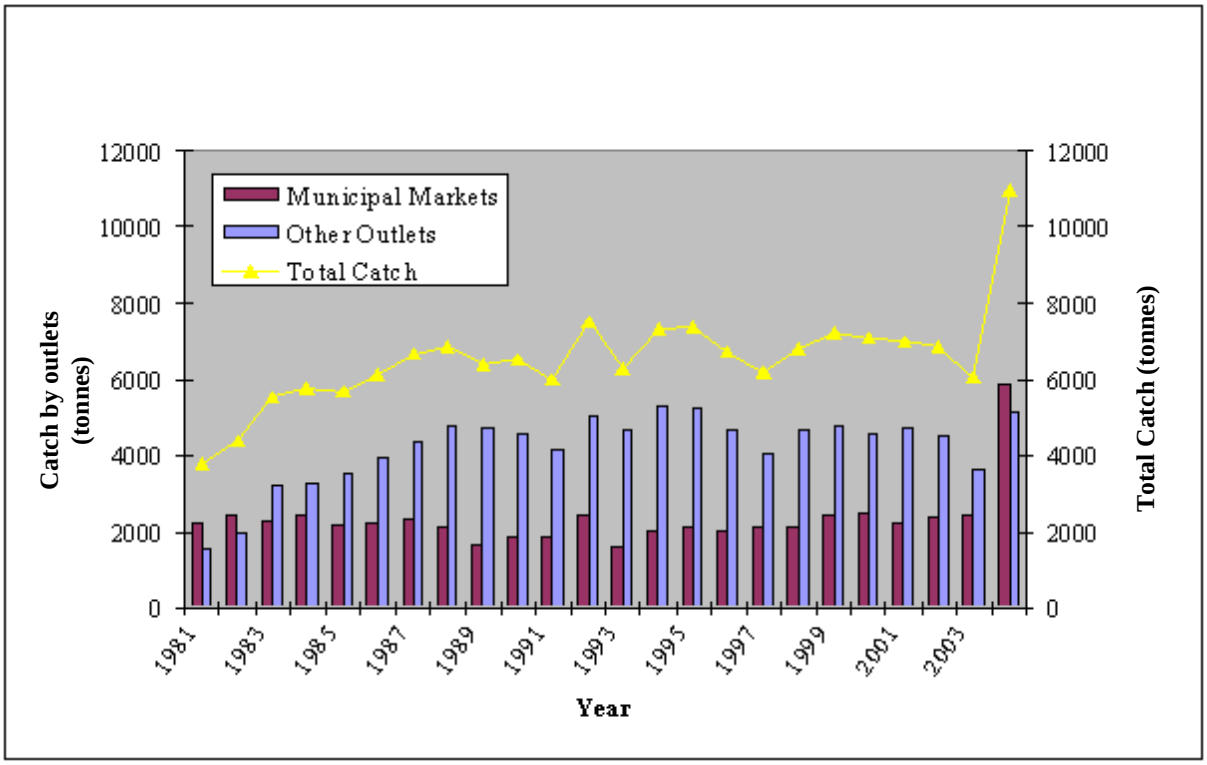

Figure 3: A trend in the total landed artisanal catch by markets and other outlets from 1981-2004.

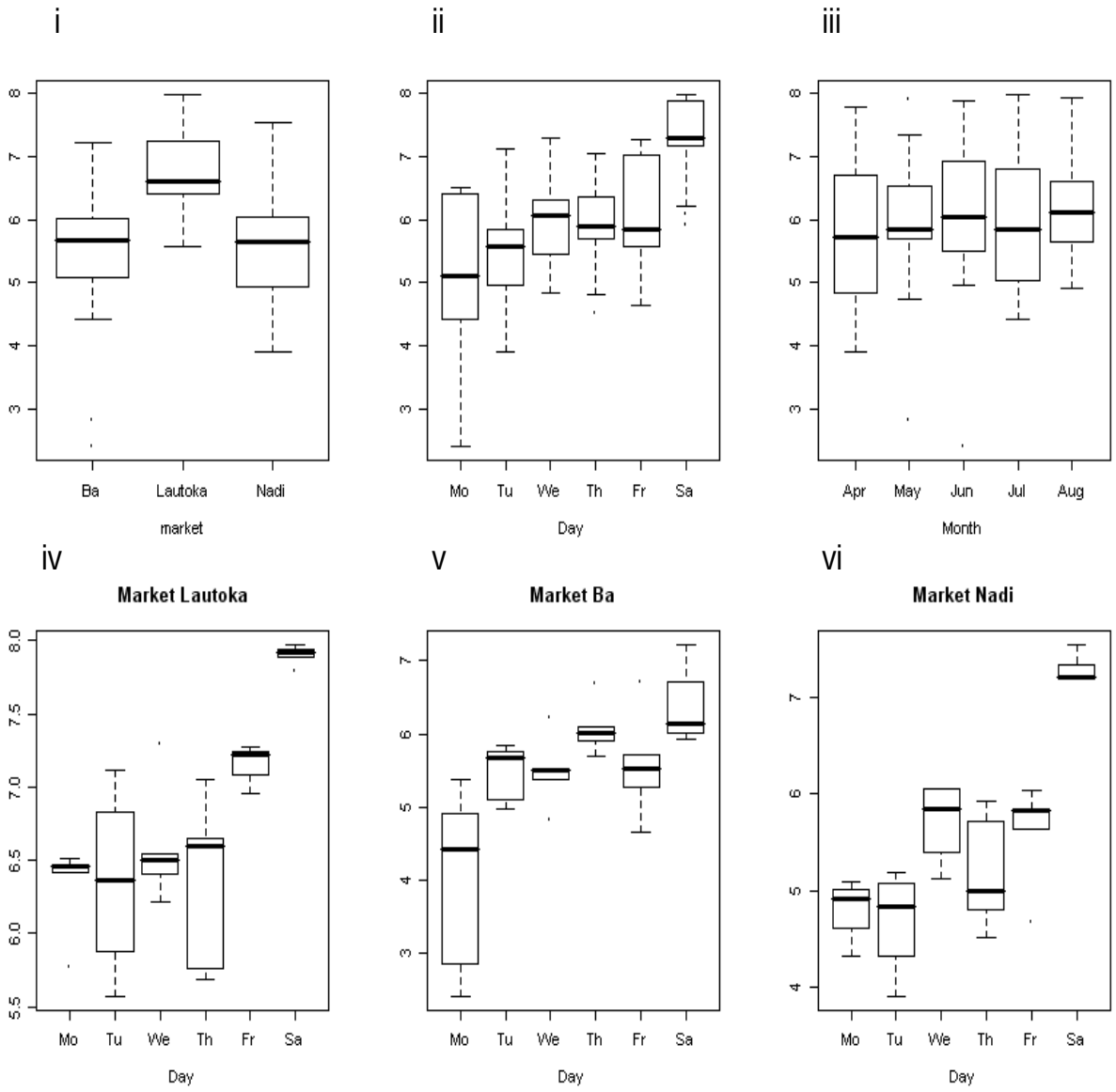

Figure 4: Box plots of log-transformed total landed catch weight by (i) market (ii) day (iii) month (iv) days within Lautoka market (v) days within Ba market (vi) days within Nadi market.

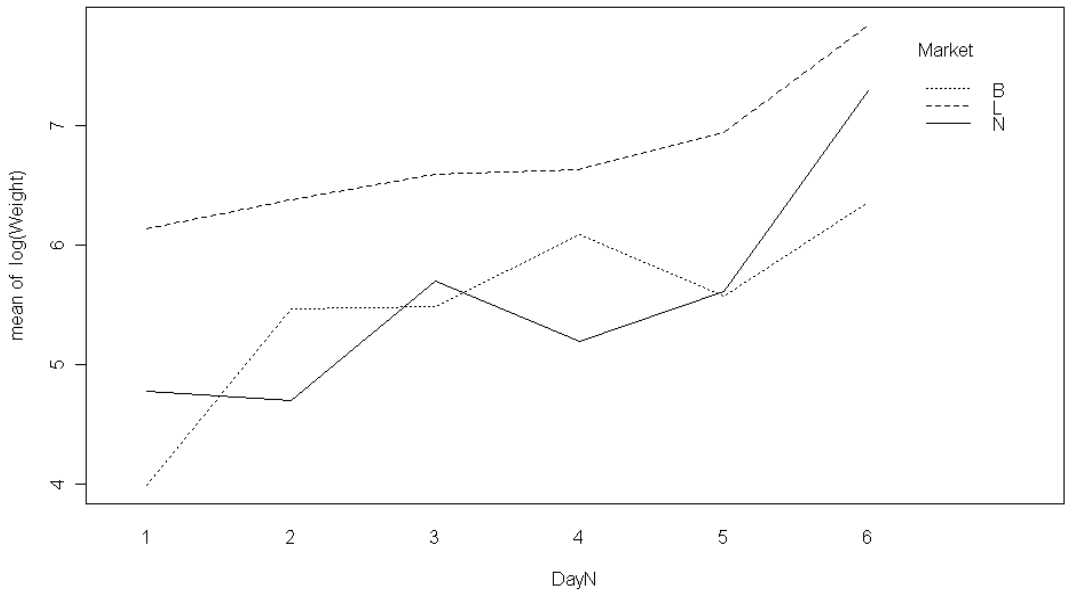

Figure 5: ANOVA interaction between markets Lautoka, Ba, Nadi and days (Monday – Saturday) for total landed catch weight.

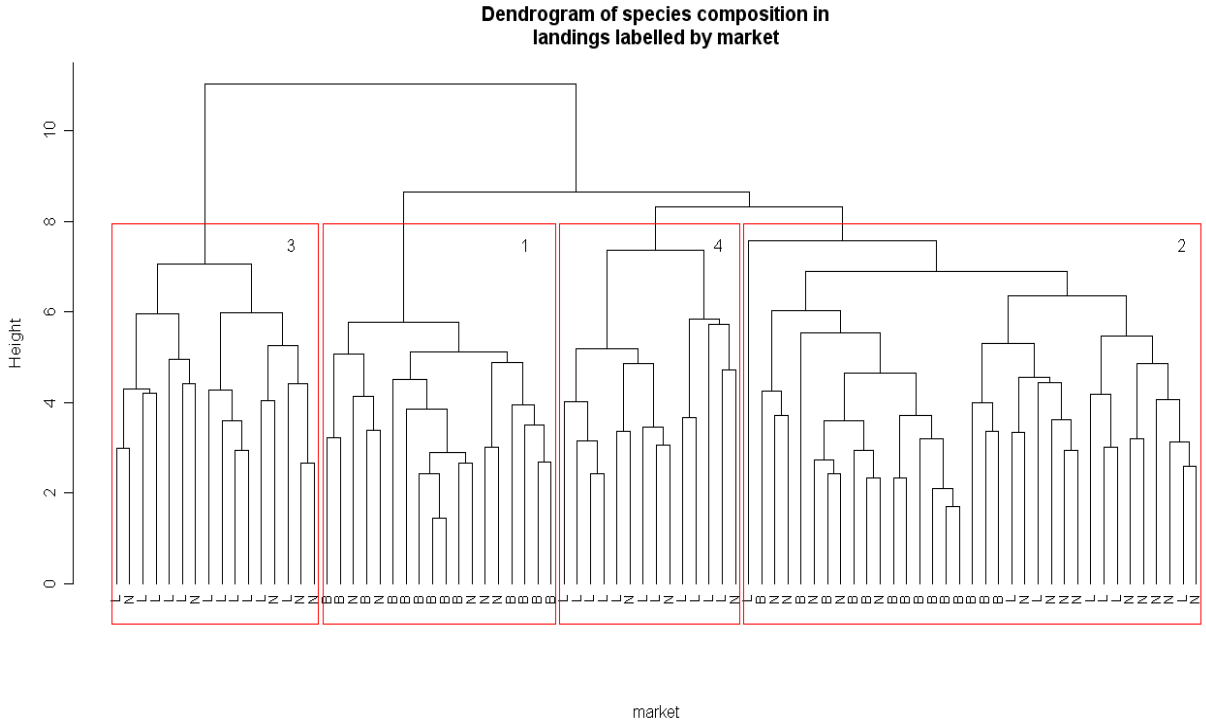

Figure 6: Dendrogram of species assemblage - labelled by market.

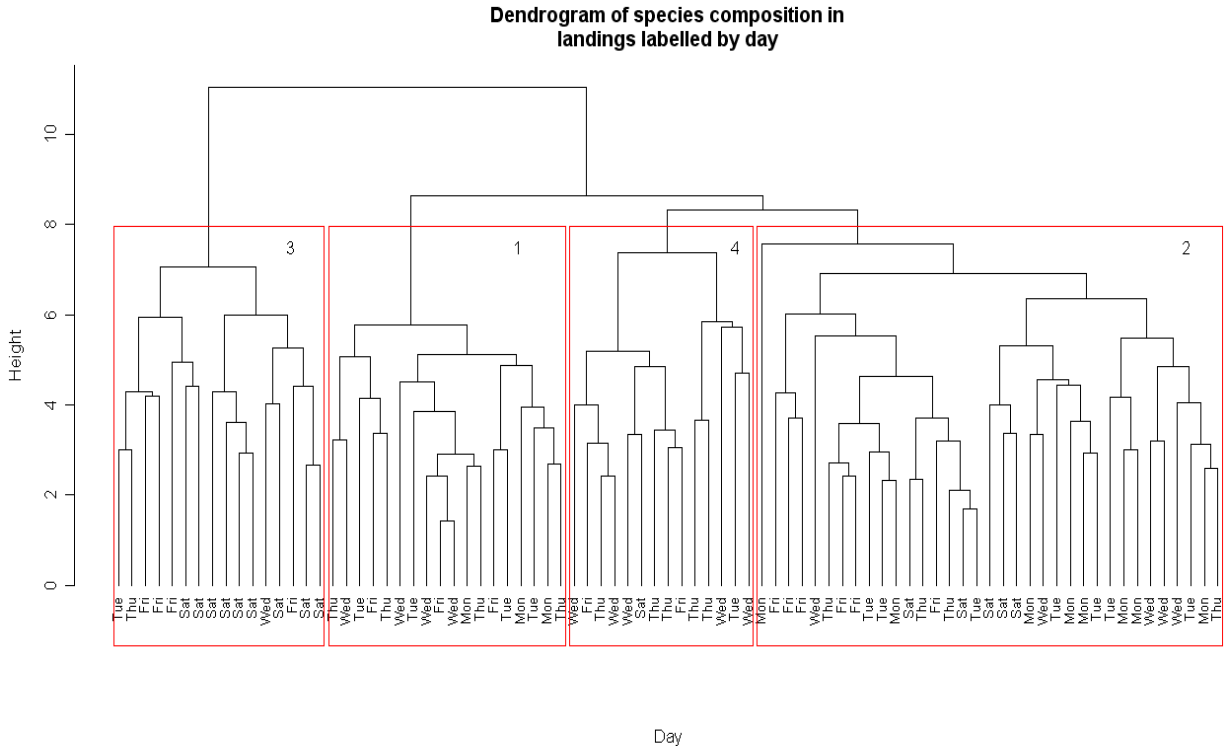

Figure 7: Dendrogram of species assemblage - labelled by days.

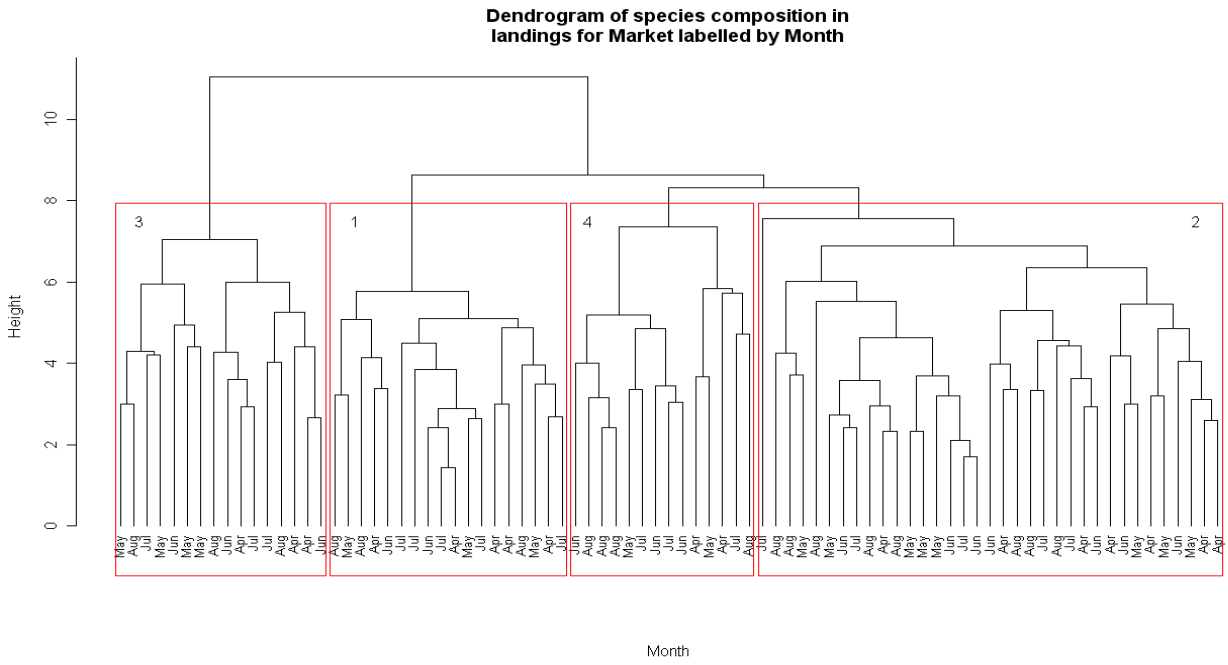

Figure 8: Dendrogram of species assemblage - labelled by month.

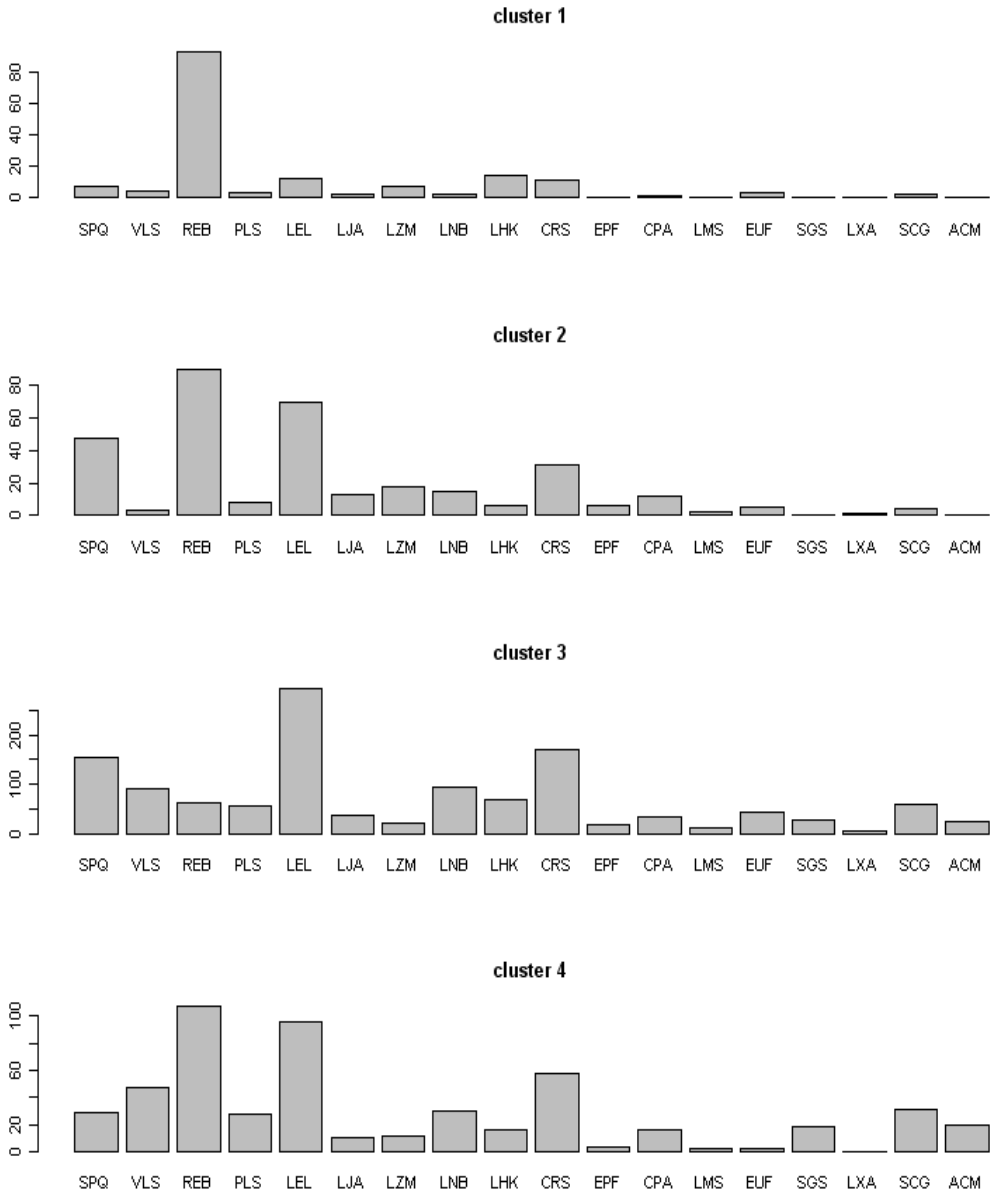

Figure 9: Distribution of the total catch of the 18 major species studied (obtained by sum of all observations in each cluster) for the four identified clusters.

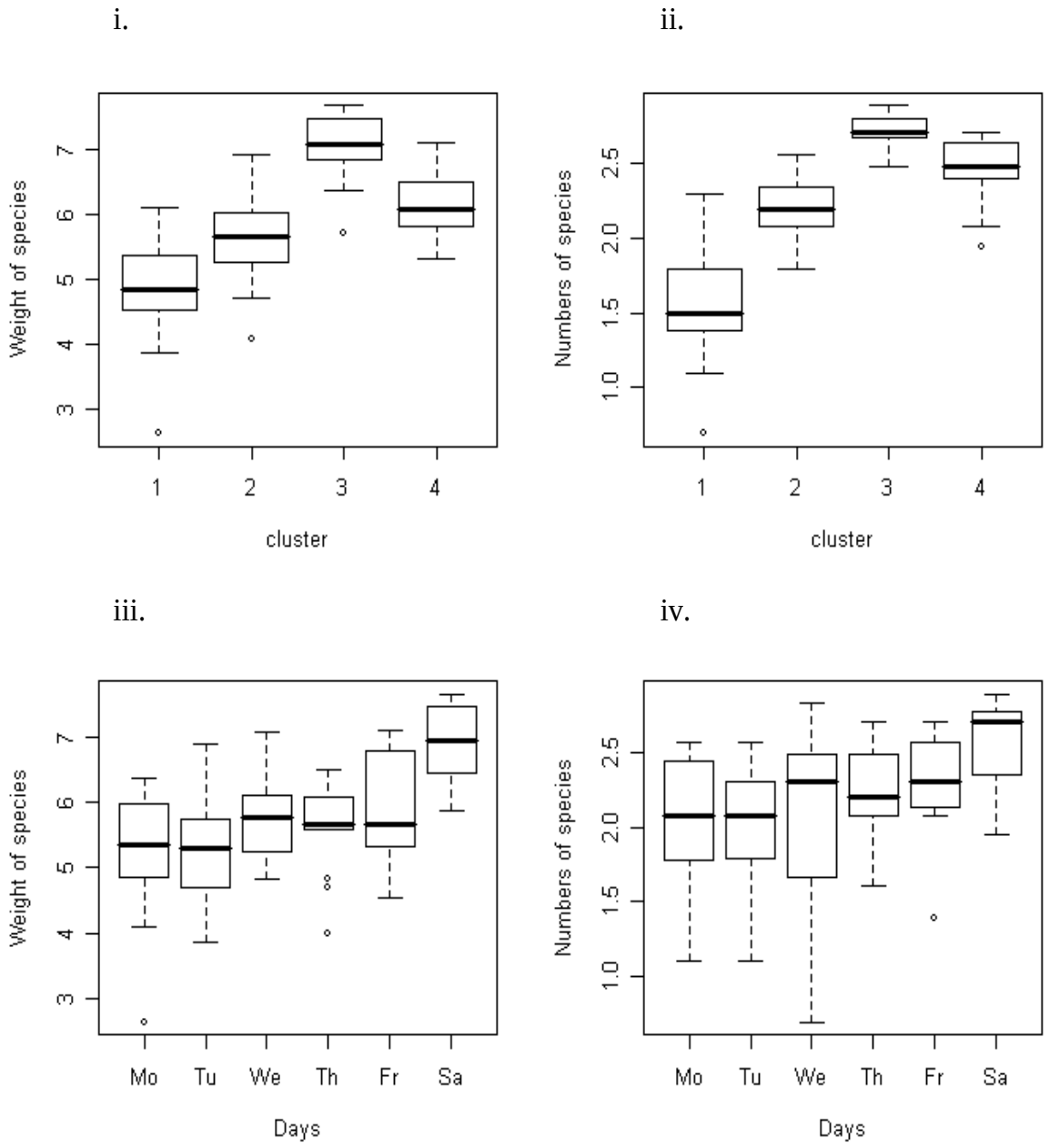

Figure 10: Box-plots of log-transformed total landed catch weight by (i) cluster (iii) day & total number of species landed by (ii) cluster (iv) day.

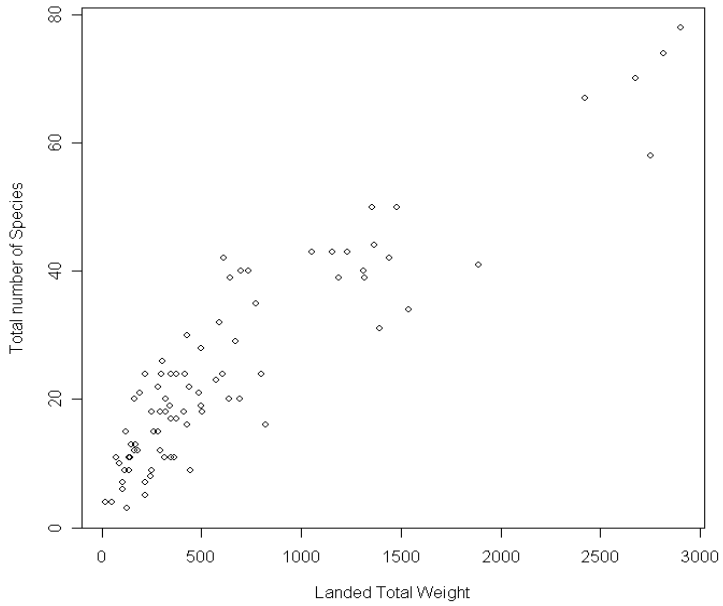

Figure 11: Correlation between landed catch weight and total number of species in the landed catch for markets Lautoka, Ba and Nadi combined.

Figure 12: Map showing the locations of the surveyed communities for which subsistence catch was estimated.

7 ACKNOWLEDGEMENTS

My sincere gratitude goes to Dr. Einar Hjörleifsson for his continual supervision throughout this study and for his words of wisdom and encouragement.

Dr. Lorna Taylor provided her technical guidance and assistance throughout for which I am immensely grateful.

I am earnestly thankful to my senior officers and my colleagues at work for making available the required data and other qualitative information.

I would also like to acknowledge the co-ordinating team of the United Nations University Fisheries Training Programme, Dr. Tumi Tómasson, Mr. Þór Ásgeirsson and Ms. Sigriður Kr. Ingvarsdóttir for making me a part of this training programme, which has been extremely beneficial, and for their support and guidance all the way through.

8 LIST OF REFERENCES

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9 APPENDIX

Appendix 1a: Artisanal Fishery Market Data Collection form

MINISTRY OF FISHERIES AND FORESTS
Fisheries Division
P.O. Box 3165, Lami, Fiji

Name of Market:…… **Time In:……** **Name of Recorder:……**

Date/Day:……. **Time Out:…….**

Fish Species	Total number of particular species	Total Weight (kg)	Average Length (cm) (Standard length)	Selling Price per kg ($)	Fishing Location

COMMENTS:

Appendix 1b. Artisanal fishery other outlets data collection form

FISHERIES DEPARTMENT
P.O. BOX 3165,
LAMI,
FIJI ISLANDS.

Phone: 3361122; 3361479
Fax: 3361184; 3363170

Please provide the purchase details for the required month.

Month: _____ Attention: _____

Outlet: _____ Purchasing Officer: _____

SPECIES	Total Weight (kg)	Selling Price/kg	Fishing Area *(If applicable)*
FISH			
INVERTEBRATES			

(Fishing Area: Location of catch)

Appendix 1c: Fisheries Department Fishing License Questionnaire (DOF 2005)

19. What are the main types of non-fish (shellfish, lobster, crab etc.) that you usually catch?

---

20. Are any of these becoming more common or less common? (state which) _____

---

21. Who do you sell your catch to, and where? _____

LICENCING OFFICER _____

Appendix 2a: Tukey multiple comparison tests for analysis of total catch variations

i. ii. iii.

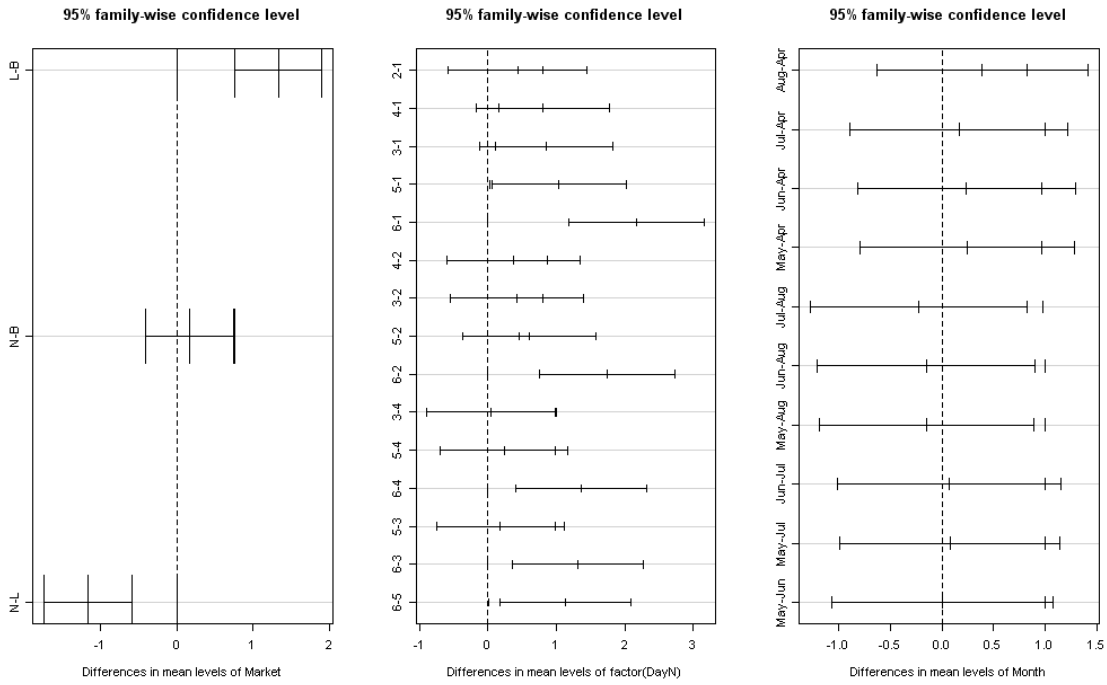

Figure 13: Tukey test results for (i). markets Lautoka Ba and Nadi (ii). days Monday-Saturday (iii.) months April - September.

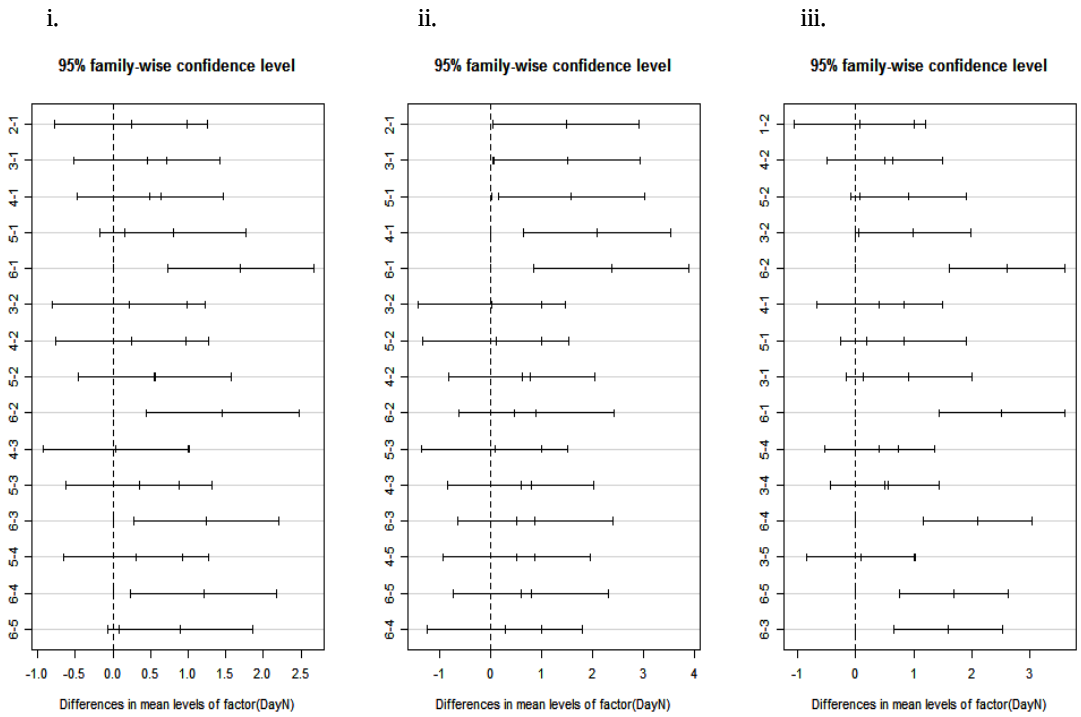

Figure 14: Tukey test results for days within market (i). Lautoka (ii). Ba (iii). Nadi

Appendix 2b: List of 18 major species utilised for analysis of catch composition

Table 13: Eighteen major species used for studying species assemblage in the hierarchical cluster analysis.

Code	Scientific name	Fijian name	Common name
LEL	*Lethrinus elongatus*	Dokonivudi	Long-nosed emperor
SPQ	*Sphyraena qenie*	Oqo	Dark finned barracuda
LNB	*Lethrinus nebulosus*	Kawago	Spangled emperor
CRS	*Caranx sp.*	Saqa	Trevally
SCG	*Scarrus ghoban*	Ulavi	Parrot fish
REB	*Restrelliger brachysoma*	Salala	Chub mackerel
LHK	*Lethrinus harak*	Kabatia	Thumbprint emperor
VLS	*Valamugil seheli*	Kanace	Blue-tail mullet
PLS	*Plectropomus sp.*	Donu	Coral Trout
CPA	*Cephalopholis argus*	Kawakawa	Rockcod
LJA	*Lutjanus argentimacalatus*	Damu	Mangrove jack
LMS	*Lethrinus mahsena*	Sabutu	Yellow-tailed emperor
SGS	*Siganus sp.*	Nuqa	Rabbit fish
EPF	*Epinephilus fucus*	Kasala	Marbled cod
LXA	*Lethrinus xanthochilus*	Kacika	Slender emperor
ACM	*Acanthurus mata*	Balagi	Surgeon fish
LZM	*Liza melinoptera*	Molisa	
EUF	*Euthynnus affinis*	Mackerel Tuna	Mackerel Tuna

Appendix 2c: Relationship between the total landed catch weight and total number of species

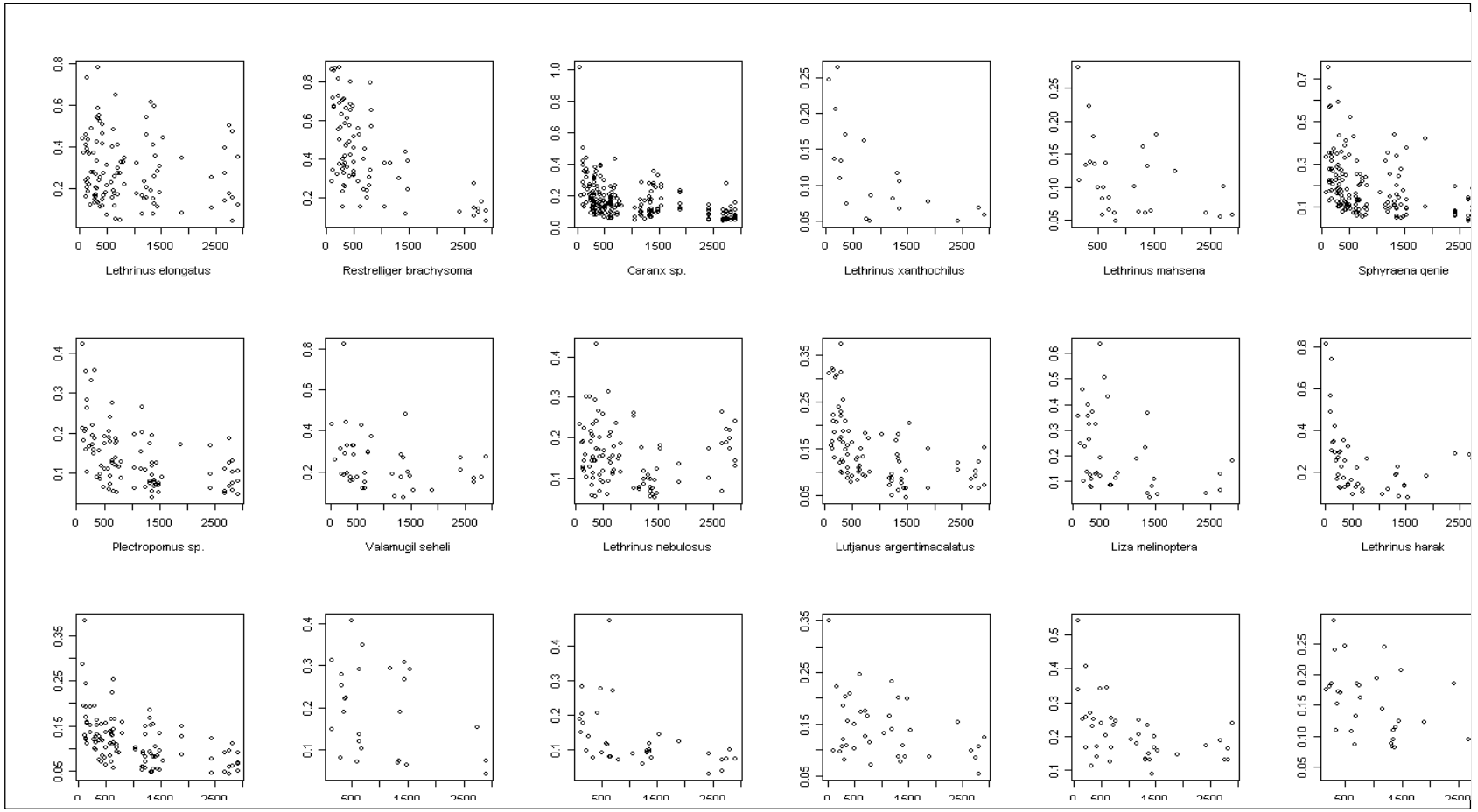

Figure 15: The relationship between landed catch weight and proportion to total landed catch weight for the eighteen major studied species for markets Lautoka, Ba and Nadi combined.

Appendix 3: Household Survey Questionnaire used in the socio-economic survey conducted by the Fisheries Department for the 7 studied communities (DOF 2005)

FISHING INTERVIEW SURVEY QUESTIONNAIRE

Confidential

SECTION 1: RESPONDENTS IDENTIFICATION

1. INTERVIEWER		2. CODE NUMBER	
3. DATE		4. TIME	
5. VILLAGE		6. TIKINA	
7. AREA CODE		8. RESPONDENT	
9. HOUSEHOLD STATUS		10. RACE	

SECTION 2: PERSONAL AND SOCIOECONOMIC

1. NUMBER PERMANENTLY LIVING IN HOUSEHOLD

2. COMPOSITION OF HOUSEHOLD:-

	NUMBER	AGES
ADULT MALE		
ADULT FEMALE		
CHILD MALE		
CHILD FEMALE		

3. HOUSEHOLDS MAIN SOURCES OF INCOME:

	RANK	SEASON
SALE OF MARINE/FRESHWATER PRODUCTS		
SALE OF COPRA		
FARMING		
WAGE EMPLOYMENT		
OWN BUSINESS		
OTHER		

4. IF MARINE/FRESHWATER PRODUCTS ARE SOLD, THEN HOW OFTEN?

HOW OFTEN? FREQUENTLY (> 1/WEEK)

OCCASIONALLY (> 1/ MONTH)

INFREQUENTLY (< 1/ MONTH)

5. WHAT TYPES OF MARINE/FRESHWATER PRODUCTS ARE SOLD?

	RANK	TO WHAT MARKET?	AT WHAT PRICE? DOLLARS/AMOUNT	HOW MUCH/HOW OFTEN AMOUNT/TIME PERIOD
FISH			/	/
SHELLFISH			/	/
BECHE-DE-MER			/	/
SHARK FIN			/	/
SHELLS			/	/
OTHER			/	/

6. MEMBERS OF THE FAMILY WHO GO FISHING AND HOW OFTEN DO THEY MAKE FISHING TRIPS?

	NUMBER	3-7 WEEK	1-2 WEEK	> 1 MONTH	<1 MONTH
ADULT MALE					
ADULT FEMALE					
CHILD MALE					
CHILD FEMALE					

7. AMOUNT OF FISH CAUGHT BY HOUSEHOLD WHICH IS CONSUMED BY THE HOUSEHOLD?

ALL

SOME

NONE

8. IF NOT ALL WHAT ABOUT REST — RANK

SOLD

GIVEN TO FAMILY

GIVEN TO FRIENDS

GIVEN TO ANIMALS

OTHERS

SECTION 3: FISHING METHODS

1. WHAT ARE THE MAIN FISHING METHODS USED BY THE MEMBERS OF THE HOUSEHOLD?

	RANK	BY WHO	USUAL TIME	MOON PHASE	JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
HAND LINE					
DROP LINE					
TOW LINE					
GILL NET (SET)					
GILL NET (DRIVE)					
SPEAR					
COLLECTION					
DUVA					
YAVIRAU					
QOLI SAMU					
FISHING POLE					
CAST NET					
PUSH NET					
CRAB TRAP					
OTHER					

2. WHAT IS THE MAIN HOOK BAIT USED?

	RANK
CRAB	
SQUID/OCTOPUS	
SMALL FISH	
LARGER FISH	
OTHER	

3. DOES ANYONE IN YOUR HOUSEHOLD USE LIGHTS DURING ANY OF THEIR FISHING OPERATIONS? YES or NO [ ]

IF YES, GIVE DETAILS?

SECTION 4: FISHING ASSETS

1. NUMBER POSSESSED BY HOUSEHOLD?

	NUMBER	SIZE
HAND LINE		
DROP LINE		
TOW LINE		
SPEAR (GUN)		
SPEAR (HAND)		
DIVING GOGGLES		
GILL NET		
PUSH NET		
FISHING POLE		
U/W TORCH		
SCUBA GEAR		
OTHER		

2. NUMBER POSSESSED BY HOUSEHOLD?

	NUMBER	BOAT SIZE			ENGINE HP
PADDLE CANOE					
MARINE PLYWOOD BOAT					
FIBREGLASS BOAT					
LOCAL WOODEN PUNT					
FAO DESIGN					
OTHER					

3. NUMBER OF ICE BOXES OWNED BY HOUSEHOLD?

	NUMBER
HOMEMADE ICEBOX	
PLASTIC ESKIES	

4. DOES YOUR HOUSEHOLD USE ICE? YES [ ] NO [ ]

5. IF YES, FROM WHERE?

Appendix 4a: Details of fishing behaviour for the studied communities.

Namatakula Village

57% of the households' fish 1 – 2 times per week while 33% of the households' fish 3 – 4 times per week. The remaining are not frequent fishers. The time spent out at sea is between 1 – 4 hrs by majority of the fishers. Only a small fraction of the population spends longer hours at sea. The most targeted habitats for fishing are the shoreline and lagoon (shallow and deep water). Some fishing takes place among the mangroves but only a few people fish on and outside the reef. The dominant gears used are hand lines and spears. Some fishermen also use duva (poison) and gillnets. The villagers consume fish 1 – 3 times per week on average. Apart from consuming fresh catch, 5% of the households also report consuming canned fish. Two commercial fishermen operate in this community. 2 households possess fishing licenses.

Komave

Fishing is carried out 1 – 2 times per week with trip duration between 1 – 4 hours. Fishing occurs along the shoreline and lagoon area (shallow and deep water). The dominant gears used are hand lines and spears. Fish consumption rate is 1 – 3 times per week on average. One household reported consuming canned fish apart from consuming fresh fish. No commercial fishermen are in operation in this area. None of the households have fishing license.

Taqage

Fishing is carried out 1 – 2 times per week with the fishers spending 1 – 4 hours at sea mainly. Fishing occurs along the shoreline and lagoon area (shallow and deep water). The dominant gears used are hand lines and spears, with some fishers using gillnets. Fish consumption rate is 1 – 3 times per week on average with one reported case of consuming fish everyday. All the households' sampled eat canned fish also apart from fresh fish that they catch. No commercial fishermen are in operation. None of the households have fishing license.

Lami

Majority of the households carry out fishing activities 1 – 2 times per week. Approximately 13% are more frequent fishers making fishing trips 3 – 4 times per week and 13% are less frequent fishers who go fishing once or twice a month. 32% of the households are non-fishers and have wage employment. Majority of the fishers carry out fishing between 1- 4 hours with some 30% spending between 4 – 12 hours out at sea. The major fishing area is the lagoon (shallow and deep water). Some fishers target the reefs and some fish along the shoreline and among mangroves. The

dominant gear used is hand lines. Few households use spears, gillnets and do hand collection. Fish consumption rate is 1 – 3 times per week for 54% of the reported households. 40% of the households reported consuming fish once a week and few households eat fish 4 – 6 times a week. Both fresh and canned fish are consumed by most of the households. 1 household operates on a commercial basis.

Suvavou

Generally fishing is carried out in the lagoon and occasionally along the shoreline, reef and estuary. The sample indicates that majority of the households' fish 1 – 2 times per week and mostly with trip duration between 1 – 4 hours. However a third of the fishers are out at sea for longer, between 4 – 12 hours Fish consumption rate is 1 – 3 times per week. Some households consume fish once a week. 35% of the sampled households reported consuming canned fish also. 2 households possess a fishing license.

Vugalei

Vugalei is a small rural village located in Labasa Tikina, with a population of 25 people and 5 households according to the 1996 census. Males and females are equally involved in fishing. The mean number of people fishing per household is 1.57 ± 0.20 with an estimated average catch of 0.19 tonnes per household. The total subsistence catch was estimated at 1.82 ± 0.78 tonnes. (Table …) The targeted habitats are shoreline and lagoon with occasional fishing among mangroves. Most of the households (70%) spend between 1 – 4 hours fishing and while the fish for longer hours. Fish consumption rate is 1 – 3 times per week for 60% of the community and the remaining households consume fish 4 – 6 times per week. Majority of the households (85%) also consume canned fish apart from the fresh catch. None of the households are commercial fishers.

Nasavusavu

Nasavusavu area is a combination of rural and urban settlements. The area is dominated by rural villages and only 30% of the households are in the urban area. This Tikina is a part of Cakaudrove province located in Vanua Levu and comprises of 1892 households and a population of 10,025 with males and females are being equally involved in fishing. The mean number of people fishing per household is 1.68 ± 0.28 with an estimated average catch of 0.58 tonnes per household. The total subsistence catch was estimated at 1095.89 ± 246.91 tonnes. (Table …) The fishermen mostly target the shoreline and shallow lagoon. Some fishing is also carried out among mangroves and deep lagoon. Most of the households (70%) spend between 1 – 4 hours fishing and the rest spend 4 – 12hours. About 60% households consume fish 1 – 3 times and the remaining households consume fish 4 – 6 times per week. Majority of the households (85%) also consume canned fish apart from the fresh catch. There are 8 fishing license holders in this area.

Appendix 4b: Distribution of the catch, length of fishing trip, number of fishing trips & relationship between number of trips and catch/trip for the 7 studied communities

***Key**: NM – Namatakula, KV – Komave, TQ – Taqage, VG – Vugalei, SU – Suvavou, LM – Lami, NS – Nasavusavu*

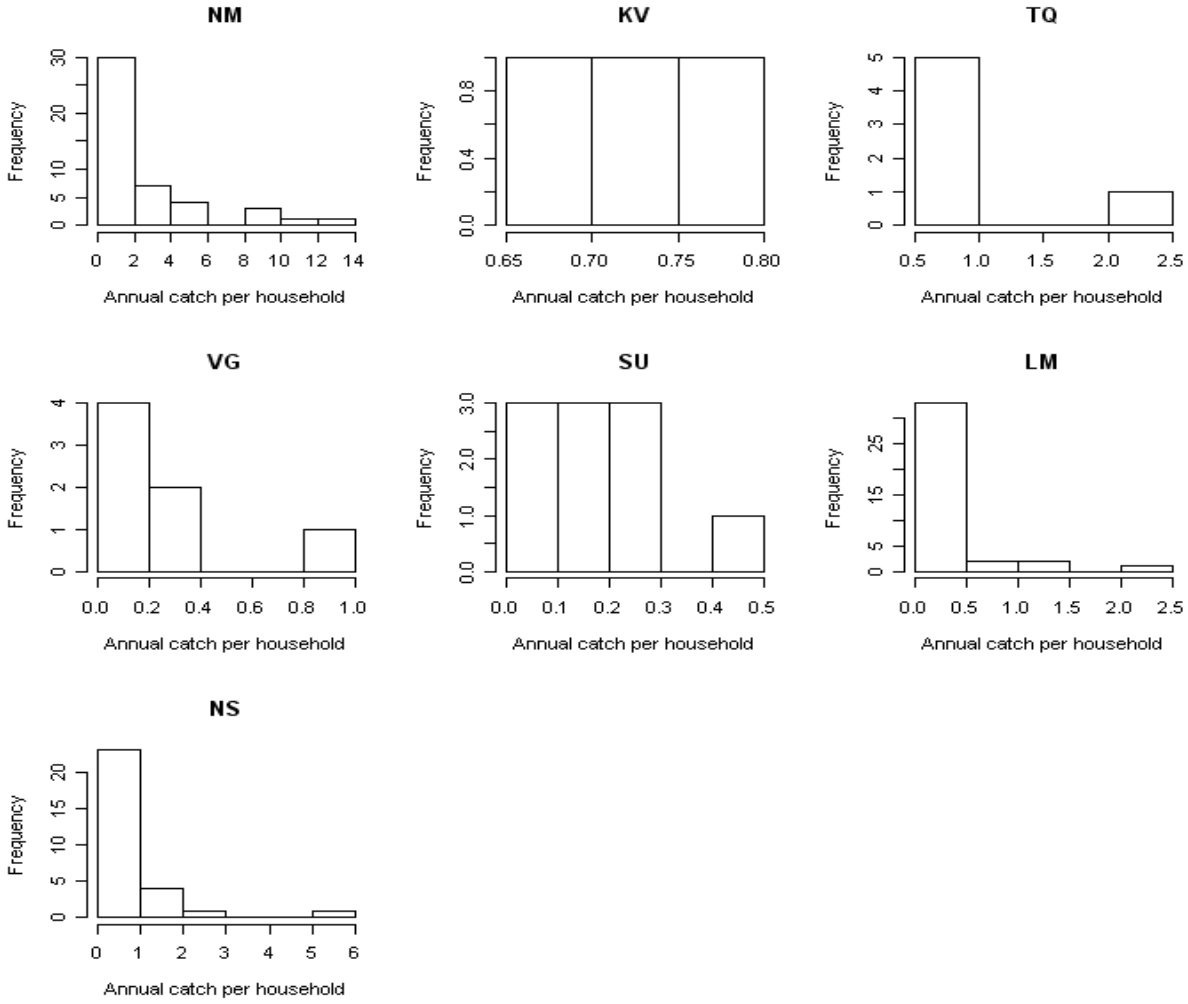

Figure 16: Distribution of the annual catch per household for the 7 communities

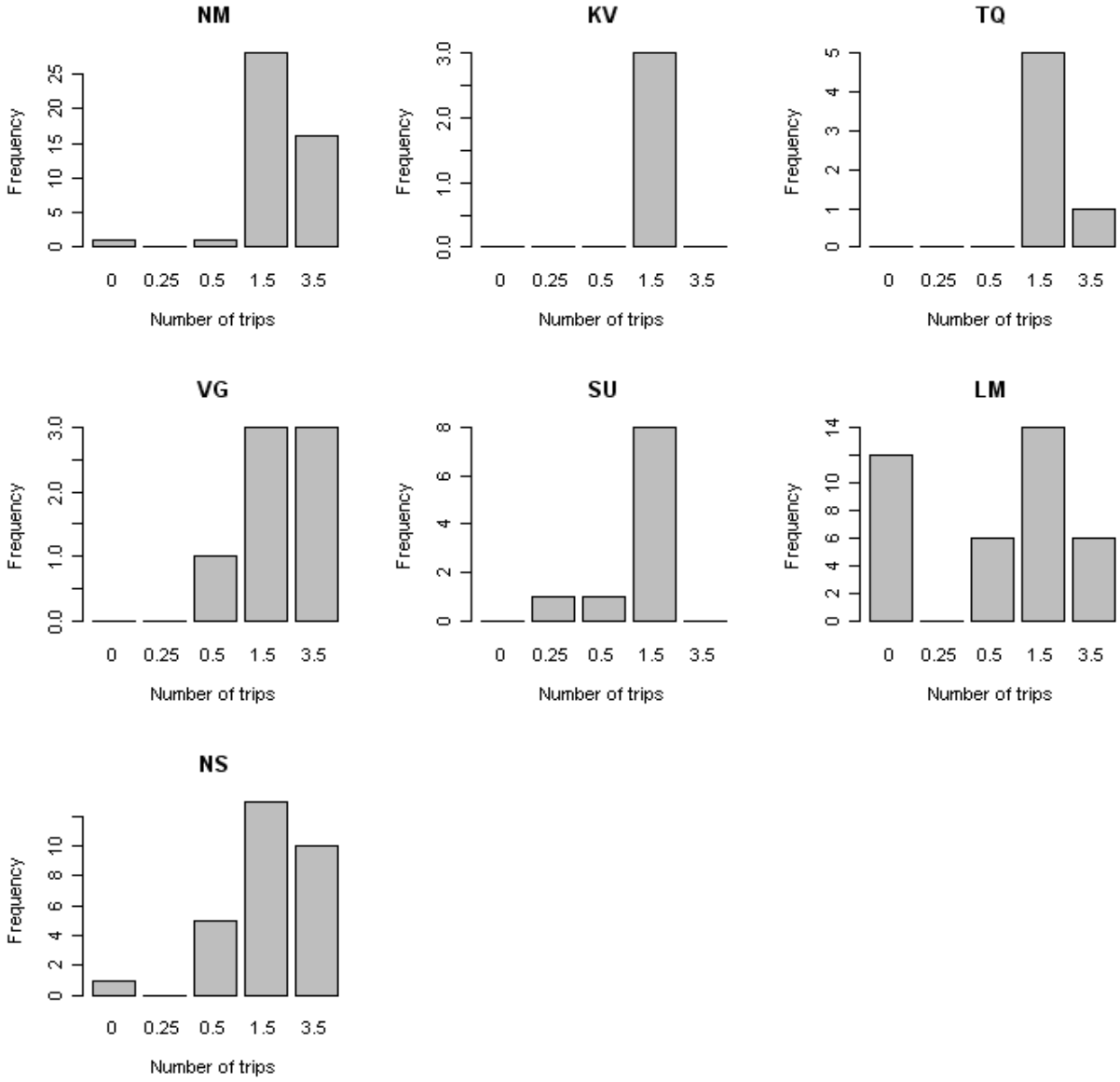

Figure 17: Distribution of the number of fishing trips per household for the 7 studied communities.

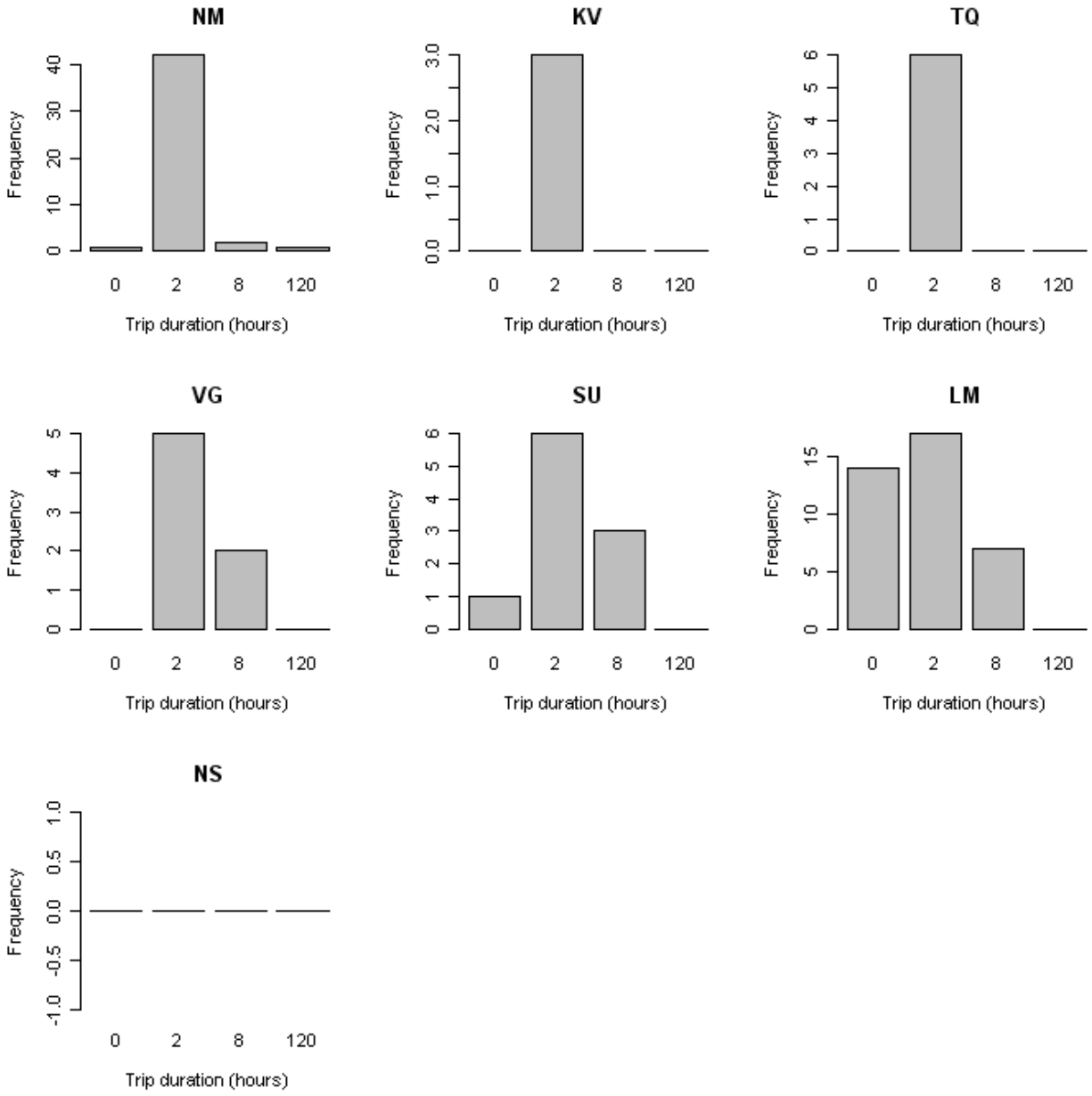

Figure 18: Distribution of the fishing trip duration per household for the 7 studied communities.

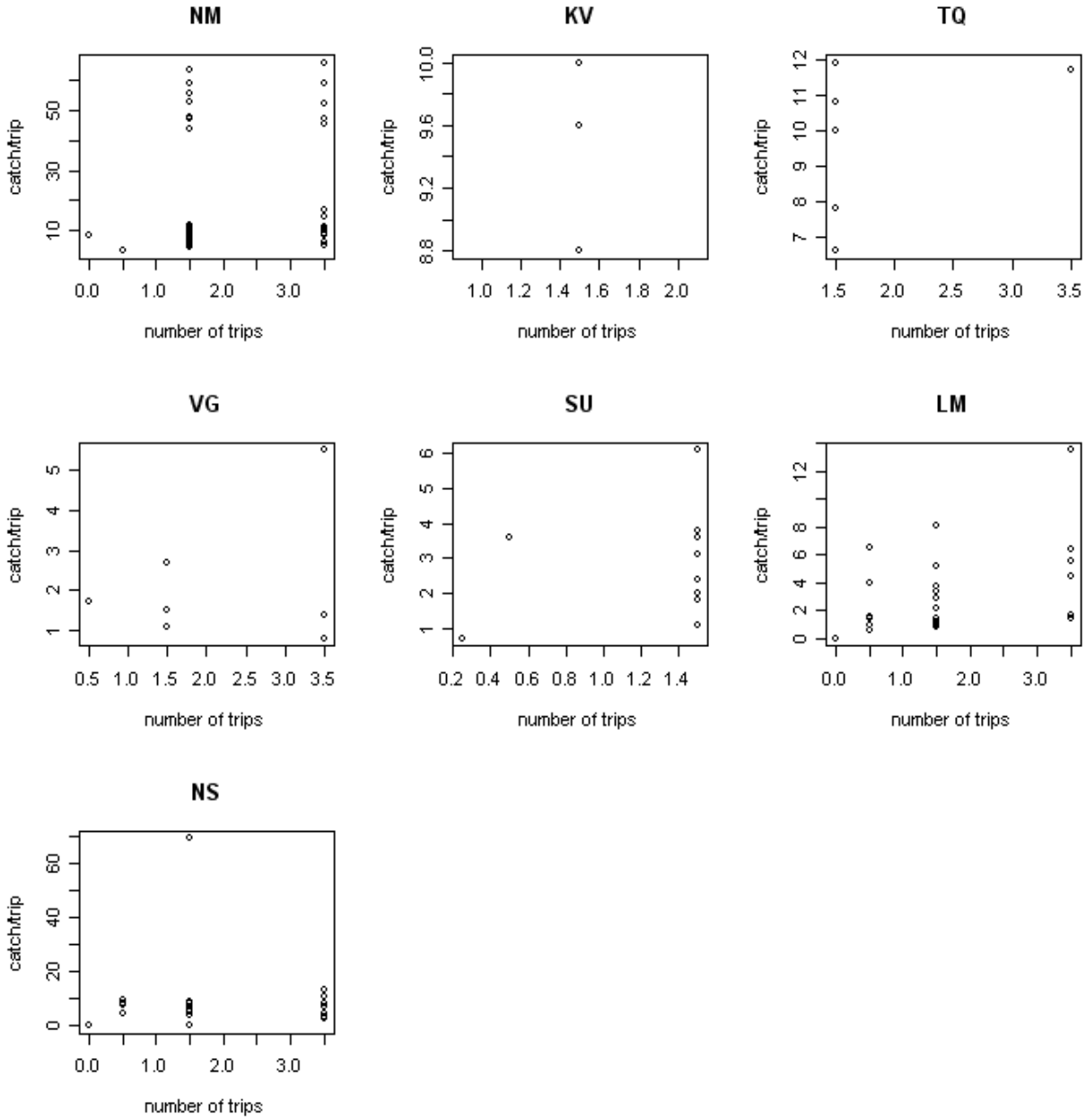

Figure 19: Relationship between the number of trips and catch/trip for the 7 studied communities.

Appendix 4c: Subsistence catch by species

Table 14: Estimated Subsistence catch [tonnes] by species for the 7 studied communities.

Fijian Name	Scientific Name	Common Name	NM	KM	TQ	LM	SU	VG	NS
Balagi	Acanthurus mata	Surgeon fish	0.04			0.15			34.20
Busa	Hemirhamphus far	Barred garfish				0.70			1.50
Corocoro	Myripristis violaceus	Soldier fish	0.05						
Cumu	Pseudobalistes flavimarginatus / Balistapus undulatus	Trigger fish	0.06						
Damu	Lutjanus argentimacalatus	Mangrove Jack	0.22			1.00	1.23	0.23	4.14
Daniva	Herklotsichthys quadrimaculatus	Goldspot herring							0.02
Donu	Plectropomus sp.	Big-spotted coral trout, Coral trout	0.86						24.10
Kabatia	Lethrinus harak	Thumbprint emperor	11.25		3.106	10.96	14.99	0.65	119.20
Kacika	Lethrinus xanthochilus	Slender emperor	1.30	0.84			0.12		4.99
Kaikai	Leiognathus equulus/ Gazza minuta	Pony fish				1.10	3.59	0.05	
Kake	Lutjanus sp.	Blue-lined snapper, black-spot seaperch	0.11		0.666	0.82	1.59	0.14	1.42
Kanace	Valamugil seheli	Bluetail mullet	1.86	2.53	4.900	0.39			19.38
Kasala	Epinephilus fucus/ Cephalopholis miniatus	Spotted fin cod/ Marbled cod	2.31						
Kawago	Lethrinus nebulosus	Spangled emperor	3.54		0.26				
Kawakawa	Cephalopholis argus	Peacock rockcod	10.10	5.62	5.013	0.85	1.11		187.47
Kerakera	-	-				0.10			
Ki	-	-	0.20			0.47		0.11	
Maimai	Coryphaena hippurus	Dolphin Fish						0.12	
Mama	Gymnocranius robinsoni/ Monotaxis grandoculis	Bream				0.02			
Marshi	Etelis carbunculus	Red Snapper			0.312				
Mataroko	-	-					2.19		
Matu	Gerres sp.	Silver body					1.26	0.21	13.83
Mosula	-	-	0.13						

Nuqa	Siganus spinus/ vermiculatus	Rabbit fish/ Spine foot	0.18			0.02	4.81		7.48
Ogo	Sphyraena qenie	Barracuda	1.09		1.747	0.66			43.13
Ose	Mulloidichthys vanicolensis	Goatfish	0.03			0.08			
Qitawa	Therapon jarbua	Crescent perch	0.21			1.18	3.50	0.11	
Sabutu	Lethrinus mahsena	Yellow-tailed emperor	13.55	4.49	4.930	1.99	2.64	0.04	44.76
Salala	Restrelliger brachysoma	Chub mackerel	0.40			0.15			45.12
Saqa	Caranx sp.	Trevally	0.59	1.68		1.03	0.81		167.58
Senikawakawa	Epinephilus merra	Honey comb rockcod				0.74	0.28		8.73
Sokisoki	Diodon hysterix	Porcupine fish	0.18				1.06		27.01
Ta	Naso unicornis	Yellowfin surgeon fish	0.65						2.32
Tabace	Acanthurus guttatus	Surf surgeon fish			0.200				5.07
Tivitivi	-	-	0.88						
Tulele	-	-	0.14						
Ulavi	Scarrus sp.	Parrotfish	4.97	3.79	3.494	1.24			85.70
Ululoa	-	-							1.75
Walu	Scomberomorus commerson	Spanish Mackerel							14.96
Yatunitoga	Thunnus albacares	Yellowfin tuna						0.09	
-	-	Shark					2.64		17.81
-	-	Crab	1.00		1.082	0.07	0.71	0.09	16.90
-	-	Prawns	0.80		0.886		0.88		4.16
-	-	Lobster	0.20						12.27
-	-	Shells	0.06		0.736				
-	-	Turtle	87.46						140.51

Cawaki	Tripneustes gratilla	Sea urchin	0.02				
Civicivi	Pinctada sp.	Pigmy pearlshell	0.03				
Dridri	-	-	0.01				4.53
Gera	Strombus gibberulus	Stromb	0.44		0.421		
Kaikoso	Anadara cornea	Ark Shell	0.04				1.46
Kuita	Octopus sp.	Octopus	3.15	0.91	1.733		30.10
Lairo	Cardisoma carnifex	Land Crabs					0.40
Lumi		Seaweed	0.05		1.581	0.49	
Nama	Caulerpa racemosa	Sea grapes	0.41				4.16
Sici	Trochus niloticus	Trochus Shell	0.92		0.154		3.08
Tadruku	Acanthozostera gemmata	Chiton	0.46				