What's the Catch: Uncovering the Catch Volume and Value of Fiji's Coral Reef-Based Artisanal and Subsistence Fisheries

by

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Abstract

Coral reef-based fisheries, which have long provided food, income and livelihoods to millions of coastal inhabitants in tropical developing countries around the world, are regularly overlooked and underappreciated in regard to their economic and social values. Despite their importance, there is limited formal information that can be used to help guide the sustainable development and management of these small-scale fisheries. In this thesis, I use Excel-based models to estimate catch volume, catch value, costs and benefits, and the number of fishers, middlemen and vendors, in regard to the coral reef-based artisanal and subsistence fisheries of the Republic of the Fiji Islands. For the artisanal fisheries, I conduct a more detailed economic analysis, which includes an in depth look at individuals' costs and benefits. Results suggest that the artisanal and subsistence fisheries, together, deliver an annual catch of over 17,000 tonnes of reef-associated finfish, invertebrates and marine plants, which have a gross value of approximately US$ 54 million per year. In addition, it is estimated that there are more than 28,000 fishers that rely on Fiji's coral reefs for food and/or income. The results from this study will help raise the profile of Fiji's reef-fisheries, in the eyes of government decision-makers, and may contribute to the development and implementation of resource use strategies that are sustainable, profitable and equitable. Lastly, I make recommendations for the direction and content of future reef fisheries research and monitoring activities.

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Co-Authorship Statement

Rashid Sumaila and Yvonne Sadovy are the principal investigators of a larger project, which my thesis is a part of. Rashid and Yvonne have contributed thoughts and recommendations on the direction and content of Chapter 2, and will be co-authors in a version of the chapter that is planned for submission. I performed the research and data analysis for chapter 2, and am the primary author. Chapter 3 was completed with contributions from Fisheries Centre PhD students Louise and Lydia Teh, who helped develop the Monte Carlo-based model. Louise and Lydia also conducted interviews in Fijian fishing communities. Select data from these interviews were used as inputs in the Monte Carlo-based model. I performed the research and data analysis (excluding the interviews) for chapter 3 and will be the first author, with co-authors Lydia, Louise, Rashid and Dirk Zeller, in the planned submission of a version of this chapter.

Chapter 1

Introduction

1.1 Problem statement

Coral reefs have long been a source of food, employment and cultural identity for millions of coastal inhabitants in tropical developing countries around the world (Munro, 1996). However, these reefs are under increasing pressure from anthropogenic activities such as intensive agricultural practices, deforestation, urbanization, destructive and unsustainable fishing methods, unregulated tourism, and global climate change (Moberg and Folke, 1999; Ahmed et al., 2005). As a result, people that depend on coral reef fisheries for social and economic stability, which are often some of the most vulnerable groups in regard to food security, exposure to natural disasters and social, economic and political marginalization, are prone to recurring or persistent hardships (Whittingham et al., 2003; Bene et al., 2007).

Inherently small-scale, reef fisheries typically exist in geographic, socio-economic and political remoteness from decision and policy makers in urban centers (Pauly, 1997). Consequently, political interest in coral reef-based fisheries is generally low (Staples et al., 2004), as demonstrated by the regularity in which industrial-scale offshore fisheries receive the majority of government funding for fisheries monitoring, management and research (Cycon, 1986; Mahon, 1997). With insufficient data on catch volume and value, market transactions and the distribution of benefits, reef fisheries tend to be overlooked and under-appreciated in regard to their economic and social significance (Sadovy, 2005; Zeller et al., 2006). This may result in development decisions being made in favor of other sectors, such as tourism or agriculture, at the expense of the fisheries sector (Sugiyama, 2005). The limited data that are available on reef-based fisheries, and the values of coral reefs in general, are often under-utilized in coastal investment, development and policy decisions, resulting in short-sighted resolutions that fail to maximize the long-term economic potential of coral reef ecosystems and fisheries (Roxburgh and Spurgeon, 2005; Burke et al., 2008).

Recognizing these trends, and upon observing a decline in the health of their own coral reef fisheries, the Fiji Fisheries Department, and other coral reef stakeholders, determined that an important step towards protecting Fiji's coral reef ecosystems and fisheries resources involved obtaining a comprehensive understanding of the fisheries' economic and social values (Sadovy and Batibasaga, 2006). In turn, the Fisheries Department's decision to better understand the values of Fiji's coral reef fisheries led to the development of a collaborative research project between the University of British Columbia, the Fiji Fisheries Department, the University of the South Pacific and the University of Hong Kong/Society for the Conservation of Reef Fish Aggregations. This project, in part, aims to quantify the direct use values of Fiji's coral reefs, while determining to what extent certain individuals benefit from different uses of reef resources. My thesis research is part of this larger project, and looks specifically at the catch volumes, and economic benefits and costs, associated with Fiji's reef-based artisanal and subsistence fisheries.

As used in this thesis, artisanal fishing refers to small-scale fishing that results in the catch being sold in domestic markets, while subsistence fishing refers to fishing that results in the catch being consumed by the fisher or their family, given away as a gift or bartered locally. The distinction between artisanal and subsistence fishers, however, can be blurry, as most fishers generally keep some portion of their catch and sell some portion. As such, further clarification on this topic will be provided when necessary.

1.2 Research objectives

My research focuses on Fiji's small-scale, coral reef-based artisanal and subsistence fisheries. I aim to advance the understanding of the fisheries by producing new information and improved estimates on the fisheries' catch volume and value, employment numbers, and the costs and benefits for individuals, groups and for the fisheries as a whole. It is my hope that this work will help raise the profile of Fiji's reef fisheries and help guide resource use management strategies related to investment, development and conservation of coral reef and coastal resources.

For this research, I develop models that produce outputs that fill existing data and information gaps associated with Fiji's artisanal and subsistence fisheries. Specifically the objectives of this research are to:

- Improve the existing information on catch volume, catch value, and the number of participants associated with Fiji's artisanal and subsistence fisheries;
- Raise the profile of Fiji's reef fisheries in the eyes of governing officials;
- Develop models that can be used by reef fisheries stakeholders to continually update and improve national-level catch volume and value estimates for Fiji's inshore fisheries;
- Identify gaps and shortcomings in existing data, information and monitoring methods, and make recommendations for future research, monitoring and management of Fiji's reef fisheries;
- Develop a model framework that can potentially be used to estimate catch volume and value of artisanal and subsistence fisheries throughout the south Pacific region.

1.3 Methods

From November 15th-December 15th, 2007 I traveled throughout Fiji's two main islands, Viti Levu and Vanua Levu, acquiring data and information to be used in this thesis. Although I did not develop and administer surveys for primary data collection, I acquired a wealth of secondary data, literature and information through informal meetings with representatives of several governmental agencies, non-governmental organizations, academic institutions and private enterprises. A list of the people and organizations I met with while in Fiji can be found in Appendix A. My understanding of fisheries related market and financial transactions was supplemented by opportune discussions with fishers, middlemen and vendors participating in the fisheries.

While in Fiji, I also visited the Fiji Fisheries Department's library in Lami, the Pacific Islands Marine Resources Information System collection at the University of the South Pacific's (USP) lower campus, and the Pacific collection at USP's central library. I also utilized the Secretariat of the Pacific Community's library, located in Noumea, New Caledonia, as a colleague of mine visited and was able to retrieve material I requested. These libraries provided access to hard-to-find publications and theses that deal specifically with fishing and fishing communities in the south Pacific.

As my research is part of a larger project, involving three other university students conducting their own research, I also utilized data that my colleagues collected through formal surveys administered in Fijian fishing communities. This information was used primarily in the subsistence portion of my thesis, Chapter 3. Further details on the interviews can be found in Chapter 3.

Drawing from literature on natural resource economic valuation and cost benefit analysis, I developed economic models for the finfish and invertebrate portions of Fiji's artisanal fisheries (Chapter 2). These models incorporate information on the characteristics of fishing activities and market transactions with cost of fishing data specific to Fiji. For Fiji's subsistence fisheries (Chapter 3), a Monte Carlo simulation was developed. The input variable value ranges used in this simulation are defined by peer-reviewed and grey literature as well as primary interviews conducted in Fiji's fishing communities. Modeling for both the artisanal and subsistence fisheries was done using Excel software.

1.4 Thesis outline

This thesis consists of four chapters. The first is an introduction that states the objectives of the research and outlines the structure of the thesis. Additionally, I provide a background on the economic valuation of coral reefs and an overview on socioeconomic research, related to coral reef resource use that has been carried out within Fiji. This literature review is supplemented by a chronological overview of coral reefs' economic, social, cultural and political importance in Fiji, which is found in Appendix A.

The second chapter covers the reef-based artisanal fisheries of Fiji, of which a version is planned for publication submission. The central focus of this chapter is the development of economic models that depict Fiji's reef-associated finfish and invertebrate artisanal fisheries. I describe how the models operate and present results on the catch volume, catch value and employment associated with Fiji's reef-based artisanal fisheries. Additionally, I present a detailed examination on the costs and benefits to individual participants in the fisheries. The results from this study are then compared with Fiji's offshore fishing sector, in an attempt to raise the profile of the economic and social importance of Fiji's reef fisheries. Lastly, I identify knowledge gaps in existing data and information and make recommendations for future management, monitoring and research in regard to Fiji's artisanal fisheries.

Chapter three focuses on Fiji's subsistence fishing sector, and is also planned for submission to the primary literature. The main objective here is to develop a reliable method for estimating Fiji's annual subsistence catch that is inexpensive and doesn't require extensive fieldwork or technical expertise. As such, I develop a model that estimates subsistence catch using available data and information on Fiji's subsistence fisheries. In this chapter, I provide background information on Fiji's subsistence fisheries and a critical summary of past subsistence catch estimates, as well as the methods utilized in the subsistence catch model. I provide catch volume and value estimates of Fiji's subsistence fishery while distinguishing between finfish and invertebrates as well as reef-associated and non-reef associated species. I also present costs and benefits, at a fisher and fisheries level, for Fiji's subsistence fisheries.

The fourth chapter summarizes the findings of my research and discusses their significance. In this chapter, I identify gaps and shortcomings in existing research and monitoring, and make recommendations for the future research and monitoring of Fiji's artisanal and subsistence fisheries. Lastly, I offer a personal reflection on this research and discuss future research interests.

1.5 Background and literature review

This section consists of two parts. The first provides an overview of projects and publications that have focused on the economic valuation of coral reef ecosystems, drawing attention to valuation's role in coral reef conservation. The second part provides general information on Fiji and Fiji's coral reefs, as well as an overview of past studies that have profiled one or more of the economic, social and ecological components of Fiji's inshore fishing sector. A complimentary, more detailed account of Fiji's coral reef resources' use, value, management and association with political and social issues, can be found in Appendix B. Together, these overviews help establish a solid foundation for the detailed economic analysis of Fiji's coral reef-based artisanal and subsistence fisheries, as part of this thesis.

1.5.1 Economic valuation of coral reefs and small-scale fisheries

Studies reporting on the economic values associated with coral reef ecosystems first began to appear in the late 1980s, as individuals and organizations sought new means to promote reef conservation. Prior to this, a conservation message formulated around coral reefs' ecological wealth and biodiversity largely failed to influence the behavior of individuals and companies damaging reefs, or to engage agencies in a position to implement conservation oriented policies (David et al., 2007). As such, some of the first coral reef valuation publications focused on the economic costs of coral reef degradation (i.e. Hundloe 1987; Hodgson and Dixon, 1988; McAllistair, 1988).

In 1992, the concept of total economic value (TEV) was applied to coral reefs, increasing stakeholders' awareness of their wide-ranging direct and indirect values (Spurgeon and Aylward, 1992). Applying TEV to coral reefs provided a practical framework for categorizing and assessing the values associated with the multi-faceted ecosystems. Figure 1 shows the various categories and attributes associated with the TEV of coral reefs.

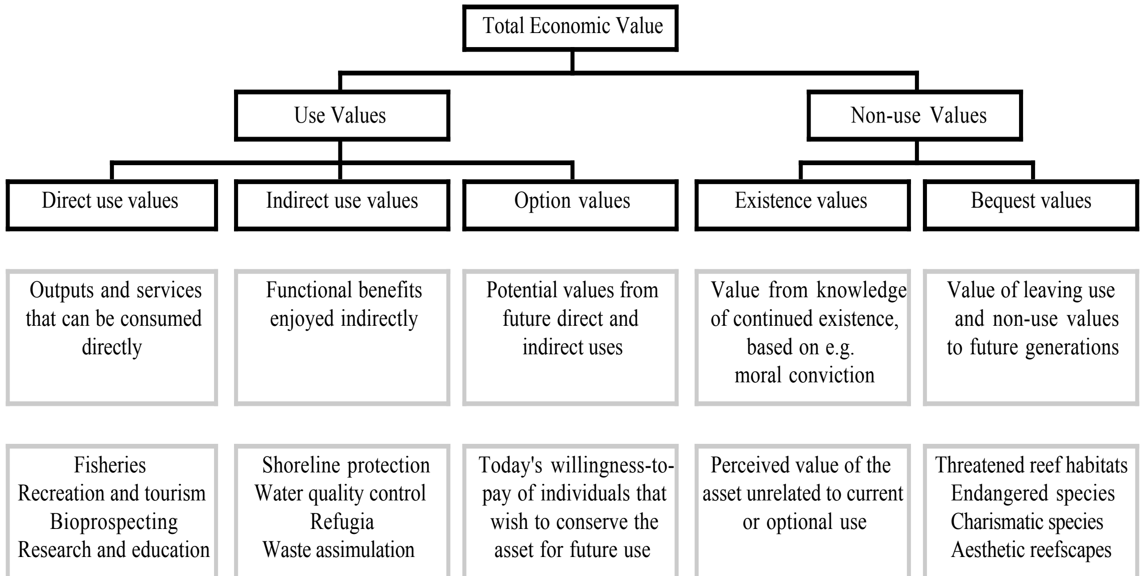

Figure 1.1 Schematic showing value categories, value category description and value category examples, as part of coral reefs' total economic value (based on Ahmed et al., 2005; Cesar 2000).

Studies on coral reef economic valuation have become more common over the last two decades or so, with topics ranging from the recreational value of coral reefs (Leeworthy, 1991; Yeo, 2001; Brander et al., 2007), the economic benefits of marine parks (Dixon, 1993; Driml, 1994), the value of coral reef protection (Wright, 1994; Pendleton, 1995), and the economic losses of destructive behavior towards coral reefs (Berg et al., 1998; Pet-Soede et al. 1999; White et al., 2000).

Recently, a number of international organizations and agencies have become actively involved in coral reef valuation projects. Each project has recognized the role that economic valuation can play in establishing beneficial resource use strategies and devising cost-effective policy interventions to manage and protect coral reefs. For example, during the late 1990s, the World Bank initiated a project that, in part, attempted to adapt and refine existing valuation methods to take into account the key characteristics of coral reefs. In doing so, the project helped establish methods for the derivation of more accurate estimates on coral reef benefits and the costs of coral reef degradation (Gustavson, 1998; Ruitenbeck and Cartier, 1999; Cesar, 1996; 1999; 2000; Cesar et al., 2002; 2003).

A second organization, the WorldFish Center, first became involved in coral reef valuation in 2001, when they hosted an international workshop that focused on economic research relevant to coral reefs. The workshop resulted in the publication of a collection of papers and case studies focusing on the theory and practice of economic valuation and the socioeconomics of coral reefs, and their role in coral reef management (Ahmed et al., 2005).

The World Resource Institute (WRI) is currently overseeing a coral reef valuation project, which aims to refine valuation methods while making them more accessible to coral reef stakeholders. The study applies knowledge and experience gained from multiple case studies in the Caribbean to develop a user-friendly, Excel-based, coral reef valuation tool, allowing reef stakeholders to explore the recreational, fisheries and shoreline protection values of coral reefs in their area (Burke et al., 2008).

Although the aforementioned projects and publications have done a commendable job determining the economic values associated with coral reef ecosystems, they have largely failed to provide comprehensive economic information on small-scale, coral reef-based fisheries. Many of these publications do include a rough estimate of the value of inshore fisheries, but in insufficient detail to effectively guide coral reef resource use and management decision. Notable exceptions include economic assessments of artisanal fisheries by Gustavson (2002) and Kronen (2004; 2007), although these studies do not make a definitive distinction between catch consisting of reef-associated species and non reef-associated species.

1.5.2 Fiji and coral reef-based fisheries

The Republic of the Fiji Islands consists of 106 inhabited islands scattered throughout an exclusive economic zone of 1.26 million km^2 (Richards, 1994). With an ocean to land ratio of 70:1 (World Bank, 2000) and over 5,000 km of coastline (FAO, 2008), it is no wonder that marine ecosystems have been an integral part of the lives of Fijians since the first settlers arrived over three thousand years ago (Nunn et al., 2007). Straddling the 18th degree of southern latitude, Fiji's expansive marine boundaries encompass approximately 10,000 km^2 of biologically rich coral reef structures (Spalding et al., 2001). These reef ecosystems have long provided Fijians a majority of their animal protein (Salvat, 1980), while being a source for livelihoods, cultural identity, and more recently, income generation and foreign exchange (Veitayaki, 1995).

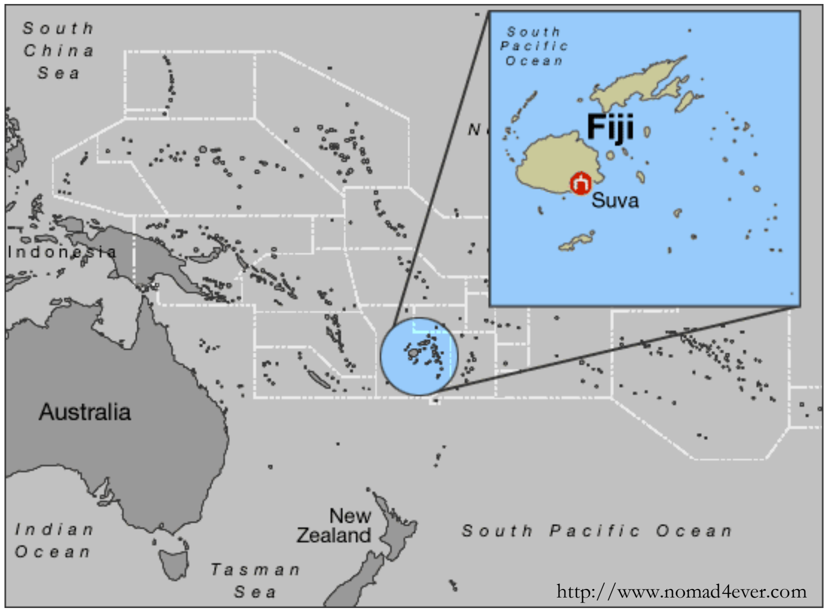

Figure 1.2 Map of Fiji

Fiji's coral reef fisheries are largely the domain of small-scale artisanal and subsistence fishers, and as such, involve labor-intensive fishing, processing and distribution technologies (FAO, 2004). Using a variety of fishing gears and methods, men, women and children target a wide range of finfish and marine invertebrates; including the finfish families Scaridae, Diodontidae, Lethrinidae, Serranidae, Labridae, Lutjanidae, Balistidae, and Acanthuridae, and invertebrate species of crustaceans, gastropods and bivalves (Richards, 1994; Rawlinson et al., 1995; Kuster et al., 2005).

Although several reports have profiled Fiji's fishing sectors (Cook 1986; Richards, 1994; Hand et al., 2005), there has been no coordinated, national-level study and assessment of Fiji's coral reef fisheries. There have been, however, numerous site-specific studies on the subsistence and artisanal fishing sectors of Fiji's main islands (Rawlinson et al. 1995) and outer islands (Jennings and Polunin, 1995a, 1995b, 1996a, 1996b; Jennings, 1998; Kuster et al., 2005; Turner et al., 2007). Overall, these studies provide localized data and information on catch rates and yields of reef fisheries, biomass and ecological changes of coral reef ecosystems, and the social-economic conditions of coastal fishing communities.

Economic studies covering coral reefs, inshore fisheries and coastal communities specific to Fiji are limited, but have become more common in recent years. In 1984, Iwakiri and Ram published a paper on the socioeconomics of small island fishing communities in the south Pacific, including Fiji. More recently, Passfield (1994) calculated a rough estimate of the monetary value of the commercial and subsistence fisheries of two Fijian villages, while O'Garra (2007) estimated the TEV of the Locally Manage Marine Area (LMMA) of Navakavu, on Viti Levu. Focusing specifically on Fiji's artisanal fisheries, a Fijian economist, working at the University of the South Pacific, investigated the role of property rights in the fisheries' technical efficiency, profitability and sustainability (Reddy 2004; 2006). The Secretariat of the Pacific Community is also active in Fiji, having carried out a study examining the socio-economics of six Fijian fishing communities in regard to marine resource status and use (Anon., 2004). Similarly, Veitayaki et al. (undated) report on the socio-economics of a coastal fisheries development assistance project in Macuata province, Vanua Levu. Studies that have estimated values of Fiji's inshore fisheries at a national level, although not specific to coral reefs, include Gillett and Lightfoot's (2001) re-estimation of fisheries contribution to the economy of Fiji, and an Asian Development Bank report by Hand et al. (2005) that summarizes the value of Fiji's industrial, small-scale commercial and subsistence fisheries.

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Chapter 2

Economics of Fiji's coral reef-based artisanal fisheries[1]

2.1 Introduction

Tropical coral reef ecosystems are some of the most biologically diverse and productive ecosystems on earth (Connell, 1978). Despite occupying less than 0.2% of the global ocean area (Spalding and Grenfell, 1997), coral reefs are estimated to supply between 5-10% of total marine fish landings (Salvat, 1992; Whittingham et al., 2003), and provide millions of coastal inhabitants a source of food, employment and cultural identity (Salvat, 1980; Munro, 1996; Veitayaki, 2000; Spalding et al., 2001).

Inherently the domain of small-scale fishers, coral reef fisheries are particularly important to developing countries (Munro, 1996), where, despite limited data and information, they are generally recognized for their ability to generate significant economic benefits and make meaningful, sometimes critically important, contributions to poverty alleviation and food security (Bene et al., 2007). Unfortunately, governing federal agencies often fail to acknowledge the economic and social significance of small-scale fisheries, instead focusing limited human and financial resources for fisheries management, monitoring and research on supposedly more valuable industrialized offshore fisheries (Mahon, 1997). As a result, small-scale coral reef based fisheries are largely overlooked and underappreciated in terms of their

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contributions to a nation's employment sector, food security and Gross Domestic Product (GDP) (Sadovy, 2005; Zeller et al., 2006).

The lack of data, information and effective governance of reef-based fisheries is particularly evident in developing island nations of the South Pacific, where reef fishing is regarded as one of the most important livelihood activities for coastal communities (Ruddle et al., 1992; Veitayaki, 1993; Zann and Vuki, 2000). Fittingly, in 2006 and 2007, the Fiji Fisheries Department, in collaboration with the Society for the Conservation of Reef Fish Aggregations (SCRFA), hosted workshops in order to address growing concerns on the perceived decline in the health of Fiji's coral reef fisheries (Anon., 2006). Although past studies have covered various components of Fiji's artisanal fisheries at a community or regional level (Zann, 1981; Iwakiri and Ram 1984; Passfield 1994; Anon., 2004a; Aalbersberg et al., 2005; Veitayaki et al., 2006; O'Garra, 2007), none have attempted to differentiate between reef and non-reef species, or to quantify costs, benefits and employment opportunities associated with the fisheries at a national level. As such, one of the top recommendations to emerge from the workshops was the need to assess the full economic and social value of Fiji's coral reef fisheries (Sadovy and Batibasaga, 2006).

Given the needs of the Fiji Fisheries Department, the limited availability of reliable data and information, and the apparent under-appreciation of coral reef fisheries, the objectives of this chapter are to derive national-level estimates on the value, volume and employment associated with Fiji's coral reef-based artisanal fisheries. This study focuses specifically on artisanal catch of reef-associated species, and does not consider artisanal catch consisting of pelagic and estuarine species. As such, I use existing data and information to develop models that produce estimates on the total catch volume and value of Fiji's reef-associated finfish, invertebrate and marine plants, the total number of fishers, middlemen and vendors that are able to derive income by participating in Fiji's reef-based artisanal fisheries, and detailed estimates on the costs and benefits for individuals, groups and the fisheries as a whole. The models are created with the intention that they may be used by the Fiji Fisheries Department to continually update and improve existing information on the country's reef-based fisheries. The improved understanding of Fiji's reef fisheries will allow for straightforward comparisons with the country's offshore fishing sector, encouraging increased recognition of reef fisheries' economic and social importance. The resulting knowledge may also be used to inform government level policy and decision makers in the development of fisheries research, monitoring and management strategies.

2.2 Background

The Republic of the Fiji Islands consists of over 844 islands, cays and islets and is home to some of the largest and best-developed coral reef systems in the South Pacific region (Vuki et al., 2000). The flora and fauna associated with Fiji's approximately 10,000 km^2 of fringing, barrier, platform, line and patch reefs play a significant role in providing food, livelihood and employment options for numerous coastal inhabitants (Spalding et al., 2001; Kuster et al., 2005).

As no single definition of artisanal fishing exists (Schorr, 2005), it is important to clarify its meaning for this paper. Artisanal fishing typically refers to fishing activities that use low technology, are labor intensive, target multiple species and occur in nearshore habitats (Schorr, 2005). Artisanal fishing, as used in this paper, conforms to this general description, with one addition, that all catch is sold domestically in either municipal or non-municipal market outlets. This differs from subsistence fishing, where catch is kept by the fisher for personal or household consumption, given away as gifts, or bartered locally (Berkes, 1998). In Fiji, the distinction between artisanal and subsistence fishing activities can be particularly blurry, as the exact fate of a fisher's catch is often decided only after he or she returns from a fishing outing. Consequently, a single fishing trip can yield an assortment of fish that will be used for both artisanal and subsistence purposes.

Some clarification is also required on the term *fish*. Here, *fish* refers to finfish, invertebrates and marine plants, collectively. To distinguish between different types of *fish*, I refer to them specifically as *finfish*, *invertebrates* or *marine plants*.

2.2.1 The fisheries

Artisanal fishing in Fiji takes place predominantly in the area between the shoreline and the outer slope of barrier or fringing reefs (Rawlinson et al., 1995). This inshore area encompasses a number of productive fishing habitats that are utilized by artisanal fishers, including patch reefs, fringing reefs, lagoons, mangroves and estuaries (Rawlinson et al., 1995). Although there is not an exact boundary between these often complimentary and overlapping systems (Moberg and Folke, 1999), this study focuses exclusively on the catch of species characterized by their life-history association with coral reefs.

The most common fishing gears used by Fiji's artisanal fishers for targeting finfish include handlines, spears and an assortment of different sized nets. Derris, a natural toxin locally known as *duva*, is also widely used. Harvesting reef-associated invertebrates and marine plants requires a great deal of agility, skill and species-specific knowledge, collection techniques and strategies (Vunisea, 2005). Because many coral reef-associated invertebrates and plants are found in shallow water and move slowly, or not at all, the prominent invertebrate fishing technique is hand collection, also known as gleaning. Some invertebrates, such as lobsters and octopus, are caught with the aide of a stick or spear, while other species are simply picked from the reef or surrounding area.

Men, women and children all take part in Fiji's artisanal fishing activities. Men are more likely to engage in fishing activities that require boats, take place in more distant fishing grounds and use handlines and spears to target species of finfish. Women, on the other hand, tend to fish near the shore and on reef flats, gleaning and net fishing, while targeting shellfish, octopus, echinoderms, crabs and schools of small finfish (Chapman, 1987). Although very little is known about children's contribution to Fiji's artisanal fisheries, it is recognized that they often accompany their mothers fishing (Kronen, 2004).

Fiji's reef fisheries occur predominantly in the country's 411 recognized customary fishing areas, known as *qoliqolis*. Although the ownership of living marine resources is held by the government, each Native Fijian has the "right of usage" to the marine resources of their ancestral *qoliqoli* (Kunatuba, 1983). For each *qoliqoli*, a designated chief, or group of chiefs, regulate fishing activities and resource use. In fact, to receive an Inside Demarcated Area

(IDA) fishing license from Fiji's Fisheries Department, a fisher must first get permission from the chief of the *qoliqoli* they wish to fish in. Currently, the Fisheries Department reports issuing about 2,500 IDA fishing licenses per year (Anon., 1998b; Anon., 2006). These licenses are issued at the discrepancy of *qoliqoli* chiefs and the Fisheries Department, typically without regard for the capacity of the resource base (Sadovy and Batibasga, 2006). These licenses, however, do not reflect the true number of artisanal fishers, as Native Fijians are unlikely to obtain an IDA license to fish within their ancestral *qoliqoli* (N. Kuridrani[2], pers. comm.). Rawlinson et al. (1995) estimate the number of artisanal fishers, on Fiji's main island of Viti Levu, alone, to be over 8,000.

2.2.2 Selling the catch

There are a number of options with regard to whom fishers sell their catch, including middlemen, vendors or directly to consumers. To realize higher profits, a fisher would always want to sell directly to consumers. However, given time and resource limitations, this is typically impractical. Therefore, a fisher will often utilize the services of a middleman. Reddy (2004) reports that 38% of artisanal fishers in Fiji sell at least a portion of their catch to middlemen and an additional 21% sell a portion of their catch to middlemen or consumers. Unquestionably, middlemen play a significant role in linking artisanal fishers and their catch to vendors and consumers.

Domestic fish sales occur in municipal and non-municipal market outlets throughout Fiji. Municipal markets are formal markets run by municipal authorities and tend to be in the vicinity of urban centers, while non-municipal markets are found in rural and urban settings, and include everything from roadside stalls to supermarkets, fishing wharfs, butcher shops and hotels. Consistently, a majority of domestically sold fish is retailed through non-municipal markets.

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[2] N. Kuridrani is a Fisheries Officer with the Fiji Fisheries Department.

2.2.3 Monitoring fish sales

Observing and recording the domestic sale of finfish, invertebrates and seaweeds in municipal and non-municipal markets has been carried out by Fiji's Fisheries Department since 1977 (Gillett, 2004). The monitoring takes place in three of the four geographic regions of Fiji; the eastern division is not monitored due to its physical remoteness and lack of perceived fish sales that occur there. Fish caught in the eastern division, however, are increasingly being brought to markets in urban centers, as recently established ice plants allow fish to be stored until ships visit the outer islands and can transport the them to urban centers.

In Fiji's 11 municipal markets, designated fisheries officers record daily market sales a total of six times every three months; one visit for each day of the week, excluding Sundays. Fisheries officers spend a full day observing one market, using data sheets to record species names, total weight and selling price of all fish and invertebrates sold that day. The data collected is then extrapolated; Monday's data is used for every Monday in the three-month time period, Tuesday's data for every Tuesday, and so on. Using this method, annual domestic fish sales and average selling prices are estimated. The same survey sheets are used to record fish sales from roadside stalls, of which, only around 35% are monitored (S. Singh[3], pers. comm.), and only once or twice per month.

Non-municipal markets, such as supermarkets, butcher shops and hotels, are typically visited by fisheries officers only once per month. At the time of visit, the previous month's completed survey sheets are picked up while blank survey sheets are dropped off. The survey sheets are filled in by an employee of the non-municipal market, and include information on species name, total weight and selling price. About 25-30% of Fiji's non-municipal markets are monitored in this way (S. Singh, pers. comm.). Data from these markets are extrapolated to, theoretically, account for all non-municipal markets in Fiji.

With limited resources available within the Fisheries Department, monitoring the domestic sales of Fiji's artisanal fisheries is far from perfect. There is often a lack of designated

[3] S. Singh is a fisheries officer with Fiji Fisheries Department.

transport, manpower and financial capital to reach and effectively monitor the market outlets. Additionally, the fisheries officers in charge of monitoring are often contract workers that are re-contracted every year, although some have been working as fisheries officers for many consecutive years. According to a Fiji fisheries officer familiar with the situation, it is not uncommon for a geographic division to be missing their fisheries officer for several weeks, even months, as funding becomes available during the year's first quarter (S. Singh, pers. comm.). For example, Fiji's northern division has recently been without a fisheries officer responsible for monitoring artisanal fish sales for over a year. These shortcomings will affect the accuracy of the monitoring program, and are taken into consideration in my estimation of the catch volume of reef-associated species.

2.3 Methods

Two economic models for the reef-based artisanal fisheries of Fiji are developed. The first model incorporates reef-associated finfish while the second model incorporates reef-associated invertebrates and marine plants. The separate models are similar in their input requirements, functionality and outputs, but each model is developed to best represent the fishing strategies and marketing transactions unique to each component of the fishery. By having separate models, I do not suggest that fishers, middlemen or vendors deal exclusively in either finfish or invertebrates, instead, this approach is taken in order to simplify modeling the behaviors and interactions of the participants of the fisheries.

The finfish and invertebrate models rely on an assortment of sources for quantifying their input variables. Much of the data and information used is based on peer-reviewed and grey literature from previous studies conducted within Fiji and the surrounding South Pacific region. Personal communications and first-hand observations are relied upon when essential information is absent from existing literature. A list of the finfish and invertebrate model variables, and their sources, can be found in Appendix C.

2.3.1 Fishers

Catch composition and volume

For this study, I consider the portion of Fiji's artisanal catch that consists of reef-associated species only. There are a number of species targeted and caught by artisanal fishers that are not associated with coral reefs, for example the estuarine bivalve *Anadara* spp. and several species of pelagic finfish. To determine the annual catch, I first identified all reef species caught by Fiji's artisanal fishers. Relying on the online databases of FishBase and SeaLifeBase, a report summarizing Fiji's living marine resources (Richards, 1994), and Annual Reports produced by the Fiji Fisheries Department (Anon., 2002; Anon., 2004b), I identified 68 finfish, 31 invertebrates and 3 marine plants that are reef-associated and are sold domestically throughout Fiji. The invertebrate and plant species, are categorized into 9 groups, including; sea urchins, trochus, seaweeds, octopus, gastropods, crustaceans, bivalves, *beche-de-mer* and other. A complete list of reef-associated finfish, invertebrates and marine plants can be found in Appendix D.

The official data on the domestic sale of all finfish, invertebrate and marine plant species, as reported in the Fisheries Department's Annual Reports, relies on extrapolating observed sales to account for unvisited markets. The actual sales, however, are thought to be greater than the official extrapolation estimates (Rawlinson et al., 1995). This under-reporting is due, in part, to the insufficient human and financial resources available to the Fisheries Department. With inadequate funding, transport and manpower, monitoring domestic fish sales in markets dispersed throughout Fiji cannot be carried out as formally intended, leading to inconsistent spatial and temporal coverage of market outlets. As a result, it is estimated that the actual domestic sales of finfish, invertebrates and marine plants are 20% greater than the official sales volume estimates (S. Singh, pers. comm.; A. Asis, pers. comm.). This 20% is applied towards estimating the domestic sales of Fiji's coral reef species.

Individual fisher's annual finfish catch was determined by the fishing gear used (Rawlinson et al., 1995; Jennings and Polunin, 1995; Dalzell et al., 1996; Kuster et al., 2005), the gear's average catch per unit effort (CPUE), expressed in kilograms per person per hour (Rawlinson et al., 1995; Dalzell et al., 1996; Jennings and Polunin, 1996; Kuster et al., 2006), and the hours per year spent fishing using specific gears, which is based on information on gear use frequency (Rawlinson et al., 1995; Jennings and Polunin, 1995; Kuster et al., 2005).

Annual invertebrate catch was determined by the collection method, its corresponding CPUE (Rawlinson et al., 1995; Dalzell et al., 1996; Fay et al., 2007) and the hours a fisher spends targeting invertebrates over the course of a year. Because of the lack of published information on invertebrate fishing, fishing hours per person per year are based on the assumption that, in most cases, invertebrate fishing is not a full-time income earning activity.

Number of fishers

The number of fishers participating in Fiji's reef-based artisanal fisheries was assumed to be dependent on the total annual catch volume of reef-associated finfish, invertebrates and marine plants. The rational behind this assumption is that fishers can fish only so many hours per year, and with a fixed average CPUE, can catch only so many kilograms of fish per year. As such, the larger the catch volume, the greater the number of fishers it will take to land that volume, everything else being equal.

In Fiji's finfish fisheries, the hours spent fishing each week varies among individual fishers (Anon., 2004a). Some fishers fish full-time, assumed to be 35 hours per week, on average, others fish part-time, assumed to be 12 hours per week, on average, while most fishers likely fish somewhere between full and part-time. In the results section of this paper, I present a range for the potential number of fishers involved in the fisheries. The lower limit of the range is based on the assumption that all fishers are full-time fishers while the upper limit of the range is calculated as if all fishers were part-time fishers. The equation used to calculate the number of fishers, f, is as follows:

$$f = \frac{h}{CPUE \cdot t} \tag{2.1}$$

where h is catch volume and $CPUE$ is average catch per unit effort, in kilograms per person per hour. The number of hours a fisher spends fishing in one year, t, is the only variable that changes when calculating the number of full-time or part-time fishers.

Similarly, equation 2.1 was used to estimate the number of fishers it takes to land the catch volume associated with each of the nine coral reef invertebrate groups. With the invertebrate groups, however, there is not a fixed number of fishing hours or CPUE. Instead, each invertebrate group has a unique number of fishing hours and CPUE, which are defined by assumptions based on the literature (Dazell et al., 1996; Passfield, 1997; Anon., 2004a; O'Garra, 2007) (see Appendix C).

Costs

It is assumed that Fiji's artisanal fishers work variable hours per day and week, target multiple species of fish and use different gear types, over the course of a year. Consequently, over time, their total fishing costs differ considerably from one another. Therefore, individual fisher's costs, as reported in this paper, are averages of the annual costs incurred by all fishers, and are reported as a range depending on the fisher's employment status as full or part-time.

Fishing costs are classified either as variable or fixed. Variable costs are expenses that change in proportion to the time spent fishing and the volume of fish and invertebrates caught. In this study, variable costs include operational costs and opportunity costs of labor. Operational costs incorporate costs for fishing gear, boat and engine maintenance, ice, fuel, food, batteries, flashlights, and any other accessories used during fishing. The opportunity cost of labor is the amount foregone by choosing one option over another; in this case the wage a fisher could have received working a different job. As Fiji's unemployment rate is around 7-8% (Reserve Bank of Fiji, 2003), I assume employment opportunities for unskilled laborers are available. As such, I use an opportunity cost of US$ 0.70/hour, which is reported as the Fijian wage for unskilled labor (O'Garra, 2007).

The only fixed costs fishers incur are capital costs for boats and engines. Capital costs are one-time purchases of capital equipment, which continually depreciate in value throughout their limited life span. In this study, I apply the straight-line depreciation method in order to calculate annual depreciation expenses, *d,* as expressed in equation 2.2.

$$d = \frac{c_f - v_s}{l} \tag{2.2}$$

Where c_f is the cost of the fixed asset and l is the life-span of the asset in years. I assume the scrap value, v_s, of boats and engines to be zero.

Fishers' costs in both the finfish and invertebrate models are estimated assuming that fishers own their boats and pay all costs associated with fishing. In reality, this is not always the case. It is common for a second party to own a fishing boat and rent it to fishers or hire men to fish for them, being paid with an hourly wage or a percentage of total catch (L. Teh and N. Kuridrani, unpublished data from interviews conducted in Fiji, 2008). When a second party owns a fishing boat there will be various financial arrangements between boat owners and fishers with regard to paying for operational costs. For example, a boat owner will often pay some portion of the fuel, bait, ice or gear costs prior to a fishing trip, getting reimbursed with fish upon the return of the fishers (Reddy, 2004). To simplify the situation for modeling purposes, I assume that fishers own all boats used for fishing, are responsible for all fishing costs and retain all the benefits, as determined by the value of the fish they sell. I justify this approach by assuming that fisher's costs and net benefits would be roughly the same whether they rent or own a boat. For a list of fishing costs used in this study, and their sources, see Appendix E.

Benefits

The gross benefits a fisher receives partially depends on who they sell their fish to; middlemen, vendors, or directly to consumers. According to discussions with fishers, middlemen and vendors of Fiji's artisanal fisheries, there is an approximately US$ 0.67 mark up, on a US$ 3.00/kg fish, between each step in the value chain (B. Starkhouse, personal observation). Reddy (2004) confirms this when he reports that a 40% mark-up in unit price from a middleman to a consumer is typical in Fiji's artisanal fisheries. Given this information, I assume a fisher will be paid 60%, 80% or 100% of a fish's market value when selling to a middleman, vendor or consumer, respectively.

Fishers' net benefits, b_n, are calculated by subtracting total costs, which consist of capital costs, c_c, and variable costs, c_v, from gross benefits, b_g.

$$b_n = b_g - (c_c + c_v) \tag{2.3}$$

Net benefits, however, do not represent a fisher's take home earnings, as net benefits are calculated by subtracting opportunity costs, among other costs, from gross benefits. Instead, value added, an economic term that expresses the difference between the value of goods produced and the costs of materials and supplies, known as intermediate costs (Philipson, 2006), can provide a better indication of fishers' take-home financial benefits. Value added consists of wages, opportunity costs, profits and depreciation of capital purchases. Intermediate costs include fishing gear and supplies, fuel and oil, ice, bait, and boat and engine maintenance. Value added can be expressed in multiple ways; as a total value, as a ratio of the gross value of output (value added divided by gross market value), or as a value per tonne of product sold.

2.3.2 Middlemen and vendors

The methods used to derive outputs for middlemen and vendors are similar to one another and will be described simultaneously.

Sales volume

The volume of reef-associated finfish, invertebrates and marine plants that middlemen and vendors buy and sell is dependent on the volume made available to them by individuals lower in the resources' value chain. Literature describing the proportions of fish bought and sold amongst individuals within the fisheries' value chain is particularly scarce. Based on survey results from Reddy (2004) and personal field observations of transactions taking place at Fiji's fishing wharfs and markets, I assume that fishers sell between 25-45% of their catch to middlemen, 30-40% to vendors and 25-35% directly to consumers. Middlemen sell 100% of their catch to vendors; if a middleman sold directly to a consumer then he would no longer be considered a middleman, but a vendor.

Within the invertebrate model, fishers sell varying portions of their catch to middlemen, vendors and consumers, depending on the particular invertebrate group. For example, fishers sell a majority of *beche-de-mer* and lobsters to middlemen and vendors (L. Teh and N. Kuridrani, unpublished data from interviews conducted in Fiji, 2008), while selling a majority of seaweeds, trochus meat and sea urchins directly to consumers (B. Starkhouse, personal observation).

The amount of finfish, invertebrates and plants that an individual middleman or vendor handles (buys and sells) in a year is based on the volume that a typical individual handles per day and the number of days worked per year. For example, if a middleman buys and sells, on average, 25 kg of fish per working day and works 225 days per year, they handle a total of 5,625 kg of fish per year. In the finfish and invertebrate models, the amount of fish handled by middlemen and vendors is based on personal communication with middlemen and vendors at fishing wharfs and fish markets in Suva, Lautoka and Labasa. See Appendix C for specific quantities regarding middlemen and vendors' handling of fish.

Number of middlemen and vendors

The number of middlemen and vendors employed through Fiji's coral reef-based artisanal fisheries is determined by the total volume of finfish, invertebrates and marine plants available to them and the average amount an individual handles in a year. The number of middlemen and vendors is calculated using:

$$I_{m,v} = \frac{h_{m,v}}{d_{m,v}} \qquad (2.4)$$

Where I is the number of individual middlemen or vendors, h is the total catch available to all middlemen or vendors annually, and d is the volume of fish handled by an individual annually. The subscripts m and v refer to middlemen and vendors, respectively.

Similar to the number of fishers, I present a range of the number of potential middlemen and vendors that derive income through buying and selling reef-associated species. The range is defined by the number of days an individual works per week, and the weeks worked per year. As with the number of fishers, the low end of the range is defined by all middlemen and vendors working full-time, while the high end of the range is defined by all middlemen and vendors working part-time.

Costs and benefits

Total costs to middlemen include the cost of buying fish, opportunity costs of labor, capital costs of owning a vehicle and transportation costs. Costs that vendors incur include the cost of buying fish, opportunity costs of labor and in some cases, the cost of using market space. The net benefits to middlemen and vendors are calculated by subtracting total costs from gross benefits. Gross benefits are determined by the quantity of fish sold. As per fishers, value added is a better indication of take-home earnings, and is defined as the difference between gross benefits and intermediate costs.

2.4 Results

Some of the following results are presented as a range of values. In each case, one end of the range is determined as if all participants in the fisheries are working full-time, while the other end of the range is determined as if all participants work part-time. Furthermore, individual cost and benefit estimates are averaged across the finfish and invertebrate models.

2.4.1 Catch volume and value

Fiji's domestic finfish sales consist of approximately 86% reef-associated species, by weight, and invertebrate and marine plant sales consist of approximately 24% reef-associated species, by weight. The remaining sales consist of primarily of pelagic and oceanodromous fish species and estuarine shellfish such as *Anadara* spp.. When compensating for the shortcomings and inaccuracies of monitoring and recording Fiji's domestic fish sales, the total annual catch volume of reef-associated finfish is estimated to be 6,401 (tonnes) t, while reef-associated invertebrates and marine plants contribute an additional 1,342 t. Together, reef species are estimated to have a gross market value of US$ 33.4 million. Further, the net benefits of the fisheries are estimated to be between US$ 11.2 million and US$ 12.8 million, while the fisheries' value added contribution ranges from US$ 18.2 million to US$ 20.1 million. The value added ratio is estimated to range from 55% to 60% and the value added per tonne of fish sold ranges from US$ 2,354 to US$ 2,601.

2.4.2 Number of participants

Fiji's reef-based artisanal fisheries provide employment for between 5,336-12,183 fishers, 421-842 middlemen, and 1,240-2,480 vendors (see Figure 2.1).

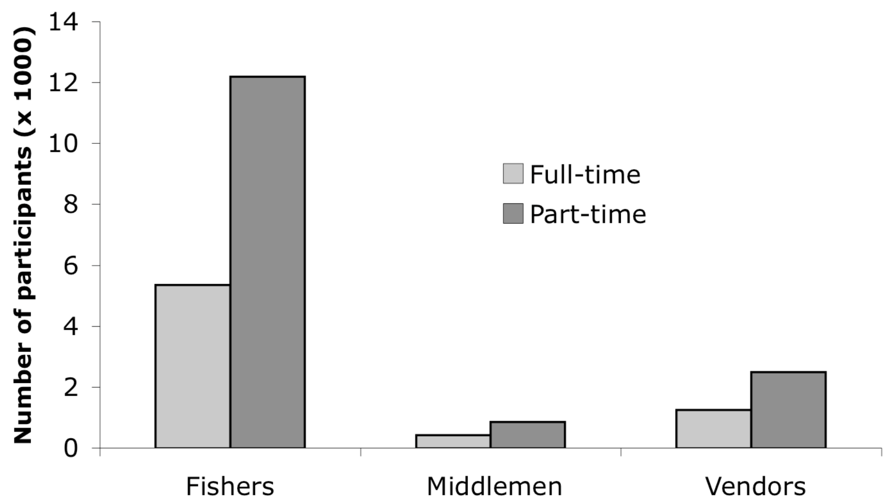

Figure 2.1 Estimated number of fishers, middlemen and vendors. The light grey represents the low end of the estimate range, where all participants are assumed to work full-time, while the dark grey represent the high end of the range, where all participants are assumed to work part-time.

2.4.3 Individual costs and benefits

Annual net benefits for participants of Fiji's reef fisheries working full-time range from US$ 1,019 to US$ 4,023, while the net benefits to individuals working part-time are between US$ 611 and US$ 1,637. As mentioned earlier, value added is a better representation of an individual's take home earnings. Individuals' estimated value added is between US$ 2,046 and US$ 5,136 for full-time employment and from US$ 1,084 to US$ 2,055 for part-time employment. Individuals' annual gross benefits, net benefits and value added are shown in Table 2.1.

Table 2.1 Individuals' average annual gross benefits, net benefits and value added (US$). Shown for part-time and (full-time) employment.

Participation group	Gross benefits		Net benefits		Value added	
Fishers	2,033	(4,643)	611	(1,019)	1,084	(2,046)
Middlemen	11,686	(23,371)	1,569	(4,023)	2,126	(5,136)
Vendors	9,731	(19,463)	1,637	(3,274)	2,055	(4,110)

The models also provide itemized cost estimates for all individual participants of the fisheries. As an example, Figure 2.2 shows an itemization of costs and benefits for the average full-time finfish fisher. The costs for fishing supplies, fuel for boat's engines and the opportunity cost of labor constitute roughly 40%, 26% and 29% of all costs, respectively. Costs associated with fishers transporting their catch to markets and the capital costs of boats and engines make up a small percentage of a full time finfish fisher's annual expenses at 4% and 1%, respectively. As reported here, a finfish fisher's capital costs for boats and engines are noticeably low. This is because costs for the *average* full-time finfish fisher are presented, when not all fishers own or use boats for fishing.

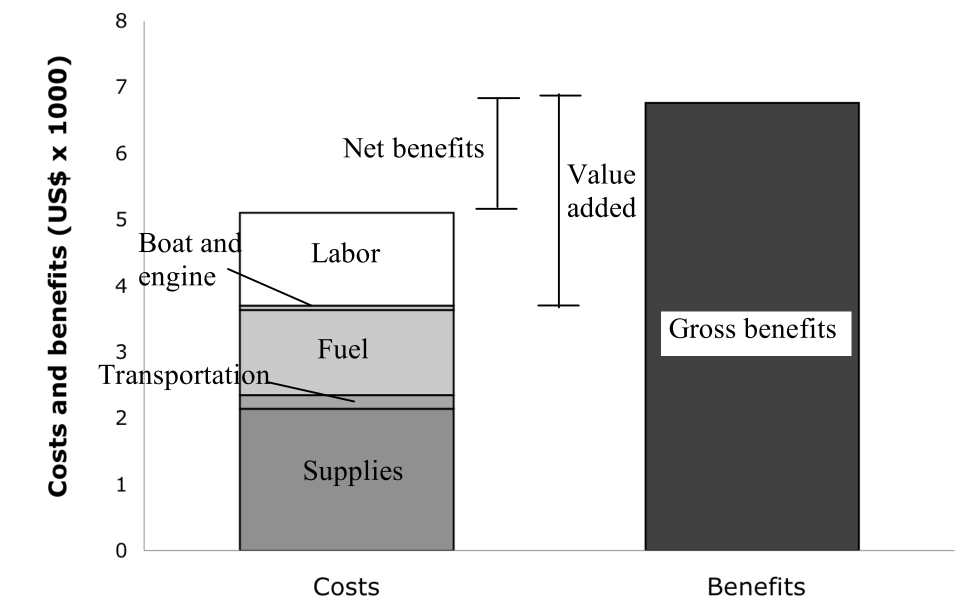

Figure 2.2 Costs and benefits for an average full-time finfish fisher.

2.5 Discussion

2.5.1 Comparison with Fiji's offshore fisheries

Profiling Fiji's reef-associated artisanal fisheries, at a national level, allows for a direct comparison with the country's industrialized offshore fishing sector. According to the Asian Development Bank's *Fiji Fisheries Sector Review*, the 2003 annual gross revenue from Fiji's offshore fisheries totaled roughly US$ 40 million, in 2008 dollars (Hand et al., 2005). The same study reveals the offshore fisheries have a value added ratio of 33% (value added divided by gross value) and a value added per tonne of fish caught (value added divided by catch) of approximately US$ 1,100. In comparison, I estimate that Fiji's reef-based artisanal fisheries generate a gross market revenue of roughly US$ 33 million, have a value added ratio of between 55-60%, and a value added per tonne of fish caught between US$ 2,354-2,601. Table 2.2 summarizes the comparison between Fiji's offshore industrial fishing sector and the artisanal reef-based fishing sector.

This comparison draws attention to the economic significance of Fiji's artisanal fisheries, relative to the country's highly regarded offshore fisheries. Although, in terms of gross value, Fiji's reef-based artisanal fisheries, alone, are not as valuable as the country's offshore fisheries, the higher value added ratio and value added per tonne, associated with the reef-based artisanal fisheries, are evidence of their greater economic efficiency. This means that, for every unit of intermediate cost put towards artisanal or offshore industrial fishing, the artisanal fisheries produces greater economic benefits. In itself, this is not surprising, as small-scale fishers are known to operate with greater economic efficiency (McGoodwin, 1990; Sumaila et al., 2001; Bene et al., 2007). It is important, nonetheless, because it provides poor fishers income-earning opportunities that make efficient use of their limited financial resources.

In addition to having greater economic efficiency than the country's offshore fishing sector, Fiji's reef-based artisanal fisheries also provide considerably more employment opportunities. Given the small-scale and dispersed nature of coral reef fisheries and the industrial organization of offshore fisheries, this should not come as a surprise. Though the exact number of jobs associated with Fiji's offshore fishing sector is uncertain, it is estimated to provide 1,057 domestic catching and processing jobs (Gillett et al., 2001) or 550 full-time employment equivalents (Hand et al., 2005). In comparison, I estimate the number of jobs associated with Fiji's reef-based artisanal fisheries to be between 6,997 and 15,505, depending on full-time or part-time employment. If each artisanal fisher lives in an average household (4.75 people per household, according to the 2007 National Census), the role of small-scale fisheries to income generation and poverty alleviation is amplified, further demonstrating the importance of Fiji's reef-based artisanal fisheries.

Table 2.2 Comparison between Fiji's industrialized offshore fisheries and artisanal reef-based fisheries.

	Employment	**Gross value (US$)**	**Value added (US$)**	**Value added ratio (%)**	**Value added per tonne of fish caught (US$)**
Artisanal reef fisheries*	6.997-15,505	33.4 million	18.2-20.1 million	55-60	2,354-2,601
Industrialized offshore fisheries**	550-1,057	40 million	13 million	33	1,100

*Based on this study
**Based on Gillett et al., 2001 and Hand et al., 2005

It should be emphasized, that these comparisons feature just the reef-based artisanal fisheries and the industrialized offshore fisheries. Fiji's subsistence fisheries, which are thought to contribute significantly to the catch volume and value or Fiji's fisheries, are examined on their own in Chapter 3.

The comparisons between Fiji's small-scale, reef-based artisanal fisheries, and the country's industrialized offshore fisheries, help draw attention to reef fisheries nationwide economic and social significance. Establishing reef fisheries' importance may influence policy and decision makers within the federal government to allocate more time, as well as financial and human resources, towards research, monitoring, management and enforcement of the country's reef-based fisheries.

2.5.2 Contributing to future reef fisheries management

One objective of creating the finfish and invertebrate models was for them to be used by stakeholders of Fiji's reef fisheries, in particular, the Fiji Fisheries Department, to continually update and improve the accuracy of the models' outputs. As such, the models are able to accommodate and incorporate the most recent data and information, as well as the fisheries-related knowledge and experience of individual and group model users. The models' input flexibility also allows model users to explore the influence that different inputs have on economic related fisheries outputs. For example, a fisheries manager might adjust the models' input variables to mimic a prospective fisheries management strategy prior to its implementation. The fisheries manager could then observe the management strategy's impact on outputs, such as the fisheries' employment capacity, participant's individual incomes or value added contribution to Fiji's economy. In this way, the models may contribute to the development of fisheries management strategies that address the economic needs of fishers and fishing communities.

Additionally, the examination of existing literature, data and monitoring protocol, required for the development and operation of the finfish and invertebrate models, has helped in the identification of existing data and knowledge gaps, and may help in defining future research and data collection priorities. For example, there is very little existing or available information on the livelihoods of middlemen and vendors, and the role they play as a link between resource exploitation and consumption. Similarly, it would be useful to know, from a fisher's perspective, what percentage of their catch they sell to middlemen, vendors and consumers, and why. Furthermore, the role of women in Fiji's reef fisheries is largely undocumented, even though they are known to actively participate in reef fishing and gleaning (Fay et al., 2007; Fay-Sauni et al., 2008). In fact, the collection of reef invertebrates and plants, in general, is poorly understood. As these knowledge gaps represent a significant portion of Fiji's artisanal fisheries, it is recommended that future research and monitoring projects adjust their objectives to address them. However, identifying knowledge gaps and urging researchers to fill them is only fully useful if the resulting information is made widely available. To this end, I strongly encourage all entities engaged in research and monitoring to make their work publicly available, and to work collaboratively when possible.

Further recommendations relevant to future management and monitoring of Fiji's artisanal fisheries are as follows. First, collection of fisheries data could be improved by increasing the involvement of the participants in Fiji's artisanal fishing sector. Traditional resource owners, who play an important role in overseeing and regulating resource use within customary resource areas, should play an increased role in monitoring and recording the number of fishers and volume of catch, in regard to their *qoliqoli*. Similarly, fishers, middlemen and vendors, with minimal training, could significantly contribute to fisheries data collection coverage. Providing minimal monetary compensation to genuinely interested individuals would likely increase their engagement and improve the reliability of data collected. In this manner, the Fisheries Department could broaden and improve their coverage of Fiji's municipal and non-municipal markets.

Second, I recommend that Fiji's Fisheries Department shift their focus from developing small-scale fisheries, to a more conservative management approach. This approach could entail establishing a greater number of temporal and spatial limitations on fishing, and restrictions on permissible fishing gears. As Fiji's reef fish catches are thought to be declining (Sadovy, 2005), it is important to allocate greater attention to conservation strategies to ensure reefs can continually provide food and income security to coastal communities (Whittingham et al., 2003). Similarly, the high value of inshore resources to livelihoods and food merits additional and consistent government funding to study, monitor and enforce the fisheries.

Third, further opportunities for adding value to products of small-scale fishing should be explored. Post-catch processing such as cleaning, drying or cooking may help fishers and fishing households obtain higher incomes, without actually increasing the volume of fish being taken from reef ecosystems. Given access to resources (financial, technical, physical, etc.) and the freedom to pursue value-adding projects, individuals may effectively increase the incomes they derive from the fisheries

To ensure that Fiji's reef-fisheries stakeholders are able to effectively utilize the finfish and invertebrate models, and benefit from the study in general, it is important to engage the appropriate stakeholders in an informative dialogue. Such a dialogue would facilitate shared learning of Fiji's reef fisheries, while providing a platform to discuss how this work may best be integrated into, and utilized by, the Fiji Fisheries Department. This discussion would also allow for a detailed explanation of the models' functionality and intricacies. For these reasons, it is my intention to interact with Fiji's reef fisheries stakeholders by attending and participating in Fiji's 2009 reef-fisheries workshop.

Lastly, limited and contrasting data and information on reef-based fisheries is not unique to Fiji. Throughout the Indo-Pacific region, small-scale fisheries are overlooked by governing bodies due to difficulties in data collection and the perception that small-scale fisheries are less economically important than offshore industrial fisheries (Sadovy, 2005; Zeller et al., 2006). Although the models in this paper were created for Fiji, the basic model framework could be applied to small-scale fisheries throughout the region, as the models can operate with limited country or fisheries specific data and information. In this way, economic modeling, such as presented in this paper, can play an important role in filling knowledge and data gaps on the economic characteristics of small-scale fisheries, raising the profile of the fisheries in the eyes of government officials, and helping in the development of management strategies that aim to instill economic equity and living wages among fisheries participants.

2.6 Conclusion

In this paper, I use Fiji as a case study for an economic analysis of a coral reef-based artisanal fishery. The results from this study differ from the Fisheries Department's artisanal catch estimates and other studies associated with Fiji's artisanal fisheries for three primary reasons; (1) this study focuses exclusively on reef-associated species while omitting the portion of the artisanal catch that consist of pelagic and estuarine species, (2) this study provides cost, benefit and employment numbers while differentiating between fishers, middlemen and vendors, and (3) this study takes into consideration the deficiencies in monitoring domestic fish sales caused, in part, by inadequate funding, transport and manpower.

Comparing the economic and employment figures of the reef-associated artisanal fisheries with the respective figures for Fiji's industrialized offshore fisheries reveals three important points; (1) the reef-based artisanal fisheries generate gross revenues similar to the industrial fisheries, (2) the reef-based fisheries appear to operate with greater economic efficiency than the offshore fisheries, and (3) many more people are able to derive income by participating in the artisanal fisheries, as apposed to the industrial fisheries. As such, the estimates generated in this study may help reef fisheries gain appropriate recognition for their contributions to the country's economy and employment.

Lastly, the models for this study were developed to be used by Fiji's Fisheries Department as a cost and time effective way to generate preliminary and recurrent nationwide estimates on the economic values associated with Fiji's reef-based fisheries. It is expected that a more complete understanding of Fiji's reef fisheries, in addition to an enhanced appreciation for their economic and social importance, will help promote a greater commitment of time and resources from government level policy-makers and fisheries managers for research, monitoring, management and enforcement of coral reef-associated fisheries.

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Chapter 3

The Subsistence Fisheries of Fiji: Estimating Catch Volume and Value[4]

3.1 Introduction

Virtually every coastal village in the Pacific islands is involved in subsistence fishing activities (Gillett, 2000). As such, subsistence fisheries play an important role in regional food security, social networking and subsistence economies (Kronen, 2004a; Bell et al., 2008; King and Lambeth, 2000). Despite their importance, there is little formal published information on subsistence fisheries that can be used to guide coastal fisheries development, management or conservation (Veitayaki and Noaczek, 2003).

The common argument is that subsistence fisheries are difficult to quantify, due to their wide geographic dispersal and their low dependence on established infrastructure (Schumann & Macinko, 2007). Additionally, governing agencies distributing limited federal resources for fisheries management, monitoring and research often overlook subsistence fisheries, focusing instead on seemingly more valuable, industrial-scale fisheries targeting large stocks of pelagic and oceanodromus fish species (Mahon, 1997). As evidence of governments' failure to properly acknowledge subsistence fishing, only one Pacific island country, Tonga, has even defined subsistence fishing in legislation (Gillett, 2005). Consequently, subsistence landings are frequently underestimated or missing entirely from national statistics (World

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Bank, 2000). As subsistence catches are often substantial compared to artisanal and commercial fishing sectors (Dalzell et al., 1996), omitting them leads to a potentially substantial underestimation of the overall fisheries catch and creates a misleading picture about the state of the fisheries resources. A limited understanding of subsistence catch, in turn, may lead to undervaluing the resource's contribution to a country's total economic production (Zeller et al., 2006).

In this study, I argue that the magnitude and value of subsistence catches can be reasonably estimated with little or no supplemental field data collection required. This approach is neither data-intensive nor technically challenging, and can be completed relatively quickly. Therefore, it is useful where limited funds and technical expertise might be an obstacle towards quantifying the landings of subsistence fisheries. I apply this approach to estimating the subsistence fisheries catch for Fiji, a Pacific island country where coastal communities have traditionally relied on inshore marine resources for the majority of their animal protein (Salvat, 1980).

3.2 Background

3.2.1 Subsistence fishing

Although no universally accepted definition of subsistence fishing exists, the term is typically used to describe local, small-scale fisheries oriented to the procurement of fish for consumption by the fishers, their families, and the community (Berkes, 1988). Adding sustenance to the term, Schumann and Macinko (2007) cite Polanyi (1957) in describing a subsistence economy as revolving around a matrix of social relations that typically include reciprocity (an individual makes a gift to another with the expectation that he will later receive one), redistribution (goods are delivered to a central figure to be allocated among members of a community) and householding (families produce for their own consumption).

For this study, subsistence fishing refers to any fishing activity that results in the catch being eaten by the fisher or their family, or given away or bartered to friends and neighbours. As such, subsistence catch is not just the product of subsistence fishers. Small-scale commercial fishers, whose main focus is to sell their catch, often keep a portion of it for personal or family consumption. Therefore, both artisanal and subsistence fishers contribute to subsistence catch. In this study, any catch, or portion of catch, that does not enter markets driven by monetary exchange, is regarded as subsistence catch.

The role of coral reef ecosystems in food security and livelihood provision, for coastal communities, cannot be understated. Coral reefs are estimated to contribute between 5-10% of global marine fisheries landings (Whittingham et al., 2003), while providing food for millions of people around the world (Munro, 1996). In Pacific island countries, coral reef fisheries are characterized by a strong predominance of fishing for subsistence purposes (Labrosse et al., 2006), with an estimated 80% of coastal fisheries catch consumed directly by the fisher and their communities (Adams et al., 1995). Given the importance of coral reefs in subsistence fisheries, I use this study to report results for Fiji's total subsistence catch and, separately, Fiji's reef-associated subsistence catch. Total subsistence catch consists of coral reef species as well as fish and invertebrate species more closely related with estuarine or pelagic environments, while reef-associated subsistence catch consists exclusively of coral reef species, as identified using FishBase and SeaLifeBase.

3.2.2 Subsistence fishing in Fiji

Characteristics

Subsistence fishing occurs extensively throughout Fiji, taking place predominantly in the area between the shoreline and the outer slope of barrier and fringing reefs. This inshore area encompasses a number of productive fishing habitats that are utilized by Fiji's subsistence fishers, including patch reefs, fringing reefs, lagoons, mangroves and estuaries (Rawlinson et al., 1995). Finfish families typically consumed for subsistence include Lethrinidae, Scombridae, Labridae and Acanthuridae (Jennings and Polunin, 1995), while invertebrate harvests include species of sea urchin, mud crabs, sea cucumber, octopus, and many species of bivalves such as the estuarine shellfish, *Anadara* spp. (Fay et al., 2007). Around 5% of fishers are reported to fish on the ocean side of fringing reefs and in *distant fishing grounds*, targeting both finfish and invertebrates (Rawlinson et al., 1995).

Fijian fishers, like many other Pacific islanders, have tremendous fishing knowledge (Veitayaki, 2005). They use a number of fishing and collection techniques that demonstrate their extensive and sophisticated understanding of the behaviors of marine species and the habitats in which they are found (Veitayaki, 1995). Many subsistence fishing activities are associated with fishing lore, skills and traditional institutions that have been established over many years and passed down through generations (Vunisea, 2005). The gears employed by Fiji's subsistence fishers include many forms of hook and lines, nets, spears, traps and poisons.

Men, women and children all actively participate in Fiji's subsistence fisheries, albeit in different capacities. Generally, men make use of hand lines and spears to target finfish, often using boats or canoes to reach otherwise inaccessible fishing grounds. Women, on the other hand, tend to fish near the shore and upon reef tops, gleaning and net fishing, while targeting shellfish, octopus, echinoderms, crabs, other invertebrates and schools of small finfish (Chapman, 1987). Although it has been shown that women account for more than 50% of subsistence catch (Rawlinson et al., 1995), many studies do not acknowledge their involvement (Vunisea, 2005). The role of children as subsistence fishers has also largely been overlooked. One study in rural Fijian fishing villages, however, reports that children are actively involved in subsistence fishing and can make meaningful contributions to catch (Kronen, 2004b). As rural communities become more monetized and access to market outlets improve, both men and women are increasingly apt to sell a portion of their catch.

The total number of subsistence fishers in Fiji is essentially unknown. Estimates exist, but are based on broad assumptions of fishing activity and vary considerably. The Asian Development Bank (ADB) provides an estimate for the number of full-time fisher equivalents in Fiji, claiming 3,000 (Hand et al., 2005). However, the ADB report does not define what a full-time equivalent is. The United Nation's Food and Agricultural Organization estimate that there are 30,000 subsistence fishers in Fiji, (FAO, 2008), and the Secretariat of the Pacific Community claims that half of all rural households partake in some form of subsistence fishing (SPC, 2008). Visser (1997) estimates there were 64,500 full-time, part-time or occasional fishers in Fiji in 1994, without differentiating between the fishers' involvement as commercial, artisanal and subsistence. As no nation-wide study of subsistence fishing has taken place in Fiji in nearly 30 years, it is unclear how accurate these estimates are.

Past attempts at estimating Fiji's subsistence catch

Prior to 1978, very little was known about the scope and magnitude of subsistence fishing activities in Fiji. Regardless, the Fiji Fisheries Department estimated annual subsistence catch to be around 2,500 tonnes (t) (Anon., 1978). This estimate was based primarily on information attained through informal discussions with a few Fisheries Officers familiar with subsistence fishing in various areas throughout Fiji.

An improved subsistence catch estimate was attained through a 1978/79 survey that the Fiji Fisheries Department administered to 62 out of 850 (7%) Fijian coastal villages. By interviewing one representative per village, the survey produced estimates on the mean catch per village per month for each province in Fiji. This province-specific catch average was then multiplied by the number of villages in each province to get an estimate for subsistence catch per province per month. From here, each estimate was extrapolated to one year and all provinces were aggregated to give a nation-wide subsistence catch estimate, which turned out to be 13,826 t for 1979 (Anon., 1979).

While the 1978/79 survey provided a greatly improved estimate of Fiji's subsistence catch, it was only meant to be a working figure (Anon., 1981) and its limitations have been widely recognized (Anon, 1979; Cook, 1986; Hand et al., 2005). Taking a closer look at the survey's methodology reveals some methodological shortcomings. For example, the survey relies on a single individual in each village to recall the entire village's subsistence catch for the previous month. As such, the subsistence catch estimate for the entire country depends on the subjective opinion of a handful of individuals and their ability to recall 30 days of seafood consumption for dozens of households and scores of individuals.

Another problematic aspect of the 1978/79 survey is that it was administered in two parts, over two years: part one in 1978 and part two in 1979. If the two parts of the survey are used independently to estimate total subsistence catch for the whole country, part one results in 4,095 t per year, while part two results in 23,437 t per year (Anon., 1979). There are at least three possible explanations for this discrepancy; (1) how the informants were asked to report their village's catch, (2) the seasonality of important subsistence species, and (3) the two parts of the survey covering areas of Fiji that have very different subsistence activities. Further explanation is as follows.

According to the survey's results, catch per village per month was expressed as a single figure in part one of the survey, while, in part two of the survey, the interviewee was asked to recall catch per species per fisher per day, and to extrapolate these figures to estimate the village's monthly subsistence catch. The data collection technique used in the second part of the survey requires a series of multiplications to arrive at the final figure, which is believed to contribute to an overestimation of subsistence catch (Anon., 1979).

The catch of certain species targeted by Fiji's subsistence fishers, and by fishers throughout the Pacific, is known to be seasonal (O'Garra, 2007). As the 1978/79 survey was administered over a long time period, it is possible that the two parts captured different 'seasons' of subsistence fishing activity. Accordingly, the mean number of fishing days per month resulting from part one and two of the survey are 14.5 and 22.8, respectively, while the mean catch per village per month is 517 kg and 2,313 kg, for part one and two of the survey, respectively (Anon., 1979). These discrepancies substantially contribute to the difference in the estimated catch per month for the survey's two parts and may be a result of fishing seasonalities.

Last, part one and two of the subsistence catch survey were administered in different provinces. It is possible that the villages visited in the first part of the survey are less reliant on subsistence fishing than the villages in the second part of the survey.

Regardless of the 1978/79 survey's limitations, it forms the base of Fiji's current official subsistence catch estimate. In order to derive each additional year's subsistence catch, the

Fisheries Department adds 200 t to the previous years total, in order to correct for population growth (refer to Appendix B). Though not yet reported in the Fisheries Department's Annual Reports, a catch estimate generated using this method would result in a subsistence catch of 19,600 t for 2008.

Although the 1978/79 survey is used for the official subsistence catch estimate, there have been other, more recent surveys and estimates. In 1987, the Fisheries Department planned a subsistence fisheries survey that addressed many of the shortcomings of the 1978/79 survey. A detailed plan of the 1987 survey can be found in Cook (1986), and although the survey was completed, for unknown reasons the results were never made available or used to revise the 1978/79 subsistence catch estimate. According to Anon. (1991), another subsistence fisheries survey was planned for 1992; however, there is no evidence the survey was ever administered. Other estimates of Fiji's subsistence catch include Zann and Vuki (1998) 17,000 t, the World Bank (2000) 18,057 t, and Gillett and Lightfoot (2001) 21,600 t. These estimates, however, are largely based on the Fisheries Department's official catch estimate figure.

Perhaps the most comprehensive approach to estimating Fiji's subsistence catch was undertaken by Rawlinson et al. (1995). However, their estimate was only for Fiji's main island of Viti Levu. In their study, subsistence catch was estimated to be 3,515 t per year. Rawlinson et al.'s study, highly regarded for its thoroughness, was intended to revise the methods used to determine the official subsistence catch estimate for the entire country, but this has never occurred.

The contribution of invertebrates to Fiji's subsistence catch is not addressed in most subsistence catch estimates, likely a result of insufficient information on the role of women fishers, and the collection of invertebrates in general. Only the World Bank's subsistence catch estimate differentiates between finfish and invertebrates, with finfish contributing 11,015 t per year and invertebrates 7,042 t per year (World Bank, 2000). In this study, the split between finfish and invertebrates is done using the same ratio as the split between the recorded domestic sale of finfish and invertebrates for a given year.

3.3 Methods

The catch volume and value of Fiji's subsistence fishing sector is calculated using a Monte Carlo model. Inputs for the model are obtained from field interviews[5] and from peer-reviewed and grey literature.

3.3.1 Interviews

To obtain information about subsistence fishing activities at the village level, 47 interviews were conducted from May to June 2008 in 12 villages in Viti Levu, Yasawa Islands, Kadavu, and Vanua Levu. Relevant interview data for the model pertained to catch rates and fishing frequency. Interviews were conducted at villages made up mainly of artisanal fishers as well as at villages where people fished primarily for subsistence. From this coverage of fishers with varying fishing priorities, a more representative picture of the range of subsistence fishing activities was established.

3.3.2 Subsistence catch model

Microsoft Excel was used to run a Monte Carlo simulation routine to estimate the annual volume and value of Fiji's subsistence catch. Monte Carlo is a sampling method which uses repeated random sampling to compute results when there is uncertainty and lack of knowledge about the inputs of the system being modeled, in this case the system being Fiji's subsistence fishery. The simulation involved sampling 10,000 random draws, from a designated range for each input variable, assuming a triangle distribution within each range. Data for these input variables were gathered from interviews and from the literature.

3.3.3 Model inputs and calculations

Subsistence catch volume

Total annual subsistence catch, *catch,* was calculated as follows:

[5] Interviews were conducted by L.C.L Teh, L.S.L. Teh and N. Kuridrani.

$$catch = fishers \cdot CPUE \cdot freq \cdot wks \tag{3.1}$$

Where *fishers* is the number of fishers that retain some portion of their catch for subsistence purposes, *CPUE* is the catch per unit effort (kg per trip), *freq* is the weekly fishing frequency (trips per week), and *wks* is the number of fishing weeks per year. This calculation is used to determine the contribution of both subsistence and artisanal fishers to Fiji's annual subsistence catch. I elaborate on the derivation of these input variables in the following sub-sections.

Number of fishers

The total number of fishers that keep a portion of their catch for subsistence purposes consists of Native Fijian and Indo-Fiji artisanal and subsistence fishers. To estimate the total number of fishers, I used two separate approaches. The first approach is based on data sourced from the literature, and is calculated independently from the Monte Carlo model. The second approach is calculated within the model, and incorporates data from the literature, as well as data from field interviews. The two estimates define the upper and lower bounds for the number of artisanal and subsistence fishers used in the Monte Carlo model.

Approach 1: Literature based

In this approach, I calculated the number of fishers living in rural areas only, as done in Rawlinson et al.'s (1995) socio-economic survey of subsistence and artisanal fishing on Fiji's main island of Viti Levu. Accordingly, the estimated number of fishers was calculated by multiplying the number of rural households in Fiji by the percentage of rural households that engage in subsistence or artisanal fishing. The resulting number of subsistence and artisanal fishing households was then multiplied by the number of subsistence and artisanal fishers per fishing household that fish at least once per week. To summarize, the number of fishers was calculated as follows:

$$fishers_1 = rural\ households \cdot \%\ fishing\ households \cdot fishers\ per\ fishing\ household \tag{3.2}$$

The total number of rural Fijian households, according to Fiji's 2007 Population Census, is 84,157 (Anon., 2007). Artisanal and subsistence fishing households as a percentage of all rural households, and the number of subsistence and artisanal fishers per artisanal and subsistence fishing household, are based on survey results from Rawlinson et al., (1995). The calculated number of fishers is inclusive of both finfish and invertebrate fishers, since Rawlinson et al.'s (1995) survey includes women and children, who generally undertake subsistence gleaning. The calculated number of fishers is also inclusive of Indo Fijian fishers, as this survey differentiates between Native Fijian and Indo-Fijian fishers. A summary of the data used to calculate the number of fishers in approach 1 is shown in Table 3.1.

Table 3.1 Summary of data used to calculate the number of fishers in Fiji (Based on Rawlinson et al., 1995).

	Fishing households as a % of rural households		**Number of rural fishing households**		**Average number of fishers per fishing household**	
	Native Fijian	Indo-Fijian	Native Fijian	Indo-Fijian	Native Fijian	Indo-Fijian
Artisanal	37	5	20,445	1,514	1.54	1.33
Subsistence	48	24	25,377	8,080	1.12	0.21

Approach 2: Literature and field based

In the second approach, the total number of fishers that keep a portion of their catch for subsistence purposes ($fishers_2$) is determined by first calculating the total number of Native Fijian fishers ($fishers_{FIJ}$), as follows:

$$fishers_{FIJ} = CV \cdot HH \cdot \%F \cdot HHF \tag{3.3}$$

Where *CV* is the number of coastal villages, *HH* is the number of households per village, *%F* is the proportion of households that fish for subsistence, and *HHF* is the number of people per fishing household who fish. An important point to note is that 'villages' are inhabited by Native Fijians only, whereas Indo-Fijians live in 'settlements'. Therefore, only Native Fijian fishers are accounted for in coastal villages.

Computation of *CV* was determined as follows: There are 850 coastal villages in Fiji (Anon., 1978). I made the assumption that some degree of subsistence fishing takes place in all coastal villages, but at varying levels. I then differentiated between coastal villages that are removed from urban markets, for example villages in Yasawa, Lau, and parts of Kadavu, which I refer to as remote areas (*RA*), and coastal villages that are close to, or have established links to commercial markets, which I refer to as market accessible areas (AA).

Coastal villages were then further differentiated by the presence or absence of employment other than fishing. In villages that are removed from major markets and lack income earning opportunities (*RA*), I assume that most households fish for subsistence purposes, with excess fish sometimes being sold within the village or shared. In such situations, the proportion of households that engage in fishing is high. Likewise, the proportion of fishing households is high in villages where artisanal fishing is the main source of income. Such villages lack alternative employment in the immediate vicinity, but are close to urban markets or have a method of accessing markets regularly. I refer to these villages as AA_{art}. Finally, in villages close to urban markets where other sectors, such as tourism or agriculture, provide the major source of income, I made the assumption that the proportion of households that engage in fishing is low, and that fishing is undertaken for subsistence purposes only. I denote these villages as AA_{sub}. Therefore,

$$CV = CV_{RA} + CV_{AAart} + CV_{AAsub} \tag{3.4}$$

where CV_{RA} and CV_{AAsub} are coastal villages dominated by subsistence fishers, and CV_{AAart} refers to coastal villages where fishing is primarily artisanal.

HH ranges between 8-50, and is taken from the average number of households at the village level, as recorded in the 1986 Small Area Enumeration Data (Anon., 1989). *HHF* ranges between 1.1 to 2.4 fishers per fishing household (L. Teh and N. Kuridrani, unpublished data based on interviews conducted in Fiji, 2008), and represents total gleaners and finfish fishers, including men, women and children, who partake in subsistence fishing.

The model utilizes two values for the percentage of households that fish for subsistence use (*%F*), depending on the presence of alternative employment as described above. $\%F_{hi}$ ranges from 40% to 96% (Rawlinson et al., 1995; Kuster et al., 2005), and is applied to CV_{RA} and CV_{AAart}. $\%F_{low}$ is defined by a lower limit of 12% and an upper limit of 58% (Rawlinson et al., 1995), and is applied to CV_{AAsub}.

Finally, I accounted for subsistence and artisanal Indo-Fijian fishers ($fishers_{IND}$) by applying a ratio of Indo-Fijian to Native Fijian fishers. The percentage of Indo-Fijian fishers (*IND*) ranges from 6% (Rawlinson et al., 1995) to 20% (N. Kuridani[6], pers. comm.) of the total fisher population.

The total number of fishers who keep a portion of catch for subsistence use is thus:

$$fishers_2 = fishers_{FIJ} + fishers_{IND}; \qquad (3.6)$$

where $$fishers_{FIJ} = HH \cdot HHF\left[\left(\%F_{hi} \cdot CV_{RA}\right) + \left(\%F_{hi} \cdot CV_{AAart}\right) + \left(\%F_{low} \cdot CV_{AAsub}\right)\right]; \qquad (3.7)$$

and $$fishers_{IND} = \frac{fishers_{FIJ}}{1 - IND} - fishers_{FIJ} \qquad (3.8)$$

Catch rate

Catch per fishing trip was split by artisanal catch ($CPUE_{art}$), and subsistence catch ($CPUE_{sub}$). I estimated these inputs from fishers' interview responses. Responses for finfish catches were given either as a) bundles of fish; b) numbers of fish; or c) kilograms of cleaned fish. Each bundle of fish consisted of 2 to 18 fish, depending on the size and species of fish being sold, which was specified during interviews. The weight (kg) of fish was obtained by using the weight-length relationship formula $W=aL^b$ (Kulbicki et al., 1993) to convert the number and size of fish to weight. For responses given in kilograms of cleaned fish, I used a cleaned to uncleaned ratio of 0.9 to account for the removal of innards (L. Teh and N. Kuridrani, unpublished data based on interviews conducted in Fiji, 2008).

[6] N. Kuridrani is a Fisheries Officer for the Fiji Fisheries Department.

Subsistence catches of finfish and invertebrates per subsistence fisher ranged from 1.5 to 7 kg per trip ($CPUE_{sub}$). Subsistence catches of finfish and invertebrates by artisanal fishers ($CPUE_{art}$) ranged from 1 to 1.8 kg per trip (L.Teh and N. Kuridrani, unpublished data based on interviews conducted in Fiji, 2008).

Fishing frequency

Fishing frequency was estimated from fishers' interview responses, and was also split between subsistence ($freq_{sub}$) and artisanal ($freq_{art}$) sectors. The mean number of fishing trips taken by subsistence fishers averaged 2.2 per week, with a range of 2 to 3. This frequency is applied to *RA* and AA_{sub} households. Artisanal fishers fished at a higher intensity, with a mean number of 3.8 trips per week, ranging from 3 to 5 trips per week. This value is applied to AA_{art} households. Saturdays are usually set aside for subsistence fishing in preparation for the Sunday meal. Over a one-year period, the number of fishing weeks (*wks*) for all fishers was estimated to range from 35 to 50 weeks. This estimate is based on time taken off for factors like bad weather, gear maintenance, tending crops, or sickness, as suggested by an experienced Fisheries Department field officer (S. Batibasaga[7], pers. comm.).

Invertebrate catch as a percentage of total subsistence catch

Fiji's subsistence catch consists of finfish and invertebrates. Upon calculating the total subsistence catch, invertebrate catch was determined according to an input variable defined by invertebrates' contribution to total subsistence catch. This variable (*invert*) ranges from 24% to 39% and is based on two sources; the Fiji Fisheries Department's Annual Reports on the domestic sale of finfish and invertebrates (Anon., 2004), and on subsistence catch surveys administered in remote Fijian islands, as reported in Kuster et al. (2005).

Reef-associated subsistence catch

According to Annual Reports compiled by the Fiji Fisheries Department, there are 123 species of finfish and 41 species of invertebrates sold in domestic markets, as identified by their Fijian name (Anon., 2004). Using the Fisheries Department's data, I categorized each species as reef-associated or non reef-associated, according to information from the online,

[7] S. Batibasaga is an extension Fisheries Officer for the Fiji Fisheries Department.

peer-reviewed databases of FishBase and SeaLife Base, and a report commissioned by the Forum Fisheries Agency titled *Fiji Fisheries Resources Profiles* (Richards, 1994). Upon analysis, reef-associated finfish and invertebrate species were found to comprise approximately 86% and 24%, by weight, of all domestic finfish and invertebrate sales, respectively. I applied this information to reef-associated finfish ($reef_{ff}$) and reef-associated invertebrate ($reef_{inv}$) input variables. Because the exact ratio of reef and non-reef species utilized for subsistence and artisanal purposes likely differs, I define the range of the $reef_{ff}$ and $reef_{inv}$ input variables with a ± 5% deviation from the calculated reef-associated finfish and invertebrate percentages.

The number of total fishers needed to land Fiji's reef-associated subsistence catch was also calculated. The following equation was used:

$$reef\ fishers = \frac{reef\ catch}{catch\ per\ fisher} \tag{3.8}$$

where *reef catch* is catch per year, and *catch per fisher* is the calculated annual catch per fisher for all subsistence fishing activity.

Subsistence catch valuation

The gross value of Fiji's total subsistence catch and reef-associated subsistence catch was determined by multiplying the finfish and invertebrate catch volumes by the artisanal fisheries' average ex-vessel price. An ex-vessel price is defined as the price that fishers receive when they sell their catch straight off the boat (Sumaila et al., 2007), which, in this study, is estimated to be 60% of market price, as suggested in Reddy (2004). Utilizing data collected by the Fiji Fisheries Department, I calculate the average ex-vessel price for domestically sold finfish and invertebrates to be US$ 2.05 per kilogram[8]. Because actual ex-vessel prices likely fluctuate throughout the year, the ex-vessel input variable used in this study (*price*), is defined by a range of ± US$ 0.15. Using ex-vessel prices to determine the

[8] Using this price may slightly overestimate subsistence price, as those fishers that have reliable access to markets are likely to sell valuable species while keeping less valuable species for personal consumption.

value of subsistence production, as done in this study, has been used in other valuation studies, including Gillett and Lightfoot (2001) and Zeller et al. (2006).

Table 3.2 Summary of the Monte Carlo input values.

Abbreviation	Description	Values
CV_{RA}	Number of coastal villages, remote areas	315
CV_{AAart}	Number of accessible area coastal villages with fishing income	407
CV_{AAsub}	Number of accessible area coastal villages with non-fishing income	129
HH	Number of households per village	8 – 50
$\%F_{hi}$	Proportion of fishing households in CV_{RA} and CV_{AAart}	0.40 – 0.96
$\%F_{low}$	Proportion of fishing households in CV_{AAsub}	0.12 – 0.58
HHF	Number of fishers per fishing household	1.1 – 2.4
IND	Proportion of Indo-Fijian fishers, subsistence and artisanal	0.06 – 0.20
$CPUE_{sub}$	Subsistence catch per trip, by subsistence fishers (kg)	1.5 – 7.0
$CPUE_{art}$	Subsistence catch per trip, by artisanal fishers (kg)	1.0 – 1.8
$freq_{sub}$	Number of days fishing per week, subsistence	2 – 3
$freq_{art}$	Number of days fishing per week, artisanal	3 – 5
invert	Proportion of total catch consisting of invertebrates	0.24 – 0.39
wks	Number of fishing weeks per year	35 – 50
$reef_{ff}$	Proportion of total finfish catch consisting of reef species	0.81 – 0.91
$reef_{inv}$	Proportion of total invert catch consisting of reef species	0.19 – 0.29
price	Ex-vessel price (US$)	1.90 – 2.20

3.3.4 Subsistence fisheries economic analysis

An economic analysis of Fiji's subsistence fisheries is carried out at both the fisher and fisheries level, and consists of calculating an assortment of subsistence fishing costs and benefits. The costs associated with landing Fiji's subsistence catch include intermediate costs (fishing gear and other fishing supplies, fuel, and boat and engine maintenance), capital costs (boat and engine purchases) and the opportunity costs of wages forgone. These costs are largely determined according to the total quantity of fish caught for subsistence purposes and the effort (time) it takes to catch the specified volume. This approach allows me to estimate costs attributed, specifically, to landing subsistence catch. The full amount of these costs are determined according to data from fishers' interviews, from existing literature of relevant regional studies, and from consultation with individuals familiar with Fiji's small-scale fisheries. Specific costs associated with fishing are shown in Appendix E. The gross benefits of Fiji's subsistence fisheries are calculated by multiplying the ex-vessel price by the catch, while net benefits are calculated by subtracting total costs from gross benefits.

Value added, an economic term that expresses the difference between the gross value of goods produced and the intermediate costs of materials and supplies used to produce them, (Philipson, 2006), is also calculated. Value added includes wages, opportunity costs, capital depreciation and profits, while intermediate costs include fishing gear and supplies, fuel and oil, bait, and boat and engine maintenance. Value added can be expressed several ways; as a whole number value, as a ratio of the gross value of output (value added divided by gross benefits), or as a value per tonne of fish landed.

3.4 Results

Results are shown for total subsistence catch and for the portion of total subsistence catch that consists of reef-associated species. The total subsistence catch is inclusive of pelagic, estuarine and reef-associated species. Results are shown as a mean, ± one standard deviation.

3.4.1 Total subsistence catch

Catch volume

The mean annual subsistence catch is estimated to be 15,186 t (± 3,507 t), consisting of 10,405 t (± 2,446 t) of finfish and 4,782 t (± 1,206 t) of invertebrates. Subsistence and artisanal fishers account for 68% (10,258 t) and 32% (4,928 t) of the annual subsistence catch, respectively.

Number of fishers

The mean number of fishers who keep some portion of their catch for subsistence purposes is estimated to be 43,475 (± 3,543). Of this, 22,793 (± 3,074) are estimated to be subsistence fishers, while 20,685 (± 1,766) are estimated to be artisanal fishers.

Catch value

The gross value of Fiji's subsistence catch is estimated to be US$ 31.0 million (± US$ 7.3 million). Finfish account for US$ 21.3 million (± 5.1 million), while invertebrates account for US$ 9.7 million (± 2.5 million). The total cost of subsistence fishing is estimated to be US$ 15.2 million with intermediate costs comprising US$ 5.9 million. The net benefits are estimated to be US$ 15.8 million. The value added is US$ 25.1 million, with a resulting value added ratio of 81%. For individual fishers, the average annual gross benefits are US$ 875 while total costs are US$ 428, with intermediate costs comprising US$ 166 of total costs.

3.4.2 Reef-associated subsistence catch

Catch volume

The portion of Fiji's subsistence catch comprised of reef-associated species is estimated to be 10,034 t (± 2,373 t). The finfish portion of the catch is 8,893 t (± 2,096 t), while the invertebrate portion of the catch is 1,141 t (± 578 t). Figure 3.1 shows the distribution of annual reef-associated subsistence catch outputs, according to the model presented in this chapter.

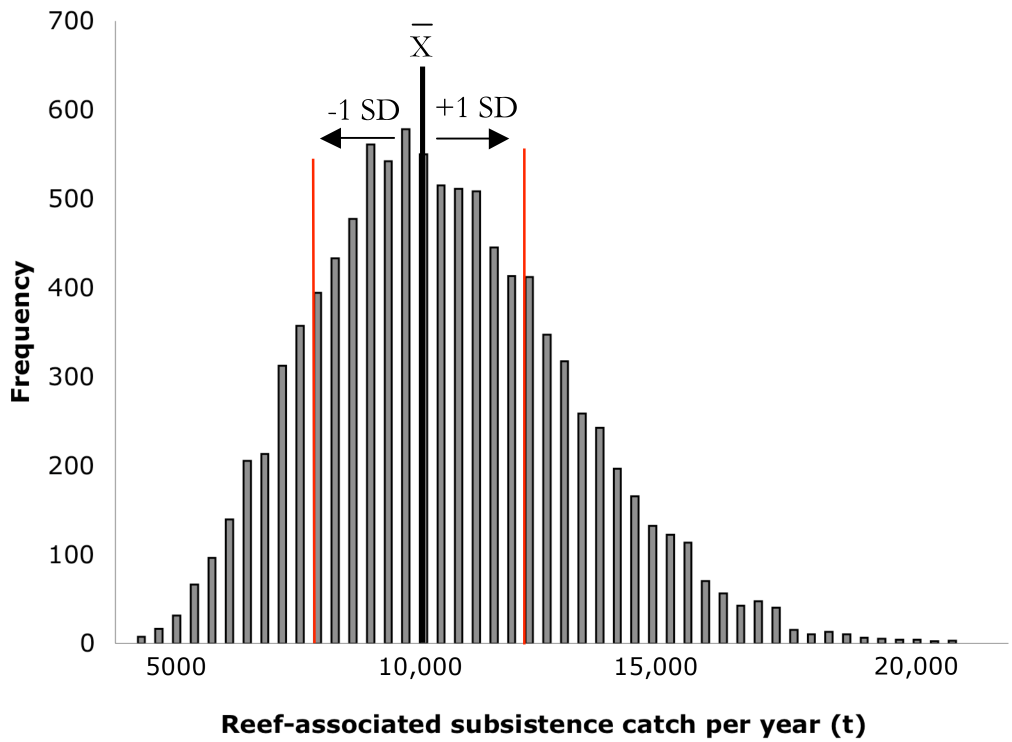

Figure 3.1 Model output distribution of the estimated reef-associated subsistence catch in tonnes per year.

Number of fishers

The number of fishers involved in catching the reef-associated portion of Fiji's subsistence catch is estimated to be 28,820 (± 2,977). The distribution of the reef-associated fishers, as derived from the subsistence model, is shown in Figure 3.2. The mean number of fishers that fish solely for subsistence purposes is estimated to be 15,117 (± 2,262), while the mean number of fishers that keep and sell portions of their catch is estimated to be 13,703 (± 1,461).

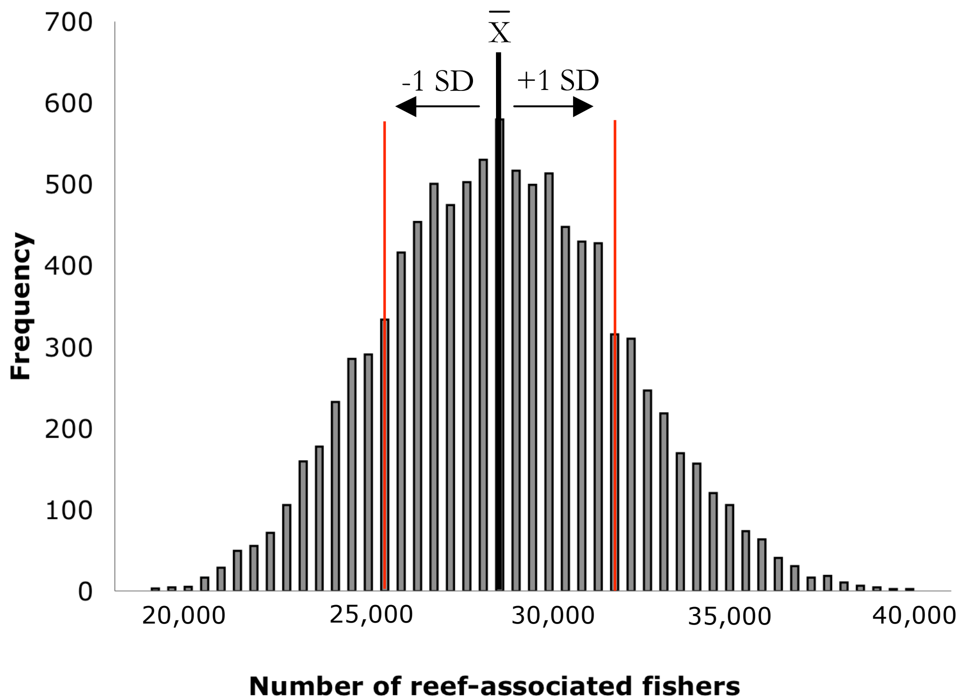

Figure 3.2 Model output distribution of the estimated number of fishers needed to land Fiji's reef-associated subsistence catch.

Catch value

The gross value of Fiji's reef-associated subsistence catch is estimated to be US$ 20.6 million (± 5.0 million). Finfish are estimated to contribute US$ 18.3 million (± 4.3 million), while invertebrates are estimated to contribute US$ 2.3 million (1.2 million). The total costs for landing the reef-associated subsistence catch are US$ 10.6 million, of which intermediate costs comprise US$ 4.4 million. The net benefits and value added of Fiji's reef-associated subsistence catch are therefore calculated to be US$ 10.0 million and US$ 16.2 million, respectively. The value added ratio is 79%. For individual fishers, the average annual gross benefits are US$ 886 while total costs are US$ 454, with intermediate costs comprising US$

187 of total costs. Table 3.3 summarizes the gross benefits, net benefits and value added for Fiji's subsistence fisheries.

Table 3.3 Gross benefits, net benefits and value added associated with Fiji's subsistence fisheries (US$ millions).

	Gross benefits	Net benefits	Value added
Reef-associated species	20.6	10.0	16.2
Non reef- associated species	10.4	5.8	8.9
Total	31.0	15.8	25.1

3.5 Discussion

3.5.1 Catch comparison

The results from this study indicate a potentially lower subsistence catch (15,186 t) than the government's most current official subsistence catch estimate (19,600 t). However, this comparison should be observed with a degree of caution, as the government's official catch estimate lays just 1.3 standard deviations away from the mean catch volume derived from the model presented in this study.

If the government's subsistence catch estimate is indeed an overestimation of actual subsistence catch, there could be a number of contributing factors. One obvious possibility is declining annual catch volumes and catch rates. These trends have been observed in several separate studies. For example, in examining regional fisheries data, Sadovy (2005) detected a decline in annual catch per fisher in Fiji and other Pacific island countries. Further evidence includes a broad consensus among a diverse group of reef stakeholders that there has been widespread declines in Fiji's reef fisheries (Sadovy and Batibasaga, 2006), while subsistence fishers throughout Fiji have indicated their catches have decreased, and that it is more difficult to catch certain fish species now, as compared to the recent past (Matthews, 1998; World Bank 2000; L. Teh unpublished data). Evidence of declining catches can even be found on remote Fijian Islands, such as Ono-i-Lau, where important subsistence fish species of mullets, mackerels, rabbitfish and parrotfish have become conspicuously rare in the last 10 years (Kuster et al., 2005). Lastly, the abundance of kaikoso clams, *Anadara cornea*, a particularly important subsistence food source in Fiji, has shown decline in certain localities (Tawake et al., 2006).

The possibility of diminishing subsistence catch, but especially declining catch rates, is, or should be, a genuine concern for the government of Fiji. The loss of subsistence fisheries resources not only jeopardizes the food security for fishing communities, but may also have adverse health effects. For example, concerns have been raised about the prevalence of non-communicable diseases, such as diabetes, obesity and hypertension, when traditional fish and root crop based diets are replaced with refined cereals, sugars and tinned meat (Schoeffel, 1992).

A second factor, potentially contributing to the government's possible overestimation of subsistence catch, is the practice of adding an additional 200 t to the previous year's estimate, to make up for a growing population. This may have been an acceptable extrapolation during the 1980s, but according to Fiji's most recent national census, the nation's population has been shrinking for at least a decade. In particular, Fiji's rural population, which is more likely to participate in subsistence fishing activities (Rawlinson et al., 1995), has declined by over 8,000 people over the last decade (Anon., 2007). No subsistence catch estimate, up to this point, has accounted for a shrinking rural population and potentially fewer subsistence fishers. This is especially relevant in areas such as Fiji's Coral Coast, where tourism development in the past 10 to 20 years has likely diverted considerable subsistence fishing effort to tourism-based employment.

3.5.2 Potential applications of model

As described earlier, the survey on which the current official subsistence catch estimate is based was never meant to be more than a rough guideline and has regularly been criticized for using dubious methodologies (Anon, 1979; Cook, 1986; Hand et al., 2005). More recent subsistence catch estimates, largely based on the official estimate, are adjusted under the assumption that Fiji's official subsistence catch estimate is underestimated as a result of the inadequacies of the 1978/79 subsistence survey. Consequently, it has been nearly 30 years since a study or survey has produced, and published, an original nation-wide catch estimate for Fiji's subsistence fisheries.

Clearly, a reliable, straightforward and relatively easily implemented method for formally and representatively estimating subsistence catch is needed. The approach described in this study offers such a method, while being sensitive to the limited government resources available for additional data collection. The strength of the current approach lies in its ability to accommodate uncertainty, as well as its relatively low data and technical requirements. Subsistence catch estimates can be generated without relying on extensive monitoring of catch volumes, catch rates or fishing effort. These qualities make the model especially useful where limited financial and human resources may otherwise constrain fisheries monitoring and data collection efforts, as is the case in Fiji, and most, if not all, Pacific island countries.

For the Fisheries Department to effectively utilize the model in deriving robust subsistence catch estimates, it will be necessary to refine some of the input data. Narrowing the ranges of select inputs can likely be accomplished with relative ease and efficiency, if coordinated with existing nation-wide data collection arrangements, such as the national census. Some of the inputs with the largest ranges include the number of households per coastal village (HH), the percentage of fishing households per village (%F) and the number of fishers per fishing household (HHF). These inputs, in particular, could be updated and refined if integrated into the national census. Also, further stratification of select inputs would likely reduce output uncertainty. In the current model $\%F_{hi}$ is used to estimate the percentage of fishing households in rural and accessible coastal villages (CV_{RA} and CV_{AAart}). Assigning a unique input range for the percentage of fishing households per village (%F) in each group of coastal villages (CV_{RA}, CV_{AAart} and CV_{AAsub}) would likely contribute to narrowing output ranges derived from the model. Taking these refinements into consideration, the Fisheries Department could make effective use of the model, to regularly generate national subsistence catch estimates, without directly measuring catch or landings.

In addition to Fiji, many small island countries in the south and west Pacific have incomplete and vague information regarding their subsistence fisheries (Gillett and Lightfoot, 2001). As such, the methods used in this study could also prove effective in improving nation-wide estimates for these countries, in regard to subsistence catch volume and value, and the number of fishers keeping a portion of their catch for subsistence purposes. With existing data and the informed knowledge of fisheries officials serving as sources of input, national-level estimates on subsistence fishing activities could be obtained. Refining the ranges of specific input variables by coordinating data collection priorities with established national censuses can help reduce uncertainty in the model's outputs, with minimal financial obligation on the part of the national Fisheries Department.

3.5.3 Reef-associated subsistence catch

Although this discussion primarily focuses on the total catch of Fiji's subsistence fisheries (pelagic, estuarine and reef-associated species), the significance of reef species to subsistence catch should not be understated. As shown in this study, the role of coral reefs in Fiji's subsistence fisheries is substantial, accounting for approximately 66% of total subsistence catch volume and value. Until now, however, no study has quantified, at a national level, the contribution of coral reef species to subsistence catch. As such, gaining, and maintaining, federal support for protecting coral reef ecosystems and reef-based fisheries, on the basis of their contribution to the country's food security and social stability, is difficult. Subsistence catch volume (10,034 t) and value (US$ 20.6 million) estimates specific to coral reef species, as obtained in this study, provide policy and decision makers with tangible evidence of coral reefs' social and economic importance, and may contribute to developing and sustaining coral reef conservation and sustainable management strategies.

3.6 Conclusion

Subsistence fishing plays a significant role in the lives of coastal inhabitants throughout Fiji. The magnitude of this role, however, is largely unknown, as subsistence fishing activities go essentially unmonitored. Because nearly 30 years have passed since the last nation-wide subsistence catch survey published original results, there is a genuine need for updated information on the volume and value of subsistence catch originating from Fiji's inshore and coral reef habitats. In addition to addressing this information gap, this study offers a framework for continually updating catch volume and value, which does not require extensive fisheries specific data collection, financial resources or technical expertise. This approach is intended to be used by fisheries stakeholders and can easily accommodate updated information and the personal knowledge of individuals familiar with subsistence fishing activities. Coordinating data collection priorities, with the existing national census, is a cost and time effective means for improving the accuracy of the catch estimates. It is believed that this work will help raise the profile of Fiji's subsistence fishing sector in the eyes of policy and decision makers, and help guide coastal fisheries development, management and conservation.

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Chapter 4

Conclusion

4.1 Fiji's reef-based artisanal and subsistence fisheries

The objectives of this study were to estimate the catch volume and value of Fiji's coral reef-based artisanal and subsistence fisheries, to determine the economic significance of the fisheries at an individual and national level, to identify gaps and shortcomings in existing data, information and monitoring methods and to develop recommendations for future research, monitoring and management of Fiji's reef fisheries. To fulfill these objectives, I developed models that provide reef species catch estimates and fisheries related cost and benefit estimates. The resulting outcomes indicate that, together, Fiji's coral reef-based artisanal and subsistence fisheries play an important role in sustaining coastal inhabitants by supplying an estimated 17,777 t of finfish, invertebrates and seaweed, per year, for local consumption. The fisheries also provide income and/or nutrition for up to 28,880 fishers, 842 middlemen and 2,480 vendors. With an estimated gross value of US$ 54.0 million, net benefits between US$ 21.2-22.8 million and value added between US$ 34.4-36.3 million, Fiji's reef-based fisheries are seemingly more valuable than the country's highly regarded offshore fisheries. The offshore fisheries, which primarily target species of tuna, are estimated to have a gross value of US$ 40 million and a value added of US$ 13 million (Hand et al., 2005). These results strongly suggest that Fiji's reef-based fisheries deserve greater recognition and support for their economic and social contributions to the country, and a proportional share of federally administered financial and human resources for fisheries management, research monitoring and enforcement.

Estimates of catch, catch value and the number of individuals able to derive income by participating in Fiji's reef fisheries may bring greater recognition to the fisheries, in the form of federally administered economic and human resources, but the results from this study are also expected to contribute to a larger dialogue on Fiji's local and national food security. Similar to most Pacific islanders, Fijians depend heavily on seafood to fulfill their dietary needs, as seafood makes up an estimated 35% of all protein consumed in Fiji (Fiji Ministry of Health, 2004). Although Fiji's exact per capita seafood consumption is unknown, it is assumed to be around 50 kg/person/year (Gillett and Lightfoot, 2001; Vatucawaqa, 2003). Given Fiji's current population, estimated per capita seafood consumption and the results from this study, Fiji's reef-based artisanal and subsistence fisheries supply nearly half of all seafood consumed in Fiji, with non-reef species and imported fish making up the other half. This is consistent with information in Fiji's 2003 Food Balance Sheet. If the health of Fiji's coral reefs and reef-based fisheries are in decline, as some literature has suggested (Matthews et al., 1998; Hoffman, 2002; Sadovy, 2005; Sadovy and Batibasaga, 2006), it will be increasingly important to include food security concerns in discussions regarding coral reef development and management strategies.

Over the course of this thesis, I have become quite familiar with the strengths and weaknesses of the past and present research, monitoring and management of Fiji's artisanal and subsistence fisheries, in addition to obtaining a thorough understanding of the current economic and social conditions of these fisheries. Drawing from this experience, I have a number of recommendations that the Fisheries Department may want to consider as they plan for the future of the country's coral reef fisheries. First, collection of fisheries data could be improved by increasing the involvement of the participants in Fiji's artisanal and subsistence fishing sectors. Traditional resource owners, who play a substantial role in overseeing and regulating resource use within customary resource areas, known as *qoliqolis*, should play an increased role in monitoring and recording the number of fishers and volume of catch, in regard to their *qoliqoli*. Similarly, fishers, middlemen and vendors, with minimal training, could significantly contribute to fisheries data collection coverage. Providing minimal monetary compensation to certain individuals would likely increase their engagement and improve the reliability of data collected. Second, I recommend that Fiji's Fisheries Department should shift their focus from the development of small-scale fisheries, to a more conservation oriented management approach. As Fiji's reef fish catches are thought to be declining (Sadovy, 2005), it is important to allocate greater attention to conservation strategies to ensure reefs can continually provide food and income security to coastal communities (Whittingham et al., 2003). Third, opportunities for adding value to products of small-scale fishing should be explored. Post-catch processing such as cleaning, drying or cooking may help fishers and fishing households obtain higher incomes, without actually increasing the volume of fish being taken from reef ecosystems. Given access to resources (financial, technical, physical, etc.) and the freedom to pursue value-adding projects, individuals may effectively increase the incomes they derive from the fisheries.

As mentioned in the introductory chapter, my thesis is part of a larger research project looking into the direct use values of Fiji's coral reefs and the socio-economic impacts of the different uses. The project's results are intended to help inform the Fiji Fisheries Department, and other reef fisheries stakeholders, in the process of designing and implementing resource use management strategies and monitoring protocols. As the larger project nears completion, our project team will continue to collaborate with the Fisheries Department in an effort to integrate our work and recommendations with their reef fisheries development, management and monitoring objectives.

4.2 Knowledge gaps, reflections and future work

Through the pursuit of my research objectives and the progression of my work, I have come to realize some of the limitations of existing data and literature relevant to Fiji's artisanal and subsistence fisheries. Although these fisheries receive considerable attention from academic and non-governmental research and development groups, considerable gaps in knowledge still exist. For instance, the role of women and children in Fiji's reef-fisheries is largely undocumented, even though they are known to actively participate in reef fishing and gleaning (Fay et al., 2007; Fay-Sauni et al., 2008). In fact, the collection of reef invertebrates and plants, in general, is poorly understood. In addition to women and children, there is very little information on the livelihoods of middlemen and vendors, and the role they play as a link between resource exploitation and consumption. Similarly, it would be useful to know, from a fisher's perspective, what percentage of their catch they sell to middlemen, vendors and consumers, and why. These gaps in information represent a significant component of Fiji's small-scale fisheries, and therefore, it is recommended that future research and monitoring projects adjust their objectives to address them.

The process of researching Fiji's reef-based fisheries, and developing the artisanal and subsistence models, exposed me to an abundance of research covering the economic and living conditions of fishers and fishing communities. Expectedly, a wealth of literature supports the notion that small-scale fishers generally have low incomes (Copes, 1989; Loayza and Sprague, 1992; Cunningham, 1994; Bene, 2003) and may even be among the poorest of the poor (Bailey et al., 1986; Kremer 1994). As my thesis research wraps up, my attention and efforts are moving towards addressing the issue of small-scale fishers' relatively low incomes. I recognize that reef fisheries are susceptible to overfishing (Roberts, 1995; Jennings and Polunin, 1996; Sadovy, 2005), and subsidizing increased fishing effort for the purpose of higher incomes, can, in the long run, be counter-productive (Pauly et al., 2002, Sumaila and Pauly, 2006). Alternatively, supporting livelihoods that ease fishing pressure, such as eco-tourism, raising livestock or handicraft production, may be a viable option for improving Fijian fishers' financial security in a sustainable manner (Veitayaki et al., 2007; Gillett et al., 2008). As such, micro-credit programs are increasingly being used to provide individuals and groups access to capital to support business ventures and education opportunities (Tietze and Villareal, 2003). Providing micro-finance services, such as loans, money transfers and insurance, to fishing communities, may help families develop micro-enterprises, increase their income and manage risk better, thus, reducing their economic and social vulnerabilities (FAO, 2004). Micro-finance has experienced widespread success, but is only recently being applied specifically to fishing communities. As I move into other fisheries related research, micro-finance for fishing communities is a topic of particular interest and something that I plan to pursue in coming years.

Overall, this thesis has provided me with a strong background in the design and function of natural resource economic valuations, and an understanding and appreciation of how economics can be used as a tool in resource management. As economics continue to play an increasingly important role in resource use decision-making, the experience I have acquired from completing this thesis will allow me to meaningfully contribute to ensuring fishing activities are carried out in an economically sustainable and equitable manner, wherever they may be.

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Appendix A: People contacted while in Fiji

Table A.1: Individuals corresponded with while in Fiji, Nov. 15 – Dec. 15, 2007. Last names are absent if unknown.

Name	Title/position	Affiliation
Aisake Batibasaga	Head of Fisheries Research Division	Fiji Fisheries Department, Lami
Alifereti Tawaki	Scientific officer	Fiji Locally Managed Marine Areas Network
Anesh	Fish buyer, middleman	Labasa fishing wharf
Apisai Sesewa	Senior fisheries officer	Fiji Fisheries Department, Labasa
Arunesh Asis	Fisheries officer, monitoring	Fiji Fisheries Department, Lami
Ashwin	Statistician	Fiji Bureau of Statistics, Suva
Betani Salusalu	Project manager	Momanuda Environmental Society (MES)
Bill Aalbersberg	Director	University of the South Pacific
Bob Gillett	Consultant	Gillett and Associates
Cherie Morris	Faculty	University of the South Pacific, Coral Reef Initiatives for the Pacific
Ed Lovell	Faculty	University of the South Pacific
Fulori Nainoca	Eco-tourism officer	Foundation of the Peoples of the South Pacific International
Helen Pippard	CITES/coral and live rock trade	International Union for Conservation of Nature
Hugh Govan	Program manager	Foundation of the Peoples of the South Pacific International
Isoa Korovulavula	PhD student: Environmental economics	University of the South Pacific
Joeli Veitayaki	Professor	University of the South Pacific
Joji	Fisheries officer	Fiji Fisheries Department, Savusavu
Kelly	Employee	Walt Smith International
Kenneth MacKay	Director	Coral Reef Initiatives for the Pacific
Lepani Daivalu	Fisheries officer	Fiji Fisheries Department, Latoka
Loraini Sivo	Fiji coordinator	Conservation International
Louise Isimeli	Aquarium trade specialist	Fiji Fisheries Department, Suva HQ
Nanise Kuridrani	Research division	Fiji Fisheries Department, Lami
Nanise Odrovakavula	Tourism officer	Fiji Ministry of Tourism, Suva
Penina Vatucawaqa	Research officer	Fiji Ministry of Food and Nutrition
Sanivalati Navuku	Project officer	Worldwide Fund for Nature (WWF)
Senijiele Bose	Lands manager	Fiji Ministry of Lands, Suva
Shalen Drasing	Fisheries officer	Fiji Fisheries Department, Suva HQ
Sunia Waqainabete	Fisheries officer	Fiji Fisheries Department, Lami
Tanya O'Garra	Environmental economist	Coral Reef Initiatives for the Pacific
Vina Ram-Bidesi	Professor	University of the South Pacific

Appendix B: A brief history of Fiji's coral reef-based fisheries

Gaining a comprehensive understanding of Fiji's coral reef-based fisheries involves more than becoming familiar with current fishing effort, catch composition, fishing gear and ecological conditions; it is also important to obtain a firm appreciation and thorough understanding of reef-based fisheries' historical, political, cultural and social significance within Fiji. Therefore, I provide a chronological summary of Fiji's coral reefs' uses, value, management and association with political and social issues. In an effort to encourage and guide improved monitoring and additional research studies, I also identify some of the prominent knowledge and information shortcomings regarding Fiji's coral reef fisheries.

Initial settlement of Fiji: 1500 B.C. – 1800 A.D.

Traveling west to east against prevailing trade winds, the earliest settlers of the Fijian archipelago arrived via western Melanesia. As inhabitants of the Indo-Pacific region, these settlers maintained an intimate relationship with the sea, relying on it for nearly all of their dietary needs (Johannes, 1978). These Melanesian migrants settled into their new home and established prosperous societies amongst the abundant natural resources. Archaeological accounts indicate that a significant portion of native Fijian's diet consisted of coral reef fish species, particularly from the families Scaridae, Diodontidae, Lethrinidae, Serranidae, Labridae, Lutjanidae, Balistidae, and Acanthuridae, and marine gastropods such as conch (Strombus *spp.*) and surf clams (Atactodea *striata*) (Nunn et al., 2007). Sea turtles were also an important part of Fijians' diets. Considered a delicacy, sea turtles would only be eaten at important feasts by high-ranking officials (Luna, 2003).

As time passed, these societies developed a variety of straightforward and seemingly successful means for managing inshore marine resources. A particularly effective approach, the allocation of inshore resource ownership, is perhaps the single most important conservation measure in all of Oceania (Johannes, 1978). Effectively establishing property rights, clan leaders from a coastal region would assemble and decide upon inshore fishing boundaries. Incorporating natural features such as reef channels, distinctive trees and immovable boulders, the boundaries commonly extended from the shoreline to the outer slope of the reef for several kilometers along the coast (Iwakiri, 1983; Kunatuba, 1983; Fong, 1994; Veitayaki, 1995). Known as *qoliqolis*, these traditional fishing grounds endowed inhabitants of the participating clans with exclusive ownership to marine resources within their *qoliqoli*. In Fiji, a clan, or *yavusa*, consists of two to four villages. Sometimes one clan would oversee an entire *qoliqoli*, but more commonly a group of clans would share the responsibility.

Although defined fishing boundaries were generally respected, people would often fish in *qoliqolis* other than their own. Fishers seeking permission to fish in a neighboring clan's *qoliqoli* would follow the custom of *sevusevu,* or presenting gifts to a chief, often the mildly intoxicating plant and national drink *yagona*. Upon receiving permission, the fishers could access the resources of the *qoliqoli* following the agreement made with the chief. As additional compensation, the fishers would typically give a portion of their catch to the chief of the *qoliqoli*. These traditional management arrangements were, and to some extent, still are, accepted as part of the social system. Those who defied the authority would be publicly shunned or, following particularly serious offences, killed (Tippett, 1959).

A second method of marine conservation applied by early Fijian clans, and used widely throughout Oceania, is known as *tabu* (Veitayaki, 1997). Within the boundaries of a *qoliqoli,* a village chief could declare a certain area off limits to fishing, designating it a *tabu* area. *Tabu* areas were established for several reasons. An area might be declared *tabu* leading up to or following a special event such as the passing of a respected chief, a celebrated birth or the marriage of prominent individuals (Ravuvu, 1983). Typically areas remained *tabu* anywhere from 120 days to 1 year. Upon lifting the *tabu*, the living marine resources from the formerly closed area would be caught and eaten in a celebratory manner. Effectively, *tabu* systems helped reduce the occurrence of marine resource over-exploitation within a clan's *qoliqoli*.

Supernatural beliefs also played an important role, intentional or not, in the conservation of inshore resources (Veitayaki, 2005). A number of beliefs based on appeasing certain gods and ancestral spirits helped ensure that fish and fishing grounds received respectful treatment. As such, certain fishing grounds were considered sacred; believed to be a physical manifestation of the vital link between the living and the dead (Siwatibau, 1984).

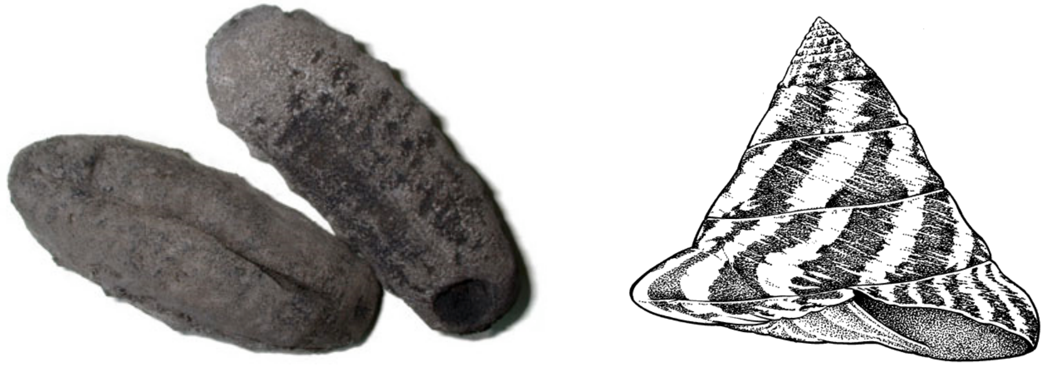
The above examples were all deeply embedded in Fiji's cultural traditions and contributed to the conservation of inshore marine resources. Although the primary objective of traditional marine management was not conservation, but to protect resources from their neighbors and to increase fishing success (Aswani and Hamilton, 2004), creating a limited entry fishery and assigning property rights to inshore resources helped to ensure sustainable levels of exploitation for future generations. Additionally, influenced by folklore and belief in supernatural powers, these self-proclaimed owners of marine resources had an incentive to pursue sustainable fishing practices.

Period of colonization: 1800-1913

The lure of sandalwood trees and other natural resources brought European and American traders to Fiji around the year 1800. Aside from rapidly depleted stands of sandalwood, settling Westerners established successful trades in *beche-de-mer*[9], trochus[10], and tortoise shells (Howard, 1991). As these trades developed, traditional methods of conserving resources were negligently eroded, driven by an eagerness to maximize the material wealth or social status of those involved. As non-owners of the reef resources, western traders did not have an incentive to fish at sustainable levels. *Qoliqoli* chiefs, on the other hand, allowed massive quantities of resources to be caught from within their jurisdiction, often in exchange for foreign supplies of weapons, guns and ammunition (Scarr, 1984).

[9] The term *beche-de-mer* refers to dried sea cucumbers.

[10] A large marine gastropod, trochus shells are used for fabricating mother-of-pearl button blanks, a valuable commodity throughout Asia, Europe and North America.



1. 2.

Figure B.1 (1) *Beche-de-mer* (2) Trochus

The *beche-de mer* trade began in earnest, in 1813, as demand originating from China fueled intense exploitation of Fiji's sea cucumbers. Between 1828 and 1848, Fiji exported an estimated 1,500 tonnes of *beche-de-mer* (Adams, 1988). Upwards of 20 trading ships running regular routes between Fiji and Asia caused significant depletion of sea cucumbers (Scarr, 1984) and by 1852, the *beche-de-mer* trade had slowed considerably. As a result of the *beche-de-mer* industry's success, traders established some of Fiji's first Western settlements and many of Fiji's most well-know Western surnames can be traced to these early communities (Adams, 1988).

After three-quarters of a century of resource exploitation, trade, eroded customs, settlement, sicknesses and missionaries, Fiji officially succumbed to the United Kingdom's colonization in 1874. While discussing terms of cession, Governor Sir George William des Voeux stated that it was the Queen's desire that Native Fijians should not be deprived any rights to coral reefs that they enjoyed under their own laws and customs (Hornell, 1940). Fiji's chiefs responded by trusting the Queen to "govern them righteously and in accordance with native usages and customs" (Wilkenson, 1908). This correspondence resulted in Fijians retaining their 'native customary fishing rights' but forfeiting the actual ownership of marine resources to the Queen; although legislation supporting this is scarce and quite vague. In 1880, the Native Lands and Fisheries Commission was established in order to arbitrate, settle and record all claims to customary fishing grounds (Dalzell and Adams, 1995).

During the period of colonialism, subsistence fisheries consisted of a diverse assemblage of marine fish species, primarily from the families of *Serranidae*, *Mugilidae* and *Lethrinidae* (Hornell, 1940). An equally diverse collection of invertebrates, including numerous species of gastropods, bivalves, crustaceans and echinoderms likely provided a majority of the subsistence catch, by weight. Frequently, Green and Hawksbill sea turtles would be caught for use in traditional ceremonial feasts (Kunatuba, 1983). Based on historic population records (http://populstat.info/populhome.html) and recent trends of per capita seafood consumption for urban and rural areas (Kuster et al., 2005; Foraete, 2001; Jennings and Polunin, 1995; Vuki, 1990), it is reasonable to assume that inshore fisheries supplied nearly 7,000 tonnes for subsistence purposes in 1874.

Period of colonization: 1914-1970

Intending to establish a stable economic base for the colony, the new colonial government actively developed the sugar cane industry within Fiji by securing investments from Australia's Colonial Sugar Refining Company. Lacking the necessary work force, the government negotiated a deal to bring indentured laborers from India. The government financed Indian settlements near sugar plantations, and as early as 1914, a council of Fijian chiefs expressed concern that the growing Indian population's commercial success undermined Native Fijians' national domination (Howard, 1991). In total 60,000 Indian workers made their way to Fiji, approximately 40,000 of them remaining to live beyond their 5-year indenture period. The immigration and subsequent increase in the population of Indians would impact Fiji's social and political unity for years to come, substantially affecting the use and management of coral reefs and other inshore marine resources.

The first comprehensive written account of Fiji's reef fisheries came about at the request of Sir Harry Luke in 1940. Commissioned by Luke, James Hornell described a commercial reef fishery that was notably underachieving and lacked government involvement (Hornell, 1940). His investigations stated that there was no shortage of fish, but only a shortage of fishermen. He declared that the native Fijians, who by heritage should be the backbone of the industry, could not "awaken from their apathy and indifference to the riches which the sea offers" (Hornell, 1940). Hornell observed that subsistence fishing on the reefs provided Fijians with all the fish they could eat while requiring very little effort. Even at this time, fishing outside barrier reefs occurred very infrequently, in large part because the vast reefs provided all the resources necessary for comfortable living. Hornell's criticism of Fijians fishing effort exemplifies Western cultures' influence on resource use within Fiji and throughout the south Pacific.

Shortly after Hornell's visit to Fiji, the colonial administered Fisheries Act of 1941 (Fisheries Ordinance 1941) appeared in legislation. The act officially recognized Fijians' right to fish in customary fishing grounds, but left ownership in the hands of the state. The act also allowed the owners of customary fishing rights to advise the Fisheries Department as to which commercial fishermen could fish in their area. According to the Act, fisherman could receive a license to fish within a *qoliqoli* only after obtaining permission from the *qoliqoli's* chief, similar to historic traditions.

Independence: 1970-present

Fiji regained independence on October 10th, 1970. Prior to, and following Fiji's independence, Native and Indian Fijians have consistently debated access rights to inshore fisheries resources. Native Fijians have sought to legally regain ownership of the resources within their *qoliqolis* while Indian Fijians have aspired to secure more favorable access rights to these same resources. In recent years, a controversial legislative bill, know as the Qoliqoli Bill, has emerged. If passed, the bill would finally transfer the full ownership of *qoliqoli* resources from the state of Fiji to traditional resource rights-holders. Since all customary fishing rights owners are Native Fijians, passing the Qoliqoli Bill would keep Indian Fijians at a significant disadvantage in their ability to utilize inshore marine resources for generating income and as a source of food. Even without the Qoliqoli Bill, the power that Native Fijians hold in their fishing rights is thought by some to be the one of the most comprehensive recognitions of customary fishing rights in the world (Ledua, 1995).

In any case, acquiring accurate, complete and up-to-date data and information on Fiji's artisanal and subsistence fisheries remains difficult. The Fiji Fisheries Department estimates current subsistence catch by extrapolating the results from a survey administered in 1977-78 (Anon., 1978). The extrapolation involves simply adding 200 metric tonnes to the previous year's total, in order to correct for population growth. Although the survey methodologies are questionable (Hand et al., 2005) and the inaccuracies recognized (Anon., 1990), this survey still provides the official estimate for the nation's subsistence catch. Though not yet confirmed by the Fisheries Department, a catch estimate generated by these methods would result in a 2008 subsistence harvest of 19,600 mt.

The number of subsistence fishers is largely unknown. Estimates provided by the Food and Agriculture Organization of the United Nations indicate that there are 30,000 subsistence fishers in Fiji (FAO, 2008), although it is not reported how this number is calculated. Also, the Secretariat of the Pacific Community reports that half of all rural households partake in some form of subsistence fishing (SPC, 2008). In 2007 there were over 87,000 rural households in Fiji (Fiji Islands Bureau of Statistics, 2007). If half of these households contained one subsistence fisher, then there would be over 43,000 subsistence fishers in Fiji.

Monitoring Fiji's artisanal fisheries has fared better than the subsistence fisheries, but serious concerns still exist. One fisheries officer in each of the north, west and central divisions is assigned the task of monitoring the sales volume and corresponding value of domestic fish sales within their division; the eastern division is not monitored because of its remoteness and perceived lack of fish sales that occur there. The limited availability of government funding has left fisheries officers responsible for monitoring domestic fish sales in only the western and central divisions. Consequently, it is estimated that only 70-90% of actual artisanal fish landings are accounted for (Chana pers. comm. 2007; Drasing pers. comm. 2007). In 2004, the Fisheries Department reported inshore fish sales to be 10,969 tonnes, worth US$ 30.1 million (Anon., 2004). Estimates on the number of individuals able to derive income by participating in Fiji's artisanal fisheries vary greatly. For example, the Fisheries Department reports issuing 2,124 inshore fishing licenses in 2004 while Rawlinson et al. (1995) estimates there are 8,335 artisanal fisheries on Fiji's main island of Viti Levu alone.

Exploiting Fiji's reef resources for international trade has persisted since the early days of *beche-de-mer* and trochus, but has increased in scope and scale in the last three decades due to a greater market integration and globalization (FAO, 2004). During this time, two fisheries have developed that consist of catching reef fish and transporting them alive to international markets. These fisheries, the marine aquarium and the live reef food fish (LRFF) fisheries, involve reef species that can fetch high prices throughout the value chain. Additional reef-associated items bound for international markets include fresh, frozen and dried reef fish, black pearls, an assortment of invertebrates and coral itself. Unfortunately, the trade statistics kept by Fiji are too broad and do not identify specific species of fish. According to data available from the United Nations, Fiji exported approximately 3,340 tones of living marine resources, excluding pelagic and aquarium species, worth an estimated US$ 14.1 million, in 2005 (United Nations Commodity Trade Statistics Database, 2008).

Because of the high value of select marine commodities, individuals and communities taking part in export fisheries can potentially make substantial profits. However, along with the prospect for high profits comes the potential for ecological and social degradation. Although the volume and value of Fiji's reef-associated export fisheries has increased significantly during the past few decades, very little attention has been paid to the economic, social and ecological impacts of export driven fisheries on artisanal and subsistence fishers, fishing communities and fishing habitat. This represents a considerable gap in knowledge that will be addressed in the larger project that my thesis is a part of.

Although Fiji's reef-based fisheries are socially and economically important, there are other uses of Fiji's coral reefs, particularly tourism. The number of annual visitors to Fiji has fluctuated in recent years as a result of their political instability, but it is estimated that approximately 570,000 international tourists will visit Fiji in 2008 (Fiji Islands Visitor Bureau, 2008). Past studies have shown that many of these tourists participate in coral reef associated activities such as scuba diving, snorkeling, fishing and reef walks (Fiji Ministry of Tourism, 2004). Although there are several publications reporting coral reefs as a major draw for tourists (Plange, 1996; McDonnell and Darcy, 1998), there is no quantitative data or information on the economic contribution of coral reef-based tourism to Fiji's economy. Regardless, coastal tourism undoubtedly affects artisanal and subsistence fisheries and will inevitably influence future fisheries development and management strategies (Gillett, 2002).

Other notable direct uses of Fiji's coral reefs include using coral pieces in septic system soakage pits, using coral sand in cement production and pharmaceutical bio-prospecting of coral reef flora and fauna (Anon., 2002; Tangley, 1996; Aalbersberg et al., 1999). There is practically no research and monitoring done within Fiji in regard to the volume and value of these uses of coral reefs.

As part of Fiji's Ministry of Primary Industries, the Fisheries Department is assigned the task of monitoring, managing and developing fisheries resources. The two main pieces of legislation used to regulate current fishing activities in Fiji's national waters are the Fisheries Act, which pertains solely to Fijian owned fishing vessels, and the Marine Spaces Act, which aims to regulate the fishing activities of foreign owned fishing vessels (Forum Fisheries Agency, 1998). The Fisheries Act is most applicable to inshore and reef fishing activities, regulating fishing methods, gears and areas.

For many years the Fisheries Department has emphasized developing Fiji's fisheries through a number of schemes, including the introduction of motorized fishing boats, improving fishing gear, establishing marketing and transportation systems, developing ice-making and cold storage facilities and improving landing and berthing facilities in main fishing centers (Veitayaki, 1995). However, quarterly operating funds are often substantially delayed, inhibiting the Fisheries Department's ability to carry out day-to-day operations and see through long-term projects. In this environment, it's possible that the Fisheries Department's inshore fisheries conservation and management efforts get overlooked for seemingly more lucrative fisheries development projects and industrial scale offshore fishing.

In addition to the Fisheries Department, there are several regional and international organizations and institutions playing a role in inshore fisheries research, monitoring and management, and the development of alternative livelihood options. Although too numerous to mention, one organization is particularly active and visible; the Fiji Locally Managed Marine Area (FLMMA) Network. FLMMA stands out because of the number of locations they work and their commitment to facilitating collaboration between government agencies, academic institutions, non-governmental organizations and local communities of resource users. FLMMA's management strategies are based on combining traditional resource use practices with modern methods of biological, social and economic monitoring (Veitayaki et al., 2003). Currently, the Network has initiated a logbook program to collect fisheries related data from coastal communities throughout Fiji. This data collection scheme figures to significantly contribute to future conservation efforts by the Fiji Fisheries Department and other groups working within the FLMMA Network. Another organization working closely and collaboratively with the government of Fiji, with the specific aim of conserving reef fish spawning aggregations, is the Society for the Conservation of Reef Fish Aggregations.

Conclusion

Coral reefs, and their associated flora and fauna, have played a significant role in the lives of Fijians for millennia. However, the island nation's long dependence on reef-associated species for food, income, livelihoods and tradable commodities faces an uncertain future. Increasing fishing effort to meet growing domestic and international demand is undoubtedly affecting the economic, social and ecological conditions in Fiji's fishing communities and coastal environments. However, federally funded research, monitoring, management and enforcement of reef-based fisheries are consistently underprovided for, in regard to financial and human resources. In fact, just two people are currently employed to monitor domestic fish sales for the entire country, while official subsistence catch estimates are made according to a survey last administered nearly 30 years ago. As shown in this overview, existing literature addresses a number of important economic, social, cultural and ecological aspects of Fiji's reef-based fisheries, but significant data and information gaps remain. Insufficiencies in data paint an incomplete picture of the fisheries and can lead to ill-informed management decisions. This literature overview helps ground my research and provides a background to help guide future discussions on coral reef resource management, conservation, research and development strategies.

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Appendix C: Input variable descriptions, values, notes and sources

Table C.1 Finfish model input variables, values and references.

Variables	Value	Notes	References
General			
Accuracy of Fisheries Department monitoring (volume)	1.2	Represents catch under-estimation	Pers. comm., A. Asis; S. Singh
Inflation (2002 prices into Jan 2008 prices)	1.28	Food price inflation	Fiji Islands Bureau of Statistics http://www.statsfiji.gov.fj/
Average number of fishers per boat with an engine	3.64		DemEcoFish survey data, 2004
Average number of fishers per boat without an engine	2.14		DemEcoFish survey data, 2004
Catch Per Unit Effort (kg/person/hour)	1.78	CPUE varies depending on fishing gear used; spearfishing 1.78, handline 1.5, net fishing 2.25. Numbers represent an average CPUE for each gear type, determined by existing literature	Rawlinson et al., 1995; Dalzell et al., 1996; Jennings and Polunin, 1996; Kuster et al., 2006
Fishers' Costs			
The % of total fishing hours fished by FT fishers	100	Distributes total fishing hours amongst FT and PT fishers. The models can be run as if all fishers were FT, all fishers PT, or a given percentage of FT and PT fishers	
The % of total fishing hours fished by PT fishers	0		
Labor cost multiplier for working (not fishing)	1.33	Multiplied by hours spent fishing to get total working hours.	Estimates based on personal observations of fishers' activities at fishing wharfs in Suva and Lautoka

Table C.1 Cont'd

Variables	Value	Notes	References
Labor cost multiplier for selling to middlemen	1	Represents additional work required to sell to middlemen	Labor cost multipliers are my estimates, based on general observations of fishers' selling to middlemen, vendors and consumers
Labor cost multiplier for selling to vendor	1.25	Represents additional work required to sell to vendors	
Labor cost multiplier for selling direct to consumer	1.5	Represents additional work required to sell to consumers	
Hours fishing per week for full-time fishers	30	This number is for hours fishing (gear in the water) and does not include transiting, cleaning fish, etc.	Based on: Rawlinson et al., 1995; DemEcoFish, 2004.
Hours fishing per week for part-time fishers	12		
Number of fishing trips per week	5		Based on: Rawlinson et al., 1995; DemEcoFish, 2004.
Number of weeks worked per year	40		
% of PT fishers that use a boat with an engine	30		All values on fishers using boats with engines, without engines or not using boats at all are based DemEcoFish, 2004; as well as personal communications and observations
% of PT fishers that use a boat w/o an engine	50		
% of PT fishers that don't use a boat	20		
% of FT fishers that use a boat with an engine	50		
% of FT fishers that use a boat w/o an engine	35		
% of FT fishers that don't use a boat	15		
% of hours using motor, compared with fishing hours	60	Represents the amount of time a motor is being used (full throttle) in comparison to the amount of hours spent fishing. Average motor is 25 horsepower	My estimate
<u>**Fishers' Benefits**</u>			
% of catch sold to middlemen	45	Represents the percentage of the fishers' catch that is sold to different levels of the products value chain	Based on Reddy, 2004; personal observations of fish sales in Suva, Labasa, Lautoka and Savusavu
% of catch sold to vendors	30		
% of catch sold directly to consumers	25		
% of market value received when selling to a middleman	60	Represents the % of market value received by a fisher when selling to different levels of the value chain	Based on Reddy, 2004; personal observations of fish sales in Suva, Labasa, Lautoka and Savusavu
% of market value received when selling to a vendor	80		
% of market value received when selling to a consumer	100		

Table C.1 Cont'd

Variables	Value	Notes	References
Middlemen			
Hours worked per day	7		There is virtually no existing information on the role of middlemen in Fiji's artisanal fisheries. Therefore, all middlemen variable values are informed estimates based on personal communications with middlemen and personal observations at fishing wharfs and markets in Suva, Labasa, Lautoka and Savusavu
Days worked per week	5		
Weeks worked per year	45		
Kilograms of fish handled per day	40		
Hours worked per year per middleman	1575	Determined by hours worked per day and days worked per year	
Kilograms of fish that a middleman handles per year	9000	Determined by fish handled per day and days worked per year	
Middleman FT and PT multiplier	1	Used to adjust hours worked and fish handled according to FT or PT employment	
Vendors			
Market vendor fees/kg of fish sold	0.33	Usage or rental fees are typically charged to use retail space at municipal markets	Personal communication, municipal market fish vendors
Hours worked per day	6		Vendor variable values are informed estimates based on personal communication with vendors and personal observations at fish markets in Suva, Lautoka and Savusavu
Days worked per week	5		
Weeks worked per year	45		
Kilograms of fish sold per day	25		
Hours worked per year per vendor	1350	Determined by the hours worked per day and days worked per year	
Kilograms of fish that a vendor sells per year	5625	Determined by fish sold per day and days worked per year	
Vendor FT and PT multiplier	1	Used to adjust hours worked and fish sold according to FT or PT employment	

Table C.2 Invertebrate model input variables, values and references.

Variable	Sea Urchin	Trochus (meat)	Seaweed	Octopus	Gastropod	Crustacean	Bivalve	BDM	Other	References
	Invertebrate group name									
General										
Inflation (2002-2008)	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	Fiji Islands Bureau of Statistics http://www.statsfiji.gov.fj/
Accuracy domestic sales monitoring	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	Pers. comm., A. Asis; S. Singh
Fishers										
Hours worked per week	10	14	14	14	14	8	14	20	6	Based on Rawlinson et al., 1995.
Days worked per week	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	It is assumed that fishers do not
Weeks worked per year	40	40	40	40	40	40	40	40	30	spend as much time targeting invertebrates as finfish
% of harvest sold to middlemen	30	30	10	30	30	60	20	90	40	Based on Reddy, 2004; personal observations of fish sales in
% of harvest fishers sold to vendors	30	30	30	30	30	30	30	10	30	Suva, Labasa, Lautoka and Savusavu. It is assumed that
% of harvest fishers sold to consumers	40	40	60	40	40	10	50	10	30	fishers sell to middlemen more for items that require processing, and less for items that do not require processing
CPUE (kg per hour)	1.50	0.20	1.00	1.00	1.50	1.00	2.50	1.00	0.50	Based on: Rawlinson et al., 1995; Dalzell et al, 1996; Passfield, 1997; O'Garra, 2007
Fishers per boat w/engine	3.64	3.64	3.64	3.64	3.64	3.64	3.64	3.64	3.64	DemEcoFish, 2004
Fishers per boat w/o engine	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	DemEcoFish, 2004

Table C.2 Cont'd

Variable	Invertebrate group name									References
	Sea Urchin	**Trochus (meat)**	**Seaweed**	**Octopus**	**Gastropod**	**Crustacean**	**Bivalve**	**BDM**	**Other**	
Labor multiplier for selling to middlemen	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	Labor cost multipliers are my estimates, based on general observations of fishers' selling to middlemen, vendors and consumers
Labor multiplier for selling to vendors	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	
Labor multiplier for selling to consumers	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	
% of fishers that use a boat	30	40	40	40	40	70	20	50	20	Based on: DemEcoFish, 2004; as well as personal communications and observations. It is assumed that boats are used less when targeting invertebrates, as apposed to finfish
% of boats with an engine	20	30	10	20	30	50	10	30	0	
% of boats without an engine	80	70	90	80	70	50	90	70	100	
% of hours using motor compared to time spent fishing	30	30	30	30	30	40	30	30	0	My estimate
% of market value received when selling to a middleman	60	60	60	60	60	40	60	40	60	Based on Reddy, 2004. It is assumed that fishers receive a smaller percentage of market price for items that demand higher market prices, or require processing before final market sale.
% of market value received when selling to a vendor	80	80	80	80	80	60	80	70	80	
% of market value received when selling to a consumer	100	100	100	100	100	100	100	100	100	

Table C.2 Cont'd

Variable	Sea Urchin	Trochus (meat)	Seaweed	Octopus	Gastropod	Crustacean	Bivalve	BDM	Other	References
	Invertebrate group name									
Middlemen										
Middleman hours worked/person/day	7	7	7	7	7	7	7	7	7	There is virtually no information available on middlemen's' participation in domestic invertebrate sales. As such, estimates are made based on personal communications and observations at fish markets in Suva, Lautoka and Savusavu.
Middleman days worked/person/week	5	5	5	5	5	5	5	5	5	
Middleman weeks worked/person/year	45	45	45	45	45	45	45	45	45	
Middleman hours worked/person/year	1575	1575	1575	1575	1575	1575	1575	1575	1575	
Middleman trips to the market/person/year	225	225	225	225	225	225	225	225	225	
Middleman kilograms sold/person/day	15	10	15	10	10	10	20	20	5	
Middleman kilograms handled/person/year	3375	2250	3375	2250	2250	2250	4500	4500	1125	
Vendors										
Vendor hours worked/person/day	7	7	7	7	7	7	7	7	7	There is virtually no information available on vendors' participation in domestic invertebrate sales. As such, estimates are made based on personal communications and observations at fish markets in Suva, Lautoka and Savusavu.
Vendor days worked/person/week	3	3	3	3	3	3	3	3	3	
Vendor weeks worked/person/year	45	45	45	45	45	45	45	45	45	
Vendor hours worked/person/year	945	945	945	945	945	945	945	945	945	
Vendor kilograms sold/person/day	15	15	15	15	15	15	15	15	15	

Table C.2 Cont'd

Variable	Invertebrate group name									References
	Sea Urchin	**Trochus (meat)**	**Seaweed**	**Octopus**	**Gastropod**	**Crustacean**	**Bivalve**	**BDM**	**Other**	
Vendor kilograms sold/person/year	2025	2025	2025	2025	2025	2025	2025	2025	2025	
Vendor's market fees F$/kg	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	Personal communication, municipal market fish vendors

Appendix D: Coral reef associated finfish, invertebrates and marine plants

Table D.1 Coral reef-associated finfish

Family	Genus	Species	Common Name	Fijian Name
Acanthuridae	*Acanthurus*	*triostegus*	Convict surgeonfish	tabace
Acanthuridae	*Naso*	*unicornis*	Bluespine unicornfish	ta
Acanthuridae	*Acanthurus*	*xanthopterus*	Yellowfin surgeonfish	balagi
Albulidae	*Albula*	*neoguinaica*	Sharpjaw bonefish	yawakio
Belonidae	*Tylosuros*	*crocodilus crocodilus*	Hound needlefish	Saku
Carangidae	*Caranx*	spp	Giant trevally, bigeye trevally, brassy trevally	saqa
Carangidae	*Caranx*	*melampygus*	bluefin trevally	bluefin trevally
Carangidae	*Selar*	*crumenophthalmus*	Bigeye scad	yatule
Carangidae	*Caranx*	*lugubris*	black trevally	saqaloa
Carangidae	*Elagatis*	*bipinnulatus*	Rainbow runner	rainbow runner
Chirocentridae	*Chirocentrus*	*dorab*	Dorab wolf-herring	voivoi
Clupedidae	*Herklotsichthys*	*quadrimaculatus*	bluestripe herring	Daniva
Dasyatidae	*Dasyatis*	*kuhlii*	bluespotted stingray	Vaidina
Didontidae	*Diodon*	*hystrix*	spotfin porcupinefish	sokisoki
Elopidae	*Megalops*	*cyprinoides*	Indo-Pacific tarpon	Yavula
Engraulidae	*Thryssa*	*balama*	Baelama anchovy	vaya
Gerreidae	*Gerrus*	spp		matu
Haemulidae	*Plectorhynchus*	spp	sweetlips	sevaseva
Hemirhamphidae	*Hemirhamphus*	spp	Blackbarred halfbeak	Busa
Holocentridae	*Myripristis*	*violacea*	Lattice soldierfish	corocoro
Kuhliidae	*Kuhlia*	*bilunulata*	silver flagtail	mataba
Kuhliidae	*Kuhlia*	*rupestris*	rock flagtail	ikadroka
Kyphosidae	*Kyphosus*	*spp*	Blue seachub	sirisiriwai
Labridae	*Cheilinus*	*undulatus*	humphead wrasse	Varivoce
Lethrinidae	*Lethrinus*	*mahsena*	Sky emperor	Sabutu
Lethrinidae	*Gymnocranius*	spp	Breams	Mama
Lethrinidae	*Lethrinus*	*nebulosus*	Spangled emperor	Kawago
Lethrinidae	*Lethrinus*	*xanthochila*	Yellowlip emperor	Kacika
Lethrinidae	*Lethrinus*	*elongatus*	Smalltooth emperor	Dokonivudi
Lethrinidae	*Monotaxis*	*grandoculis*	large-eyed bream	bu
Lethrinidae	*Lethrinus*	*kallopterus*	Orange-spotted emperor	Sabutudamu
Lethrinidae	*Lethrinus*	*reticulatus*	Red snout emperor	Kabatia
Lutjanidae	*Aprion*	*virescens*	green jobfish	utouto
Lutjanidae	*Paracaesio*	*kusakarii*	saddleback snapper	uluqa
Lutjanidae	*Aphareus*	*rutilans*	rusty jobfish	sewidri
Lutjanidae	*Lutjanus*	*timorensis*	timor snapper	rosinibogi
Lutjanidae	*Lutjanus*	*malabaricus*	malabar blood snapper	rosinibogi
Lutjanidae	*Pristipomoides*	spp		opakapaka

Table D.1 Cont'd

Family	Genus	Species	Common Name	Fijian Name
Lutjanidae	*Symphorus*	*nemattophorus*	chinamanfish	laidamu
Lutjanidae	*Lutjanus*	*argentimaculatus*	Mangrove red snapper	damu
Lutjanidae	*Lutjanus*	*gibbus*	humpback red snapper	bo
Lutjanidae	*Lutjanus*	*rivulatus*	blubberlip snapper	regua
Lutjanidae	*Lutjanus*	*quinquelineatus*	five-lined snapper	kake
Lutjanidae	*Lutjanus*	*fulvus*	blacktail snapper	kake
Lutjanidae	*Lutjanus*	*fulviflamma*	dory snapper	kake
Lutjanidae	*Lutjanus*	*bohar*	two-spotted red snapper	bati
Lutjanidae	*Paracaesio*	*kusakarii*	Kusakar's snapper	bedford
Mugilidae	*Liza*	*vaigiensis*	Squaretail mullet	kava
Mugilidae	*Valamugil*	*seheli*	Bluespot mullet	kanace
Mugilidae	*Liza*	*melinoptera*	Otomebora mullet	molisa
Mullidae	*Parupeneus*	*indicus*	Indian goatfish	mataroko
Mullidae	*Mulloidichthys*	*vanicolensis*	yellow goatfish	ose
Mullidae	*Upeneus*	*vittatus*	Yellowstriped goatfish	ki
Ostraciidae	*Ostracion*	*tubaculatus*	Yellow boxfish	toa
Platacidae	*Platax*	*orbicularis*	Orbicular batfish	vunavuna
Polynemidae	*Lactarius*	*lacterius*	False trevally	Kela
Scaridae	*Scarus*	spp	parrotfish	Ulavi
Scaridae	*Bolbometopon*	*muricatus*	green humphead parrotfish	Kalia
Scatophagidae	*Scatophagus*	*argus*	spotted scat	batekau
Scombridae	*scomberomorus*	*commerson*	Narrow-barred Spanish mackerel	walu
Scombridae	*Scomberoides*	spp	Doublespotted queenfish	votonimoli
Scombridae	*Grammatorcynus*	*bilineatus*	double-lined makerel	salalanitoga
Scombridae	*Megalaspis*	spp		salalanitoga
Scombridae	*Gymnosarda*	*unicolor*	Dogtooth tuna	dogtooth
Serranidae	*Epinephelus*	*fuscoguttatus*	Brown-marbled grouper	kawakawa
Serranidae	*Epinephelus*	*lanceolatus*	Giant grouper	kavu
Serranidae	*Epinephelus*	*microdon*	Camouflage grouper	kasala
Serranidae	*Plectroponus*	spp	coral groupers	donu
Serranidae	*Epinephelus*	*fuscoguttatus*	Brown-marbled grouper	delabulewa
Serranidae	*Epinephelus*	*merra*	Honeycomb grouper	senikawakawa
Serranidae	*Cephalopholis*	*miniatus*	Coral hind	kasaledamu
Siganidae	*Siganus*	*vermiculatus*	Vermiculated spinefoot	nuqa
Siganidae	*Siganus*	*chrysospilos*	Goldspotted spinefoot	nuqa
Siganidae	*Siganus*	*doliatus*	Barred spinefoot	nuqa
Siganidae	*Siganus*	*spinus*	*Little spinefoot*	nuqa
Sphyraenidae	*Sphyraena*	*forsteri*	Forster's seapike	silasila
Sphyraenidae	*Sphyraena*	spp	barracuda	Ogo
Tetraodontidae	*Arothron*	*stellatus*	Starry toadfish	sumusumu

Table D.2 Coral reef-associated invertebrates and marine plants.

Family	Genus	Species	Common name	Fijian name
Aplysiidae	*Dolabella*	*auricularia*	green seahare	veata
Arcidae	*Anadara*	*cornea*	arkshell	kaikoso
Caulerpaceae	*Caulerpa*	*racemosa*	sea grapes	nama
Chitonidae	*Acanthozostera*	*gemmata*	chiton	tadruku
Diadematidae	*Tripneustes*	*gratilla*	sea urchin	cawaki
Gracilariaceae	*Gracilaria*	*verrucosa*	glassweed	lumiwawa
Holothuriidae	*Microthele*	*fuscogilva*	white teatfish	sucuwalu
Holothuriidae	*Actinopyga*	*miliaris*	Blackfish	Dri
Holothuriidae	*Metriatyla*	*scabra*	sandfish	dairo
Holothuriidae	*Microthele*	*nobillis*	black teatfish	loaloa
Holothuriidae	*Bohadschia*	*marmorata*	brown sandfish	vula
Hypneaceae	*Hypnea*	*pannosa*	maidenhair	lumicevata
Mesodesmatidae	*Atactodea*	*striata*	surf clam	sigawale
Naticidae	*Polinices*	*flemingiana*	moon snail	drevula
Neritidae	*Nerita*	*polita*	polished nerite	madrali
Octopodidae	*Octopus*	spp	octopus	kuita
Palinuridae	*Panulirus*	*versicolor*	painted rock lobster	uraudina
Palinuridae	*Panulirus*	*ornatus*	ornate rock lobster	uraudina
Palinuridae	*Panulirus*	*penicillatus*	golden rock lobster	uraudina
Pteriidae	*Pinctada*	*magaritifera*	black lip pearl oyster	civa
Scyllaridae	*Parribacus*	*caledonicus*	slipper lobster	slipper
Spondylidae	*Spondylus*	*ducalis*	Ducal thorny oyster	kalokalo
Stichopodidae	*Stichopus*	*chloronotus*	greenfish	greenfish
Strombidae	*Lambis*	*lambis*	spider shell	yaga
Strombidae	*Strombus*	*gibberulus*	stromb	golea
Tridacnidae	*Tridacna*	*derasa*	smooth giant clam	vasuadina
Tridacnidae	*Tridacna*	*maxima*	rugose giant clam	katavatu
Tridacnidae	*Tridacna*	*squamosa*	fluted giant clam	cega
Trochidae	*Trochus*	*niloticus*	trochus shell	sici
Trochidae	*Trochus*	*pyramis*	top shell	tovu
Turbinidae	*Turbo*	*chrysostomus*	turban shell	lasawa
Veneridae	*Gafrarium*	*tumidum*	venus shell	qaqa

Appendix E: Costs associated with fishing

Table E.1 Costs associating with fishing. All prices in Fijian dollars. (F$ 1.00 = US$ 0.67, February 2008)

Item	Cost	Notes	Sources
Handline	22.20	Per year	O'Garra, 2007
Spear gun	36.07	Per year	O'Garra, 2007
Spear	8.32	Per year	O'Garra, 2007
Goggles/mask	24.05	Per year	O'Garra, 2007
Net	50.00	Per year	O'Garra, 2007
Flashlight	18.50	Per year	O'Garra, 2007
Labor	1.05	Per hour	O'Garra, 2007
Bait	37.84	Per boat per trip	Reddy, 2004
Ice	8.37	Per boat per trip	Reddy, 2004
Food	20.58	Per boat per trip	Reddy, 2004
Battery	3.95	Per boat per trip	Reddy, 2004
Kerosene	1.55	Per boat per trip	Reddy, 2004
Fuel	2.05	Per liter	Fiji Daily Post, March 4, 2008
Fuel (fishers)	19.42	Per boat (25hp) per hour of engine use	My calculation based on price of fuel; DemEcoFish, 2004; my estimate of engine use
Fuel (middlemen)	9.32	Per day (truck)	Based on price of fuel and my assumption on km driven per day
Public transit	6.00	Per day	Personal observation
Boat maintenance (without engine)	144.37	Per year	O'Garra, 2007; DemEcoFish 2004
Boat maintenance (with engine)	544.69	Per year	O'Garra, 2007; DemEcoFish 2004
Boat ownership (without engine)	97.00	Annual depreciation	O'Garra, 2007; DemEcoFish 2004; Personal communication, boat owners
Boat ownership (with engine)	183.00	Annual depreciation	O'Garra, 2007; DemEcoFish 2004; Personal communication, boat owners
Baskets	1.11	Each	O'Garra, 2007

Appendix F: UBC Research Ethics Board

Certificate of Approval

The University of British Columbia
Office of Research Services
Behavioural Research Ethics Board
Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

CERTIFICATE OF APPROVAL - FULL BOARD

PRINCIPAL INVESTIGATOR:	INSTITUTION / DEPARTMENT:	UBC BREB NUMBER:
Rashid U. Sumaila	UBC/College for Interdisciplinary Studies/Fisheries	H07-02289

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
N/A	N/A

Other locations where the research will be conducted:
Field work for this study will be conducted in Fiji, in fishing villages and at the offices of government fisheries agencies, academic institutions, and non-governmental institutions.

CO-INVESTIGATOR(S):
Lydia Teh
Louise Teh
Ben Starkhouse

SPONSORING AGENCIES:
The Kingfisher Foundation

PROJECT TITLE:
ECONOMIC AND TRADE IMPACTS OF CORAL REEF RESOURCE USE IN FIJI

REB MEETING DATE:	CERTIFICATE EXPIRY DATE:
October 25, 2007	October 25, 2008

DOCUMENTS INCLUDED IN THIS APPROVAL: **DATE APPROVED:** November 15, 2007

Document Name	Version	Date
Protocol:		
research proposal	N/A	September 17, 2007
Consent Forms:		
verbal consent_info sheet	N/A	November 7, 2007
verbal consent_4nov	N/A	November 4, 2007
verbal consent	N/A	September 17, 2007
Questionnaire, Questionnaire Cover Letter, Tests:		
fisher sample questionnaire	N/A	September 17, 2007
expert interview sample questionnaire	N/A	September 17, 2007
Letter of Initial Contact:		
letter of initial contact_4 nov	N/A	November 4, 2007

The application for ethical review and the document(s) listed above have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board and signed electronically by one of the following:

Dr. M. Judith Lynam, Chair
Dr. Jim Rupert, Associate Chair
Dr. Laurie Ford, Associate Chair