

DISCOUNT RATES, SMALL-SCALE FISHERIES, AND SUSTAINABILITY

by

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Abstract

In the face of overexploited and declining fisheries worldwide, a question that is central to the future sustainability of fisheries resources is how willing are fishers to sacrifice their current fishery benefits in order to be able to enjoy higher benefits in the future? Fishers' rate of time preference, or discount rate, indicates how willing they are to delay current consumption, and is the primary topic of investigation in this thesis. I aim to answer three research questions, focusing on small-scale reef fisheries in developing countries: 1) what is the discount rate of fishers?; 2) what socio-economic conditions predict low discounting behaviour among fishers?; and 3) are discount rates reflective of the exploitation status of fisheries? I use an experimental economics approach to elicit fishers' discount rates in Sabah (Malaysia) and Fiji, and then use regression analysis to identify the predictors of low discount rates. Further, I integrate economic and ecological concepts to infer fishers' private discount rates, as well as to explore whether discount rates are representative of fisheries exploitation status. My main findings are that, first, small-scale reef fishers have high discount rates, with a plausible average annual range of 100 to 300%. This appears to apply to fishers in both open access (Sabah), as well as traditionally managed (Fiji) reef fisheries. There is a surprisingly larger proportion of fishers with low discount rates in the open access, compared to the traditionally managed fishery. Second, site and fishery level variables predict low discount rates among fishers, but the effect is different depending on the local socio-economic context. Overall however, it is not clear what specific site level dynamics contribute to the lower observed discount rates in Sabah. Lastly, I find that official discount rates that are used for policy making appear to be too low to fully reflect the short term outlook of reef fishers. Fishers' higher private discount rates may be more likely to capture the exploitations status, and may be more appropriate to use for evaluating policies that affect fishers' current and future fishing activities.

Preface

Chapter 2 is modified from a publication in *Fisheries Research*, authored by myself, Lydia CL Teh, and Rashid Sumaila. I led all stages of the research: obtaining the data, analysing the results, and writing the manuscript. LCLT helped with collecting and analysing the results of a prior study on which this chapter is based. LCLT and RS contributed to interpreting the results.

Chapter 3 is modified from a Fisheries Centre working paper authored by myself, Lydia CL Teh, and Rashid Sumaila. It has been submitted to a peer reviewed journal. I led all stages of the research: conducting the interviews, and analysing the results. LCLT assisted with conducting the interviews. RS contributed to interpreting the results and reviewing the manuscript.

Chapter 4 is modified from a publication in *Sustainability*, authored by myself, Lydia CL Teh, and Rashid Sumaila. I led all stages of the research, conducted the interviews, and developed the logistic regression model. LCLT helped with conducting the interviews. RS contributed to interpreting the results and reviewing the manuscript.

Chapter 5 is authored by myself. William Cheung of the UBC Fisheries Centre wrote the computer code for the algorithm to estimate the intrinsic growth rate of species.

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Chapter 1: Introduction

1.1 Objectives

It is generally accepted that fisheries are on a decline worldwide, and there is a need to stem further overexploitation of marine resources and ecosystems (Pauly et al., 2002; Worm et al., 2009). The challenge for fisheries managers is to identify effective strategies that will sustain the livelihoods of people dependent on coastal marine resources, while adjusting exploitation to sustainable levels. There is increasing recognition that successful fisheries management requires understanding why fishers make the fishing effort decisions they do (Wilén et al., 2002; Salas and Gaertner, 2004). A fisher's discounting behaviour has a potentially large effect on their exploitation rate, and hence future sustainability of marine resources (Clark, 1973; Sumaila, 2004). Yet, how fishers discount the future has received limited attention in the fisheries literature to date. The aim of this thesis is to improve our understanding of the discounting behaviour of fishers, in order to fill this research gap. Specifically, I will address three research questions:

- i) What are the private discount rates of fishers?;
- ii) Under what socio-economic conditions do fishers have high or low discount rates?; and
- iii) Are discount rates reflective of the exploitation status of fisheries?

I focus on the small-scale fisheries of developing countries, which are the most significant to society in terms of their social, economic, and food security contributions (Berkes et al., 2001; Béné, 2006).

1.2 Exploitation of fisheries

The global problem of overfishing threatens the capacity of fisheries to sustain societal needs into the future. Simply put, overfishing results from removing fish at a rate that is greater than that at which the fish population can replenish itself. If this persists for long enough, the fish population is eventually reduced. In my thesis, I examine overexploitation from the perspective of fishers' private discount rates. However, this is but one aspect of many other possible drivers motivating fishers to overexploit marine resources. Other reasons, including the absence of property rights, the presence of perverse economic incentives, poor socio-economic conditions, weak or non-existent management, and lack of scientific knowledge about targeted fish populations all contribute to overfishing. Further, the occurrence of

natural catastrophic events decreases the capacity for fish populations to recover from fishing, thus accentuating the impacts from overfishing.

A fish stock can be viewed as a form of natural capital that is capable of producing a flow of sustainable yield (fish catch) and resource rent to the resource owner. In a time dynamic setting, fishery resource owners are faced with the task of deciding on what optimal fishing effort to use at each time period. According to economic theory, the owner of a resource will use a level of effort that maximises the total discounted present value of resource rent from the fishery (Clark and Munro, 1975):

$$\underset{\{E(t)\}}{\text{maximize}} \int_0^{\infty} e^{-\delta t} R(t) dt \quad [1.1]$$

where δ is the discount rate, and $R(t)$ and $E(t)$ denote time dependent resource rent and effort, respectively. An essential component of this equation is the discount rate, which indicates the decision maker's preference for current over future revenue. I will cover discount rates in more detail in a later section.

The economically optimal harvest strategy which maximises discounted present value involves the resource owner using an effort level that adjusts the initial biomass $x(t)$ as quickly as possible towards a long-term target optimal stock level x_{opt} , which is given as:

$$G'(x_{opt}) - \frac{c'(x_{opt})G(x_{opt})}{p - c(x_{opt})} = \delta \quad [1.2]$$

where $G(x_{opt})$ describes the biological growth function of the fish, and $G'(x_{opt})$ represents the marginal productivity of the fish stock, δ is the discount rate, p is the fish price, and $c(x_{opt})$ and $c'(x_{opt})$ are unit and marginal cost of fishing, respectively. The optimal stock level may be larger or smaller than x_{MSY} , the stock level which maximises sustainable yield. Equation [1.2] shows that x_{opt} is a decreasing function of the discount rate; thus, discounting favours a stock level that is less than x_{MSY} .

In essence, the discount rate indicates, to a degree, the tradeoff the resource owner is willing to make for fishing heavily now, but obtain smaller catches in the future. This is the main premise of investigation for my thesis. However, besides the discount rate, the degree of tradeoff is also influenced by other economic and biological parameters in the model. In my thesis, I focus primarily on the discounting aspect of exploitation in Chapters 3 and 4, and incorporate biological considerations in Chapter 5; however, I do not explicitly consider the

model's economic parameters (e.g., fishing prices and costs). Nevertheless, economic factors can motivate fishers' decisions for entering or leaving a fishery, and are therefore crucial considerations if we are concerned about sustainable fishing effort.

Economic incentives can be drivers of overfishing. For instance, the provision of government subsidies in the form of fuel, gear, and other capacity enhancing subsidies to the fishing industry encourages excessive effort by reducing fishing costs. Consequently, this has encouraged fishing fleets to continue fishing even when it is not profitable to do so, thereby encouraging the overexploitation of fisheries resources (Clark et al., 2005, Sumaila et al., 2008; Sumaila et al., 2010). Fisheries trade and the globalization of markets has also contributed to overfishing, leading to concerns about food security and the depletion of certain valuable marine species (Sadovy et al., 2003a; ICTSD, 2006; Smith et al., 2010). Management inertia can also lead to, or prevent recovery from overfishing, as political incentives to maintain the status quo fail to curtail excessive fishing effort (Rosenberg, 2003).

Overfishing can also be driven by pressures arising from the larger socio-economic environment. Malthusian overfishing refers to the situation in many developing countries, where the combined effects of poverty, population growth, and unemployment compel poor fishers to overexploit coastal fisheries in an effort to maintain their incomes and source of food (Pauly et al., 1989). A lack of economic prospects in other sectors of society draws people to fishing, which is normally seen as an occupation of last resort due to its relatively low cost and absence of barriers to entry. As the number of participants in the fishery increase, fishers have to fish harder and turn to destructive gears in order to maintain their catches in the face of dwindling fish stocks (Pauly et al., 1989; Mangi et al., 2007; McClanahan et al., 2008). Since many developing country fisheries lack the management capacity to regulate fishing effort, a vicious cycle ensues, and can ultimately lead to economic and biological overfishing, as catches and income per fisher decrease. An underlying reason why this cycle can continue is because of the free and unregulated nature of many developing country coastal fisheries, which is described by the 'Tragedy of the Commons' (Hardin, 1968).

The commons tragedy refers to the fact that unregulated, open access resources such as marine fisheries inevitably suffer degradation because a lack of property rights over these resources means that individual users, acting upon their own self-interest, will ultimately

overexploit limited, open fisheries, even though it is in no one's long term interest for this to occur. Gordon's (1954) classic economic model describes the motivation fishers have to overexploit in such an open access fishery. Assuming that fishers are profit maximisers who act rationally and individually, Gordon's model predicts that each fisher will only consider his own benefits when deciding how much fishing effort to exert. Fishers will ignore the fact that increasing one's catch lowers the returns to other fishers, as well as hurts the future productivity of all fishers by affecting the fish stock. In an undeveloped fishery, resource rent can be gained; however, since the fishery is open to all, Gordon's static model shows that fishers will enter the fishery until all economic rent is dissipated and a bionomic equilibrium is reached. This situation is known as economic overfishing, and may also coincide with biological overfishing.

Fish population declines can also occur as a result of natural population fluctuations, or as a response to environmental events that change the productivity of a population (Hutchings and Reynolds, 2004). Catastrophic events such as coral bleaching or hurricanes can lead to ecosystem phase shifts and loss of species productivity (Hughes, 1994; Bell et al., 2006). Although these phenomena do not by themselves cause overfishing, they can amplify the effects of fishing. At the same time, uncertainty about fish population dynamics can lead scientists to make misinformed harvesting recommendations that can result in overfishing (Charles, 1998; Clark, 2006). The advancement and development of new fishing technology can also be a major contributor to overexploitation (Kennelly and Broadhurst, 2002). For example, the development of engines, Global Positioning System (GPS) devices, and fish sounders enabled fishing fleets to impose greater fishing mortality, as they were able to find and catch previously protected fish stocks that lived in unreachable habitats, e.g., in the deep sea (Norse et al., 2011).

1.3 Time discounting

1.3.1 Overview

Many individual and public decisions involve consequences that occur some time in the future. An individual's time preference refers to how he/she values goods and services at different points in time. Discounting addresses the issue of time preference through the use of a discount rate, which reflects one's willingness to trade current for future consumption. Strictly speaking, the concept of time preference and discounting differ in that time preference refers solely to one's preference for immediate over delayed utility, whereas time

discounting is used to encompass any reason for caring less about a future consequence (Frederick et al., 2003). However, for the purpose of my research, I will use both terms synonymously.

Time discounting is a subject that spans both economics and psychology, with each discipline having different perspectives and approaches to studying it. Economic research on time preference tends to focus on the theoretical aspects and application of the discounted utility model (Samuelson, 1937). In contrast, psychological research on inter-temporal choice focuses on finding out why individuals are more likely to value present outcomes more than future ones. Studies have ranged from measuring differences in individuals' ability to delay gratification to determinants of impulsivity, and cognitive and emotional mechanisms underlying inter-temporal choice (Loewenstein et al., 2003).

The original concept of inter-temporal choice, in fact, had psychological underpinnings. It was first put forward by John Rae in the 1800s, who attributed the difference in levels of savings and investment in a society to a psychological factor he termed "the effective desire of accumulation" – meaning the willingness to delay gratification. A shift towards an economic perspective of inter-temporal choice occurred with the introduction of the discounted utility model by Samuelson in the 1930s.

The discounted utility (DU) model of inter-temporal choice states that an individual's utility function (U) for a certain outcome or good C (e.g., money, oranges, etc.), is equal to the sum of the discounted utilities of each outcome in period t , such that a person's inter-temporal utility function (U^t) is described by:

$$U^t(c_t, \dots, c_T) = \sum_{k=0}^{T-t} D(k)u(c_{t+k}) \quad [1.3]$$

Where $D(k) = \left(\frac{1}{1 + \rho} \right)^k$

In the above formula, $u(c_{t+k})$ refers to an individual's utility, or well being, in period $t + k$. $D(k)$ can be interpreted as the relative weight the individual attaches in period t , to his/her well-being in period $t + k$, while ρ refers to the individual's discount rate. As t increases, the value of the discounted utility becomes less. The simplicity of the DU model made it widely accepted as the model of choice for analysing inter-temporal decisions. However, it is not without controversy; the main contention is that the DU model does not incorporate

psychological considerations behind inter-temporal choice, as it condenses all such factors into a single discount rate (Frederick et al., 2003). In addition, there has been little empirical support for the DU model (Soman et al., 2005). Nevertheless, I will adopt the DU model for estimating fishers' discount rates in the ensuing chapters, as psychological aspects of discounting are not the main thrust of this research, and the discounted utility model continues to be the dominant model used in economic analysis.

Discounting is central for comparing the net economic benefits of different alternatives that incur costs and benefits through time. The standard procedure for cost benefit analysis (CBA) is to compare the net present values of the alternatives by discounting the streams of benefits and costs of each alternative using a discount rate. The option with the largest time weighted benefit is chosen. Discounting the future heavily (i.e., having high discount rates) puts less weight on future consequences when making decisions in the present, such that options with long-term costs but near-term benefits appear more attractive than those that have near-term costs but long-term benefits.

The serious implications of high discount rates for natural resource policies have been extensively highlighted (Ramsey, 1928; Costanza, 1991; Barbier et al., 1994). Discounting environmental costs and benefits also brings up significant ethical issues such as intergenerational equity, as discounting inherently places less value on the preferences of future generations relative to our present one (Padilla, 2002). This has generated considerable debate over the choice of discount rate, discounting technique, and whether discounting should be used at all for evaluating environmental projects or policies (Fearnside, 1989; Kolb and Scheraga, 1990; Markandya and Pearce, 1991; Barbier et al., 1994; Sumaila, 2004; Sumaila and Walters, 2005; Sáeza and Requenab, 2007). To incorporate intergenerational considerations, alternative techniques of discounting have been developed, such as intergenerational discounting (Sumaila, 2004; Ainsworth and Sumaila, 2005; Sumaila and Walters, 2005), gamma discounting (Weitzman, 2001), and a two-step discounting procedure proposed by Rabl (1996).

1.3.2 Application of discounting to resource management

While much attention has been focused on the broad environmental and sustainability implications of discounting at the societal level, less attention has been paid to the effects of private discounting on natural resource use and sustainability. Private discounting refers to

the intuitive discounting that fishers and other resource users apply in their decision-making processes. It is this aspect of discounting that my research seeks to address, as many decisions about exploiting natural resources are made privately (Markandya and Pearce, 1991). This is especially true for small-scale artisanal and subsistence fisheries, where fishing is still predominantly carried out by individual fishers.

The important role that fishers' discount rates play in determining the sustainability of a fisheries resource has been well established theoretically (Clark, 1973; 1985; Sumaila and Walters, 2005). Not incorporating fishers' discount rates when analysing policies that affect fishers (e.g., no-take areas, rebuilding, effort allocation) will likely result in dissatisfaction and non-compliance with the management strategy. For example, Clark (1985) pointed out that disagreement between regulators and the fishing industry over acceptable catch levels were essentially an argument over discount rates. Despite this, empirical studies investigating private discount rates within the context of natural resource use have mainly been done in the fields of agriculture and forestry. For instance, Ethiopian farmers with higher discount rates were less likely to invest in soil conservation practices (Yesuf and Bluffstone, 2008), and were also less likely to recognise soil erosion being a problem (Shiferaw and Holden, 1998). In contrast, upland farmers in the Philippines still adopted soil conservation practices despite having high discount rates (Lumley, 1997). Gunatilake et al. (2007) found that in Sri Lanka, individuals with higher rates of time preference caused forest resource depletion, while Casse et al. (2005) found that observed discount rates of inhabitants in highly deforested areas were significantly higher than those living in other areas.

Only a handful of studies have documented the private discount rates of fishers (Curtis, 2002; Akpalu, 2008; Fehr and Leibbrandt, 2008; Nguyen, 2009). Of these studies, Akpalu (2008) found that fishers with higher discount rates had a higher intensity of violating fishing gear regulations. Similarly, Fehr and Liebbrandt (2008) found that Brazilian fishers who were more patient exerted less pressure on fisheries resources. These two studies provide some empirical evidence that high private discount rates appear to be unfavourable for sustainable fisheries resource use.

For fisheries management, it is useful to not only know what the discount rate of fishers is, but also under what conditions high or low discount rates may occur. There is, to my knowledge, no study which examines the correlates of low or high discount rates among

fishers. In the broader social science literature, researchers have found that socio-economic and demographic variables such as income, wealth, age, and education level are correlated with discount rates (Pender, 1996; Becker and Mulligan, 1997; Godoy and Jacobson, 1999; Kirby et al., 2002). Poverty is commonly thought to be a driver of high discount rates (Mink, 1993), and this is a particular concern in small-scale fisheries, which predominate in tropical, less developed countries (Béné et al., 2007; 2010).

1.4 Small-scale fisheries

Although they differ according to location, small-scale fisheries can generally be characterised as being multi-gear and multi-species, with almost all of the catch being used as food fish. Half of the world's supply of food fish originates from small-scale fisheries, and it has been estimated that 90% of fishers worldwide are small-scale fishers (Béné, 2006). As 95% of these fishers reside in developing countries (FAO 2004), small-scale fisheries are fundamental for the livelihood, welfare, and food security of coastal communities in some of the world's poorest countries. An important welfare dimension of small-scale fisheries is their ability to serve as social safety nets, and to absorb, or act as a buffer for excess labour (Béné 2005).

The scattered and unorganised nature of small-scale fisheries makes them difficult to monitor, and this is compounded by the fact that small-scale fishing communities normally consist of the rural poor, who face social and political marginalisation (Pauly, 1997). Thus, despite their importance, small-scale fisheries generally lack management (Berkés et al., 2001; Salas et al., 2007; Charles, 2011), and their socio-economic contributions have largely been disregarded by policy makers (Zeller et al., 2006a). Consequently, most small-scale fisheries exist in a data-poor condition, making it difficult to capture the economic and social contributions of these fisheries, and leading to their undervaluation and under-appreciation in many countries (Gillett and Lightfoot, 2002; Zeller et al., 2006a; b; Andrew et al., 2007).

1.4.1 Coral reef fisheries

I focus on small-scale fisheries which occur in the vicinity of coral reefs, and target the large variety of fish and invertebrate species that live in coral reefs and reef associated habitats. These fisheries are dominated by small-scale subsistence and artisanal fishers, who use gears ranging from hook and line, gillnet, traps, and spears, to destructive techniques such as dynamite and cyanide (Dalzell, 1996; Dalzell et al., 1996). It has been estimated that coral

reef fisheries make up approximately 2 to 5% of global marine fisheries catches (Pauly et al., 2003). While the absolute yield from reef fisheries may not count as significant, their relative importance to the subsistence and livelihood of coastal communities is enormous (McManus, 1997; Whittingham et al., 2003; Sadovy, 2005; Loper et al., 2008). This is especially pertinent in parts of Southeast Asia and Oceania, where coastal communities are heavily dependent on fisheries (McManus, 1997; Pauly, 1997; Kronen et al., 2010a).

A recent assessment of coral reef fisheries sustainability by Newton et al. (2007) found that over 50% of the reef fisheries they studied were exploited unsustainably. Although customary marine tenure of coral reef resources is practiced in parts of Oceania, Indonesia and East Africa (Mantjoro, 1996; McClanahan et al., 1997; Johannes, 2002; Cinner et al., 2005), well-managed reef fisheries are rare, with most coral reef fisheries being essentially unmanaged (Sale, 2008). The management of coral reef fisheries is even more challenging due to factors such as their open access nature, the presence of multiple landing sites and large numbers of participants (Sadovy, 2005). As with small-scale fisheries in general, tropical reef fisheries are often marginalised from mainstream policy makers (Pauly, 1997), leading to less than adequate management attention and resources spent on monitoring these valuable fisheries (Sale, 2008). These factors compound the current lack of data about the dynamics of fishing communities and the behaviour of reef fishers (Clua et al., 2005).

Fishing on coral reefs reduces the abundance of species targeted by the fishery, alters the size and age distribution of target fish, and possibly alters the trophic structure of reef communities and habitats (Jennings and Polunin, 1995; Jennings and Lock, 1996; Dulvy et al., 2004a; Graham et al., 2005). Overfishing also reduces reef species diversity, and can cause local extinctions of both target and non-targeted reef fish species (Roberts, 1995; Dulvy and Polunin, 2004). In recent decades, the relentless expansion of the live reef fish trade has led to serial local depletions of economically valuable, but biologically vulnerable species such as humphead wrasse (*Cheilinus undulatus*), and coral grouper (*Plectropomus* spp.) throughout the Indo-Pacific (Sadovy et al., 2003a; Warren-Rhodes et al., 2003; Scales et al., 2007). At the extreme, overfishing leads to the loss of key functional groups, eventually reducing and threatening the resilience of coral reef ecosystems (Roberts, 1995; Nyström et al., 2000; Wilson et al., 2006).

To ensure that reef fisheries can continue to contribute to the sustenance of present and future generations, current social and economic dependence on reef fisheries resources must be reduced. There is consensus that bio-physical centred management strategies for conserving coral reef ecosystems are unlikely to be adopted in developing countries (Bell et al., 2006; McClanahan et al., 2009a). Instead, successful management has to fit within the local socio-cultural and economic context (Cinner et al., 2009b; McClanahan et al., 2009a). Recent emphasis has been placed on management policies that can adapt to local socio-ecological conditions and build the capacity of communities to cope with change (Bell et al., 2006; Cinner et al., 2009b; McClanahan et al., 2009a; 2009b). At the root of these strategies is the need for an increased understanding of fishers' outlook about their future, i.e., how willing are fishers to sacrifice their current fishery benefits in order to be able to enjoy higher benefits in the future? This is the main topic I investigate in my thesis.

1.5 Thesis overview

My thesis presents 4 studies that address two research gaps in the socio-economic aspects of fisheries:

- 1) The chronic underestimation and undervaluation of small-scale fisheries' socio-economic contribution;
- 2) The time preference of small-scale fishers.

In the next section, I outline how I will address each of these questions in my thesis chapters (Chapters 2-5). In the final chapter (Chapter 6), I summarise my main findings and discuss my study's contribution to the current state of knowledge about fishers' discounting behaviour. I also consider the strengths and limitations of my research, and provide some recommendations for the practical application of my results, and direction for future research.

In Chapter 2, I set the context for why my study focuses on small-scale fisheries. Using the small-scale fisheries of Sabah, Malaysia, as a case study, I illustrate the crucial role small-scale fisheries play in supporting different levels of economy, and also address the chronic data poor state, and resulting undervaluation, of these fisheries. Specifically, I quantify the present and historical (1950-2009) socio-economic contribution small-scale fisheries make in supporting Sabah's economy and coastal livelihoods. I show that this contribution has been substantially undervalued or even unaccounted for, historically and in present fisheries statistics.

In Chapter 3, I first use an experimental economics approach to quantify the private discount rates of fishers in two developing country coral reef fisheries – Sabah (Malaysia), and Fiji. I then compare the discount rates from both study sites, which differ in that Sabah has essentially open access fisheries, whereas Fiji's marine resources are governed under a customary marine tenure system. In doing so, I test whether a fundamental fisheries economics theory, that fishers in an open access fishery have 'infinite' discount rates (Clark, 1990), applies to fishers in Sabah. I find that fishers under both institutional systems have high discount rates; however, those in Sabah are not excessively high as to be considered 'infinite'. Interestingly, there is no lower tendency to have high discount rates in traditionally managed versus open access fisheries.

In Chapter 4, I attempt to identify the socio-economic predictors of low discounting behaviour among small-scale fishers in Fiji and Sabah. I use the private discount rates obtained from Chapter 3 to define a low discount rate, and then use a logistic regression model to identify predictors of low discount rates. I find that a substantial proportion (42%) of fishers have low discount rates. In a pooled model that includes fishers from both Fiji and Sabah, site and village level variables are significant predictors of low discount rates. In two site-specific models that include observations from Sabah or Fiji only, boat ownership and relative catch differentiate low discounting from non-low discounting fishers, but these variables have contradictory effects in Sabah and Fiji. This suggests that local socio-cultural, economic, and ecological conditions have to be considered in the process of designing management interventions.

In Chapter 5, I move from site specific studies to a global study of discounting in coral reef fisheries. I use the theory of 'economics of overexploitation' developed by Clark (1973) to revisit my first research question about what the private discount rates of fishers are, and also address whether discount rates are reflective of the exploitation status of reef fisheries. My results show that the private discount rates of fishers are high, which contrasts with the substantially lower official discount rates used by fishery managers for evaluating projects. The discrepancy between these two sets of discount rates suggests that the future outlooks of those who manage and those who use fisheries resources do not coincide. This divergence may potentially affect the successful implementation of reef fisheries management strategies

in the present and future, and suggests that in order to improve the chances of success, policies which affect local fishers may need to be evaluated using private discount rates.

Chapter 2: Quantifying the overlooked socio-economic contribution of small-scale fisheries in Sabah, Malaysia

2.1 Introduction

Small-scale fisheries occur throughout the world, but predominate in tropical, less developed countries (Berkes et al., 2001). Although they differ according to location, small-scale fisheries can generally be characterised as being multi-gear and multi-species, with almost all of the catch being used as food fish. These fisheries make substantial social and economic contributions to society at the national, local, and individual levels (Béné et al., 2007). Half of the world's supply of food fish originates from small-scale fisheries, and it has been estimated that 90% of fishers worldwide are small-scale fishers (Béné, 2006). As 95% of these fishers reside in developing countries (FAO, 2004), small-scale fisheries are fundamental for the livelihood, welfare, and food security of coastal communities in some of the world's poorest countries. An important welfare dimension of small-scale fisheries is their ability to absorb, or act as a buffer for excess labour. They also serve as social safety nets in the sense that people may temporarily turn to fishing in times of economic stress or disaster (Béné, 2006).

Knowing the macroeconomic contribution of the fishery sector is essential for understanding the potential of fish stocks to generate wealth and contribute to social welfare (Cunningham et al., 2009). In order to manage small-scale fisheries so that they can continue to contribute to coastal livelihoods, it is thus necessary to understand the magnitude and extent of their current socio-economic contribution. Yet, in spite of their importance, small-scale fisheries generally lack management (Berkes et al., 2001), and their socio-economic contributions have largely been disregarded by policy makers (Zeller et al., 2006b). The scattered and unorganised nature of small-scale fisheries makes them difficult to monitor, and this is compounded by the fact that small-scale fishing communities normally consist of the rural poor who face social and political marginalisation (Pauly, 1997). In addition, policy makers tend to overlook small-scale fisheries in favour of commercial fisheries, such as tuna, which are important foreign exchange earners (Gillett and Lightfoot, 2002). Consequently, most small-scale fisheries exist in a data-poor condition, making it difficult to capture the economic and social contributions of these fisheries, and leading to their undervaluation and under-appreciation in many countries (Zeller et al., 2006b; Andrew et al., 2007). Even though

this situation prevails in developing countries, insufficient or lack of monitoring also occurs in the small-scale fishing sectors of some developed countries (Guyader et al., 2007).

Likewise, small-scale fishers in Sabah, Malaysia are removed from mainstream society due to the mainly rural and poor socio-economic backdrop of coastal fishing communities (Abdul Mannan, 1982; Wood, 2001; Teh et al., 2005). Despite their low socio-economic status, small-scale fishers have historically played a vital role in contributing to food security, trade, and economic activity in Sabah (Sather, 1997; Mohd. Ariff, 1999). Yet, this economic contribution has not been explicitly quantified to date. To address this, my objective is to quantify the present and historical socio-economic contribution small-scale fisheries make in supporting Sabah's economy and coastal livelihoods. I base my estimation on a previous study which quantified the historical catches of commercial and small-scale fisheries in Sabah (Teh et al., 2009a). In this study, I show the contribution small-scale fisheries make to different levels of the economy by quantifying: i) historical and current landed value of Sabah's small-scale fisheries catch from 1950-2009; ii) current profitability of fishing to individual fishers; iii) employment and number of dependents supported by the small-scale fishing sector from 1950-2009; and iv) the economic output supported by current levels of small-scale fisheries catch value.

2.1.1 Fisheries in Sabah

Sabah is a Malaysian state situated on the northeast corner of Borneo (Fig. 2.1). It is bordered by the South China Sea in the west, the Sulu Sea to the north-east, and the Sulawesi Sea to the south-east (Fig.2.1). Sabah's history can be divided into two periods for the time scale (1950-2009) considered in this study. Prior to 1963, Sabah was under British colonial rule, and was known as British North Borneo. It then gained independence and became a Malaysian state in 1963, changing its name to Sabah.

Sabah's marine capture fisheries were mainly small-scale until the introduction of commercial trawlers in the 1960s. In present time, small-scale fisheries continue to provide the main source of income and meat protein for a large proportion of Sabah's rural coastal communities (Institut Penyelidikan Marin Borneo, 2003; Foo et al., 2006). Small-scale fisheries are concentrated in the inshore area, targeting mainly reef and reef associated estuarine species, and small pelagics (Biusing, 2001; Wood, 2001; Teh et al., 2005). Fishing is done for both subsistence and artisanal purposes, using a variety of manually operated

gears, including hook and line, gillnets, traps, spears and spear guns. Sabah's inshore fisheries resources are extensively exploited, with signs that reef fisheries are overfished in parts of Sabah (Teh and Sumaila, 2007). Meanwhile, destructive fishing techniques using dynamite and cyanide are still common, and have damaged or destroyed unprotected reefs throughout the state (Oakley et al., 1999; Pilcher and Cabanban, 2000).

Local small-scale fishers in Sabah belong mainly to the Bajau, Ubian, Suluk, and Brunei Malay ethnic groups (Biusing, 2001). There is also a large population of migrant fishers originating from the southern Philippines and Indonesia. The number of fishers in Sabah increased rapidly in the mid 1970s to 1980s as refugees fleeing political instability in the southern Philippines settled along coastal areas or outer islands of Sabah, and turned to fishing for a livelihood (Cooke, 2008).

Prior to Sabah's independence in 1963, British colonial reports provided data only on the quantity of exported fisheries commodities. After independence, statistics on marine fisheries landings, the registered number of vessels, fishers, and fishing gears have been compiled by the Sabah Fisheries Department. However, these data are not complete in their coverage (Cabanban and Biusing, 1999; Teh et al., 2009a). Before 1991, marine fish landings statistics were estimated from fish market surveys, trawler logbooks, fish processing plant reports, and export data.

An improved system was introduced in 1991, which used a stratified random sampling approach to estimate landings of selected fishing gears in Sabah's 16 coastal districts (Biusing, 2001). However, this has resulted in the underestimation of small-scale landings, and in many cases, the catches from fishers living in offshore islands or rural villages go unrecorded (Teh et al., 2007). Consequently, the reported economic value of Sabah's small-scale fisheries is also underestimated. In addition, the reported number of fishers is considered to be an underestimate due to the exclusion of many illegal or transient migrant fishers (Biusing, 2001). To address the apparent gaps in fisheries monitoring, a prior study reconstructed Sabah's historical marine fish catches, and found that from 1950-2006, fish caught from Sabah waters were on average 2.5 times higher than landings data recorded in fisheries statistics (Teh et al., 2009a). In this chapter, I use the reconstructed catches from Teh et al. (2009a) as the basis for quantifying the historic and present economic contribution of Sabah's small-scale fisheries to society.

2.2 Method

2.2.1 Data

All fisheries landings and landed value statistics unless stated otherwise were extracted from the Malaysian Department of Fisheries Annual Reports (www.dof.gov.my/v2/perangkaan.htm). Small-scale fisheries are referred to as traditional fisheries in the Malaysia Department of Fisheries statistics, and I use the two terms interchangeably. Data for Sabah were available from 1965 to 2009; however, the reporting of data was not consistent throughout the years, with coarser data available in the earlier years. Due to a change in fisheries statistical recording system in 1991, I compared my results to reported statistics from 1991 onwards in order to work with a consistent data set.

2.2.2 Summary of reconstructed small-scale catches

I refer the reader to Teh et al. (2009a) for a detailed description of the methodology used for reconstructing the historical commercial and traditional fish catches of Sabah. Briefly, the authors used published, including grey literature to obtain information on small-scale fishing catch rates and fisher population in order to build a bottom up estimate of the amount of fish caught in Sabah waters from 1950-2006.

For the small-scale sector, the authors explicitly accounted for the large unlicensed fisher population, many of whom were illegal immigrants, and who were not captured in the official statistics. The Sabah Fisheries Department does not know how many of these migrant fishers reside in Sabah (Biusing 2001). Therefore, Teh et al. (2009a) estimated the total number of local and migrant fishers using annual population and demographic data. To summarise, the number of local fishers (inclusive of both commercial and traditional fishers) were estimated from the population of ethnic Bajau living in coastal communities in Sabah, while migrant fishers were estimated from available data on migrant arrivals. All estimated fishers were assumed to be traditional from 1950-1965, as commercial fisheries commenced in the 1960s. From 1991-1999, Biusing (2001) reported that an average of 78.5% of local fishers were traditional, while 40.7% of non-Malaysian fishers were traditional fishers. This proportional breakdown was applied to the estimated number of local and migrant fishers for 1991-2006. The proportion of local fishers considered to be traditional was linearly decreased from 100% in 1965 to 78.5 % in 1991; the same procedure was applied to non-Malaysian fishers. I used the same procedure to update the reconstructed catch and number of small-scale fishers estimates for 2007-2009.

Catch rates for 3 periods that roughly coincided with prevailing economic conditions affecting small-scale fishers were estimated based upon existing literature: 1950-1969, 1970-1999, and 2000-2006. For 1950-1969, an annual catch rate of $3.09 \text{ t fisher}^{-1} \text{ year}^{-1}$ was derived from an anthropological study of a Bajau fishing community in 1965 (Sather, 1985;1997). There were no available catch rate data for 1970-1999. However, based upon historic information on the socio-economic development of Sabah, and on fisher interview data, Teh et al. (2009a) assumed that catch rates for 1970-1989 were higher than the ensuing period of 1990-2006. A conservative annual catch rate of $5 \text{ t fisher}^{-1} \text{ year}^{-1}$ was applied from 1970-1980; starting from 1981, the catch rate was linearly decreased to $3.68 \text{ t fisher}^{-1} \text{ year}^{-1}$ in 2000. The annual catch rate of $3.68 \text{ t fisher}^{-1} \text{ year}^{-1}$ used for the period 2000-2006 was based on the average catch rate reported in a case study of small-scale reef fisheries in Sabah (Teh et al., 2007). The times series of annual small-scale catch was calculated by multiplying the estimated number of traditional fishers by the annual catch rate.

I used the reconstructed number of traditional fishers and the reconstructed traditional catch from Teh et al. (2009a) as a starting point for estimating the economic contribution of Sabah's small-scale fisheries (Appendix A). The reconstructed small-scale catch time series from 1950 to 2006 summed to 9.7 million t, while the number of reconstructed fisher estimates for 1988 to 2006 were 2.5 times higher than the number of traditional fishers reported in the fisheries statistics for the same period. Compared to landings data reported in the Annual Fisheries Statistics from 1965 to 2006, the reconstructed catch was on average 220% larger.

The magnitude of reconstructed traditional catch and number of traditional fishers may even be larger relative to reported statistics than indicated in Teh et al. (2009a), as that study considered commercial gears to consist of trawlers and purse seines only. In this chapter, I included gillnets, which was categorised as a traditional gear by Teh et al. (2009a), as a commercial gear. This was done to be consistent with the Malaysia Department of Fisheries categorisation of commercial gears, which is comprised of trawlers, seine nets, and gill nets. Traditional gears consisted of hook and line, lift and barrier nets, stationary and portable traps, shellfish collection, and miscellaneous gears (inclusive of spears, drive-in nets, push nets, tidal traps, and hand hooks). As a result of allocating gillnets to the commercial sector, the reported traditional landings and number of fishers I used in this chapter was smaller than

that used in the Teh et al. (2009a) study. However, this did not affect the reconstructed catch or number of traditional fishers estimated by the authors.

2.2.3 Economic indicators

I used 4 economic indicators to show the contribution of Sabah's small-scale fisheries to different levels of economy: 1) landed value measured the gross direct benefit of the small-scale fisheries catch; 2) profits from fishing was an indicator of fisheries' benefit to individual fishers; 3) Employment and number of fishers' dependents were indicators of societal benefits of small-scale fisheries; and 4) economic impact quantified the value of small-scale fisheries output throughout the state economy.

2.2.3.1 Landed values

Landed value of reconstructed small-scale catches

Landed value for each year i was calculated as

$$V_i = C_i \times P_i,$$

Where V = landed value, C = reconstructed traditional catch and P = ex-vessel price.

Ex-vessel price is the per unit fish price that fishers receive when they land their catch. Ex-vessel price may be calculated from reported landed values and landings (Sumaila et al., 2007). However, the annual landed values reported in the Malaysia Department of Fisheries Annual Reports are based on wholesale prices, and not ex-vessel prices. Therefore, I took an indirect approach to estimate ex-vessel prices for 2 separate periods as detailed below:

1950-1964:

There were no reported landed value data for Sabah available for these years, so I estimated ex-vessel prices from reported retail prices for Peninsular Malaysia. Retail prices were reported by fish grade (Grade I, II, III, manure fish, prawns). I allocated these fish grades to the appropriate fish groups according to the traditional fish catch composition used by Teh et al. (2009a) to obtain an annual average retail price weighted according to traditional catch composition (Table 2.1). To convert Peninsular Malaysia retail prices to ex-vessel prices in Sabah required 2 steps: 1) a factor to account for the higher retail prices in Peninsular Malaysia versus Sabah; and 2) a factor to account for the mark-up in price from fisher to retailer.

1) I had reported annual average retail prices for both Sabah and Peninsular Malaysia for 2006-2009 from the Annual Fisheries Statistics. In addition, a report by Abdul Mannan

(1982) had average retail prices for Sabah for 1974-1979. For these years, I was able to calculate a ratio of Peninsular: Sabah retail prices. On average, retail prices in Peninsular Malaysia were 1.37 times higher than those in Sabah for 2006-2009 and 1.81 times higher in the 1970s. It was noted by Sather (1997) that fish prices in Sabah were very low during the 1960s. Therefore, I decided to take the higher ratio (1.81), and assumed that retail fish prices in Peninsular Malaysia were roughly 80% higher than those in Sabah for 1950-1964.

2) I used information from 2 sources to adjust Sabah retail prices calculated in step (1) to ex-vessel prices: i) According to a socio-economic survey of Sabah small-scale fishers done by Abdul Mannan (1982), fish prices were marked up by 200% from producer to retailer; ii) During the late 1960s to 1990s, it was common for fish buyers to buy fish from fishers in bundles of 15-20 individual fish (Mohd. Ariff, 1999). The fish buyer would pay the fisher according to the number of bundles, and then sell the fish at market for the same price, except with a reduced number of fish per bundle. Normally, the number of fish would be reduced by a third to a half per bundle (Mohd. Ariff, 1999). As fish in each bundle were approximately the same size, I assumed that the retail price in terms of weight was approximately 40% to 100% higher than that received by the fisher. Based on (i) and (ii), I conservatively assumed that the estimated average retail price in step (1) was about double the ex-vessel price.

1965-2009:

Method 1: I extended the same 2 step procedure used to estimate ex-vessel prices for 1950-1964 to 1965-2009.

Method 2: This method was based on information independent from fisheries statistics. An anthropological study done in Semporna, south-east Sabah, in the 1960s noted that fishermen earned about 30 cents for a kati of fish (equivalent to 50 cents a kg)(Sather, 1997). Ex-vessel prices obtained from field studies in a fishing village in Pulau Banggi, Sabah, were available for 2004, 2005, 2007, and 2009 (L.Teh, unpublished data). I assumed a linear increase in fish prices for the entire period, and linearly interpolated the prices in between 1965 and 2004, and for the intervening years from 2005 to 2009. I used an average of Methods 1 (retail price based) and 2 (statistics independent) prices for all ensuing calculations.

Landed value of reported landings

Data on annual landings broken down by commercial and traditional sectors was available for 1982-2009. However, annual landed value data for the same period was not available by fishing sector. To estimate the annual landed value of the traditional sector from 1982-2009, I

multiplied reported annual traditional landings by the calculated ex-vessel price described above.

Real prices and landed values

Real annual ex-vessel prices and landed values were calculated by adjusting the estimated nominal figures by the Consumer Price Index (CPI). CPI data for 1950-2009 were obtained from the World Bank databank online (<http://databank.worldbank.org/ddp/home>).

2.2.3.2 Profitability

I defined profitability as the ratio of net monthly fishing income to monthly fishing revenue. This was computed for 2009 only, and was not extrapolated to other years. I based my estimate on information gathered from semi-structured interviews conducted with 75 small-scale fishers in 2009. Interviews were conducted in 11 fishing villages concentrated in 2 geographical areas: Pulau Banggi off the northern coast of Sabah, and the Semporna islands off the south eastern coast of Sabah (Fig. 2.1). These interviews included questions pertaining to the socio-economics of fishing, including each fisher's fishing income, costs, and fishing effort. I will elaborate on these interviews in Chapter 3.

Fishing villages in both the surveyed locations are rural, with those in Pulau Banggi being particularly remote from the mainland and nearest town centre. Fishers fished for both subsistence and artisanal purposes, and targeted reef and reef associated fish. Fishers along the west coast of Sabah tend to focus more on pelagic species. However, as the gears used by the surveyed fishers represented the main gears used by small-scale fishers throughout Sabah, and I could not find data on fishing costs and revenue for small-scale fishers on the west coast, I found it reasonable to use the interview data to represent profitability for small-scale fishers in all of Sabah. Profitability for each fisher was calculated as:

$$P = NI/R,$$

where NI=net fishing income per month, R=fishing revenue per month, P=profitability; and

$$NI = R - C_o - C_f,$$

where C_o = operating cost per month, C_f = fixed cost per month. Fixed cost referred to the depreciation of a fisher's boat, which was calculated on a straight-line basis to obtain an annual depreciation cost per boat.

2.2.3.3 Employment and number of people supported

I made no distinction between full or part time fishers, and so considered employment in the small-scale sector to be equivalent to the reconstructed number of traditional fishers estimated by Teh et al. (2009a) (Appendix A). I estimated the number of people directly dependent on small-scale fisheries income by multiplying the annual estimated number of traditional fishers by the number of dependents per fisher, i.e., for each year i :

$$D_i = F_i * d_i$$

where D_i is the number of individuals directly dependent on small-scale fishers in Sabah, F_i is the number of reconstructed traditional fishers, and d_i is the number of dependents per fisher.

I obtained estimates for the number of dependents per fisher for 2 periods:

- 1) 1950-1981: Abdul Mannan (1982) reported that each traditional fisher had on average 7 dependents in 1981. I applied this number from 1950 to 1981, based on the assumption that the size of fishing households was the same, or larger during this period.
- 2) 1982-2009: Fieldwork I conducted in 2009 indicated that the average fishing household size in rural and remote fishing villages was still 7, whereas the average household size for rural areas in Sabah was 5.2 in 2009 (Department of Statistics Malaysia, 2009a). I used the average of these two information sources to obtain an average rural fishing household size of 6.1 for 2009. A previous study indicated that there were on average 1.36 fishers per household (Almada-Villela, 1997). I subtracted this from the average fishing household size to obtain 3.49 dependents per fisher in 2009, and then linearly decreased the number of dependents from 7 in 1981 to 3.49 in 2009.

2.2.3.4 Economic impact of small-scale fisheries on Sabah economy

I estimated the total output in Sabah's economy that was dependent to some extent on the output from small-scale fisheries. Counting landed value as the only contribution a fishery offers to economic output is an underestimate of a fishery's full economic impact because it ignores the variety of secondary activities supported by fisheries (e.g., boat building, fish processing, etc.). To address this, I used the fishing output multiplier developed by Dyck and Sumaila (2010) to estimate how much output is generated by Sabah's small-scale fishery catches (i.e., landed catch value). The main concept of multipliers is that the different sectors which make up an economy are interdependent. As such, fisheries output multipliers account for the direct, indirect, and induced economic effects of marine fisheries on the global economy. Dyck and Sumaila (2010) used an input-output method to estimate fisheries output multipliers for each maritime country.

Input-output analysis is a method used to track the flow of dollars between industries in the production of output for a certain sector. Inter-industry transaction data are used to compute a coefficient matrix which summarises how much output from a certain industry x is required to produce a unit of output for industry y . Dyck and Sumaila (2010) applied the Leontief technological coefficient to estimate total output supported throughout the economy at 2003 fisheries production levels, where production was measured as landed value. The landed value weighted multiplier for Malaysia was estimated to be 2.58. This meant that an extra unit of fisheries demand would generate 2.58 units of output in Sabah's economy. Following Dyck and Sumaila's (2010) methodology, I used landed catch value as a measure for fisheries demand. As multipliers were available only by country level, I used the Malaysian multiplier for Sabah. The total economic impact of small-scale fisheries to Sabah's economy in 2009 was estimated as:

$$E = V \times \alpha,$$

where E = economic output, V = landed value of catch in 2009, and α = weighted multiplier.

2.3 Results

2.3.1 Ex-vessel prices and landed value

Estimated annual average nominal and real ex-vessel prices were variable, but in general showed an increasing trend from 1950-2009. Ex-vessel prices increased substantially in the 1970s and the early to mid 1990s, reaching the highest of RM 3.9 kg⁻¹ in the most recent year (2009) (Fig. 2.2). Similarly, the nominal and real landed value of small-scale catches showed an increasing trend from 1950-2009, reaching a maximum value of RM 664 million in 2009 (Fig. 2.3). The cumulative nominal landed value of small-scale catches for the entire analysis period totalled RM 9.3 billion, while it was RM 7.2 billion from 1991-2009. In comparison, the estimated value of reported traditional landings for 1991-2009 amounted to RM 2.6 billion, suggesting a cumulative undervaluation of RM 4.5 billion (USD 1.4 billion), or an average of RM 252.9 million (USD 80.5 million) per year. The spread between estimated catch value and reported landed value was greatest in the most recent years (Fig. 2.4). The reconstructed time series of nominal catch value per fisher showed an increasing trend, whereas the real catch value per fisher actually declined following a peak in the late 1970s, and only started to move upwards again around 2007 (Fig. 2.5).

2.3.2 Profitability of small-scale fishing

I report the profitability of small-scale fishing across all gears because many fishers used more than one gear type. Fishing was the only source of income for the majority (75%) of respondents. The average net monthly fishing income (\pm standard error) was RM 442 \pm 60, with profitability of 0.45 (Table 2.2). Fuel made up the largest cost component, accounting for 73% of all operating costs on average. Although small-scale fishing appeared profitable, monthly net fishing income was still below the 2004 Sabah poverty line income of RM 704 month⁻¹ (UNDP, 2007). Mean household expenditures were approximately RM 276 month⁻¹ (L. Teh, unpublished data); thus, in most cases fishers were making enough just to meet household living expenses. Seventy-five percent of fishers did not have savings.

2.3.3 Employment and dependents

On average, the estimated number of fishers employed by Sabah's small-scale sector was 4.7 times higher than the number of traditional fishers reported in the fisheries statistics for 1991-2009. In the most recent year (2009), the estimated number of small-scale fishers was 48,833, making up 1.5% of Sabah's population. In contrast, there were 8,544 traditional fishers recorded in the fisheries statistics for 2009 (Appendix A).

The time series for the number of dependents supported by the reconstructed number of traditional fishers is presented in Table 2.3. On average, small-scale fishers may have supported up to 19% of Sabah's population during the 1950s, although the proportion decreased so that in 2009, an estimated 48,833 traditional fishers potentially supported up to 170,197 dependents, equivalent to 5% of the state population. In contrast, applying the same number of dependents per fisher to the 8,544 reported number of traditional fishers in 2009 statistics yielded 59,739 dependents, or 2% of the population.

2.3.4 Economic impact

Applying a multiplier of 2.58 to the total current (2009) estimated catch value of RM 664 million generated potential economic output amounting to RM 1.71 billion. Of this, up to RM 1.36 billion (79%) may have been due to the unaccounted value of reconstructed traditional catches.

2.4 Discussion

My findings indicate that Sabah's small-scale catches may have been undervalued by up to 225% from the early 1990s to the present. This reflects the general disregard of small-scale fisheries' contribution to economies (Béné, 2006; Zeller et al., 2006b; Andrew et al., 2007). One of the main reasons government agencies tend to overlook the small-scale fishing sector is because of their relatively negligible economic contribution at the macro-level, which typically range from 0.5 to 2.5% (Béné et al., 2007). Yet, this mentality ignores the crucial welfare and livelihood role of small-scale fisheries, as illustrated by this case study.

Sabah's fishing sector is not a major contributor to the state economy. Among agricultural sectors, the gross value of fisheries output in 2009 was valued at RM 164.4 million, compared to a gross value of RM11.3 billion for crops and livestock (Department of Statistics Malaysia, 2009b). In terms of employment, the 39,300 individuals employed in the fishing sector is a fraction of the 323,000 employed in agriculture, forestry, and hunting in 2006 (Department of Statistics Malaysia, 2007). Nevertheless, the important point of my results is the extent to which the socio-economic contribution of Sabah's small-scale fisheries has been undervalued. I estimate that direct fisheries value was RM 664 million in 2009, compared to the value of reported traditional landings of RM 136 million. This undervaluation of more than 350% has to be rectified, as it can potentially lead to distorted outcomes if used as the basis for policy decisions.

I estimate that small-scale fishers potentially support up to 170,197 dependents, equivalent to 5% of the state population. In contrast, basing my calculation on the reported number of fishers in 2009 would have resulted in 59,739 dependents, a potential underestimate of 185%. My estimate itself is likely conservative as I only considered dependents within a fisher's household, and did not include individuals such as fish traders who are also dependent on the output of small-scale fishers. Overall, my estimate implies that a decline in inshore marine resources will have a much more widespread impact than currently anticipated.

Using a fisheries economic multiplier to assess the total economic impact of small-scale fisheries indicates that unaccounted small-scale fisheries value in 2009 can potentially generate RM 1.36 billion in output to Sabah's economy, which is equivalent to 4% of Sabah's 2009 gross domestic product (GDP). Accounting for this would have increased the combined GDP contribution of commercial and traditional fisheries from the reported 2009

level of 2.1% to 6%, essentially increasing fisheries contribution by 200% and making it comparable in magnitude to the manufacturing industry, which contributed RM 2.4 billion to GDP in 2009 (Department of Statistics Malaysia, 2011). My results are consistent with a study which found that the contribution of small-scale fisheries to GDP was underestimated by a factor of 5 (Zeller et al., 2006b), and imply that a decline in small-scale fisheries will resonate beyond the fishing sector.

One of the fundamental roles of small-scale fisheries is in supporting the welfare of coastal communities (Béné, 2006), but this welfare dimension is under-represented by official statistics in Sabah. For example, Teh et al.'s (2009a) reconstructed number of traditional fishers was 370% higher than reported numbers from 1991 to 2006. This arose from the inclusion of illegal migrant fishers, who are not documented in official statistics. As these migrant fishers cannot easily find legal employment, fishing served as their labour buffer and social safety net; these two crucial functions of small-scale fisheries have been demonstrated in other parts of Asia and Africa as well (e.g., Jul Larsen, 2003; Béné et al., 2010).

Poverty alleviation is one of the central contributions of small-scale fisheries (Béné, 2006). In some countries, small-scale fishing boats are profitable and economically viable (e.g., Adeogun et al., 2009). My profitability analysis shows that small-scale fishing in Sabah functions to prevent further poverty, rather than to alleviate it. Even though small-scale fishing generates positive profits, average monthly fishing income is below the Sabah poverty line income, and is barely enough to cover household expenses. Thus, fishing cannot generate sufficient wealth to lift fishers out of poverty. Rather, it helps to sustain livelihoods and prevent fishing households from falling deeper into deprivation. This aspect of small-scale fisheries contribution is even more important given that Sabah is one of the poorest Malaysian states (Leete, 2008), and social welfare options are limited. Overall however, the real (i.e., inflation adjusted) annual catch value per fisher has been declining temporally, suggesting that the ability of fishing income to support economic needs has decreased from the past. These factors bring up concerns about the vulnerability of fishing households (Allison and Ellis, 2001), especially given the apparent declines in Sabah's inshore coral reef resources (Cabanban and Busing, 1999; Scales et al., 2007; Teh and Sumaila, 2007).

Food security is another key contribution of small-scale fisheries (Béné et al., 2007). Sabah's fisheries were small-scale in nature until the 1960s, but these operations were able to supply

enough fish for the domestic market as well as for export during this period (Mohd. Ariff, 1999). Nowadays, with the exception of valuable live reef food fish species, the fish caught by traditional fishers is consumed locally. In contrast, a considerable proportion of commercial trawler landings consist of trash fish which are processed into fishmeal (Busing, 2001), and hence do not contribute to local food security. Though not directly quantified here, my study brings to light that food security enjoyed by Sabah society at large can be attributed to small-scale fishers. Yet, small-scale fishers often face social marginalisation, and their crucial contribution is not widely recognised.

In contrast to other developing countries where the traditional small-scale sector is omitted from official statistics (e.g., Zeller et al., 2006a), the Sabah Fisheries Department does monitor traditional fish landings and values. However, the problem is that the system fails to capture the entire scale of the small-scale fishing sector, largely due to the social marginalisation of small-scale fishers. In particular, the Bajau Laut, who are the traditional maritime people of this region, have often been shunned by other segments of society for their nomadic sea faring way of life (Saat, 2003; Torres, 2005). In addition, the increasing number of illegal migrant small-scale fishers in the past few decades is difficult to account for, as they tend to settle in rural offshore islands (Piper, 1984; Fisher, 2000; Busing, 2001). The presence of illegal immigrants is a contentious social and political issue in Sabah (Sadiq, 2009). Nevertheless, it is essential to start documenting this hidden segment of small-scale fishers, not only to obtain a better estimate of small-scale fisheries' socio-economic contribution, but also to obtain a better understanding of the level of inshore fisheries exploitation.

Teh et al. (2009a) showed that the largest increase in small-scale catches occurred in the 1990s, which corresponded to the period of highest population growth. Sabah's population doubled from 1990 to 2009 (Department of Statistics Malaysia, 1995; 2009a), in large part due to the arrival of illegal immigrants (Sadiq, 2009). The fisheries impact of population growth spurred by migrant fishers raised concerns in a case study of migrant fishers in neighbouring Indonesia (Kramer et al., 2002), but this issue has not been sufficiently addressed in Sabah.

Although coarse, my time series analysis offers a more encompassing quantification of the historical economic value of Sabah's fisheries catches from 1950-1963, as British records

only reported the value of exported processed fisheries products for this period. By doing so, my study provides an approximate baseline by which to assess the socio-economic impact of future changes to Sabah's inshore marine resources. My quantification complements existing social economic studies which tend to have focused on the anthropological aspects of Sabah's traditional fishing communities (e.g., Sather, 1997; Ono, 2010), or have been based on government fisheries data (e.g, Mohd. Ariff, 1999; Busing, 2001; Noh and Tai, 2001).

My approach for estimating historical and present socio-economic contribution tackles the difficulty of dealing with the data-poor nature of small-scale fisheries, which is a major obstacle to their management (Johannes, 1998). I relied on a combination of formal and informal sources -fisheries data, grey and published literature, and field observations – which are typically publicly available or collectible at minimal cost, to fill in data gaps. At the same time, I acknowledge that this approach entails uncertainty and a certain degree of subjectivity. However, sensitivity analysis shows that the study's overall trends are consistent even if certain variables change. For example, if the price variable is increased by 10%, estimated reconstructed catch value increases by 5%, but the magnitude by which reported landings are underestimated remains unchanged. Further, the economic impact of Sabah's small-scale fisheries may be overestimated because the fisheries multiplier calculated by Dyck and Sumaila (2010) was a country average for Malaysia. The rural nature and low economic integration of many Sabah fishing communities means that the multiplier for its small-scale fisheries may be lower than the national average. Using a multiplier that is 25% lower would result in an economic impact of RM 1.28 billion in 2009, and this would lower the current estimated fisheries contribution to Sabah GDP from 4% to 3%.

On the other hand, the national fisheries multiplier may be a conservative estimate because of economic leakage, which lowers a multiplier. Economic leakage occurs when the earnings obtained in one sector do not remain within the sector, but are spent in another sector instead. Kamaruddin and Abdul Rashid (2007) found moderate leakage in the Malaysian fishing industry. However, given the absence of a state specific fisheries multiplier for Sabah, the economic impact calculated based on the national average multiplier is my best estimate. Overall, given the general paucity of data and comparable studies on which to calibrate my findings, I contend that my results present the current best estimate of Sabah's small-scale fisheries socio-economic contribution with regards to the factors measured. My intent is that these figures be treated as first attempt estimates which can be refined and improved upon.

In summary, my study shows that the social and economic contributions of small-scale fisheries to Sabah society have been substantially undervalued or even unaccounted for historically and in the present fisheries statistics. The significant undervaluation of fisheries output implies that fishing pressure on Sabah's inshore marine resources is probably a lot higher than presently perceived, and illustrates the risk associated with the prevailing indifference towards understanding the 'true' magnitude of small-scale fishing. For Sabah, my study strongly suggests the need for more encompassing fisheries monitoring and data collection methods which include the large undocumented population of small-scale fishers. A necessary complementary step may be for Sabah's Fisheries Department to start addressing the persistent issue of illegal immigrant fishers in tandem with state immigration and other relevant social welfare authorities. Even though my results are specific to Sabah, they are relevant for all small-scale fisheries where monitoring of the sector is minimal or does not exist. Importantly, my results dispel the common notion that small-scale fisheries are of negligible economic importance. Fully accounting for small-scale fisheries contribution shows that although they do not have a heavy impact at the macro-economic level, the socio-economic contribution of small-scale fisheries to the welfare and livelihood of coastal communities is crucial.

Table 2.1. Summary of traditional fish catch composition and breakdown of weighted retail price by retail fish grade categories.

Traditional fish catch composition ¹		
<u>Fish groups</u>	<u>Percentage of catch</u>	
Small pelagic (SP)	0.10	
Medium and large pelagic (MLP)	0.45	
Demersals (DM)	0.31	
Crustaceans (CR)	0.06	
Molluscs and misc. invertebrates (MIV)	0.02	
Trash fish (TF)	0.06	
Breakdown of weighted retail price		
<u>Retail fish grade category</u>	<u>Fish group composition</u>	<u>Retail weight</u>
Grade I	MLP, DM, CR	0.38
Grade II	MLP,DM	0.38
Grade III	SP, MIV	0.12
Crustaceans	CR	0.06
Manure fish	TF	0.06

¹Source: Teh et al. (2009a).

Table 2.2. Average profitability of small-scale fishing across all gears for 2009.

Variable	RM month⁻¹ (Mean± std. error)
Fishing revenue	1141±254.1
Fishing costs	697±219
Net income	442±60.3
Average profitability (%)	0.45

¹The currency exchange rate on 5 December 2010 was USD 1 = RM 3.14.

Table 2.3. Estimated number of dependents of small-scale fishers as a proportion of Sabah's population 1950-2009.

Year	Estimated no. of dependents	% of Sabah population
1950	67671	0.19
1951	63958	0.19
1952	64528	0.19
1953	65758	0.18
1954	66101	0.18
1955	66577	0.18
1956	67387	0.17
1957	68189	0.17
1958	69436	0.17
1959	70403	0.16
1960	72877	0.16
1961	73326	0.16
1962	73584	0.15
1963	73648	0.15
1964	74205	0.14
1965	74675	0.14
1966	70249	0.12
1967	69401	0.12
1968	68990	0.11
1969	68878	0.11
1970	68968	0.10
1971	69882	0.09
1972	68882	0.09
1973	70169	0.09
1974	74796	0.09
1975	76480	0.09
1976	79245	0.09
1977	81589	0.09
1978	84107	0.09
1979	85537	0.09
1980	88919	0.09
1981	86916	0.08
1982	90183	0.08
1983	93102	0.08
1984	96388	0.08
1985	99632	0.08
1986	102968	0.08
1987	106452	0.08
1988	109408	0.08
1989	113823	0.08
1990	118446	0.08
1991	127456	0.07
1992	133852	0.07
1993	140330	0.07
1994	151291	0.07
1995	154230	0.06
1996	158501	0.06
1997	160447	0.06
1998	161999	0.06
1999	169486	0.06
2000	155850	0.06
2001	157656	0.06
2002	155490	0.06
2003	157243	0.06
2004	159226	0.06
2005	162566	0.05
2006	161509	0.05
2007	163012	0.05
2008	163260	0.05
2009	170197	0.05

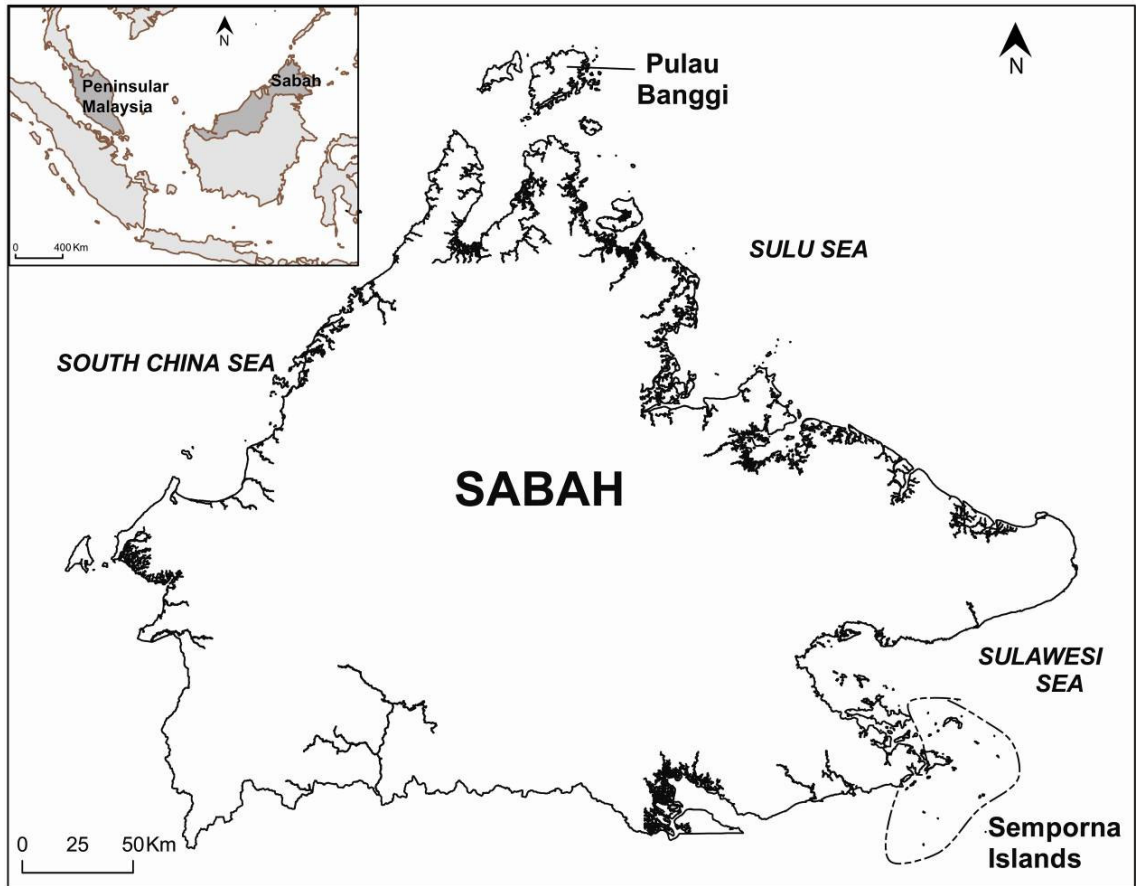


Figure 2.1. Map of Sabah state, showing the interview sites of Pulau Banggi and the Semporna Islands. The inset map shows Malaysia shaded in grey.

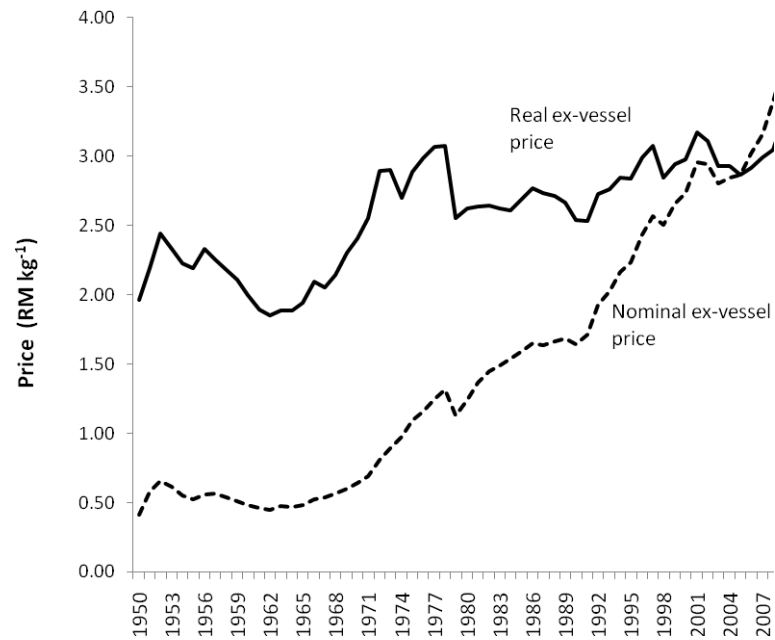


Figure 2.2. Annual average nominal and real ex-vessel fish prices.

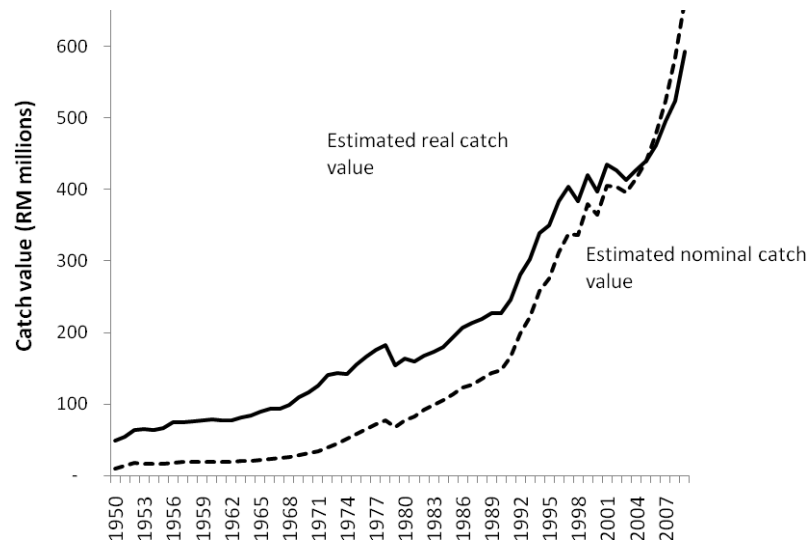


Figure 2.3. Annual nominal and real catch value for Sabah's reconstructed traditional fish catch.

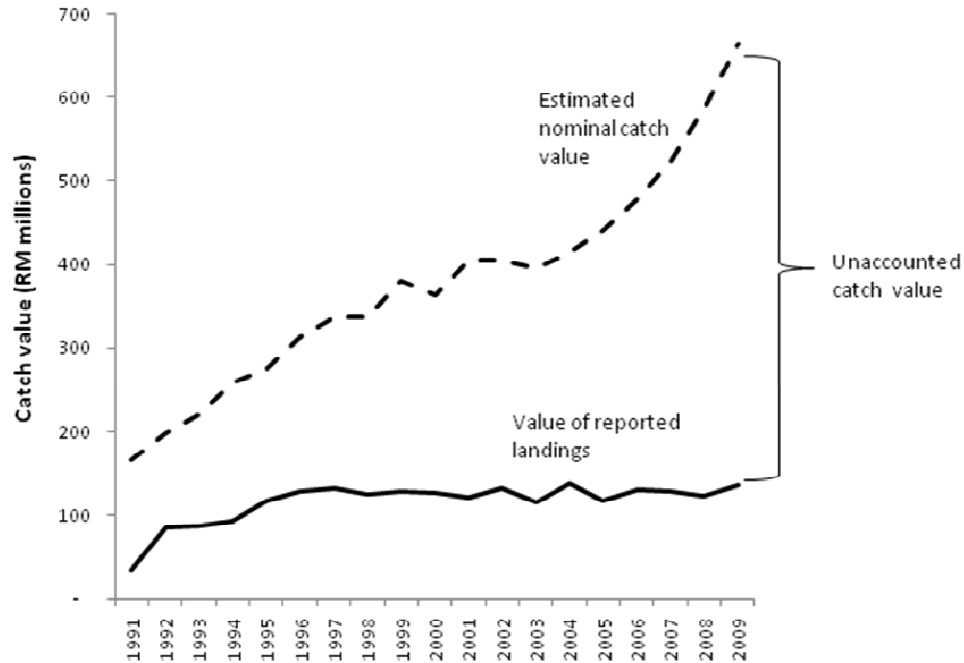


Figure 2.4. Annual estimated nominal value of reconstructed traditional fish catch versus value of reported landings. The gap between the two curves show the catch value unaccounted for in reported statistics.

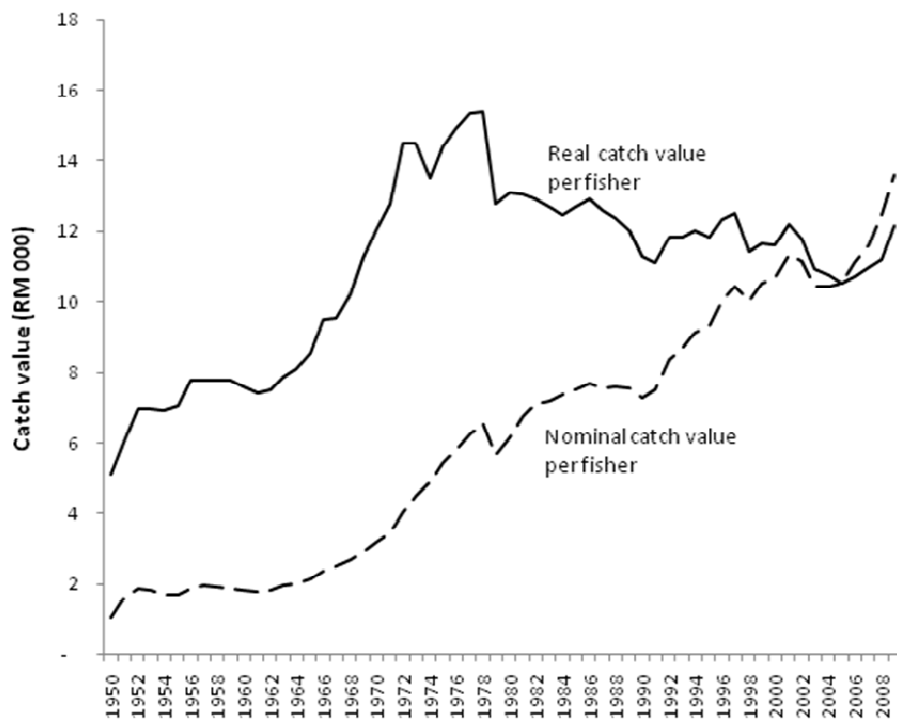


Figure 2.5. Annual nominal and real catch value per fisher.

Chapter 3: Time preference of small-scale fishers in open-access and traditionally managed reef fisheries

3.1 Introduction

The majority of the world's coral reefs occur along the coasts of tropical developing countries, where socio-economic dependence on reef fisheries is disproportionately large (Whittingham et al., 2003; Bell et al., 2006). Yet, inshore coral reef resources are being overexploited globally, with serious biodiversity, social, economic, and cultural consequences (Bellwood et al., 2004; Newton et al., 2007). Malthusian overfishing is widespread in many tropical inshore fisheries (Pauly et al., 1989; Teh and Sumaila, 2007; McClanahan et al., 2008), which are mostly unmanaged and operate under an essentially open access regime (Sadovy, 2005; Sale, 2008). I define an open access fishery as one in which fishing rights are non-existent or ill-defined, access to the fishery is unrestricted, and there are no regulations governing the use of the fishery resource (Greboval and Munro, 1999). In contrast to open access systems, customary marine tenure is practiced in the Pacific islands and parts of Indonesia and East Africa (Mantjoro, 1996; McClanahan et al., 1997; Johannes, 2002).

Fisheries economics theory suggests that overexploitation occurs when fishers' discount rates are high (Clark, 1973; Sumaila and Walters, 2005), i.e., they prefer receiving an immediate, certain, smaller benefit over future, uncertain, but potentially larger benefits. Weak fishery institutions provide further incentives for high discount rates. The problem of overfishing stems from the 'tragedy of the commons' (Hardin, 1968), in which unrestricted access to a fishery leads to overexploitation because individual fishers have no incentive to conserve, since they have no assurance that the fishery resource will persist into the future. Therefore, in theory, fishers in an open access fishery are compelled to discount the future heavily when making fishing decisions, despite the fact that their individual private discount rates may be low. In essence, the open access environment forces fishers to use a discount rate of infinity (Gordon, 1954; Clark, 1990). Although an 'infinite' discount rate is theoretically possible, it is likely not realistic in practical terms. In this chapter, I use 'infinite' discount rate to refer to a very high discount rate.

Despite the serious implications the open access theory has for the management of small-scale reef fisheries in developing countries, there has, to my knowledge, been no empirical

study investigating this assumption. I fill this gap by examining the discount rates of fishers in two small-scale tropical reef fisheries operating under different institutional environments: 1) an open access regime in Sabah, Malaysia; and 2) customary marine tenure (CMT) in Fiji. I seek to answer the following questions:

- 1) What are the discount rates of fishers in open access and traditionally managed fisheries?
- 2) Do fishers in an open access fishery have ‘infinite’ discount rates?

An individual’s time preference refers to how one values goods and services at different points in time, and is expressed through a discount rate, which reflects one’s willingness to trade current for future consumption. The importance of individuals’ time perspective for policy development has been recognised in fields where decisions involving future outcomes are critical, e.g., in health and credit markets (Pender, 1996; Poulos and Whittington, 2000; Amadja, 2008). Recent studies have shown that discount rates elicited for one domain can be applicable to other domains and context (Hardisty and Weber, 2009), as well as behaviour (Chabris et al., 2008). As such, investigating fishers’ time preference is of policy interest because it can inform us about fishers’ tendency towards future behaviour regarding fisheries extraction. As outlined in Chapter 1, I view high discount rates as indicators of unsustainable marine resource use (Clark, 1973; Sumaila, 2004; Akpalu, 2008). Relationships of high discount rates corresponding to less sustainable natural resource use have also been observed in studies of forest clearing and agriculture (Shiferaw and Holden, 1998; Casse et al., 2005; Gunatilake et al., 2007).

Fishery institutions play a key role in influencing how fishers respond to local and global pressures to exploit fisheries resources (Clark et al., 2010a; Smith et al., 2010). The competition inherent in a pure or regulated open access fishery, where fishers have no security to future resources, motivates fishers to engage in myopic behaviour consistent with high discounting. This is evidenced by the ‘race to fish’ mentality that has led to the depletion, and even collapse, of various fisheries around the world (Costello et al., 2008). In contrast, fisheries managed under customary or other rights-based systems are characterised by a well defined group of users and by the presence of rules or norms which regulate individual use. Rights-based management systems are more likely to provide fishers with an incentive to use fishery resources sustainably (Dietz et al., 2003; Grafton et al., 2006; Costello et al., 2008). Consequently, I expect these fishers to possess a longer term outlook, which is expressed through a lower discount rate. For instance, Asche (2001) shows that

discount rates in well developed quota systems are relatively low. At the same time, Clark et al. (2010a) demonstrate that complete privatisation of fisheries may not lead to long-term oriented behaviour.

Coral reef resources have traditionally formed the backbone of fishing economies along the coasts of Sabah and Fiji (Sather, 1997; Gillett and Lightfoot, 2002). Fishing communities in both countries tend to be poor, with high reliance on inshore reef resources for food and income. In the past decade, inshore fisheries resources in Sabah and Fiji have shown signs of overfishing, and fishers in both countries have similarly noted a decrease in catch rates and the size of fish caught (Teh and Sumaila, 2007; Turner et al., 2007; Teh et al., 2009b).

In Sabah, a spatial zoning system is used to regulate fishing activity. The traditional fishing zone is reserved exclusively for small-scale subsistence and artisanal fishing vessels, but is rarely enforced. There are no formal fisheries governance institutions at the village level, especially in rural communities such as those in Pulau Banggi and the Semporna islands, where this study takes place (Teh et al., 2005). Fishers have free access to the majority of fishing grounds around the study areas, although this may change in the future because Marine Protected Areas (MPAs) are in the process of being set up at both sites.

Fiji has an established customary marine tenure system (CMT), in which inshore fishing grounds are divided into customary fishing rights areas called *qoliqolis* (Cooke et al., 2000). Outsiders wishing to fish within a certain *qoliqoli* are required to obtain the permission of the *qoliqoli* owners, who are able to impose fishing restrictions on fishing method, area, season, or species (Veitayaki, 1998). Nevertheless, Fiji's traditional system has been undermined in recent decades as villages have become more urbanized and integrated into the market economy (Matthews et al., 1998).

3.2 Method

Data for this study were obtained from 122 interviews conducted with fishers in Fiji and Sabah. The interviews were semi-structured and followed a prepared questionnaire, although interviewees had the flexibility to expand on topics of interest. The discount rate elicitation questions formed part of a longer questionnaire that also covered socio-economics, spatial use of fishing grounds, and perceptions of change to fishery management (Appendix B and C).

3.2.1 Study sites

Sabah

Sabah is a Malaysian state situated on the northeast corner of Borneo, within the Coral Triangle (Fig. 2.1). The population of Sabah was 3.2 million in 2009 (Department of Statistics Malaysia, 2009a). My study was conducted in 11 rural fishing villages grouped into two main geographical areas: 4 villages were located in the Semporna group of islands, off the south-eastern coast of Sabah, while another 7 villages were located in Pulau Banggi, which is off the northern tip of Sabah (Fig. 2.1).

Fiji

Fiji is an archipelago situated in a biodiversity rich area of the South Pacific (Fig. 3.1) (WWF, 2003). Fiji's population in 2007 was 837,271 (Fiji Islands Bureau of Statistics, 2007). Interviews for this study took place in 9 villages and 2 settlements located on Viti Levu and Vanua Levu, the two largest and most developed islands, as well as on the smaller islands of Yasawa and Kadavu. Interview sites were selected to provide a wide geographical coverage of Fiji, as well as being inclusive of both artisanal and subsistence fishing communities.

3.2.2 Fisher interviews

Sabah

I interviewed 75 fishers in Pulau Banggi and the Semporna islands in April and May 2009, with the assistance of another graduate student from the University of British Columbia Fisheries Centre. We conducted interviews in Malay, with each interview taking between 45 minutes to one hour to complete. I used opportunistic sampling at each village, walking from house to house to interview fishers after obtaining permission from the village headman. In Sabah, all the fishers I interviewed were men, as they are the fishers in the household. Women may occasionally glean on the reef, but in general do not participate in fishing.

Fiji

I interviewed 47 small-scale fishers in Fiji in May and June 2008. My interview team consisted of two research officers from the Fiji Fisheries Department and a graduate student from the University of British Columbia Fisheries Centre. We conducted interviews in English or Fijian, and each interview lasted from half an hour to 45 minutes. Permission from the village chief was obtained prior to conducting our interviews. In some villages, fishers

were already gathered in a community hall upon our arrival, and we were able to interview as many fishers as possible from those who were present. Where fishers were not already gathered, we walked from house to house to conduct interviews. Women made up 34% of the respondents.

3.2.3 Estimating relative poverty

To assess the relative poverty level in fishing communities in Sabah and Fiji, I calculated a fisher poverty index (Sumaila, 2003). This was measured as the monthly net fishing income divided by the poverty line income in each country. The 2004 poverty line income in Sabah was RM 704 month⁻¹ (USD 207 month⁻¹) (UNDP, 2007), while the Fiji poverty line income of USD 254 month⁻¹ was based on a Basic Needs Poverty Line income of FJD125 week⁻¹ (USD 64) in 2003 (Fiji Islands Bureau of Statistics, 2009). These figures were adjusted using the Consumer Price Index to provide a poverty line income of USD 236 month⁻¹ in 2009 dollars for Sabah, and USD 294 month⁻¹ in 2008 dollars for Fiji.

3.2.4 Estimating personal discount rates

To estimate each respondent's private discount rate, I provided a series of binary choices involving monetary payments that occurred at different points in time. I used hypothetical payments in both Fiji and Sabah due to budgetary and logistical considerations. While other studies have used food or cash payments (Kirby et al., 2002; Fehr and Leibbrandt, 2008), there has been no conclusive evidence that real payments result in more realistic answers (Frederick et al., 2003).

The choice series followed a 'multiple price list' format similar to Harrison et al. (2002), and was chosen because it was easy for respondents to quickly grasp how to do the exercise. For example, I asked "Would you prefer \$100 today or \$100 + x in one month?" The value of each subsequent delayed payment increased while the immediate payment remained constant. I inferred that the respondent's discount rate was higher than $x\%$ per month if they chose the immediate option and less than $x\%$ per month if they chose the delayed payment. Consequently, each payment choice was bounded by upper and lower discount rates (r), which were calculated as $r = -\ln(x/y)/t$, where x and y are the immediate and delayed payment, respectively, and t is the time delay. I used the midpoint of this range as the discount rate for each choice, and a respondent's discount rate was determined by the point at which they switched from choosing the immediate to future payment.

Each series had two unbounded ranges. The first unbounded range occurred if the respondent chose to receive the first future payment offered. In this case I assumed that discount rates were non-negative, and used the midpoint between 0 and the discount rate corresponding to the first payment. The second unbounded range occurred if the respondent always chose the immediate option, resulting in a discount rate that was between the last delayed payment and infinity. Although an infinite discount rate is mathematically possible, it is probably not realistic. To remain conservative, I used the discount rate corresponding to the last delayed payment to represent fishers who had ‘infinite’ discount rates. Fishers who chose the first (i.e., smallest) future payment offered were considered ‘patient’, whereas those with ‘infinite’ discount rates were ‘impatient’.

Fijian fishers completed two sets of choice series. Series A_F had a one-month delay period while Series B_F had a one-year delay. Both series had an immediate payment of FJD 400 (USD 204), which was approximately the average monthly income of fishers. Each series consisted of 13 choices, with associated annual discount rates ranging from 29 to 471 % for Series A_F, and 27 to 103% for Series B_F (Table 3.1). Forty-five out of 47 respondents completed both choice series.

Preliminary inspection of Fiji field data showed that the different discount rate ranges used in series A_F and B_F may have affected the analysis of time consistency. Consequently, I used the same discount rate range for all choice series in the next iteration of interviews. Further, I also found that almost half of the respondents chose endpoint options for each series (i.e., always chose the immediate payment or selected the first future payment offered). This may have suggested strategic response behaviour, which other researchers have addressed by using a front end delay in the choice series. I did not get an opportunity to implement these changes in Fiji due to limited resources, but did so for interviews in Sabah.

Fishers completed three sets of choice series in Sabah. Series A_S and B_S had delays of 1 and 6 months, respectively. Series C_S had a front end delay of one year, so that the choice was between payment in one year and one year plus one month. Each series had 14 choices. Delayed payments in all 3 series were calculated so as to correspond to the same annual discount rate range of 29 to 619%. The immediate payment for Series A_S and B_S was RM 100 (USD 29), while for Series C_S it was RM 500 (USD 146) (Table 3.1). These payments were

roughly equivalent to a fisher's net income for one week, and one month, respectively. Of the 75 participants, 70 completed all three series. The complete choice series with corresponding discount rates for Fiji and Sabah are presented in Appendix D.

To account for the different discount rate ranges in Sabah and Fiji, I computed a 'patience proxy', which was the standardised ratio of each respondent's discount rate to the maximum discount rate for each series (i.e., the discount rate corresponding to the largest delayed payment). A high 'patience proxy' represented an individual who was relatively more 'impatient' than one with a low proxy.

3.3 Results

3.3.1 Fishery characteristics

Coral reef fisheries in both Sabah and Fiji are small-scale, making use of multiple gears to catch a wide variety of reef and reef associated species (Table 3.2). In both locations, fishing for international trade commodities such as live reef food fish species and sea cucumbers provided a valuable source of income. As both Sabah and Fiji's fisheries lacked catch and effort time series data, I used fishers' perceptions about temporal changes in fish catch as an indicator of the extent of fisheries exploitation.

Sabah

Fishers in Sabah were on average around 40 years old and had been fishing for 20 years. The majority of fishers had no education, and fishing was the only source of income for 75% of respondents, reflecting its importance as a source of livelihood in these villages (Table 3.2). The mean catch per unit effort (CPUE) across all gears in Sabah was $16.0 \pm 3.8 \text{ kg person}^{-1} \text{ trip}^{-1}$, although seasonal effects might mean this was not representative for the entire year (Teh et al., 2007). Eighty percent of respondents had experienced a temporal decline in fish catch, with the remainder having experienced no change in the amount of fish they caught.

Fiji

Similarly, the average age of Fijian fishers was almost 40, and fishing was the only source of income for 65% of respondents. Fishers had been fishing for an average of 14 years, and their mean CPUE of $15.4 \pm 1.8 \text{ kg person}^{-1} \text{ trip}^{-1}$ was slightly lower than that recorded in Sabah. The majority of fishers (73%) noticed a temporal change in their fish catch. Of these, almost all (97%) had experienced a decline in the quantity and/or size of fish caught. Fijian fishers were

generally better educated and had a higher mean net monthly fishing income than those in Sabah (Table 3.2).

Cross-site comparison

In general, Sabah and Fiji could be considered similar in terms of the fishery and socio-economic characteristics I measured. Tests of means showed that for fishery characteristics, only the number of years a fisher had been fishing was significantly different between sites (Welch $F(1, 110) = 14.66$, $p < 0.01$), with Sabah fishers fishing on average about 7 more years than Fijian fishers. Mean monthly net fishing income was significantly higher in Fiji (Welch $F(1, 70) = 4.96$, $p < 0.05$). However, poverty levels at both sites were similar, as there was no significant difference in fishing poverty index between Sabah and Fiji, although the index was higher in Fiji (0.79 vs. 0.59). To assess whether the site characteristics which differed across Sabah and Fiji (number of years fishing and monthly net fishing income) were related to fishers' discount rates, I examined the correlation between these two factors and fishers' discount rates. I found no significant relationship in either Fiji or Sabah.

3.3.2 Annualised discount rate of fishers

The mean annualised discount rate of fishers in Sabah was high, over 200% for each of the three choice series (Table 3.3). The median and mode discount rates for all series were lower because overall, 31% ($n=70$) of fishers chose to be 'patient', i.e., always chose the first, smallest future payment option offered. In contrast, 19% were 'impatient', as they chose to receive the immediate payment for all choices. A breakdown of fishers according to their choice of discount rates showed that in series A_S and C_S , at least half of the respondents preferred to be 'patient', while for series B_S , 40% of respondents preferred to be 'patient' (Table 3.3). Series C_S , which had a front end delay of one year, had a lower but non-significant mean discount rate than series A_S .

There was no significant difference in discount rates between male and female respondents in Fiji, so I report the overall average here. Fijian fishers had mean annual discount rates of 208% and 61% for Series A_F (1 month delay) and Series B_F (1 year delay), respectively. The median and mode discount rates were substantially lower (Table 3.3). Compared to Sabah, a lower proportion of fishers in Fiji chose the 'patient' option, while over 50% of respondents chose non-endpoint options (Table 3.3). At the same time however, a higher proportion of

fishers in Sabah chose the immediate option, which was consistent with having ‘infinite’ discount rates (Table 3.3).

Due to a higher number of respondents at each of the two main study areas in Sabah, I was able to examine cross-area differences in Sabah, but not in Fiji. Compared to Semporna, a larger proportion of fishers in Banggi were ‘patient’. At the same time, the ratio of ‘patient’ to ‘impatient’ fishers in Banggi for each series was approximately 2 to 1, whereas in Semporna the ratio was less than 1 (Table 3.4). This indicated that some inherent characteristic of the two geographical areas may have been influencing discount rates. Mean discount rates in Semporna were higher than those in Banggi for all choice series (Table 3.4), but the difference was not statistically significant. A further breakdown of responses by village for the two series with different time delays (Series A_s and B_s) showed that the villages that consistently had the highest proportion of ‘patient’ fishers for both series were situated in Banggi. These included the villages of Maligu, Manawali, Batu Sireh, and Damaran.

3.3.3 Patience proxy

I aggregated individuals’ patience proxies across all choice series to examine if these differed between Sabah and Fiji. The proxy for Sabah was significantly lower at 0.41 ± 0.03 , compared to Fiji at 0.51 ± 0.04 (t-test, $t=2.07$, $p<0.05$). This suggested that regardless of the absolute value of their discount rates, fishers in Sabah were relatively more willing to delay gratification than fishers in Fiji. In addition, the mode of the proxy for Sabah was 0.05, which corresponded to the lowest discount rate. In contrast, the mode for Fiji was 1, which corresponded to the ‘infinite’ discount rate option.

3.4 Discussion

I aimed to determine whether the theory that open access fishers have ‘infinite’, or very high, discount rates was applicable in real world fisheries. I found that in absolute terms, fishers in both open access and traditionally managed fisheries had high annual average discount rates of 265% and 208%, respectively, for choices involving a one month delay.

Theoretically, each fisher in an open access fishery has an infinite discount rate. Therefore, the average rate of 265% in Sabah could be interpreted as an infinite rate. If that was the case, then we would expect the Fijian discount rate to be a lot lower. The fact that the average rate

in Fiji was also over 200% suggests that the observed Sabah rate may not be equivalent to an 'infinite' rate. Moreover, when comparing the absolute value of discount rates, 200% is high, but still within the bounds of discount rates of individuals in comparable resource and socio-economic environments. For example, Akpalu (2008) also found a high average annual discount rate of 130% for fishers in Ghana. In terrestrial ecosystems, comparable annual discount rates ranging from 117-208% were estimated for farmers in Madagascar (Casse et al., 2005), while horticulturists in Bolivia had extremely high rates of between 4380-5110% (Kirby et al., 2002). Other studies found lower annual rates ranging from 13-34% for forest users in Sri Lanka (Gunatilake et al., 2007) to 35-61% for farmers in the Philippines (Lumley, 1997). It should be noted that comparing discount rates across studies is complicated due to methodological differences (Frederick, 1999; Cardenas and Carpenter, 2008), and for this study, exacerbated by a lack of studies done in developing countries involving communities dependent on natural resources.

Nevertheless, in light of the above comparisons, it appears that fishers in the open access Sabah fishery, on average, did not have 'infinite' discount rates. This may at first appear contrary to theory; however, a clarification of the difference between open access and non open access discount rates should help explain this. The discount rates estimated from the elicitation exercises represented fishers' private discount rates if they fished in a non open access fishery (regardless of whether they currently fish in an open or restricted access fishery). This is because, as mentioned above, the default open access discount rate is infinity, regardless of the fisher's personal discount rate. Thus, a way to interpret my results is that Sabah fishers' private discount rates are high, but not infinite. However, when faced with fishing decisions, they may be forced to use an 'infinite' discount rate, which although is abstract, implies that they would exploit at a rate higher than suggested by the observed 265%. This appears to be supported by the higher occurrence of infinite discounting in the open access fishery, as indicated by 30% of Sabah fishers choosing the 'infinite' option, compared to 20% of Fijian fishers for the one month delay option. At the same time, if Sabah's fisheries shifted from an open access to limited access regime, fishers may then use a discount rate of 265% when making fishing decisions.

On the whole, my results indicate that the private discount rates of small-scale fishers are high, regardless of whether a fishery is open access or managed under a customary tenure system. This contradicts expectations of a customary marine tenure system coinciding with

more sustainable use, and hence, longer-term outlooks for fishers. It suggests that having traditional ownership over fishing grounds does not necessarily equate to greater conservation orientation among resource users. This supports parallel arguments about the limits of using fishing rights as a means of preventing fisheries overexploitation (Clark et al., 2010a). Poverty is commonly thought to contribute to high discount rates (Mink, 1993). Therefore, I speculate the poor socio-economic conditions that exist in Sabah and Fijian fishing communities may be a reason for the high discount rates observed in both locations. I will further investigate the relationship between socio-economic conditions and discounting behaviour in Chapter 4.

Methodological differences in discount rate elicitation experiments, e.g., in the type and amount of payment offered, length of delay, and framing of the question, could have affected respondents' choices (Frederick et al., 2003). Interviewer credibility is often a concern when conducting surveys, and with time preference surveys, lack of interviewer credibility tends to make people appear more impatient than they really are (Cardenas and Carpenter, 2008).

Other researchers have mitigated the interviewer credibility problem by using a front end delay in time preference surveys. Similarly, I used a front end delay in the third choice series (C_s) in Sabah, but still observed a similar pattern, with 80% and 65% of responses choosing the endpoint options for Series A_s and C_s , and B_s , respectively. Eliminating the endpoint responses would have resulted in a considerably larger difference in annual discount rates between Sabah and Fiji. For the one month delay series, average private discount rates for Sabah and Fiji would have been 303 and 198%, respectively. Other studies have attempted to control for strategic responses by providing real payments (e.g., Pender, 1996; Kirby et al., 2002). Nevertheless, in a study of horticulturists in Bolivia, Kirby et al. (2002) also found a high proportion of endpoint responses, even though they used real payments and a different binary choice format for eliciting discount rates. Overall, these factors provide some assurance that fishers in Fiji and Sabah were likely revealing their preferences, rather than providing strategic responses in the interviews.

Nevertheless, the potentially confounding methodological factors necessitate that we interpret the absolute value of estimated discount rates with caution. The different discount rate ranges at the two study sites also affected the mean rates obtained. I addressed this effect by calculating a patience proxy to facilitate comparison between Fiji and Sabah. The

significantly lower proxy in Sabah suggested that open access fishers did not have higher discount rates than those in the customary managed fishery. When comparing within each location, the proportion of fishers who chose the smallest future payment over the immediate option was substantially larger in Sabah. At least half the interviewed fishers chose the 'patient' option in Sabah for the one-month delay series, compared to approximately one-quarter in Fiji. The trend was similar for the other two series in Sabah, though of lesser magnitude for the six months delay. Although this again seemed counter-intuitive in the context of fisheries institutional theory, it may be explained by a similarity among the villages with the highest proportion of 'patient' fishers.

Three out of four of these villages - Batu Sireh, Manawali, and Maligu, had taken the initiative to protect the fishing grounds adjacent to their village from outside fishers. The ability to self-organise and collectively implement rules and regulations demonstrates social capital (Pretty, 2003; Grafton, 2005), and this behaviour is consistent with that displayed in community based management systems, where trust building and rule making are important institutional factors that facilitate management of fisheries resources (Jentoft et al., 1998; Lobe and Berkes, 2004; Sekhar, 2007). It may therefore be plausible that social capital is associated with the lower discount rates observed in these three villages. However, I emphasise that my findings do not permit me to infer a causal relationship between discount rates and the prevailing fishery institutional structure.

Differences in fishers' private discount rates were also likely the result of multiple interacting drivers acting at the individual level. For instance, socio-economic, psychological, and ethical factors affect one's time preference (Becker and Mulligan, 1997; Lumley, 1997; Frederick et al., 2003). In particular, factors that are relevant to the marginalised context of small-scale fishing communities, such as wealth, income, and education, have been correlated with discount rates (Pender, 1996; Becker and Mulligan, 1997; Poulos and Whittington, 2000; Kirby et al., 2002). In addition, non-local factors, such as global demand for coral reef resources that undergo 'boom and bust' cycles, may influence a short-term outlook among fishers. More in-depth examination of these motivators of time preference could enable managers to further identify intervention policies for encouraging a longer-term outlook among fishers, and is a priority for further analysis.

In summary, the open access nature of many developing country reef fisheries is a major hurdle to their management and sustainability. Turning an open access fishery to one that is regulated should, theoretically, lower fishers' discount rates (Clark, 2006). However, my results indicate that the private discount rates of small-scale inshore fishers are high, even in a non open access environment. Consequently, it suggests that emphasis on understanding what contributes to fishers' conservation orientation may be just as important as implementing regulations to overcome the open access problem.

My study adds a new perspective to a crucial theory in fisheries economics, which surprisingly, has not been examined empirically within the context of coral reef resource conservation. While theory predicts that fishers in an open access fishery by default have an infinite discount rate, my results suggest that, contrary to expectations, private discount rates are also very high in a fishery with a formal institutional framework in place. Furthermore, it appears that a larger proportion of open access fishers are more patient than those in the customary managed fishery. This is encouraging for conservation because it implies that many open access fishers may be open to more sustainable fishing practices once the competitive nature of open access fisheries is eliminated. There is therefore a lot of scope to carry out similar studies to further investigate the applicability of the open access-high discount rate theory. Such studies would be most useful if they use a standard methodology for eliciting discount rates.

Table 3.1. Payment amounts for choice series in Fiji and Sabah. Payments for series A_F and B_F are in FJD, and series A_S, B_S, and C_S are in RM¹.

FIJI (FJD)			SABAH (RM)				
Immediate	Future	Future	Immediate	Future	Future	Immediate	Future
payment	payment for	payment	payment	payment	payment	payment	payment
for A _F and	A _F (1 month	for B _F (1	for A _S and	for A _S	for B _S	for A _C	for A _C
B _F	delay)	year	B _S	(1 month	(6	(in 1 year)	(1 year +1
		delay)		delay)	months		month)
					delay)		
400	420	550	100	105	134	500	525
400	435	600	100	110	177	500	550
400	450	650	100	115	231	500	575
400	465	700	100	120	299	500	600
400	480	750	100	125	381	500	625
400	495	800	100	130	483	500	650
400	510	850	100	135	605	500	675
400	525	900	100	140	753	500	700
400	540	950	100	145	929	500	725
400	555	1000	100	150	1139	500	750
400	570	1050	100	155	1386	500	775
400	585	1100	100	160	1677	500	800
400	600	1150	100	165	2017	500	825
			100	170	2413	500	850

¹ The exchange rate on 27 October 2010 was 1 USD = 1.9 FJD and 1 USD = 3.1 RM.

Table 3.2. Fishery and socio-economic characteristics of survey sites. Standard errors are provided with mean values.

	<u>Sabah</u>	<u>Fiji</u>
<u>FISHERY</u>		
Mean no. of years fishing	21.2±1.4	14.2±1.4
Mean CPUE (across all gears, kg person ⁻¹ trip ⁻¹)	16.0±3.8	15.4±1.8
Perceived change in fishery resource	Declining	Declining
Fishery management structure	Open access	Customary management
Main fishing gears	Handline, gillnet, speargun, traps	Handline, spear/speargun, nets, traps
Main target fish groups	Serranidae, Lutjanidae, Lethrinidae, Carangidae, Scombridae, Nemipteridae	Lethrinidae, Lutjanidae, Serranidae, Scombridae, Acanthuridae, Mugilidae, Mullidae
<u>SOCIO-ECONOMIC</u>		
Mean age (years)	39.6±1.4	38.9±1.7
Mean household size (no. people household ⁻¹)	7.0±0.4	6.3±0.5
Education level		
<i>Primary</i>	45%	32%
<i>Secondary</i>	7%	68%
<i>Tertiary</i>	1%	-
<i>None</i>	47%	-
Mean net fishing income (USD month ⁻¹)	138±19	249±36
Fishing poverty index	0.59±0.08	0.79±0.12
Fishing the only source of income	75%	65%

Table 3.3. Summary statistics of fishers' annual discount rates (%) and breakdown of choices for payment options in Fiji and Sabah.

Choice series	Summary statistics for annual discount rates			Proportion of respondents (%) choosing each option		
	<u>Mean \pm SE (%)</u>	<u>Median (%)</u>	<u>Mode (%)</u>	<u>Immediate¹</u>	<u>First²</u>	<u>Other</u>
<u>Sabah</u>						
A _S (1 month delay)	265 \pm 33	29	29	30	51	19
B _S (6 months delay)	277 \pm 31	141	29	25	40	35
C _S (1 yr+1 month) delay)	240 \pm 32	29	29	29	53	18
<u>Fiji</u>						
A _F (1 month delay)	208 \pm 27	121	29	20	27	53
B _F (1 year delay)	61 \pm 5	36	36	24	24	51

¹ Choosing the immediate payment for every choice, equivalent to having an 'infinite' discount rate.

² Choosing the first, smallest future payment offered, equivalent to being 'patient'.

Table 3.4. Mean annual discount rate (%) and breakdown of Sabah respondents according to those who chose to receive the smallest future payment offered ('patient'), and those who chose the immediate payment for all choices ('impatient').

Series	Annual discount rate % (Mean \pm SE)		Proportion of 'patient' respondents (%)		Proportion of 'impatient' respondents (%)	
	<u>Semporna</u>	<u>Banggi</u>	<u>Semporna</u>	<u>Banggi</u>	<u>Semporna</u>	<u>Banggi</u>
A _S	343 \pm 57	214 \pm 38	38	55	42	24
B _S	347 \pm 56	229 \pm 35	25	48	38	19
C _S	318 \pm 63	187 \pm 35	39	60	48	19

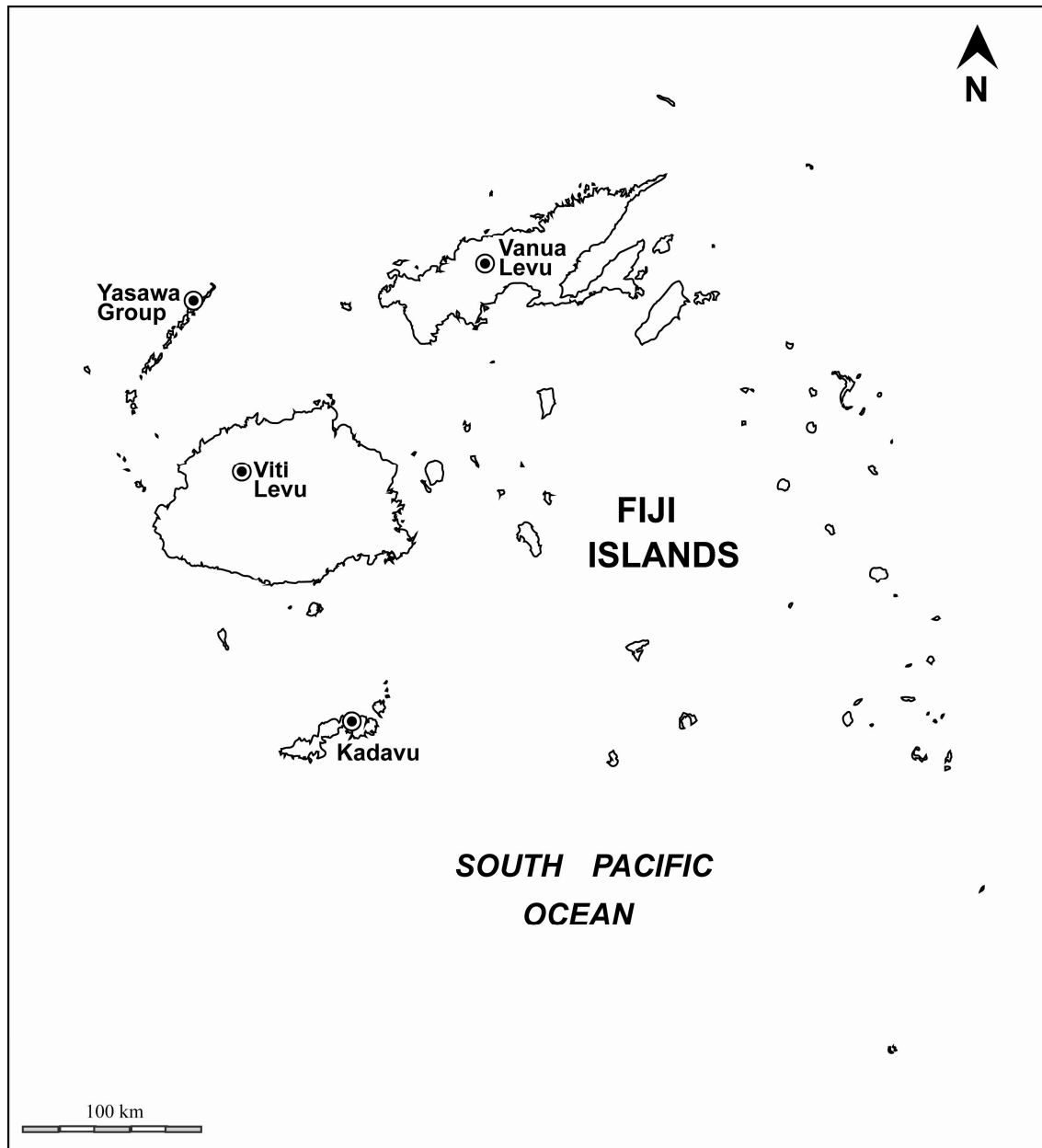


Figure 3.1. Map of Fiji with circles marking the islands where interviews were conducted.

Chapter 4: Low discounting behaviour among small-scale fishers in Fiji and Sabah, Malaysia

4.1 Introduction

The combined pressures of dwindling fish stocks and the need to earn a livelihood have led many fishers to engage in resource destructing activities (Pauly et al., 1989), a behaviour which is consistent with having a high discount rate, or an inability to delay economic gratification. In this context, I adopt the standpoint that low, rather than high discount rates are desirable for achieving the goal of sustainable marine resource use for both current and future generations. Consequently, understanding the socio-economic factors that are associated with a longer-term outlook among fishers may be useful for designing appropriate fisheries management and conservation policies. Pollnac and Poggie (1978) examined factors that affect small-scale fishers' economic gratification orientation, a parallel concept to discounting. However, I do not know of any study that explicitly deals with the socio-economic predictors of fishers' discount rates. To address this research gap, my objective in this chapter is to identify the socio-economic characteristics that are associated with fishers who have low discount rates. I continue to use the small-scale reef fisheries of Sabah, Malaysia, and Fiji as my case studies.

Factors such as wealth, income, education, and age are thought to lower individuals' discount rates (Becker and Mulligan, 1997), although case studies involving communities in comparable socio-economic settings to Sabah and Fiji have provided inconclusive evidence. For example, Pender (1996) and Holden et al. (1998) found that income was inversely related to discount rates, but Poulos and Whittington (2000) found no relationship. Similarly, education and age have been both positively and negatively related to discount rates (Godoy and Jacobson, 1999; Kirby et al., 2002). Differences in individuals' discount rates are also likely due to neurophysiological features (e.g., impulsiveness), personality, or learning differences (Kirby et al., 1999; Frederick et al., 2003). I focus on the socio-economic correlates of discount rates, as these bear the most relevance in terms of developing management policies for small-scale reef fisheries.

Resources from coral reefs and adjacent mangrove and seagrass ecosystems have traditionally formed the backbone of fishing economies along the coasts of Sabah and Fiji

(Sather, 1997; Gillett and Lightfoot, 2002). As outlined in Chapter 3, coral reef fisheries in both locations are small-scale, and make use of various manually operated gears to catch a wide variety of reef and reef associated species (Table 3.2). In addition to fish for domestic consumption, fishing for internationally traded organisms such as live reef food fish species and sea cucumbers provide a valuable source of income for fishers in both locations (Adams, 1992; Teh et al., 2005; Ovasisi, 2006).

Inshore fisheries resources in Sabah and Fiji have shown signs of overfishing, and fishers in both places have similarly noted a decrease in catch rates and the size of fish caught (Chapter 3.3.1). The depletion of coral reef fisheries resources has serious socio-economic consequences for fishing communities in both locations, as these tend to be poor, with high reliance on inshore reef resources for food and income (Teh et al., 2007; Turner et al., 2007). Faced with the pressure of having to meet immediate consumption needs from declining inshore marine resources, reef fishers in Sabah and Fiji can be expected to engage in high discounting. In this chapter, I will first identify those fishers who, contrary to expectations, have low discount rates, and then examine what socio-economic factors may predict their low discounting behaviour.

4.2 Method

I used discount rates elicited from fishers in Fiji and Sabah as outlined in Chapter 3.2. Interviews in Fiji were carried out in 4 main geographical areas, whereas those in Sabah were concentrated in 2 areas (Table 4.1). The difference in discount rate ranges used in Sabah and Fiji described in Chapter 3.2.4 did not affect my current analysis because I did not focus on fishers' absolute discount rate values. Rather, I was interested in low discounting fishers, whom I defined as those who chose the smallest future payment presented to them. I considered all other payment choices to be non-low discounting because they represented some degree of unwillingness to delay consumption.

4.2.1 Explanatory variables

My study was exploratory, with the aim of identifying factors associated with low discount rates. As such, the study was not designed to determine the direction of causality between low discount rates and socio-economic variables. I split the explanatory variables into 3 groups as detailed below and summarised in Table 4.2:

Demographic

Age – The effect of age on discount rates is ambiguous. Becker and Mulligan (1997) suggested a U shape relationship between age and discount rate, indicating that discount rates decrease through childhood, reach some minimum during adulthood, and then increase again as people grow older. In contrast, Kirby et al. (2002) found a positive relationship between age and discount rates.

Education – Education is expected to focus attention on, and facilitate planning for the future (Becker and Mulligan, 1997). It is also assumed that people with higher education levels are more likely to earn larger incomes, which are associated with lower discount rates.

Household size – Households with more children may be more forward looking; thus, larger households may be associated with lower discount rates (Holden et al., 1998). On the other hand, having a higher number of dependents may be associated with higher discount rates due to the pressure of having to fulfil larger immediate consumption needs. Therefore, the effect of household size appears to be ambiguous.

Socio-Economic

Poverty index – People with lower income levels tend to be less patient due to the need to provide for current consumption, which leads to an inverse relationship between discount rates and income or wealth (Pender, 1996; Becker and Mulligan, 1997; Holden et al., 1998). I used a poverty index (Sumaila, 2003) as a standardised measure of income for fishers in Fiji and Sabah. This was calculated as a fisher's net monthly fishing income standardised to the monthly poverty line income of Fiji or Sabah.

Boat ownership – Owning a boat is indicative of economic security and may thus be associated with a fisher who is more oriented towards delaying gratification (Pollnac and Poggie, 1978); the maintenance that has to be done on a boat also requires a fisher to be future oriented. Boat ownership was coded as a dichotomous variable with 0 and 1 indicating not owning and owning a boat, respectively.

Relative catch – A fisher who catches more relative to others may exhibit an unwillingness to delay current consumption, everything else being equal. Relative catch was calculated as the total catch per fisher per week, standardised to the average weekly catch for all fishers in Sabah and Fiji.

Presence of an alternate job or income source - Due to the seasonal and periodic nature of fishing, having another source of income or livelihood other than fishing is indicative of increased economic security, which has been found to be positively related with a deferred gratification orientation (Pollnac and Poggie, 1978).

Temporal decline in fish catch – I hypothesized that fishers’ perceptions about whether there had been a temporal change in their fish catch would affect their willingness to conserve fisheries resources. Perceiving a temporal decline may incite a fisher to become more aware about the need to conserve for the future. On the other hand, it may also motivate a fisher to fish harder and adopt a shorter term focus.

Location specific

Site – A dummy variable was used to control for site differences, with Sabah=1 and Fiji=0.

Market access—Having good market access may mean that fishers are more certain that their produce will be sold for a reasonable price. This added certainty may decrease discount rates. The accessibility of each fishing village was categorised as ‘good’ or ‘poor’, based on the distance to the nearest main town or fish market, and how accessible it was transport-wise. In both Sabah and Fiji, 8 villages (73%) were considered to have poor market access. These villages were either situated on outlying islands located away from the mainland or main island, or were isolated villages located far from main fish markets.

Protection initiative – Previous findings in Chapter 3 indicated that lower discount rates may be associated with villages where inhabitants had taken the initiative to protect their village fishing grounds from outside fishers. At the study villages, forms of protection included: i) marine reserves in which no fishing was allowed; and ii) semi-protected fishing grounds which outside fishers were prevented from fishing, but villagers were allowed to fish. Three villages in Sabah had protection initiatives, as opposed to one in Fiji.

4.2.2 Analysis

I fitted a binary logistic regression model using R software (www.r-project.org) to investigate which socio-economic factors predicted the probability that fishers would choose low discount rates. I had 3 regression models: separate models for Sabah and Fiji, and a pooled model for both Sabah and Fiji. Excluding two missing values in Sabah and Fiji led to sample sizes of 118, 73, and 45 for the pooled, Sabah, and Fiji models, respectively.

The correlations between all independent variables were examined for collinearity. I also checked for excessive multi-collinearity using Variance Inflation Factor (VIF) values. I found that market access and protection initiative (PI) were almost perfectly correlated ($r=-0.98$), and decided to leave market access out of the regression because my Chapter 3 findings indicated that PI may be associated with low discounting behaviour. The dummy variables for site and boat ownership were also highly correlated ($r=0.8$). As other studies had found

inter-country differences in discount rates or willingness to defer gratification (Pollnac and Poggie, 1978; Poulos and Whittington, 2000), I decided to leave site in the pooled model, and used boat ownership in the individual location models instead.

I used my results from the choice experiments to create a dichotomous indicator variable to identify low discounting individuals. I considered two options for identifying low discounters: i) one who chose the smallest future payment offered in Series A, or ii) one who chose the smallest payment offered in all series. Hyperbolic discounting behaviour may have confounded individuals' choices for option (ii). Therefore, I decided to use option (i), which involved the same one month period delay for both Fiji and Sabah. The dichotomous dependent variable was defined as $Y=1$ for those who chose the smallest future payment offered in Series A, and $Y=0$ otherwise. For each model, I started with a “full” model containing the explanatory variables of interest. The logistic regression equation I tested was:

$$Y = \alpha + \beta X + \gamma Z + \delta W + \varepsilon \quad [1]$$

where X , Z and W were matrices of demographic, socio-economic and location variables, respectively, as defined in Table 4.2. The term α is a constant and the residual term, ε , was assumed to be normally distributed $\varepsilon \stackrel{iid}{\sim} N(0,1)$. I tested this equation using the full sample of fishers from Sabah and Fiji as well as two more models on a subset of observations consisting of only fishers from either Sabah or Fiji. I controlled for site and village level variation by using dummy variables for site and protection initiative, respectively. Nevertheless, I acknowledge that lack of independence in the Y values may be a possibility due to the hierarchical nature of my sampling, and this may have resulted in overestimates of significance for these terms.

As I was undertaking exploratory analysis, it was appropriate to use a stepwise model selection procedure in both directions to identify a model which presented the “best” fit to the data. Akaike information criterion for small samples (AICc) was used to compare between models fitted to the same data. I accepted significance levels of 0.1 due to the exploratory nature of the analysis, and because I was making observations of human behaviour, which may by nature be more unpredictable (Menard, 1995). Following model selection, I assessed the model goodness of fit and predictive accuracy using the log likelihood test and receiver operating characteristic (ROC) curve. Residual and leverage plots were visually inspected to check for severe outliers and for data points which exerted excessive influence on the parameter estimates.

4.3 Results

4.3.1 Site comparisons

4.3.1.1 Between site comparisons, all fishers

Overall, 42% of fishers chose the low discount rate option in Series A; a substantially higher proportion in Sabah chose this option, compared to Fiji (51% vs. 27%). Fishers in Sabah and Fiji were similar in terms of age, household size, and dependence on fishing as the only source of income (Table 4.3). As reported in Chapter 3 (Table 3.2), the mean catch per unit effort (CPUE) across all gears in Sabah was 16.0 ± 3.8 kg person⁻¹ trip⁻¹. Mean CPUE in Fiji was slightly lower, at 15.4 ± 1.8 kg person⁻¹ trip⁻¹, but the difference was not statistically significant. Poverty levels at both sites were similar, with no significant difference in fishing poverty index between Sabah and Fiji, although it was higher in Fiji (0.79 vs. 0.59). Fishers in Fiji also had higher levels of education, and were less likely to own their own boats. Twenty-seven percent of fishers in Sabah resided in villages with some form of protection initiative, compared to 9% in Fiji.

4.3.1.2 Within site comparisons of low and non-low discounting fishers

Low discounting fishers in Sabah tended to be slightly older than non-low discounters, had slightly smaller families, less education, and a higher boat ownership rate (Table 4.3). In contrast, low discounting fishers in Fiji tended to be slightly younger than non-low discounters, achieved a higher level of education, and had a lower boat ownership rate. A larger proportion of low discounting fishers in Fiji had alternative income sources, had noticed a temporal decline in catches, and lived in accessible villages, whereas the proportion for these variables was roughly the same in Sabah. The difference in proportions between low and non-low discounting fishers who lived in PI villages was statistically significant within Sabah (Fisher's exact test, $p < 0.01$), but not in Fiji (Table 4.3). There was no other outstanding factor that distinguished low discounting from non-low discounting fishers within sites, as none of the other independent variables were statistically different at the 0.05 level between low and non-low discounting fishers.

4.3.2 Logistic regression models

4.3.2.1 Pooled model

The stepwise procedure indicated that the following variables had non-significant relationships with fishers' choice of a low discount rate: age, education, poverty index,

relative catch, temporal decline, and the presence of an alternate job or income source. I removed these from the model and tested the model using the 3 significant regressors: site, protection initiative, and household size (Table 4.4). The location specific variables (site and protection initiative (PI)) were significant predictors of a low discount rate. Although the coefficient estimate for household size was not statistically significant, I left it in the final model because a nested Chi test showed that its inclusion significantly improved the model fit. The significance of the overall model meant that the explanatory variables as a set allowed me to make better predictions of low discounting fishers than I could have made without the explanatory variables.

Holding the other explanatory variables constant, the odds of a low discount rate for a fisher from a PI village was about 5 times higher than that for a fisher from a non PI village. The odds that a Sabah fisher chose a low discount rate was about 2.6 times over that for a Fijian fisher. Having a larger household decreased the likelihood of choosing a low discount rate, although this effect was statistically insignificant. The Nagelkerke R^2 value of 0.21 indicated that the model had low usefulness for predicting the probability of fishers choosing a low discount rate. The ROC measure of 0.71 suggested moderate discriminating ability.

4.3.2.2 Sabah and Fiji models

The overall model for Sabah was significant, and included protection initiative, boat ownership, and relative catch as significant predictors of a low discount rate. Owning a boat or living in a PI village increased the odds that a fisher would have a low discount rate, whereas high relative catch decreased the odds of choosing a low discount rate (Table 4.4). The Nagelkerke R^2 of 0.32 indicated a moderate relationship between the independent and dependent variables, while the ROC measure of 0.73 indicated that the model had moderate discriminating ability.

One data point was removed from the Fiji model due to a high deviance residual, so that the final model was fitted to a sample of 44. The removal did not affect the overall model results. The Fiji model also included boat ownership and relative catch as significant predictors of low discount rates. Interestingly, in contrast to Sabah, boat ownership in Fiji decreased the odds that a fisher would choose a low discount rate, while an increase in relative catch actually increased the odds of a fisher choosing a low discount rate (Table 4.4). The model had moderately high discriminating ability with a ROC measure of 0.79, and the Nagelkerke

R^2 of 0.26 indicated a moderate relationship between the independent and dependent variables.

4.4 Discussion

I find that 42% of the fishers in this study have low discount rates, which is encouraging given the urgency of conserving coral reef resources. It also appears that the common assumption that small-scale fishers have high discount rates (Pollnac, 1985) may not be applicable in all cases. In fact, other researchers have also found that fishers' discount rates are not excessively high (Asche, 2001; Curtis, 2002), while both Ngyuen (2009) and Poggie (1978) showed that small-scale fishers had lower discount rates compared to workers in other occupations within the same community.

The significance of the site dummy variable in the pooled model is consistent with the few other studies which have compared discount rates across developing countries (Pollnac and Poggie, 1978; Holden et al., 1998; Poulos and Whittington, 2000). It suggests that socio-economic variables I have not controlled for, or some emergent property of local conditions, (e.g., cultural values and traditions (Holden et al., 1998), or local geographical conditions (Moseley, 2001)) may account for the observed difference in the distribution of fishers choosing low discount rates in Sabah and Fiji. The use of certain fisheries management tools may also encourage fishers to develop a longer term planning horizon. For instance, based on two well-developed ITQ (individual transferable quota) systems in Iceland and New Zealand, Asche (2001) estimated that fishers' discount rates decreased through time.

The protection initiative (PI) variable is significant in the pooled and Sabah models. All PI villages have low accessibility, as they tend to be situated on islands away from the main island or the mainland. Pomeroy et al. (2007) found that social and economic conditions prevalent in small island communities, such as constant face to face interaction among villagers, and sharing similar activities and backgrounds, increased the likelihood of villagers cooperatively undertaking a joint venture such as implementing community marine protected areas. Although I did not explicitly measure these attributes, the findings of Pomeroy et al. (2007) are consistent with studies which suggest that the presence of social capital among community members can lead to more sustainable marine resource management (Ostrom, 1990; Jentoft, 2000; Grafton, 2005). Having said this, I acknowledge that factors which I was not aware of, such as villagers' exposure to marine education campaigns, or political

incentives, could have spurred villagers to initiate protection of their village fishing grounds. In any case, my results highlight the need for future research to explore the linkage between fishers' time preference and social capital.

The same fishery related variables affect low discounting in both Sabah and Fiji, albeit with contrary effects. While the Sabah model results are consistent with other empirical studies, the Fiji model results counter expectations. Owning a boat increases the chances of a low discount rate in Sabah, which supports another study that found boat ownership to be associated with a deferred economic gratification orientation among small-scale fishers (Pollnac and Poggie, 1978). Boat owning fishers have invested in the fishery, and are therefore more likely to have a longer term perspective about the fishery compared to non-boat owners, who have no investment, hence likely have less interest or stake in the future well-being of the fishery. The fact that boat ownership is lower in Fiji may explain the lack of the positive boat ownership-low discount rate relationship observed in the Sabah model.

An increase in the relative catch variable is associated with a decrease in the probability of choosing a low discount rate in Sabah. This makes sense if a higher fish catch is due to a fisher intentionally catching more in order to gain as much as possible from the fishery today. Pursuing one's short-term interests that ultimately leads to outcomes which are in no one's long-term interest is a characteristic problem with common pool resources (Ostrom et al., 1999). In Sabah, this type of short-sighted and competitive behaviour is likely exacerbated by the essentially open access nature of small-scale fishing grounds. On the other hand, a higher catch may also indicate a better skilled fisher who catches more relative to others. If this effect is stronger than the competitive effect, the negative relationship between relative catch and low discount rate may not be present. This appears to be the case in Fiji, where the presence of a customary marine tenure system may be dampening the competitive mentality that seems to occur in Sabah.

Surprisingly, demographic variables are not significant predictors of a low discount rate, even though age, education, and poverty have been correlated with discount rates in other studies of resource dependent communities in developing countries (Godoy et al., 2001; Kirby et al., 2002; Tanaka et al., 2010). The lack of statistical relationship between poverty and discount rates may be because fishers in my study are not completely cash constrained, as fishers in both Sabah and Fiji are able to obtain credit from fish buyers or from their friends and

families, without having to repay interest. The lack of an explicit debt load may play a role in reducing the pressure for fishers in this study to catch as much as they possibly can, but this was not completely captured in using fishing income as an indicator. The weak relationships between independent and dependent variables may also be because my models do not account for risk attitudes, ethical considerations or psychological and neurophysiological traits, which others have found to be related to discount rates (Lumley, 1997; Frederick et al., 2003). Overall, we must bear in mind that due to the relatively small sample size and exploratory nature of this study, my results should be regarded as tentative, rather than conclusive.

In summary, I find that over 40% of the fishers in my study have low private discount rates, although the proportion of patient fishers in Sabah is nearly double that in Fiji. This is encouraging for conservation of the region's coral reefs, particularly in Sabah, where marine protected areas are in the process of being established in both Pulau Banggi and the Semporna islands. My results suggest that location and fishery related variables differentiate low discounting from non-low discounting fishers. Policies which aim to motivate a long-term conservation orientation among fishers may therefore wish to focus on the community and fishery level, rather than on individuals. The fact that the same boat ownership and relative fish catch variables have contradictory effects on low discount rates in Fiji and Sabah cautions against implementing blanket solutions without first carefully considering local socio-cultural, economic, and ecological conditions.

Table 4.1. List of interview villages in Sabah and Fiji.

Site	Island(s)	Village
SABAH	Banggi	Batu Sireh, Damaran, Dogoton, Maligu, Manawali, Sibogo Air, Sibogo Balak
	Semporna	Denawan, Hampalan Laut, Mabul, Omadal
FIJI	Vanua Levu	Galoa, Moata, Tavea, Vunivutu
	Viti Levu	Nakavita, Natawarau, Seroa
	Kadavu	Galoa, Namouna
	Yasawa	Malakati, Nacula

Table 4.2. Expected relationship between explanatory variables and low discount rates.

Explanatory variable	Variable type	Variable definition	Expected relationship with a low discount rate
<u>Demographic</u>			
Age	Continuous	Age in years	+/-
Education	Dichotomous	0 if not educated or primary education, 1 if secondary education or higher	+
Household size	Continuous	No. of people in household	+/-
<u>Economic</u>			
Poverty index	Continuous	Standardised measure of net monthly fishing income	+
Boat ownership	Dichotomous	1 if own a boat, 0 if do not own a boat	+
Relative catch	Continuous	Standardised measure of catch (Kg) per fisher per week	-
Alternate income	Dichotomous	1 if have an alternate income, 0 if none	+
Temporal decline	Dichotomous	1 if perceive decline, 0 if none	+/-
<u>Location</u>			
Site	Dichotomous	1 if survey site is Sabah, 0 for Fiji	?
Market access	Dichotomous	1 if village is accessible, 0 if poor accessibility	+
Protection initiative	Dichotomous	1 if there is community initiative to protect fishing area, 0 if none	+

Table 4.3. Between and within site comparison of socio-economic variables for low (DRLOW=1) and non-low (DRLOW=0) discount rate respondents.

Variable	SABAH (n=73)			FIJI (n=45)		
	<u>Non-low</u> <u>discounting</u> <u>fishers</u>	<u>Low</u> <u>discounting</u> <u>fishers</u>	<u>All</u> <u>fishers</u>	<u>Non-low</u> <u>discounting</u> <u>fishers</u>	<u>Low</u> <u>discounting</u> <u>fishers</u>	<u>All</u> <u>fishers</u>
Age	37.3±1.9	41.9±1.9	39.6±1.4	39.4±2.4	37.0±2.4	38.9±1.7
Household size (people household ¹)	8.1±0.9	7.0±0.6	7.0±0.4	6.4±0.6	5.8±0.9	6.3±0.5
No. years fishing	20.3±2.0	22.2±1.9	21.2±1.4	13.6±1.5	14.7±3.1	14.2±1.4
Relative catch	1.0±0.4	1.5±0.7	1.3±0.4	0.9±0.2	1.2±0.4	1.0±0.2
Poverty index	0.6±0.1	0.6±0.1	0.6±0.1	0.8±0.1	0.9±0.3	0.8±0.1
Education						
None (%)	37	61	47	0	0	0
Primary (%)	57	32	45	42	25	32
Secondary/Tertiary (%)	6	8	8	58	75	68
Boat ownership =1 (%)	84	95	89	39	17	9
Alternate income =1(%)	24	21	25	33	42	35
Temporal decline = 1(%)	89	89	90	52	67	56
Accessible =1 (%)	24	21	23	30	58	38
Protection initiative =1 (%) ¹	11	42	27	6	17	9

¹ Significant difference between low and non-low discounting fishers within Sabah (Fisher's exact test, p<0.01).

Table 4.4. Regression coefficients and standard errors for logistic regression models of socio-economic variables predicting the probability of fishers choosing a low discount rate. Z values are provided in brackets, and italics indicate the odds ratio for each variable.

Significance levels are indicated by asterisks.

Variable	Pooled	Sabah	Fiji
Intercept	-0.55±0.55 (-1.00)	-2.83±1.22 (-2.32)**	-1.40±0.55 (-2.56)**
Site	0.96±0.44 (2.18)** <i>2.61</i>	n/a	n/a
Protection initiative	1.64±0.54 (3.06)*** <i>5.16</i>	2.85±0.99 (2.89)*** <i>17.29</i>	n/a
Household size	-0.11±0.07 (-1.45) <i>0.90</i>	n/a	n/a
Boat ownership	n/a	2.77±1.22 (2.27)** <i>15.96</i>	-2.91±1.47 (-1.97)** <i>0.05</i>
Relative catch	n/a	-0.17±0.10 (-1.75)* <i>0.84</i>	0.81±0.42 (1.93)* <i>2.25</i>
χ^2	19.81(df=3)***	19.65 (df=3)***	8.44 (df=2)**
Log-likelihood	68.97 (df=4)	-40.71 (df=4)	-20.52 (df=3)
Nagelkerke R ²	0.21	0.32	0.26
ROC	0.71	0.71	0.79
Sample size	118	73	44

* p<0.1 ** p<0.05 ***p<0.01

Chapter 5: Investigating the economics of fisheries overexploitation

5.1 Introduction

It is well established that fisheries are declining worldwide (Pauly et al., 2002; Worm et al., 2009), as catch rates and abundance of fish populations have decreased across ecosystems. The problem of overfishing may be attributed to the tragedy of the commons (Hardin, 1968), that is, the competition inherent in the open access nature of fisheries leads to overexploitation because no single fisher has the incentive to conserve. Even if access to a fishery was restricted, Clark (1973) showed that, in a non open access fishery, it may still be economically optimal for the sole owner of a fishery resource to drive it to extinction. According to Clark, under the condition that the value of fish exceeds the cost of fishing, a private owner will have an incentive to fish a stock to extinction if the fisher's discount rate, δ , is sufficiently higher than the biological productivity (intrinsic population growth rate, r) of the targeted fish, such that $\delta > 2r$. Further, the incentive to overexploit a fish stock, although not necessarily to extinction, exists any time $\delta > r$.

A special condition applies to open access fisheries, in which fishers have no assurance that the fishery resource will persist into the future. This forces fishers, by default, to use a very large, or infinite discount rate when making fishing decisions (Clark 1990). A distinction is made here between the default infinite discount rate and the fisher's individual (private) discount rate. The private discount rate can be regarded as the rate used in a non open access condition since there is no competition to compel fishers to entirely discount the future. Subsequently, one can interpret the discount rate from Clark's theory as the rate under a 'best case' fishery scenario, as it pertains to a non open access fishery.

Although discounting is a crucial factor in understanding the exploitation of fishery resources, there are few empirical studies of fishers' private discount rates. Clark's theory is especially relevant for small-scale fisheries in developing countries, many of which are open access fisheries (Béné et al., 2007). As such, I use this theory in the context of small-scale coral reef fisheries to investigate two questions:

- 1) How do discount rates relate to the exploitation status of fisheries?
- 2) What are the private discount rates of fishers?

To answer the first question, I compare whether applying Clark's theory to reef finfish fisheries worldwide matches a prior assessment of reef fisheries sustainability carried out by Newton et al. (2007). In that study, the authors found that over half of the 49 island country reef fisheries they assessed were unsustainable according to their exploitation status or ecological footprint, which measured how much annual reef fish landings exceeded maximum sustainable yield. I then address the second question by inferring the value of fishers' private discount rates based on the exploitation status and biological productivity of reef fisheries.

5.1.1 Discount rates

In this chapter, I examine Clark's theory using two perspectives of discount rates. The first interpretation treats the discount rate as a financial measure of the rate of return from the next best use of capital invested in the fishery. This is consistent with the figure managers apply when assessing the costs and benefits of government intervention to protect fisheries resources or the marine environment. For instance, the U.S. National Oceanic and Atmospheric Administration uses a discount rate of 7% (<http://www.scs.noaa.gov/coastal/economics/discounting.htm>). Discount rates can also be viewed as an individual's time preference, in which case private discount rates measure an individual's willingness to delay economic gratification. It is reasonable to expect small-scale fishers in developing countries to have high discount rates, due to their need to fulfil immediate livelihood requirements. As outlined in Section 5.1, the private discount rates of fishers in open access fisheries are, theoretically, expected to be infinite. Consequently, there are 3 forms of discount rates that may apply to Clark's theory: i) official discount rate; ii) private, non open access discount rate; and iii) private open access discount rate. As the private open access discount rate is essentially known, I will use official and private non open access discount rates in this analysis.

5.1.2 Reef fisheries

Coral reef fisheries occur predominantly in tropical developing countries (Fig. 5.1), and are dominated by small-scale subsistence and artisanal fishers, who use gears ranging from hook and line, nets, traps, and spears, to destructive techniques such as dynamite and cyanide (Dalzell, 1996; Jennings and Polunin, 1996). It has been estimated that coral reef fisheries make up approximately 2 to 5% of global marine fisheries catches (Pauly et al., 2003). While

the absolute yield from reef fisheries may not count as significant (but see Zeller et al., 2006a; 2007), their relative importance to the socio-economic well-being of coastal communities is enormous, as coral reef fisheries sustain the livelihoods and food security of millions of people worldwide (Whittingham et al., 2003; Loper et al., 2008). Despite their socio-economic importance, overexploitation is threatening the future of reef fisheries worldwide (Bell et al., 2006).

Fishing on coral reefs reduces the abundance of species targeted by the fishery, alters the size and age distribution of target fish, and possibly alters the trophic structure of reef communities and habitats (Jennings and Polunin, 1995; Jennings and Lock, 1996; Dulvy et al., 2004a; Graham et al., 2005). Overfishing also reduces reef species diversity, and can cause local extinctions of both target and non-targeted reef fish species (Roberts, 1995; Sadovy et al., 2003b; Dulvy and Polunin, 2004). Subsequently, removing the threats from overfishing is key for ensuring resilient coral reef ecosystems that can continue to sustain ecological functions and processes, as well as provide ecosystem goods and services for present and future generations.

In general, as a reef fishery becomes progressively overfished, fish catch compositions shift from being dominated by large, slow-growing predatory fish such as groupers and snappers, to one where the bulk of the catch comprises herbivores such as parrotfish and rabbitfish, or faster growing predatory species (Butler et al., 1993; Jennings and Polunin, 1996; McManus et al., 2000). The relentless expansion of the live reef food fish trade illustrates how incessant targeting of low productivity (r) species, such as humphead wrasse and large groupers, has led to the depletion and local extinction of these species from many coral reef ecosystems (Sadovy et al., 2003a; Warren-Rhodes et al., 2003; Scales et al., 2007).

5.1.3 Intrinsic growth rate

The intrinsic rate of population increase (r) provides an estimate of the average population growth rate of a severely depleted stock, and represents a species' productivity, or resilience. A population with a lower r is less productive and thus less able to tolerate high exploitation rates (Reynolds et al., 2005). The intrinsic rate of population increase can be estimated by the maximum annual reproductive rate ($\tilde{\alpha}$) of a fish population (Myers et al., 1997).

Reproduction in fish populations may be represented as a spawner-recruit curve, which shows the relationship between parental population and the number of offspring produced.

The slope at the origin of the stock-recruitment relationship (α) represents the maximum rate of recruit production per unit of spawner abundance (kg of spawner). This slope, α , can be used to approximate r . In order to do so, the slope at the origin (α) is first standardised to the number of spawners produced per spawner per lifetime ($\hat{\alpha}$) (Myers et al. 1997):

$$\hat{\alpha} = \alpha \cdot SPR_{F=0}, \quad [5.1]$$

where $SPR_{F=0}$ is the spawning biomass resulting from each recruit.

This is then standardised to an annual rate, i.e., the number of spawners produced per spawner per year, or, the maximum annual reproductive rate ($\tilde{\alpha}$):

$$\tilde{\alpha} = \hat{\alpha}(1 - p_s) = \alpha \cdot SPR_{F=0_s}(1 - p_s), \text{ where } p_s \text{ is adult survival.} \quad [5.2]$$

Once the maximum annual reproductive rate ($\tilde{\alpha}$) is calculated, the intrinsic population growth rate can then be estimated iteratively from:

$$(e^r)^a - p_s(e^r)^{a-1} - \tilde{\alpha} = 0, \text{ where } p_s \text{ is adult survival and } a \text{ is age at maturity.} \quad [5.3]$$

Steepness parameter

The intrinsic population growth rate can be used to measure the replacement rate, or potential recovery rate of exploited fish stocks, which are greatly reduced in size (Dulvy et al., 2004b). Recovery rate is affected by the steepness, or slope, of the stock-recruitment curve. The steepness (h) of the stock-recruitment relationship is defined as the proportion of recruits produced, relative to recruitment at equilibrium with no fishing, when the spawning biomass is reduced to 20% of its unfished level. The steepness parameter h ranges from 0.2 to 1, and can be expressed as a function of the lifetime number of spawners produced per spawner ($\hat{\alpha}$) (Myers et al., 1999):

$$h = \frac{\hat{\alpha}}{4 + \hat{\alpha}} \quad [5.4]$$

A higher value of h represents higher expected productivity (recruitment) at low levels of spawning biomass. Rose et al. (2001) estimated steepness (h) values from the slope at the origin of spawner-recruit curves that had previously been fitted by Myers et al. (1999). The slope at the origin of the fitted spawner-recruit curve was converted from an annual to a lifetime rate as per Myers et al. (1999), and then used to compute a steepness value. The h values of the assessed species were then grouped into three general life-history strategies:

i) periodic; ii) opportunistic; and iii) equilibrium, according to Winemiller and Rose (1992). The average h value and description for each of the 3 life-history strategy groups are summarised below:

- i) Periodic – A periodic life history strategy is associated with fishes that have longer life spans, larger body size, and higher fecundity. These fishes tend to mature later in order to obtain a larger size that improves their chances of producing a large clutch of eggs and increasing adult survival when environmental conditions are suboptimal (e.g., groupers, Serranidae). Periodic spawners spread their reproductive effort over many years and spatial areas, so that high larval or juvenile survivorship in a particular year or spatial zone will offset bad years or zones (Winemiller and Rose, 1992). Mean $h=0.7$ (range 0.55-0.87)
- ii) Opportunistic – An opportunistic life history strategy is associated with high adult mortality, fast larval growth, early maturation, and an extended spawning season during which reproduction occurs frequently. This strategy is typical of small, short-lived species such as anchovies (Engraulidae) and silversides (Atherinidae). Mean $h=0.56$ (range 0.56-0.7)
- iii) Equilibrium – Equilibrium species produce a small number of large eggs, invest in parental care of their young, and reside in relatively stable environments (e.g., gobies, Gobiidae). Mean $h=0.57$ (range 0.3-0.85)

5.2 Method

To investigate whether discount rates are indicative of the exploitation status of reef fisheries, I assessed whether the condition $\delta > r$ corresponded to an overexploited reef fishery as determined by Newton et al. (2007) for each country under consideration. I also assessed whether Clark's (1973) condition for depletion, $\delta > 2r$, applied to the fisheries considered in this analysis, even though Newton et al. (2007) did not indicate whether any of the overexploited fisheries were actually depleted. I extended Clark's formula to the fishery level by developing a fishery level r for reef fisheries worldwide. I then applied Clark's framework to infer the private discount rates of fishers for each reef fishery. Estimating a fishery level intrinsic rate of increase involved two steps: i) determining the r of each species caught in the fishery; and ii) developing a fishery level r by weighting the r of all targeted fish according to the catch composition of each fishery.

5.2.1 Estimating intrinsic growth rates (r)

I estimated the intrinsic population growth rate (r) for each species by iteratively solving for r in equation [3], under the condition of a steepness value h (equation [5.4]). Since h values

range from 0.2 to 1 (Myers et al. 2001), I estimated intrinsic growth rates for h values between this range, in 0.05 increments. I then selected the appropriate h -r estimate based on the resilience of each species, as described in Section 5.2.1.1.

I used a life table to generate the population parameters required for estimating r . A life table is a discrete, age structured model that tracks the age specific reproductive and mortality rates of the female population through time. This required the following life history input parameters for each fish species: maximum age (t_{\max}), age of maturity (t_m), natural mortality rate (M), von Bertalanffy growth parameter (K), a and b length-weight relationship parameters. These data were extracted from FishBase (Froese and Pauly 2011) for reef and reef-associated species ($N=642$ species). If life history parameters for a specific species were not available, the parameters for a similar species from the same genus with the same geographical distribution were used instead. If no comparable species were available, K , M , t_{\max} and t_m were estimated based on the empirical relationships detailed below (Pauly, 1980; Froese and Binohlan, 2000; Froese and Pauly, 2011):

$K = -\ln(1 - L_m / L_{\text{inf}}) / (t_m - t_0)$, where t_0 = a parameter of the von Bertalanffy growth function, which represents the hypothetical age at which the fish would have a length of zero.

$M = 10^{(0.566 - 0.718 \text{ Log}(L_{\text{inf}}) + 0.02 T)}$, where T = average water temperature.

$$t_{\max} = t_0 + 3 / K$$

$$t_m = t_0 - \ln(1 - L_m / L_{\text{inf}}) / K$$

I used the life table to estimate the following parameters: i) spawning biomass resulting from each recruit ($\text{SPR}_{F=0}$) in the absence of fishing mortality; and ii) $\hat{\alpha}$ - The number of spawners produced by each spawner over its lifetime at low spawner abundance (assuming no density dependence). These parameters were then utilised to solve for r iteratively.

5.2.1.1 Estimating the steepness parameter (h)

An appropriate steepness parameter had to be chosen in estimating r for each fish species. In fishery stock assessments, h is estimated from stock and recruitment data. However, these data are limited for exploited coral reef fish stocks (Sadovy et al., 2007). As h is indicative of

resilience or vulnerability (Dulvy et al., 2004b), I selected a h value for each species based on its resilience status as reported in FishBase, and its life history strategy as outlined in Rose et al. (2001) and described in Section 5.1.3. I used the mean steepness values from Rose et al. (2001) to correspond to medium resilience. I then used the 90th and 10th percentile values to correspond to a high and low resilience, respectively (Table 5.1).

Coral reef fish are commonly characterised as being broadcast spawners that release a large number of eggs into the plankton (Sale, 1991). As such, I categorised relatively large, demersal coral reef fish as periodic spawners. Species which invest in parental care were considered to be equilibrium strategists. Parental investment is exhibited in species which bear live young, such as sharks and rays (Carcharhinidae and Dasyatidae). In addition, small species such as damselfish (Pomacentridae) tend to invest more in offspring, e.g., by guarding their demersal eggs, because they have to keep their vulnerable eggs out of the plankton until their young are well developed enough to settle onto appropriate habitat before dispersing. Reef associated small pelagics that are commonly targeted by small-scale reef fisheries were identified as opportunistic strategists. This group included the sardines and herrings (Clupeidae and Engraulidae), and small species of scombrids and carangids, such as *Rastrelliger brachysoma* and *Atule mate*.

5.2.2 Catch composition of reef fish catches

I covered small-scale fisheries, which target reef and reef associated finfish. Coral reef is broadly defined to include reef and reef associated habitats such as lagoons, channels, mangroves, and seagrass (Dalzell et al., 1996; Unsworth and Cullen, 2010), as fish are able to traverse and inhabit more than one of these zones (Wright, 1993). Further, reef fishers generally move between habitats, depending on target species, environmental factors, and socio-economic considerations. Therefore, fish species in this study consisted of demersal reef species (e.g., groupers (Serranidae), triggerfish (Balistidae), parrotfish (Scaridae)), as well as reef associated nearshore pelagics (e.g., trevallies and scads (Carangidae), small tuna and mackerels (Scombridae)) and estuarine, seagrass, and lagoon species (e.g., mullets (Mugilidae), emperors (Lethrinidae), and rabbitfish (Siganidae)).

I searched the literature, both published and grey, to find case studies which documented the catch composition of small-scale reef fisheries. I did not distinguish between artisanal and subsistence fishing, but considered a fishery to be small-scale if it met the following criteria:

i) fish were caught using manually operated gears (hand line, traps, spear/speargun, gill or seine nets); ii) fishing trips lasted one day (no multi-day trips); iii) fishing was done in inshore, shallow areas (except if a steep bank was within a short distance from the fishing port or village). Studies which involved experimental fishing using local gears and were carried out in actively fished fishing grounds were included.

I did not derive reef fish catch compositions from landings statistics recorded by national fisheries departments, as there is generally a lack of, or limited, coverage of small-scale fisheries catches in national statistics (Zeller et al., 2006a). The exceptions were Anguilla and Antigua-Barbuda, for which I used landings data recorded by the Fisheries Division due to the absence of studies documenting the reef fish catch from small-scale fisheries.

Selection of countries and territories: I selected countries and territories primarily based on the study by Newton et al. (2007), and on the availability of case studies. There were 48 countries and territories in total, of which 43 were the same as those included in Newton et al.'s study. Of the remaining 5 different countries, 3 were in Southeast Asia (Malaysia, Indonesia, and East Timor), as this region was not well represented in the Newton et al. (2007) study. Kenya and Puerto Rico were also added due to the substantial amount of research available on the respective reef fisheries (Jimenez and Sadovy, 1997; McClanahan and Mangi, 2004; Marshak et al., 2008; McClanahan et al., 2008; McClanahan et al., 2010). With the exception of Barbados and the Bahamas, the countries covered in this study were classified as developing countries according to the United Nations Human Development Index (UNDP, 2011).

Selection of time period: I attempted to find studies which took place in the past decade (2000 onwards); however, this was not possible for some countries and territories. Thus, the time period for case studies spanned from 1981 to 2010. I was able to find studies covering different time periods for 7 countries, although the studies were not all conducted at the same location or with the same gear each time. Given the declining temporal trend of world fisheries (Pauly et al., 2002; Worm et al., 2009), and lack of effective management of reef fisheries (Sale, 2008), catch compositions based on the early period case studies likely reflected conditions which have since changed for the worse. Consequently, this would make the estimated fishery level r conservative.

In most cases, the catch composition documented in each case study was provided as a percentage of total catch weight. In cases where the catch composition was expressed as a percentage of total number of fish caught, and the lengths of fish were recorded, I converted the number of fish to weight via the length-weight relationship: $W=aL^b$. The a and b parameters were obtained from FishBase. If fish lengths were not recorded, the catch composition was based on the total number of fish caught; however, this only applied to 3 cases.

Case studies broke down catches to species or family level. If the catch composition was broken down to family level only, I obtained a list of the species for each family that occurred in the respective country from FishBase. I then calculated a family level r by averaging the r across the species. In cases where an ‘others’ group was included in the catch composition, I redistributed the portion of ‘others’ equally among all other families listed in the catch. In total, I had 66 case studies documenting fish catches from 48 countries (Table 5.2). Some case studies recorded reef fish catches from multiple locations or multiple gears; each location or gear specific catch composition was considered as a separate case, so that in total, I had 151 cases of fish catch compositions.

5.2.3 Assessing whether discount rates are indicative of exploitation status

I tested Clark’s theory by comparing discount rates to the fishery level r obtained for each catch composition case. A fishery was considered to be depleted if $\delta > 2r$, and overfished if $\delta > r$. As outlined in Section 5.1.1, there were 3 types of discount rates applicable to Clark’s theory: official, open access, and private non open access discount rates. An open access discount rate of infinity ($\delta_{OA}=\infty$) automatically implied that all reef fisheries were overexploited, since $\delta_{OA} > r$ for all cases. That left official and private non open access discount rates to assess. Clark (1973) did not specify which type of discount rate to use. As data on private discount rates were not available on a worldwide basis, I chose to use official discount rates instead. These were proxied by national bank lending rates used to meet short and long term financing needs of the private sector. Lending rates were used because discount rates represent the rate of return from the next best use of fishing capital. Revenue obtained from fishing could potentially be lent out at the market lending rate. Lending rates were obtained from the International Monetary Fund (<http://www.imf.org/external/data.htm>). Where lending rates were not available, assumed rates of 7% and 10% were used for developed and developing countries, respectively. The 7% discount rate for developed

countries was based on the recommended discount rate by the United States Office of Management and Budget (OMB, 1992), while the 10% was based on the recommended discount rate of 10-12% the World Bank uses for evaluating projects (Belli et al., 1998). It should be noted that in general, small-scale fishers in developing countries rarely have access to regular lending banks. Rather, it is often the case that they have to resort to high interest loans from informal lenders (Béné et al., 2007). Thus, while official discount rates may be relevant to fishery managers for conducting cost-benefit analysis, they are essentially irrelevant to small-scale fishers.

The result obtained from testing Clark's theory was then compared to the exploitation status from Newton et al. (2007), who classified the reef fisheries of 49 island countries and territories as being either overexploited, underexploited, or fully exploited (Table 5.2). I classified countries assessed to be 'under/fully exploited' or 'fully/overexploited' as being fully exploited. The authors also assessed whether each country's reef fishery was sustainable or unsustainable based on its ecological footprint (Table 5.2). For the 5 countries in this study which differed from Newton et al., I based the exploitation status on literature. Four of these countries were considered to have overexploited reef fisheries: Kenya (McClanahan and Mangi, 2004; McClanahan et al., 2008), Indonesia (Ainsworth et al., 2008), Malaysia (Biusing, 2001; Teh and Sumaila, 2007), and Puerto Rico (Matos-Caraballo, 2005). East Timor was considered to be underexploited (McWilliams, 2003; FAO, 2009), although other authors have noted that overfishing may already be occurring (Deutsch, 2003; Barbosa and Booth, 2009). As all the overexploited reef fisheries in Newton et al.'s study also had unsustainable footprints, I found it reasonable to categorise the reef fisheries of Kenya, Puerto Rico, Indonesia, and Malaysia as unsustainable, while East Timor was considered sustainable.

Discount rates were assumed to be indicative of exploitation status if:

- 1) $\delta > r$ or $\delta > 2r$, and the reef fishery was considered overexploited by Newton et al. (2007);
- 2) $\delta < r$, and the reef fishery was considered under or fully exploited by Newton et al. (2007).

5.2.4 Inferring fishers' private discount rates

I used Clark's formula to infer ranges for fishers' private discount rates (δ_p), using the fishery intrinsic growth rate as a proxy for the status of the fishery. As specified in Section 5.1.1, these were assumed to be non open access private discount rates, and therefore could be

considered conservative since many developing country fisheries are open access, and hence operate under an infinite discount rate.

1) For overexploited fisheries, I assumed that fishers' private discount rates were greater than the fishery intrinsic growth rate, but less than $2r$ (the point at which depletion occurs), i.e., $r < \delta_p < 2r$.

2) For underexploited fisheries, r was treated as an upper bound for δ_p . There were 2 previous estimates of reef fishers' private discount rates in Fiji and Sabah (Malaysia) (Chapter 3). The lowest average discount rate at both locations was 29%, which I used as a lower bound for δ_p , such that $0.29 < \delta_p < r$.

3) For fully exploited fisheries, δ_p was set equal to r .

I used the mid-point of the ranges in 1) and 2) to represent the private discount rate of fishers in the respective fishery.

5.2.5 Sensitivity analysis

I evaluated the sensitivity of species r to changes in the steepness parameter (h). I conducted the sensitivity analysis using steepness values of 0.9 and 0.55. The high h of 0.9 was intended to represent a scenario of environmentally driven recruitment, while values of approximately 0.55 were found to be either a median or best estimate for h in data poor situations (Mangel et al., 2010).

5.3 Results

5.3.1 Intrinsic growth rates (r)

Species level r

Reef fisheries in this study targeted 642 species from 86 families, with Serranidae having the most number of species (76), followed by Lutjanidae, Carangidae, Scaridae, Acanthuridae, and Labridae, with 50, 36, 35, 35, and 35 species, respectively. The estimated intrinsic population growth rate for all fish species ranged from a minimum of 0.03 for blue spotted ray (*Taeniura lymma*), to a maximum of 3.58 for oxeye scad (*Selar boops*) (Appendix E). Averaging across all species, the family level r for common reef food fish targets such as groupers (Serranidae) was 0.44, 0.57 for snappers (Lutjanidae), 1.04 for parrotfish (Scaridae), 0.93 for surgeonfish (Acanthuridae), 0.60 for emperors (Lethrinidae), 2.21 for rabbitfish (Siganidae), and 2.05 for small mackerels or scads (*Atule* spp., *Decapterus* spp., *Selar* spp., *Selaroides* spp.).

Fishery level r (by country/territory)

At the fishery level, the mean r across all fisheries was 0.88 ± 0.02 , ranging from a low of 0.28, to a maximum of 1.82. (Fig. 5.2). Using family level r as a baseline, about 8% of cases fell within the r range corresponding to groupers (Serranidae); the majority of fishery intrinsic growth rates fell within the range comparable to surgeonfish (Acanthuridae) (Fig. 5.2). The top 3 records with highest fishery r were from Mauritius, Philippines, and Kenya, while the 3 lowest fishery r values were from the Turks and Caicos, Netherlands Antilles, and Seychelles. The r values for these fisheries, along with the catch compositions are provided in Table 5.3. The catch compositions for the high and low r fisheries differed substantially. Herbivorous reef fish such as rabbitfish (Siganidae), parrotfish (Scaridae), and surgeonfish (Acanthuridae) comprised the major families in high r fisheries. In contrast, carnivorous fish such as snappers and groupers contributed to the bulk of the catch in low r fisheries. A summary of the top 5 fish families making up the catch for each case is provided in Appendix F.

Temporal level r

The mean r value for studies that were conducted pre-2000 was 0.82 ± 0.05 , which was lower than the mean r of 0.90 ± 0.03 for studies done in year 2000 and later; this difference was not statistically significant. The countries for which there was inter-temporal catch composition data did not provide conclusive evidence for this trend. The fishery intrinsic growth rates for Bermuda and Barbados were lower in an earlier study, whereas the fishery r values for Fiji remained almost constant at 0.66 and 0.64 in 2002 and 1993, respectively. Studies done in Jamaica in 1990/1991 and in 2001/2002 also had similar fishery r values of 1.2. Another study done in 2000/2001 (same location as the 1990/1991 study) actually had a slightly lower fishery r value of 1.1 compared to the pre-2000 study. Likewise, the fishery level r for the same fishery recorded at the same location in Mauritius was slightly lower in 2007 compared to 2002 (1.24 vs. 1.51). In contrast, fishery r values in Apo Island (Philippines), which is adjacent to a marine reserve, decreased temporally, from 0.96 in 1981 to 0.67 in 2001. A similar pattern was also observed for non-protected sites, with a study done in 1987 having a higher fishery r value of 1.79 compared to a 1991 study with a fishery r value of 1.08. Two studies covering predominantly similar areas in Kenya overlapped in time. The first study done in 1995-1999 had a fishery level r of 1.48, while the second study from 1998-2006

presented fishery level r values of 1.71 and 0.53 for the trap and handline fisheries, respectively.

Regional level r

There was a significant difference in fishery r values between regions (ANOVA $F=4.69$, $df=3$, $p<0.01$), with the Caribbean and Southeast Asia having the lowest and highest mean fishery r values of 0.73 ± 0.05 and 0.99 ± 0.07 , respectively (Table 5.4).

Fishery status level r

The reef fisheries assessed to be overexploited by Newton et al. (2007) had, on average, the highest r (0.92 ± 0.03). Underexploited fisheries had a slightly lower mean fishery r value of 0.88 ± 0.05 , whereas those assessed as fully exploited had the lowest mean r of 0.77 ± 0.05 . There was no significant difference in fishery r values between exploitation status. Sustainable reef fisheries had a mean r value of 0.80 ± 0.03 , which was significantly lower than the mean of 0.96 ± 0.04 for unsustainable fisheries ($F=11.49$, $p<0.01$).

5.3.2 Discount rates and reef fishery status

The official discount rates (δ) for all countries or territories were considerably lower than the fishery r values (Table 5.5). According to Clark's formula, this would mean that none of the reef fisheries would be at threat of being overfished or depleted. In comparison, half the countries or territories were considered to be overexploited in Newton's study.

In most cases, the mean family level intrinsic growth rates for each case were also higher than official discount rates, suggesting there was minimal threat of overfishing most types of fish. There were 13 families for which r values were lower than official discount rates (Table 5.6). These families were caught in the reef fisheries of 13 countries, and mainly consisted of the slow growing sharks and rays (Carcharhinidae, Ginglymostomatidae, Squalidae, Rhinobatidae, and Dasyatidae), or of fish that were not important food fishes (e.g., Tetraodontidae, Monacanthidae). There was one important food fish family - barracudas (Sphyraenidae), because the catch consisted primarily or entirely of *Sphyraena barracuda*, which is a slow growing species within this family.

5.3.3 Private discount rates

The mean annual private discount rate inferred across all fisheries cases was $107\pm4\%$. The estimated private discount rate for each country or territory is provided in Table 5.5 (these are

averaged values if there were multiple cases per country). Overall, the mean annual private discount rate of fishers in overexploited fisheries was 137%, while those for under and fully exploited fisheries were 58% and 79%, respectively. Fishers in Southeast Asia had the highest mean annual private discount rate (145%), while those in Oceania had the lowest (89%) (Table 5.7).

5.3.4 Sensitivity Analysis

Using $h=0.9$ increased the estimated intrinsic growth rate of all species by an average of 36%, such that the overall average r across all species increased from 0.88 to 1.18. Changes in species specific r values ranged from no change, to a maximum increase of 89%. The maximum change applied only to 3 species of sharks, which made up insignificant proportions of the fisheries in which they were caught. Using a h of 0.55 decreased the average species r to 0.49, a decline of 58%. The subsequent effect on fishery intrinsic growth rate for the top 3 cases with highest and lowest fishery r levels are shown in Table 5.8. Individual cases within each of the high and low fishery level r groups responded similarly to changes in h values. A h of 0.9 caused the fishery level r values of the high fishery r cases to increase by 7 to 12%, while those in the low fishery r cases increased by 84 to 100%. On the other hand, a h of 0.55 decreased the fishery level r of the high fishery r cases by around 56%, whereas the low fishery r cases decreased by 18 to 26%.

5.4 Discussion

The purpose of this study was to apply Clark's (1973) 'economics of overexploitation' theory to investigate two aspects of discounting in small-scale reef fisheries worldwide: first, whether discount rates are indicative of the exploitation status of reef fisheries, and second, to find out what the private discount rates of small-scale reef fishers are.

As Clark's theory did not specify whether to use official or private discount rates, I first applied it by comparing official discount rates to the implicit growth rate of each fishery case. This comparison indicated no threat of overfishing or depletion because for each case, the official rate was lower than the implicit growth rate of the fishery. However, only 26% of the cases corresponded to an underexploited assessment as defined by Newton et al. (2007), whereas 57% were assessed as overexploited. This suggests that official discount rates may not appropriately capture the short-term outlook fishers place on exploiting coral reef resources. Indeed, small-scale fishers rarely have access to regular bank lending rates, and

fishing communities in parts of Asia normally face annual interest rates of 96-144% from informal money lenders (Béné et al., 2007). Thus, using official discount rates as the basis for fisheries policy analysis may result in overly optimistic decisions that are at odds with fishers' preferences. In contrast, all open access fisheries are, theoretically, considered overexploited, since the open access discount rate is infinite, leading to $\delta_{OA} > r$ for all cases. As many developing country small-scale fisheries remain open access, this suggests the need for managers to use high, rather than low, discount rates for evaluating policy options.

Comparison of official discount rates to species' intrinsic growth rates showed that in most cases, those families likely to be overfished were elasmobranchs (sharks and rays). This raises concerns for the conservation of elasmobranchs, given the general lack of protective measures afforded to sharks, despite the decline in their populations globally (Baum et al., 2003; Robbins et al., 2006). On a more positive note, the recent creation of shark sanctuaries and bans on shark fishing in Chile, Honduras, and the Bahamas in 2011 (Pew Environment Group, 2011) indicates that shark protection and conservation is starting to take a turn for the better.

Clark (1973) showed that even a sole owner who is the only person fishing a resource has the incentive to deplete the stock if his/her discount rate is sufficiently high. It is important to note that the private discount rates inferred in this chapter relate to a non open access fishery, and are therefore conservative estimates. In reality, the private discount rates of small-scale fishers may be a lot higher due to the open access nature of many developing country small-scale fisheries. Moreover, the incentive for high discounting exists even in non open access fisheries if the regulations are not well enforced. The average annual non open access discount rate inferred from Clark's theory -107%- is fairly consistent with the few empirical studies of fishers' discount rates from developing countries. For instance, Akpalu (2008) found average rates of 130% in Ghana, although fishers' discount rates in Sabah and Fiji were higher, at 265% and 208%, respectively (Chapter 3).

Nevertheless, the overall average of 107% is high, and does not bode too well for the future sustainability of reef fisheries. The potential for unsustainable fishing is amplified by the open access nature of many reef fisheries, where fishers are forced to entirely discount the future (Clark, 1990). Given private discount rates of this magnitude, it is not surprising that slow-growing but valuable reef species such as those targeted for the live reef food fish trade

have been progressively fished out throughout the Indo-Pacific (Sadovy et al., 2003a; b; Scales et al., 2007). The ‘roaming bandit’ style (Warren-Rhodes et al., 2003) of fishing typical of this trade further illustrates the short-term horizon adopted by trade participants, and underlines the crucial role discounting plays in determining the future sustainability of reef fisheries.

The future sustainability of coral reef fisheries depends on fishers’ willingness to participate in conservation. However, the high private discount rates estimated here pose a challenge for achieving this goal, as they imply that fishers would rather front load and obtain benefits from the fishery now, rather than later (Sumaila, 2004). Given the poor socio-economic backdrop of many coral reef fishing communities, this is not surprising because poverty is commonly thought to contribute to high discount rates (Mink, 1993). This is demonstrated by the widespread occurrence of Malthusian overfishing, in which poverty, population pressures, and lack of economic opportunities leads to destructive fishing behaviour (Pauly et al., 1989).

The highest private discount rates were found in Southeast Asia, and this warrants particular conservation concern because the global centre of coral reef biodiversity, the Coral Triangle, is situated in this region. Oceania had the lowest private discount rates. This may reflect the presence of a traditional conservation ethic among many in the Pacific Islands (Johannes, 1978). On the other hand, in Chapter 3, I found that private discount rates of Fijian fishers were similarly high to those in Sabah, Malaysia. Moreover, overfishing is prevalent in many Pacific Island countries and territories (Kronen et al., 2010b), suggesting that private discount rates may not be as low as indicated in this analysis. The comparatively low private discount rates inferred for Oceania may be due to the fact that many of this region’s reef fisheries were assessed as being underexploited by Newton et al. (2007), thus leading to a low inferred private discount rate. As Newton et al.’s study covered the time period from 1997-2001, the status of these reef fisheries may have declined since then.

The discrepancy in official discount rates and fishers’ private discount rates imply that fisheries managers do not appropriately capture the perspective of fishers. Differing perceptions among marine resource stakeholders may lead to management failure (Ruddle and Hickey, 2008). For instance, the substantially lower official discount rates used by managers may result in long-term oriented policies that protect coral reef resources, e.g., marine protected areas. However, this is in conflict with the more short-term oriented outlook

of fishers, which in many instances leads to non-compliant behaviour such as poaching within MPAs. Importantly, this highlights the need for understanding and integrating the perspectives of different resource users during the decision making process.

On average, the reef fisheries in this study had a productivity level equivalent to a surgeonfish, which are mainly herbivorous fish that feed on benthic algae. This implies that reef fisheries are overexploited, as catches that are dominated by highly productive, herbivorous species are characteristic of overfished fisheries (Koslow et al., 1988; Dalzell et al., 1996; Friedlander and DeMartini, 2002). Cases with above average fishery level r (i.e., $r > 0.88$) were mostly also assessed as overexploited by Newton et al. (2007). Thus, fishery level r was fairly representative of exploitation status for this group of cases. However, a larger proportion of cases that had below average fishery level r were considered to be over, rather than underexploited, by Newton et al. (2007).

A possible reason for the weak correspondence could be because Newton's assessment concentrated on catch rates and sustainable yield, which was not incorporated in this study. Their assessment also covered invertebrates, the status of which may have differed from those of finfish, even within a country. I also recognise that the fishery level r estimates represented a snapshot of reef catch compositions for a specific location and time, and this local heterogeneity may not have been captured in the country level parameters used in Newton et al.'s assessment of exploitation status and ecological footprints.

The assumed steepness parameter used in estimating the intrinsic growth rates of reef species, and hence private discount rates, could have affected my results. I chose to assign h values based on species' resilience because I considered this method more realistic than using the common assumption of $h=0.9$. Sensitivity analysis showed that using uniform assumed steepness values of either 0.9 or 0.55 caused the estimated r values for all species to increase or decrease by an average of 36% and 58%, respectively. Although different h assumptions result in considerable changes in estimated species r values, the overall findings of this study do not appear to be affected. This is because fishery cases with similar catch compositions respond similarly to changes in r values; thus, the general patterns about fishery level intrinsic growth rates and private discount rates remain robust to these changes. Further, another method that could have been used under similar data limited circumstances is the empirical relationship $r=2M$, where M is the natural mortality rate (Norse et al., 2011). The r

estimates generated using this technique were, in general, higher than the estimates I obtained. Therefore, I can consider my results to be conservative.

It is acknowledged that the perpetual lack of reef fisheries data should not hinder research (Johannes, 1998). Therefore, it was necessary to take the ad hoc approach of using case studies to obtain global catch composition data, even though this resulted in cases that were not uniform in time and gear type. It also necessitated the assumption that the case studies were representative of reef fisheries at the country or territory level, although I acknowledge that seasonal and habitat differences within countries and territories could lead to location specific differences in catch composition. Nevertheless, the potential for location bias was minimized to an extent because reef fish families usually remain the same between countries, and show similar responses to fishing, even though dominant species may change between places (Clua et al., 2005).

The use of different gears could have biased the fishery r estimates; however, removing each gear sequentially did not change the overall mean fishery level r significantly. The removal of nets did lower the r for overexploited fisheries, but this decrease was not statistically significant. The finding that the earlier time period (pre-2000) fisheries had, on average, lower intrinsic growth rates suggests that the results of this study are conservative. This is because the general pattern of temporal decline in reef fisheries worldwide (Cheung et al., 2007) means it is likely that the same fisheries would be in a worse shape now (i.e., higher r), except in cases where effective management restrictions have been implemented (e.g., McClanahan and Hicks, 2011). Excluding all pre-2000 cases lowered the fishery r value for Southeast Asia, and also increased the mean fishery r value for overexploited fisheries. However, the overall exploitation status and regional patterns of fishery intrinsic growth rates was not affected, suggesting that the study results are fairly robust.

Not all countries with temporal catch composition data indicated an increase in fishery r values through time. This was surprising, particularly for the cases of the Philippines and Jamaica, as reef fisheries in these two countries have been extensively overexploited for the past two decades (Koslow et al., 1988; Lavides et al., 2010). I acknowledge that this was possibly because I did not have studies that were matched in space and time. However, a reason for the temporal decrease in fishery level r for Apo Island (Philippines) may be due to

its location adjacent to a marine reserve, and the subsequent benefit from spillover effects (Russ et al., 2004).

Similarly, the implementation of a fisheries management policy may have contributed to the lower fishery r estimated for the heavily fished Discovery Bay area in Jamaica in 2000 compared to 1990/1991. A programme which exchanged large for small mesh sized traps was started in the early 1990s, and a shift in the catch composition to larger and more valuable species was subsequently documented (Sary et al., 1997). These cases demonstrate that the fishery level r appears to be a consistent measure of catch composition, and may be a useful measure to use in conjunction with other indicators such as fishing effort and fish size (Clua et al., 2005) to assess the status of a fishery.

From a behavioural perspective, the cases of Apo Island and Jamaica imply that it may be possible for fishers' conservation orientation to change (lowering of discount rates) if the proper incentives are put in place. Sumaila (2005) proposed 'stick and carrot' incentives as a mean of compelling those with high discount rate to apply lower discount rates to marine resources. Asche (2001) showed that fishers' discount rates decreased following the implementation of individual transferable quotas in Iceland and New Zealand. This shows that for open access fisheries, the use of properly enforced management initiatives may be able to alter the private discount rates of fishers from infinity to the private non open access rate. This may be possible if fishers' self-interest in the sustainability of the fishery drive compliance and cooperation with monitoring and management. The use of territorial use rights (TURFS) in the formerly open access Chilean artisanal shellfish fishery is an example of such a co-management system (Parma et al., 2003). Overall, there is little research on what motivates fishers' willingness to delay gratification, making this an important topic for further research and understanding. In Chapter 4, I found that site and fishery specific conditions were associated with low discounting behaviour among small-scale fishers. This supports other research which emphasizes that effective management interventions first need to understand the local socio-economic context under which fishers operate (Cinner et al., 2009a).

I apply Clark's theory to infer private discount rates, but acknowledge that several factors may confound the direct application of this theory. A recent debate has centred on the assertion that, contrary to Clark's theory, it may not be economically optimal to exploit a fish

population to extinction, even if it has a very low intrinsic growth rate (Grafton et al., 2010). However, Clark et al. (2010b) show that the Grafton result holds only if the authors' assumed parameter combination of discount rate, price, fishing costs, and technology are held constant through time. In reality, this is not probable, as fish prices, fishing effort costs, and technology are prone to temporal change (Tietze et al., 2005).

In summary, this study is one of the first to examine Clark's classic theory about the 'economics of overexploitation' in the context of reef fisheries worldwide. It makes two key contributions to the small-scale reef fisheries literature. First, it estimates a fishery level intrinsic growth rate which may serve as an indicator for the status of reef fisheries. Second, it provides an estimate of reef fishers' private discount rates worldwide, which is, as far as I am aware, the first estimate of its kind. Importantly, reef fishers' private discount rates may in fact be a lot higher than inferred in this study, as theoretically, the open access nature of many reef fisheries implies that fishers are compelled to discount their future at an infinite rate.

Although I have focused on coral reef fisheries, the approaches developed in this study can also be readily applied to other marine fisheries. In terms of policy implications, my results show that high private discount rates of fishers, and discrepancy between these discount rates and those utilized by fishery managers, are issues which will potentially affect the status of reef and other fisheries in the present and future. This suggests that in order to improve the chances of success, fisheries policies which affect local fishers may need to be evaluated using private discount rates. Addressing the divergent future outlooks of those who manage and those who use fisheries resources is a starting point for sustainable, conservation oriented fisheries management.

Table 5.1. List of families grouped under periodic, equilibrium, or opportunistic life history strategies, and corresponding range of steepness parameters (h values).

Life history strategy	Families	Steepness (h value)		
		High	Medium	Low
Periodic	Acanthuridae, Albulidae, Aulostomidae, Belonidae, Bothidae, Bramidae, Caesionidae, Callionymidae, Carangidae, Centropomidae, Chaetodontidae, Chirocentridae, Coryphaenidae, Dactylopteridae, Diodontidae, Echeneidae, Elopidae, Ephippidae, Exocoetidae, Fistulariidae, Gempylidae, Gerreidae, Haemulidae, Holocentridae, Kuhlidae, Kyphosidae, Labridae, Lethrinidae, Lutjanidae, Malacanthidae, Monodactylidae, Mugilidae, Mullidae, Muraenidae, Nemipteridae, Ostraciidae, Paralichthyidae, Pempheridae, Pinguipedidae, Platycephalidae, Pomacanthidae, Pomacentridae, Priacanthidae, Scaridae, Sciaenidae, Scombridae, Scorpaenidae, Serranidae, Siganidae, Sillaginidae, Sparidae, Sphyraenidae, Synodontidae, Triakidae, Trichiurinae, Xiphiidae, Zanclidae	0.87	0.7	0.55
Equilibrium	Balistidae, Blenniidae, Carcharhinidae, Dasyatidae, Eleotridae, Ginglymostomatidae, Monacanthidae, Plotosidae, Pomacentridae, Rajidae, Rhinobatidae, Sphyrnidae, Terapontidae, Tetraodontidae, Triacanthidae, Torpedinidae	0.85	0.57	0.3
Opportunistic	Atherinidae, Carangidae ¹ , Clupeidae, Engraulidae, Exocoetidae, Hemiramphidae, Leiognathidae, Scombridae ²	0.7	0.56	0.56

¹ *Atule mate*

² *Rastrelliger brachysoma*

Table 5.2. Summary of catch composition case studies by country or territory, with corresponding exploitation and sustainability status as assessed by Newton et al (2007). Under=underexploited, Over=overexploited, Full=fully exploited, S=sustainable, U=unsustainable.

Country	No. of cases	Source	Study year	Gear (“-” =no specified gear)	Status ¹	Sustainable ¹
Anguilla	1	Anguilla Fisheries Division, pers. comm.	2010	-	Under	S
Antigua & Barbuda	1	Horsford 2004	2004	-	Over	U
Bahamas	1	Cushion and Sullivan Sealey 2007	2007	-	Full	S
Barbados	2	a. Selliah et al. 2001	1999	-	Over	U
		b. Maraj et al. 2011	2010	Net		
Bermuda	2	a. Butler et al. 1993	1993	-	Over	S
		b. Luckhurst and Ward 1987	1975-1981	Trap		
British Virgin Islands	1	Boulon and Clavijo 1986 ²	1984	Trap	Over	S
Comoros	1	C3 Madagascar and Indian Ocean Islands Programme 2010	2010	-	Over	S
Cook Islands	3	Pinca et al. 2009a	2007	-	Under	S
Cuba	1	Bustamante et al. 2000	1996	-	Full	S
Dominica	2	Gobert 2000	1990-1992	-	Over	U
East Timor	1	Barbosa and Booth 2009	2000	-	Under ³	S
Federated States of Micronesia	9	a. Rhodes and Tupper 2007	2003	-	Full	S
		b. Houk et al. 2010	2008-2009	-		
		c. Kronen et al. 2009c	2006	-		
Fiji	11	a. Jennings and Polunin 1995	1992-1993	-	Over	S
		b. Friedman et al. 2010	2002-2009	-		
French Polynesia	3	Kronen et al. 2008	2003-2006	-	Under	S
Grenada	1	Jeffrey 2000	1986-1993	-	Over	S
Guadeloupe	2	Gobert 2000	1990-1992	-	Over	U
Guam	1	Myers 1993	1981-1990	Spear/ speargun	Over	S
Indonesia	8	a. Pet-Soede and Erdmann 1998	1998-1999	Dynamite	Over ³	U
		b. May 2004	2002-2003	Handline, net, trap, spear/ speargun		
Jamaica	8	a. Picou-Gill et al. 1991	1990-1991	-	Over	U
		b. Sary et al. 2003	2000-2001	Handline, net, trap, spear/ speargun		
Kenya	3	c. Murray and Aiken 2005	2001-2002	-		
		a. McClanahan and Mangi 2001	1995-1999	-	Over ³	U
		b. McClanahan et al. 2010	1998-2006	Handline, trap		
Kiribati	5	Awira et al. 2008	2004	-	Under	U
Madagascar	8	a. Laroche and Ramananarivo 1995	1990	Handline, net	Over	U
		b. Laroche et al. 1997	1991	-		
		c. Davies et al. 2009	2008	Handline, net, spear/ speargun		
Malaysia	2	a. Teh et al. 2005	2004	Handline	Over ³	U
		b. Teh et al. 2007	2005	-		
Maldives	1	Sattar 2008	2006-2007	-	Under	S
Marshall Islands	4	Pinca et al. 2009b	2007	-	Under	S
Martinique	2	Gobert 2000	1987-1992	Trap	Over	U
Mauritius	4	a. Lynch et al. 2003	2002	Handline, net, trap	Over	U
		b. Hardman et al. 2008	2007	Net		
Mayotte	1	Minet and Weber 1992	1989	-	Under	U
Nauru	1	Sauni et al. 2007	2005	-	Full	S
Netherlands	2	a. Toller and Lundvall 2008	2007	-	Under	S
Antilles		b. Johnson 2010	2008	Trap		
New Caledonia	5	Kronen et al. 2009a	2003-2007	-	Under	S

Country	No. of cases	Source	Study year	Gear (“-” =no specified gear)	Status ¹	Sustainable ¹
Niue	1	Kronen et al. 2009b	2005	-	Under	S
Palau	3	Friedman et al. 2009a	2007	-	Full	S
Papua New Guinea	3	McClanahan and Cinner 2008	2001-2002	Handline, net, spear/speargun	Under	U
Philippines	9	a. Amar et al. 1996 b. Campos et al. 1994 b. Maypa et al. 2002	1991-1992 1987-1988 1980-2001	- - -	Over	U
Puerto Rico	1	Jimenez and Sadovy 1997	1990	Trap	Over ³	U
Reunion	1	Biais and Taquet 1992	1988	-	Over	U
Samoa	9	a. Craig et al. 2008 b. Vunisea et al. 2008	2002 2005	- -	Over	U
Seychelles	1	Pistorius and Taylor 2009	1995-2007	-	Full	S
Solomon Islands	5	Pinca et al. 2009c	2006	-	Full	S
Sri Lanka	2	Anandappa and Simon 2008	2006	-	Over	U
Tonga	5	Friedman et al. 2009b	2001-2008	-	Over	S
Trinidad and Tobago	1	Cesar and Oxenford 2005	2001	-	Over	U
Turks and Caicos	2	a. Keegan 1986 b. School of field studies	1981 2008	Trap -	Full	U
Tuvalu	4	Sauni et al. 2008	2004-2005	-	Under	S
U.S. Virgin Islands	1	Garrison et al. 2004	1992-1994	Trap	Over	S
Vanuatu	3	Friedman et al. 2008	2003	-	Under	S
Wallis and Futuna	3	Kronen et al. 2009d	2005	-	Under	S

¹Source: Newton et al. 2007.

² Study stated that the catch composition from British Virgin Islands was similar to that recorded for this study of the US Virgin Islands.

³ See text for source of exploitation status.

Table 5.3. Top and bottom 3 records with highest and lowest fishery level r values, respectively.

Country/territory	Fishery r	Major families	Source
<u>Highest fishery r</u>			
Mauritius	1.82	Siganidae (52%), Acanthuridae (17%), Scaridae (10%), Mullidae (8%), Serranidae (4%), others (10%)	Lynch et al. 2003
Philippines	1.79	Siganidae (48%), Scaridae (19%), Labridae (11%), Gobiidae (5%), others (17%)	Campos et al. 1994
Kenya	1.71	Siganidae (36%), Lethrinidae (27%), Scaridae (24%), Mullidae (6%), others (8%)	McClanahan et al. 2010
<u>Lowest fishery r</u>			
Turks and Caicos	0.30	Serranidae (33%), Lutjanidae (26%), Haemulidae (15%), Labridae (9%), other (17%)	School of Field Studies (pers. comm.) 2011
Netherlands Antilles	0.31	Lutjanidae (46%), Haemulidae (15%), Serranidae (15%), Balistidae (10%), other (14%)	Toller & Lundvall 2008
Seychelles	0.36	Serranidae (56%), Lutjanidae (24%), Lethrinidae (20%)	Pistorius & Taylor 2009

Table 5.4. Mean fishery r value by region

Region	No. of cases	Mean \pm std. error
Caribbean	31	0.73 \pm 0.05
Indian Ocean ¹	22	0.98 \pm 0.09
Oceania	78	0.88 \pm 0.03
Southeast Asia ¹	20	0.99 \pm 0.07

¹ Significant mean difference with Caribbean (Tukey test, p<0.05).

Table 5.5 Comparison of official discount rate (δ) with fishery r (r) and corresponding exploitation status. Inferred private discount rates (δ_p) are provided in the last column.

Country	δ	r	$\delta > r?$	$\delta > 2r?$	Status ¹	δ_p
Anguilla	0.10	0.49	no	no	Under	0.39
Antigua and Barbuda	0.11	0.61	no	no	Over	0.92
Bahamas	0.05	0.28	no	no	Full	0.28
Barbados	0.10	0.96	no	no	Over	1.43
Bermuda	0.07	0.51	no	no	Over	0.77
British Virgin Islands	0.10	0.58	no	no	Over	0.87
Comoros	0.11	0.76	no	no	Over	1.15
Cook Islands	0.10	0.91	no	no	Under	0.60
Cuba	0.10	0.48	no	no	Full	0.48
Dominica	0.10	0.68	no	no	Over	1.02
East Timor	0.10	0.83	no	no	Under ²	0.56
Federated States of Micronesia	0.16	0.96	no	no	Full	0.89
Fiji	0.06	0.69	no	no	Over	1.04
French Polynesia	0.10	1.09	no	no	Under	0.69
Grenada	0.10	0.30	no	no	Over	0.45
Guadeloupe	0.10	0.84	no	no	Over	1.26
Guam	0.07	0.74	no	no	Over	1.11
Indonesia	0.16	1.13	no	no	Over ²	1.69
Jamaica	0.18	1.00	no	no	Over	1.50
Kenya	0.13	1.12	no	no	Over ²	1.86
Kiribati	0.10	0.60	no	no	Under	0.44
Madagascar	0.28	1.10	no	no	Over	1.49
Malaysia	0.13	0.73	no	no	Over ²	1.10
Maldives	0.14	0.65	no	no	Under	0.47
Marshall Islands	0.10	0.88	no	no	Under	0.58
Martinique	0.07	1.14	no	no	Over	1.50
Mauritius	0.21	1.38	no	no	Over	2.06
Mayotte	0.07	0.63	no	no	Under	0.46
Nauru	0.10	1.15	no	no	Full	1.15
Netherlands Antilles	0.09	0.63	no	no	Under	0.46
New Caledonia	0.07	0.90	no	no	Under	0.60
Niue	0.07	1.15	no	no	Under	0.72
Palau	0.10	0.88	no	no	Full	0.88
Papua New Guinea	0.11	1.18	no	no	Under	0.74
Philippines	0.15	0.88	no	no	Over	1.41
Puerto Rico	0.10	0.58	no	no	Over ²	0.86
Reunion	0.07	0.57	no	no	Over	0.85
Samoa	0.10	1.08	no	no	Over	1.62
Seychelles	0.10	0.36	no	no	Full	0.36
Solomon Islands	0.10	0.76	no	no	Full	0.76
Sri Lanka	0.07	0.74	no	no	Over	1.10
Tonga	0.12	0.84	no	no	Over	1.26
Trinidad and Tobago	0.10	0.37	no	no	Over	0.71
Turks and Caicos	0.07	0.37	no	no	Full	0.50
Tuvalu	0.10	0.76	no	no	Under	0.53
U.S. Virgin Islands	0.07	0.54	no	no	Over	0.80
Vanuatu	0.08	1.29	no	no	Under	0.79
Wallis and Futuna	0.07	0.81	no	no	Under	0.55

¹Source: Newton et al. (2007)

²See text for source of exploitation status

Table 5.6. Summary of families which may potentially be overfished ($r < \delta$) for each country or territory.

Country/territory	δ	Families with $r < \delta$
Anguilla	0.10	Ginglymostomatidae
Antigua and Barbuda	0.11	-
Bahamas	0.05	-
Barbados	0.10	-
Bermuda	0.07	-
British Virgin Islands	0.10	-
Comoros	0.11	-
Cook Islands	0.10	-
Cuba	0.10	Carcharhinidae, Dasyatidae
Dominica	0.10	-
East Timor	0.10	Carcharhinidae, Rajidae
Federated States of Micronesia	0.16	Bolbometopon muricatum
Fiji	0.06	-
French Polynesia	0.10	-
Grenada	0.10	-
Guadeloupe	0.10	-
Guam	0.07	-
Indonesia	0.16	Sphyrnidae
Jamaica	0.18	Muraenidae
Kenya	0.13	Sphyrnidae
Kiribati	0.10	-
Madagascar	0.28	Congridae, Dasyatidae, Fistularidae, Muraenidae, Rhinobatidae, Tetraodontidae, Torpedinidae, Carcharhinidae, Sphyrnidae,
Malaysia	0.13	Dasyatidae, Monacanthidae, Rhinobatidae, Carcharhinidae
Maldives	0.14	-
Marshall Islands	0.10	-
Martinique	0.07	-
Mauritius	0.21	Monacanthidae, Tetraodontidae, Fistularidae
Mayotte	0.07	-
Nauru	0.10	-
Netherlands Antilles	0.09	Carcharhinidae
New Caledonia	0.07	-
Niue	0.07	-
Palau	0.10	-
Papua New Guinea	0.11	-
Philippines	0.15	-
Puerto Rico	0.10	Dasyatidae, Ginglymostomatidae
Reunion	0.07	-
Samoa	0.10	Carcharhinidae, Dasyatidae
Seychelles	0.10	-
Solomon Islands	0.10	-
Sri Lanka	0.07	-
Tonga	0.12	-
Trinidad and Tobago	0.10	-
Turks and Caicos	0.07	-
Tuvalu	0.10	-
U.S. Virgin Islands	0.07	-
Vanuatu	0.08	-
Wallis and Futuna	0.07	-

Table 5.7. Private discount rates (annual rate per year) by region and exploitation status.

	Mean \pm std. error
<u>Region</u>	
Caribbean	1.02 \pm 0.09
Indian Ocean	1.42 \pm 0.14
Oceania	0.89 \pm 0.04
Southeast Asia	1.45 \pm 0.11
<u>Status</u>	
Overexploited	1.37 \pm 0.05
Underexploited	0.58 \pm 0.02
Fully exploited	0.79 \pm 0.05

Table 5.8. Results of sensitivity analysis of different h assumptions on fishery level intrinsic growth rates for the 3 cases with highest and lowest fishery level r .

Fishery case	Fishery level r		
	<u>Current h</u>	<u>$h=0.9$</u>	<u>$h=0.55$</u>
<u>Top 3 highest fishery level r</u>			
Mauritius	1.82	2.00	0.79
Philippines	1.79	1.92	0.78
Kenya	1.71	1.91	0.76
<u>Top 3 lowest fishery level r</u>			
Bahamas	0.28	0.56	0.23
Turks and Caicos	0.30	0.57	0.23
Netherlands Antilles	0.31	0.57	0.23

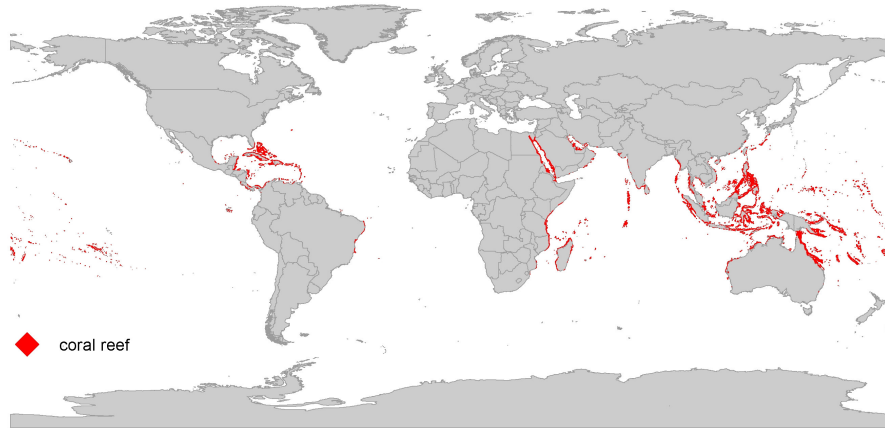


Figure 5.1. Map of global coral reef distribution. Source: coral reef distribution data from UNEP-WCMC (<http://data.unep-wcmc.org>).

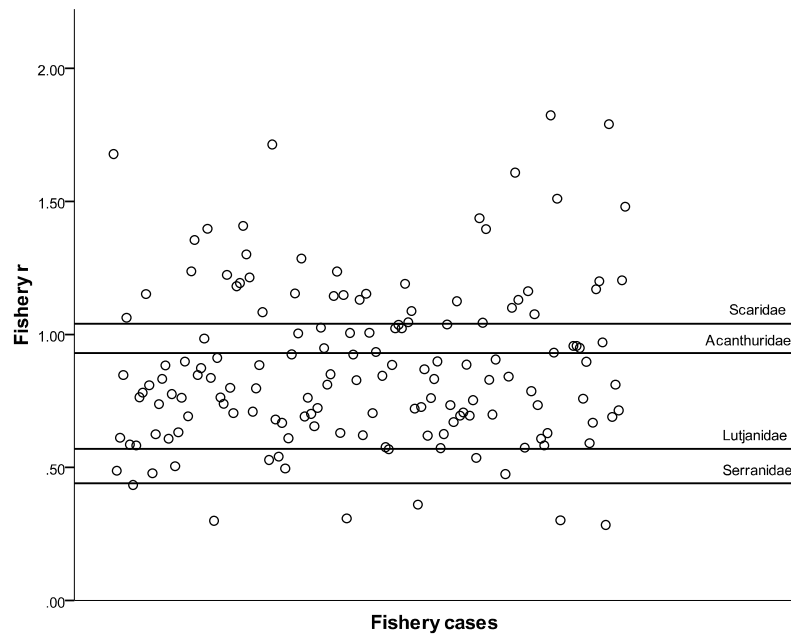


Figure 5.2. Distribution of fishery r values for all cases. The horizontal lines show the mean family intrinsic growth rate for Serranidae (groupers), Lutjanidae (snappers), Acanthuridae (surgeonfish), and Scaridae (parrotfish).

Chapter 6: Conclusion

The linking thread through the chapters in this thesis is an attempt to better understand the dynamics of discounting among small-scale fishers. I have examined this under different contexts: contrasting fisheries management systems, socio-economic conditions, and stages of fisheries exploitation. I started the thesis by using a case study to illustrate why small-scale fisheries warrant our attention. I then addressed my first and second research questions (what is the discount rate of fishers, and under what conditions fishers have low discount rates) in Chapters 3 and 4. Finally, I expanded my case studies to a global study of reef fisheries in order to further investigate the magnitude of private discount rates, and the relevance of discount rates to fisheries exploitation status. In the next section I discuss how my results have addressed the research questions I set out with, and the contribution and significance of my results given the current state of knowledge about fishers' private discount rates. I then outline some limitations of this research, and identify directions for future research.

6.1 What are the private discount rates of fishers?

Small-scale fishers have commonly been characterised as having high discount rates (Pollnac, 1985), although there is sparse empirical evidence to support this. Using two different approaches, I found that the absolute values of reef fishers' private discount rates were indeed high (Chapter 3 and 5). In Sabah and Fiji, average annual discount rates for receiving one month delayed payments were 265% and 208%, respectively (Chapter 3), while an average of 107% was inferred for reef fishers worldwide (Chapter 5). As noted in the respective chapters, these represent fishers' private discount rates in non open access situations, and are consistent in magnitude with the average of 130% Akpalu (2008) estimated for fishers in Ghana. On the other hand, they are substantially higher than the median of 30-40% estimated for fishers in Ireland (Curtis, 2002). While there are two other studies on fishers' discount rates in developing countries (Fehr and Leibbrandt, 2008; Nguyen, 2009), the authors did not document the absolute rates. Thus, given the present limited studies, it appears that, at least in developing countries, a probable range for fishers' annual discount rates is from 100% to 300%. This suggests that overall, fishers discount the future heavily, i.e., they are impatient and want to obtain benefits from the fisheries resources immediately.

6.2 Under what conditions do fishers exhibit low discounting?

There are numerous studies in other fields examining the demographic and socio-economic correlates of discount rates (e.g., Pender, 1996; Becker and Mulligan, 1997; Godoy and Jacobson, 1999; Poulos and Whittington, 2000; Kirby et al., 2002). Although there are contradictory findings about the direction of relationship between explanatory variables and discount rates, it seems that variables such as age, education, and income are common correlates of discount rates. In contrast, I found that demographic and socio-economic variables were not useful predictors of low discounting behaviour among fishers (Chapter 4). Instead, fishery (boat ownership and relative fish catch) and site (protection initiative and study site) level variables predicted low discount rates among fishers in Sabah and Fiji. Some of these results are consistent with the literature. For instance, Pollnac and Poggie (1978) also found boat ownership to be correlated with a delayed economic gratification orientation, which is analogous to a low discount rate, among fishers.

The significance of the protection initiative variable supports my result from Chapter 3, wherein fishers from villages where there was some form of fishing ground protection had lower discount rates. As discussed in Chapter 4, this brings up the possibility that social capital may contribute to a conservation orientation, but I was not able to further address this with the data I had. There are additional questions arising from this chapter's results that I could not resolve. First, I could not single out what local socio-cultural, economic, or environmental factors made fishers in Sabah more likely to choose low discount rates compared to Fiji. A related question is why the same variables had contradictory effects on low discounting in Sabah and Fiji. Overall, my results did not provide a conclusive answer to my research question. Rather, the best answer I can provide is that low discounting behaviour appears to depend on local socio-cultural, economic, or ecological factors that I have not managed to fully capture in my model. This reiterates other research which point to the importance of understanding local conditions in order to understand why fishers make the fishing allocation decisions that they do (Cinner et al., 2009a; McClanahan et al., 2009a). Thus, although inconclusive, this outcome provides a starting point for pursuing further investigations.

6.3 Are discount rates reflective of the exploitation status of fisheries?

Chapter 5 presented evidence that official discount rates, which are the rates that fisheries managers most likely use for evaluating projects, do not fully reflect the short term

perspective fishers employ when making fishing decisions, and subsequently offer too optimistic a perception about the state of fisheries. Instead, fishers' private discount rates are more likely to capture the exploitation status. This provides two unique insights for management: First, there is a clear discrepancy in the future outlooks of managers and fishers which has to be rectified, or at least articulated in the decision making process. The results in Chapter 5 support an earlier observation by Clark (1985), who stated that disagreement over fisheries policies stems from a difference in discount rates. Second, to address this discrepancy, managers should consider using private discount rates to evaluate policies which affect local fishers, as this will likely increase the chances of acceptance and compliance by the fishing community. A more comprehensive comparison of discount rates and exploitation status will require a more uniform set of data on reef fish catch composition across space, time, and gears; this in turn points to the need for improved monitoring of reef fisheries catches, a long standing challenge in reef fisheries management (Johannes, 1998; Zeller et al., 2006a; 2007).

6.4 Significance and limitations of thesis research

The overall significance of this research is that it has shown that small-scale fishers' discount rates are generally high, a theme that has been repeated in the fisheries literature, but has limited empirical support. In addition, my study has contributed several unique insights about fishers' private discount rates, an area of research that has not received much attention in the fisheries literature to date. The first is that discount rates in both open access and traditionally managed fisheries are similarly high, which is counter-intuitive to theoretical expectations. It is further intriguing that a greater proportion of fishers in the open access system chose low discount rates. Second, my research is perhaps one of the few to examine the socio-economic predictors of discounting behaviour among fishers. This research adds a new perspective to the growing body of literature on fishers' behaviour, which is increasingly recognised as being necessary for more successful fisheries management (Salas and Gaertner, 2004). Lastly, Chapter 5 provides a comparative analysis between discount rates and fisheries exploitation status on a worldwide basis that has not been examined to date.

An important application of this study is that it provides fishery managers with an approximate range for fishers' discount rates, so that managers can now take steps to address, and close the gap between official and fishers' private discount rates. For instance, managers can consider using private discount rates instead of official rates to assess regulations that

will affect fishers. Another application of this study is that the estimation approach I took in Chapter 2 can readily be applied by fishery managers or other researchers to quantify the socio-economic contribution of small-scale as well as commercial fisheries.

The strength of this research is the integration of economic and ecological concepts to examine fishers' discount rates. It is, as far as I am aware, the first to investigate fisher's private discount rates on a case study basis as well as globally through the use of experimental and inferential techniques. Using a combination of social, experimental economics, quantitative, and theoretical approaches, I have obtained similar estimates for the magnitude of fishers' private discount rates, thus providing some assurance about the validity of my results.

There are, however, limitations to this study. One limitation is that I cannot identify the drivers that lead to the observed discount rates, as the comparative study in Chapter 3 and logistic regression model in Chapter 4 were not intended to examine causative factors of discount rates. Instead, the results raise interesting suggestions for correlates or predictors of discount rates that warrant further investigation. Further, a limitation of using case studies in Chapter 5 is the possibility of confounding factors on the composition of reef fish catches, due to the lack of uniformity in time and gear. However, I showed that these factors had minimal influence on the results. I acknowledge that due to the lack of data, parts of my analysis necessitated making assumptions which may have been subjective. However, as indicated in Chapters 2 and 5, the general picture of my findings remains consistent, even though the magnitude of the outcomes may change under different assumptions of certain variables.

6.5 Future directions

This thesis has investigated a relatively new research topic on which there is sparse literature for comparative purposes. I see two main research topics on fishers' discount rates that would benefit from further research. First, there is a need for more empirical studies that elicit the private discount rates of fishers in order to establish a more representative range of fishers' discount rates. The diverse discount rate elicitation methods currently in use in experimental economics makes it difficult to compare discount rates across studies (Cardenas and Carpenter, 2008). Thus, further empirical studies of fishers' discount rates should follow a consistent elicitation methodology.

Second, there is a lot of scope for research on the correlates or drivers of fishers' discounting behaviour. The results from the logistic model in Chapter 4 indicate that we need a better understanding of the interaction between local conditions and fishers' discounting behaviour. Further research that aims to find a clearer picture of what factors predict or are correlated to fishers' discount rates will need to identify explanatory variables that are more representative, or are better able to capture local differences in socio-cultural, environmental, or economic conditions. In Chapters 3 and 4, I suggested that social capital attributes may be correlated to lower discount rates, and this relationship warrants further research. As such, existing frameworks for assessing social capital (e.g., Rudd, 2004; Grafton, 2005) can be incorporated into surveys to elicit fishers' discount rates. Once the correlates of fishers' discount rates are established, future research can also focus on examining the causal relationship between socio-economic factors and discount rates. The development of such a model will enable managers to identify appropriate intervention policies which directly address the drivers of high or low discount rates.

One aspect of discounting I have not addressed in my thesis is the psychological and ethical aspects of time preference. Such studies may also provide a better insight into why fishers may make the fishing effort decisions that they do. Bearing in mind the complexity of human behaviour, and the multiple factors that affect our perceptions and future outlooks, it may be some time before we can obtain a comprehensive conceptual understanding about fishers' discount rates. However, the studies I mentioned above may be a starting point towards this goal.

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Appendices

Appendix A Reconstructed and reported traditional catch (tonnes year⁻¹) and reconstructed and reported number of traditional fishers for 1950-2009.¹

Year	Reconstructed no. of traditional fishers	Reported number of traditional fishers ²	Reconstructed traditional catch (t·yr ⁻¹)	Reported traditional landings ² (t·yr ⁻¹)
1950	9531	-	25034	-
1951	9008	-	24729	-
1952	9088	-	26028	-
1953	9262	-	27623	-
1954	9310	-	28872	-
1955	9377	-	30193	-
1956	9491	-	31687	-
1957	9604	-	33204	-
1958	9780	-	34971	-
1959	9916	-	36635	-
1960	10264	-	39141	-
1961	10328	-	40607	-
1962	10364	-	41980	-
1963	10373	-	43248	-
1964	10451	-	44815	-
1965	10518	-	46347	-
1966	9894	-	44774	-
1967	9775	-	45394	-
1968	9717	-	46278	-
1969	9701	-	47354	-
1970	9714	-	48569	-
1971	9842	-	49212	-
1972	9702	-	48509	-
1973	9883	-	49415	-
1974	10535	-	52673	-
1975	10772	-	53859	-
1976	11161	-	55806	-
1977	11491	-	57457	-
1978	11846	-	59230	-
1979	12047	-	60237	-
1980	12524	-	62619	-
1981	12242	-	60535	8387
1982	12946	-	63306	10563
1983	13627	-	65886	19892
1984	14390	-	68783	20311
1985	15177	-	71713	16616
1986	16012	-	74777	16419
1987	16906	-	78020	16221
1988	17753	4921	80953	21568
1989	18879	5035	85051	13491
1990	20092	4738	89411	12380
1991	22123	4752	97231	20378
1992	23786	5672	103231	44440
1993	25545	6351	109460	43566
1994	28228	7331	119405	42901
1995	29514	7341	123220	52795
1996	31129	7851	128250	52795
1997	32362	7851	131550	51719
1998	33581	7708	134661	49605
1999	36136	7708	142919	48784
2000	34205	7708	133400	46652
2001	35649	7708	137070	40914

Year	Reconstructed no. of traditional fishers	Reported number of traditional fishers²	Reconstructed traditional catch (t·yr⁻¹)	Reported traditional landings²(t ·yr⁻¹)
2002	36257	7708	137413	44802
2003	37847	7708	141360	41001
2004	39600	7708	145730	48920
2005	41824	7708	153911	41269
2006	43034	7708	158365	43378
2007	45041	9102	165752	41022
2008	46843	8040	172381	36172
2009	48833	8544	179705	36922

¹ Source: Teh et al. (2009a).

² Note that this differs from Teh et al. (2009a) due to the categorisation of gillnets as a commercial gear in Chapter 2.

Appendix B Interview questionnaire for Sabah (English version)

ID_____

1. Personal/Demographic

Name:

Date:

Age:

Gender:

Education: Primary/Secondary/None

Ethnicity:

Kampung:

Full-time/ Part-time:

I. DEMOGRAPHIC INFORMATION

1. Where are you originally from?

2. How long have you lived in this village? _____

3. Why did you move to this village?

Fishing	Other work	Family & friends	
Other			

4. Marital status: single____ married____

5. How many people live in your house? _____

Adult male	Adult female	Male children	Female children
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II. FISHING ACTIVITY

1. How many years have you been fishing?

2. Do you fish by yourself or with someone else?

FISH ALONE				
WITH SOMEONE	1 other	2 other	3 other	> 3 others

3. Do you own your own boat?

YES:	Pumbot / sangkut	HP:	Length:	Age:
NO:	Owner is:	Friend	Family	
	Pay rent? Y/N	RM_____per day/week/month		

Fill in table for no. 4-11

Gear, catch, effort

4. What fishing gears do you use?

5. After listing gears: Please rank the gears according to which is most important

6. How many days per week do you use each gear? (low and high)
7. How much fish do you catch with xxx gear a day? We know that the amount of fish you catch is different each day, but say on a good day, how much fish would you catch? On a bad day? On an average day?
8. How many hours do you fish each day during bad, good, average day? ** specify which months?
9. How many times do you go out each day?
10. For each gear you use, what % of your catch consists of ikan batu, tengirri, tulai/rumahan/termanung, sunnoh, ikan putih etc.
11. Do you fish from your village all year? Y/N

Fishing location	Months	Gear
Village		
Other _____		

Gear	Rank	Days per week (Low)	Days per week (High)	Bad catch (kg/day)/ season	Good catch (kg/day)/ season	Average catch (kg/day) / season	No. Hrs Good/ no. times per day	No. Hrs Bad/no. times per day	No. Hrs Average/ no. times per day	No. Ppl in household who use gear
Pancing				/	/	/	/	/	/	
Hantuk				/	/	/	/	/	/	
Tunda				/	/	/	/	/	/	
Pukat (specify type)				/	/	/	/	/	/	
Bubu				/	/	/	/	/	/	
Panar				/	/	/	/	/	/	
Cast net				/	/	/	/	/	/	
Prong (sotong)				/	/	/	/	/	/	
Gleaning				/	/	/	/	/	/	
Other				/	/	/	/	/	/	

Catch composition (%)

Gear	Ikan batu	Sunnoh (hidup)	Putih	Tengirri	Termanung/tulai/ rumahan	Other
Pancing						
Hantuk						
Tunda						
Pukat						
Bubu						
Panar						
Cast net						
Prong (sotong)						
Gleaning						
Other						

III. ECONOMIC

Fishing Income

1. How much of the fish that you catch per day is kept for food, and how much is sold?

Kept (% or kg)	Sold (% or kg)

2a. How many years have you been catching fish to sell?

2b. Before that did you fish for food, or not fish at all?

3a. Which species do you sell?

3b. What is your daily/weekly income from selling fish and other marine resources?

	Income/day/ week/month (Good)	Net?	Which months?	Income/day/ week/month (Bad)	Net?	Which months?
Ikan mati						
Ikan hidup						
Sotong						
Balat / lepas						
Other						

4. What is your fishing cost per month for fishing gear, fuel, and boat maintenance?

Item	RM	Month/week/day
Gear		
Fuel		
RM per litre/gallon/bottle:		
Boat maintenance		

Occupations (Occupational multiplicity)

1. How many people in your household work?
2. What jobs do you and other members of your household do to earn money or bring food for the family? Fill in Table

ACTIVITY	Check if applicable	No. of People	Rank of Importance	Notes/Detail
Fishing				
Gleaning				
Seaweed				
Grocery/coffee shop				
Farming				
Food stall				
Salaried Employment _____				
Tourism				
Informal Economic Activities				
Remittance from family				
Other				

3. Occupational mobility: What other work have you done in the last 5 years?

Occupation	Main job	Why stop?	Could get similar now? (y/n)	Prefer to current activity? (y/n)

Household income and expenditure

1. What is total household income from all family members per month? (net?)

2. What is household expenditure per week/ per month? (if cannot answer, then what is your expenditure in the past 2 weeks?)

Income	Time (Week/month)	Expenditure	Week/month

3. Do you have access to credit? (If you have to borrow money to buy fishing gear, food, etc., who do you borrow from?)

No (don't borrow) _____ Fish middleman _____ Store owner _____

Family/friends _____ Bank/financial institution _____ Co-operative _____

4a. If have access to credit: Do you repay your money with interest? Y/N

4b. How much interest do you have to pay?

5a. Do you have any savings? Y/N

5b. On average, how much (% or RM) of your monthly fishing income can you save?

IV. CAPACITY TO ADAPT

Capacity to anticipate change and develop response

1a. If you were to get 20% less catch **all year**, what would you do?

keep fishing at same amount	Fish harder	Fish less	move locations	change gear	leave fishery- where to?
Other					

If keep fishing, for how long?

1b. if you were to get 50% less catch **all year** what would you do?

keep fishing at same amount	fish harder	Fish less	move locations	change gear	leave fishery- where to?
Other					

If keep fishing, for how long?

Causality & intervention – perception of link between humans and marine environment

1. Is there more or less fish on the reef now compared to 5 years ago?

2. How do you know there are more/less fish now?

3. What do you think caused there to be more/less fish?
4. What can be done around here (kampung/Banggi) to increase the number of fish on the reef?

Possible responses (Tick if any are mentioned):

- a) restrict gear _____ b) stop fish bombing _____ c) ban commercial vessels _____
 d) control migrants _____

V. SOCIAL DIMENSIONS

Reciprocity and exchanges

1. Do you share your fish with friends/family?

How often? 1x/week >1x/week 1x/month <1x/month

2. Do you ever share your boat with another fisherman/take another fisherman out to fish with you?

If YES, do you charge rent for your boat? Get fish in return?

Common rules, norms, and sanctions

1. Are there any rules/regulations about marine resource use in this area?
2. Are there fishing grounds that you are not allowed to use?
- 2a. If YES – do you continue to use those fishing grounds?

Never	Sometimes	All the time
-------	-----------	--------------

Do other people in this kampung continue to use the closed off fishing grounds?

Never	Sometimes	All the time
-------	-----------	--------------

- 2b. If NO - Pretend that there is a new law that says you cannot fish in your fishing grounds.

What would you do?

Go to another fishing ground	Get another job	Continue fishing (ignore law)
------------------------------	-----------------	-------------------------------

3. Are you involved in making decisions about marine resource use / management?
4. Who would you **trust** to manage your fishing grounds?

Government (Fisheries, Sabah Parks)	Ketua kampung	Other kampung people	All fishers who fish here, including those from adjoining kampungs	NGO e.g., WWF
---	---------------	-------------------------	--	------------------

Why?

Pretend you could make decisions about the fishing grounds:

5. Which are the fishing areas you would close off? To whom?

6. Which are the fishing grounds that are essential for you, that you want to leave open (while all other areas are closed)?

7. Are there groups of fishers you want to exclude from your fishing grounds? Who?

Area to close off	Area to leave open	Who to exclude

8. Of all the people who fish in Banggi water, what do you think is their inclination to cooperate and follow new regulations?

	Not willing 1	A little willing 2	Willing 3	Very willing 4
Fishers from this kampung				
Fishers from other kampung				
Commercial fishers (trawl/ purse seine)				
Migrants				

9. What priorities are important to you if a managed area were to be created?

	Not important 1	A little bit important 2	Indifferent 3	Important 4	Very important 5
Maximise catch					
Maximise revenue					
Generate ecotourism					
Control commercial intrusion					
Conserve species					

Stop fish bombing	
Other	

Connectedness, networks and groups

1a. Is there a fishermen's organization in this kampung? Y/N

1b. If YES Are you a member?

1c. Have you participated in any meetings?

1d. How many of these meetings have you attended?

None__ Few__ Most__ All__

2. Have you been involved in any non-family related community activities in the past year (e.g. gotong royong, pesta, tamu, sporting events)?

VI. DISCOUNT RATE ELICITATION QUESTIONS

Exercise 1. Binary choice series

Now we want to do an exercise with you. The purpose of this exercise is to see how you make decisions in the future. I am going to give you a series of choices for receiving money either today, or sometime in the future. To start off with, you can choose between receiving \$100 now (show card) or \$105 in one month (show card). Which would you prefer? Continue down list, marking choices.

SERIES 1

TODAY	IN 1 MONTH
100	105
100	110
100	115
100	120
100	125
100	130
100	135
100	140
100	145
100	150
100	155
100	160
100	165
100	170

SERIES 2

TODAY	IN 6 MONTHS
100	134
100	177
100	231
100	299
100	381
100	483
100	605
100	753
100	929
100	1139
100	1386
100	1677
100	2017
100	2413

SERIES 3

1 YEAR	1 YEAR + 1 MONTH
500	525
500	550
500	575
500	600
500	625
500	650
500	675
500	700
500	725
500	750
500	775
500	800
500	825
500	850

Appendix C Interview questionnaire for Fiji

1. PERSONAL/DEMOGRAPHIC

Name:

Date:

Age:

Gender:

Education: Primary/Secondary/None

Indian/Fijian/Other:

Village:

Full-time/ Part-time:

1. How many years have you been fishing?

2. Have you always lived in this village?

If NO, where did you come from? When did you move here?

3. How many people are there in your household?

4. Marital status: single___ married___

4a. If married, how many children do you have?

2. FISHING ACTIVITY

1. What gear(s) do you use to fish?

2. How often do you use each gear?

3. What are the typical fish species you catch with each gear?

4. How many hours do you spend fishing per trip?

5. How much fish do you catch per trip?

6. Do you glean on the reef?

a. How many people in your family glean?

b. How often do you go gleaning in a week?

c. What do you collect?

d. Do you sell the collected products or keep it for your own consumption?

7. Do you fish for the purpose of

(a) keeping the fish for own consumption → go to section 2I.

(b) selling your catch and/or bartering → go to section 2II

(c) both (a) and (b) → Complete sections 2I and 2II

2I. Subsistence fishing

1. On average how much fish do you keep for your own consumption?
2. Which species of fish do you keep for your own consumption?
 - a. Has this changed over time?
3. On average how many days per week do you go fishing for food?
4. Has this fishing time increased or decreased from the past?
5. How many people do you feed with your daily catch?
6. Is the fish you catch enough to feed all the people in your household?

2II. Artisanal fishing

1. How long have you been engaged in fishing for the purpose of selling your catch (artisanal fishing)?
 2. Compared to 5 years ago, has there been an increase or decrease in artisanal fishing in this village? 10 years ago?
 3. What proportion of your catch do you sell?
 4. Do you:
 - (i) sell to a fish buyer/middleman → go to 5
 - (ii) sell the catch yourself? → go to 6
 - 5a. Who do you sell to?
 - 5b. How are the fish brought to market?
 - 5c. What price do you get for each of the species you sell? Fill in table in #9.
 6. Where do you bring the fish to sell?
 - (i) municipal market → go to # 8
 - (ii) sell to other villagers door to door/informally. → go to #7.
 - (iii) other
 - 7a. Why do you choose to sell the fish directly to villagers?
 - (i) no fish buyer in this village
 - (ii) fish buyer doesn't provide a good price
 - (iii) municipal market is too far away
 - 7b. What price do you get for the fish species you sell? Fill in table in #9
 - 8a. How many times a week do you sell fish at the municipal market?
 - 8b. How far away is the nearest municipal market that you sell your fish at?
- Do you rent a stall at the market? Y/N

If YES: How much is your rental?

8c. How many months per year do you sell fish at the market?

9. What price do you get for each of the species you sell?

<u>Species</u>	<u>Price (F\$/kg)</u>

10. How much do you earn from fishing per month? (clarify if it's revenue or net income)

a. Does this income vary throughout the year?

10a. Is fishing your only source of income? Y/N

If NO: a. What is your other job?

b. Do you work at your other job year round?

11. How much income do you get from that job ?

12. Is the income you earn from fishing enough to live on? Y/N

13. If there were other jobs available that offer the same income as fishing, would you want to switch jobs? Y / N

If NO, why?

Enjoy fishing/want to be close to the sea _____

No other skills _____

Want to be own boss _____

Other _____

14. Do other members of your household work? Y/N

If YES a. How much does each household member contribute to household income?

Response to shifts in export market

1. Do you participate in any of these trades?

Live reef food fish _____

Beche de mer _____

Aquarium fish _____

Live rock _____

Trochus _____

Fresh reef fish for sale _____

2b. When did you start participating in these trades?

3a. When you first started targeting these species, what were their prices?

3b. What are their prices now?

4. Who do you sell the live fish/beche de mer/live rock/trochus/ fresh fish to?

5. Do you know whether the species are sold domestically or exported?

6. How much income do you make from selling live fish/ beche de mer/ live rock/ trochus/ fresh reef fish trade?

7. Has participating in the trade increased your daily/monthly fishing income? Y/N

If YES By how much has it increased your daily/monthly fishing income?

8a. Do other people in this village participate in the LRFF/aquarium/beche de mer/live rock/trochus/fresh reef fish trade also?

8b. Have you noticed a change in the abundance of the target species since you started fishing for them?

8c. Has participation in the trade caused any changes to socio-economic or marine management aspects in the village? Y/N

If YES, please describe the changes

9. Compared to 5 years ago, are you more likely to sell all your fish now rather than keeping a portion for your own consumption? 10 years ago?

If MORE LIKELY → go to 10

If LESS LIKELY → go to 11

10. Why are you more likely to sell your fish now?

- Able to sell fish for higher price now
- Catch too little fish so must sell all that is caught
- Fish alternatives are more easily available
- Fish alternatives are cheaper to buy than before
- Easier to get fish to market

11. Why are you less likely to sell your fish now?

3. COST QUANTIFICATION – quantify net income from harvesting species meant for export for each part of the supply chain. [Interviews with fishers as well as with wholesalers/exporters and middlemen]

Boat & Gear costs

- 1a. Do you own your own boat/canoe?
- 1b. How many years does a boat last?
- 1c. How much did your boat cost?
- 1d. How much did your engine cost (if applicable)?
- 1e. Where did the money come from? Your own, trader or government?
- 2a. How much fuel do you use for each fishing trip on average?
- 2b. How much do you pay for fuel per fishing trip
- 3a. How much time do you spend repairing/maintaining your boat and gear every month?
- 3b. On average, how much money do you spend on maintaining your boat and gear every month?

Costs associated with selling fish:

- 4a. What is the rental per month for your stall at the market?
 - 4b. What is the transportation cost to bring your catch to the market?
 - 4c. Do you hire family or workers to help you sell the fish or transport the fish? Y/N
- If YES, what wage do you pay per month for your helper?

Cost factor	F\$/unit	# of units purchased per year
Hook & line: - Hooks - Line - Reel - Weight - Bait		
Gillnet: - net - floats		
Trap - wire - frame		
Spear and speargun Mask Snorkel Fin		

4. DISCOUNT RATE ELICITATION EXERCISE

Now we want to do an exercise with you. The purpose of this exercise is to see how you make decisions about money. I am going to give you a series of choices for receiving money either now, or sometime in the future. To start off with, you can choose between receiving \$400 now (show card) or \$405 in one month (show card). Which would you prefer? Continue down list, marking choices.

NOW (\$)	1 MONTH (\$)	Selection
400	420	A B
400	435	A B
400	450	A B
400	465	A B
400	480	A B
400	495	A B
400	510	A B
400	525	A B
400	540	A B
400	555	A B
400	570	A B
400	585	A B
400	600	A B

Now the choice is between receiving \$400 now, and \$550 in 1 year. Which would you prefer?

(Go down the list)

NOW (\$)	1 YEAR (\$)	Selection
400	550	A B
400	600	A B
400	650	A B
400	700	A B
400	750	A B
400	800	A B
400	850	A B
400	900	A B
400	950	A B
400	1000	A B
400	1050	A B
400	1100	A B
400	1150	A B

Appendix D Immediate and future payment amounts with associated discount rates for each choice series.

Appendix D1. Immediate and future payment amounts (RM) and associated discount rate (annual %) for each option in Series A_s (Sabah).

Payment today (RM)	Future payment Delay = 1 month (RM)¹	Implied mid-point discount rate (annual %)
100	105	29
100	110	86
100	115	141
100	120	193
100	125	243
100	130	291
100	135	337
100	140	381
100	145	424
100	150	466
100	155	506
100	160	545
100	165	583
100	170	619

¹ The exchange rate on 27 Oct. 2010 is 1 USD = 3.1 RM

Appendix D2. Immediate and future payment amounts (RM) and associated discount rate (annual %) for each option in Series B_s (Sabah).

Payment today (RM)	Future payment Delay = 6 months (RM)	Implied mid-point discount rate (annual %)
100	134	29
100	177	86
100	231	141
100	299	193
100	381	243
100	483	291
100	605	337
100	753	381
100	929	424
100	1139	466
100	1386	506
100	1677	545
100	2017	583
100	2413	619

Appendix D3. Payment amounts (RM) for delays of 1 year and 1 year + 1 month, and associated discount rate (annual %) for each option in Series C_s (Sabah).

Payment in 1 year (RM)	Payment in 1 year + 1 month (RM)	Implied mid-point discount rate (annual %)
500	525	29
500	550	86
500	575	141
500	600	193
500	625	243
500	650	291
500	675	337
500	700	381
500	725	424
500	750	466
500	775	506
500	800	545
500	825	583
500	850	619

Appendix D4. Immediate and future payment amounts (FJD) and associated discount rate (annual %) for each option in Series A_F (Fiji).

Payment today (FJD)	Future payment Delay = 1 month (FJD)¹	Implied mid-point discount rate (annual %)
400	420	29
400	435	80
400	450	121
400	465	161
400	480	200
400	495	237
400	510	274
400	525	309
400	540	343
400	555	377
400	570	409
400	585	441
400	600	471

¹ The exchange rate on 27 Oct. 2010 is 1 USD = 1.9 FJD

Appendix D5. Current and future payment amounts (FJD) and associated discount rate (annual %) for each option in Series B_F (Fiji).

Payment today (FJD)	Future payment Delay = 1 year (FJD)	Implied mid-point discount rate (annual %)
400	550	27
400	600	36
400	650	45
400	700	52
400	750	60
400	800	66
400	850	72
400	900	78
400	950	84
400	1000	89
400	1050	94
400	1100	99
400	1150	103

Appendix E Estimated intrinsic growth rates (r) for reef fish species

<u>Family</u>	<u>Taxon name</u>	<u>r</u>	<u>Family</u>	<u>Taxon name</u>	<u>r</u>
Acanthuridae	Acanthurus achilles	1.54	Belonidae	Pseudobalistes flavimarginatus	1.26
	Acanthurus bahianus	0.84		Rhinecanthus aculeatus	1.22
	Acanthurus blochii	0.36		Rhinecanthus rectangulus	0.65
	Acanthurus chirurgus	0.54		Rhinecanthus verrucosus	1.32
	Acanthurus coeruleus	0.23		Sufflamen fraenatum	0.45
	Acanthurus gahhm	0.75	Blenniidae	Xanthichthys ringens	1.51
	Acanthurus guttatus	1.51		Strongylura incisa	0.59
	Acanthurus leucocheilus	0.52		Strongylura leiura	0.67
	Acanthurus lineatus	1.00		Tylosurus acus melanotus	0.68
	Acanthurus mata	0.29	Bothidae	Tylosurus crocodilus crocodilus	0.43
	Acanthurus nigricauda	1.60		Omobranchus elongatus	2.99
	Acanthurus nigrofuscus	0.90	Bramidae	Bothus lunatus	0.27
	Acanthurus nigroris	1.53		Brama orcini	0.52
	Acanthurus nubilus	1.51	Caesionidae	Caesio caeruleaurea	1.51
	Acanthurus olivaceus	0.78		Caesio cuning	0.54
	Acanthurus pyroferus	0.87		Caesio lunaris	1.44
	Acanthurus tennentii	1.45		Caesio teres	1.44
	Acanthurus triostegus	2.02		Caesio xanthonota	1.44
	Acanthurus xanthopterus	0.36		Pterocaesio chrysozona	3.12
	Ctenochaetus binotatus	1.59		Pterocaesio marri	1.51
	Ctenochaetus striatus	3.18		Pterocaesio pisang	3.37
	Ctenochaetus strigosus	3.20		Pterocaesio tesellata	2.97
	Melichthys niger	0.48		Pterocaesio tile	1.58
	Naso annulatus	0.27	Callionymidae	Synchiropus corallinus	2.23
	Naso brachycentron	0.13	Carangidae	Alectis ciliaris	0.17
	Naso brevirostris	0.81		Alectis indicus	0.24
	Naso caesius	0.50		Atule mate	1.79
	Naso fageni	0.23		Carangoides bartholomaei	0.59
	Naso hexacanthus	0.28		Carangoides coeruleopinnatus	1.43
	Naso lituratus	0.78		Carangoides ferdau	0.46
	Naso minor	0.78		Carangoides fulvoguttatus	0.22
	Naso tuberosus	0.82		Carangoides gymnostethus	0.45
	Naso unicornis	0.20		Carangoides hedlandensis	1.53
	Naso vlamingii	0.36		Carangoides orthogrammus	0.49
	Zebrasoma scopas	0.20		Carangoides plagiotenia	0.75
Albulidae	Albula forsteri	0.73		Carangoides ruber	0.30
	Albula neoguinaica	0.69		Caranx crysos	1.36
	Albula vulpes	0.49		Caranx hippos	0.33
Atherinidae	Atherinomorus lacunosus	0.35		Caranx ignobilis	0.22
				Caranx latus	0.35
Aulostomidae	Aulostomus maculatus	0.25		Caranx lugubris	0.17
				Caranx melampygus	0.46
Balistidae	Abalistes stellaris	0.37		Caranx papuensis	0.86
	Abalistes stellatus	0.36		Caranx sexfasciatus	0.49
	Balistapus undulatus	0.63		Chloroscombrus chrysurus	1.54
	Balistes capricus	1.33		Decapterus macarellus	2.96
	Balistes vetula	0.44		Decapterus macrosoma	1.59
	Balistoides conspicillum	0.40			
	Balistoides viridescens	0.28			
	Canthidermis sufflamen	0.30			
	Odonus niger	0.40			

<u>Family</u>	<u>Taxon name</u>	<u>r</u>	<u>Family</u>	<u>Taxon name</u>	<u>r</u>
Carangidae contd.	Elagatis bipinnulata	0.91	Congridae	Conger cinereus	0.17
	Gnathanodon speciosus	0.60			
	Megalaspis cordyla	0.74	Coryphaenidae	Coryphaena hippurus	3.24
	Scomberoides lysan	0.72			
	Scomberoides tala	0.50	Dactylopteridae	Dactylopterus volitans	1.74
	Selar boops	3.58			
	Selar crumenophthalmus	3.10	Dasyatidae	Dasyatis akajei	0.04
	Selaroides leptolepis	3.38		Dasyatis americana	0.04
	Seriola dumerili	0.46		Taeniura lymma	0.03
	Seriola rivoliana	0.21	Diodontidae	Chilomycterus antennatus	1.39
	Trachinotus blochii	0.36		Chilomycterus antillarum	1.45
	Ulua aurochs	0.75		Diodon holocanthus	0.40
	Ulua mentalis	0.37		Diodon hystrix	0.29
Carcharhinidae	Carcharhinus amblyrhynchos	0.30			
	Carcharhinus limbatus	0.10	Echeneidae	Echeneis naucrates	0.24
	Carcharhinus melanopterus	0.06		Remora remora	0.46
	Carcharhinus perezii	0.04	Eleotridae	Eleotris fusca	0.43
	Galeocerdo cuvier	0.07			
Centrarchidae	Acantharchus pomotis	0.99	Elopidae	Elops saurus	0.66
Centropomidae	Centropomus pectinatus	1.50	Engraulidae	Stolephorus commersonni	2.06
	Centropomus undecimalis	0.52		Stolephorus indicus	2.04
Chaetodontidae	Chaetodon auriga	3.58	Ephippidae	Chaetodipterus faber	0.72
	Chaetodon capistratus	3.58		Platax orbicularis	0.56
	Chaetodon fasciatus	3.20	Exocoetidae	Cheilopogon abei	1.94
	Chaetodon guttatissimus	3.58		Cheilopogon unicolor	1.91
	Chaetodon ocellatus	3.32		Exocoetus volitans	3.21
	Chaetodon sedentarius	2.06			
	Chaetodon striatus	3.42			
	Heniochus monoceros	3.10	Fistulariidae	Fistularia commersonii	0.19
	Prognathodes aculeatus	3.58			
Chanidae	Chanos chanos	0.36	Gempylidae	Promethichthys prometheus	0.34
				Ruvettus pretiosus	0.11
Chimaeridae	Chimaera monstrosa	0.24	Gerreidae	Eugerres brasilianus	0.56
Chirocentridae	Chirocentrus nudus	0.43		Eugerres plumieri	0.57
				Gerres acinaces	0.50
Cirrhitidae	Cirrhitus pinnulatus	1.46		Gerres argyreus	1.60
	Paracirrhites hemistictus	1.56		Gerres cinereus	0.97
				Gerres erythrourus	1.43
Clupeidae	Amblygaster clupeoides	0.92		Gerres filamentosus	3.02
	Amblygaster sirm	2.03		Gerres longirostris	0.50
	Dussumieria elopsoides	0.94		Gerres oblongus	1.45
	Etrumeus teres	1.63		Gerres oyena	1.43
	Herklotsichthys quadrimaculatus	2.23	Ginglymostomatidae	Ginglymostoma cirratum	0.05
	Herklotsichthys spilurus	2.12			
	Opisthonema oglinum	0.96	Gobiidae	Acentrogobius puntang	0.50
	Sardinella gibbosa	2.23			
	Spratelloides delicatulus	2.23	Haemulidae	Anisotremus virginicus	0.49
	Spratelloides gracilis	2.23			

<u>Family</u>	<u>Taxon name</u>	<u>r</u>	<u>Family</u>	<u>Taxon name</u>	<u>r</u>
Haemulidae contd.	Diagramma picta	0.47		Sargocentron diadema	3.40
	Haemulon album	0.38		Sargocentron praslin	1.53
	Haemulon aurolineatum	0.40		Sargocentron rubrum	1.53
	Haemulon carbonarium	0.52		Sargocentron spiniferum	0.78
	Haemulon chrysargyreum	1.42		Sargocentron tiere	1.53
	Haemulon flavolineatum	0.60		Sargocentron vexillarium	3.30
	Haemulon melanurum	0.58		Sargocentron violaceum	1.40
	Haemulon parra	0.52	Istiophoridae		
	Haemulon plumierii	0.24		Istiophorus platypterus	0.40
	Haemulon sciurus	0.56	Kuhliidae		
	Haemulon striatum	0.75		Kuhlia marginata	0.59
	Haemulopsis leuciscus	0.59		Kuhlia mugil	0.23
	Plectorhinchus albovittatus	0.14	Kyphosidae		
	Plectorhinchus celebicus	0.40		Kyphosus bigibbus	0.19
	Plectorhinchus ceylonensis	0.50		Kyphosus cinerascens	0.52
	Plectorhinchus chaetodonoides	0.23		Kyphosus saltatrix	0.15
	Plectorhinchus chrysotaenia	0.43		Kyphosus vaigiensis	0.20
	Plectorhinchus diagrammus	0.53	Labridae		
	Plectorhinchus flavomaculatus	0.37		Anampses caeruleopunctatus	0.38
	Plectorhinchus gibbosus	0.38		Anampses neoguinaicus	0.57
	Plectorhinchus lessonii	0.53		Bodianus bilunulatus	0.20
	Plectorhinchus lineatus	0.55		Bodianus diana	0.42
	Plectorhinchus obscurus	0.15		Bodianus perditio	0.12
	Plectorhinchus orientalis	0.19		Bodianus rufus	0.39
	Plectorhinchus pictus	0.24		Cheilinus chlorourus	0.37
	Plectorhinchus picus	0.37		Cheilinus fasciatus	0.22
	Plectorhinchus vittatus	0.17		Cheilinus trilobatus	0.38
Hemiramphidae				Cheilinus undulatus	0.14
	Hemiramphus archipelagicus	1.61		Cheilio inermis	0.17
	Hemiramphus far	0.86		Choerodon anchorago	0.32
	Hyporhamphus dussumierii	0.84		Choerodon schoenleinii	0.12
	Zenarchopterus dispar	2.07		Cirrhilabrus exquisitus	1.53
Holocentridae				Cirrhilabrus walindi	3.39
	Holocentrus adscensionis	0.55		Clepticus parrae	0.54
	Holocentrus ascensionis	0.55		Epibulus insidiator	0.17
	Holocentrus rufus	3.18		Halichoeres bivittatus	0.41
	Myripristis adusta	1.52		Halichoeres chloropterus	0.57
	Myripristis amaena	1.54		Halichoeres garnoti	0.84
	Myripristis berndti	1.59		Halichoeres hortulanus	1.67
	Myripristis botche	1.51		Halichoeres scapularis	1.61
	Myripristis chryseres	2.99		Hemigymnus fasciatus	0.16
	Myripristis jacobus	2.90		Iniistius pavo	0.38
	Myripristis kuntee	1.62		Lachnolaimus maximus	0.14
	Myripristis murdjan	0.72		Novaculichthys taeniourus	0.54
	Myripristis pralinia	3.16		Oxycheilinus celebicus	0.59
	Myripristis violacea	1.52		Oxycheilinus unifasciatus	0.37
	Myripristis vittata	2.99		Thalassoma hebraicum	0.59
	Neoniphon opercularis	1.52		Thalassoma lunare	0.58
	Neoniphon sammara	1.55		Thalassoma purpureum	0.37
	Ostichthys kaianus	0.56		Thalassoma quinquevittatum	1.49
	Plectrypops lima	3.37		Xyrichtys martinicensis	1.49
	Sargocentron caudimaculatum	2.99	Leiognathidae		
	Sargocentron cornutum	1.61		Gazza minuta	2.08
	Sargocentron coruscum	3.40		Leiognathus equulus	2.03

<u>Family</u>	<u>Taxon name</u>	<u>r</u>	<u>Family</u>	<u>Taxon name</u>	<u>r</u>
Lethrinidae	Gnathodentex aureolineatus	0.82		Lutjanus fulvus	1.63
	Gymnocranius audleyi	0.92		Lutjanus gibbus	0.81
	Gymnocranius elongatus	0.76		Lutjanus goldiei	0.22
	Gymnocranius euanus	0.40		Lutjanus griseus	0.50
	Gymnocranius grandoculis	0.48		Lutjanus jocu	0.14
	Gymnocranius griseus	0.42		Lutjanus kasmira	0.40
	Gymnocranius microdon	0.53		Lutjanus mahogoni	0.14
	Lethrinus rubrioperculatus	0.41		Lutjanus monostigma	0.41
	Lethrinus amboinensis	0.36		Lutjanus notatus	1.63
	Lethrinus atkinsoni	0.54		Lutjanus purpureus	0.18
	Lethrinus borbonicus	0.56		Lutjanus quinquelineatus	0.40
	Lethrinus conchyliatus	0.35		Lutjanus rivulatus	0.47
	Lethrinus crocineus	0.39		Lutjanus russellii	0.55
	Lethrinus erythracanthus	0.41		Lutjanus sebae	0.28
	Lethrinus erythropterus	0.51		Lutjanus semicinctus	0.82
	Lethrinus genivittatus	1.84		Lutjanus synagris	0.40
	Lethrinus harak	0.83		Lutjanus vitta	0.41
	Lethrinus lentjan	0.57		Lutjanus vivanus	0.14
	Lethrinus mahsena	0.21		Macolor macularis	0.50
	Lethrinus microdon	0.38		Macolor niger	0.45
	Lethrinus miniatus	0.35		Ocyurus chrysurus	0.18
	Lethrinus nebulosus	0.26		Pristipomoides filamentosus	0.50
	Lethrinus obsoletus	0.55		Pristipomoides sieboldii	0.70
	Lethrinus olivaceus	0.34		Pristipomoides typus	0.51
	Lethrinus ornatus	1.50		Pristipomoides zonatus	0.47
	Lethrinus rubrioperculatus	0.41		Rhomboplites aurorubens	0.36
	Lethrinus semicinctus	1.55		Symphoricichthys spilurus	0.50
	Lethrinus variegatus	0.68	Malacanthidae	Symphorus nematophorus	0.46
	Lethrinus xanthochilus	0.20		Malacanthus plumieri	0.19
	Monotaxis grandoculis	0.39	Monacanthidae		
Lutjanidae	Aphareus furca	0.46		Aluterus monoceros	0.05
	Aphareus rutilans	0.32		Aluterus schoepfii	0.06
	Aprion virescens	0.28		Aluterus scriptus	0.12
	Apsilus dentatus	0.92		Cantherhines macrocerus	0.29
	Apsilus fuscus	0.42		Cantherhines pullus	0.61
	Etelis carbunculus	0.73	Monodactylidae	Monacanthus chinensis	0.32
	Etelis coruscans	0.16		Monodactylus argenteus	1.45
	Etelis oculatus	1.10	Mugilidae		
	Lipocheilus carnolabrum	0.52		Crenimugil crenilabis	0.52
	Lutjanus adetii	0.51		Liza melinoptera	0.51
	Lutjanus analis	0.26		Liza parsia	1.60
	Lutjanus apodus	0.59		Liza tade	0.38
	Lutjanus argentimaculatus	0.36		Liza vaigiensis	0.21
	Lutjanus bengalensis	1.50		Mugil cephalus	0.50
	Lutjanus bohar	0.52		Neomyxus chaptalii	0.50
	Lutjanus bouton	0.83		Valamugil seheli	0.48
	Lutjanus buccanella	0.24	Mullidae		
	Lutjanus campechanus	0.23		Mulloidichthys flavolineatus	0.42
	Lutjanus carponotatus	0.79		Mulloidichthys martinicus	0.76
	Lutjanus decussatus	0.83		Mulloidichthys vanicolensis	0.97
	Lutjanus ehrenbergii	0.82		Parupeneus barberinoides	1.47
	Lutjanus fulvivlamma	0.56		Parupeneus barberinus	0.43

<u>Family</u>	<u>Taxon name</u>	<u>r</u>	<u>Family</u>	<u>Taxon name</u>	<u>r</u>
Mullidae contd.	Parupeneus ciliatus	0.76	Pleuronectidae	Nematops microstoma	1.71
	Parupeneus cyclostomus	0.53	Plotosidae	Plotosus lineatus	0.63
	Parupeneus heptacanthus	0.68		Polymixia japonica	0.23
	Parupeneus indicus	0.55	Polymixiidae	Polydactylus sexfilis	0.75
	Parupeneus macronemus	0.74	Polynemidae	Holacanthus ciliaris	0.38
	Parupeneus multifasciatus	0.79		Holacanthus isabelita	0.38
	Parupeneus pleurostigma	1.42	Pomacanthidae	Holacanthus tricolor	0.54
	Parupeneus rubescens	0.74		Pomacanthus arcuatus	0.24
	Parupeneus trifasciatus	0.78		Pomacanthus paru	0.69
	Parupeneus macronemus	0.76		Pomacanthus sexstriatus	0.40
	Pseudupeneus maculatus	1.62		Pygoplites diacanthus	0.57
	Upeneus taeniopterus	1.51	Pomacentridae	Abudefduf saxatilis	0.44
	Upeneus vittatus	1.61		Abudefduf septemfasciatus	0.46
Muraenidae	Echidna nebulosa	0.37		Abudefduf sexfasciatus	1.29
	Echidna polyzona	0.50		Abudefduf sordidus	0.46
	Gymnothorax eurostus	0.37		Abudefduf vaigiensis	2.76
	Gymnothorax fimbriatus	0.40		Amphiprion clarkii	0.70
	Gymnothorax flavimarginatus	0.21		Chromis multilineata	0.47
	Gymnothorax funebris	0.15		Microspathodon chrysurus	0.45
	Gymnothorax meleagris	0.35		Neoglyphidodon melas	0.86
	Gymnothorax miliaris	0.32		Pomacentrus reidi	1.48
	Gymnothorax moringa	0.11		Stegastes adustus	1.53
	Gymnothorax pictus	0.24		Stegastes leucostictus	1.67
	Gymnothorax vicinus	0.16		Stegastes planifrons	1.63
Nemipteridae	Pentapodus emeryii	1.50	Priacanthidae	Heteropriacanthus cruentatus	1.42
	Pentapodus paradiseus	1.50		Priacanthus arenatus	1.56
	Pentapodus trivittatus	1.59		Priacanthus blochii	2.81
	Scolopsis ghanam	1.50		Priacanthus hamrur	1.59
	Scolopsis lineata	3.43	Rajidae	Dipturus canutus	0.06
	Scolopsis margaritifera	1.53		Glaucostegus typus	0.04
	Scolopsis monogramma	1.54	Rhinobatidae	Rhynchobatus djiddensis	0.04
	Scolopsis temporalis	0.86	Scaridae	Bolbometopon muricatum	0.14
	Scolopsis trilineata	1.68		Calotomus carolinus	0.50
Ostraciidae	Acanthostracion polygonius	0.39		Calotomus japonicus	1.36
	Acanthostracion quadricornis	0.67		Cetoscarus bicolor	0.27
	Lactophrys bicaudalis	0.40		Chlorurus bleekeri	0.53
	Lactophrys trigonus	0.38		Chlorurus frontalis	0.52
	Ostracion cubicus	0.98		Chlorurus japanensis	1.53
	Ostracion meleagris	0.91		Chlorurus microrhinos	0.28
	Rhinesomus triqueter	0.40		Chlorurus sordidus	1.95
Paralichthyidae	Paralichthys tropicus	0.73		Chlorurus strongylocephalus	0.50
	Pseudorhombus arsius	0.32		Hipposcarus longiceps	1.50
Pempheridae	Pempheris vanicolensis	1.51		Leptoscarus vaigiensis	1.39
Pinguipedidae	Parapercis clathrata	1.44		Scarus altipinnis	0.52
Platycephalidae	Cymbacephalus beauforti	0.39			
	Papilloculiceps longiceps	0.38			
	Platycephalus indicus	0.75			

<u>Family</u>	<u>Taxon name</u>	<u>r</u>	<u>Family</u>	<u>Taxon name</u>	<u>r</u>	
Scaridae contd.	Scarus coeruleus	0.55		Cephalopholis cyanostigma	0.52	
	Scarus dimidiatus	1.30		Cephalopholis fulva	0.67	
	Scarus forsteni	0.50		Cephalopholis igarashiensis	0.44	
	Scarus frenatus	1.02		Cephalopholis miniata	0.15	
	Scarus ghobban	0.44		Cephalopholis polleni	0.50	
	Scarus globiceps	1.50		Cephalopholis sexmaculata	0.40	
	Scarus guacamaia	0.53		Cephalopholis sonnerati	0.36	
	Scarus iseri	1.43		Cephalopholis spiloparaea	0.58	
	Scarus niger	1.66		Cephalopholis urodeta	0.59	
	Scarus oviceps	1.37		Cromileptes altivelis	0.20	
	Scarus psittacus	1.62		Epinephelus adscensionis	0.21	
	Scarus rivulatus	0.77		Epinephelus areolatus	0.55	
	Scarus rubroviolaceus	0.36		Epinephelus bilobatus	0.56	
	Scarus schlegeli	0.42		Epinephelus chlorostigma	0.56	
	Scarus spinus	1.45		Epinephelus coioides	0.34	
	Scarus taeniopterus	1.37		Epinephelus corallicola	0.40	
	Scarus tricolor	1.53		Epinephelus cyanopodus	0.13	
	Scarus vetula	1.56		Epinephelus fasciatus	0.23	
	Scarus viride	1.62		Epinephelus flavocaeruleus	0.16	
	Sparisoma aurofrenatum	0.41		Epinephelus flavolimbatus	0.13	
	Sparisoma chrysopteron	2.98		Epinephelus fuscoguttatus	0.38	
	Sparisoma rubripinne	1.56		Epinephelus guttatus	0.25	
	Sparisoma viride	0.85		Epinephelus hexagonatus	3.16	
Sciaenidae			Epinephelus howlandi	0.38		
	Argyrosomus hololepidotus	0.13		Epinephelus itajara	0.17	
	Argyrosomus thorpei	0.46		Epinephelus lanceolatus	0.06	
	Equetus lanceolatus	1.62		Epinephelus macrospilos	0.39	
	Equetus punctatus	1.59		Epinephelus maculatus	0.53	
Scombridae			Epinephelus malabaricus	0.07		
	Acanthocybium solandri	0.65		Epinephelus melanostigma	0.55	
	Euthynnus affinis	1.35		Epinephelus merra	1.61	
	Euthynnus alletteratus	0.34		Epinephelus miliaris	0.39	
	Grammatorcynus bilineatus	0.51		Epinephelus morio	0.17	
	Gymnosarda unicolor	0.15		Epinephelus morrhua	0.16	
	Katsuwonus pelamis	0.79		Epinephelus multinotatus	0.51	
	Rastrelliger brachysoma	2.23		Epinephelus niveatus	0.13	
	Rastrelliger kanagurta	3.58		Epinephelus ongus	0.58	
	Sarda orientalis	0.52		Epinephelus polyphkadion	0.13	
	Scomberomorus commerson	0.72		Epinephelus quoyanus	0.52	
	Thunnus albacares	0.67		Epinephelus retouti	0.40	
	Thunnus atlanticus	0.69		Epinephelus rivulatus	1.49	
	Thunnus obesus	0.44		Epinephelus septemfasciatus	0.10	
	Thunnus orientalis	0.13		Epinephelus socialis	0.39	
	Scorpaenidae			Epinephelus spilotoceps	0.55	
		Scorpaena plumieri	0.14		Epinephelus striatus	0.17
		Scorpaenodes caribbaeus	0.62		Epinephelus tauvina	0.18
	Serranidae			Epinephelus tukula	0.09	
		Aethaloperca rogaa	0.37		Gracila albomarginata	0.52
Alphestes afer		0.94		Hypoplectrus chlorurus	1.70	
Anyperodon leucogrammicus		0.21		Hyporthodus mystacinus	0.09	
Cephalopholis argus		0.37		Hyporthodus nigritus	0.18	
Cephalopholis aurantia		0.37		Mycteroperca bonaci	0.22	
Cephalopholis boenak		0.80		Mycteroperca interstitialis	0.09	
Cephalopholis cruentata		0.59		Mycteroperca microlepis	0.17	

<u>Family</u>	<u>Taxon name</u>	<u>r</u>	<u>Family</u>	<u>Taxon name</u>	<u>r</u>
Serranidae	Mycteroperca tigris	0.16	Sphyrnidae	Sphyrna lewini	0.03
	Mycteroperca venenosa	0.24		Sphyrna zygaena	0.03
	Paranthias furcifer	0.41	Synodontidae	Synodus intermedius	1.41
	Plectropomus areolatus	0.20		Synodus jaculum	3.32
	Plectropomus laevis	0.13	Terapontidae	Pelates quadrilineatus	0.44
	Plectropomus leopardus	0.48		Terapon jarbua	0.33
	Plectropomus maculatus	0.39	Tetraodontidae	Arothron hispidus	0.40
	Plectropomus oligacanthus	0.19		Arothron stellatus	0.05
	Plectropomus pessuliferus	0.13		Canthigaster rostrata	3.29
	Plectropomus punctatus	0.16		Diodon liturosus	0.52
	Rypticus saponaceus	0.55	Torpedinidae	Torpedo sinuspersici	0.02
	Saloptia powelli	0.50		Triacanthus biaculeatus	0.30
	Serranus tabacarius	1.42	Triacanthidae	Triacanthus biaculeatus	0.30
	Variola albimarginata	0.21		Mustelus canis	0.05
	Variola louti	0.37	Triakidae	Trichiurus lepturus	0.41
Siganidae	Siganus argenteus	2.99		Xiphias gladius	0.51
	Siganus canaliculatus	3.58	Trichiuridae	Zanclus cornutus	1.68
	Siganus doliatus	1.59			
	Siganus fuscescens	3.15	Xiphiidae		
	Siganus guttatus	3.58			
	Siganus lineatus	1.59	Zanclidae		
	Siganus luridus	0.56			
	Siganus puellus	1.50			
	Siganus punctatus	1.49			
	Siganus randalli	1.61			
	Siganus rivulatus	0.99			
	Siganus spinus	3.58			
	Siganus sutor	3.09			
	Siganus vermiculatus	2.23			
	Siganus vulpinus	1.63			
Sillaginidae	Sillago ciliata	0.93			
Sparidae	Acanthopagrus bifasciatus	0.40			
	Calamus bajonado	0.18			
	Calamus calamus	0.61			
	Calamus penna	0.38			
	Calamus pennatula	0.41			
	Calamus proridens	0.39			
	Cheimerius nufar	0.11			
	Crenidens crenidens	1.10			
	Diplodus bermudensis	0.54			
	Rhabdosargus sarba	0.50			
Sphyraenidae	Sphyraena acutipinnis	0.44			
	Sphyraena barracuda	0.12			
	Sphyraena flavicauda	0.55			
	Sphyraena forsteri	0.38			
	Sphyraena jello	0.15			
	Sphyraena novaehollandiae	0.19			
	Sphyraena picudilla	0.46			
	Sphyraena putnamae	0.73			
	Sphyraena qenie	0.12			

Appendix F Top 5 families making up the catch composition for each fishery case

Country	Case No.	Family	% catch	Country	Case No.	Family	% catch
Anguilla	2	Lutjanidae	0.38	Marshall Islands	64	Serranidae	0.40
Anguilla	2	Haemulidae	0.11	Marshall Islands	64	Lutjanidae	0.23
Anguilla	2	Acanthuridae	0.10	Marshall Islands	64	Siganidae	0.14
Anguilla	2	Sparidae	0.09	Marshall Islands	64	Lethrinidae	0.11
Anguilla	2	Serranidae	0.07	Marshall Islands	64	Acanthuridae	0.05
Antigua and Barbuda	3	Serranidae	0.22	Marshall Islands	65	Acanthuridae	0.20
Antigua and Barbuda	3	Lutjanidae	0.21	Marshall Islands	65	Lutjanidae	0.18
Antigua and Barbuda	3	Haemulidae	0.16	Marshall Islands	65	Siganidae	0.15
Antigua and Barbuda	3	Scaridae	0.15	Marshall Islands	65	Serranidae	0.13
Antigua and Barbuda	3	Acanthuridae	0.14	Marshall Islands	65	Scaridae	0.13
Bahamas	153	Lutjanidae	0.62	Marshall Islands	66	Serranidae	0.34
Bahamas	153	Serranidae	0.17	Marshall Islands	66	Lutjanidae	0.14
Bahamas	153	Haemulidae	0.10	Marshall Islands	66	Acanthuridae	0.12
Bahamas	153	Balistidae	0.05	Marshall Islands	66	Siganidae	0.10
Bahamas	153	Carangidae	0.03	Marshall Islands	66	Lethrinidae	0.09
Bahamas	153	Sphryaenidae	0.03	Marshall Islands	67	Serranidae	0.30
Barbados	4	Scaridae	0.24	Marshall Islands	67	Lutjanidae	0.20
Barbados	4	Monacanthidae	0.12	Marshall Islands	67	Lethrinidae	0.12
Barbados	4	Acanthuridae	0.12	Marshall Islands	67	Acanthuridae	0.08
Barbados	4	Serranidae	0.11	Marshall Islands	67	Kyphosidae	0.07
Barbados	4	Holocentridae	0.10	Martinique	68	Muraenidae	0.44
Barbados	5	Mullidae	0.15	Martinique	68	Squalidae	0.18
Barbados	5	Ostraciidae	0.10	Martinique	68	Carangidae	0.15
Barbados	5	Pomacanthidae	0.09	Martinique	68	Holocentridae	0.12
Barbados	5	Pomacentridae	0.07	Martinique	68	Lutjanidae	0.11
Barbados	5	Belonidae	0.07	Martinique	69	Scaridae	0.69
Bermuda	6	Serranidae	0.25	Martinique	69	Balistidae	0.39
Bermuda	6	Carangidae	0.20	Martinique	69	Lutjanidae	0.24
Bermuda	6	Scaridae	0.15	Martinique	69	Mullidae	0.19
Bermuda	6	Lutjanidae	0.13	Martinique	69	Serranidae	0.14
Bermuda	6	Acanthuridae	0.04	Mauritius	70	Siganidae	0.28
Bermuda	6	Sparidae	0.04	Mauritius	70	Mullidae	0.21
Bermuda	6	Haemulidae	0.04	Mauritius	70	Mugilidae	0.11
Bermuda	6	Balistidae	0.04	Mauritius	70	Carangidae	0.11
Bermuda	6	Labridae	0.04	Mauritius	70	Lethrinidae	0.10
Bermuda	6	Holocentridae	0.04	Mauritius	136	Siganidae	0.52
Bermuda	6	Kyphosidae	0.04	Mauritius	136	Acanthuridae	0.17
Bermuda	7	Lutjanidae	0.41	Mauritius	136	Scaridae	0.10
Bermuda	7	Kyphosidae	0.28	Mauritius	136	Mullidae	0.08
Bermuda	7	Haemulidae	0.20	Mauritius	136	Serranidae	0.04
Bermuda	7	Sparidae	0.06	Mauritius	137	Serranidae	0.39
Bermuda	7	Holocentridae	0.04	Mauritius	137	Siganidae	0.15
British Virgin Islands	8	Serranidae	0.17	Mauritius	137	Sphryaenidae	0.12
British Virgin Islands	8	Acanthuridae	0.16	Mauritius	137	Mullidae	0.10
British Virgin Islands	8	Balistidae	0.12	Mauritius	137	Acanthuridae	0.08
British Virgin Islands	8	Haemulidae	0.11	Mauritius	138	Signidae	0.40
British Virgin Islands	8	Ostraciidae	0.11	Mauritius	138	Acanthuridae	0.13
Comoros	9	Serranidae	0.18	Mauritius	138	Chanidae	0.10
Comoros	9	Scombridae	0.03	Mauritius	138	Carangidae	0.08
Comoros	9	Carangidae	0.02	Mauritius	138	Mullidae	0.07
Comoros	9	Lutjanidae	0.02	Mayotte	71	Scombridae	0.00
Comoros	9	Lethrinidae	0.01	Mayotte	71	Lutjanidae	0.00
Cook Islands1	10	Kyphosidae	0.39	Mayotte	71	Serranidae	0.00
Cook Islands1	10	Acanthuridae	0.22	Mayotte	71	Sparidae	0.00
Cook Islands1	10	Scaridae	0.12	Mayotte	71	Carangidae	0.00
Cook Islands1	10	Mullidae	0.08	Nauru	72	Acanthuridae	0.37
Cook Islands1	10	Serranidae	0.06	Nauru	72	Holocentridae	0.14
Cook Islands2	11	Serranidae	0.29	Nauru	72	Lutjanidae	0.11
Cook Islands2	11	Kyphosidae	0.26	Nauru	72	Scaridae	0.09
Cook Islands2	11	Holocentridae	0.13	Nauru	72	Serranidae	0.09
Cook Islands2	11	Labridae	0.12	NetherlandAntilles	73	Lutjanidae	0.46
Cook Islands	11	Acanthuridae	0.12	NetherlandAntilles	73	Haemulidae	0.15

Country	Case No.	Family	% catch	Country	Case No.	Family	% catch
Cook Islands	12	Scaridae	0.75	NetherlandAntilles	73	Serranidae	0.15
Cook Islands	12	Serranidae	0.08	NetherlandAntilles	73	Balistidae	0.10
Cook Islands	12	Lutjanidae	0.07	NetherlandAntilles	73	Scombridae	0.07
Cook Islands	12	Mugilidae	0.04	NetherlandAntilles	143	Scaridae	0.40
Cook Islands	12	Holocentridae	0.03	NetherlandAntilles	143	Haemulidae	0.20
Cuba	13	Lutjanidae	0.62	NetherlandAntilles	143	Acanthuridae	0.13
Cuba	13	Carangidae	0.18	NetherlandAntilles	143	Lutjanidae	0.12
Cuba	13	Sphyraenidae	0.06	NetherlandAntilles	143	Chaetodontidae	0.04
Cuba	13	Centropomidae	0.04	New Caledonia	74	Scaridae	0.23
Cuba	13	Elopidae	0.02	New Caledonia	74	Lethrinidae	0.20
Dominica	14	Monacanthidae	0.25	New Caledonia	74	Acanthuridae	0.17
Dominica	14	Serranidae	0.12	New Caledonia	74	Mullidae	0.13
Dominica	14	Dactylopteridae	0.10	New Caledonia	74	Serranidae	0.12
Dominica	14	Holocentridae	0.10	New Caledonia	75	Mugilidae	0.49
Dominica	14	Balistidae	0.09	New Caledonia	75	Lethrinidae	0.20
Dominica	15	Muraenidae	0.16	New Caledonia	75	Siganidae	0.11
Dominica	15	Lutjanidae	0.15	New Caledonia	75	Mullidae	0.08
Dominica	15	Mullidae	0.13	New Caledonia	75	Serranidae	0.03
Dominica	15	Scaridae	0.09	New Caledonia	76	Scaridae	0.27
Dominica	15	Serranidae	0.08	New Caledonia	76	Acanthuridae	0.25
East Timor	16	Lutjanidae	0.10	New Caledonia	76	Siganidae	0.20
East Timor	16	Caesionidae	0.10	New Caledonia	76	Serranidae	0.14
East Timor	16	Acanthuridae	0.07	New Caledonia	76	Lethrinidae	0.10
East Timor	16	Scombridae	0.06	New Caledonia	77	Mugilidae	0.25
East Timor	16	Hemiramphidae	0.04	New Caledonia	77	Lethrinidae	0.21
East Timor	16	Clupeidae	0.04	New Caledonia	77	Siganidae	0.20
East Timor	16	Belonidae	0.04	New Caledonia	77	Acanthuridae	0.07
FSM ¹	27	Scaridae	0.36	New Caledonia	77	Hemiramphidae	0.06
FSM	27	Acanthuridae	0.27	New Caledonia	77	Gerreidae	0.06
FSM	27	Serranidae	0.18	New Caledonia	78	Lethrinidae	0.24
FSM	27	Lethrinidae	0.10	New Caledonia	78	Serranidae	0.22
FSM	27	Mullidae	0.03	New Caledonia	78	Mugilidae	0.19
FSM	28	Scaridae	0.52	New Caledonia	78	Acanthuridae	0.11
FSM	28	Serranidae	0.28	New Caledonia	78	Hemiramphidae	0.06
FSM	28	Acanthuridae	0.19	New Caledonia	78	Scaridae	0.06
FSM	29	Acanthuridae	0.44	Niue	79	Kyphosidae	0.24
FSM	29	Scaridae	0.21	Niue	79	Carangidae	0.22
FSM	29	Siganidae	0.13	Niue	79	Holocentridae	0.21
FSM	29	Carangidae	0.08	Niue	79	Cirrhitidae	0.09
FSM	29	Lethrinidae	0.04	Niue	79	Serranidae	0.07
FSM	30	Acanthuridae	0.34	Palau	80	Lethrinidae	0.33
FSM	30	Scaridae	0.23	Palau	80	Siganidae	0.21
FSM	30	Siganidae	0.17	Palau	80	Scaridae	0.14
FSM	30	Carangidae	0.14	Palau	80	Lutjanidae	0.10
FSM	30	Gerreidae	0.11	Palau	80	Mugilidae	0.10
FSM	31	Carangidae	0.47	Palau	81	Lethrinidae	0.28
FSM	31	Siganidae	0.15	Palau	81	Lutjanidae	0.17
FSM	31	Sphyraenidae	0.12	Palau	81	Scaridae	0.13
FSM	31	Scaridae	0.11	Palau	81	Serranidae	0.10
FSM	31	Acanthuridae	0.08	Palau	81	Acanthuridae	0.09
FSM	84	Acanthuridae	0.28	Palau	82	Lethrinidae	0.32
FSM	84	Scaridae	0.15	Palau	82	Siganidae	0.19
FSM	84	Serranidae	0.15	Palau	82	Serranidae	0.15
FSM	84	Lutjanidae	0.10	Palau	82	Lutjanidae	0.10
FSM	84	Carangidae	0.09	Palau	82	Acanthuridae	0.07
FSM	155	Scaridae	0.57	Papua New Guinea	123	Lutjanidae	0.28
FSM	155	Acanthuridae	0.30	Papua New Guinea	123	Lethrinidae	0.26
FSM	155	Lethrinidae	0.08	Papua New Guinea	123	Carangidae	0.11
FSM	155	Kyphosidae	0.05	Papua New Guinea	123	Serranidae	0.07
FSM	156	Acanthuridae	0.36	Papua New Guinea	123	Balistidae	0.05
FSM	156	Scaridae	0.27	Papua New Guinea	124	Lethrinidae	0.23
FSM	156	Carangidae	0.14	Papua New Guinea	124	Mugilidae	0.14
FSM	156	Kyphosidae	0.11	Papua New Guinea	124	Gerreidae	0.10
FSM	156	Lethrinidae	0.07	Papua New Guinea	124	Lutjanidae	0.09

Country	Case No.	Family	% catch	Country	Case No.	Family	% catch
FSM	157	Scaridae	0.42	Papua New Guinea	124	Acanthuridae	0.09
FSM	157	Acanthuridae	0.30	Papua New Guinea	125	Siganidae	0.30
FSM	157	Kyphosidae	0.07	Papua New Guinea	125	Acanthuridae	0.29
FSM	157	Lethrinidae	0.06	Papua New Guinea	125	Lethrinidae	0.11
FSM	157	Mullidae	0.05	Papua New Guinea	125	Scaridae	0.08
Fiji	17	Lethrinidae	0.21	Papua New Guinea	125	Clupeidae	0.05
Fiji	17	Mugilidae	0.14	Philippines	83	Scombridae	0.63
Fiji	17	Lutjanidae	0.10	Philippines	83	Serranidae	0.14
Fiji	17	Leiognathidae	0.08	Philippines	83	Lethrinidae	0.01
Fiji	17	Balistidae	0.07	Philippines	83	Scaridae	0.01
Fiji	19	Lethrinidae	0.30	Philippines	83	Lutjanidae	0.01
Fiji	19	Mugilidae	0.17	Philippines	130	Carangidae	0.47
Fiji	19	Acanthuridae	0.11	Philippines	130	Acanthuridae	0.25
Fiji	19	Scombridae	0.08	Philippines	130	Scombridae	0.13
Fiji	19	Lutjanidae	0.07	Philippines	130	Scaridae	0.07
Fiji	20	Lethrinidae	0.46	Philippines	130	Caesionidae	0.04
Fiji	20	Serranidae	0.12	Philippines	131	Acanthuridae	0.23
Fiji	20	Carangidae	0.10	Philippines	131	Belonidae	0.21
Fiji	20	Acanthuridae	0.09	Philippines	131	Caesionidae	0.19
Fiji	20	Scaridae	0.04	Philippines	131	Exocoetidae	0.10
Fiji	21	Lethrinidae	0.35	Philippines	131	Scombridae	0.08
Fiji	21	Serranidae	0.14	Philippines	144	Carangidae	0.29
Fiji	21	Haemulidae	0.13	Philippines	144	Scombridae	0.29
Fiji	21	Acanthuridae	0.12	Philippines	144	Acanthuridae	0.19
Fiji	21	Carangidae	0.08	Philippines	144	Caesionidae	0.17
Fiji	22	Lethrinidae	0.57	Philippines	144	Scaridae	0.03
Fiji	22	Gerreidae	0.11	Philippines	145	Scombridae	0.32
Fiji	22	Hemiramphidae	0.08	Philippines	145	Acanthuridae	0.26
Fiji	22	Lutjanidae	0.08	Philippines	145	Carangidae	0.25
Fiji	22	Scaridae	0.07	Philippines	145	Caesionidae	0.10
Fiji	23	Lethrinidae	0.26	Philippines	145	Lutjanidae	0.03
Fiji	23	Lutjanidae	0.16	Philippines	146	Carangidae	0.41
Fiji	23	Serranidae	0.11	Philippines	146	Acanthuridae	0.25
Fiji	23	Mugilidae	0.09	Philippines	146	Scombridae	0.22
Fiji	23	Acanthuridae	0.06	Philippines	146	Lutjanidae	0.06
Fiji	132	Lethrinidae	0.36	Philippines	146	Caesionidae	0.04
Fiji	132	Acanthuridae	0.16	Philippines	147	Scombridae	0.35
Fiji	132	Serranidae	0.12	Philippines	147	Carangidae	0.30
Fiji	132	Carangidae	0.10	Philippines	147	Acanthuridae	0.28
Fiji	132	Balistidae	0.06	Philippines	147	Lutjanidae	0.04
Fiji	133	Lethrinidae	0.39	Philippines	147	Caesionidae	0.02
Fiji	133	Serranidae	0.19	Philippines	148	Carangidae	0.48
Fiji	133	Others	0.09	Philippines	148	Acanthuridae	0.30
Fiji	133	Acanthuridae	0.09	Philippines	148	Caesionidae	0.09
Fiji	133	Lutjanidae	0.07	Philippines	148	Scombridae	0.05
Fiji	134	Serranidae	0.24	Philippines	148	Scaridae	0.04
Fiji	134	Lethrinidae	0.22	Philippines	149	Carangidae	0.48
Fiji	134	Acanthuridae	0.11	Philippines	149	Acanthuridae	0.25
Fiji	134	Others	0.08	Philippines	149	Scombridae	0.13
Fiji	134	Lutjanidae	0.07	Philippines	149	Scaridae	0.07
Fiji	135	Lethrinidae	0.17	Philippines	149	Caesionidae	0.04
Fiji	135	Others	0.16	Philippines	154	Siganidae	0.48
Fiji	135	Serranidae	0.14	Philippines	154	Scaridae	0.19
Fiji	135	Scombridae	0.12	Philippines	154	Labridae	0.11
Fiji	135	Acanthuridae	0.11	Philippines	154	Gobiidae	0.05
French Polynesia	24	Acanthuridae	0.34	Philippines	154	Lethrinidae	0.03
French Polynesia	24	Scaridae	0.26	Philippines	154	Muraenidae	0.03
French Polynesia	24	Serranidae	0.12	Puerto Rico	85	Lutjanidae	0.29
French Polynesia	24	Holocentridae	0.08	Puerto Rico	85	Holocentridae	0.16
French Polynesia	24	Lethrinidae	0.07	Puerto Rico	85	Serranidae	0.13
French Polynesia	25	Acanthuridae	0.22	Puerto Rico	85	Ostraciidae	0.08
French Polynesia	25	Carangidae	0.15	Puerto Rico	85	Mullidae	0.05
French Polynesia	25	Mullidae	0.15	Reunion	86	Lethrinidae	0.67
French Polynesia	25	Serranidae	0.12	Reunion	86	Scaridae	0.22

Country	Case No.	Family	% catch	Country	Case No.	Family	% catch
French Polynesia	25	Siganidae	0.11	Reunion	86	Acanthuridae	0.14
French Polynesia	26	Carangidae	0.44	Reunion	86	Muraenidae	0.07
French Polynesia	26	Priacanthidae	0.18	Reunion	86	Haemulidae	0.07
French Polynesia	26	Lutjanidae	0.07	Samoa	1	Balistidae	0.13
French Polynesia	26	Acanthuridae	0.07	Samoa	1	Mullidae	0.13
French Polynesia	26	Lethrinidae	0.07	Samoa	1	Scaridae	0.10
Grenada	32	Serranidae	0.82	Samoa	1	Mugilidae	0.08
Grenada	32	Lutjanidae	0.16	Samoa	1	Muraenidae	0.08
Grenada	32	Balistidae	0.00	Samoa	1	Sphyracidae	0.08
Grenada	32	Malacanthidae	0.00	Samoa	87	Scaridae	0.20
Guadeloupe	33	Dactylopteridae	0.17	Samoa	87	Lethrinidae	0.18
Guadeloupe	33	Muraenidae	0.15	Samoa	87	Acanthuridae	0.14
Guadeloupe	33	Mullidae	0.13	Samoa	87	Holocentridae	0.07
Guadeloupe	33	Haemulidae	0.12	Samoa	87	Lutjanidae	0.06
Guadeloupe	33	Holocentridae	0.12	Samoa	88	Acanthuridae	0.24
Guadeloupe	34	Mullidae	0.22	Samoa	88	Scaridae	0.15
Guadeloupe	34	Muraenidae	0.17	Samoa	88	Lutjanidae	0.09
Guadeloupe	34	Lutjanidae	0.16	Samoa	88	Lethrinidae	0.09
Guadeloupe	34	Carangidae	0.10	Samoa	88	Mugilidae	0.08
Guadeloupe	34	Holocentridae	0.09	Samoa	89	Lethrinidae	0.19
Guam	35	Scaridae	0.41	Samoa	89	Acanthuridae	0.16
Guam	35	Acanthuridae	0.22	Samoa	89	Scaridae	0.15
Guam	35	Labridae	0.08	Samoa	89	Mugilidae	0.12
Guam	35	Serranidae	0.07	Samoa	89	Siganidae	0.10
Guam	35	Kyphosidae	0.06	Samoa	90	Acanthuridae	0.24
Indonesia	36	Lethrinidae	0.34	Samoa	90	Scaridae	0.18
Indonesia	36	Mullidae	0.16	Samoa	90	Lethrinidae	0.11
Indonesia	36	Siganidae	0.12	Samoa	90	Holocentridae	0.11
Indonesia	36	Scaridae	0.12	Samoa	90	Mugilidae	0.09
Indonesia	36	Clupeidae	0.09	Samoa	91	Acanthuridae	0.21
Indonesia	37	Lethrinidae	0.68	Samoa	91	Lethrinidae	0.17
Indonesia	37	Labridae	0.08	Samoa	91	Scaridae	0.14
Indonesia	37	Serranidae	0.08	Samoa	91	Siganidae	0.12
Indonesia	37	Siganidae	0.04	Samoa	91	Serranidae	0.10
Indonesia	37	Gerreidae	0.03	Samoa	92	Acanthuridae	0.28
Indonesia	38	Lethrinidae	0.27	Samoa	92	Scaridae	0.19
Indonesia	38	Serranidae	0.27	Samoa	92	Lethrinidae	0.14
Indonesia	38	Lutjanidae	0.20	Samoa	92	Holocentridae	0.08
Indonesia	38	Carangidae	0.07	Samoa	92	Lutjanidae	0.06
Indonesia	38	Holocentridae	0.07	Samoa	93	Acanthuridae	0.29
Indonesia	39	Scaridae	0.33	Samoa	93	Scaridae	0.17
Indonesia	39	Mullidae	0.31	Samoa	93	Lethrinidae	0.14
Indonesia	39	Labridae	0.07	Samoa	93	Holocentridae	0.14
Indonesia	39	Acanthuridae	0.06	Samoa	93	Muraenidae	0.09
Indonesia	39	Lethrinidae	0.06	Samoa	94	Scaridae	0.49
Indonesia	40	Lethrinidae	0.33	Samoa	94	Acanthuridae	0.19
Indonesia	40	Siganidae	0.21	Samoa	94	Lutjanidae	0.15
Indonesia	40	Labridae	0.12	Samoa	94	Lethrinidae	0.12
Indonesia	40	Scaridae	0.08	Samoa	94	Labridae	0.05
Indonesia	40	Mullidae	0.08	Seychelles	95	Serranidae	0.56
Indonesia	41	Lethrinidae	0.18	Seychelles	95	Lutjanidae	0.24
Indonesia	41	Siganidae	0.17	Seychelles	95	Lethrinidae	0.20
Indonesia	41	Gerreidae	0.16	Solomon Islands	96	Scaridae	0.27
Indonesia	41	Lutjanidae	0.08	Solomon Islands	96	Serranidae	0.15
Indonesia	41	Mullidae	0.07	Solomon Islands	96	Labridae	0.11
Indonesia	42	Hemiramphidae	0.84	Solomon Islands	96	Lutjanidae	0.11
Indonesia	42	Clupeidae	0.09	Solomon Islands	96	Balistidae	0.11
Indonesia	42	Labridae	0.03	Solomon Islands	97	Lutjanidae	0.18
Indonesia	42	Mullidae	0.02	Solomon Islands	97	Carangidae	0.12
Indonesia	42	Nemipteridae	0.02	Solomon Islands	97	Scaridae	0.11
Indonesia	43	Caesionidae	0.66	Solomon Islands	97	Serranidae	0.10
Indonesia	43	Acanthuridae	0.09	Solomon Islands	97	Haemulidae	0.10
Indonesia	43	Serranidae	0.04	Solomon Islands	98	Serranidae	0.25
Indonesia	43	Lutjanidae	0.04	Solomon Islands	98	Carangidae	0.23

Country	Case No.	Family	% catch	Country	Case No.	Family	% catch
Indonesia	43	Siganidae	0.04	Solomon Islands	98	Holocentridae	0.11
Jamaica	44	Carangidae	0.32	Solomon Islands	98	Scombridae	0.09
Jamaica	44	Serranidae	0.21	Solomon Islands	98	Lethrinidae	0.08
Jamaica	44	Lutjanidae	0.17	Solomon Islands	99	Serranidae	0.25
Jamaica	44	Holocentridae	0.09	Solomon Islands	99	Holocentridae	0.13
Jamaica	44	Sphyraenidae	0.07	Solomon Islands	99	Lutjanidae	0.10
Jamaica	45	Carangidae	0.44	Solomon Islands	99	Carangidae	0.09
Jamaica	45	Haemulidae	0.22	Solomon Islands	99	Lethrinidae	0.06
Jamaica	45	Scaridae	0.14	Solomon Islands	100	Lethrinidae	0.24
Jamaica	45	Lutjanidae	0.11	Solomon Islands	100	Lutjanidae	0.20
Jamaica	45	Acanthuridae	0.04	Solomon Islands	100	Serranidae	0.11
Jamaica	45	Sphyraenidae	0.04	Solomon Islands	100	Scaridae	0.08
Jamaica	46	Sphyraenidae	0.35	Solomon Islands	100	Mugilidae	0.07
Jamaica	46	Scaridae	0.35	Sri Lanka	101	Scaridae	0.30
Jamaica	46	Serranidae	0.08	Sri Lanka	101	Serranidae	0.23
Jamaica	46	Mullidae	0.06	Sri Lanka	101	Monodactylidae	0.15
Jamaica	46	Acanthuridae	0.06	Sri Lanka	101	Labridae	0.15
Jamaica	47	Scaridae	0.42	Sri Lanka	101	Clupeidae	0.10
Jamaica	47	Acanthuridae	0.18	Sri Lanka	102	Mugilidae	0.30
Jamaica	47	Lutjanidae	0.10	Sri Lanka	102	Carangidae	0.30
Jamaica	47	Holocentridae	0.06	Sri Lanka	102	Serranidae	0.10
Jamaica	47	Haemulidae	0.05	Sri Lanka	102	Scaridae	0.10
Jamaica	48	Sphyraenidae	0.74	Sri Lanka	102	Monodactylidae	0.05
Jamaica	48	Scombridae	0.16	Sri Lanka	102	Scombridae	0.05
Jamaica	48	Belonidae	0.10	Sri Lanka	102	Sphyraenidae	0.05
Jamaica	150	Scaridae	0.42	Sri Lanka	102	Haemulidae	0.05
Jamaica	150	Acanthuridae	0.15	Tonga	103	Lethrinidae	0.67
Jamaica	150	Holocentridae	0.10	Tonga	103	Scaridae	0.07
Jamaica	150	Pomadasyidae	0.06	Tonga	103	Carangidae	0.07
Jamaica	150	Serranidae	0.06	Tonga	103	Gerreidae	0.04
Jamaica	151	Scaridae	0.48	Tonga	103	Lutjanidae	0.04
Jamaica	151	Acanthuridae	0.15	Tonga	104	Acanthuridae	0.22
Jamaica	151	Holocentridae	0.08	Tonga	104	Lethrinidae	0.19
Jamaica	151	Pomadasyidae	0.06	Tonga	104	Scaridae	0.18
Jamaica	151	Serranidae	0.05	Tonga	104	Serranidae	0.16
Jamaica	152	Scaridae	0.34	Tonga	104	Siganidae	0.09
Jamaica	152	Sphyraenidae	0.15	Tonga	105	Lethrinidae	0.30
Jamaica	152	Acanthuridae	0.11	Tonga	105	Serranidae	0.19
Jamaica	152	Lutjanidae	0.07	Tonga	105	Acanthuridae	0.15
Jamaica	152	Serranidae	0.07	Tonga	105	Scaridae	0.13
Jamaica	158	Scaridae	0.41	Tonga	105	Lutjanidae	0.09
Jamaica	158	Mullidae	0.18	Tonga	106	Lethrinidae	0.69
Jamaica	158	Holocentridae	0.09	Tonga	106	Lutjanidae	0.14
Jamaica	158	Acanthuridae	0.08	Tonga	106	Serranidae	0.14
Jamaica	158	Serranidae	0.08	Tonga	106	Carangidae	0.03
Kenya	49	Lethrinidae	0.63	Tonga	106	Holocentridae	0.00
Kenya	49	Labridae	0.14	Tonga	107	Acanthuridae	0.39
Kenya	49	Lutjanidae	0.11	Tonga	107	Scaridae	0.24
Kenya	49	Mullidae	0.02	Tonga	107	Siganidae	0.19
Kenya	49	Scaridae	0.01	Tonga	107	Lethrinidae	0.09
Kenya	50	Siganidae	0.36	Tonga	107	Holocentridae	0.03
Kenya	50	Lethrinidae	0.27	Trinidad & Tobago	120	Lutjanidae	0.95
Kenya	50	Scaridae	0.24	Trinidad & Tobago	120	Haemulidae	0.03
Kenya	50	Mullidae	0.06	Trinidad & Tobago	120	Serranidae	0.02
Kenya	50	Acanthuridae	0.04	Trinidad & Tobago	121	Lutjanidae	0.87
Kenya	159	Scaridae	0.28	Trinidad & Tobago	121	Balistidae	0.05
Kenya	159	Others	0.23	Trinidad & Tobago	121	Haemulidae	0.05
Kenya	159	Scavengers	0.20	Trinidad & Tobago	121	Serranidae	0.03
Kenya	159	Scaridae	0.18	Trinidad & Tobago	122	Lutjanidae	0.66
Kenya	159	Mullidae	0.10	Trinidad & Tobago	122	Sparidae	0.10
Kiribati	51	Lethrinidae	0.35	Trinidad & Tobago	122	Balistidae	0.09
Kiribati	51	Mullidae	0.11	Trinidad & Tobago	122	Haemulidae	0.09
Kiribati	51	Gerreidae	0.08	Trinidad & Tobago	122	Holocentridae	0.03
Kiribati	51	Belonidae	0.07	Turks & Caicos	108	Haemulidae	0.38

Country	Case No.	Family	% catch	Country	Case No.	Family	% catch
Kiribati	51	Lutjanidae	0.07	Turks & Caicos	108	Lutjanidae	0.26
Kiribati	52	Serranidae	0.41	Turks & Caicos	108	Scaridae	0.24
Kiribati	52	Scaridae	0.15	Turks & Caicos	108	Serranidae	0.06
Kiribati	52	Holocentridae	0.10	Turks & Caicos	108	Mullidae	0.03
Kiribati	52	Labridae	0.09	Turks & Caicos	139	Serranidae	0.33
Kiribati	52	Lethrinidae	0.07	Turks & Caicos	139	Lutjanidae	0.26
Kiribati	53	Mugilidae	0.34	Turks & Caicos	139	Haemulidae	0.16
Kiribati	53	Albulidae	0.28	Turks & Caicos	139	Labridae	0.09
Kiribati	53	Lethrinidae	0.10	Turks & Caicos	139	Carangidae	0.07
Kiribati	53	Mullidae	0.10	Turks & Caicos	140	Lutjanidae	0.50
Kiribati	53	Gerreidae	0.10	Turks & Caicos	140	Haemulidae	0.39
Kiribati	54	Chanidae	0.65	Turks & Caicos	140	Serranidae	0.05
Kiribati	54	Albulidae	0.17	Turks & Caicos	140	Carangidae	0.05
Kiribati	54	Serranidae	0.07	Turks & Caicos	141	Serranidae	0.72
Kiribati	54	Mugilidae	0.05	Turks & Caicos	141	Haemulidae	0.21
Kiribati	54	Acanthuridae	0.03	Turks & Caicos	141	Lutjanidae	0.03
Kiribati	55	Lutjanidae	0.43	Turks & Caicos	141	Scaridae	0.01
Kiribati	55	Carangidae	0.40	Turks & Caicos	141	Holocentridae	0.01
Kiribati	55	Serranidae	0.09	Turks & Caicos	142	Serranidae	0.33
Kiribati	55	Lethrinidae	0.08	Turks & Caicos	142	Lutjanidae	0.25
Madagascar	56	Carangidae	0.39	Turks & Caicos	142	Haemulidae	0.17
Madagascar	56	Sharks	0.21	Turks & Caicos	142	Carangidae	0.09
Madagascar	56	Lutjanidae	0.12	Turks & Caicos	142	Labridae	0.07
Madagascar	56	Gerreidae	0.08	Tuvalu	109	Lethrinidae	0.26
Madagascar	56	Sphyrnidae	0.07	Tuvalu	109	Serranidae	0.25
Madagascar	57	Haemulidae	0.33	Tuvalu	109	Lutjanidae	0.24
Madagascar	57	Serranidae	0.22	Tuvalu	109	Acanthuridae	0.14
Madagascar	57	Scombridae	0.21	Tuvalu	109	Kyphosidae	0.04
Madagascar	57	Nemipteridae	0.14	Tuvalu	110	Acanthuridae	0.27
Madagascar	57	Isiophoridae	0.10	Tuvalu	110	Kyphosidae	0.16
Madagascar	57	Lethrinidae	0.10	Tuvalu	110	Lethrinidae	0.15
Madagascar	58	Scombridae	0.09	Tuvalu	110	Mugilidae	0.10
Madagascar	58	Carangidae	0.06	Tuvalu	110	Lutjanidae	0.08
Madagascar	58	Mugilidae	0.05	Tuvalu	110	Serranidae	0.08
Madagascar	58	Scaridae	0.05	Tuvalu	111	Mugilidae	0.52
Madagascar	58	Gerreidae	0.04	Tuvalu	111	Kyphosidae	0.12
Madagascar	58	Clupeidae	0.04	Tuvalu	111	Lutjanidae	0.09
Madagascar	59	Clupeidae	0.15	Tuvalu	111	Gerreidae	0.07
Madagascar	59	Siganidae	0.14	Tuvalu	111	Acanthuridae	0.06
Madagascar	59	Carangidae	0.13	Tuvalu	112	Lutjanidae	0.14
Madagascar	59	Belonidae	0.13	Tuvalu	112	Serranidae	0.14
Madagascar	59	Gerreidae	0.12	Tuvalu	112	Acanthuridae	0.13
Madagascar	60	Lutjanidae	0.34	Tuvalu	112	Carangidae	0.11
Madagascar	60	Labridae	0.34	Tuvalu	112	Exocoetidae	0.10
Madagascar	60	Lethrinidae	0.10	U.S. Virgin Islands	113	Scaridae	0.28
Madagascar	60	Serranidae	0.08	U.S. Virgin Islands	113	Balistidae	0.19
Madagascar	60	Sparidae	0.07	U.S. Virgin Islands	113	Serranidae	0.17
Madagascar	126	Lethrinidae	0.34	U.S. Virgin Islands	113	Acanthuridae	0.13
Madagascar	126	Siganidae	0.23	U.S. Virgin Islands	113	Holocentridae	0.09
Madagascar	126	Labridae	0.10	Vanuatu	114	Lethrinidae	0.36
Madagascar	126	Acanthuridae	0.08	Vanuatu	114	Siganidae	0.23
Madagascar	126	Gerreidae	0.04	Vanuatu	114	Mullidae	0.17
Madagascar	127	Clupeidae	0.80	Vanuatu	114	Scaridae	0.06
Madagascar	127	Pomacentridae	0.04	Vanuatu	114	Serranidae	0.04
Madagascar	127	Scaridae	0.02	Vanuatu	115	Scaridae	0.48
Madagascar	127	Mullidae	0.02	Vanuatu	115	Acanthuridae	0.29
Madagascar	127	Atherinidae	0.01	Vanuatu	115	Balistidae	0.04
Madagascar	128	Acanthuridae	0.28	Vanuatu	115	Carangidae	0.04
Madagascar	128	Mullidae	0.15	Vanuatu	115	Mullidae	0.03
Madagascar	128	Muraenidae	0.13	Vanuatu	116	Siganidae	0.24
Madagascar	128	Tetraodontidae	0.06	Vanuatu	116	Mugilidae	0.17
Madagascar	128	Balistidae	0.06	Vanuatu	116	Acanthuridae	0.12
Madagascar	129	Scaridae	0.41	Vanuatu	116	Carangidae	0.11
Madagascar	129	Acanthuridae	0.23	Vanuatu	116	Albulidae	0.10

Country	Case No.	Family	% catch	Country	Case No.	Family	% catch
Madagascar	129	Haemulidae	0.06	Wallis and Futuna	117	Acanthuridae	0.33
Madagascar	129	Holocentridae	0.05	Wallis and Futuna	117	Mugilidae	0.16
Madagascar	129	Siganidae	0.05	Wallis and Futuna	117	Carangidae	0.11
Malaysia	61	Scombridae	0.29	Wallis and Futuna	117	Holocentridae	0.08
Malaysia	61	Carangidae	0.21	Wallis and Futuna	117	Serranidae	0.07
Malaysia	61	Lethrinidae	0.15	Wallis and Futuna	118	Lethrinidae	0.24
Malaysia	61	Serranidae	0.14	Wallis and Futuna	118	Carangidae	0.18
Malaysia	61	Lutjanidae	0.05	Wallis and Futuna	118	Acanthuridae	0.18
Malaysia	62	Serranidae	0.37	Wallis and Futuna	118	Lutjanidae	0.16
Malaysia	62	Lethrinidae	0.16	Wallis and Futuna	118	Scaridae	0.07
Malaysia	62	Nemipteridae	0.10	Wallis and Futuna	119	Acanthuridae	0.33
Malaysia	62	Lutjanidae	0.08	Wallis and Futuna	119	Mugilidae	0.19
Malaysia	62	Carangidae	0.05	Wallis and Futuna	119	Carangidae	0.14
Maldives	63	Holocentridae	0.26	Wallis and Futuna	119	Lethrinidae	0.08
Maldives	63	Lutjanidae	0.22	Wallis and Futuna	119	Scaridae	0.07
Maldives	63	Scombridae	0.15				
Maldives	63	Lethrinidae	0.12				
Maldives	63	Serranidae	0.07				

¹ Federated States of Micronesia