Livelihood diversification for conservation: Interactions between seaweed farming and fishing in Danajon Bank, central Philippines

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Declaration of originality

This thesis is the result of my own work, and the work of all others is appropriately acknowledged and referenced in the text.

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Abstract

Livelihoods-based approaches are increasingly used within conservation projects in developing countries to help reduce the exploitation of species for food or income. The objective of these livelihood interventions is often to provide a more attractive substitute for that exploitation. However, the evidence for whether they do manage to achieve conservation goals is scarce, and where present, mixed. In this thesis I examine the case study of seaweed farming and fishing on Danajon Bank, central Philippines. I show that seaweed farming and declining fish catches are associated with reductions in fisher numbers in some villages, but not others. The form of income and risk profile associated with an alternative occupation such as seaweed farming can be more important than its profitability in determining its potential to substitute for fishing. The level of engagement in different occupations with different risk profiles correlates with a range of socioeconomic variables, particularly the level of existing experience in an occupation. Household livelihood portfolios vary between those self-defining as primarily fishers or seaweed farmers, as well as with wealth. Finally, seaweed farming is only associated with lower fishing income when it is perceived to be the most important occupation in the livelihood portfolio. This case study demonstrates the challenges to livelihoods-based approaches, indicating that while they may contribute to increased resilience of households faced with declining fish catches, the conservation benefits are more elusive. The results indicate that greater effort should be put into reducing the risks associated with alternative occupations, and careful consideration should be given to the frequency and timing of income obtained. They also indicate that, because of the potential for perverse incentives and the offsetting effects of increasing human populations, livelihoods-based approaches should be closely linked to direct forms of resource management, such as effort or spatial restrictions, and human population management.

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Abbreviations

AIC	Akaike's information criterion
AICc	corrected Akaike's information criterion (corrected for small sample size)
BFAR	Bureau of Fisheries and Aquatic Resources (Philippines)
DENR	Department of Environment and Natural Resources (Philippines)
df	degrees of freedom
GLM	Generalised linear model
GLMM	Generalised linear mixed effects model
ha	Hectares
KAMADA	Alliance of Small-Scale Fisherfolk of Danajon Bank
kg	Kilograms
km	Kilometres
L	Litres
LGU	local government unit (see section 2.2.3)
lme4	Mixed effects models package in R
LMM	Linear mixed effects model
ln	Natural logarithm [mathematical notation]
MSL	Material style of life (proxy for wealth score)
MuMIn	Multi-model Inference package in R
NGO	Non-governmental organisation
NSCB	National Statistical Coordination Board (Philippines)
NSO	National Statistics Office (Philippines)
P	Philippine Pesos (local monetary currency). The 2009 exchange rate was P47.64 : US$1
PCA	Principal Components Analysis
PO	People's Organisation (see section 2.2.4)
PSF	Project Seahorse Foundation for Marine Conservation (see section 2.2.6)
RI	Relative Importance [statistical term]
sd	Standard deviation
SE	Standard error
SWF	Seaweed farming

CHAPTER 1

Introduction

In developing countries, there is an increasing tendency towards the use of livelihoods-based approaches in efforts to reduce the unsustainable exploitation of species for food or income (e.g. from hunting, fishing or gathering). Livelihoods-based approaches target households of the people engaged in this unsustainable exploitation, and attempt to manipulate the trade-offs within the livelihood portfolios of these households. In effect, they are attempting to manipulate household utility functions in order to increase the relative utility of other income- or food-generating opportunities in relation to the exploitation of species for food or income.

Livelihoods-based approaches have arisen in many different guises and are used within a range of contexts, including integrated conservation and development projects (Brandon & Wells 1992), community-based conservation (Hulme & Murphree 1999), and integrated coastal management (Olsen & Christie 2000), among others. Livelihoods-based approaches can be grouped into three broad and overlapping categories. In the first, manipulations are designed to raise the opportunity costs of unsustainable exploitation by improving the incomes attainable in **alternative occupations**. The expectation of this type of livelihood intervention is that the higher opportunity costs afforded by the alternative occupation will lead to a reduction in overall exploitation levels (Godoy et al. 1995; Hulme & Murphree 1999; Allison & Ellis 2001; Sievanen et al. 2005). In the second, manipulations are used to **compensate** local communities for foregoing hunting, fishing or gathering within protected areas. These changes are often attempted through improving access to services (e.g. financial services, infrastructure, access to markets) so that incomes from occupations that do not exploit the target species can be improved, or to develop alternative sources of income. They differ from alternative occupations in that they do not necessarily aim to raise the opportunity costs for the exploitation of target species. However, they do hope that this compensation will increase support for conservation activities and reduce poaching (Brandon & Wells 1992; Gibson & Marks 1995; Alpert 1996; Pollnac et al. 2001a; Tobey & Torell 2006; Torell et al. 2010). In the third, utility functions are manipulated for the purpose of creating **incentives** to conserve target species or limit the exploitation of target species to sustainable levels by increasing the value of those species (Salafsky & Wollenberg 2000). These changes are attempted indirectly through the development of environmentally linked enterprises such as tourism or trophy hunting, or more directly through direct payments (Wunder 2000; Ferraro 2001; Ferraro & Kiss 2002; Hutton & Leader-Williams 2003; Bell et al. 2006; Sommerville et al. 2009; Sachedina & Nelson 2010).

The common theme with all these livelihoods-based approaches is that they attempt to provide an alternative means of making a living that reduces pressure on exploited resources. By manipulating household utility functions, they aim to partially or completely substitute for the income or food that would normally be obtained from the unsustainable exploitation of target species. The differences lie in the degree of linkage to the target species, ranging from high (incentive-based) to none (alternative occupations). Livelihoods-based approaches are also used for purposes other than the conservation of exploited species, including reducing activities that degrade habitats and environmental services (e.g. environmentally degrading agricultural practices) or changing attitudes towards animals seen as pests (e.g. Abbot et al. 2001; Arjunan et al. 2006; Lybbert et al. 2011). The case study addressed in this thesis falls within the use of livelihoods-based approaches to reduce the unsustainable exploitation of species for food or income, so these applications form the focus of this introduction.

It is unclear whether and when livelihoods-based approaches do help to reduce pressure on exploited species. Reasons for their failure can be broken down into distinct ‘process failures’. First, the increased economic opportunities created by the intervention can lead to increased immigration that in turn increases demand for exploited species and swamps the economic benefits of the intervention (Oates 1995; Noss 1997; Sievanen et al. 2005). Second, weak or inadequate institutions can result in inequitable distribution of benefits, such that those engaged in the unsustainable exploitation of target species are excluded (Brandon & Wells 1992; Belsky 1999; Corbera et al. 2007; Fabinyi 2010). Third, the particular tool used or enterprise developed may not be financially viable, people may not have the necessary skills or knowledge to be able to take advantage of the opportunities created, or the opportunity created may not suit the aspirations and characteristics of the individuals involved (Salafsky et al. 2001; Torell et al. 2010). For example, local communities may not possess the skills or knowledge to make a success of community-based ecotourism ventures without significant outside assistance (Kiss 2004). Fourth, even interventions that successfully generate incomes for the ‘right’ people may not fully substitute for the exploitation of target species, instead providing a supplementary source of income with exploitation continuing at similar levels, or even subsidising higher levels of exploitation (Sievanen et al. 2005). Finally, the tool used may itself have direct impacts on the target species or the habitat of the target species, or have other detrimental environmental effects. For example, seaweed farming has been shown to affect fish community structure in Zanzibar (Eklöf et al. 2005) and to smother native corals in India (Mandal et al. 2010). Quotas set for trophy hunting of target species aimed at increasing their value and therefore incentives for conservation are not always sustainable (e.g. Palazy et al. 2011).

One of the reasons for the popularity of livelihoods-based approaches and their inclusion in broader conservation with development projects (e.g. integrated conservation and development projects) is their perceived potential to contribute towards both conservation and development objectives. Some authors have suggested that the apparent failures of projects that integrate conservation and development objectives is reason enough for conservation groups to return to the ‘protectionist’ era of the 1970s and abandon efforts to manipulate livelihoods (Oates 1999; Terborgh 2000). Others point out the shortcomings of protectionist approaches and suggest that increased efforts should be focused on learning from the experiences of these combined conservation and development projects thus far (Brechin et al. 2002), and on understanding the shortcomings and trade-offs between conservation and development objectives that often occur (McShane et al. 2011; Miller et al. 2011; Minteer & Miller 2011). Within this context, it is not sufficient to examine livelihoods-based approaches only in terms of success or failure without attempting to understand the factors that contributed to those outcomes, the limitations of these approaches, and how they could be improved. Some studies have begun to examine particular components of livelihoods-based approaches. For examine, Torell et al. (2010) examine the factors associated with making enterprises “successful” (in terms of revenue generation). They examined a range of factors associated with the form of support provided, the type of enterprises, and the characteristics of the people involved, and found that all have important consequences for enterprise viability. However, one of the key questions that still remains to be answered about these approaches is whether and when the incomes generated from (financially viable) enterprises can substitute for (partially if not completely) the food or income obtained from the exploitation of target species.

This thesis aims to explore whether and under what conditions the revenues generated from a particular type of livelihoods-based approach (the promotion of alternative occupations) can substitute for income obtained from the unsustainable exploitation of target species. I specifically examine the case study of seaweed farming and fishing on Danajon Bank in the central Philippines.

Seaweed farming has often been promoted as a potentially lucrative alternative occupation to fishing in Southeast Asia, with the assumption that it will raise the opportunity costs of fishing and help to reduce fishing pressure (Sievanen et al. 2005). As such, it can be classified as a successful enterprise in terms of its potential for income generation (Hurtado-Ponce et al. 1996; Hurtado et al. 2001). However, the effect of seaweed farming on fishing pressure is unclear, with indications that seaweed farming has substituted for fishing in some sites across Southeast Asia and for some fishers, while in other sites fishers continue fishing at similar levels to those prior to starting seaweed farming (Sievanen et al. 2005). I use this case study to examine the way in which seaweed farming is used within the livelihoods of fishers, and when, why and how it may partially or completely substitute for fishing. Although seaweed farming has not been promoted as an incentive or as compensation for reduced access to fishing, the findings of this thesis are applicable to any situation where interventions attempt to provide substitutes for the income or food obtained from the unsustainable exploitation of target species. Irrespective of the degree of linkage of these interventions to the target species or other conservation activities (i.e. incentive / compensation / alternative), unless these tools can provide an adequate replacement for the exploitation of target species, the motivation will remain for those involved in that exploitation to continue with their original behaviour. The success of livelihoods-based approaches depends on understanding why people engage in the exploitative behaviours in the first place, the role that those behaviours play within people’s livelihoods, and the features that need to be replicated by livelihoods-based approaches in order to replace the need for those behaviours.

In the remainder of this chapter I first consolidate recent advances in the understanding of how different sources of income interact within individual’s livelihoods. Second, I introduce the context of fisheries management in developing countries and the expansion of seaweed farming in Southeast Asia. Finally, I outline key knowledge gaps that limit our understanding of whether and when occupations such as seaweed farming help to reduce fishing pressure, and how this thesis will contribute to filling those gaps.

In this thesis, "alternative occupations" is used as a catch-all phrase for any income-generating occupation (such as seaweed farming) that does not involve exploiting the natural resource of interest (in this case fishing).

Livelihoods of the rural poor

Recent improvements in understanding livelihoods in developing countries reflect an increased awareness of people's adaptations to poverty. Poverty is not solely a function of the size of income, but is complex and multidimensional and incorporates concepts such as vulnerability to risk and uncertainty and having the assets needed to maintain wellbeing (MacFadyen & Corcoran 2002; Béné 2003). The rural poor often lack access to insurance services, so many individuals prefer strategies that spread risk and uncertainty rather than maximise profits (Dercon 1996; Zimmerman & Carter 2003; Tucker et al. 2010). One strategy for spreading risk is to engage in a wide range of occupations so that if one occupation fails the individual may fall back on another. As such the rural poor often pursue a diverse range of occupations (Ellis 2000a; Barrett et al. 2001; Allison & Ellis 2001), including some family members migrating to urban areas in order to obtain jobs and send income back to the home (Reardon 1997; Adger et al. 2002; Niehof 2004; Rigg 2006, 2007; Haggblade et al. 2010). The process of constructing a diverse portfolio of occupations is known as 'diversification' (Ellis 1998).

The 'sustainable livelihoods approach to poverty reduction' recognises the importance of diversification to the rural poor and provides a framework for interpreting the mix of occupations in which individuals engage (Allison & Horemans 2006). The sustainable livelihoods approach stems from the 'capitals and capabilities' framework which recognises that the mix of occupations in which a household engages (the livelihood strategy) is in part determined by their assets and the institutions that govern access to those assets and occupations (Sen 1981; Bebbington 1999; Allison & Ellis 2001; Béné 2003; Ellis & Allison 2004). The unit of interest is usually the household as this is typically considered the social group that makes joint or coordinated decisions over resource allocation and income pooling (Allison & Horemans 2006). Within the sustainable livelihoods approach, a *livelihood* is defined as comprising:

> "the assets (natural, physical, human, financial and social capital), the activities, and the access to these (mediated by institutions and social relations) that together determine the living gained by the individual or household" (Ellis 2000b)

and is defined as sustainable:

> "if people are able to maintain or improve their standard of living related to wellbeing and income or other human development goals, reduce their vulnerability to external shocks and trends, and ensure their activities are compatible with maintaining the natural resource base" (Allison & Horemans 2006).

Diversification is often interpreted as complete economic substitution of occupations (Ireland et al. 2004; Sievanen et al. 2005; Brugère et al. 2008). However, within the sustainable livelihoods approach, diversification (through the addition or enhancement of alternative occupations) is promoted as a feature that reduces unsustainable activities. It is assumed that diversified livelihoods can allow individuals to respond to periods of low abundance in natural resources by reallocating labour elsewhere (Allison & Ellis 2001; Torell et al. 2010). This assumption is supported by empirical research in coastal systems that suggests fishers with greater access to non-fishing occupations may be more willing to exit declining fisheries (Cinner et al. 2009a). Rather than making the assumption of complete economic substitution, the sustainable livelihoods approach predicts that diversified livelihoods allow individuals to adapt the level to which they exploit natural resources in response to the abundance of those natural resources. The sustainable livelihoods approach also points towards the importance of institutions and an individual's asset holdings in determining an individual's ability to diversify (Allison & Ellis 2001).

While the sustainable livelihoods framework encourages the consideration of institutions and assets in understanding the livelihood strategies of the rural poor, it is limited in the consideration of reasons for engaging in different occupations beyond the need to reduce vulnerability, and largely considers diversification only in terms of the number of occupations rather than the characteristics of those occupations. However, different occupations may be associated with different risk profiles (Mace 1993; Dercon 1996; Tucker et al. 2010). Individuals may engage in occupations for reasons not directly associated with vulnerability, such as to improve social status, to control pests, or for enjoyment (Gibson & Marks 1995; Béné & Tewfik 2001; Pollnac et al. 2001b; Pollnac & Poggie 2008; Walsh 2009). Furthermore, preferences and attitudes to risk and uncertainty vary among individuals, and are influenced by socioeconomic factors such as wealth, the demographic life-cycle stage of their household, experience, and social status, as well as less tangible factors such as individual's values and aspirations which may themselves vary with socioeconomic factors (Rosenzweig & Binswanger 1993; Dercon 1998; Smith et al. 2005; Perz et al. 2006; Dorward et al. 2009; Coulthard et al. 2011).

Fishing and seaweed farming

In contrast to mammals and birds, fish have traditionally not been considered as wildlife (Wadewitz 2011), so management efforts have traditionally focused on attempting to ensure sustainable yield rather than setting aside large areas for wildlife conservation. Although there is increasing interest in marine protected areas, they are primarily promoted for fisheries purposes (Roberts et al. 2001; Gell & Roberts 2003; McClanahan 2006) and the area under protection is a small fraction of that considered necessary to support sustainable fisheries and ecosystems (Mora et al. 2006; Roberts 2007; Wood et al. 2008; Weeks et al. 2010). Efforts to maintain sustainable yields have traditionally focused on the contested linkages between the open-access nature of fisheries and artisanal fishers' resource dependence that together lead to resource degradation, poverty and marginalisation (see Allison & Ellis 2001; Béné 2003). The solutions advocated for these problems have traditionally centred on improving the economic efficiency of artisanal fisheries while attempting to conserve fish stocks by enticing current participants to leave the fishery (e.g. Salayo et al. 2008). However, fisheries management has traditionally taken a limited sectoral view that disregards the complexities of fisher's livelihoods (Allison & Ellis 2001) and makes the assumption that fishers will be willing to switch out of fishing if they have more lucrative opportunities (Sievanen et al. 2005). The sustainable livelihoods approach to poverty reduction in fishing communities is being increasingly advocated with the aim of incorporating a more complete understanding of people's livelihoods into management and policy, and transcending traditional sectoral boundaries where fisheries are managed independently of sectors such as agriculture and social services. Thus, this approach advocates diversification as a tool to reduce dependence on declining fish stocks, but recognises that diversification is unlikely to lead to complete economic substitution (Allison & Horemans 2006).

Seaweed farming in Southeast Asia is primarily focused on two species widely known by their trade-names as cottonii (*Kappaphycus alvarezii*) and spinosum (*Eucheuma denticulatum*; Zuccarello et al. 2006). Seaweed farming of these species is primarily to produce hydrocolloids (extracted from dried seaweed) for the international market, particularly carrageenans, agar and alginates. The use of these hydrocolloids began to expand in the 1950s (Sievanen et al. 2005). Their primary market is the processed food industry where they serve as texturing agents and stabilizers, although there is a wide and growing range of applications (Bixler & Porse 2011).

Seaweed farming has been noted as a very lucrative and accessible alternative occupation to fishing in Southeast Asia (Crawford 2002; Sievanen et al. 2005; Supporting Information). It has relatively low entry costs as very little equipment or technical expertise is required (Ask 1999; Hurtado et al. 2001; Hurtado 2003). Many analyses on the economic feasibility of seaweed farming emphasise the high returns on investment that seaweed farming can generate and the high incomes relative to fishing (Samonte et al. 1993; Hurtado-Ponce et al. 1996; Hurtado et al. 2001; Hurtado & Agbayani 2002). Additionally, they report that many seaweed farmers were formerly fishers.

While there is evidence that people have left fishing for seaweed farming in some sites, in other sites fishers reported continuing to fish at the same level even after taking up seaweed farming (Sievanen et al. 2005). There are two main reasons given for people continuing to fish after taking up seaweed farming. The first is that fishing provides daily income and puts food on the table, while income from seaweed farming is only received after harvest which is several months after planting. The second is that women and children can tend seaweed farms whilst men are out fishing (Crawford 2002; Sievanen et al. 2005). Additionally, seaweed farming has undergone boom and bust cycles in many sites due to disease and price fluctuations, causing even those that did stop fishing to move back into fishing. In some cases, profits from seaweed farming have been invested into more efficient fishing gear (Crawford 2002; Sievanen et al. 2005). Although these analyses have shed some light on how individuals respond to seaweed farming, they are limited in two ways. First, there is no indication of why there was variation in the way individuals in different sites responded to seaweed farming, making it difficult to determine whether reductions in fishing effort could be replicated elsewhere. Second, there is no indication of how overall fishing effort has been affected by seaweed farming, and therefore whether any net conservation benefit has been achieved. This thesis will examine these issues in more detail.

Cottonii and spinosum originate from the Philippines and Indonesia (Bixler & Porse 2011). Although seaweed farming is known to influence fish community structures and benthic habitats in Zanzibar and India respectively (Eklöf et al. 2005, 2006; Bagla 2008; Chandrasekaran et al. 2008; Mandal et al. 2010), very little is known about the biological impacts of seaweed farming in the Philippines. This thesis focuses on the interactions between seaweed farming and fishing within people's livelihoods, and does not address the benthic or other direct biological impacts. However, a PhD study is currently being undertaken by James Hehre of Project Seahorse, University of British Columbia, Vancouver, on the biological effects of seaweed farming, working in the same area of the central Philippines that this thesis considers.

Contribution of the thesis

An overarching question that remains unanswered is how alternative occupations interact with the exploitation of natural resources within the livelihoods of the rural poor. For example, what characteristics of alternative occupations influence the extent to which those alternative occupations substitute fishing income? Who is most likely to change their dependence on fishing as a result of alternative occupations, and how? And what support needs to be provided to local communities in order to facilitate the substitution of fishing with income from alternative occupations? Until such questions are answered, the understanding of if and how alternative occupations help to achieve conservation goals remains limited. These questions apply as much to approaches that use alternative occupations to raise the opportunity costs of unsustainable exploitation, as to those approaches that use alternative income sources as incentives or compensation for conservation activities. Incentive or compensation approaches are unlikely to reduce levels of exploitation if they fail to reduce local communities' dependence on natural resources.

This thesis explores the interaction between seaweed farming and fishing on Danajon Bank, central Philippines. Danajon Bank is one of the most degraded reefs in the world (Marcus et al. 2007) and has experienced unsustainable levels of fishing effort in recent decades (Armada et al. 2009). As a relatively confined area with many island villages, Danajon Bank provides the opportunity to examine the interaction between fishing and seaweed farming in several communities that share similar institutional and ecological conditions (Chapter 2). Following chapter 2, which outlines the study sites and methods common to each data chapter, this thesis consists of four data chapters.

Chapter 3 examines the hypothesis that seaweed farming has resulted in an overall reallocation of labour out of fishing given the substantial declines in fish stocks on Danajon Bank. It uses recall information and key informant estimates to determine trends in fisher numbers for ten villages on Danajon Bank, and establishes whether seaweed farming was associated with any changes in those trends, thus providing information on the aggregate effects of seaweed farming.

Chapter 4 explores the characteristics of seaweed farming, fishing and other occupations, with specific focus on the frequency and magnitude of income events from these occupations rather than overall income levels, and the risk profiles of fishing and seaweed farming and the roles these occupations play within household's livelihoods. Thus, Chapter 4 provides an understanding of why people engage in fishing, and the potential for seaweed farming to substitute for the function of fishing.

Chapter 5 examines how socioeconomic and demographic characteristics correlate with the level of household engagement (in terms of income and effort) in fishing, seaweed farming and other occupations. This chapter therefore provides an indication of the characteristics of households that engage the most in these occupations, and which characteristics influence the way that households trade-off the risks and opportunities provided by fishing and seaweed farming.

Chapter 6 looks at the interactions between fishing, seaweed farming and other occupations within household livelihood portfolios, and examines how people that self-define as fishers or seaweed farmers differ in their livelihood portfolios both in terms of which other occupations they engage in and relative levels of income from those other occupations. Chapter 6 also examines the characteristics of households that self-define as seaweed farmers, and whether and how engagement in seaweed farming is correlated with levels of fishing income.

In all chapters, interventions that could improve the potential of seaweed farming to substitute for fishing are discussed. The concluding chapter discusses the contribution of these new insights to understanding when and how alternative occupations, and livelihoods-based approaches more broadly, may help to achieve conservation goals.

CHAPTER 2

Site description and methods

2.1 Introduction

This chapter provides background to the study site and an overview of the data collection methods and data sets used in subsequent chapters of this thesis. Details of the data and analyses specific to individual chapters are discussed in the relevant chapters.

The current chapter is organised into six subsequent sections. Section 2.2 provides background on the study sites. Section 2.3 defines key terms that are used throughout the thesis. Section 2.4 describes the data-collection process including the training of local research assistants. Section 2.5 provides information on the extensive survey methods that were used for Chapter 3 and Chapter 6. Section 2.6 provides information on the intensive survey methods that were used to collect data for Chapter 4 and Chapter 5. Section 2.7 briefly summarises the data collection procedures and how the data were used in the relevant data chapters.

2.2 Study area: Danajon Bank, central Philippines

2.2.1 Site description

Danajon Bank is a double barrier reef approximately 130 km long, running between Bohol and Cebu Provinces in the central Philippines (Fig. 2.1). Seventeen municipalities (from four provinces and two regions) each have areas of jurisdiction over Danajon Bank. For the areas of Danajon Bank covered by Region VII (Central Visayas), 10 municipalities are within Bohol Province and two within Cebu Province. For those in Region VIII (Eastern Visayas), four municipalities are within Leyte Province and one in Southern Leyte Province. Danajon Bank has 40 small islands ranging from 2-3 ha to about 300 ha. There are 234 coastal and island villages (*barangays*) on and around Danajon Bank with an estimated 28,238 fishers, 7,338 motorized fishing boats and 8,766 non-motorized fishing boats (Armada et al. 2009). This thesis only engages with island villages from five of the municipalities within Bohol Province.

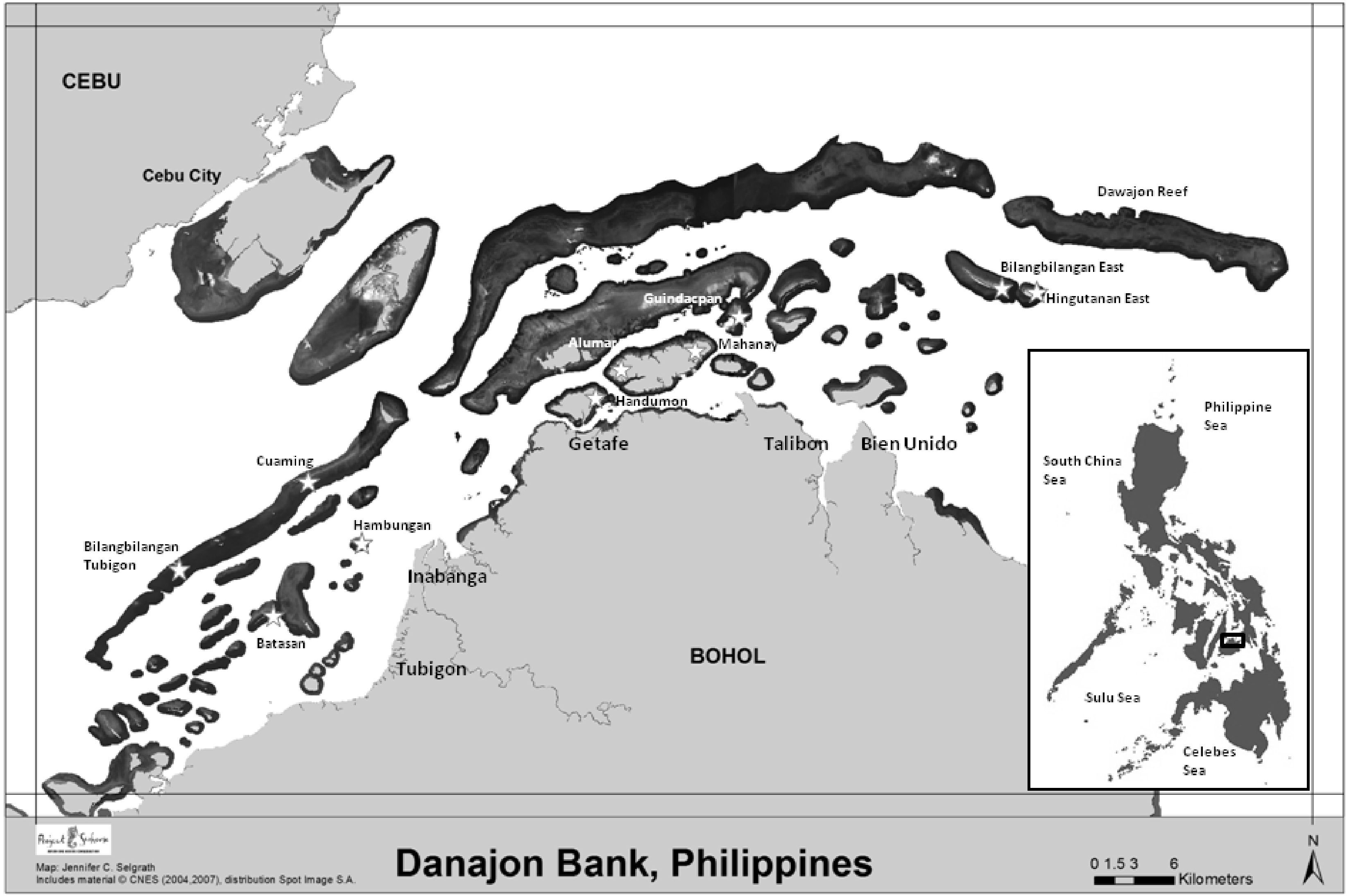

Figure 2.1. Map of study sites (stars) on Danajon Bank (dark areas) between Cebu and Bohol Provinces in the central Philippines (inset). Nearest market towns and Cebu City are shown in larger bold font. Light grey areas are land and mangrove. White areas are sea. Darker areas are the shallow waters of Danajon Bank, where seaweed farming occurs. Some islands (e.g. Guindacpan, Bilangbilangan Tubigon, Batasan, Cuaming and Hambungan) are too small to appear as land on the map.

Danajon Bank suffers from high population densities and high incidences of poverty. The island villages of Danajon Bank are highly dependent on marine resources including fishing and seaweed farming as there are very few alternative income-generating opportunities (Green et al. 2000, 2004; Christie et al. 2006; Armada et al. 2009). The coastal land area surrounding Danajon Bank has an average population density of over 500 people km^{-2} (Armada et al. 2009). Population densities and growth rates on Danajon Bank itself are hard to quantify due to the complexities of calculating rates across regions, provinces and municipalities it encompasses, but the highest growth rates are on the islands on the outer reef (Christie et al. 2006). The overall population of Bohol had an average annual growth rate of 2.95% between 1995 and 2000, which was higher than the national average of 2.36% and the Central Visayas (Region VII) average of 2.81%. However, for unknown reasons, the annual population growth rate of Bohol decreased to 1.06% between 2000 and 2007, which was lower than both the national average of 2.04% and the Central Visayas average of 1.59% (NSO 2008). 41.0% of families in Bohol lived below the annual per capita poverty threshold of P18,062 (equivalent of US$379) in 2009 (NSCB 2011).

Danajon Bank has high ecological and conservation value, but is heavily degraded. The Philippines is the global centre of marine shore fish biodiversity (Carpenter & Springer 2005), but faces the greatest level of threat of all marine hotspots (Roberts et al. 2002) and substantial challenges to marine conservation from poverty and population pressure (White et al. 2000; DeVantier et al. 2004). The Philippines is recognised as a country with one of the highest dependencies on coral reefs and the least capacity and resilience (Burke et al. 2011). Danajon Bank is right in the centre of this centre of biodiversity (Carpenter & Springer 2005), but is one of the most degraded coral reefs in the world (Marcus et al. 2007). Unsustainable levels of fishing effort plus the use of illegal and destructive fishing methods, such as the use of dynamite and cyanide, have lead to declining fisher's catches, further compounding the issue of poverty (Green et al. 2000, 2004; Christie et al. 2006; Armada et al. 2009).

2.2.2 The people of Danajon Bank and fishing

Danajon Bank is predominantly inhabited by people of Visayan ethnicity. Approximately 90% of the population on Danajon Bank are Roman Catholic, while the remaining 10% are from other Christian denominations (Green et al. 2000). The predominant language is Cebuano from the Visayan group of languages (Green et al. 2000).

There are a wide range of fishing gears and methods in operation on Danajon Bank, with over 20 generic types of gear and 44 specific types of gear inventoried from four of the municipalities (Christie et al. 2006). These gears and methods range from hook and line to bottomset gillnets, driftnets, drive-in gillnets, trammel nets, fish corrals, seine nets, lift nets, traps, lantern fishing, flashlight fishing, gleaning and compressor fishing. There are also many highly destructive gears and methods in use including blast fishing, cyanide fishing and Danish seine. Almost all fish and invertebrates are targeted and are either marketed or consumed by the fisher, including the poisonous pufferfish and juvenile fish and seahorses. Squid (locally known as *nokos*) and blue crabs (*Portunus pelagicus*, locally known as *lambay*) are important target species and form a large component of the landings (Christie et al. 2006).

Many of these gears are operated by individuals, but in some cases they are operated by small groups of three to six individuals. Where cooperative fishing occurs, income sharing arrangements can be complex and vary from case to case. The most common form of income sharing arrangements include the “tripartite” sharing systems (where the income is divided between the boat owner, the gear owner and the crew) and the “resale” system (where the crew sell the catch to the owner for a low price, after deducting costs for food and fuel, and the owner makes profit through reselling the catch for a higher price). Depending on the arrangement, sharing can occur on a daily basis or at the end of a week. More complex sharing systems are in practice for larger operations such as the Danish seine (locally known as *liba-liba*).

Fishing gears tend to be funded by relatively few wealthy individuals in each village, known as *capitalista*. These individuals tend to be middlemen that are involved in the trade of specific species or classes of marine products. Arrangements between *capitalista* and their fishers vary, but normally involve an agreement to sell all or part of the fisher’s catch to the *capitalista*. Some arrangements include repayment schedules, whilst others are linked indefinitely. These arrangements are discussed in a little more detail in Appendix S4.

Fresh produce markets occur once a week in each of the main municipal towns in Bohol Province. Fishing gear is also sold in these towns. Access to these market towns is via pumpboat, a motorised outrigger canoe, and island villages are normally well connected to these municipal towns with regular passenger boats. Cebu City also has a large fish market and markets for fishing gear, as well as being a centre for trade to international markets. Many species caught on Danajon Bank enter into the international market, including seahorses destined for the traditional Chinese medicine trade, aquarium fishes destined for Europe and North America, and blue crabs destined for Europe. Regular passenger boats to Cebu City run from many of the large municipal towns on Bohol, and traders from Cebu City often come direct to the islands to buy fish and other marine products. Transport between municipal towns on Bohol is by local bus, jeepney or van.

Fishing is an important component of the culture for many people on Danajon Bank. As well as fishing their own waters, people from Danajon Bank are known for fishing in distant waters, including places as far away as Palawan and the Sulu Archipelago (Guieb 2008; Fabinyi 2009). With the exception of seaweed farming (section 2.2.5), access to other occupations on the islands is limited, but includes handicrafts such as mat weaving, water collecting and selling, labouring on fish ponds, and entrepreneurial occupations such as owning a small store (Guieb 2008). Very few coastal households have ownership of agricultural land (Green et al. 2000), and in some cases even residential land is not owned by the household (section 2.6.2). Migration of young household members to nearby urban areas (e.g. Cebu City or the municipal towns) or overseas for work as wage labourers has been a feature of these communities for many years, but is becoming increasingly important (Guieb 2008).

2.2.3 Administrative organisation and legislation of marine resources in the Philippines

Traditional systems of tenure have been heavily influenced by the political history of the Philippines. This includes a long history of colonial rule. First colonised by the Spanish in the 16th century, the Philippines was then ruled by the Americans from the late 1890s. The Japanese Empire invaded during the Second World War, but were defeated by the allies in 1945. The Philippines finally gained independence in 1946. Ferdinand Marcos, elected president in 1965, declared martial law in 1972 and ruled the country until his exile in 1986. This turbulent history has resulted in a complex history of tenure arrangements for land and sea resources and systems of management which are discussed in detail by Guieb (2008). A summary of the current system of management is given in this section.

Villages, known as *barangays*, are the lowest level of administrative organisation in the Philippines with their own elected officials including a *barangay captain* and seven *barangay kagawad* (councillors). Regions are not a political unit, but are administrative units of the different departments and agencies of the national government. Legislation is passed at a national level, and the implementation of legislative measures is under the jurisdiction of local government units, which are hierarchical and composed of (in descending order) province, municipality, city and *barangay*, each with their own locally-elected officials. Laws passed by these local government units (LGUs) are subsidiary in nature to and must be consistent with national laws.

Under the Local Government Code of 1991 (RA 7160), municipalities have management jurisdiction over the waters surrounding the villages and have exclusive authority to grant fishery privileges in those waters and impose rentals, fees or charges. This also includes the authority to grant privileges for seaweed farming and other forms of aquaculture in municipal waters. The Fisheries Code of 1998 (RA 8550) adopts a policy of preferential use of and access to municipal waters for municipal fishers and local communities. In the municipality of Getafe in 2006, the annual license fee for 1 ha for seaweed farming was Philippine Pesos (P) 460, and the annual registration permit for a fishing boat was: P360 (under 1 gross tonne), P460 (over 1 gross tonne), P560 (over 2 gross tonnes) and P100 for additional boats (per person). Community engagement in management and planning processes are through representation in the form of People's Organisations (section 2.2.4) and non-governmental organisations (section 2.2.6) in the City or Municipal Fisheries and Aquatic Resources Management Councils. Municipal waters extend for 15 km from the coastline of the municipality, though many of the boundaries are disputed within the context of Danajon Bank (Guieb 2008).

Despite the current governance system and a long history of centralised control over marine resources during the colonial and martial law eras, some traces of traditional tenure systems are still evident. Areas of reef are sometimes named after people that have found them or people that lay claim to them, or families have ownership of specific areas for the use of fish traps based on ancestral ownership. In some cases ownership is formalised by the payment of annual municipal fisheries fees and access restricted by the owners (Guieb 2008). However, formally, villages do not have jurisdiction over the waters surrounding them.

Despite high targets for protection of marine resources in the Philippines and an abundance of laws governing the use of marine resources, levels of protection and law enforcement are low. The Fisheries Code of 1998 (RA 8550) requires a minimum of 15% of coastal municipal waters to be protected within no-take marine protected areas. The Philippine Marine Sanctuary Strategy of 2004 aims to protect 10% of coral reefs in no-take marine protected areas by 2020 (Weeks et al. 2010). However, the area under protection in the Philippines is a fraction of this (Weeks et al. 2010), with only around 0.5% of Danajon Bank currently estimated to be under protection (Ban et al. 2009). While there are many laws governing the use of marine resources on Danajon Bank, weak and inadequate law enforcement resulting primarily from a lack of funds and a lack of capacity has been identified as a core fisheries problem (Christie et al. 2006; Armada et al. 2009).

2.2.4 People's Organisations (POs)

People's Organisations (POs) are a focal point within villages for community-based coastal resource management activities, including seaweed farming development programmes. POs originally developed as protest groups of economically or politically disenfranchised people during the years of martial law under the Marcos regime (1972-1983). Towards the end of the Marcos regime, community-based coastal resource management became a component of an alternative development strategy advocated by POs and non-governmental organisations (NGOs) (Guieb 2008). Following the Marcos' regime, POs and NGOs seized the opportunity of decentralization to take a more active role in decision making and resource management (Guieb 2008). NGOs and POs came together to form large networks, including the National Coalition of Fisherfolk for Aquatic Reform and, in the early 2000s, the National Alliance of Small-Scale Fisherfolk to Protect the Seas and Sanctuaries in the Philippines (*PAMANA ka sa Pilipinas*). POs are now generally referred to without reference to their political roots. They are formed at the village level and are officially recognised at the local government level as organisations that can participate as stakeholders in discussions of resource management (Guieb 2008). These POs are separate to the village-level government and are formed of members who elect their own representatives. POs are often used as an entry point together with the village-level government officials for community-based resource management on Danajon Bank. Officially registered POs can apply to the government and its agencies for development and assistance programmes, such as financial and technical assistance with seaweed farming (section 2.2.5). For this thesis, where POs existed, they and elected village officials acted as entry points for research conducted on the islands. Membership of POs was also recorded as an explanatory variable for household surveys.

2.2.5 Seaweed farming in the Philippines and on Danajon Bank

Seaweed farming started in the Philippines in the 1960s and has since developed into a major export industry. Seaweed farming arrived in the Philippines because the seaweed industry sought to secure stability in supply and prevent overexploitation of natural beds (Sievanen et al. 2005). New strains of red seaweed (including *K. alvarezii* and *E. denticulatum)* were discovered in the Sulu Archipelago, which became the largest producer of seaweed in the Philippines (Trono Jr 1990; Sievanen et al. 2005). The Philippines started exporting dried seaweeds in 1967, although production from 1967 until 1972 was mostly collection of wild growth (Trono Jr 1990). Farming technology started to become widespread in the mid-1970s, and mostly focused on the two species currently farmed, *E. denticulatum* and *K. alvarezii*, although some other species were collected from wild growth including *Gracilaria* spp, *Gelidiella* spp, *Caulerpa* spp and *Sargassum* spp (Trono Jr 1990). Seaweed farming in the Philippines then grew rapidly to become one of the country's main fishery exports in 1980 (Trono Jr 1990). There has been and continues to be substantial investment in research and development that has improved the productivity of strains of seaweed, developed more productive and lucrative farming methods, and developed new product uses and applications (e.g. Hurtado-Ponce 1992; Trono Jr & Lluisma 1992; Dawes et al. 1993; Hurtado & Agbayani 2002; Ask & Azanza 2002; Luening & Pang 2003; Nobre et al. 2010; Bixler & Porse 2011).

Seaweed farming started on a small area of Danajon Bank in the 1960s where it was very quickly adopted and proved to be more lucrative than fishing (Trono Jr 1990). Seaweed processors established factories in nearby Cebu City and farmhouses on Dawajon Reef, an outer reef of the Danajon Bank (Fig. 2.1). In 1979 there were over 200 farm houses and drying platforms constructed and 500 ha of reef planted, with approximately 2,000 people working daily on the farms and 8,500 people fully or partially dependent on seaweed farming (Trono Jr 1990). Seaweed farming was quickly noted as being a lucrative alternative to fishing on Danajon Bank and there were recommendations that it should rank high on the government's agenda to help develop poor fishing communities (Trono Jr 1990). In 1979, reported average net daily incomes from fishing (P12) meant that fishers were earning approximately P360 per month, whereas one hectare of seaweed farm netted a farmer an estimated average of P1,200 per month (Trono Jr 1990).

Government actively started promoting seaweed farming within fishing communities on Danajon Bank in the mid-1990s. Assistance is primarily provided in the form of financial and technical assistance via POs to help PO members take up seaweed farming. Recognised POs can apply to the government for assistance through the municipal local government unit. Seed capital is provided that is used to buy seedlings and monolines which are distributed among

PO members in the form of a loan per member. The municipal LGU also provides a license for a seaweed farming area that the PO members divide among themselves. The municipal agricultural officer is usually involved in helping to provide technical assistance and in sourcing the seedlings and equipment. Assistance programmes are normally set up as a savings and credit facility. A dedicated bank account is set up in the municipal town, and members are expected to make monthly repayments. The monthly repayments vary among POs, but are generally composed of a quantity that counts as the equity capital build-up (which effectively pays back the value of the capital assistance, with a low level of interest associated with it), a quantity for an operational fund, and a quantity that contributes towards an emergency fund. Repayment is reliant on peer pressure and is not enforced by the municipal local government unit. The objective is that the PO can self-administer the savings and reinvest the credit after each pay-back schedule is completed.

Areas of the reef are claimed by individuals or households for their seaweed farming use. These areas can vary in size depending on the resources of the individual or household and their ability to farm that area. Seaweed farmers are required to register these areas (up to 1 ha per household) with the municipal agricultural officer, and pay a license fee for its use (section 2.2.3). Sometimes, the municipal agricultural officer will then formalise the boundaries, normally by visiting the site and recording the location of the boundaries on a handheld global positioning system device. Not all households register their area, but registration is becoming increasingly widespread. Relatively wealthy and politically well-connected households often have access to the largest and most convenient areas (Guieb 2008). The owners of large seaweed farming areas may not be seaweed farmers themselves, but hire labourers for their seaweed farms (Guieb 2008). Even for those seaweed farming households that do own seaweed farms, households may hire in and hire out labour depending on labour requirements and availability. Payment for such labour is normally based on the quantity of work undertaken, in terms of the number of monolines planted or harvested. This labour may be undertaken by men, women or children.

2.2.6 Non-governmental organisations (NGOs) on Danajon Bank

Many organisations work actively on Danajon Bank together with local government (section 2.2.3) to help restore and rebuild marine resources. For example, the USAID-funded Fisheries Improved for Sustainable Harvest (FISH) project have worked towards building the capacity for an ecosystem-based fisheries management system with local agencies and local government units. The management tools for this included limitations on fishing effort and gear, limiting the harvest of important species during specific life stages, licensing, zoning, coastal law enforcement, and the development of "alternative livelihoods" (Armada et al. 2009). Promotion of "alternative and supplemental livelihoods" is primarily targeted at the poor who are affected by fishery regulations (Armada et al. 2009), with seaweed farming promoted regionally as one potential alternative livelihood (DA-BFAR 2004). Non-governmental organisations (NGOs) have also been active in marine resource management. Over 60 municipal- and community-led marine protected areas have also been established on Danajon Bank, 34 of them with the support of Project Seahorse Foundation for Marine Conservation (PSF) and others with the support of FISH (Christie et al. 2006). These community-managed marine protected areas tend to be small, ranging in size from about 5 to 250 ha. The PATH Foundation Philippines (PFPI) is also active around Danajon Bank in a Population-Health-Environment Network that aims to provide support for sustainable population, health, and environment development in Bohol.

2.2.7 Collaborators

This PhD study was conducted in collaboration with Project Seahorse. Project Seahorse is a marine conservation organisation committed to the conservation and sustainable use of the world's coastal marine ecosystems. An association of academics and conservation practitioners, Project Seahorse has members all over the world. The main headquarters are at the University of British Columbia, Vancouver and the Zoological Society of London. During the course of this PhD study, I spent three months at the University of British Columbia working with other members of the Project Seahorse team.

Fieldwork was conducted in collaboration with Project Seahorse Foundation for Marine Conservation (PSF). PSF is an independent Filipino NGO closely linked to Project Seahorse, with headquarters in Cebu City, Philippines. PSF's work focuses on Danajon Bank and uses seahorses as a flagship species for a broad range of marine conservation initiatives, particularly community-managed marine protected areas. Project Seahorse provides research support and expertise to PSF. Many PhD students have worked and continue to work with PSF on issues that are of relevance and interest to their conservation work. PSF has several programmes within its five year strategic plan, and one of those programmes, the Seaweed Farming and Ecosystem Programme, focuses on the ecological and socioeconomic issues associated with seaweed farming on Danajon Bank. I worked closely with PSF during the course of this PhD study within this programme, and results from this thesis will be summarised in management briefings and reported to PSF staff and to their partners. PSFs partners include (among others) the Alliance of Small-Scale Fisherfolk of Danajon Bank (KAMADA), POs and village officials within target villages, the municipal Local Government Units of target municipalities, the Bohol Provincial Office of Agriculture, the regional office of the Bureau of Fisheries and Aquatic Resources, and the Bohol office of the Department of Environment and Natural Resources.

2.3 Definitions

2.3.1 Household

A household is defined as “a group of persons sharing a home or living space, who aggregate, and share their incomes, as evidenced by the fact that they regularly take meals together” (Marshall 1994). This definition allows for but fails to portray the dynamic nature and flexibility of households in rural poor areas. Households are not a fixed entity but vary in space and time and often comprise the extended family (Malleret-King 2000). In livelihood frameworks, the unit often considered is the extended household including members who are away from home but send back remittances (Allison & Ellis 2001). This has changed more recently to “the social group which resides in the same place, shares the same meals and makes joint or coordinated decisions over resource allocation and income pooling” (Allison & Horemans 2006) and the related but more simplistic definition of a household that was adopted for this thesis as “people living together and sharing meals” (e.g. Cinner et al. 2010; Cinner & Bodin 2010). The key feature of this social unit is that this is the level at which household resources are typically pooled and decisions are made. All members therefore draw on or contribute to household resources, and composition is flexible from day to day. In the context of Danajon Bank, some family units shared their time between different households where they were involved in different occupations. These cases were fairly uncommon. More commonly, some individuals would spend most of their time elsewhere, either in education or in wage labour jobs, and come back to the household relatively rarely. These individuals were only regarded as household members on days when they were present in the household.

2.3.2 Livelihoods

A *livelihood* is defined as comprising “the assets (natural, physical, human, financial and social capital), the [occupations and activities], and the access to these (mediated by institutions and social relations) that together determine the living gained by the individual or household” (Ellis 2000b). The unit of interest for livelihoods in this thesis is the household.

2.3.3 Occupations

An *occupation* is defined as a source of monetary or non-monetary income that is used to maintain or improve a livelihood, or is part of a livelihood, e.g. fishing and seaweed farming are occupations (see 2.3.5 for occupational categories).

2.3.4 Activities

An *activity* is defined as a specific workload or job that contributes towards an occupation, e.g. fishing is an occupation that may involve activities such as collecting bait, preparing the nets or lines, travelling to or from the fishing site, setting the nets or lines, hauling the nets or lines, processing the catch, selling the catch.

2.3.5 Occupational diversity

Occupational diversity is defined as the total number of occupations that a household engages in, based on categories of occupations. The categories are as follows: fishing (including gleaning); seaweed farming; trading of fish/shellfish products; trading of seaweed; agriculture (including livestock, coconuts and arable); salaried employment (e.g. village official or teacher); business (e.g. selling of food or water); casual labouring; handicraft; housemaid; trade of other products (e.g. firewood); independent trade work (e.g. carpentry or mechanical), and; remittances sent by family members living elsewhere. ‘Other’ was used for unpaid work such as volunteering for village beach clean-ups and day-care supervision.

2.3.6 Informal sector occupations

Informal sector occupations are all those categories listed in section 2.3.5 that could be defined as casual labour or entrepreneurial occupations that provided *ad hoc* income, and included: business (e.g. selling food or water); sale of other products (e.g. firewood); independent trade work (e.g. carpentry/mechanic) and casual labour.

2.3.7 Diversification

Diversification is defined as: “the process by which rural families construct a diverse portfolio of [occupations] and social support capabilities in their struggle for survival and in order to improve their standards of living” (Ellis 1998). As per this definition, diversification can occur at a household level in terms of adding more occupations to the portfolio of occupations. However, diversification can also occur at a broader scale so that there are greater numbers of occupations available to households within villages, but households may choose to engage in only a subset of these occupations (Brugère et al. 2008).

2.3.8 Alternative occupation

An *alternative occupation* is defined as an occupation that does not involve exploiting the natural resource of interest for conservation (e.g. where fish stocks are the natural resource of interest for conservation, alternative occupations are all non-fishing occupations such as seaweed farming), irrespective of whether that occupation substitutes, supplements or even subsidises the exploitation of natural resources. This term is used to distinguish from a general term like “other occupations” that may refer to an undefined group of occupations. *Alternative occupation* is also distinct from the term “alternative livelihood” that is often used in the context of Integrated Coastal Management or Integrated Conservation and Development Programmes, which implies a substitution of all the assets and occupations that are used by households in generating a living (Ireland et al. 2004; Sievanen et al. 2005).

2.3.9 Income

Income is used throughout this thesis as a catch-all phrase to refer to the sum of both monetary and non-monetary income received by household members from an occupation. Non-monetary income refers to food or goods that are obtained from an occupation but given away as gifts. Non-monetary income is assigned a monetary value by using the market value of these goods. Income is also used in this thesis independently of the way it was received from an occupation; whether it was received for own activities, as payment for labour, or through an income sharing arrangement (e.g. in the case of cooperative fishing), and it specifically refers to household income (e.g. in the case of cooperative fishing, the share of monetary and non-monetary income that was received by members of the household).

2.4 Local research assistants

All surveys, interviews and focus group discussions were conducted in the local dialect, Visayan, by one of four trained and experienced local research assistants. These local research assistants were employed by PSF, and all but one had worked previously as a local research assistant for PSF. All research assistants were from island villages on Danajon Bank. Research assistants were fluent in English and Visayan.

Two research assistants worked exclusively on the extensive surveys (section 2.5), and another two worked exclusively on the intensive household-level surveys (section 2.6). These research assistants worked simultaneously in different island villages. For the intensive household-level surveys each research assistant was assigned one of the villages in order to build community relations and trust over the course of the year, as well as to provide some consistency in data collection, although two-weekly exchanges were run to ensure consistency among research assistants (section 2.6). Training and experience with the methods were essential. Training specific to the survey methods was provided to all research assistants before going into the field. Training consisted of presenting and discussing detailed descriptions of the aims and objectives of the project, the information that we aimed to collect, and providing practical training in the methods to be used to collect the information (e.g. mock interviews). Included in this training were methods to triangulate information, including asking questions in different ways, verifying with different members of the household, and through direct observation. Additionally, training was provided on respondent and data confidentiality, and ethical conduct. As part of this, all research assistants were required to keep completed datasheets under lock and key. Lockable boxes were provided in Handumon and Guindacpan for each research assistant where they could deposit and store completed datasheets.

Datasheets and questionnaires were designed by myself in conjunction with the research assistants, and prepared for all survey and interview work. Datasheets and questionnaires were translated into Visayan by the research assistants, and translations were cross-checked by other PSF staff and the other research assistants by translating them back into English. Role-plays and trial surveys were used on each other and me to build up familiarity with the questionnaires and surveys. Finally, I asked the research assistants to explain the aims and objectives of the project back to me, including describing the information that we were aiming to collect and the methods to be used. I also questioned them thoroughly to ensure they fully understood the aims and methods. No fieldwork was conducted until they had a thorough understanding of the methods. The training period took 6 weeks for the intensive surveys, and four weeks for the extensive surveys. Questionnaires and surveys were then trialled and modified accordingly. During the field work, the research assistants working in the same project (e.g. intensive survey) spent one day per month with their colleague in their field site and accompanied them during their surveys. This ensured consistency of methods and allowed them to cross-validate each other's work.

I reviewed all completed questionnaires and datasheets, normally within one week of completion, and any points that were not clearly recorded were clarified with the relevant research assistant. During the 12-month period that I was in the Philippines (3 week pilot trip in November 2007, followed by trips from April to July 2008, November to April 2009, and in June 2009), I had weekly contact with each research assistant and held monthly progress reviews, and spent much of my time in the study villages. Monthly meetings were also used as an opportunity to discuss any issues or queries. When I was away from the Philippines (August and September 2008, and May 2009) a permanent member of staff at PSF was nominated to visit the research assistants and provided with a check-list to check on their welfare and progress and ensure they had the necessary survey materials. I retained ongoing contact with the research assistants via mobile phone texts and called them when they had any queries or problems. During the time I was in the Philippines I learned a modest amount of Visayan so I could hold basic conversations with people in the villages, and I joined community-members on fishing trips and seaweed farming activities in Guindacpan and Handumon. I was involved in all village meetings, feedback sessions and focus group discussions. I also had the opportunity to directly observe some of the activities of fishers and respondents. I initially participated in surveys immediately following the training period, but limited my direct involvement in surveys.

2.5 Extensive surveys

2.5.1 Introduction

Extensive surveys refer to a set of methods that were applied in 10 villages on Danajon Bank, including questionnaires that were conducted once per household in each of those villages. Extensive surveys were conducted between November 2008 and May 2009 to obtain an overview of whether fisher numbers have changed as a result of seaweed farming (Chapter 3), and how seaweed farming interacts within livelihoods (Chapter 6). Different response variables were collected for each of these chapters, but the households interviewed were the same. The response variables are described in detail in the appropriate chapter, as are other methods used in these villages to collect information specific to those chapters. The sampling strategy of the villages and households common to both chapters are provided in detail here.

2.5.2 Study villages

The 10 villages selected were distributed along the length of Danajon Bank; two from each of five municipalities from Bohol Province (Fig. 2.1). Villages were selected in this way for two reasons. First, anecdotal information suggested that seaweed farming had spread from the east to the west of Danajon Bank over time, so there may have been geographical trends in the uptake and experience of seaweed farming. Second, municipal local government units have jurisdiction over municipal waters (section 2.2.3), so selecting two villages from each municipality allows for some control for differences in policy and management approaches. The availability of key contacts that could facilitate the work in each village by arranging meetings with the village officials and POs was essential to working in those villages. Therefore a further criterion for selection of villages came from the recommendations of the community organiser staff members of PSF and the municipal agricultural extension workers. Only island villages were selected, and no two villages from the same island were selected. The villages selected were Batasan and Bilangbilangan (Tubigon municipality), Cuaming and Hambungan (Inabanga municipality), Alumar and Handumon (Getafe municipality), Guindacpan and Mahanay (Talibon municipality), Bilangbilangan East and Hingutanan East (Bien Unido municipality; Fig. 2.1).

Village-level characteristics such as village area, human population sizes and distances to markets were obtained from secondary data sources. Distances of each island to their nearest market towns (where fish is sold) and to Cebu City (where the carrageenan producers are based) were measured from maps using straight line distances in Google Earth. Area information for each island was collected from *barangay* profiles held by village officials, municipal officials and PSF. There were often multiple and conflicting area estimates for each village, possibly because of the small size of the islands, fringing mangroves, and a tendency in some villages to “expand” islands by laying down coral rocks to create more land for constructing new households (e.g. Batasan; Guieb 2008). Where there was variation among estimations, these were checked against rough estimates from measurements made in Google Earth. Best estimates indicated that the 10 villages ranged from 5 to 200 ha, with only one village (Mahanay, Talibon) being estimated at over 100 ha. Population estimates were obtained from the National Statistics Office based on the 2007 national census, and ranged from 563 to 2,848 people. Villages are between 4 and 16 km from their nearest market town (the municipal centre), and between 22 and 63 km from Cebu City. Detailed results for the village-level variables are presented in Chapter 3.

2.5.3 Selection of households for interview

Within each village, a systematic sampling design (every n^{th} household) with randomized start point based on the latest village census list (2008/2009) was used to select 30 households for interview. This represented between 5-27% of the households in a village. Respondents for these households were heads of household or main income earners, and often included both husband and wife who were interviewed together (a total of 162 women and 291 men from 300 interviews).

2.5.4 Data collected from individual households

Each household was interviewed once. These interviews collected information on their perceptions of changes in fisher numbers in their villages over time (Chapter 3), and occupations that they engaged in and the income earned from those occupations (Chapter 6). These response variables are described in detail in the relevant chapters.

Socioeconomic and demographic attributes of the sampled households were analysed as explanatory variables in both Chapters 3 and 6 as they can influence livelihood strategies (Allison & Ellis 2001). These variables included wealth, household size, education, age, income levels and occupational diversity for all interviewed households. Additionally, information was collected on seaweed farming variables from those households interviewed that engaged in seaweed farming. The questionnaires used to collect this information can be found in the Supporting Information to this chapter (Supporting Information). These explanatory variables were examined at different levels of aggregation for Chapters 3 and 6, so summary statistics for the level of aggregation are presented in the Supporting Information for the relevant Chapter.

Material style of life (MSL) was used as a proxy for wealth, and was calculated for each household based on information on household structure and possessions (Table 2.1). MSL is a widely used indicator of wealth in developing countries that provides a useful and robust indicator of relative social status (Pollnac & Crawford 2000; McKenzie 2005; Vyas & Kumaranayake 2006; Cinner et al. 2009a). The MSL wealth score was calculated for each household by running a principal components analysis (PCA) on all the variables with the ade4 package in the statistical software R (Dray & Dufour 2007). The first principal component explained 35.2% of the variation (Fig. 2.2) and coefficient loadings were consistent with expectations for the relationship between wealth and asset ownership (Table 2.1). Scores for the first principal component were therefore used as the MSL score for each household, and ranged from -2.91 (poorest) to 7.33 (wealthiest).

Household size was calculated as the number of people of all ages that were household members as per the definition of household (section 2.3.1). Education levels were recorded for each household member as the total number of years they had spent in education. Education was then calculated for each household as the average of the years of education received by the heads of household. Household-level education was only based on the heads of household in order to ensure comparability among households which consisted of children of different ages and stages in their education. Age was recorded in years for each household member. Age was then calculated for each household as the average age of the heads of household only (when more than one head of household, otherwise just the age of the head of household).

Respondents were asked to provide details on all their occupations, as well as the occupations of each household member. Respondents were then asked to estimate their monthly income from each source, based on the latest month. If income was earned less frequently than monthly, their last income event was recorded together with the number of months per income event, and income per month was calculated. Total monthly household income was calculated as the sum of monthly income from all sources. Occupational diversity was calculated as the number of occupations that a household engaged in using the occupation categories provided in section 2.3.5.

Table 2.1. Material Style of Life (MSL) variables used in Principal Components Analysis (PCA) to calculate wealth score for households from the extensive surveys of 10 villages, with the principal component coefficients for the first three axes. Axis 1's coefficients are consistent with the expected relationship between wealth and asset ownership.

Variable	Type (range)	Description	Axis 1	Axis 2	Axis 3
Wall of house	Score (1-3)	1=native (e.g. bamboo), 2=mixed, 3=non-native (e.g. concrete)	0.36	-0.14	-0.23
Roof of house	Score (1-3)	1=native (e.g. *nipa* palm), 2=mixed, 3=non-native (e.g. tin)	0.32	-0.39	0.20
Floor of house	Score (1-3)	1=native (e.g. sand), 2=mixed, 3=non-native (e.g. tiled)	0.37	-0.37	0.08
# bedrooms	Count (0-3)	0 bedrooms if bedroom and living space not differentiated	0.32	-0.25	0.27
Flush toilet	Count (0-1)	Flush toilet on their property	0.36	-0.15	-0.19
Pumpboat	Count (0-7)	A local style boat with engine	0.31	0.32	0.44
Baroto	Count (0-2)	Local style canoe (no engine)	-0.21	-0.47	-0.54
Generator	Count (0-1)		0.32	0.47	-0.43
Electrical appliances	Count (0-8)	Including TV, radio, sound systems, dvd/vcd, karaoke machine, iron, fan	0.40	0.23	-0.34
Cumulative variance explained			35.2%	47.6%	59.3%

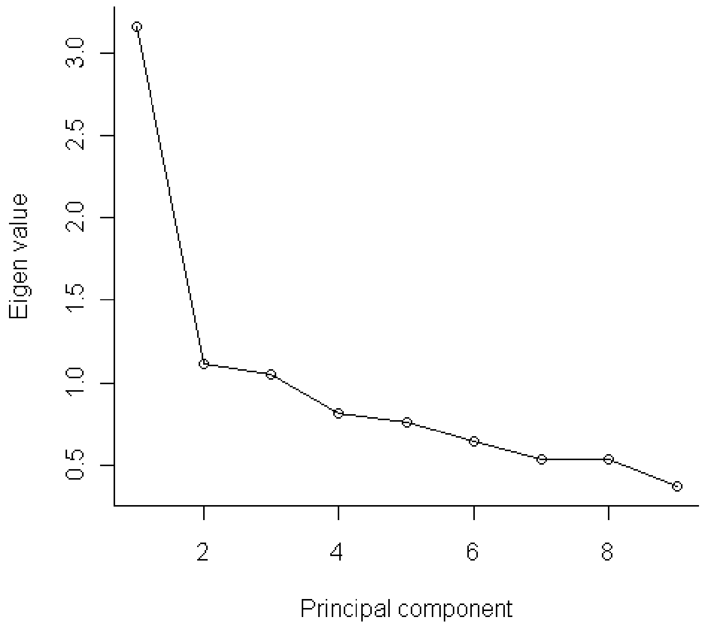

Figure 2.2. Scree-plot from PCA of Material Style of Life (MSL) variables for households from the extensive surveys in 10 villages.

Seaweed farming variables included the size of the respondent's seaweed farm (ha), whether they owned that farm (yes/no), whether they had received any training from a seaweed farming technician (yes/no), whether they were a member of a PO relevant to seaweed farming (yes/no), their source of start-up capital (personal/external), and their satisfaction with their seaweed productivity (satisfied/not satisfied). The size of seaweed farm was recorded in local units (*dupa* – the same as a fathom) and later converted to hectares. The source of start-up capital was recorded as personal if the household had used their own savings or financial capital to buy the materials necessary for seaweed farming or had inherited it from a parent. If the household had obtained a loan from another individual or institution, or had started by receiving seedlings and equipment from their PO, the funding source was considered external. Satisfaction with seaweed productivity was asked in relation to growth rates and was used as a proxy for biological productivity as it was not possible to measure the growth rates of seaweed in each of the areas used by different villages.

2.6 Intensive household-level surveys

2.6.1 Introduction

Intensive household-level surveys refer to methods that involved revisiting individual households on a regular basis to obtain more detailed information on their daily activities. These intensive surveys were used to explore the possible mechanisms behind the interaction between fishing and seaweed farming in people's livelihoods. Twenty-four hour recall surveys were conducted once per week per household over a 13 month period (May 2008 to June 2009) to monitor the activities of 83 households from two villages. This information was used to examine the patterns of income from fishing, seaweed farming and informal sector occupations (Chapter 4), and to examine the relationship between levels of engagement in these occupations and socioeconomic and demographic variables (Chapter 5).

2.6.2 Study villages

The two villages selected for this study were also included in the extensive surveys (section 2.5.2). The two villages selected were Handumon in Getafe municipality and Guindacpan in Talibon municipality, both within Bohol Province (Fig. 2.1). These two villages were selected because both seaweed farming and fishing were known to be widespread within these villages and there was high variation in household-level engagement in fishing and seaweed farming, enabling direct comparisons to be made between the two occupations.

Handumon and Guindacpan differ in terms of their size and livelihood opportunities. Guindacpan is a very small (roughly 6 ha) sandy island of roughly triangular shape with fringing mangroves on one side. Guindacpan lies on a circular reef. It is roughly 10 km from the nearest point on mainland Bohol (Fig. 2.1), and is an hour's pumpboat ride from Tubigon's municipal centre. Guindacpan is a very low-lying island, with spring high tides regularly covering much of the island and entering people's houses. Guindacpan has a large number of people for its size (2,204 in 2007 (NSO 2007), giving it an estimated population density of 36,733 people km^{-2}). Land is owned by a relatively few people, some of whom live in the village whilst others live elsewhere. Households that use this land pay a small monthly rent to the owner. Rainwater is collected in a few rainwater tanks on the island, and when these run dry fresh water must be brought in from elsewhere. Because of the small size of the island there are few opportunities for land-based occupations, so the primary occupations are fishing and seaweed farming. However, because of the large population size there are more opportunities for small entrepreneurial trade-based businesses. There is a PO in Guindacpan with a remit for seaweed farming, but members had not met for many years prior to the survey work for this thesis.

Handumon is one of three villages on Jandayan Island, which has more space and more livelihood opportunities than Guindacpan, plus a functioning PO. Jandayan Island is a complex shape with many inlets and mangroves. The total area of Jandayan Island is 182.9 ha, while the surrounding mangroves cover 1,321 ha. The island is reached by a five minute pumpboat trip from Getafe's municipal centre. Handumon occupies a larger land area (81 ha) than Guindacpan with a smaller population (1,012 in 2007 (NSO 2007), giving it an estimated population density of 1,249 people km^{-2}). The island is vegetated with good soil that has historically been used for agriculture, including rice paddies and corn fields. However, in recent decades there has been limited agriculture primarily because of land ownership issues as much of the land is owned by people outside of Handumon who do not allow the land to be cultivated (Guieb 2008). There are also 96 ha of fishpond that have been converted from mangrove areas. These fishponds are owned by people outside of Handumon, and many now lie idle. However, some are used for farming milkfish (*Chanos chanos*, known locally as *bangus*) and shrimp, so some villagers are employed to work as caretakers on these ponds (Guieb 2008). These caretakers are usually renumerated with a percentage of the value of the fishpond production, or per meter of dyke that they have repaired or constructed. However, incomes are low and they are usually among the poorer members of the village. Jandayan Island also has deep water wells from which water can be drawn for drinking. It is one of few islands with such a resource, so water-selling to nearby islands is an important entrepreneurial occupation that is limited to Jandayan Island (Guieb 2008). Finally, Handumon has been a focal point for PSF's conservation activities since 1995, as it is a centre for lantern fishing which involves the capture of seahorses that are dried and sold into the traditional Chinese medicine trade (Jacobsen et al. 2004; Vincent et al. 2004, 2007; Yasué et al. 2010). Some of this work has involved the development of livelihood initiatives such as handicrafts (Oliver et al. 2004). Therefore, Handumon has a strong and functioning PO that is engaged in seaweed farming and management of their marine protected area.

Three seasons were identified for the purposes of this thesis; *amihan* (November to March), *hot* (April to July) and *habagat* (August to October). Seasons are composed of a complex mix of relatively wet (June to February) and dry (March to May) months, northeast (November to May) and southwest (June to November) monsoons, and hot (April to July) and cool (December and January) months. These seasonal patterns are made more complicated by the fact that switches in monsoons are interspersed with variable winds and can vary from year to year, and rainfall is affected by La Niña and El Niño events. As such, different people give very different indications of which months are associated with each of these types of weather, and there are no consistent patterns of income from fishing or other sources across villages (e.g. Jacobsen et al. 2004). Informal discussions with respondents and local fishers and seaweed farmers identified the primary drivers of seasonality in fishing and seaweed farming as being *amihan* (the northeast monsoon), *habagat* (the southwest monsoon), and the hot and often low or variable wind months that occur towards the end of the *amihan* and leading up to the *habagat*.

2.6.3 Overview of data collected

The objective of the intensive household-level surveys was to collect information on the daily income and activity of household members in all of their occupations, and to be able to relate this to socioeconomic and demographic characteristics of the households concerned. The different methods used to collect information were:

- 24-hr recall surveys (section 2.6.4) were conducted roughly once per week for each household from May 2008 to June 2009 to obtain information on who in the household was engaged in each occupation, how long they spent in those occupations, the money spent on those occupations (expenses), and the income (both monetary and non-monetary) obtained from those occupations.
- Participatory wealth ranking exercises (section 2.6.5) were completed in June 2009 in order to compare with the material style of life scores (sections 2.6.6 and 2.5.4), and in order to determine the contribution of fishing, seaweed farming and other occupations to wealth status and changes in wealth status.
- Household profile surveys were carried out in June 2009 to obtain information on all household members (age, education, gender, positions of authority) and household structure and possessions (used to calculate material style of life scores; section 2.6.6).
- Household timelines were carried out in June 2009 to obtain information on length of time spent in each occupation. During these interviews, respondents were also asked to list reasons for engaging in seaweed farming and fishing.

2.6.4 Twenty-four hour recall surveys

One hundred households were originally selected for the 24-hr recall surveys; 55 from Guindacpan and 45 from Handumon. More households were initially selected in Guindacpan because of its larger population size, and because of the smaller area of the village which enabled faster travel between households. Surveys were discontinued for twenty-seven of these households after the first three months because the research assistants had reason to believe they were not providing accurate information (when comparing responses to direct observation) or because members of the household chose not to continue. Of the remaining 83 households, 43 were in Handumon and 40 in Guindacpan.

Meetings were initially held with the heads of each household to explain the objectives of the research and how the data would be recorded, stored and analysed. Respondents were assured of confidentiality. Consent was requested for their participation in the surveys, and they were informed that they could withdraw from the study at any time. Consent was subsequently requested before each survey. Questions were only posed to respondents over the age of 16 unless the express consent of a parent present at the time was provided.

Households were selected by peer recommendation following discussion with village leaders and PO members, on the basis that they represented a range of involvement in both fishing and seaweed farming, a range of wealth status, and were distributed throughout the village. To ensure there was no bias as a result of peer recommendation, each of the seven village councillors in each village were asked to recommend ten households from each of their *puroks* (the seven subdivisions of the *barangay* that the councillors are elected to represent). Village transects were then carried out with PO members and the village secretary in order to obtain a list of all the households in the village and information on their housing condition (materials of walls and roof) and main occupations. Seven to eight households were then selected from each *purok* list to ensure that there were similar numbers of households with low quality housing materials (all native materials) and higher quality materials (tin roofs and brick walls), and similar numbers of households that were engaged in fishing, seaweed farming and both occupations. The intention was not to ensure that these households represented a random sample of the households in each village, but that they represented sufficient variation in engagement in fishing and seaweed farming and in wealth status in order to meet the objectives of the relevant chapters. The distribution across *puroks* was also important because related families often settle close to each other and therefore different families were often associated with different *puroks*.

Twenty-four hour recall surveys were conducted roughly once per week per household over a 13 month period (May 2008 to June 2009). 24-hr recall techniques have previously been used to collect information on household consumption, production and sales of wild foods and income from household occupations (e.g. de Merode et al. 2004; Allebone-Webb 2009). For the purposes this thesis, 24-hr recall was used to collect information on the time that each household member spent in any activities relating to each occupation, and the total expenses spent on each occupation and monetary and non-monetary (e.g. value of catch that was eaten, bartered or given away as gifts) income obtained from each occupation during the 24-hrs of the previous day. Any activity relating to these occupations that occurred within this 24-hr period was recorded, including equipment purchase or maintenance, processing of the catch or harvest, travel to sell or buy goods relating to the occupation, and receipt of income or payment of expenses. This included activities relating to own production, or from hiring out labour to other households or participating in cooperative activities. Where activities related to hiring out of labour to another household or participating in cooperative activities, this information was recorded along with the payment or income sharing method (e.g. tripartite, resale or salary basis; section 2.2.2), but this income was still linked to the occupation and in subsequent analyses will be summed together with other forms of income from the same occupation. Income was measured as Philippine Pesos (P) and included any money received and the value of any non-monetary income that was realised during the 24-hr period (e.g. household production that was consumed or given away as gifts during that period), including any payment or income received for work completed on other days. Expenses were also measured as Philippine Pesos (P) and included any money that was spent during the 24-hrs of the previous day. The price and quantity of items bought or sold was recorded where possible in order to triangulate and verify the results. Time spent in activities relating to each occupation was recorded as the number of hours (in fractions) spent by each household member.

Surveys were completed in the respondent's home, questions were addressed to the heads of household or main income earners, and responses were written directly onto datasheets (Supporting Information). To ensure information on all activities for each household member were included, questions were first asked about the occupations that household members engaged in during the previous day, then they were asked about any occupations that they did not mention (e.g. fishing or seaweed farming), and finally questions were asked about the activities of each household member. Following this, questions were asked about any other sources of income that were received or expenses paid on their occupations, including whether they received any income for fish caught on previous days or seaweed sold on previous days, and whether they had received any remittances. Information was also recorded on household membership during the previous 24-hrs, including whether any members were temporarily living as part of another household, or people that were living as part of this household temporarily. Where the respondent did not know specific details (e.g. income or time) about the activities of other household members, these household members were sought out for confirmation. Where confirmation was not received within 48 hours of the activity, involvement in the occupation was recorded but the specific details that the respondent did not know were recorded as missing. The identity of each of the household members spoken with during the survey was recorded on the survey sheet, and respondents were asked to check, sign and date the completed datasheets.

Surveys were stratified across days of the week. Practical constraints meant that surveys could not always be conducted every week for each household (e.g. the appropriate household members could not be found within sufficient time).

Feedback sessions were completed once every three months in each village, to which members of all respondent households were invited, and which were attended by myself, a community organiser from PSF and the research assistant. During these sessions, respondents were updated on the progress of the research, and reminded of the aims and objectives of the research. There was then a general discussion to give respondents the opportunities to raise any queries or concerns they had about the process of the research. These feedback sessions proved very important and ultimately lead to surveys completed in Handumon between 28th July and 27th November 2008 to be rejected from subsequent analyses. The reasons for this were that some respondents felt that during this period the research assistant was cutting corners during the surveys and failing to complete all the questions appropriately. Extensive investigation of this incident revealed that roughly a third of all surveys in Handumon were likely to have been affected during this period, which occurred when the research assistant struggled to find the appropriate household members required for the survey. At this point, the research assistant had occasionally interviewed household members a few days after he was supposed to, and recorded information he obtained opportunistically and informally (e.g. when encountering the necessary household members in passing on the street) without completing the full interview procedure. Rather than rejecting the survey, the research assistant felt that he could include these surveys so that survey targets were met. As it was not possible to identify exactly which surveys were affected, all surveys from this period were rejected. Through extensive investigation by myself and PSF staff, we established that respondents and the research assistant concerned were confident that this problem did not apply before 28th July, and regular verification with respondents indicated no other problems after 27th November. This incident lead to the adoption of the system whereby respondents would check, sign and date each household survey after they had been completed.

In total, 3,341 surveys were completed, but only 2,654 (17-43 per household) were accepted for anlaysis due to a combination of missing information and the surveys rejected from Handumon. The rejection of surveys between 28th July and 27th November 2008 in Handumon meant that there were no surveys for the *habagat* season from Handumon (Table 2.2). There were 198 to 220 surveys per day of the week in Guindacpan, and 128 to 201 surveys per day of the week in Handumon. The mean (sd) number of surveys per day of the week per household was 5.35 (0.96, *n*=280) in Guindacpan and 3.84 (1.64, *n*=301) in Handumon.

Table 2.2. Number of surveys per household in each village by season for intensive household surveys. n=40 households in Guindacpan, and n=43 households in Handumon.

Village and season	Mean (sd) number of surveys per household	Range number of surveys per household
Guindacpan		
Amihan	14.13 (2.36)	9-19
Habagat	12.53 (0.96)	9-13
Hot	10.83 (1.55)	8-14
Total	37.48 (3.59)	29-43
Handumon		
Amihan	11.42 (2.07)	6-14
Habagat	-	-
Hot	15.44 (3.00)	7-20
Total	26.86 (4.48)	17-33

2.6.5 Participatory wealth ranking

Towards the end of the study, three participatory wealth ranking sessions were conducted in both Guindacpan and Handumon to discuss people's concepts of wealth, how households can change their wealth status, and to classify each household into a group of similarly wealthy households within each village. This participatory approach has been shown to be a valid way to stratify households into wealth groups that correlates with economic, demographic and health variables (Adams et al. 1997). Between three and five village members were selected for each wealth ranking session. The three sessions per village targeted people from different age groups and gender; one for adult males, one for adult females, and one for youths from age 18 to 30. Respondents were selected for being relatively well informed members of the village, sometimes being in a position of authority (e.g. village secretary, village captain) or other position (e.g. PO president, youth group president).

Each session started with a general discussion about their interpretation of wealth and the factors that constitute wealth, with care taken to ensure no definitions were imposed by the interviewers. Each household within the village was represented on a card, with the name of the household heads (including their nicknames) and, where necessary to ensure households could be distinguished from others with similar names, other household members. The list of households was taken from the most recent village census. Respondents were then asked to place each household into a group that contained households of similar wealth. The only stipulation was that there were five wealth groups, but they were otherwise free to determine how those groups were defined.

Respondents jointly decided which of the five wealth groups a particular household belonged to. Adjustments were made as the ranking exercise progressed with the inclusion of additional households, and each wealth group was reviewed. The households of respondents present at the wealth ranking session were not included in that ranking. Households that could not be identified by the respondents were excluded. In Guindacpan, 385 of the 394 households were ranked, and in Handumon, all of the 195 households were ranked. After the households had been allocated, there was a general discussion about the common features of households from each group, and then a discussion about whether and how households could move between each of these wealth groups. Each group session took between 2-3 hours.

After the ranking exercises were complete, groups were numbered from 1 (wealthiest) to 5 (poorest) and the median wealth rank was taken as the final wealth group of each household. The definition of wealth groups were generally very similar across wealth ranking sessions and villages (Table 2.3) and conform with expectations from the literature on how poverty is defined (MacFadyen & Corcoran 2002; Béné 2003). Most households were placed in wealth groups 3 and 4 (Fig. 2.3). The households monitored with 24-hr recall mostly belonged to wealth groups 3 and 4 (Fig. 2.4).

Table 2.3. Descriptions of wealth groups from participatory wealth ranking sessions in Guindacpan and Handumon.

General description of groups	**Guindacpan**	**Handumon**
Wealthiest (*kinadadto-an* or *andunahan* meaning 'very much' or 'rich')	Big concrete house. Big business (known as *Capitalista* e.g. fish buyer direct to Cebu or export, or seaweed buyer direct to Cebu). Owns pumpboats and large transport boats. Many have a household member that is an overseas worker. Owner of big store and land. Owner of service such as water tank or generator. Complete appliances. College education. Has helpers / employees. Excess money. Can save money for other business.	Big house and lot. Regular income. Complete appliances. Many big businesses (e.g. seaweed exporter). Big transport boat for seaweed delivery. Political person. Big reliable income. Large seaweed farming area. Children professional.
2nd (*Dadto* or *medyo adunahan* meaning 'much' or 'less rich')	Big concrete house. Small business (e.g. wet seaweed or fish buyer for resale to traders on island, food kiosk, generator for electricity). 3-4 pumpboats for fishing – hire fishers rather than go fishing themselves. Owns large seaweed farming area. Has appliances (e.g. tv). Small land ownership. Can save some money for business or education.	Big concrete house. Own generator. Almost complete appliances. Own fishpond/land area. Small business (e.g. local lending, buyer of wet seaweed, larger store/kiosk). Own pumpboat. Service motorcycle. Regular/reliable income. Own seaweed farming area. Maybe children overseas workers.
3rd (*Kasagaran* meaning 'moderate')	Moderate house – mixed concrete and native materials. 1-2 pumpboats for fishing. Owns seaweed farming area. Maybe some trade of low value products. High school education.	House semi-concrete. Owner of livelihood e.g. fishing. Incomplete appliances. Maybe small kiosk. Own some land. Hard working. Own pumpboats for fishing. Some trade. Sometimes good income from fishing. Smaller seaweed farming area. Skilled labourer (e.g. carpenter). Relatively few children. Vices (e.g. gambling / drinking).
4th (*Pobre* meaning 'poor')	House of native materials. Own paddleboat (*baruto*). Hire out fishing labour. Not own seaweed farming area – maybe use someone elses and have loan for materials. Children may live elsewhere to help family. Elementary grade education.	Small house native materials. Own paddleboat. Not regular income. Illegal fisher. Supported by child. Irregular hire out labour. Not own fishing gear. Small seaweed farming area. Vices (e.g. gambling / drinking).
Poorest (*Kinapobrehan* meaning 'very poor')	Small house of native materials. Supported by others (e.g. old or housewife with dead/no husband, or sick). No boat at all. Little livelihood – maybe gleaner only or occasional fishing crew.	Broken house/no permanent house, of native materials. No livelihood. Old/sick. Not eating 3 times a day. Supported by children – has many children. Maybe sell firewood. Vices (e.g. gambling / drinking). Not hard working. No seaweed farming area.

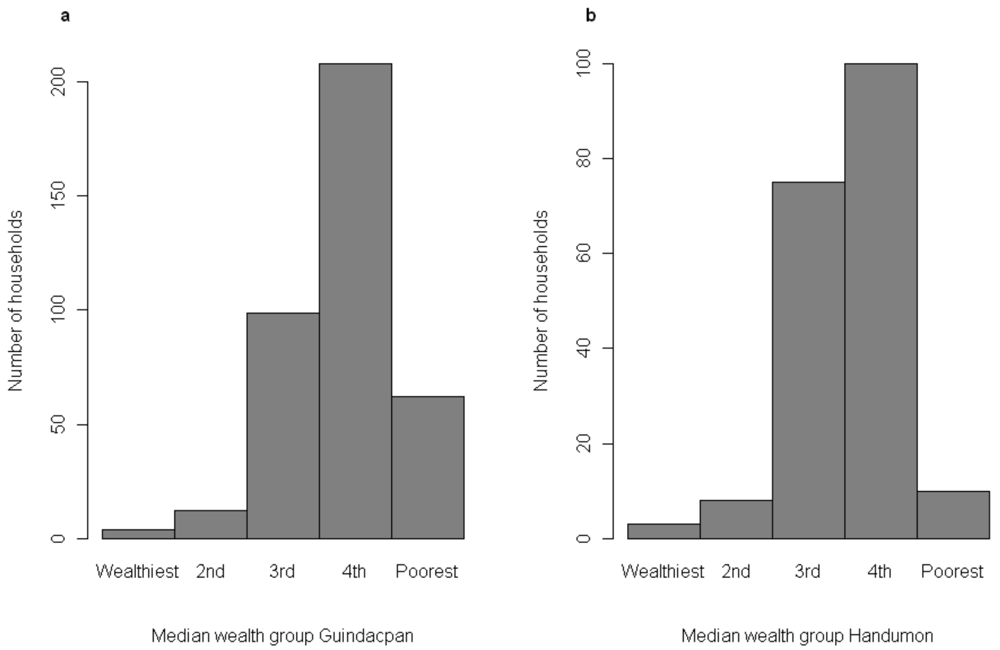

Figure 2.3. Allocation of households to different wealth groups for (a) Guindacpan and (b) Handumon according to participatory wealth ranking exercises.

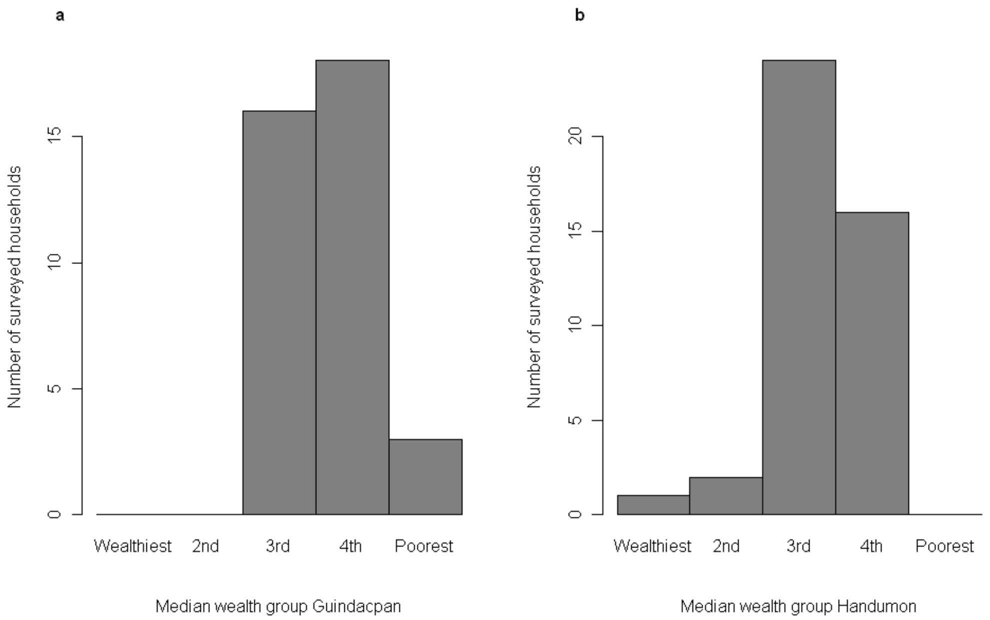

Figure 2.4. Distribution of households selected for monitoring for the household-level study among the participatory wealth groups for (a) Guindacpan and (b) Handumon.

2.6.6 Household profile surveys: Socioeconomic and demographic information

Household profile surveys were conducted in June 2009 and were used to collect information on the socioeconomic and demographic characteristics of households. Information was collected on household materials and possessions in order to calculate material style of life as a proxy for wealth (as per the extensive surveys; section 2.5.4). Information was also collected on the age, gender, number of years of education and any positions of authority for all household members. During these profiles, respondents were asked to identify all their occupations during the preceding year, plus whether they had received any remittances and whether they had received any loans. Where they had received loans, information was requested on the sources of the loans, repayment schedules, and the size of the loans if they were willing to provide this information.

The socioeconomic and demographic information from the household profiles is used only in Chapter 5, while information on loans is used only in Chapter 4. These variables are therefore described in more detail in those chapters. Material style of life is described here in relation to the wealth groups determined from participatory wealth ranking, as this has implications across multiple chapters, notably for the use of material style of life in Chapter 5 and also in Chapters 3 and 6.

Material style of life (MSL) was calculated as a proxy for wealth in the same way as it was calculated for households in the extensive surveys (section 2.5.4). Many of the variables considered important determinants of wealth during the participatory wealth ranking sessions (Table 2.3) were used to calculate MSL. The resulting first principle component explained 29% of the variation (Fig. 2.5). Although the second and third axes also retained a substantial proportion of the variation in the data, the component loadings on the first axis were consistent with the expected relationship between wealth and asset ownership (Table 2.4), and so was used as the MSL score.

Table 2.4. Variables used in Principal Components Analysis (PCA) to calculate material style of life (MSL) wealth scores and their principal component loadings for the first three axes for households from the intensive surveys. PCA based on 83 households sampled for the 24-hr recall surveys. This demonstrates that axis 1's coefficients are consistent with the expected relationship between wealth and asset ownership.

Variable	Type (range)	Description	Axis 1	Axis 2	Axis 3
Wall of house	Score (1-3)	1=native (e.g. bamboo), 2=mixed, 3=non-native (e.g. concrete)	0.42	-0.37	0.09
Roof of house	Score (1-3)	1=native (e.g. *nipa* palm), 2=mixed, 3=non-native (e.g. tin)	0.20	-0.60	0.05
Floor of house	Score (1-3)	1=native (e.g. sand), 2=mixed, 3=non-native (e.g. tiled)	0.46	-0.24	0.04
# bedrooms	Count (0-5)	0 bedrooms if bedroom and living space not differentiated	0.34	-0.11	-0.15
Flush toilet	Count (0-1)	Flush toilet on their property	0.25	0.21	-0.24
Pumpboat	Count (0-2)	A local style boat with engine	0.26	0.30	0.56
Baroto	Count (0-2)	Local style canoe (no engine)	-0.23	-0.26	-0.61
Generator	Count (0-1)		0.33	0.37	-0.37
Electrical appliances	Count (0-5)	Including TV, radio, sound systems, dvd/vcd, karaoke machine, iron, fan	0.40	0.31	-0.28
Cumulative variance explained			**29.1%**	**47.5%**	**61.4%**

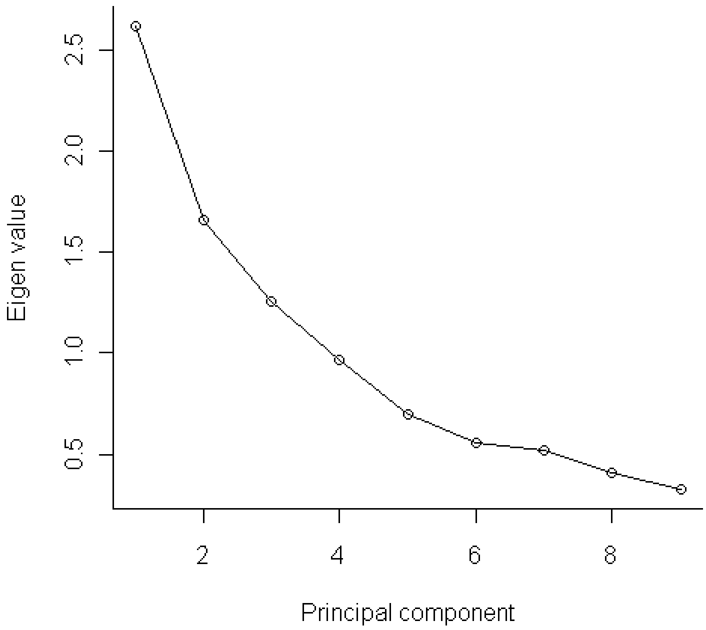

Figure 2.5. Scree plot of PCA components from calculation of the material style of life (MSL) score.

There was a close association between the MSL scores and participatory wealth groups assigned to sampled households (Fig. 2.6), indicating MSL is a good proxy for wealth. Analysis of variance (ANOVA) was used to explore the relationship between the wealth groups assigned to households during the participatory wealth ranking exercises and MSL wealth scores. The three households from wealth groups 1 and 2 were left out of this analysis because they had Cook's distance approaching 1, indicating they had undue influence. The analysis demonstrated a strong relationship between MSL wealth score and participatory wealth group for both Guindacpan (df=2, F=11.09, p<0.001, r^2=0.36) and Handumon (df=1, F=21.9, p<0.0001, r^2=0.35), with MSL scores declining for households assigned to poorer wealth groups (Fig. 2.6). The one major exception to this relationship was the only household from participatory wealth group 1 (in Handumon), which had an MSL score more similar to wealth group 3. Also notable were two households in Handumon in participatory wealth group 3 that received very high MSL scores. This suggests there may be some socioeconomic circumstances which are not well reflected by the MSL score, but overall MSL performs well as a proxy for wealth.

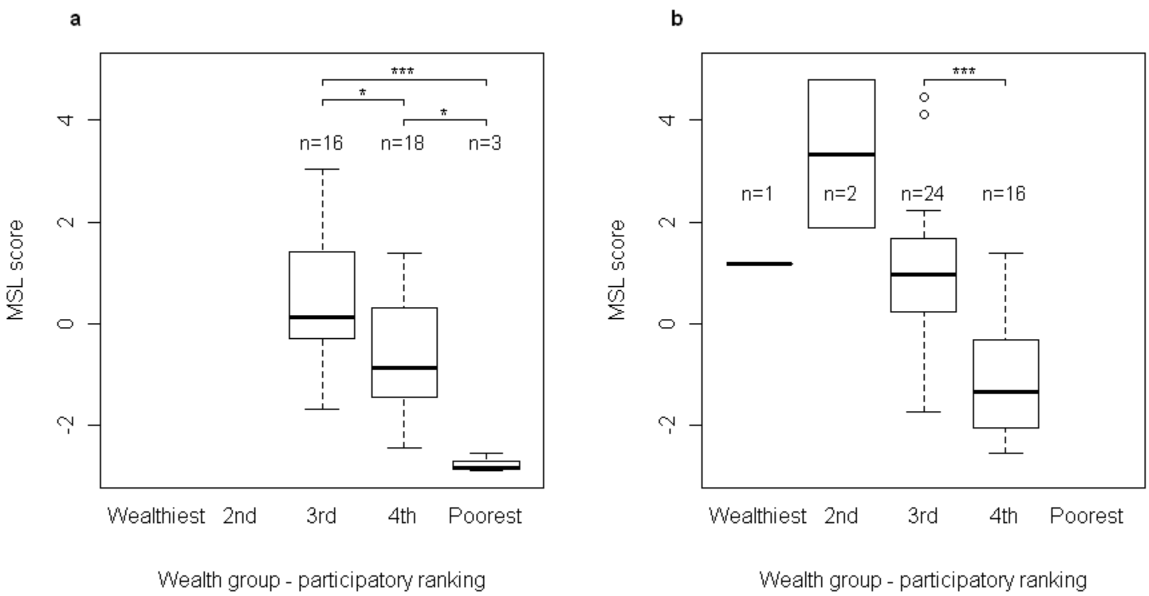

Figure 2.6. Relationship between MSL scores and wealth group assigned to households during the participatory wealth ranking exercises for (a) Guindacpan and (b) Handumon. Pairwise comparisons represent significance of Tukey's Honest Significant Difference tests between households from different wealth groups (*** p<0.001, ** p<0.01, * p<0.05). n= the number of households assigned to each wealth group in the participatory wealth ranking session.

2.6.7 Household timelines

Questionnaires were used in the final month of the survey work in order to determine household members' experience in different occupations, and to ask household members why they engage in fishing and/or seaweed farming. Questions were address to the heads of the household only. Timelines were used as a tool to record the information on experience, and respondents were asked to score a list of reasons for their engagement in fishing and seaweed farming. Methods and results for the reasons for engaging in fishing and seaweed farming are discussed in Chapter 4, and methods and results for the timelines and experience in different occupations are discussed in Chapter 5.

2.7 Summary of data collected and their use in data chapters

To summarise, the data used in this thesis were collected using two approaches. The first was an 'extensive' survey in 10 villages on Danajon Bank, and the second was an 'intensive' survey of 83 households from two of these villages. During the extensive surveys (section 2.5), heads of household from 30 households in each village were surveyed once each to ask them their perceptions of how the number of fishers had changed in their villages and to collect information on their socioeconomic and livelihood characteristics. Information was also collected via key informant interviews and focus group discussions in each of these villages. The intensive surveys (section 2.6) involved repeated surveys of households using 24-hour recall over 13 months to obtain a detailed picture of their daily income and effort associated with all the occupations in which they engage.

Chapter 3 draws on information from the extensive survey in order to provide a broad overview of the effects of seaweed farming on the number of fishers in each village. Chapters 4 and 5 then draw on information from the intensive survey to further investigate the relationship between seaweed farming and fishing by examining the characteristics of these occupations and how engagement in them varies for different households. Chapter 6 then pans back out to the broader scale and uses information on socioeconomic and livelihood characteristics from the extensive survey in order to explore the bigger picture for interactions between seaweed farming and fishing within people's livelihoods, bringing together findings from chapters 4 and 5 and helping to explain the patterns observed in chapter 3.

Supporting Information

Supporting information for this chapter can be found in Appendix S2, and includes: datasheets for the questionnaires used for the extensive survey methods (S2.1), and; datasheets for the intensive 24-hr recall surveys (S2.2).

CHAPTER 3

The interaction between seaweed farming as an alternative occupation and fisher numbers in the central Philippines

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Abstract

Alternative occupations are frequently promoted as a means to reduce the number of people exploiting declining fisheries. However, there is little evidence that alternative occupations reduce fisher numbers. Seaweed farming is frequently promoted as a lucrative alternative occupation for artisanal fishers in Southeast Asia. In this chapter, I examined how the introduction of seaweed farming has affected village-level changes in the number of fishers on Danajon Bank, central Philippines, where unsustainable fishing has lead to declining fishery yields. To determine how fisher numbers had changed since seaweed farming started, interviews were conducted with the heads of household from 300 households in 10 villages to examine their perceptions of how fisher numbers had changed in their village and the reasons they associated with these changes. Key informants (people with detailed knowledge of village members) were then asked to estimate fisher numbers in these villages before seaweed farming began and at the time of the survey. I compared the results of how fisher numbers had changed in each village with the wealth, education, seaweed farm sizes, and other attributes of households in these villages, which were collected through interviews, and with village-level factors such as distance to markets. Respondents were also asked why they either continued to engage in or ceased fishing. In four villages, respondents thought seaweed

farming and low fish catches had reduced fisher numbers, at least temporarily. In one of these villages, there was a recent return to fishing due to declines in the price of seaweed and increased theft of seaweed. In another four villages, fisher numbers increased as human population increased, despite the widespread uptake of seaweed farming. Seaweed farming failed for technical reasons in two other villages. The results suggest seaweed farming has reduced fisher numbers in some villages, a result that may be correlated with socioeconomic status, but the heterogeneity of outcomes is consistent with suggestions that alternative occupations are not a substitute for more direct forms of resource management.

3.1 Introduction

Unsustainable fishing may be better predicted by development status and access to markets than by human population size (Cinner & McClanahan 2006; Cinner et al. 2009b; Kronen et al. 2010). Nevertheless, finding strategies that successfully reduce fisher numbers in developing countries remains a key concern for fisheries managers and policy makers (Salayo et al. 2008; Torell et al. 2010).

The development of alternative occupations (i.e. non-fishing occupations) is frequently promoted as a means to reduce fisher numbers in developing countries (Salayo et al. 2008). This approach is often based on the assumptions that fishers fish because they have no alternative occupations (see Béné 2003) and that fishers will replace fishing with more lucrative alternative occupations if they are available (Sievanen et al. 2005). These assumptions ignore increasing evidence that the rural poor often pursue a diverse range of occupations to reduce risk and uncertainty in meeting their livelihood needs (Ellis 2000a; Barrett et al. 2001; Allison & Ellis 2001). Furthermore, the rural poor may fish for noneconomic and economic purposes (Pollnac et al. 2001b); thus, they may fish even when alternative occupations are available.

The importance of livelihood diversification is recognized in the sustainable livelihoods approach to poverty reduction, which promotes the development of alternative occupations as a complement to rather than a replacement for fishing (Allison & Horemans 2006). Diversified livelihoods could allow households to respond to periods of low fish abundance by reallocating labour elsewhere (Allison & Ellis 2001). Empirical research under hypothetical scenarios suggests fishers with greater access to alternative occupations may be more willing to stop fishing sooner as catches decline (Cinner et al. 2009a).

Few studies provide empirical evidence of the effect of alternative occupations on fishing levels, and those that do focused on individual-level fishing effort. Interviews with Southeast Asian fishers reveal that in some places individuals have ceased fishing after starting seaweed farming , but in other places individuals who have started seaweed farming continue to fish at the same level (Sievanen et al. 2005). In Kiribati fishers' individual-level effort varies in response to a program that subsidizes cultivation of coconut, but the average fishing effort has increased, mainly for noneconomic reasons such as enjoyment of fishing (Walsh 2009). Because new people may enter the fishery as others cease fishing, there is a need to understand the changes in total fisher numbers and to understand when and why the availability of alternative occupations may result in reduced fisher numbers.

I sought to explore the village-level effects of an alternative occupation on fisher numbers. Implementation of alternative occupations rarely includes evaluation (Walsh 2009), so post hoc assessments are often required. In the absence of baseline data, one approach is to draw on people's memories to establish retrospectively the effect of an intervention (e.g. Salafsky & Margoluis 1999). I analyzed the effect of seaweed farming on fisher numbers in 10 villages on Danajon Bank, central Philippines. The number of fishers does not directly reflect fishing intensity, which results from the number of fishers and their fishing effort and technology within a defined area. However, robust measures of effort are difficult to obtain due to the diversity of fishing methods used on Danajon Bank and the technological changes that have occurred in recent decades (Green et al. 2004). Changes in fisher numbers reflect reallocations of labour, can be compared to the expected responses of fishers to declining catches (Cinner et al. 2009a), and are of interest to managers and policy makers (Salayo et al. 2008).

I examined whether seaweed farming has affected trends in fisher numbers in these villages and why people have chosen to continue or cease fishing. I then explored socioeconomic and seaweed-farming factors that may correlate with different outcomes. Fishing effort on Danajon Bank is unsustainable and catches have declined considerably in recent decades (Green et al. 2004; Christie et al. 2006; Armada et al. 2009). The human population near Danajon Bank has increased in recent decades (Armada et al. 2009), which in the absence of many alternative occupations to fishing will likely lead to an increase in fisher numbers. On the basis of this reasoning and information in the literature (Allison & Ellis 2001;

Cinner et al. 2009a), I hypothesized that fisher numbers decreased or stabilize after seaweed farming started as labour was reallocated to seaweed farming.

3.2 Methods

Site description

Danajon Bank is a good study site for three reasons. First, it is a double barrier reef that stretches approximately 130 km between Bohol and Cebu provinces (Chapter 2, Fig. 2.1), so it is a relatively small and discrete area where fish stocks are shared among 17 municipalities (Armada et al. 2009). All resource users face similar resource conditions, and because human population densities are high, they are highly dependent on coastal resources and have few alternatives to fishing and seaweed farming (Armada et al. 2009). Second, the area comprises 40 small islands, each with associated villages. Each village has its own governance structure and elected officials and falls within the jurisdiction of a municipality that is responsible for the governance of marine resources. Seaweed farming was introduced in these villages at different times (from 1960s to 2008) and in a variety of ways, so the villages can be considered independent experimental units. Third, seaweed farming can be a lucrative endeavour for artisanal fishers in the region because start-up costs are low (Hurtado et al. 2001; Sievanen et al. 2005) and global demand for the hydrocolloids that are extracted from seaweed outstrips supply (Bixler & Porse 2011). Thus, there is growing interest in seaweed farming locally (Armada et al. 2009) and globally as a means to diversify livelihoods and reduce dependence and pressure on declining fisheries.

Ten villages were selected for this study, distributed along the length of Danajon Bank, two from each of five municipalities within Bohol Province: Bilangbilangan and Batasan (Tubigon), Cuaming and Hambungan (Inabanga), Handumon and Alumar (Getafe), Mahanay and Guindacpan (Talibon), and Bilangbilangan East and Hingutanan East (Bien Unido). These villages were small (in 2007 5-300 ha and 563-2,848 people) with high population densities (>1,000 persons km^{-2}). All villages were <20 km from the nearest market town, where there were weekly fish markets, and 20-65 km from Cebu City, where there were commercial factories that process dried seaweed into hydrocolloids for export (Chapter 2, Fig. 2.1). The most common income sources outside fishing or seaweed farming included selling food (e.g.

from a produce stand) or water, independent trade (e.g. carpentry or mechanical), remittances sent by family members working in urban areas, and public service (e.g. village police or councillor).

Effect of seaweed farming on fisher numbers

Fieldwork was conducted between November 2008 and May 2009. To examine how seaweed farming has affected fisher numbers, I applied a four-stage approach. First, focus-group discussions were conducted with village and People's Organisation (community organisations) representatives to record the history of seaweed farming in their village, including how and when seaweed farming started. The year seaweed farming started was defined as the year from which seaweed had been consistently farmed by villagers.

Second, a systematic sampling design (every n^{th} household) with a randomized start point based on the latest census list (2008/2009) was used to select 30 households from each village (5-27% of the households in a village). Respondents were heads of household or primary income earners; often husband and wife were interviewed together (162 women and 291 men). Respondent's perceptions of changes in fisher numbers in their villages were recorded on timelines, a graphic for recording and analyzing information (Bunce et al. 2000). Key events in respondent's lives (marriages and birth of children) and within the village were used as memory aids and to orient respondents to the timeline. Respondents were asked about changes in fisher numbers, which were indicated on the timeline (e.g. positive slope represents increasing fisher numbers). Respondents were free to choose the time intervals they felt appropriate for these changes and were not constrained to discussing changes in relation to the onset of seaweed farming. Respondents were then asked why these changes had occurred and noted their responses on the timeline (Supporting Information). Information was also gathered on the respondent's involvement in fishing (current fisher, ceased fishing, or never fished). Analysis of variance was used to examine whether there were differences between villages in the number of years that respondents could recall.

The proportion of respondents that said the number of fishers increased, decreased, and did not change was calculated per village for each year for which more than one respondent provided information. These proportions were interpreted as the strength of belief in how fisher numbers had changed. Villages were categorised as having decreased or increased numbers of fishers on the basis of the majority consensus on the dominant trend in fisher numbers since seaweed farming started (Fig. 3.1). To examine potential sources of disagreement in perceived trends (e.g. shifting baselines; Pauly 1995), Fisher's exact tests were used to analyse the association between respondents experience and their responses. The measures of experience I examined included a respondent's baseline year (first year of their timeline) relative to the year seaweed farming began (before or after seaweed farming started for villages where seaweed farming started after 1980 and before or after 1980 for villages where seaweed farming started before 1980) and the respondent's involvement in fishing (given above).

On the basis of a cursory examination of the full data set, reasons given for changes in fisher numbers were placed into one of six categories: seaweed farming (people substituted fishing with seaweed farming); reliability of fishing income; human population growth; lack of employment options; problems with seaweed farming (e.g. theft); seaweed farming in addition to fishing; other (reasons that did not fit into any of the other categories). For the years after seaweed farming started, I tallied the number of respondents per village citing each of these reasons for each direction of change. Respondents could indicate different directions of change at different times and multiple reasons for these changes.

Third, to supplement the information from timelines, key informants (people with detailed knowledge of village members) from each village recalled and listed (with the aid of census information) all the households in their villages and which of these households had a head of household engaged in fishing or seaweed farming. Due to time constraints, this information was only collected for the year before seaweed farming started (fishing only) and 2008 in each village. Because the availability of census information varied among years and villages, key informants were asked to focus on whether a head of household was involved in fishing or seaweed farming rather than total numbers of fishers or seaweed farmers. Between four and 12 key informants per village were involved in this exercise, depending on the size of the village, the number of households that key informants could recall, and census information available. Key informants were selected on the basis of their knowledge of the households and their occupations through peer recommendations and discussions with village leaders, and they were fishers and seaweed farmers that had been resident in the village most of their lives, including the period of interest. At least one of the key informants from each village had held official positions in the village, such as health worker, that required good knowledge of the households and their livelihoods (Supporting Information).

Fourth, to help explain differences in the effect of seaweed farming on fisher numbers among villages, the systematic household surveys were also used to collect information on basic socioeconomic attributes of village members that could influence livelihood strategies (Allison & Ellis 2001), including wealth, household size, education, income levels, and other sources of household income for all interviewed households, size of seaweed farms, training from a seaweed farming technician, membership in a People's Organisation relevant to seaweed farming, source of start-up capital (personal or external, such as government or investor), and satisfaction with seaweed productivity for households involved in seaweed farming. Wealth scores were based on principal components analysis of household structure and possessions, and these scores ranged from -2.91 (poorest) to 7.33 (wealthiest) (Chapter 2, section 2.5). Data were also gathered on factors that influence "livelihood landscapes" (i.e. a "set of occupations and their interrelations") (Cinner & Bodin 2010), including village distance to markets and population size, from secondary sources, including maps, national population censuses, and village profiles held by village officials (Supporting Information).

To allow for the hierarchical sampling design, mixed-effects models were used to determine whether there were differences in socioeconomic status and seaweed farming factors between villages where fisher numbers increased and villages where fisher numbers decreased. Mixed-effects models enabled the within-village error to be partitioned from the residual error; thus, I avoided the problem of non-independence of errors (Bolker et al. 2009). The likelihood ratio test was used for mixed-effects models to calculate p values for differences between villages where the number of fishers increased and villages where the number of fishers decreased, using the lme4 package in R (Bates et al. 2011). I used t-tests to examine whether there were differences in village-level variables between the two types of villages.

Reasons for continuing or ceasing to fish

To address why people continue or cease fishing, respondents from the surveyed households that were involved in or had ceased fishing were asked to rank a list of reasons why they engaged in or had ceased fishing and to provide other reasons not included on the list. The list of reasons was generated on the basis of pilot studies I conducted in these villages (Supporting Information). The importance of each reason was scored as an integer from 0 (not important) to 3 (very important).

3.3 Results

Effect of seaweed farming on fisher numbers

The year that seaweed farming started in each village ranged from 1962 (Hingutanan East) to 2008 (Batasan) (Fig. 3.1). Seaweed farming was introduced to villages through encouragement by the hydrocolloid industry (Hingutanan East and Bilangbilangan East), transfer among villages by residents who had seen seaweed farming in operation elsewhere (Handumon, Cuaming, Guindacpan, Hambungan and Alumar), and government assistance programs (Mahanay and Batasan). In Hingutanan East and Bilangbilangan East, the hydrocolloid industry initially established large seaweed farms and employed village members to work on those farms. Seaweed farmers from Hingutanan East subsequently established their own farms, whereas most seaweed farmers from Bilangbilangan East continued to work on farms owned by the hydrocolloid industry or by individuals from Hingutanan East and to collect wild seaweed. All villages received government assistance (Fig. 3.1) and had access to training facilities and technicians. Government assistance took the same form in all villages and was composed of start-up capital distributed to individual members of People's Organisations in the form of seedlings and equipment and some basic training in seaweed-farming methods. Seaweed farming was not established in Bilangbilangan Tubigon because disease killed early crops and later seedlings died during transport to the island. Focus-group discussions indicated that prior to seaweed farming, fishers in Alumar and Mahanay struggled to cope with declining fish catches because they could not change their fishing methods in order to target other fisheries. Bilangbilangan Tubigon and Batasan were excluded from analyses because there was no seaweed farming in these villages for more than a year before the study was completed.

Most respondents were able to recall periods of 10-40 years (mean [SD] = 26.3 years [13.24]), and there was no significant variation among villages in number of years recalled (analysis of variance, $F=1.46$, $df=9$, $p=0.16$). In four villages the majority of respondents perceived continued increases in fisher numbers after seaweed farming was introduced (Fig. 3.1) and associated the increase with population growth and lack of other employment options (Table 3.1). The high number of respondents that said they had no other employment options indicates seaweed farming was not perceived as a potential alternative to fishing, despite the fact seaweed farming had started in these villages. Respondents' comments indicated fishing provided the primary source of income for daily household requirements. Although not a

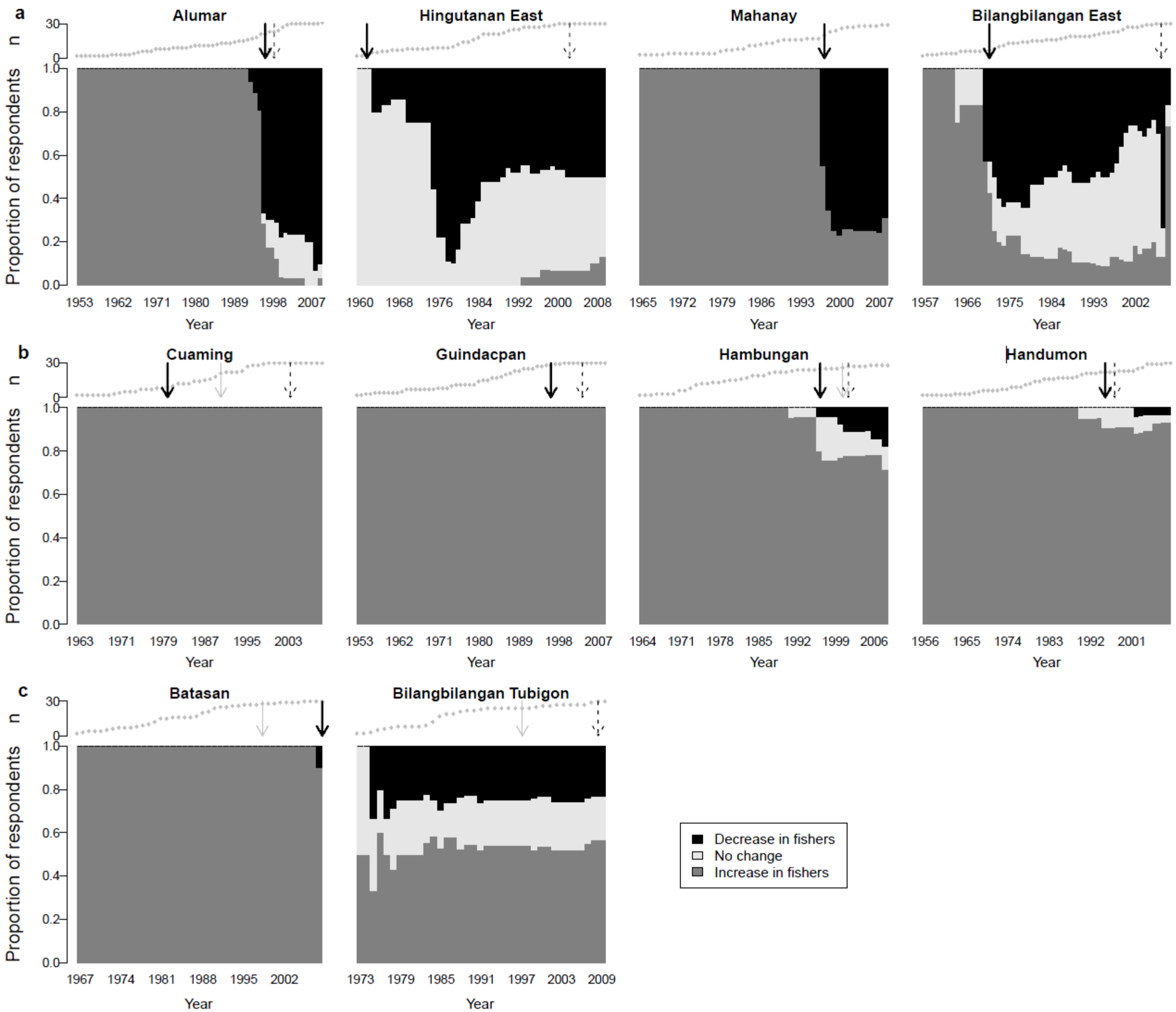

Figure 3.1. Perceived changes in fisher numbers by village from the extensive surveys in 10 villages: (a) decrease in number of fishers, (b) increase in number of fishers, and (c) villages where seaweed farming had not been going for more than 1 year. The bottom and largest portion of graphs shows proportion of respondents that perceived each direction of change in the number of fishers per year. Dotted lines at the top of each graph show the number of respondents (*n*) that referred to each year (minimum 2, maximum 30). Bold arrows indicate when seaweed farming became established; dashed arrows indicate when a government assistance program for seaweed farming was initiated; and grey arrows indicate other forms of seaweed farming introduction. Where dashed arrows are missing it is because the assistance program coincided with the onset of seaweed farming.

direct reason for fisher numbers increasing, 17% of respondents from villages where number of fishers increased indicated seaweed farming was additional to fishing rather than a substitute because it provided sporadic income that was useful for nondaily household needs such as buying clothes, school fees, or house maintenance.

In four other villages, the majority of respondents (maximum 73-93% of respondents per village per year) perceived decreases in fisher numbers after seaweed farming started, and seaweed farming was perceived as the main factor associated with reductions in numbers of fishers (Table 3.1).Relatively few respondents from these villages per year reported further increases in numbers of fishers in subsequent years, except in Bilangbilangan East, where in the year preceding the study perceived changes in fisher numbers changed abruptly from 73% of respondents indicating fisher numbers decreased to 73% indicating fisher numbers increased within a year (Fig. 3.1). Reasons given for this sudden perceived change centred around a global surge in seaweed prices in early 2008, which caused people to move into seaweed farming and out of fishing. This was followed by increased incidence of seaweed stealing and a rapid reduction and stabilization in the price of seaweed, which resulted in people moving out of seaweed farming and into fishing. These price fluctuations were reported in all villages, but only had a detectable effect in Bilangbilangan East.

Not all respondents in villages where number of fishers decreased agreed on directions of change in fisher numbers per year, but disagreements were generally not associated with experience. In Alumar the only respondents that reported increases in number of fishers after seaweed farming started (n=7) were those with a baseline before seaweed farming started (n=24), which resulted in an association between baseline year and perceived changes in number of fishers (Fisher’s exact test, $p<0.05$). However, all of these respondents also reported decreases in number of fishers as well. There was no association between experience variables and perceived changes in fisher number in any other villages where number of fishers decreased (Fisher’s exact tests; baseline year, Mahanay p=0.68, Hingutanan East p=0.09, Bilangbilangan East p=0.83; fisher status, Alumar p=0.70, Mahanay p=0.80, Hingutanan East p=0.47, Bilangbilangan East, p=1).

Table 3.1. Number of respondents perceiving change in fisher numbers since the onset of seaweed farming and the reasons for the changes.

	Villages with increased number of fishers				*Villages with decreased number of fishers*			
Change in fisher numbers and reasons for change	*Alumar*	*Hingutanan East*	*Mahanay*	*Bilangbilangan East*	*Cuaming*	*Guindacpan*	*Hambungan*	*Handumon*
Decrease*	**28**	**15**	**22**	**26**	**0**	**0**	**5**	**1**
declining fish catches	9	5	3	11	0	0	1	1
seaweed farming	26	10	22	22	0	0	5	1
other	0	0	0	1	0	0	0	0
Increase*	**7**	**4**	**14**	**24**	**30**	**30**	**23**	**28**
fishing income reliable	0	0	3	1	3	4	3	5
human population growth	1	3	6	4	27	27	15	21
no other employment options	2	0	2	3	14	12	11	18
seaweed farming unreliable	1	1	3	19	1	1	2	0
seaweed farming additional to fishing	0	0	0	1	11	0	6	3
other	0	0	0	1	0	1	0	1
No change*	**6**	**22**	**0**	**21**	**0**	**0**	**7**	**2**
declining fish catches	0	6	0	1	0	0	1	1
fishing income reliable	1	1	0	1	0	0	0	0
human population growth	0	1	0	2	0	0	1	1
seaweed farming	3	7	0	6	0	0	5	1
seaweed farming additional to fishing	4	0	0	12	0	0	1	0
other	0	0	0	0	0	0	0	1

* The number of respondents that indicated this change in number of fishers for any year since seaweed farming started. Respondents could indicate different trends in fisher numbers for each year since seaweed farming started, so the values do not sum to 30 (maximum sample size per village) within each village. Each of these respondents could also indicate multiple reasons for each change.

Key informant estimates indicated that involvement in seaweed farming was high in all villages (30-95% of households) (Fig. 3.2). Key informant estimates showed substantial growth in the total number of households since seaweed farming started (2-6%/year) in all villages except Guindacpan (1.0%/year), with the largest increases in Alumar (5.8%/year) and Hingutanan East (4.2%/year). Key informant estimates showed the proportion of households where heads of household engaged in fishing decreased since seaweed farming started in Alumar, Mahanay, and Hingutanan East (-29% to -64%), but increased slightly (1%) in Bilangbilangan East. The number of households with heads of household engaged in fishing decreased only in Mahanay (-34%) and Hingutanan East (-37%), but increased in Alumar (44%) since seaweed farming started (Supporting Information).

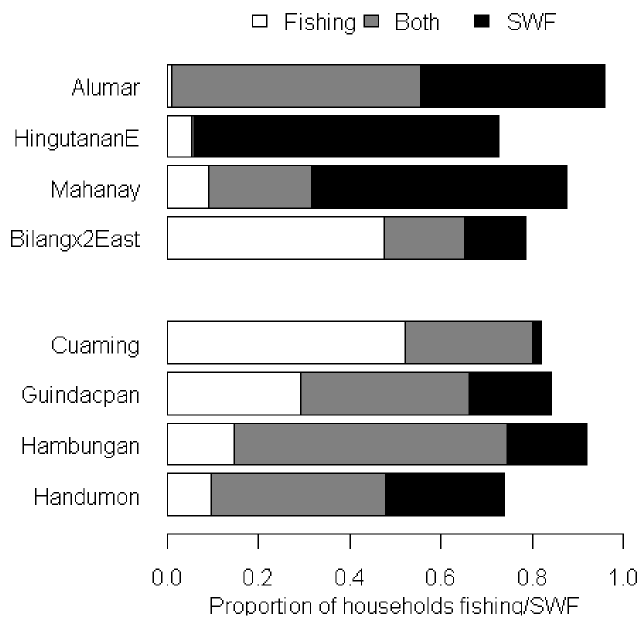

Figure 3.2. Proportions of all households by village where heads of household were involved in fishing, seaweed farming, or both at the time of the survey: (a) villages where the number of fishers decreased and (b) villages where the number of fishers increased. Data were from estimates made by key informants on the basis of census data (Supporting Information). SWF = seaweed farming.

Socioeconomic factors did not differ between villages with increased numbers of fishers and those with decreased numbers of fishers (Table 3.2), although it was not possible to test for interactions among variables. Villages where numbers of fishers decreased had both the highest and lowest wealth scores (Hingutanan East, mean [SE] = 1.32 [0.44]; Alumar, -1.02 [0.29]; Mahanay, -0.45 [0.26]) and years of education (Hingutanan East; mean [SE] = 8.25

[0.68], Alumar; 4.55 [0.39], Mahanay; 4.58 [0.34]) (Supporting Information). Two municipalities each contained a village with increased numbers of fishers and a village with decreased numbers of fishers, which suggests governance arrangements such as license fees or regulations did not influence the outcomes. Outcomes were also not consistent with the way seaweed farming was introduced to villages or other village-level variables. Less than 36% of seaweed farmers were members of People's Organisations (through which government assistance programs were administered) or had received technical training in every village except Hambungan (79% members of People's Organisations and 55% received training). Over 80% of seaweed farmers owned their seaweed farms in both village types, except Bilangbilangan East (14%). Seaweed farms were larger in villages where the number of fishers decreased than in villages where the number of fishers increased, and a higher proportion of seaweed farmers in villages where number of fishers decreased used their personal capital for seaweed farming than in villages where number of fishers increased (Table 3.2).

Reasons for continuing or ceasing fishing

High importance was attached to what local fishers term jackpot – the potential for windfall catches – as a reason to fish (89% of fishers across all villages; n=231) (Table 3.3). The provision of food and income and the reliability of fishing were considered highly important reasons for fishing by many fishers (70%, 47%, and 56% of fishers, respectively). Lifestyle, tradition, and gear ownership were also considered highly important reasons for fishing by many fishers across all villages (85%, 59%, and 70% of fishers, respectively). A lack of options was considered a highly important reason for continuing to fish by 71% of fishers in villages where number of fishers increased (n=105), whereas 37% of fishers in villages where number of fishers decreased thought this was a highly important reason to continue fishing (n=68).

Seventy-three percent of respondents who had ceased fishing (n=45) were from villages where number of fishers decreased (Table 3.3). Of these respondents (n=33), 70% assigned high importance to seaweed farming, 55% to declining catches, and 48% to the increasing unreliability of fishing income as reasons for ceasing fishing. Of the 10 respondents who had ceased fishing in villages where number of fishers increased, 20% assigned high importance to seaweed farming and 60% to health or age as reasons for ceasing fishing (Table 3.3).

Table 3.2. Summary (mean [SE]) of mean socioeconomic and seaweed farming attributes for members of villages in which the numbers of fishers increased or decreased and for village population and distance to markets for villages of each type.[a] *p*<0.001 = ***, *p*<0.01 = **, *p*<0.05 = *, ns = non-significant

Attribute	*Fishers decreased*	*Fishers increased*	
Socioeconomic factors[b]			
number of other income sources	0.68 (0.11)	0.63 (0.12)	ns
wealth score[c]	0.05 (0.51)	0.07 (0.18)	ns
education of heads of household (years)	5.99 (0.89)	4.79 (0.27)	ns
number of people per household	5.08 (0.21)	5.46 (0.25)	ns
median monthly income – ln(P)	8.73 (0.08)	8.67 (0.13)	ns
Seaweed farming factors[b]			
seaweed farm sizes – ln(ha)	-0.61 (0.26)	-1.66 (0.18)	**
proportion of seaweed farmers with privately owned farms	0.70 (0.19)	0.89 (0.03)	ns
membership of People's Organisation (proportion)	0.21 (0.06)	0.38 (0.14)	ns
personal capital for seaweed farming as opposed to external funding (proportion)	0.75 (0.08)	0.50 (0.05)	*
satisfied with seaweed production (proportion)	0.94 (0.03)	0.93 (0.02)	ns
receipt of technical assistance (proportion)	0.19 (0.06)	0.10 (0.29)	ns
Village[d]			
population size 2007	1,251.5 (342.50)	1,658.0 (526.00)	ns
distance to seaweed market (km)	49.50 (7.27)	31.25 (4.23)	ns
distance to fish market (km)	12.00 (2.12)	8.00 (1.83)	ns

[a] For values by village see Supporting Information.

[b] Socioeconomic factors and seaweed-farming factors were measured for individual households within villages. The mean of these values per village were used to calculate mean (SE) for village types. Significance is based on mixed-effects models that partition the error within villages from the residual error (see text for details). For details of how these factors were measured, see Supporting Information.

[c] Wealth scores were calculated from principal components analysis on household structure and possessions, based on the first principal component which explained 35.2% of the variation among households and ranged from -2.91 (poorest) to 7.33 (wealthiest) (Supporting Information)

[d] Village-level attributes measured once per village.

Table 3.3. Number of households (n=30) engaged in fishing, ceased fishing, or never fished, and that assigned high importance to the reasons listed for either continuing to fish or for having ceased fishing.

	Fishers decreased				*Fishers increased*				*Other villages*	
Fishing status and reason behind status	*Alumar*	*Hingutanan East*	*Mahanay*	*Bilangbilangan East*	*Cuaming*	*Guindacpan*	*Hambungan*	*Handumon*	*Batasan*	*Bilangilangan Tubigon*
Fishes	**20**	**7**	**15**	**26**	**29**	**24**	**29**	**23**	**29**	**29**
no other employment options	2	3	1	19	24	13	23	15	27	29
enjoyment	11	5	11	21	28	21	23	20	28	29
traditional	14	3	9	21	24	2	17	5	17	25
gear ownership	16	4	8	21	24	12	11	22	24	20
income	0	0	9	0	10	7	16	9	28	29
food	7	3	12	15	27	6	15	20	27	29
reliable	1	2	3	7	28	14	13	9	28	25
jackpot*	17	6	14	23	24	20	26	23	24	29
Ceased fishing	**8**	**12**	**10**	**3**	**1**	**5**	**1**	**3**	**1**	**1**
seaweed farming	6	9	6	2	0	1	0	1	0	0
health / age	3	4	1	1	1	3	0	2	1	1
other livelihood	2	1	3	0	0	3	0	0	0	1
gear loss	1	3	2	2	1	1	0	1	0	0
declining catches	4	6	6	2	0	2	0	1	0	1
income unreliable	5	6	4	1	1	0	0	1	0	1
enforcement of illegal fishing	0	2	3	0	0	0	0	0	0	0
Never fished	**2**	**11**	**5**	**1**	**0**	**1**	**0**	**4**	**0**	**0**

* Potential for windfall catches

3.4 Discussion

The results demonstrate the value of timelines as a tool to collect information on historical trends in the absence of formal records. Key informant reconstructions of fisher numbers took a long time to compile, and such reconstructions can mask changes in trends, as was found for Bilangbilangan East. In the other villages timeline results generally were consistent with the results of the key-informant estimates, except for Alumar. The substantial increases in human population size and decreases in the proportion of fishers that key informants estimated for Alumar may have resulted in a dilution effect, which resulted in respondents perceiving a decrease in fisher numbers when they were actually increasing. However, key-informant estimates were based on whether a head of household was involved in fishing, whereas timelines focused on perceived trends in total fisher numbers. It is possible therefore that decreases in fisher numbers occurred through reduced labour allocations to fishing within households in Alumar.

The perceived decreases in fisher numbers associated with seaweed farming and declining catches in the villages where fisher numbers decreased is consistent with how fishers with access to alternative occupations indicate they would respond to reduced catches (Cinner et al. 2009a). The return to fishing in one village where number of fishers decreased as a result of problems with seaweed farming emphasizes the occupational mobility and opportunistic nature of the rural poor (Allison & Ellis 2001) and highlights that people return to fishing when profits from seaweed farming decrease. It is unclear why the declining seaweed prices in 2008 led to returns to fishing in only Bilangbilangan East, but this occurrence may be related to the small proportion of seaweed farms that are owned in Bilangbilangan East. Lower ownership reflects lower capital investment, which is associated with higher mobility among occupations (Smith & McKelvey 1986).

Despite widespread engagement in and institutional support of seaweed farming in villages where number of fishers increased, respondents emphasized that seaweed farming did not provide for daily household needs as effectively as fishing. Results of other studies show that the capacity of fishing to generate nearly instantaneous income (Béné et al. 2009) leads to preferences for fishing over delayed-return occupations such as seaweed farming (Sievanen et al. 2005; Torell et al. 2010). Such preferences suggest that fishing may not be an easily replaced source of income (Smith et al. 2005). This may be especially relevant in areas with limited access to financial services for savings and borrowing and where people may therefore struggle to match infrequent incomes against frequent consumption requirements (Dorward et al. 2009). Additionally, the reasons identified by current fishers for continuing to fish are consistent with other research that finds people fish for both economic and noneconomic reasons (Pollnac et al. 2001b).

Number of fishers were not found to have decreased or stabilized after seaweed farming started in all villages as hypothesized, but instead there was heterogeneity in the changes in number of fishers among villages. The heterogeneity of outcomes found among villages poses a challenge to making simple predictions about the effect of alternative occupations on, and therefore their role in, managing fisher numbers. Seaweed farming is widely supported by government policy in the region. The proportions of people who received such support or training were generally low across villages, indicating any differences in the form of support or training provided would likely have little effect on the changes in number of fishers. Given these findings and that fishers across Danajon Bank faced declining fish catches (Armada et al. 2009), it seems reasonable to expect decreases in number of fishers in each village.

There are two possible explanations for the differences in how number of fishers changed in each village. First, in villages where number of fishers increased, seaweed farms were relatively small and more seaweed farmers used external funding than in villages where number of fishers decreased. The length of seaweed line planted and measures of wealth are positively related in other locations (Sievanen et al. 2005), which suggests constraints on the area available for seaweed farming could affect the profitability of seaweed farming. The use of external funding sources may involve interest payments, possibly in the form of unfavourable price arrangements because traders often provide funding in order to secure cheap and regular supplies (Platteau & Abraham 1987). Such arrangements may reduce the profitability of seaweed farming. However, I could not distinguish between cause and effect because small farm sizes and use of external funding may reflect decisions to invest household resources in occupations other than seaweed farming rather than limited access to suitable seaweed-farming areas or personal capital.

Second, the different outcomes among villages may have been due to the differences in the wealth status of the villages. Livelihood specialization is most likely to occur as part of a “survival” strategy (Smith et al. 2005) or in communities of higher development status (Cinner

& Bodin 2010). Livelihood diversification is otherwise perceived to be the norm when multiple occupations are available (Barrett et al. 2001; Smith et al. 2005). Households from Hingutanan East had the highest levels of wealth and education and Bilangbilangan East was a close second. Both these villages were more specialized in either fishing or seaweed farming than households from other villages, which points to a potential link between specialization and relatively high wealth status.

Households from the other two villages where the number of fishers decreased (Alumar and Mahanay) had the least wealth and relatively low levels of education, and they lacked fishing capital when seaweed farming started. Rapid increases in the local price of fresh fish (1,400% in 20 years) (Green et al. 2004) and increasing access to high-value markets such as the aquarium trade (Christie et al. 2006) may have helped keep fishing economically viable for those fishers who could change target species in response to changes in price and abundance. Such movement of effort among fisheries in response to price has occurred in the Philippines (Fabinyi 2010). A lack of fishing capital of households in Alumar and Mahanay may have prevented them from changing target species, which means switching from fishing to seaweed farming may have been part of a survival strategy. Relatively low investment in fishing assets is typically seen as a strategy to allow opportunistic movement among fisheries and other occupations (Smith & McKelvey 1986). However, a lack of capital assets increases a household’s vulnerability to poverty (Allison & Ellis 2001). Thus, seaweed farming, with its relatively low entry costs (Hurtado et al. 2001) and financial support from government assistance programs, may have kept households in Alumar and Mahanay from pursuing occupations with continually decreasing returns (Cinner et al. 2009a).

It remains to be seen whether the measurement of any variables before the introduction of an alternative occupation can help predict effect of that occupation on fisher numbers. Given the array of potential variables that could interact at local and regional levels to determine livelihood strategies (Allison & Ellis 2001), the most relevant variables may be site specific. My results add weight to the suggestion that alternative occupations may not be a substitute for other resource management tools (Sievanen et al. 2005). However, the development of alternative occupations may help increase support for conservation actions (Pollnac et al. 2001a) and may be useful as a component of an approach that integrates population and coastal resource management (D’Agnes et al. 2010).

This chapter illustrates the importance of understanding socioeconomic processes when managing the number of people exploiting declining species. The next chapter examines the income patterns and risk profiles associated with fishing and seaweed farming in two of these sites, to improve understanding of why this heterogeneity of outcomes may have been observed among villages.

Supporting Information

Supporting information for this chapter can be found in Appendix S3, and includes: further details of the methods and results from key-informant estimates (S3.1), values for household- and village-level variables by village (S3.2) and, examples of timelines used to collect perceptions on changes in fisher numbers (S3.3).

CHAPTER 4

Cash machines in the sea: An analysis of risk and patterns of income in fishing and seaweed farming.

Abstract

This chapter examines the patterns of income and risk associated with fishing, seaweed farming and informal sector occupations on Danajon Bank, central Philippines, in order to establish the role these occupations play within people's livelihoods. Previous studies have suggested that seaweed farming may complement, rather than substitute for, fishing because of differences in the patterns of income which influence the role these occupations play within livelihoods. Fishing is expected to resemble a 'cash machine', which provides immediate returns to effort for daily needs (e.g. to buy food). Seaweed farming is expected to resemble a 'savings account', which provides delayed returns for more sporadic financial needs (e.g. for school fees or house repairs). This chapter explores these suppositions in detail by using 24-hr recall surveys and mixed effects models to determine the patterns of income from these occupations (probability and magnitude of income events) in relation to long-term and short-term measures of effort (labour time and expenses invested). Additionally, data gathered from focus group discussions and interviews were analysed to determine the risks associated with each occupation. Contrary to expectations, these analyses showed that seaweed farming was able to provide regular access to liquid assets (seaweed) in a similar way to fishing provides access to liquid assets (fish). However, seaweed farming income was also positively related to long-term financial investments and subject to substantial short-term risk. Therefore, seaweed farming more closely resembles an 'instant access savings account', but with low levels of security. The role seaweed farming played within household livelihoods was dependent on the levels of risk seaweed farming investments were exposed to. Fishing was subject to long-term risk due to declining catches but, as expected, provided immediate access to liquid assets (fish). Informal sector income showed mixed 'cash machine' and 'savings

account' capability dependent on the specific occupation, with income positively associated with long-term financial investments and same day effort. Seaweed farming provided the best opportunity to increase wealth, but this opportunity was limited by the high levels of risk. The results illustrate that seaweed farming could be a more attractive opportunity than fishing only if the risks to seaweed farming investments can be reduced. Tipping the balance of risks and payoffs in the favour of seaweed farming will require the provision of locally-appropriate insurance services or schemes to mitigate against or minimise risk.

4.1 Introduction

Seaweed farming is promoted in many coastal areas of developing nations both to increase the supply of seaweed for carrageenan production and to provide an opportunity for fishers exploiting declining fisheries resources. Seaweed farming requires little equipment or technical expertise and, since the 1970s, has been promoted as a potentially lucrative alternative occupation for fishers with low incomes in coastal poor areas of Southeast Asia (Samonte et al. 1993; Hurtado-Ponce et al. 1996; Hurtado et al. 2001). Carrageenans are primarily used in the processed food industry as texturing agents and stabilizers, and are extracted from species of tropical seaweed mostly cultivated in the Philippines and Indonesia. Global demand for carrageenan outstrips supply as production of the most widely used carrageenan has been hampered by insufficient supplies of the most valuable seaweed, locally known as 'cottonii' (*Kappaphycus alvarezii*) (Bixler & Porse 2011). The potential for this supply gap to provide a conservation-development "win-win" situation (McShane et al. 2011) has been duly recognised by organisations involved in integrated coastal management, who often use seaweed farming as a tool to help reduce fishing pressure and enhance the socioeconomic status of poor fishers (Sievanen et al. 2005).

The development of alternative occupations, defined here as non-fishing occupations such as seaweed farming, is regarded as beneficial for both fisheries and fishers. Managers and conservation practitioners have often assumed that alternative occupations will substitute for fishing activity, leading to a reduction in fishing pressure (Sievanen et al. 2005; Brugère et al. 2008). Whilst it is now recognised that complete economic substitution is unlikely, diversification (the process of increasing the number of occupations that individuals or households engage in) is expected to enable fishers to respond to declining catches by reallocating labour elsewhere (Allison & Ellis 2001). This supposition is supported by empirical research under hypothetical scenarios which finds that fishers with greater access to alternative occupations would be willing to exit declining fisheries sooner (Cinner et al. 2009a). In addition to alleviating pressure on a declining fishery, diversification is expected to benefit fishers livelihoods because it can help to reduce vulnerability to shocks and disturbances (e.g. market fluctuations or sickness) and increase livelihood security (Ellis 2000a; Barrett et al. 2001; Allison & Ellis 2001). Diversification through the development of alternative occupations is therefore promoted within the 'sustainable livelihoods approach to poverty reduction' (Allison & Horemans 2006). However, the expected interaction between alternative occupations and fishing effort remains largely untested, and expectations for diversification do not fully appreciate the contrasting and complementary roles that different occupations can play within people's livelihoods (Smith et al. 2005).

The frequency of income events and uncertainties associated with returns on effort are important features to consider when comparing seaweed farming and fishing. Seaweed farming can generate very lucrative returns on investment (Samonte et al. 1993; Hurtado-Ponce et al. 1996; Hurtado et al. 2001). However, indications are that it is a "delayed return" occupation (Woodburn 1982) that delivers sporadic income 40-50 days after effort is expended, which, in most situations, complements rather than substitutes for daily income from fishing (Sievanen et al. 2005; Chapter 3).

Reasons for the suggested lack of substitutability are two-fold. First, although fishing is regarded as a highly uncertain and risky occupation on a per-trip basis (van Oostenbrugge et al. 2001, 2004; Allison & Ellis 2001; Pollnac & Poggie 2008), there is the capacity for multiple income events and rewards to effort are normally same-day (Tucker et al. 2010). On the other hand, the fate of effort expended in planting seaweed is uncertain as it may be damaged by disease, predation, strong winds, or changes in price during the growing period (Trono Jr & Lluisma 1992; Luxton 1993; Ask & Azanza 2002; Sievanen et al. 2005; Hung et al. 2008). These uncertainties during the waiting time represent a risk to the effort invested and engender higher levels of anxiety than "immediate return" occupations (Woodburn 1982) such as fishing (Tucker et al. 2010). Second, fishers are used to receiving small regular income, and typically face constraints in saving cash between sporadic large income events (Tucker et al. 2010; Torell et al. 2010). The capacity of fishing to generate almost daily revenues from the "bank in the water" therefore represents a substantial advantage over occupations that only generate returns on discrete occasions (Béné et al. 2009). Such immediate return occupations, where income is dependent on effort that day, provide a ‘cash machine’ function, allowing regular withdrawals for cash as required.

The reason for the suggested complementarity of fishing and seaweed farming income is that the sporadic income from seaweed farming can function as a ‘savings account’ to help meet sporadic needs (Chapter 3). As well as regular and relatively small consumption requirements, people have intermittent and large investment and consumption needs (Dorward et al. 2009). Without access to savings institutions, fishers have little opportunity to build savings incrementally from relatively small daily fishing income (Torell et al. 2010). As such, they are often dependent on informal credit schemes to meet sporadic large income needs (e.g. housing materials), but which are often associated with unfavourable labour- or production-binding conditions (Platteau & Abraham 1987; Crona et al. 2010). “Delayed return” occupations (Woodburn 1982) that provide discrete and relatively large incomes are therefore often regarded as important and complementary to fishing (Torell et al. 2010), as they provide some freedom from such restrictive credit arrangements.

The hypothesis that seaweed farming provides a ‘savings account’ service that complements rather than substitutes for the ‘cash machine’ service of fishing is consistent with observations where fishing levels were maintained following the introduction of seaweed farming (Sievanen et al. 2005; Chapter 3). However, it does not explain reductions in fisher numbers or fisher effort in other sites where seaweed farming has been introduced and become the dominant occupation (Sievanen et al. 2005; Chapter 3). Within this context, the objective of this chapter was to examine the validity of the assumption that fishing and seaweed farming play complementary but non-substitutable roles. This chapter therefore examines the patterns of income and risk profiles associated with fishing and seaweed farming in two villages on Danajon Bank, central Philippines.

4.2 Methods

Study sites

Danajon Bank is a double barrier reef approximately 130 km long, running between Bohol and Cebu Provinces in the central Philippines (Chapter 2, Fig. 2.1). Danajon Bank has 40 islands, each with associated villages. These islands are small with high population densities and substantial poverty. Dependence on marine resources is high with few alternatives to the dominant occupations of fishing and seaweed farming (Armada et al. 2009; Chapter 3). Seaweed farming was introduced to some islands on Danajon Bank by the carrageenan industry in the late 1960s and spread to other areas of Danajon Bank in the 1990s (Chapter 3). The coral reefs of Danajon Bank are some of the most degraded in the world (Marcus et al. 2007), mainly because they have been subjected to unsustainable and destructive fishing methods. Current catch rates for fishing are thus very low (Armada et al. 2009). As such there has been substantial interest in promoting seaweed farming (through government assistance programmes) as a means to diversify livelihoods and reduce dependence and pressure on declining resources (Chapter 3).

Two villages, in which both seaweed farming and fishing were widespread, were selected for this study; Handumon (Getafe municipality) and Guindacpan (Talibon municipality), from Bohol Province. Fisher numbers have continued to increase (due to continued human population increases) since seaweed farming started in both villages (Chapter 3). Within this aggregate picture, however, there was sufficient variation in household-level involvement in fishing and seaweed farming within Guindacpan and Handumon to identify the range of income patterns that these occupations can produce.

24-hr recall

24-hr recall surveys (de Merode et al. 2004) were conducted to explore the patterns of income from fishing, seaweed farming and other occupations. 83 households from Handumon and Guindacpan were surveyed roughly once per week per household over a 13 month period (May 2008 to June 2009). These households were selected by peer recommendation following discussion with village leaders, on the basis that they represented a range of involvement in both fishing and seaweed farming. Households were visited roughly once per week, and households members interviewed about their activities during the previous day. Information collected included the time and expenses (e.g. payment for labour or fuel) that each household member invested in each occupation (see Chapter 2 section 2.3 for definitions of occupations), as well as monetary and non-monetary (e.g. food consumed) income earned from them during the previous day, irrespective of how the income was earned or time spent (i.e. whether it was own production, hiring out labour to another household, or participation in cooperative activities; section 2.6). Income was only recorded in relation to an occupation where the value had been realised during the previous day (e.g. cash received, or food from production consumed). Income (including the value of non-monetary income) and expenses were recorded in Philippine Pesos (P; average exchange rate of P47.64 : US$1 in 2009) and time as hours and minutes. Information recorded included support activities relating to occupations, such as gear maintenance or processing of catch. Details of any goods bought or sold relating to an occupation were recorded with their price. Interviewers also asked about respondents' use of loans and credit and other sources of income, and recorded any discussion or comments that were had during the survey about the occupations they engage in. All surveys were conducted in the local dialect, Visayan, by trained and experienced local research assistants. Questions were addressed to the heads of household or primary income earners. Where the respondent did not know specific details (e.g. income or time) about the activities of other household members, these household members were sought out for confirmation (Chapter 2, section 2.6).

Surveys were stratified across days of the week. Practical constraints meant that surveys could not always be conducted every week for each household (e.g. appropriate household members could not be found). No surveys were accepted for analysis from Handumon between 28th July and 27th November 2008 (Chapter 2, section 2.6.4). 17-43 surveys were completed per household, resulting in a total of 2,654 surveys that were accepted for analysis (Chapter 2, section 2.6).

Occupational sectors

Occupations were grouped into the following six sectors for analysis (e.g. Cinner et al. 2009; Cinner & Bodin 2010): fishing, seaweed farming, trade of fish/shellfish, trade of seaweed, the informal sector, agriculture and salaried.

Fishing was defined as any occupation that gathered fish or shellfish from the sea for sale or consumption, and included gleaning. Seaweed farming was defined as any occupation that involved the harvest of seaweed from the sea, which included the collection of wild/washout seaweed. Activities relating to the trading of fish/shellfish or trading of seaweed that was not from own production (i.e. middleman) were separate sectors to fishing and seaweed farming. For those households engaged in trading of seaweed (5 households), income and effort associated with trade of seaweed and seaweed farming could not be distinguished. The seaweed activities of these five households were therefore included as seaweed trading.

Informal sector occupations were defined as casual labour or entrepreneurial occupations that provided *ad hoc* income, and most commonly included selling food (e.g. from a produce stand) or water and independent trade work (e.g. carpentry or mechanical), but also included handicrafts, housemaid work and working as a fish pond caretaker. The maximum number of informal sector occupations per household was two.

Out of the 2,654 survey days across 83 households, the most common sectors were fishing (1,424 days recorded across 73 households), seaweed farming (1,199 days recorded across 74 households) and informal (1,065 days recorded across 73 households). Other sectors were recorded on less than 10% of days (agriculture: 239 days recorded across 50 households; salaried: 148 days recorded across 26 households; fish / shellfish trade: 115 days recorded across 10 households).

Analysis of patterns of income

One of the aims of this chapter was to determine if the patterns of income associated with these occupations represented a 'cash machine' or 'savings account' service. An occupation with a 'cash machine' service is defined as one where income is received almost every time that the occupation is engaged in, and where the magnitude of income received is closely related to effort that day (same-day effort). In contrast, an occupation provides a 'savings account' service when income is received on only a small proportion of days that an occupation is engaged in, and the magnitude of income is positively related to effort expended over a longer time period. Engagement in an occupation was defined as receiving income from that occupation or expending time or expenses in that occupation.

Patterns of income, as analysed in this chapter, entail two response variables: (1) the probability of obtaining income from an occupation on a given day, given that the occupation was engaged in, and; (2) the magnitude of income on the day that income was received. Patterns of income are distinguished from patterns of engagement in an occupation, the latter being defined as the proportion of survey days for which engagement in the occupation was recorded. Analysis is focused on the patterns of income for the most common occupational sectors: fishing, seaweed farming and informal. Other sectors were assessed descriptively due to the low rates of participation and hence limited data. Six separate mixed effects models were thus developed; one for each combination of response variable and sector. Mixed effects models were used to partition variance among households from residual variance.

The principle explanatory variables of interest were four different measures of effort; classified by time span of the measurement (same-day or long-term) and unit of measurement (time or expenses). Same-day effort was the effort expended by the household that day (daily effort), given that the occupation was engaged in. Long-term effort was the daily effort averaged across all survey days for each household (including days when the household was not engaged in the occupation). Measures of time and expenses were each summed across all household members. They were expected to be independent representations of effort because expenses can replace time spent in occupations (e.g. by hiring labour in) or be additional to time spent in occupations (e.g. by spending money on fuel). Within the units of measurement, long-term and short-term measures of effort were not closely related because calculation of long-term effort included days when the household was not engaged in the occupation. Collinearity among the effort variables was explored using pairwise plots, pairwise Kendall's correlation tests and variance inflation factors. The maximum correlation was 0.6 (for long-term and same-day fishing expenses) and did not indicate any problems with collinearity (Supporting Information). Same-day measures of effort were transformed as $\ln(x + 1)$ to improve the distribution of residuals and because zero values of effort were possible (e.g. zero time when all labour hired in). Long-term measures of effort were not transformed.

Other explanatory variables included in the analyses were season and village, and a term to identify whether the respondents spoken to were those engaged in the occupation that day. Season was included as a factor with three levels: *habagat* (August – October 2008), *amihan* (November 2008 – March 2009), and *hot* (June – July 2008 and April – June 2009). Due to exclusion of some surveys from Handumon, there was no information from the *habagat* season for this village. Village was a two-level factor: Guindacpan and Handumon. The term for the respondent was a categorical term with two levels (yes the respondent was engaged in the occupation / no the respondent was not engaged in the occupation). This respondent term helped control for bias because household members that engaged in an occupation would not always report the full extent of their income to other household members, retaining a small portion of the income (in what was referred to by respondents as their 'secret pocket') for their recreational use.

The probability of obtaining income from an occupation on a given day, given that the occupation was engaged in, was modelled with binomial generalised linear mixed effects models (GLMMs). The response variable was 1 for days when income was earned, and 0 for days when the occupation was engaged in but no income was earned. Same-day time and both long-term measures of effort were included as continuous explanatory variables. Same-day expenses were included as a binomial explanatory variable (1 where expenses were incurred, 0 where no expenses were incurred) due to a large number of zero-expense days, which presented a challenge for GLMM fitting procedures (Supporting Information). Patterns of engagement (proportion of days that an occupation is engaged in) were included as a control variable and to verify that patterns of income and engagement were independent. Binomial GLMMs were random intercept models, with household included as a grouping factor in the random effects.

The magnitude of income received was modelled with linear mixed effects models (LMMs) where the response variable was the log-transformed non-zero income earned from the occupation on a given day. Same-day and long-term measures of effort were included as continuous explanatory variables. For models where same-day measures of effort included zero values that resulted in patterns in the residuals, binomial dummy variables were included for the relevant measure of effort (1 when no effort expended that day, 0 when effort was expended) to improve the distribution of residuals. The proportion of occupation days on which income was obtained (per household) was also included as an explanatory variable to check for a relationship between probability of obtaining income and magnitude of income. Random effects structures included household as a grouping factor. Random intercept and random slope (for same-day levels of effort) models were considered to control appropriately for differences among households in their relative efficiencies (e.g. different fishing gears). The best random effects structures were determined based on Akaike's information criterion (AIC) and model validation plots (Zuur et al. 2009). For fishing, random slopes for both measures of same-day effort were included. For seaweed farming and informal sector models, a random slope for same-day time was included.

A model averaging approach based on information theory (Burnham & Anderson 2002) was used to determine the relative importance and direction of the relationship between the explanatory variables and response variables. GLMMs and LMMs were run with the package lme4 (Bates et al. 2011) in R (R Development Core Team 2011). Models were run for all possible combinations of explanatory variables without interactions. Akaike weights (w_i) were calculated for all models and used to rank the models in descending order. The 95% confidence set of models (those whose cumulative Akaike weights (starting from the top) summed to the closest value to 0.95) were selected for model averaging using the Multimodel Inference package in R (MuMIn; Barton 2011). Relative importance scores for each explanatory variable were calculated from the 95% confidence set of models as the sum of Akaike weights (rescaled for the 95% confidence set) of each model in which the variable appeared (Supporting Information).

Risk and the role of different occupations within livelihoods

The second aim of this chapter was to explore the risk associated with fishing and seaweed farming and the roles that these occupations play within people's livelihoods. The risks associated with seaweed farming were explored for 10 villages on Danajon Bank including Guindacpan and Handumon. Thirty households were selected from each of these 10 villages representing 5-27% of the households in each village using a systematic sampling design (every n^{th} household) with randomised start point based on the latest census list (2008/2009). Further details of the villages and these households are provided in Chapters 2 and 3. Where the heads of these households were engaged in seaweed farming they were asked to score a list of putative risks to seaweed farming from 0 (not a problem) to 3 (a very big problem). The list of putative risks was generated from a small-scale seaweed farmers' workshop that was convened by a local NGO, Project Seahorse Foundation for Marine Conservation, in conjunction with the Bohol Provincial Agriculture Office and Bohol Office of the Bureau of Fisheries and Aquatic Resources in July 2008. In addition to this, risks to seaweed farming were further explored through discussion with respondents of the 24-hr recall surveys. Risks to fishing were solely explored through discussion with respondents of the 24-hr recall surveys.

Interviews and focus group discussions were used to explore the role of seaweed farming and fishing within household's livelihoods. In June 2009, questionnaires were conducted with the households from the 24-hr recall surveys. The heads of each household were asked to score a list of reasons for their engagement in fishing and seaweed farming, from 0 (not important) to 3 (very important). This list included "the provision of income for daily household needs", "the provision of income for savings that can be used to pay for school, housing or equipment", and "because it is possible to get a jackpot". These reasons were based upon key informant interviews and discussion with respondents over the course of the 24-hr recall surveys.

Three focus group discussions were carried out within Handumon and Guindacpan in June 2009. These focus group discussions explored the contribution of seaweed farming and fishing to livelihoods and wealth. In each village, separate focus group discussions were conducted with men, women and youths (aged 18-30, male and female). Focus group discussions ranged in size from three to six participants, who included village officials and people involved in fishing and seaweed farming and who had good knowledge of all the households in their village. Participatory wealth ranking was undertaken in these focus group discussions, followed by a discussion on the characteristics of households in different wealth groups (including the occupations they engaged in) and how households may move between wealth groups. Specific focus was on the role of fishing and seaweed farming for these wealth groups and movement between groups (Chapter 2).

4.3 Results

Patterns of income from fishing and SWF

The 24-hr recall analyses confirmed that fishing provides a ‘cash machine’ service. Although households varied substantially in their engagement in fishing, income was received on nearly every day that a household engaged in fishing (median 95.6%, n=68 households) and showed little variation among households with no differences among villages (Fig. 4.1a). The probability of obtaining income from fishing was not modelled due to the high proportion of fishing days that resulted in income and the low level of variation among households. The magnitude of fishing income (on days that it was received) showed a positive and much stronger relationship with both same-day measures of effort than with long-term measures of effort (Table 4.1). Evidence of seasonality was also found, with the highest returns to effort occurring during the *amihan* season (Table 4.1).

Table 4.1. The importance and directiona of the relationship between explanatory variables and patterns of income for seaweed farming, fishing and informal sector occupations, estimated from mixed effects models. Strong positive relationship with same-day effort indicates 'cash machine' services, while strong positive relationships with long-term effort indicates 'savings account' services (see main text). Proportion of Occupation Days (PoOD) is the proportion of surveyed days that a household engaged in the occupation (pattern of engagement), and 'PoOD with income' is the proportion of occupation days on which income was received. Probability of obtaining income was only modelled for seaweed farming (see main text for details). Respondent was included in models as a control variable so is not included here (Supporting Information). Model selection tables, coefficient estimates and relative importances are provided in Supporting Information.

Fixed effects	Probability of obtaining income from seaweed farming		Magnitude of seaweed farming income		Magnitude of fishing income	Magnitude of informal sector income
	Guindacpan	Handumon	Guindacpan	Handumon		
Same-day effort						
Time	---	·	+++	·	+++	+++
Expenses	·	·	·		+++	+++
Long-term effort						
Aggregate time	·	·	·	·	·	·
Aggregate expenses	---	-	+++	+++	·	+++
Village [factor]					·	·
Guindacpan						
Handumon						
Season [factor]	·	·	***	·	**	***
Amihan			*(=)*		*(+)*	*(-)*
Habagat		*NA*	*(+)*	*NA*	*(-)*	*(+)*
Hot			*(-)*		*(-)*	*(-)*
PoOD	·	·				
PoOD with income			·	·		·
Number of households	34	31	30	21	68	52
Number of observations	599	453	372	96	1,297	700

[a] +++, --- or *** Importance >0.99, ++, -- or ** Importance >0.95, +, - or * Importance >0.80, · Importance <0.80. Stars are used for factors, and the relative effects of each level within these variables are indicated as higher (+), lower (-) or intermediary (=). Where there is no symbol, the variable was not included in the candidate set of variables.

The results for seaweed farming are mixed, with indications that it can provide both a 'cash machine' service and a 'savings account' service, with differences between Guindacpan and Handumon. Engagement in seaweed farming was similar to that of fishing, but seaweed farming income ranged from 0% to 100% of days engaged in seaweed farming per household (Fig. 4.1b). There was substantial variation in the proportion of seaweed farming days with income between Handumon and Guindacpan (Fig. 4.1b), so the probability of obtaining income from seaweed farming was modelled separately for each village (Table 4.1).

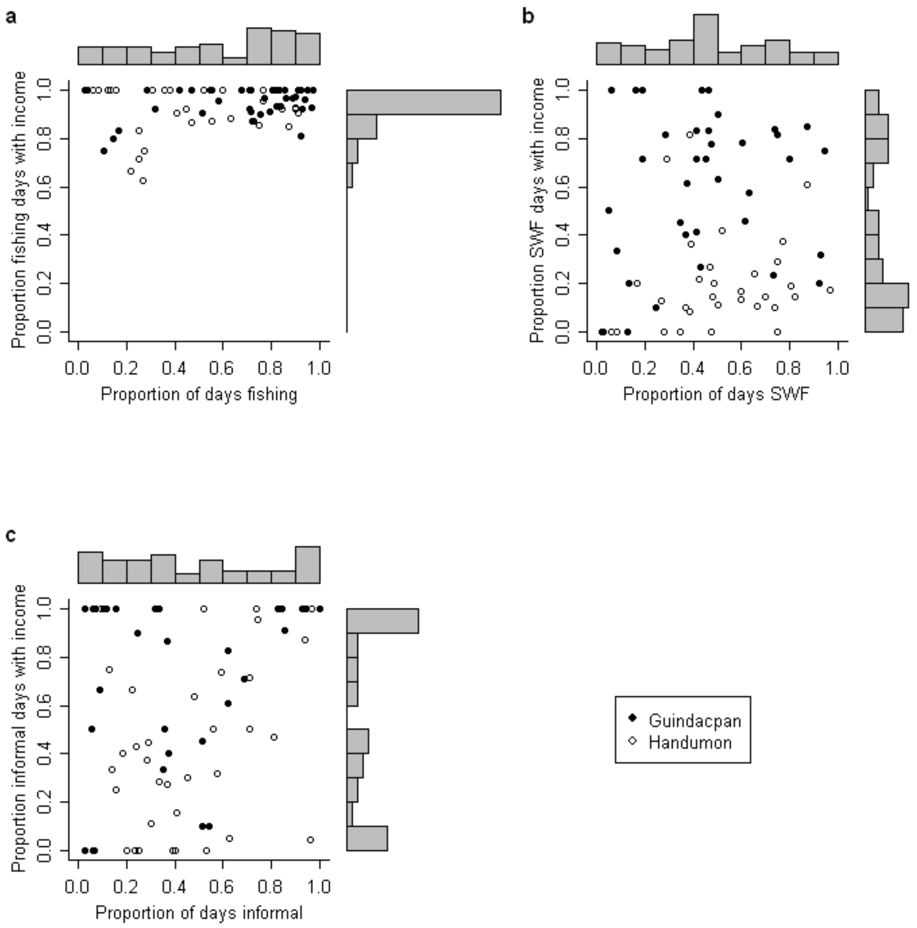

Figure 4.1. Patterns of engagement (proportion of days engaged in the occupation) against patterns of income (proportion of occupation days on which income was received) for households from Guindacpan and Handumon for (a) fishing, (b) seaweed farming (SWF), and (c) informal sector occupations. Each point represents an individual household.

Seaweed farming in Guindacpan had characteristics of both a 'cash machine' and 'savings account'. The median proportion of seaweed farming days with income for Guindacpan was 71.4%, but the probability of obtaining income had a negative correlation with same-day time and long-term expenses (Table 4.1). The negative correlation with same-day time represents a 'savings account' characteristic, as the majority of effort invested was prior to income being generated (i.e. a delayed return occupation). The negative correlation with long-term expenses indicates that those with higher long-term expenses have less frequent payments, possibly representing a choice in the way that they use seaweed income and preferring 'savings account' style income. However, the magnitude of seaweed farming income (on days that it was received) in Guindacpan had a strong positive correlation with same-day time ('cash machine') and long-term expenses ('savings account'). Seasonality had low importance for the probability of obtaining income, but high importance for magnitude of income (Table 4.1).

In contrast, seaweed farming in Handumon had characteristics of only a 'savings account'. The median proportion of seaweed farming days with income for Handumon was 14.3%, and the probability of obtaining income on a seaweed farming day was relatively weakly related to long-term expenses. When income was received from seaweed farming, the magnitude of that income showed a strong positive relationship with long-term expenses only (Table 4.1). Seasonal effects were not detected in Handumon.

A driver of the differences between Guindacpan and Handumon in the probability of obtaining income was the tendency to sell seaweed either wet or dry. Harvested seaweed was most frequently sold wet on the day of harvest in Guindacpan (97.9% of sales wet, n=332 sales), whereas in Handumon only half of seaweed sales were of wet seaweed (53.0%, n=100 sales). Drying seaweed allowed households to store harvested seaweed and to sell it in a single bulk sale at a higher price. Therefore, sales of dried seaweed tended to be of greater value (median value of sales: wet P150; dry P1,031; linear model of logged values, df=1, F=132.8, p<0.001).

The informal sector showed characteristics of both a 'cash machine' and 'savings account'. Households tended either to receive income from the informal sector almost every time they engaged in it, or very rarely (Fig. 4.1c). The variation among households was not related to differences among villages. The probability of obtaining income from the informal sector was not modelled because the tendency of most households to receive income on every informal day or none at all resulted in convergence problems during model fitting. When received, the magnitude of informal sector income corresponded closely with both same-day levels of effort and long-term expenses, and also showed a similar seasonal pattern to seaweed farming in Guindacpan (Table 4.1).

The median proportion of agriculture days with income was 0% (n=50 households), because agriculture was mainly limited to keeping pigs that were consumed for fiestas, or chickens that were used for cock-fighting, with a few rare exceptions of growing rice and coconuts and keeping cattle and goats. The median proportion of salaried days with income was 6.7% (n=26 households). The median proportion of fish trading days with income was 44.2% (n=10 households).

Risk and the role of fishing and seaweed farming within livelihoods

The risks to fishing were primarily associated with long-term declines in fish catches, storms (as a threat to personal safety and gear), high costs of gasoline, theft of gear, and being apprehended for illegal fishing. Respondents reported that declines in fish catches were making it harder to meet daily needs from fishing alone. A dramatic increase in the price of gasoline early in the study period exacerbated this problem. The price of gasoline experienced a two-fold variation during the study period, reaching a maximum of P69 L^{-1} in July 2008 and a minimum of P32 L^{-1} in January 2009. There were no corresponding trends in the price of fish during the survey period (Supporting Information).

Risks associated with seaweed farming were much more complex, and showed variation among villages, species of seaweed, and methods for obtaining seaweed. In general, risks to seaweed farming on Danajon Bank were associated with theft, seaweed disease, price fluctuations, and storms (Table 4.2). Lack of financial capital was also highlighted as a problem that contributed towards this risk (Table 4.2). Theft was a much bigger risk in Guindacpan than Handumon (Table 4.2), which may be a reason for seaweed farmers in Guindacpan selling their seaweed wet and more regularly than those in Handumon. Fluctuations in price were a much greater problem for cottonii than spinosum. During the survey period, cottonii reached a maximum price of P95 kg^{-1} dry in September and October 2008 and a minimum of P25 kg^{-1} dry in April 2009; a greater than three-fold range. Spinosum on the other hand only varied from P7 kg^{-1} dry in August 2008 to a maximum of P11 kg^{-1} dry in April 2009 (Supporting Information). Spinosum was easier to farm than cottonii as it only required spreading on the sea floor of the farm, whereas cottonii required farming off the sea-floor (i.e. tied to lines). The extra investment required for farming cottonii (tying to monolines), plus its high price and therefore greater vulnerability to theft, made cottonii a more risky species to farm than spinosum. Seaweed farmers traded off the risks and benefits of the two species. During the final surveys in June 2009, twenty of the respondent households from Guindacpan reported farming only cottonii, 11 only spinosum, and seven a mixture of both. In Handumon, four households reported currently farming only cottonii, seven only spinosum, and 22 a mixture of both.

As well as culturing seaweed, there were limited opportunities to harvest wild growth seaweed or seaweed that had washed out of other people's farms (washout). If this wild/washout seaweed was sold wet the same day, it provided an opportunity for immediate return. However, opportunities for wild or washout harvest were limited unless respondents travelled to the outer reef of Danajon Bank which is more exposed and expensive to reach. These outer reef resources were noted as important during the survey of Hingutanan East and Bilangbilangan East, which were much closer to these reefs. No households with seaweed income engaged entirely in wild or washout collection. However, during the 24-hr recall surveys, wild/washout collection was reported on a median of 25% of seaweed farming days in Guindacpan and 16% of seaweed farming days in Handumon.

Reasons given for engaging in fishing and seaweed farming illustrate a complex interaction between the risks associated with these occupations and the desire for both 'cash machine' and 'savings account' services. During focus group discussions, respondents indicated that households with a greater area of seaweed planted were generally associated with higher wealth groups. Respondents indicated that "planting more seaweed" was one way to improve wealth. Although high levels of fishing asset ownership was associated with intermediate to high wealth groups, it was noted that fishing could only help to maintain daily needs rather than to improve them.

Risk and a lack of financial capital were cited as the limiting factors for increasing the amount of seaweed planted for poorer households. Declining fish catches were cited as a reason for making it increasingly difficult to meet daily needs from fishing, and as a reason for making it impossible to improve wealth through fishing.

Both seaweed farming and fishing were cited as being important for most households to maintain their livelihoods, with seaweed farming often providing a safety net to fishing and offering the opportunity for sporadic large incomes. As one respondent indicated "we can always harvest our seaweed if we do not have enough catch from fishing". Respondents also indicated it was common to harvest seaweed on the way back from fishing in order to top-up income.

Table 4.2. Median scores of risks and related constraints to overcoming those risks perceived by seaweed farmers in their respective villages, as scored by seaweed farmers from 10 villages on Danajon Bank. Scores range from 0 (not a problem) to 3 (a very big problem). Villages are grouped depending on how fisher numbers changed after seaweed farming started (Chapter 3). Guindacpan and Handumon are shown in bold.

	Decreased fishers				Increased fishers				'Other' villages	
	Alumar	Hingutanan East	Mahanay	Bilangbilangan East	Cuaming	**Guindacpan**	Hambungan	**Handumon**	Bilangbilangan Tubigon	Batasan
Theft	2.5	2	3	2	3	**3**	3	**0**	1	0
Seaweed disease	2	2	3	2	2	**2**	2	**2**	3	0
Predation by fish	1	2.5	1	1	1	**1**	1	**1**	3	2
Marketing problems	0	0	0	0	0	**0**	0	**0**	1	0
Poor technology	0	0	1	0	0	**0**	1	**0**	3	0
Price	2	2	3	0	2	**3**	3	**2**	3	2.5
Storms	3	3	3	3	3	**3**	1.5	**3**	3	3
Lack of area for planting	0.5	0	2	0	0	**0**	1	**0**	1	2
Lack of capital	2	2.5	3	2	2	**3**	2	**2**	3	3
Access to seedlings	1	0	1	0	0	**0**	0	**0**	3	0.5
No. respondents	n=30	n=26	n=30	n=14	n=17	**n=17**	n=29	**n=27**	n=6	n=13

Of the informal sector occupations, owning a shop was indicated as providing an opportunity to increase wealth and was associated with higher levels of wealth, while trade work (e.g. carpentry) was associated with intermediate levels of wealth (Chapter 2, Table 2.3). However, owning shops or engaging in carpentry was limited for most households due to the capital costs involved and skills required. However, irregular casual work was associated with lower wealth groups.

Scores assigned to the reasons for engaging in seaweed farming illustrate the trade-off between risk and opportunities for improving wealth. 'Providing income for daily needs' was scored more highly as a reason for engaging in seaweed farming in Guindacpan than 'providing income for savings', while both reasons received similar scores in Handumon (Fig. 4.2). 'Providing income for savings' was scored slightly more highly for fishing than for seaweed farming in Guindacpan, but this pattern was reversed in Handumon (Fig. 4.2a). Reflecting the influence of risk, seaweed farmers in Guindacpan attributed lower importance to 'providing income for savings' as a reason for engaging in seaweed farming than seaweed farmers in Handumon (Fig. 4.2b). Reflecting the lack of certainty associated with the fate of planted seaweed in Guindacpan, respondents there also attributed a high importance to 'jackpot' as a reason for engaging in seaweed farming (Fig. 4.2c). The scores for 'jackpot' in Handumon were the same for both fishing and seaweed farming (Fig. 4.2c).

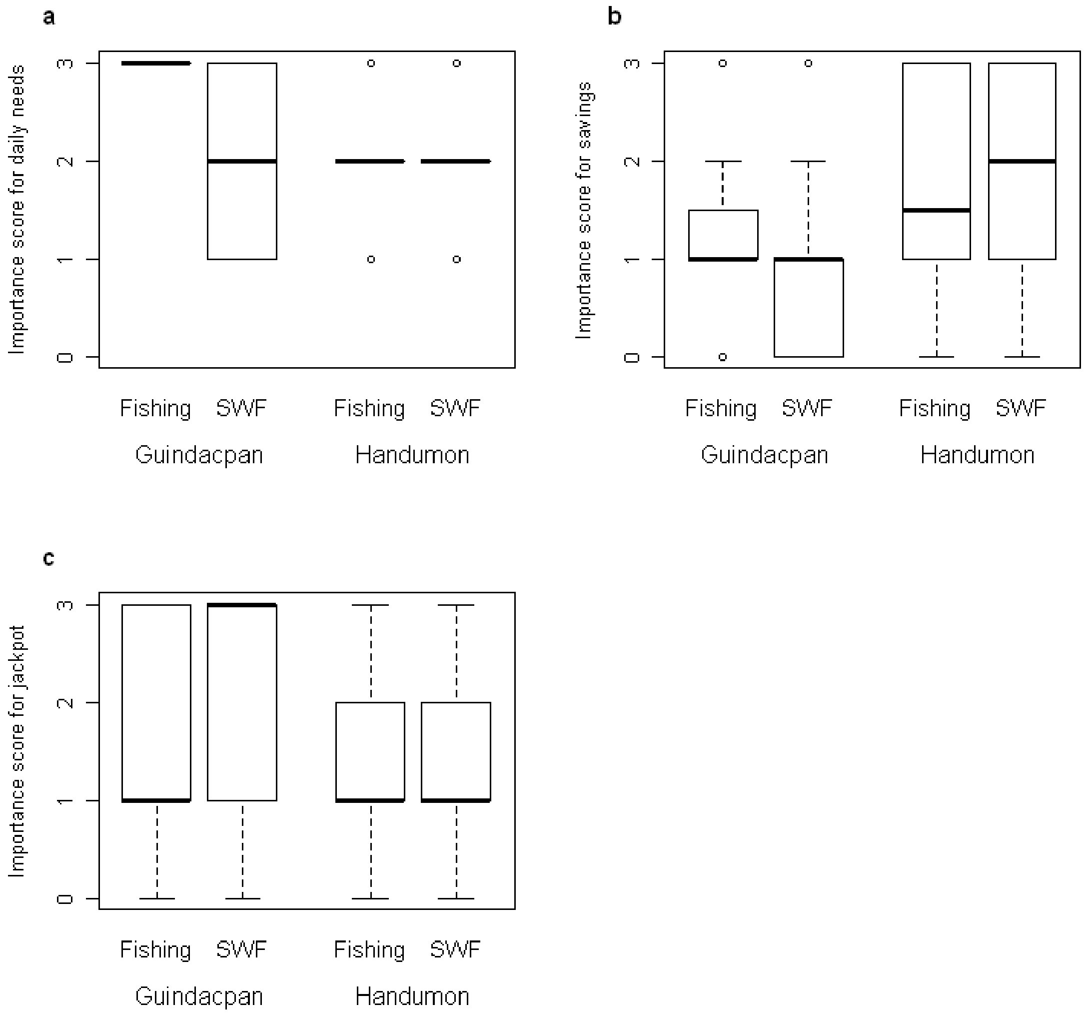

Figure 4.2. The importance associated with different reasons for engaging in fishing and seaweed farming (SWF) by households in Guindacpan and Handumon, including (a) the provision of daily needs, (b) the provision of income for saving and (c) the possibility for obtaining jackpot. These reasons were scored from 0 (not important) to 3 (very important). The thick bar represents the median score, the top and bottom of the boxes represent the 25th and 75th percentiles respectively, the whiskers represent the full range or 1.5 times the interquartile range (whichever is least), and the points represent outliers (outside of 1.5 times the interquartile range).

4.4 Discussion

Perhaps surprisingly, patterns of income from seaweed farming were found to have mixed characteristics of both a 'cash machine' and 'savings account', allowing some degree of flexibility for households engaged in seaweed farming. Frequent incomes from seaweed farming, similar to the 'cash machine' service of fishing, can be achieved in two ways. First, income can be made from seaweed farming year round, indicating there was no discrete harvest period. As such, a rotational system of planting can provide frequent income. Second, seaweed can be harvested any time after planting, and wild/washout seaweed can be collected. On the other hand, seaweed farming could also be used as a 'savings account', regardless of the planting and harvesting regime, by drying and storing seaweed for later sale in bulk.

However, while seaweed farming can result in relatively frequent harvests, it is primarily a "delayed return" occupation (Woodburn 1982) as the magnitude of income was closely related to long-term effort. Even in Guindacpan, where the regularity of income from seaweed farming was highest, the greatest investments in labour time were on days when no income was received from seaweed farming (i.e. the most effort was expended in planting on these days). Therefore, seaweed farming can be seen as an 'instant access savings account', where liquid assets (labour and financial capital) can be deposited and later withdrawn at will. In places where savings facilities are often unavailable (Torell et al. 2010) and access to credit is limited and expensive (Platteau & Abraham 1987; Crona et al. 2010), it seems reasonable to expect that the potential for seaweed farming to act as an instant access savings account would be attractive. However, seaweed grows exponentially (Dawes et al. 1993) so early harvest reduces the return on investment (a 'penalty charge'), and the security of investments in this 'instant access savings account' is low.

Risk, rather than frequency of income, represents the limiting factor in the potential for seaweed farming to substitute for fishing. Investments in seaweed farming were subject to substantial risks, so willingness to invest in this 'savings account' was limited. Even if rotational planting is assumed to be the norm, all seaweed planted prior to a storm or theft event could be lost in that event, and predation and disease can affect all seaweed irrespective of time since planting. Additionally, price fluctuations have historically plagued seaweed farming globally and continue to do so (Luxton 1993; Sievanen et al. 2005; Bixler & Porse 2011). Therefore, there was substantial uncertainty with respect to returns on investment, making seaweed farming a risky occupation. Risks such as these that are commonly associated with delayed return occupations can engender greater anxiety than immediate return occupations such as fishing (Tucker et al. 2010).

Fishing has its own set of risks that are traded off with those of seaweed farming. Fish catches have been declining on Danajon Bank for many decades (Armada et al. 2009; Chapter 3). The continuation of fishing thus comes with the long-term risk of declining income.

However, fishing income was positively correlated with both measures of short-term effort (labour and expenses), meaning risk is reduced in the short-term. Although catches fluctuate from day to day, immediate risks to returns on investment are limited and spread across multiple independent (at an individual fisher level) events (Tucker et al. 2010). However, fluctuations in the price of fuel add uncertainty (and thus risk) to the medium- to long-term prospects for fishing, as they have done for fishers in other parts of the world (Abernethy et al. 2010).

Changes to the balance of long-term and short-term risks for fishing and seaweed farming can result in differences in the way that seaweed farming is used, and potentially help to explain variation in fishers' responses to seaweed farming (Sievanen et al. 2005; Chapter 3). Slightly different risk profiles in Handumon and Guindacpan resulted in two different seaweed farming strategies. First, in Guindacpan where risks were highest, the 'instant access' function of seaweed farming was primarily used as a 'safety net' to help top up daily income from low fish catches. Second, in Handumon where risks were lower, the 'savings account' function of seaweed farming was primarily used to provide more sporadic income. However, the risks were still clearly present in Handumon, so fishing was regarded as an important occupation for ensuring daily needs.

Within this context it was possible to predict two scenarios where seaweed farming would result in reduced fishing effort. First, where short-term risks to seaweed farming are reduced or people have the ability to protect themselves against these risks (i.e. via high levels of access to wild/washout seaweed), a tipping point may be reached where seaweed farming becomes less risky than fishing. This was illustrated by the focus group discussions where respondents indicated that seaweed farming has the potential to improve wealth whereas fishing only has the potential to maintain wealth. Within this scenario, seaweed farmers make the most of the opportunities for rotational harvesting that also provide frequent income. In the second scenario, the immediate risks of fishing become higher than those of delayed return occupations when catches become so low that fishing results in many zero catches or mean returns are low relative to minimum requirements (Tucker et al. 2010). In other words, declines in fish catches are eventually expected to reach a threshold (which may vary for fishers with different fishing gear) at which fishing becomes a more risky strategy for meeting daily needs than seaweed farming.

Exactly where these tipping points or thresholds occur can be expected to vary with wealth. There are two reasons for this. First, households choose different occupations based on their tolerance to risk. Poorer households with less physical and financial capital often choose low-risk strategies, at the expense of more lucrative strategies, in order to ensure productive capacity for the longest time possible (Mace 1993; Rosenzweig & Binswanger 1993; Dercon 1998; Zimmerman & Carter 2003). Conversely, wealthier households have access to liquid assets (physical and financial capital) that can provide some level of insurance, and therefore often opt for more lucrative strategies that may entail higher risk (Adato et al. 2006; Carter & Barrett 2006). Wealthier households may also have a greater ability to mitigate those risks (e.g. through the construction of guardhouses). This potentially constitutes a "poverty trap" (Barrett et al. 2011) for the poorest households, who are limited in their ability to exploit risky but potentially more lucrative opportunities such as seaweed farming, and may therefore continue to depend on declining fisheries resources. However, timeseries data would be required to confirm the existence of any such traps (e.g. Lybbert et al. 2011; Coomes et al. 2011). The results of this study indicate that some level of risk reduction was possible through the use of different species and varieties of seaweed that have different vulnerabilities to disease and predation (Ask & Azanza 2002), and different price vulnerabilities. Such bet-hedging requires a high level of knowledge, suggesting the most experienced seaweed farmers may be better able to cope with risks. However, this bet-hedging is unlikely to reduce the risks from all threats (e.g. tropical storms), and substantial threats would still remain to the most valuable component of the investment (cottonii) through theft.

The second and linked reason that wealth is expected to influence where tipping points occur is that the magnitude of seaweed farming income was more closely related to long-term financial investment than long-term labour investment. This reflects the higher costs of materials and seedlings (and possible additional labour for tying the seedlings) required to plant the more valuable cottonii (Samonte et al. 1993; Hurtado-Ponce et al. 1996; Hurtado et al. 2001). Poorer households are expected to have less access to such financial capital, and are therefore less able to increase their seaweed farming income. Additionally, poorer households may be less willing to invest the limited excess financial capital that they have into seaweed farming because of the risks, and prefer instead to invest it into fishing, as any additional investments in fishing have the potential to generate instantaneous benefits (Béné et al. 2003). Therefore, poorer households are likely to have less to invest in seaweed farming, so are limited in their potential seaweed farming income, and what limited financial capital they do have is most likely to be invested in fishing until such point as daily needs are (almost) guaranteed, further reinforcing low seaweed farming income.

Seaweed farming represents a ‘private’ instant access savings account in which savings can be deposited, albeit with low security, whereas fishing is a cash machine to which many people have access for withdrawal purposes but not for deposits. As a result, given appropriate tools to increase security or reduce risks, increasing numbers of people would be expected to increasingly favour seaweed farming. However, without such security, many people (potentially depending on their levels of wealth) would be expected to prefer a strategy that maintains or even increases their access to the ‘cash machine’ of fishing and makes limited use of seaweed farming. Increasing access to insurance markets or developing insurance schemes appropriate to the local conditions (e.g. Chantarat et al. 2011) could help to manage the risks of seaweed farming. Even where seaweed farming has led to reductions in fishing, insurance schemes would help to prevent a return to fishing following a shock or disturbance (e.g. Bilangbilangan East; Chapter 3), as natural resources such as fisheries are often the fallback option when agricultural schemes fail (Pattanayak & Sills 2001; McSweeney 2004; Coomes et al. 2010). The construction of guardhouses could help to reduce the risks of seaweed farming by reducing theft and enabling access to more remote areas where wild/washout seaweed could be collected (which can also help to provide a form of insurance). Such strategies require a move away from the traditional focus on only providing financial assistance to start seaweed farming (Chapter 2), towards a focus on providing an enabling environment for fishers to concentrate their efforts in seaweed farming and reduce their dependence on declining fisheries.

This chapter demonstrates the importance of understanding the risk profiles and income characteristics associated with alternative occupations in order to understand their potential to substitute for fishing within people’s livelihoods. The following chapter examines the socioeconomic and demographic characteristics of households that influence their level of engagement in fishing, seaweed farming and the informal sector, providing an opportunity to explore how different types of household respond to the risks and opportunities associated with these occupations.

Supporting Information

Supporting information for this chapter can be found in Appendix S4, including: tests of collinearity among measures of effort (S4.1), weighted model averaging procedure for linear mixed effects models (S4.2), model tables for Table 4.1 (S4.3), fluctuations in price of relevant inputs and marine products during the period of the study (S4.4), and access of households to loans and credit in Guindacpan and Handumon (S4.5).

CHAPTER 5

Socioeconomic correlates of household-level engagement in fishing, seaweed farming and the informal sector.

Abstract

This chapter examines the correlates of household-level engagement in fishing, seaweed farming and informal sector occupations on Danajon Bank, central Philippines. Although seaweed farming is promoted as a potentially lucrative alternative occupation to fishing, fisher responses to seaweed farming have been varied. Level of engagement in different occupations is expected to be influenced by assets and access to resources and the way that individuals trade off the risks and opportunities of these occupations. Determining the correlates of engagement in different occupations could help to understand the variation in fisher responses to seaweed farming. This chapter examines the correlates of household-level engagement in occupations using linear mixed effects models in an information theoretic framework and 24-hr recall data for 81 households from two villages. Two measures of engagement are examined; income and labour time. The results indicate that the wealthiest households are "stepping out" of fishing and into the informal sector, possibly because of the long-term risks of declining catches. The poorest households with many young children exhibited the greatest engagement in fishing which is consistent with expectations of what types of household should be more likely to pursue asset-smoothing strategies. The results also point towards experience and concentration of household labour (specialisation) as potential mechanisms for overcoming risk associated with seaweed farming. However, it is unclear whether this specialisation is a strategy of choice or of necessity. The chapter highlights the importance of targeting the poorest households with livelihood interventions to reduce fishing pressure, but also demonstrates the complexity of interactions between assets, access and risk. The effect of interventions in such a system could be difficult to predict, suggesting that livelihood interventions cannot in themselves reduce fishing pressure, hence a broader suite of interventions is needed, including direct conservation actions.

5.1 Introduction

The development of alternative occupations to fishing is widely expected to reduce dependence on fishing and enable people to reallocate labour out of declining fisheries (Allison & Ellis 2001). The capacity to engage in alternative occupations can influence not only whether fishers may exit a declining fishery (Cinner et al. 2009a), but also how fishers react to policy (Marshall et al. 2007) and their level of support for conservation activities (Pollnac et al. 2001a; Marshall et al. 2010). However, the extent to which households can exploit alternative opportunities depends on their assets and ability, which govern access to resources (Bebbington 1999). Knowledge of the socioeconomic correlates of engagement in alternative occupations and how these differ from correlates of engagement in fishing is therefore of key importance in understanding fisher's responses to the development of alternative occupations.

Seaweed farming has been widely promoted as a potentially lucrative opportunity for fishers in Southeast Asia (Samonte et al. 1993; Hurtado-Ponce et al. 1996; Hurtado et al. 2001). However, the effect of seaweed farming on levels of fishing activity has been variable (Sievanen et al. 2005; Chapter 3). In the central Philippines, seaweed farming and fishing are associated with differing risk profiles and income patterns (Chapter 4). Levels of engagement in these occupations (measured as income and effort) are expected to be related to household assets and access to resources as well as other opportunities available to household members.

A household's access to income opportunities depends on a combination of their physical and financial assets (e.g. boats, fishing gear and savings), their human and social assets (e.g. household size and demographics, education, skills, knowledge and social networks) and the institutions that modify access (e.g. kin systems or customary rules) (Sen 1981; Bebbington 1999; Allison & Ellis 2001; MacFadyen & Corcoran 2002; Béné 2003; Smith et al. 2005). Households tailor their engagement in different occupations, within these constraints, in order to generate an adequate standard of living and to reduce risk (Allison & Ellis 2001). Considerations of risk and the trade-off between risk versus profit are an important component of decisions concerning the level of engagement in different occupations (Chapter 4).

Wealth influences both access to resources through physical and financial assets and the trade-off between risk and profit. Physical capital directly influences the ability to exploit resources, and can be associated with different degrees of specialisation and relative efficiencies (e.g. fishing gear; Smith & McKelvey 1986) or different levels of productivity (e.g. land; Coomes et al. 2011). Physical and financial capital can also influence the ability to trade off risk versus profit and, with it, individuals' aspirations and livelihood objectives (Smith et al. 2005; Dorward et al. 2009). Poorer households with less physical and financial capital often choose low-risk strategies, at the expense of more lucrative strategies, in order to ensure productive capacity for the longest time possible. Conversely, wealthier households have access to liquid assets (physical and financial capital) that can provide some level of insurance, and therefore often opt for more lucrative strategies that may entail higher risk (Mace 1993; Rosenzweig & Binswanger 1993; Dercon 1998; Zimmerman & Carter 2003). However, physical and financial assets are not the only assets that determine access to resources and the trade-off between risk and profit.

Labour availability and levels of individual experience change during a household's demographic life-cycle. Early in their life-cycle, households have young children and limited labour supply, so are often less willing to take risks. However, as the household ages, adults gain greater experience and older children start to contribute labour. This not only increases labour supply but can be associated with increased engagement in more risky but more lucrative opportunities (Perz et al. 2006; Martin 2010). Eventually, older children may migrate to urban areas and send back remittances which can in turn influence investment strategies and decisions on which occupations to engage in (Adger et al. 2002; Rigg 2007), and individuals become older and perhaps avoid risks more.

The educational and gender composition of a household can also influence access to opportunities. A lack of education constrains opportunities for employment (Teh et al. 2008), and is associated with lower willingness for occupational mobility (Pollnac et al. 2001b). Gender can have a strong influence over access to resources (Bennett 2005; Brugère et al. 2008; Weeratunge et al. 2010), and household gender composition may influence livelihood strategies through gender conflicts within the household over the distribution of labour and income (Carney 1993).

This chapter aims to examine the socioeconomic correlates of household-level engagement in fishing, seaweed farming and the informal sector in two villages on Danajon Bank. Two measures of engagement are considered; income and own-labour time. The chapter uses linear mixed effects models in an information theoretic framework to elucidate the differing profiles of households engaged in these three occupations, in order to draw conclusions about the potential barriers to, and opportunities for, engagement in each. This information is important in understanding the likely outcomes of livelihood interventions in this region, and in guiding the focus of these interventions towards addressing the constraints faced by households of particular types.

5.2 Methods

Study sites

Two island villages from the Danajon Bank, central Philippines were selected for this study; Guindacpan (Talibon municipality) and Handumon (Getafe municipality) from Bohol Province (Chapter 2, Fig. 2.1). Danajon Bank is a double barrier reef that stretches 130 km between Cebu and Bohol Provinces. It comprises some of the most degraded coral reefs in the world (Marcus et al. 2007), mainly due to unsustainable levels of fishing (Armada et al. 2009).The islands are small with high population densities and substantial poverty. Dependence on marine resources is high with few alternatives to fishing and seaweed farming (Armada et al. 2009). Detailed descriptions of these study sites are provided in Chapter 2 (section 2.6).

Data collection

24-hr recall surveys were used to collect daily information on household membership and levels of engagement in each of fishing, seaweed farming and informal sector occupations from 83 households across the two villages. Surveys were carried out roughly once per week between May 2008 and June 2009, and are described in detail in Chapter 2 (section 2.6). Fishing was defined as any occupation that gathered fish or shellfish from the sea for sale or consumption, and included gleaning. Seaweed farming was defined as any occupation that involved the harvest of seaweed from the sea, which included the collection of wild/washout seaweed (Chapter 4). The trading of fish/shellfish or seaweed that was not from own production was not included in these definitions. Time spent in these occupations included time spent by any household member in any related activities, including supporting activities (e.g. boat or gear maintenance, processing of the catch/harvest, preparation of bait or monolines). Informal sector occupations were defined as casual labour or entrepreneurial occupations that provided *ad hoc* income, and most commonly included selling food (e.g. from a produce stand) or water and independent trade work (e.g. carpentry or mechanical), but also included handicrafts, housemaid work and working as a fish pond caretaker. At most, households engaged in two informal sector occupations.

Data analysis

Two measures of engagement were used as response variables for each occupation. Income from each occupation was measured in Philippine Pesos (P) and included the value of monetary and non-monetary income received during each 24-hr survey period. Time was measured as the sum of the number of hours that each household member engaged in the occupation during each 24-hr period. Mean daily income and time values were calculated for each season and household and were used as the response variables. The seasons were: *habagat* (August – October 2008), *amihan* (November 2008 – March 2009), and *hot* (June – July 2008 and April – June 2009) (Chapter 2, section 2.6.2). There were no surveys for households from Handumon for the *habagat* season (Chapter 2, section 2.6.4). The mean number of 24-hr surveys with complete information per household per season was 12.68 (SD=2.83, n=206, Chapter 2, section 2.6). Linear mixed effects models (LMMs) were used to determine the relationship between these variables and socioeconomic characteristics of households, using the statistical package lme4 (Bates et al. 2011) in R (R Development Core Team 2011). Response variables were transformed as $\ln(x + 1)$ in order to improve the distribution of residuals.

Explanatory variables are listed in Table 5.1. Wealth was defined primarily by physical and productive assets, which are considered as important determinants of poverty by the rural poor (Narayan et al. 2000). Material style of life (MSL) was used as an indicator of wealth (Pollnac & Crawford 2000; McKenzie 2005), and was calculated from a principal components analysis based on information on household structure and possessions (Chapter 2, section 2.6). Labour availability was represented by household size and age. Household size was the mean number of household members per survey day by season. Age was the mean age of the heads of households (measured in June 2009). Age and household size together provide an indication of the stage in the household demographic life cycle (Supporting Information). Education was measured as the mean number of years of education received by the heads of household. Gender was measured as the proportion of adults (18-65 years old as of June 2009) within the household that were male, based the average number of adult males and females present in each household per season. Experience in an occupation was measured as the number of years that a household had engaged in each occupation. Experience was not included for informal sector occupations because it consisted of multiple occupations and households had frequently engaged in different informal sector occupations over the course of their history. For the analysis of each occupation, occupational diversity was measured as the number of other occupations that the household reported (during household profile surveys) as a source of income for the year preceding June 2009 (e.g. for analyses of fishing effort and income, occupational diversity was the number of non-fishing occupations; Chapter 2, section 2.6). Remittances were included separately to occupational diversity as a binary variable, indicating whether the household had received a remittance in the year preceding June 2009. Summary statistics for these variables are included in Table 5.1.

Indicators of other assets that may influence access to resources, such as social capital (Béné 2003), were considered. These included whether any members of the household held any official position within the village (e.g. village police or councillor) and membership of People's Organisations (community organisations). The use of credit or loans from moneylenders was also considered as these can be associated with labour- or production-binding arrangements that may influence engagement in occupations (Platteau & Abraham 1987; Crona et al. 2010). And other indicators of household demographics (e.g. number of adults, number of women and men, number of children) were also considered. However, in order to retain a favourable ratio of sample size to number of variables, these were excluded because of strong correlations with other variables (e.g. household size and age captures information on the number and relative age of children; Supporting Information), or because preliminary analyses indicated they had little explanatory power.

Collinearity among all non-categorical variables was explored using pairwise plots, correlation tests and variance inflation factors. Several explanatory variables were non-normally distributed so the non-parametric Kendall's correlation test was run between each pair of explanatory variables at the household level. All correlation scores for explanatory variables retained were less than 0.3 and variance inflation factors were less than 1.5, indicating no problems with collinearity (Supporting Information).

In total, 81 households had complete information for all demographic and socio-economic variables. Almost all of these households had engaged in fishing (71 households), seaweed farming (73 households) and informal sector occupations (71 households) during the study period.

Table 5.1. Socioeconomic variables examined for their relationship with measures of engagement in fishing, seaweed farming, and informal sector occupations. Histograms of these variables and pairwise plots are included in Supporting Information.

Variable	Units	Median [range]
Wealth	Material style of life score	0.06 [-2.89 – 4.79]
Experience fishing	Number of years the household has engaged in fishing	17 [0 – 49]
Experience seaweed farming	Number of years the household has engaged in seaweed farming	10 [0 – 26]
Household size	The number of people within the household per day (defined as those that live together and share incomes and meals)	5.0 [2.0 – 11.3]
Age	The mean age (yrs) of the heads of the household	43.5 [24.0 – 68.5]
Gender composition	The proportion of adults (18-65 yrs) that are male	0.51 [0.25 – 1.00]
Education	The mean number of years of education received by the heads of household	5 [1 – 15]
Remittances	Binary variable indicating whether the household had received remittances from family members living elsewhere during the year preceding June 2009	Proportion of households received: 30.9%
Occupational diversity outside fishing	Count of the number of other occupations reported by the household for the year preceding June 2009	2 [0 – 4]
Occupational diversity outside seaweed farming	Count of the number of other occupations reported by the household for the year preceding June 2009	1 [0 – 4]
Occupational diversity outside informal sector	Count of the number of other occupations reported by the household for the year preceding June 2009	2 [1 – 4]

A model averaging approach based on information theory (Burnham & Anderson 2002) was used to determine the relative importance and coefficients of wealth and other explanatory variables in the six analyses. LMMs were run as random intercept models to allow for repeated samples per household, with household included as a grouping factor in the random effects. Models were run for all possible single order combinations of explanatory variables without interactions. Akaike weights (w_i) were calculated for all subsequent models. The top models whose Akaike weights summed to the closest value to 0.95 (the 95% confidence set) were selected for model averaging of the parameters, using the Multimodel Inference package in R (MuMIn; Barton 2011). Relative importance scores for each explanatory variable were calculated from the 95% confidence set of models as the sum of the Akaike weights (rescaled for the 95% confidence set) of each model in which the variable appeared. All households were included in each model, except for analyses of seaweed farming income and effort, where households that traded seaweed were excluded because their income from seaweed farming could not be distinguished from their income from trading of seaweed (5 households). Analyses were rerun for each occupation on only those households that participated in the relevant occupation in order to verify that patterns were not unduly influenced by the relatively few households that did not participate in those occupations (Supporting Information).

Secondary analyses

In addition to the LMMs, linear models were used to explore relationships between wealth and fishing and seaweed farming capital. Fishing capital was calculated as the total value (P) of all fishing equipment owned by the household in June 2009, excluding boats (which were included in the calculation of the MSL score). Seaweed farming capital was measured as the area of seaweed farm owned by the household in June 2009. Both these response variables were square-root transformed. In both analyses, wealth (MSL score) and village were included as explanatory variables together with any other household level explanatory variables that received relative importance scores of greater than 0.7 in the LMMs. For the analysis of fishing gear, this included fishing experience, household age and household size. For the analysis of seaweed farm size, this included seaweed farming experience, gender composition and occupational diversity. Visual inspection of plots of residuals was used to ensure assumptions of normality. The significance of the term for wealth was determined using an F-test.

5.3 Results

The households with the highest level of engagement in fishing were the poorest households with large and relatively young families that have experience in fishing (Table 5.2). Wealth had a stronger negative relationship with time spent fishing than with fishing income. The difference between the two relationships is in part explained by a positive relationship between wealth and the value of fishing equipment owned by the household (linear model; df=1, F=5.91, p<0.05). Higher value of fishing equipment was expected to be associated with increased efficiency (i.e. higher income per hour spent fishing), which is consistent with these results. Experience showed the strongest positive relationship with engagement in fishing for both measures of engagement. Time spent fishing had a strong relationship with season. However, there was only a very weak seasonal pattern in fishing income suggesting that fishing time may have been adjusted to maintain income levels throughout the year.

Ten of the 81 households did not engage in fishing at all. Half of these (five) had zero recorded fishing experience, three had over 15 years fishing experience (17, 26 and 27 years respectively), and two had less than five years fishing experience (one and four years respectively). Three of the non-fishing households still owned fishing gear (those with 4, 17 and 26 years fishing experience). When non-fishing households were removed from the analysis, the negative relationship between engagement in fishing and wealth was weakened, indicating that wealthier households generally did not engage in fishing (four of the non-fishing households were among the top 10 wealthiest households). The resulting negative relationship between wealth and fishing time (without non-fishing households) had a relative importance of 0.66, while the negative relationship between wealth and fishing income had a relative importance of 0.38 (Supporting Information). The removal of non-fishing households also weakened the relationship between engagement in fishing and household size (indicating small households generally did not engage in fishing), and strengthened the negative relationship between engagement in fishing and occupational diversity outside of fishing (indicating that non-fishing households had relatively low occupational diversity). All other relationships remained largely unchanged (Supporting Information).

The households with the highest level of engagement in seaweed farming were those with the lowest occupational diversity (outside of seaweed farming), highest proportion of women among their adults and longest experience in seaweed farming (Table 5.2). Engagement in seaweed farming was not closely correlated with wealth, despite a positive relationship between wealth and size of seaweed farm owned (linear model; df=1, F=7.68, p<0.01).

Seaweed farming was the only occupation where gender composition had a strong relationship with level of engagement (Table 5.2). Seaweed farming had a more even contribution of labour from both males and females than either fishing (male dominated) or informal sector (female dominated) occupations (Supporting Information). Most of women's labour time in seaweed farming was spent in the early stages of seaweed farming (pre-planting and planting) which are crucial for the cultivation of the more valuable 'cottonii' seaweed (Supporting Information). Households in Handumon spent the most time seaweed farming, but had similar levels of seaweed farming income to households from Guindacpan. Like fishing, time spent seaweed farming had a strong relationship with season, but there was only a very weak seasonal pattern in seaweed farming income.

Table 5.2. Relationship between socioeconomic variables and seasonal measures of income (ln(income + 1)) and labour time (ln(hrs + 1)) for fishing, seaweed farming and informal sector occupations, showing the model average coefficient estimates (SE) for variables where the relative importance (RI) is greater than 0.5 (and in bold where RI is greater than 0.8) from the top 95% confidence set of linear mixed effects models based on AICc. Coefficient estimates are presented as contrasts from the intercept. Household is included as a grouping factor in the random effects. Experience was not included in the informal sector analyses (see text for details). Where a variable's RI is less than 0.5, only the direction of the effect is indicated (+ positive, - negative). MSL=Material style of life, a proxy for wealth – see text for details. Random effects estimates of variances [standard deviation] are from the global model in each case. # models refers to the number of models in the 95% confidence set of models (see main text for details). Occ. div. = occupational diversity

	Fishing				**Seaweed farming**				**Informal sector occupations**			
	Income		**Hrs**		**Income**		**Hrs**		**Income**		**Hrs**	
	Coef (SE)	RI	Coef (SE)	RI	Coef (SE)	RI	Coef (SE)	RI	Coef (SE)	RI	Coef (SE)	RI
(Intercept)	4.600 (1.287)		1.027 (0.539)		4.774 (1.131)		1.993 (0.406)		1.158 (1.666)		0.362 (0.830)	
Experience	**0.085 (0.015)**	**1.00**	**0.025 (0.006)**	**1.00**	**0.143 (0.032)**	**1.00**	**0.064 (0.011)**	**1.00**	NA		NA	
Age head of household	**-0.062 (0.019)**	**1.00**	-0.013 (0.009)	0.79	-	0.25	+	0.30	+	0.26	0.010 (0.012)	0.59
MSL^2	-0.139 (0.128)	0.70	**-0.095 (0.051)**	**0.90**	-	0.36	-	0.31	**0.493 (0.151)**	**1.00**	**0.157 (0.069)**	**0.96**
Household size	**0.153 (0.096)**	**0.86**	**0.080 (0.036)**	**0.95**	-	0.25	+	0.24	**0.220 (0.136)**	**0.86**	0.070 (0.056)	0.76
Gender ratio M	-	0.25	+	0.31	**-3.477 (1.794)**	**0.92**	**-1.567 (0.556)**	**0.99**	-	0.33	-	0.37
Barangay: Handumon	+	0.33	+	0.25	-	0.45	**0.268 (0.172)**	**0.85**	+	0.28	0.326 (0.256)	0.76
Education	-0.071 (0.082)	0.58	-0.029 (0.033)	0.59	-	0.32	-0.019 (0.027)	0.51	**0.176 (0.123)**	**0.81**	0.043 (0.046)	0.63
Season:		0.25		**0.99**		0.23		**1.00**		0.47		0.79
Habagat	+		**0.131 (0.073)**		-		**-0.554 (0.099)**		+		-0.096 (0.086)	
Hot	+		**0.184 (0.055)**		-		**-0.347 (0.073)**		+		0.065 (0.062)	
Remittances: Y	-	0.36	-	0.35	-	0.48	+	0.41	+	0.34	+	0.35
Occ. div.	-	0.49	-0.085 (0.098)	0.59	**-0.637 (0.205)**	**0.998**	**-0.285 (0.073)**	**1.00**	-0.256 (0.356)	0.51	-0.151 (0.160)	0.63
# models	173		116		172		55		177		228	
# observations	200		200		189		189		200		200	
# households	81		81		76		76		81		81	
Random effects												
Household	1.485 [1.218]		0.240 [0.490]		1.263 [1.124]		0.173 [0.416]		3.304 [1.818]		0.543 [0.737]	
Residual	0.794 [0.891]		0.114 [0.338]		1.917 [1.385]		0.199 [0.446]		1.576 [1.255]		0.135 [0.367]	

Removal of non-seaweed farming households from the analysis resulted in very few changes to the results, with the exception of a slight weakening in the relationship between gender composition and seaweed farming income (Supporting Information).

The households with the highest engagement in informal sector occupations were the wealthiest and most educated households with the largest household sizes (Table 5.2). Wealth, education and household size had slightly stronger positive relationships with income than with time spent in informal sector occupations. More time was spent in informal sector occupations in Handumon than in Guindacpan, but there was not a strong difference in informal sector income between the two villages. Like fishing and seaweed farming, season had a relatively strong relationship with informal sector time but only a weak relationship with informal sector income.

Removal of the non-informal sector households from the analysis resulted in a weakening in the positive relationship between education and informal sector income (indicating that those with low education generally do not engage in the informal sector), but very few other changes (Supporting Information).

5.4 Discussion

The finding in this chapter that the poorest households had the highest engagement in fishing could be considered consistent with conventional wisdom on poverty in fisheries (Béné 2003). The “old paradigm on poverty in small-scale fisheries” focuses on the biological and economic aspects of fishing that were believed to have been the cause of poverty in fishing households (Béné 2003). Within this conventional wisdom, assumptions about the open access nature of fisheries leading to a tragedy of the commons (Gordon 1954), low opportunity costs of fishing (Cunningham 1993), and the role of fisheries as a safety valve for people that have lost other sources of livelihood are combined to create a self-reinforcing logic that fishers are the poorest of the poor (Béné 2003). However, this fails to incorporate considerations of both risk (Tucker et al. 2010) and the role of social and institutional mechanisms that govern access to fisheries and other resources (Leach et al. 1999; Béné 2003). The findings of this study demonstrate that both these social mechanisms and considerations of risk have important implications for the relationship between poverty and fishing, and who it is that has the highest engagement in fishing. This is highlighted by the fact that nearly all households were involved in each of the sectors examined albeit to varying degrees. However, the wealthiest households had the lowest engagement in fishing (i.e. lowest fishing income and effort), despite wealthier fishers having the highest level of fishing capital. Instead, the wealthiest households had the highest engagement in the informal sector. Engagement in seaweed farming was independent of wealth and was influenced primarily by gender composition, experience and occupational diversity.

The finding that the wealthiest fishers had higher investment in fishing gear is consistent with other studies (Béné et al. 2003; Smith et al. 2005; Martin 2010) and demonstrates that the wealthiest households have the greatest access to fisheries resources (Allison 2005; Béné et al. 2009). In many instances (where fisheries resources are in good condition) this would be expected to correlate with higher fishing incomes and own-labour effort. However, Danajon Bank is one of the most degraded reefs in the world (Marcus et al. 2007) with low and declining catch rates (Armada et al. 2009; Chapter 4). This long-term risk acts as a deterrent to fishing engagement for the wealthiest households who have greater access to other opportunities (e.g. in the informal sector) with better prospects.

The analysis on fishing-only households indicated that the greater fishing capital of the wealthiest fishing households was associated with reduced time spent fishing rather than increased fishing income, representing a “stepping out” strategy (Dorward et al. 2009). The potential for investments in fishing capital to generate instantaneous income surplus represents a substantial advantage over other occupations with delayed returns (Béné et al. 2003). Additional investments in fishing capital help to ensure daily needs can be met more quickly, freeing up household resources to invest in potentially more lucrative but more risky opportunities. Additionally, labour can be hired in to help guarantee some returns, and the fishing capital provides some level of insurance that the household can resort to if non-fishing occupations fail (Coomes et al. 2004, 2010; Takasaki et al. 2010). These explanations are also consistent with the finding that half of all non-fishing households were previous fishers, and some continued to own fishing gear.

Those that engaged most in fishing did so either because they had the least access to non-fishing occupations, or because of the unfavourable risk profiles of the other occupations. The results of this study suggest a limited access to informal sector occupations for the poorest households, possibly because the best of these occupations required relatively high levels of capital (e.g. a produce stand; Chapter 4). Also, given that these occupations are primarily for the purpose of serving the local communities (e.g. selling water, selling food from produce stand, carpentry), they only provide limited opportunities that are likely to be monopolised by wealthier households (Platteau & Gaspart 2003; Fabinyi 2010). Education was also found to be a constraint to engagement in the informal sector that would be expected to disproportionately affect the poorest households.

However, risk is an important consideration, and results were consistent with expectations of who is most likely to pursue asset smoothing strategies. With the lowest levels of physical and financial capital, the poorest households tend to pursue asset smoothing strategies rather than more lucrative but potentially more risky strategies (Zimmerman & Carter 2003). In addition, those at relatively early stages in the household demographic life-cycle with responsibility for many young children, generally opt for lower-risk strategies (Perz et al. 2006). Fishing is associated with relatively low short-term risk and the ability to provide frequent income for daily needs that is closely associated with same day levels of effort (Chapter 4). In this study, households that had the highest engagement in fishing were both the poorest and relatively early in their demographic life cycle, supporting the proposition that engagement in fishing was part of a strategy to smooth assets and minimise short-term risks.

The relationship between gender composition and seaweed farming adds an interesting dimension to understanding engagement in seaweed farming. Studies elsewhere in the Philippines and Indonesia have noted that the engagement of women and children in seaweed farming allows men to continue the same level of engagement in fishing (Sievanen et al. 2005). However, the results of this study indicate that men and women combine their labour force or distribute the work load for seaweed farming. Additionally, women's labour time in seaweed farming was more valuable than men's. Households with a higher proportion of women (noting that no households in this sample had zero men) engaged more in seaweed farming and had greater returns. This was probably as a result of planting more cottonii, but the mechanism for a gender composition effect is unclear and would be a valuable area for further research.

Although seaweed farming is a potentially lucrative opportunity (Samonte et al. 1993; Hurtado-Ponce et al. 1996; Hurtado et al. 2001), it is beset with short-term risks to investments (Chapter 4). Among the sampled households in this study, there was no relationship between wealth and seaweed farming engagement, despite the wealthiest households owning the largest farms. This suggests that access to seaweed farming and the capacity to take on the risks involved is not influenced by wealth, probably because of the severity of the risks and the inadequacy of physical and financial capital alone to address the problems they pose. There is a possibility that this result may reflect a sampling issue because the sampled households were from a relatively narrow wealth range from only two villages (Chapter 2, section 2.6). However, these results suggest that gaining experience and focussing all household resources (especially labour time) in seaweed farming is a possible strategy to cope with the risks associated with seaweed farming. Experience can be used to mitigate some risks through a better understanding of the roles of different species and varieties of seaweed that have differential vulnerabilities to disease and predation (Ask & Azanza 2002; Chapter 4). Lower occupational diversity of households that engage in seaweed farming and the relatively equal contribution of both men and women can be expected to mean that a greater proportion of household labour time is available to be invested in seaweed farming. This greater proportion of labour time could enable increased levels of guarding and tending to reduce the risks from theft, disease and predation. “Specialisation” (Smith et al. 2005) can be associated with increased efficiencies and economies of scale (Anderson & Deshingkar 2005), and these results point towards such an effect with seaweed farming. However, it is unclear whether specialisation would result in greater overall income than a more diversified strategy, and it is likely to be a risky strategy that arises out of necessity rather than choice. Therefore, it is not possible to distinguish between possible cause and effect.

Experience was also an important correlate of engagement in fishing. Experience (in any occupation) is expected to be related to knowledge and skills, including knowledge associated with the risks of different occupations and how to mitigate them (Perz et al. 2006; Abernethy et al. 2007), and financial success in enterprises (Torell et al. 2010). This is probably a self-reinforcing mechanism as individuals may prefer to stick with what they know, and as such, willingness for labour mobility among occupations decreases with age (Pita et al. 2010). However, it has two important implications for the role of alternative occupations as a tool to help reduce fishing pressure. First, aside from issues of risk and access, alternative occupations are unlikely to generate rapid changes in behaviour until fishers have built up sufficient experience in that alternative occupation (Torell et al. 2010). Second, the most experienced fishers are likely to be the most resistant to reducing their level of engagement in fishing.

The findings from this study suggest that management strategies to reduce fishing pressure on Danajon Bank would benefit most from targeting the poorest households at an early stage in the demographic life-cycle. However, the results also highlight the complexity of interactions between socioeconomic variables and considerations of risk in determining levels of engagement in different occupations. It is thus a challenging task to predict the outcomes of any interventions. The potential for unintended consequences in such complicated systems is high (Barrett & Arcese 1998; Barrett et al. 2011), particularly because decisions are not made solely for economic reasons, but are also influenced by less tangible factors such as values and aspirations (Coulthard et al. 2011). An example of such unintended consequences occurred in Kiribati, where subsidization of coconut farming was expected to reduce fishing pressure. While individual responses varied, average fishing effort increased, mainly for noneconomic reasons such as enjoyment of fishing (Walsh 2009). Similarly, the development of seaweed farming was associated with increased investment in new fishing capital in some sites in Indonesia (Sievanen et al. 2005). The potential for unintended consequences on Danajon Bank is demonstrated by the apparent use of a stepping out strategy that, at least initially, involves investment in more valuable fishing capital. It is therefore important to recognise that increasing incomes on Danajon Bank could initially be associated with increased capitalisation of fishing. Even if fishers then reduce their level of engagement, this fishing capital will be available for hired labour. Therefore, any interventions designed to facilitate engagement in alternative occupations should be closely linked to direct conservation actions such as the development of marine protected areas or gear restrictions. In return for help with accessing alternative occupations, these direct conservation actions may receive increased support from local communities (Pollnac et al. 2001a; Torell et al. 2010).

This chapter has examined the correlates of engagement in fishing, seaweed farming and the informal sector individually. The next chapter makes use of livelihood networks for 300 households across 10 villages to explore the linkages between occupations, the relative importance of each of the occupations within people's livelihoods, patterns of dependence on individual occupations, and how each of these vary with wealth.

Supporting Information

Supporting information for this chapter can be found in Appendix S5, including: household demographic life-cycle – relationships between household size and age (S5.1); comparison of revealed occupational diversity and reported occupational diversity (S5.2); pairwise plots, correlation coefficients and variance inflation factors for explanatory variables (S5.3); model selection tables (S5.4); results of analyses run on only those households that engage in the relevant occupation (S5.5); engagement in each occupation by age and gender (S5.6).

CHAPTER 6

Occupational diversity and patterns of dependence in household livelihood portfolios

Abstract

This chapter examines the occupational diversity and patterns of dependence within households' livelihoods on Danajon Bank, with a focus on interactions between fishing and seaweed farming. To date there is only a limited understanding of how these occupations interact within household livelihood portfolios. This chapter makes use of network analysis tools to represent the perceived importances of and interactions between all occupations that 300 households from 10 villages engaged in. Networks were defined in terms of (a) the aggregate number of households engaged in each occupation, and (b) the aggregate income obtained from each occupation. These networks were used to examine the dependence of households on their primary occupations in terms of the number of secondary occupations and the relative amount of income from secondary occupations. Households were grouped by wealth quartiles to look for patterns in dependence and occupational relationships across wealth. Linear mixed effects models were then used to examine how household-level fishing income correlated with household socioeconomic variables and the structure of their livelihood portfolios. The results highlight the central importance of seaweed farming on Danajon Bank, and the contribution that it has played to increasing the resilience of household livelihoods due to the lack of other options accessible to most households on Danajon Bank. The wealthiest households had the greatest fishing income, but the lowest occupational and income dependence on fishing. Few of the wealthiest households that perceived seaweed farming to be their most important occupation also engaged in fishing. However, for households in the remaining wealth quartiles, fishing remained an important occupation, even for those that perceived seaweed farming to be their primary occupation. Mixed effects models demonstrated that fishing income for self-defined primary fishers was not related to

whether they were engaged in seaweed farming, but fishing income for self-defined seaweed farmers also engaged in fishing was lower than for self-defined primary fishers. This indicates that seaweed farming needs to be developed so that it is perceived as the primary occupation if resource managers hope to use seaweed farming to substitute for fishing. However, perceptions of seaweed farming as a primary occupation varied between villages, and it is difficult to predict when households are most likely to perceive seaweed farming as a primary occupation. The chapter contributes to a broader understanding of the interaction between wealth and the availability of an alternative occupation in determining the structure and diversity of livelihood portfolios, and hence household resilience in the face of resource scarcity.

6.1 Introduction

The development of alternative occupations to fishing is frequently promoted as a tool to diversify fishers' livelihoods (Allison & Horemans 2006; Brugère et al. 2008). Diversification is viewed as a critical component of household economies that helps to increase resilience to shocks and disturbances, including to declining fish catches (Ellis 2000a; Barrett et al. 2001; Allison & Ellis 2001; Smith et al. 2005). The increased resilience afforded by diversification has been implicated as an important factor for resource management, with studies investigating the role of diversification in determining whether households would exit declining fisheries (Cinner et al. 2009a), the most appropriate types of fisheries management system (Cinner 2007), the level of support for conservation activities (Pollnac et al. 2001a; Marshall et al. 2009, 2010), and how fishers respond to policy changes (Marshall et al. 2007).

A key component of resilience is dependence; households that are less dependent on any one occupation are likely to be more resilient to shocks or changes in that occupation (Adger et al. 2002; Marshall et al. 2007). Dependence on an occupation or resource is often difficult to establish. Level of use does not necessarily reflect dependence as people may have equally good options in other occupations or resources (Allebone-Webb 2009). There are many characteristics that define dependence (e.g. Marshall et al. 2007; Allebone-Webb 2009), but key characteristics of interest to this chapter are the number of occupations that a household engages in ('occupational dependence'), and the concentration of income in one occupation ('income dependence'). These measures provide different insights into dependence. For example, a household that engages in many occupations (low occupational dependence) may obtain the majority of their income (monetary or non-monetary) from a single occupation (high income dependence), whereas households that engage in few occupations (high occupational dependence) may obtain similar levels of income across those occupations (low income dependence). The degree of dependence on an occupation can be expected to vary with the characteristics of the occupation and type of household. For example, households that engage in relatively risky occupations, such as seaweed farming, may be expected to engage in a wider range of occupations (i.e. low occupational dependence) in order to spread risk. However, relatively wealthy households may have greater access to a wider variety of occupations (low occupational dependence), but also a greater potential to specialise in one of those occupations and to earn the majority of their income from that occupation (Vedeld et al. 2007). Therefore, both 'income dependence' and 'occupational dependence' need to be interpreted in the context of the magnitudes of income.

Related to, but distinct from 'dependence', is the perceived importance that households attribute to different occupations within their livelihood portfolio. The perceived importance of different occupations may be expected to relate in part to income dependence. However, income dependence may vary temporally with seasonal trends, changes in market and environmental conditions, and shocks and disturbances to the household (e.g. sickness). Changes in market and environmental conditions may enable households to "surf the waves of opportunity" while maintaining a set of core occupations to fall back on (Gönner 2011), or particular occupations may play an essential role in lean seasons or during times of high vulnerability (Allebone-Webb 2009). In this context households may perceive their safety net occupations as more important than these ephemeral opportunities, even if the overall income from the safety net is lower. The form of income provided would also be expected to influence the perceived importance of those occupations. For example, the provision of frequent and reliable income to help meet daily needs is an important feature of fishing for many fishers (Béné et al. 2003, 2009; Chapter 4). Therefore, although delayed return occupations associated with higher risk may provide greater levels of income, these incomes may be perceived as less important to households than the frequent smaller incomes from fishing.

The role of a given occupation, and hence how households define themselves in relation to an occupation, may vary with household characteristics and the livelihood strategy of households. For example, the role of frequent and small incomes from fishing may be expected to be more important for poorer households in subsistence strategies than for wealthier households in accumulation strategies (Smith et al. 2005). This may cause them to define themselves primarily as a fisher even though they may be making a lower proportion of their income from fishing than other occupations. Cultural or personal identity and noneconomic values can also play an important part in the way that people define themselves in terms of their occupation (Pollnac et al. 2001b; Coulthard et al. 2011). For example, local people in the north of Mozambique frequently define themselves as fishers, despite spending relatively few days fishing and earning relatively little income from fishing in comparison to other occupations (Hill 2005).

Examination of patterns of dependence on and perceived importance of multiple occupations as part of a livelihoods portfolio sheds light on how access to a given occupation might influence the degree of engagement in others, and the potential for alternative occupations to substitute for fishing. This chapter uses a combination of network analysis (Krause et al. 2007) for households grouped by wealth and linear modelling at the household level to explore these patterns across ten villages in the Danajon Bank. Specifically, this chapter uses network analysis to ask how groups of households that self-define as either fishers or seaweed farmers (in terms of which occupation they perceive as the most important in their livelihood portfolio) differ in the structure of their livelihood portfolios (in terms of the diversity of occupations and relative incomes). I also investigate whether the structure of their livelihood portfolios differs between wealth groups. These livelihood portfolios are examined both in terms of linkages between all occupations and the specific linkages between fishing and seaweed farming. The chapter then uses linear mixed effects models to examine how household-level fishing income correlates with household socioeconomic variables and the structure of their livelihood portfolios (in terms of the presence and perceived importance of seaweed farming in that portfolio), and generalised linear models to examine factors that may relate to the probability of a household self-defining first and foremost as a seaweed farmer.

On Danajon Bank, seaweed farming is, in the short-term, more risky than fishing, but fishing is associated with long-term declines in fish catches (Chapter 4). Additionally, wealthier households have higher engagement in informal sector occupations than poorer households, while poorer households are most engaged in fishing (Chapter 5). Given the greater access of wealthier households to informal sector occupations, I predict that wealthier households should have lower occupational dependence (i.e. higher occupational diversity) than poorer households, greater income from non-fishing occupations, and thus lower overall dependence on fishing. Second, because of the greater short-term risks to seaweed farming than fishing, I predict that households which perceive seaweed farming to be their most important occupation are more likely to retain involvement in fishing than fishing households are to engage also in seaweed farming. Finally, given the short-term risks to seaweed farming, I predict self-defined primary seaweed farmers engaged in fishing have lower fishing income than self-defined primary fishers, while fishing income for primary fishers will not vary in relation to whether they engage in seaweed farming. By testing these predictions for the case study of the Danajon Bank, I aim to contribute to improving broader understanding of the interaction between wealth and the availability of an alternative occupation in determining the structure and diversity of livelihood portfolios, and hence household resilience in the face of resource scarcity.

6.2 Methods

Site description

This chapter draws on information from 10 island villages, distributed along the length of Danajon Bank. These 10 villages were also used as the basis for analyses in Chapter 3, where the effect of seaweed farming on village-level fisher numbers was examined. Across these villages, fishing and seaweed farming vary in the extent of household engagement, thus providing an interesting study system to examine interactions among occupations and to attempt to understand how households construct their livelihood portfolios and reasons for their choices. Seaweed farming arrived in each of these villages at different times, ranging from the 1960s to 2008, and the sample also includes one village (Bilangbilangan in Tubigon) where recent attempts to introduce seaweed farming have failed (Chapter 2, section 2.5).

Data collection

A systematic sampling design (every n^{th} household) with randomized start point based on the latest census list (2008/2009) was used to select 30 households from each village, representing 5-27% of the households in a village. Respondents were heads of household or main income earners, and often included both husband and wife who were interviewed together (162 women and 291 men). All interviews, conducted once per household, were conducted in the local dialect, Visayan, by one of two trained and experienced local research assistants, between November 2008 and May 2009. Responses were recorded on prepared data-sheets and later translated into English (Chapter 2, section 2.5).

Respondents from each household were asked about all of the occupations that members of the household engage in (for food or income) or otherwise receive income from (e.g. remittances, pensions), including which of these was the most important to the household (the ‘primary occupation’). Respondents were asked to identify only one perceived ‘primary occupation’ for the household as a whole, and the remaining occupations were considered as ‘secondary occupations’. Respondents were asked to estimate the monthly income from each occupation, based on income from the previous month. Where income was received less frequently than once per month they were asked to estimate the magnitude of the last income event and how many months there were between income events, and this was converted to monthly income. A series of questions was asked to triangulate this livelihood information and ensure that even occupations where engagement levels were relatively minor were included (Chapter 2, section 2.5). Because villages were visited sequentially over a seven month period that encompasses two seasons, some variation in income estimates among villages may be expected due to seasonality and price fluctuations. However, income is generally obtained from all occupations in all seasons (Chapter 4), and seasonality is in fact found to have a relatively unimportant relationship with income from fishing, seaweed farming and informal sector occupations (Chapter 5). Thus, seasonal bias was expected to be minimal.

Occupations and sources of income were grouped (e.g. Cinner & Bodin 2010) and defined for analysis as follows: fishing, seaweed farming, trade of fish/shellfish, trade of seaweed, the informal sector, salaried, remittances, agriculture and ‘other’. Fishing was defined as any occupation that gathered fish or shellfish from the sea for sale or consumption, and included gleaning. Seaweed farming was defined as any occupation that involved the harvest of seaweed from the sea, which included the collection of wild/washout seaweed (Chapter 4). The trading of fish/shellfish or seaweed involved the buying and selling of fish/shellfish or seaweed not from own production (i.e. as a middleman). Informal sector occupations were defined as casual labour or entrepreneurial activities that provided ad hoc income, and most commonly included selling food (e.g. from a produce stand) or water and independent trade work (e.g. carpentry or mechanical), as well as handicrafts, housemaid work, the sale of firewood, and working as a fish pond caretaker. Salaried occupations included employment that resulted in a regular salary, such as government work (e.g. village councillor or police) and teaching. Remittances were any income received from family members that lived and worked separately to the household. Agriculture included the cultivation of arable crops or livestock (excluding animals kept solely for recreational purposes, e.g. cock-fighting). The 'other' sector comprised of pensions and charitable donations from outside of the household. The total number of occupations engaged in per household ranged from zero to five with a median of two (Supporting Information).

Information was also collected on the socioeconomic characteristics of each household. This included counts of the number of bedrooms within the house, the number and types of boats and appliances owned by the household, and scores for the type of walls, roof and floor of a respondent's house. Principal components analysis was used to turn this information into a Material Style of Life (MSL) score that was used as an indicator of wealth (Chapter 2, section 2.5). The MSL score ranged from -2.91 to 7.33 with a mean of zero (Supporting Information), and households were aggregated into wealth quartiles based on this score for network analysis (see below).

Other socioeconomic variables that were found to influence levels of engagement in different occupations (Chapter 5) were also collected for each household. These variables included household size, age, education, fishing experience and gender composition of adults. Household size was the number of people that live within the household and share meals and income. Age was calculated as the average age in years of the heads of household. Education was calculated as the average number of years of education received by the heads of household. Gender composition was calculated as the proportion of adult (18-65 years old) household members that were male. Fishing experience was the number of years that a household had been engaged in fishing, and was determined from a timeline constructed during the interview. In addition, information relevant to seaweed farming was collected from those households engaged in seaweed farming. This included the size of the seaweed farm they use (ha), whether they own that seaweed farm (yes/no), and whether they had membership of a People's Organisation (yes/no).

Construction and analysis of aggregate-level livelihood networks

Network diagrams are a graphical representation of the interrelationships between network components (occupations). In this chapter, they were used to represent aggregate level engagement in occupations and linkages between occupations for groups of households, and can be considered as livelihood networks (c.f. Cinner & Bodin 2010). Households were defined by the occupation they perceived as the most important (e.g. 'primary fishers' for households that perceived fishing to be the most important occupation). Linkages between two occupations occur where a household engages in both occupations. These linkages are directed because they link the primary occupation to the secondary occupations. The strength of linkages between occupations was determined by the proportion of households that engaged in a primary occupation that also engaged in another occupation as a secondary occupation (i.e. the proportion of primary fishers that also engaged in seaweed farming, and the proportion of primary seaweed farmers that also engaged in fishing). Therefore, nodes represent occupations, and arrows between nodes represent relationships between occupations based on the perceived importance of those occupations. The resulting livelihood networks were then used to calculate indicators of dependence on perceived primary occupations based on the strength of relationship between the primary and secondary occupation.

Two types of livelihood network were constructed based on two different measures of engagement; (a) one was based on the aggregate number of households engaged in each occupation (household number networks), and; (b) another was based on the aggregate monthly income reported for each occupation across all households in the network (income networks). Both of these network types were constructed at two scales, (a) once for all households aggregated together (all-household networks) and, (b) once each for four groups of households based on wealth quartiles (wealth-quartile networks). Networks were not constructed separately for each village due to sample size limitations. Summary statistics for households by wealth quartile are provided in Supporting Information.

In each network diagram, an occupation was represented by a node, and the size of the node was scaled to (a) number of households engaged in the occupation (for the household number networks), or (b) the aggregate income earned from the occupation, summed across all households included in that network (for the income networks). Included in the node was a pie chart where the darker area indicated (a) the proportion of households engaged in the occupation as their primary occupation (for the household number networks), or (b) the proportion of aggregate income earned from that occupation attributed to households that indicated it as their primary occupation (for the income networks).

An arrow between two nodes represents the households that engaged in both the originating node as their primary occupation and the destination node as a secondary occupation (linkages between secondary occupations in a household were not included). For the household number networks, the size of the arrowhead represents the proportion of the households that engaged in the originating occupation as their primary occupation that also engaged in the destination node as one of their secondary occupations. For the income networks, the size of the arrowhead represents the ratio of the aggregate income from the secondary occupation to the aggregate income from the primary occupation for those households represented by the arrow (i.e. for those households that engaged in both occupations, 1 indicates that their aggregate income from each occupation was equal, 0.5 indicates that their aggregate income from the secondary occupation was half the size of their aggregate income from the primary occupation).

The relative positions of the nodes within the network diagrams were determined using spring-embedded layout techniques within the computer program NetDraw (Borgatti 2002) in UCINET (Borgatti et al. 2002). This means that the position of a node was determined by the number of other nodes that it was connected to (via arrows) in the network, such that a node with links to a greater number of other nodes was more centrally placed, while a node with links to fewer other nodes was placed on the periphery of the diagram. Hence, centrally positioned occupations tended not to co-occur with any particular other occupations (but may do so with any or all of a wide variety of other occupations), while the occupations on the periphery of the diagram tended to co-occur with a more limited range of other occupations (relative to centrally placed occupations). Nodes placed closer to each other tended to occur together in households' livelihood portfolios more frequently than nodes placed further apart from each other.

Next, the resulting networks were used to calculate indicators of dependence on primary occupations for each measure of engagement and at each scale (all-households and by wealth-quartile). Dependencies were only calculated for fishing and seaweed farming, because 275 of the 300 households perceived one of these as their primary occupation. Two indicators of dependence were calculated. The first ('occupational dependence') was the mean number of secondary occupations that self-defined primary fishers or primary seaweed farmers engaged in. A higher mean number of secondary occupations indicated a lower level of occupational dependence on the self-defined primary occupation. The second ('income dependence') was the relative magnitude of income from all secondary occupations with respect to the primary occupation, and was calculated as the ratio of aggregate income from all secondary occupations to aggregate income from the originating node for all households engaged in the originating node as a primary occupation.

Finally, the networks were used to examine the relationship between seaweed farming and fishing in terms of the directed linkages between fishing and seaweed farming only. These directed linkages are represented by the arrowheads that link fishing and seaweed farming in both the household number network diagrams and the income network diagrams.

Household-level analyses

One of the key questions for this chapter was whether fishing income varied with the relationship between fishing and seaweed farming in a household's livelihood portfolio and with the perceived importance of seaweed farming in relation to fishing (for those households engaged in fishing). Due to the high short-term risks associated with seaweed farming compared to fishing (Chapter 4), fishing income was not expected to vary between households that perceived fishing to be the most important occupation and did or did not engage in seaweed farming, but was expected to be lower for households that perceived seaweed farming to be more important than fishing (primary seaweed farmers). To examine this, linear mixed effects models were used. The response variable was monthly fishing income per household, which was square-root transformed to normalise the distribution of model residuals. The primary explanatory variable of interest was a three-level factor that classified households as either (1) primary fishers without engaging in seaweed farming (80 households); (2) primary fishers with secondary seaweed farming (96 households); (3) primary seaweed farmers with secondary fishing (45 households). A possible 4th level (secondary fishers with another primary occupation) was excluded because there were only 9 households in this category. Other explanatory variables that have been found to correlate with fishing or seaweed farming income were also included (Chapter 5). These were wealth, age, education, household size, gender composition, fishing experience, and the number of non-fishing and non-seaweed farming occupations. Pairwise plots, correlation tests, and variance inflation factors were used to verify there were no problems with collinearity among all non-categorical explanatory variables. Kendall's correlation tests were used because some variables were non-normally distributed (Supporting Information). Linear mixed effects models were random intercept models that included village as a grouping factor, thus allowing the model intercept to vary per village. A model averaging approach based on information theory (Burnham & Anderson 2002) was used to determine the relative importance of and model coefficients for these variables, following the procedures outlined in Chapter 4.

A binomial generalised linear model was used to analyse the probability of households engaged in seaweed farming perceiving seaweed farming as a primary occupation given various household characteristics. Of the 206 seaweed farming households, 175 households were analysed as they had complete information for all explanatory variables. Village was a confounding variable in this analysis because 73.7% of primary seaweed farmers were in three villages, so there was not enough variation for village to be included as an explanatory variable. Explanatory variables included were seaweed farming experience (years), fishing experience (years), wealth, household size, age (years), size of seaweed farm (log-transformed hectares), gender ratio of the adults (proportion of males), and binary variables for whether the household was a member of a People's Organisation relevant to seaweed farming, source of capital (personal or external) for seaweed farming, and whether they owned their seaweed farm (Chapter 3). A model averaging approach (Chapter 4) was used to determine the relative importance and model coefficients for these variables.

6.3 Results

Aggregate-level livelihood networks

Fishing and seaweed farming were the most common occupations in the all-household network for Danajon Bank, with both the largest number of households engaged in them, and the greatest income earned from them (Fig. 6.1). Of the 296 households that reported engagement in any occupation, 230 engaged in fishing with aggregate reported monthly income of P933,255. 206 households engaged in seaweed farming, with aggregate reported monthly income of P732,917. The informal sector was the next most common occupation, which was engaged in by 72 households with aggregate reported monthly income of P202,216 (Fig. 6.1). Of the 296 households that reported occupations, only seven did not engage in seaweed farming or fishing at all and, furthermore, 275 households perceived either fishing (176) or seaweed farming (99) to be the most important occupation (Table 6.1).

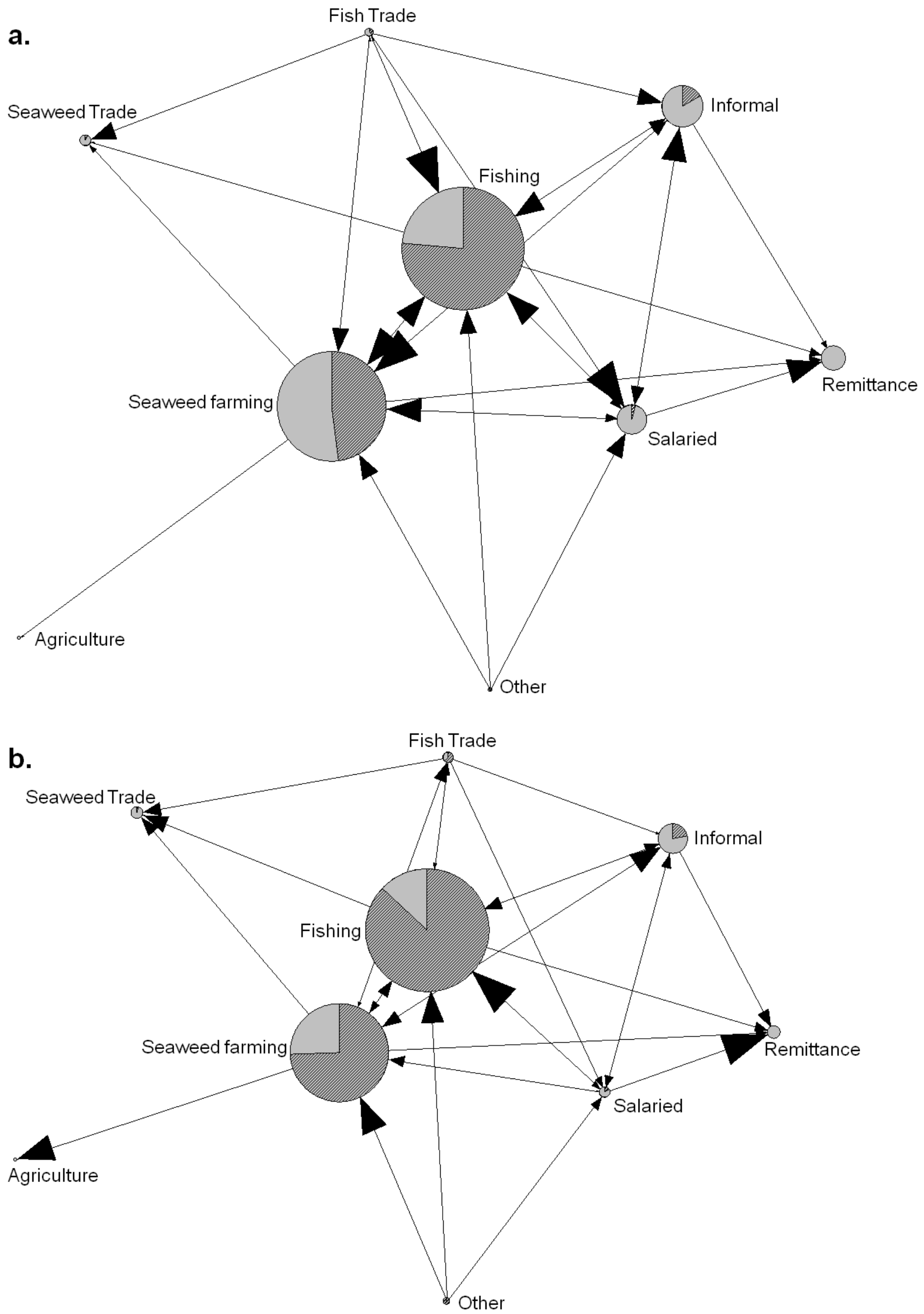

Figure 6.1. Livelihood network for all households based on (a) the number of households and (b) aggregate income. The size of the nodes represent (a) the number of households engaged in the occupation, and (b) the aggregate monthly income from these occupations across all households. The dark area represents the proportion of (a) number of households, and (b) income attributed to households that perceived that occupation as a primary occupation. Arrows link self-defined primary to secondary occupations and the arrowheads are scaled to represent (a) the proportion of households engaged in the primary occupation that also engage in the secondary occupation, and (b) the size of the income from the secondary occupation in relation to the size of income from the primary occupation for those households engaged in both (see main text for further details). This figure was based on information from 300 households.

Table 6.1. (a) Numbers of households engaged in fishing, seaweed farming (SWF) and remaining sectors, and indicators of dependence on primary occupations by wealth quartile and for all households. There are two indicators of dependence: (b) 'occupational dependence' (number of secondary occupations), and (c) 'income dependence' (ratio of secondary to primary income; see main text for details). Higher values for indicators of dependence represent lower dependence, and were only calculated for fishing and SWF due to the low primary engagement in other occupations. There were 75 households per wealth quartile.

	Wealthiest	*2nd*	*3rd*	*Poorest*	*All*
a) # households engaged [as primary occupation] in					
fishing	47 [38]	60 [44]	63 [53]	60 [41]	230 [176]
SWF	57 [24]	51 [25]	45 [18]	53 [32]	206 [99]
all other occupations	37 [13]	32 [3]	32 [4]	42 [1]	143 [21]
b) Mean # (sd) of secondary occupations for					
primary fishers	1.684	1.045	0.906	0.805	1.085
	(0.904)	(0.830)	(0.741)	(0.782)	(0.848)
primary SWF	1.250	1.000	0.833	1.188	1.091
	(0.944)	(0.764)	(0.514)	(0.693)	(0.757)
c) Relative size of all secondary occupations:					
primary fishers	0.664	0.409	0.205	0.217	0.395
primary SWF	0.440	0.427	0.310	0.802	0.486

About half of the 296 households (147 households) engaged in both fishing and seaweed farming. Of these, 96 were primary fishers, and 45 were primary seaweed farmers, and the remaining six perceived other occupations to be the most important. Of the remaining occupations, the informal sector was most commonly related to self-defined primary fishers and seaweed farmers (21.0% of primary seaweed farmers and 21.0% of primary fishers, Fig. 6.1a).

In the all-household networks, dependence on the primary occupation was slightly higher for primary fishers than for primary seaweed farmers. On average, primary fishers and seaweed farmers engaged in one secondary occupation (mean (sd); 1.085 (0.848) for primary fishers (n=176), 1.091 (0.757) for primary seaweed farmers (n=99), Table 6.1). Income dependence was slightly higher for primary fishers than primary seaweed farmers. For primary fishers, aggregate income from secondary sources was about two-fifths of aggregate fishing income (0.395). For primary seaweed farmers, aggregate income from secondary sources was about half of aggregate seaweed farming income (0.486; Table 6.1).

Engagement in occupations (for both household numbers and income) varied by wealth quartile. More households in the wealthiest quartile engaged in seaweed farming (79.2%) than in other wealth quartiles (68.0%, 60.0%, and 70.7% in the 2nd, 3rd and poorest wealth quartiles respectively; Table 6.1; Fig. 6.2). The wealthiest quartile had the lowest percentage of households engaged in fishing (62.7%) compared to other wealth quartiles (80.0%, 84.0%, and 80.0% in the 2nd, 3rd, and poorest wealth quartiles respectively; Table 6.1; Fig. 6.2). The wealthiest quartile also engaged in the greatest number of remaining occupations (Fig. 6.2), but the poorest sector had the greatest number of households engaged in the remaining occupations (Table 6.1). Aggregate income declined from the wealthiest quartile to the poorest for all occupations (Fig. 6.3). Seaweed farming contributed a greater aggregate income than fishing in the wealthiest quartile (P306,850 for seaweed farming, P263,700 for fishing), but less aggregate income than fishing in all other wealth quartiles (Fig. 6.3).

Dependence varied by wealth quartile and by primary occupation. For primary fishers, dependence on fishing increased for poorer wealth quartiles. This increasing dependence is illustrated both for occupational dependence and income dependence (Table 6.1). For primary seaweed farmers, patterns of dependence were more complicated. Primary seaweed farmers in the wealthiest and the poorest wealth quartiles had relatively low occupational dependence compared to intermediate wealth quartiles (Table 6.1). However, income dependence for primary seaweed farmers was lowest for the poorest wealth quartile, in a pattern that was almost the reverse of that for primary fishers (Table 6.1).

The relationship between fishing and seaweed farming (in terms of directed linkages) varied by wealth quartile. Seaweed farming generally played a more important role in the livelihoods of the wealthiest households, and fishing a more important role in the livelihoods of the poorest households. Three-quarters of primary fishers in the wealthiest quartile also engaged in seaweed farming (73.7%, Table 6.2). However, only 16.7% of primary seaweed farmers in the wealthiest quartile also engaged in fishing (Table 6.2; Fig. 6.2a). For all other wealth quartiles roughly half of primary fishers also engaged in seaweed farming, and roughly half of primary seaweed farmers also engaged in fishing. However, in terms of income, aggregate fishing income for primary seaweed farmers also engaged in fishing in the wealthiest quartile was roughly a quarter the size of their aggregate seaweed farming income (23.2%; Table 6.2). In contrast, aggregate fishing income for those primary seaweed farmers also engaged in fishing in the poorest wealth quartile was two-thirds the size of their aggregate seaweed farming income (68.5%; Table 6.2).

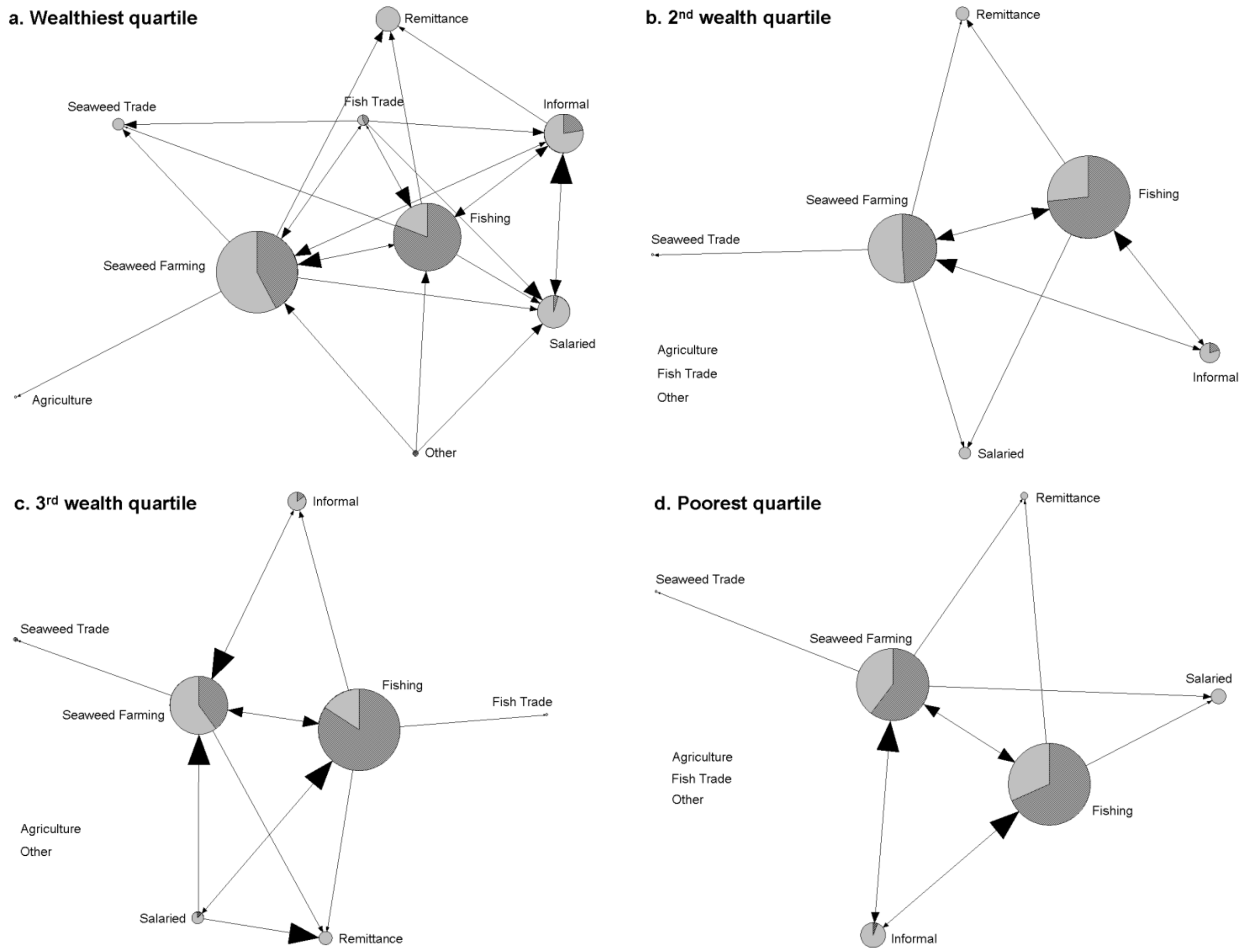

Figure 6.2. Livelihood networks by numbers of households for wealth quartiles from (a) wealthiest to (d) poorest wealth quartiles. The size of nodes indicates the number of households within each occupation, and the dark area the proportion of those households that perceive that occupation as their primary occupation. Arrows link self-defined primary to secondary occupations, and the size of the arrowheads are scaled to represent the proportion of households engaged in the primary occupation that are also engaged in the secondary occupation. The largest node size (fishing in the 3rd wealth quartile) represents 63 households, and the smallest node represents 1 household. The largest arrowhead represents 1.0 (i.e. all households engaged in the primary occupation also engage in the secondary occupation). There were a total of 75 households in each wealth quartile.

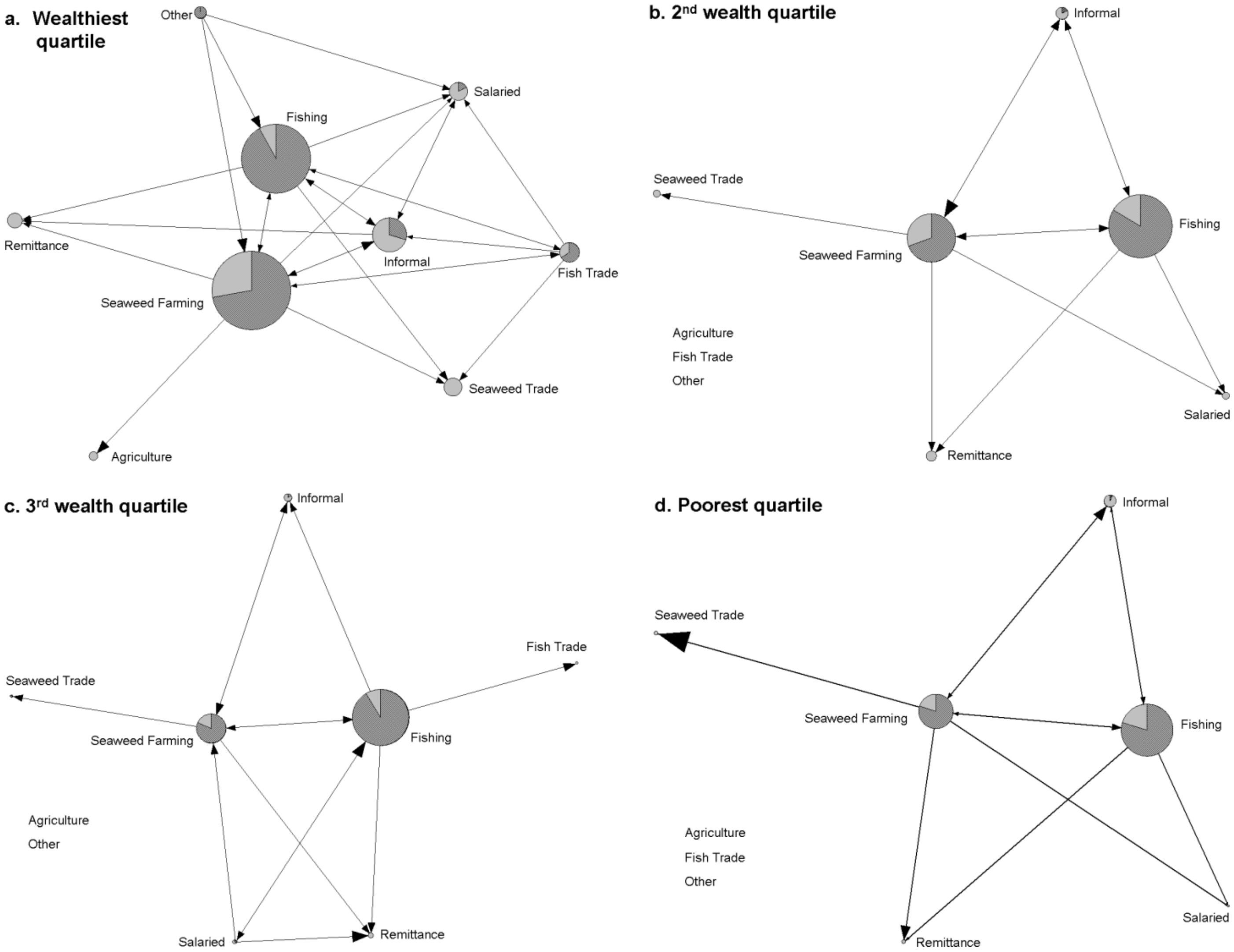

Figure 6.3. Livelihood networks by income for wealth quartiles from (a) wealthiest to (d) poorest wealth quartiles. The size of nodes corresponds to the income obtained from the relevant occupation, and the dark area represents the proportion of that income from households that perceived the occupation was their primary occupation. Arrows link self-defined primary to secondary occupations, and the size of the arrowheads are scaled to represent the aggregate income from the secondary occupation in relation to the aggregate income from the primary occupation for households that were engaged in both. The largest node size (seaweed farming in the wealthiest quartile) represents P306,850, and the smallest node size (salaried in the poorest quartile) represents P1,752. The largest arrowhead (into seaweed trade in the poorest quartile) represents 2.4 (i.e. for self-defined primary seaweed farmers engaged in seaweed trade as a secondary occupation, the income from seaweed trade was 2.4 times the size of income from seaweed farming). See Table 6.2 for the value of the arrowheads linking fishing and seaweed farming. There were a total of 75 households in each wealth quartile.

Table 6.2. Linkages between fishing and seaweed farming (SWF) for wealth quartiles and for all households, measured as (a) the % of households engaged in one as a primary occupation that are engaged in the other as a secondary occupation, and (b) the size of income from the secondary occupation in relation to the size of income from the primary occupation for households that were engaged in both (1.0 represents secondary occupations provided sum of income equal to the sum of primary occupation, 0.0 represents no income from secondary occupations).

	Wealthiest	*2nd*	*3rd*	*Poorest*	*All*
a) % of primary engaged in secondary					
fishers in SWF	73.7%	54.5%	45.3%	48.8%	54.5%
SWF in fishing	16.7%	56.0%	50.0%	56.3%	45.5%
b) Relative size of secondary occupation					
SWF for primary fishers	0.303	0.449	0.234	0.302	0.326
fishing for primary SWF	0.232	0.476	0.396	0.685	0.485

Household-level analyses

As predicted, fishing income for primary fishers did not vary with their engagement in seaweed farming, but fishing income for self-defined primary seaweed farmers (that were also engaged in fishing) was lower than fishing income for primary fishers (Table 6.3). The perceived importance of fishing/seaweed farming and wealth were the most important explanatory variables for fishing income (Table 6.3). Wealth was positively correlated with fishing income. All other explanatory variables had relative importance scores of 0.51 or less (Table 6.3), indicating very little support.

Table 6.3. Results for linear mixed effects models of square-root transformed monthly fishing income, showing the model average coefficient estimates (SE) and relative importance of each variable from the 95% confidence set of models based on AICc, based on 217 observations from 10 villages. Village was included as a grouping factor in the random effects. Random effects estimates of variance [sd] are taken from the global model. SWF = seaweed farming

	Coef (SE)	*Relative importance*
(Intercept – primary fishers no SWF)	69.08 (8.64)	
Relation of fishing to SWF		1.00
Primary fisher with SWF	3.22 (3.65)	
Primary SWF with fishing	-17.37 (4.70)	
Wealth (MSL)	3.57 (1.05)	1.00
Age (years)	-0.13 (0.18)	0.51
Fishing experience (years)	-0.07 (0.13)	0.40
Number of other occupations	-0.59 (1.54)	0.31
Household size	0.12 (0.42)	0.27
Gender ratio (proportion of males)	1.00 (5.20)	0.25
Education (years)	-0.05 (0.39)	0.24
# models in 95% confidence set	50	
Random effects		
Village	21.42 [4.63]	
Residual	435.91 [20.88]	

The probability of seaweed farming being perceived as the primary occupation was most strongly associated with village. 73.7% of primary seaweed farmers were from Alumar, Hingutanan East and Mahanay, and primary seaweed farmers accounted for 81.1% of all the sampled households in these villages. Analysis of all seaweed farming households showed that the those most likely to perceive seaweed farming as a primary occupation had the most seaweed farming experience, least fishing experience, lowest wealth, and relatively small household size (Table 6.4). The size of seaweed farm, ownership of seaweed farm, membership of PO, and source of capital for seaweed farming were relatively unimportant explanatory variables (Table 6.4).

Table 6.4. Results for the binomial generalized linear model of the probability of seaweed farming households engaging in seaweed farming as a primary occupation (1 equals primary seaweed farmer, 0 equals secondary seaweed farmer), showing the model average coefficient estimates (SE) and relative importance for each variable from the 95% confidence set of models based on AICc. Models the information for 175 households engaged in seaweed farming, 91 of them primary seaweed farmers.

	Coef (SE)	*Relative importance*
(Intercept)	-0.461 (1.379)	
Wealth (MSL)	-0.587 (0.150)	1.00
Fishing experience (years)	-0.633 (0.180)	1.00
Seaweed farming experience (years)	1.358 (0.287)	1.00
Household size	-0.251 (0.125)	0.93
Age (years)	0.040 (0.030)	0.78
Size of seaweed farm (log(ha))	0.254 (0.263)	0.64
Gender ratio of adults (proportion of males)	-1.303 (1.521)	0.59
PO membership (yes=1, no=0)	0.147 (0.355)	0.32
Source of seaweed capital (Personal=1, external=0)	0.052 (0.236)	0.26
Ownership of seaweed farm (yes=1, no=0)	-0.032 (0.322)	0.24
# models in 95% confidence set	66	

6.4 Discussion

The network analyses demonstrated the central importance of fishing and seaweed farming to the livelihood portfolios of households on Danajon Bank, both in terms of the number of households engaged in them, and aggregate income. The conventional wisdom views poverty in fisheries as arising from a lack of opportunities outside the fishery sector and fishing as “an occupation of last resort” (Béné 2003). The results from the network diagrams illustrate that this may have been the case on Danajon Bank before seaweed farming arrived. The informal sector, which comprised the next most common group of occupations, was largely composed of occupations that served the local villages. Before the additional income from seaweed farming within these villages, the opportunities in the informal sector may also have been lower. So before seaweed farming arrived there were probably very few accessible opportunities on Danajon Bank itself outside of fishing for the majority of households. However, the premise of fishing as a last resort before seaweed farming arrived ignores the labour opportunities provided by nearby Cebu City and the growing shipping industry in the Philippines, for which recent generations of islanders have increasingly been supplying labour (Guieb 2008). There has been a trend in Southeast Asia of the rural poor increasingly making use of urban labour markets (Rigg 2006). A fruitful area of further research would be to examine the effect that seaweed farming has had on that trend for Danajon Bank, and on the opportunities within other occupations such as the informal sector.

Fishing was also not solely an occupation for the poorest households on Danajon Bank. The wealthiest quartile had the greatest aggregate fishing income, despite a smaller proportion of households engaged in fishing and a much greater number of occupations available to them. The greater occupational diversity of households in the wealthy quartile was as predicted, and is consistent with the literature on diversification and wealth (Barrett et al. 2001). Primary fishers and seaweed farmers from the wealthiest quartile generally had the lowest level of occupational dependency. Consistent with Chapter 5, households in the wealthiest quartile had the greatest income from non-fishing and non-seaweed farming occupations (particularly the informal sector), and this quartile had the greatest number of households that perceived non-fishing and non-seaweed farming occupations as their most important occupation. The primary fishers in the wealthiest quartile also had the lowest income dependence on fishing. Overall, this confirms expectations that the wealthiest households have the lowest dependence on fishing, despite having the greatest aggregate income from fishing. This contrasts with the results of Chapter 5, which found the poorest households had the highest engagement in fishing, both in terms of effort and income. This difference may reflect the inclusion of a larger number of villages and therefore wider wealth range. Much of the increased income may also be attributed to ownership of greater fishing capital, consistent with Chapter 5, and increased hiring-in of labour, which may have enabled household members to engage more in non-fishing occupations and therefore have the lowest income dependence on fishing.

Overall, a greater proportion of primary fishers were engaged in seaweed farming than primary seaweed farmers were engaged in fishing. This was contrary to expectations, but the all-household network conceals a strong wealth effect on relationships between fishing and seaweed farming. Nearly three-quarters of primary fishers in the wealthiest quartile also engaged in seaweed farming, while less than one-fifth of primary seaweed farmers in the wealthiest quartile also engaged in fishing. This may reflect a strategy of “stepping out” of fishing (Dorward et al. 2009) for these households, consistent with expectations from Chapter 5. The finding that primary seaweed farmers in the wealthiest quartile also had the highest occupational diversity indicates that non-fishing rather than fishing occupations may have contributed most towards insurance against the risks of seaweed farming (Chapter 4). It would be interesting and informative to determine where these primary seaweed farmers in the wealthiest quartile obtained the majority of their income from before seaweed farming arrived. In all other wealth quartiles, the results were consistent with expectations that primary seaweed farmers were more likely to retain fishing in their livelihood portfolios than primary fishers were to retain seaweed farming, although the differences between primary fishers and seaweed farmers were relatively small.

As predicted, fishing income for primary fishers was not related to engagement in seaweed farming, but fishing income was lower for primary seaweed farmers. Elsewhere in the Philippines and Indonesia, fishers have reported continuing fishing at similar levels after the arrival of seaweed farming (Sievanen et al. 2005). This is consistent with the pattern for primary fishers in this study. Cause and effect cannot be distinguished in this case. However, the results suggest that the introduction of seaweed farming as a tool to substitute for fishing requires the promotion of seaweed farming so households perceive it as a primary occupation, and that it is insufficient to improve access to seaweed farming if households continue to perceive fishing as their primary occupation.

The perceived importance of seaweed farming as a primary occupation was closely associated with village, indicating that local context, as well as socioeconomic characteristics of households, is also an important determinant of behaviour. Of the three villages with the majority of primary seaweed farmers, Hingutanan East was both the wealthiest village and had households with the greatest seaweed farming experience and least fishing experience, and Alumar and Mahanay were the poorest villages with relatively less seaweed farming experience (Chapter 3). Therefore, the analyses of factors that correlate with seaweed farming being perceived as a primary occupation were likely to be confounded by this village-level effect. It is also likely that there are other important village-level factors that were not adequately captured by this study. For example, the relative success of a few individuals within a village can lead to others copying their example. Copying (social learning) is a widespread and successful strategy among humans (e.g. Rendell et al. 2010) that may limit the amount of risk taking and confer relatively “stable” livelihood strategies (McElreath & Henrich 2002). The increased incidence of seaweed farming as a primary occupation in particular villages could have followed as a result of a few individuals that quickly and successfully adopted seaweed farming, who were then gradually copied by others. As seaweed farming has only been in most of these villages since the mid-1990s (Chapter 3), it may take time before key individuals develop similar strategies in other villages that stand the test of time and are then copied by their neighbours. More detailed examination of the conditions associated with seaweed farming being perceived as a primary occupation would be a fruitful area for further research. These studies may also benefit from network analysis tools to examine social connections between individuals and whether perceived importance of seaweed farming correlates with these social networks. Similar approaches have been successfully used to identify the existence of opinion leaders and agents of change in fishing communities (Crona & Bodin 2010).

The perceived importance of an occupation was closely related to levels of income from each occupation. This suggests that households obtain their utility primarily from income rather than noneconomic factors, at least on Danajon Bank. However, the focus on perceived importance for the household may mask variation for individuals within a household who may perceive different occupations and resources to be most important (e.g. Carney 1993), and therefore define themselves in different ways.

This chapter demonstrates the value of network analysis for characterising relationships between occupations within livelihood portfolios, not only in terms of occupational dependence, but also income dependence. Relationships between occupations are not simple, and do not vary linearly with wealth. The application of network analysis to create livelihoods networks is limited by the fact that households have to be aggregated together across a range of socioeconomic and other factors that may influence their livelihood portfolio and engagement in different occupations. As demonstrated by the linkages between fishing and seaweed farming, such aggregate scales can hide patterns that occur for sub-groups of households (in this case by wealth quartile). The decision of how to aggregate households is therefore likely to be important to the interpretation of livelihoods networks. However, livelihood networks manage to portray a large amount of information very quickly and easily, and can readily be adapted to suit the needs of the study. This flexibility is demonstrated by the contrast between this chapter which aggregated households by wealth, and Cinner & Bodin (2010) who aggregated households across different geographical scales.

For the case study of Danajon Bank, the livelihood networks show the central role that seaweed farming now plays, alongside fishing, in people’s livelihoods. Seaweed farming clearly makes a substantial contribution to the resilience of households on Danajon Bank across all wealth quartiles, which are likely to have been much more dependent on fishing before seaweed farming arrived. However, not all households have been able to convert this increased resilience into reduced fishing activity. Seaweed farming has the greatest potential to reduce fishing for the wealthiest households. However, it remains a challenge to predict when and why households will perceive seaweed farming to be their most important occupation. Where fishing remains the perceived primary occupation, any effect of seaweed farming to increase wealth could just result in greater fishing pressure.

Supporting information

Supporting information for this chapter can be found in Appendix S6, including: number of occupations per household (S6.1); wealth scores per household (S6.2); summary of household characteristics per wealth quartile (S6.3); pairwise plots and correlation coefficients for linear mixed effects models (S6.4); model selection tables for the linear mixed effects models (S6.5), and; pairwise plots and correlation coefficients for binomial generalized linear models (S6.6).

CHAPTER 7

Discussion

It is commonly perceived that promoting alternative occupations increases the opportunity costs of exploiting wild species for food or income and enables households to refocus their efforts away from this exploitation when resources decline (Godoy et al. 1995; Hulme & Murphree 1999; Allison & Ellis 2001). The expectation that a livelihoods-based approach can succeed in reducing pressure on these exploited species is consistent with fishers' reported willingness to cease fishing when given hypothetical scenarios of declining catches (Cinner et al. 2009a). However, most studies generally consider livelihoods-based approaches in terms of the number of occupations and the opportunity costs of harvesting these wild species. This thesis demonstrates that there are several further layers of complexity that require careful consideration before supposing that promoting alternative occupations will indeed lead to reduced levels of resource exploitation. This case study of seaweed farming on Danajon Bank illustrates that key components of those layers of complexity are considerations of risk, the frequency and timing of income obtained, and the socioeconomic status of the target fishers. It also indicates that while alternative occupations may eventually lead to reduced levels of fishing, this may be preceded by increased levels of fishing at the household level, and raises questions about whether effort reductions will occur before the resource has reached an extreme degree of depletion.

As highlighted in Chapter 3, households can reallocate labour out of fishing towards alternative occupations, but such reallocations do not happen equally for all people or in all sites. The seaweed farming case study examined in this thesis highlights the importance of understanding the interactions between fishing and alternative occupations. It illustrates that the continued exploitation of declining fisheries is not only about 'quantity' of alternative occupations, but also about their 'quality'. In this sense, 'quantity' refers to the number of occupations available and the opportunity costs of fishing, and 'quality' refers to the actual potential for alternative occupations to substitute for fishing along a range of different dimensions, in the context of a given household's circumstances.

Livelihoods in tropical coastal communities are often diversified (Cinner & Bodin 2010), and as indicated in this thesis, few households rely on only one occupation (Chapter 6). Within such diversified livelihood portfolios, the role of a single occupation (i.e. fishing) and its contribution towards household income varies depending on a household's assets and access to resources, the values and aspirations of household members, and their other occupations (Smith et al. 2005; Dorward et al. 2009; Coulthard et al. 2011). Diversification can confer increased resilience to fishing households in the absence of insurance and credit markets (Reardon & Vosti 1995; Ellis 1998; Marschke & Berkes 2006). However, diversification does not necessarily mean that the role of a particular occupation is replaced or reduced. Even if alternative occupations provide potentially more lucrative opportunities than fishing, there is a constant trade-off between ensuring that immediate needs are met and improving well-being in the longer term (Zimmerman & Carter 2003). Characteristics associated with each occupation such as the frequency of income in relation to effort and the risks to investments are essential considerations that can supersede considerations of profitability (Chapter 4).

Chapter 4 demonstrates the importance of the 'cash machine' service provided by fishing. Fishing provides frequent and immediate income, almost on demand. The importance and relevance of these characteristics of fishing are just starting to be given adequate consideration in the literature (Béné et al. 2003, 2009; Tucker et al. 2010). Fishing is often considered a risky and uncertain occupation, associated with daily variations in catch and longer term changes resulting from seasonality and fluctuations in resource abundance (Allison & Ellis 2001; van Oostenbrugge et al. 2004; Pollnac & Poggie 2008). Some authors have argued that fishers continue in such a risky occupation for noneconomic reasons, primarily the job satisfaction that they obtain from fishing (Pollnac et al. 2001b; Pollnac & Poggie 2008; Walsh 2009). There is no doubt that there is an element of risk and uncertainty associated with fishing, both in terms of production and to personal safety, but production risk must be interpreted in the context of production risks associated with other occupations available. This is increasingly being recognised when compared to agriculture, where it is noted that fishing has substantial advantages over the delayed and infrequent returns received (Béné et al. 2003, 2009; Smith et al. 2005; Tucker et al. 2010). This study showed that seaweed farming is clearly perceived to have the potential for greater income than fishing, and is different from agriculture in that it can provide relatively frequent payoffs that are more similar to fishing than expected (c.f. Sievanen et al. 2005; Chapter 4). However, returns to investment are delayed, and those investments are subject to substantial levels of risk, and returns are therefore highly uncertain (Chapter 4). This uncertainty is likely to lead to greater anxiety about seaweed farming when compared to fishing (Tucker et al. 2010).

Alternative occupations are only likely to start substituting for fishing if they can do a better job of ensuring that regular daily needs are met, and pose less of a risk (actual or perceived) to investments of limited household resources (i.e. labour and financial capital). If this is not the case, the alternative occupation is likely to be taken up within a diversified livelihood portfolio to provide added insurance (i.e. top up fishing income when it falls short) and/or to fulfil a different livelihood function (i.e. 'savings'; Chapter 4). In this way seaweed farming has undoubtedly been of benefit to the local communities of Danajon Bank. This is emphasised by the fact that people from the full range of the wealth spectrum engaged in seaweed farming (Chapter 5; Chapter 6), highlighting that wealth is not a barrier to entry to seaweed farming. However, this adds another dimension to alternative occupations that is rarely considered in the literature. Different households may engage in alternative occupations for different reasons, depending on how seaweed farming is incorporated into the mix of occupations in the livelihood portfolio. Seaweed farming may be reasonably unique in this regard because of its flexibility – as an 'instant access savings account' it can contribute either towards savings or providing regular income, or a mix of both. This means that those households that are struggling to maintain daily needs from fishing or other sources can 'top-up' their income with seaweed farming. On the other hand, those households that can maintain their daily needs from fishing or other sources can use seaweed farming for 'savings'. These different strategies do not necessarily result in different levels of seaweed farming income, as illustrated for households in Handumon and Guindacpan (Chapter 5). But they have different implications for the livelihood trajectories of the households and their continued use of fishing, with different consequences for the role of seaweed farming as a substitute for fishing income.

Livelihood strategies can vary between accumulation and subsistence (Smith et al. 2005), which are also sometimes referred to respectively as "stepping up/out" or "hanging in" (Dorward et al. 2009). In the first, a household is slowly building assets and improving welfare. In the second, a household is primarily maintaining the current standard of living. This second strategy is sometimes referred to as a "poverty trap" (Barrett et al. 2011). The position of a household in either one of these strategies at a given time depends on a combination of their aspirations and their assets (human, social, physical, financial and natural capital). The position in either one of these strategies is often predicted to be relatively stable, because those in an accumulation strategy have the means to continue improving their welfare, whereas those in the subsistence strategy are forced into lower-risk activities associated with lower returns (Dercon 1998; Adato et al. 2006; Carter & Barrett 2006; Coomes et al. 2011). This thesis did not use timeseries datasets to assess changes to welfare over a number of years, so was unable to identify which households were accumulating. However, those households that can already meet their subsistence needs from fishing may find that seaweed farming (as a 'savings' account) provides an opportunity to improve welfare (i.e. to enter an accumulation strategy). The indications are that for most villages, due to the risks associated with seaweed farming, an accumulation strategy initially involves increasing fishing capital until a point is reached where the household has sufficient resources (and experience) to gradually start to "step out" of fishing – either into seaweed farming or into other occupations (Chapter 5; Chapter 6). On the other hand, those households that are struggling to maintain their needs from fishing may find that seaweed farming has provided an opportunity to prevent further declines into poverty, and to enable them to maintain their subsistence needs (i.e. "hang in"). In this case, seaweed farming may become more important as fish stocks decline or if and when the household loses the ability to exploit that resource (e.g.old age, sickness, loss or damage to fishing gear).

This analysis suggests that, eventually, fishing will start to give way to seaweed farming as fish stocks decline, and therefore that the predictions for the development of alternative occupations (Allison & Ellis 2001) are essentially correct. This is because, at some point, fish catches will become too low and fishing will become a more risky strategy for maintaining daily needs than seaweed farming. The reasons for reducing fishing will differ depending on whether the household is "stepping out" of fishing or "hanging in". Households in the "stepping out" category would have developed the capacity to minimise and mitigate against the risks from seaweed farming. This capacity may come from increased experience or the accumulation of sufficient capital for the construction of guardhouses, ownership and planting of larger farms with rotational harvests, and greater levels of physical and financial assets to provide some level of insurance. However, increased levels of fishing are likely to be observed until this point. For households in the "hanging in" category, fishing will no longer be viable due to continued declines in fish stocks and increasing pressure from an expanding population. The question then arises of when will this occur? Chapters 3 and 6 indicate that this is likely to be site specific, possibly related to the relative levels of risk to both fishing and seaweed farming in the particular villages, but the case study presented in this thesis indicates that it is often likely to be at an extreme degree of resource depletion.

These results have important implications for the conservation benefits of alternative occupations. This thesis did not directly examine the condition of fisheries resources on Danajon Bank. However, it is clear from other work in the area that, despite some conservation successes (e.g. the growth in the number of marine protected areas), the fisheries resources of Danajon Bank are already among the most degraded in the world (Marcus et al. 2007; Armada et al. 2009). Yet in many sites fisher numbers continue to increase and fishing remains the primary occupation (Chapter 3; Chapter 6). How much worse does the fishery need to become before noticeable declines in fisher numbers start to occur? It is clear that even in this heavily degraded area, some of the wealthiest households are still engaged in fishing and earning the majority of their income from fishing (Chapter 6). This demonstrates that fishing is not simply an occupation of last resort (Béné 2003). There is likely to be a point at which resource condition is so bad that sufficient numbers of people turn to seaweed farming to reduce aggregate fishing effort to a level that prevents further fish stock declines. This does not mean converting everyone to seaweed farming, but it is unclear how many people need to reduce their fishing effort, and by how much. Taking Danajon Bank as a whole, it seems unlikely that aggregate fishing effort has been reduced to a sustainable level yet as there are still no indications of fish stock recovery (Armada et al. 2009). However, even if it happens soon, would this constitute sustainable use of the fisheries resources of Danajon Bank? Are the levels of biodiversity loss that occur before reaching this threshold acceptable? Danajon Bank may be unusual in terms of market access, a factor which is known to drive unsustainable exploitation (Cinner & McClanahan 2006; Brewer et al. 2009). There are large population centres with fish markets in all of the 17 municipalities immediately adjacent to Danajon Bank, and the nearby Cebu City provides access to urban markets as well as international and national markets (Armada et al. 2009; Chapter 2, Fig. 2.1). The threshold resource condition at which seaweed farming becomes more attractive than fishing (leading to aggregate reductions in fishing effort of a sufficient scale to prevent further declines) is probably much lower for Danajon Bank than it would be elsewhere. However, if interventions were successful in reducing the risks associated with seaweed farming, greater reallocations of labour and household resources would be expected to occur at higher resource conditions. But it is unclear how much higher this threshold would need to be before it reached a level that constituted sustainable use of fisheries.

This raises an important consideration for the role of diversification as a conservation or resource management tool. How do we predict when diversification will result in fishing effort being sufficiently reduced to alleviate pressure on target species sufficiently to allow recovery? Such predictions may be possible with appropriate modelling tools that incorporate considerations of risk, the way that households combine occupations within their livelihood portfolios, and the different strategies that households take. Additionally, trends in human population size would need to be considered, because decreasing contribution of fishing to livelihoods may be offset by increasing numbers of people (Chapter 3). Thus, the ultimate question is, under what conditions will the development of alternative occupations be sufficient to ensure the sustainability of resource use, rather than only being sufficient to contribute towards the economic sustainability of livelihoods in these coastal communities? With limited available resources, there will probably be a trade-off between conservation and human needs when planning interventions to improve the status of social-ecological systems as a whole, as the latter may be less costly and easier to achieve than the former (McShane et al. 2011). These trade-offs should be recognised and the precise objectives of diversification programmes made explicit. However, any extra efforts to improve the potential of alternative occupations to achieve biological sustainability are likely to increase the benefits to local human communities as well.

Limitations and further research

This thesis provides some insights into the complexities associated with diversification as a tool to help reduce fishing pressure and some of the factors that influence how fishers respond to alternative occupations. However, it also raises several questions that could not be addressed within this thesis, but which would be valuable areas for further research.

It was not possible to track how welfare or levels of fishing effort had changed over time. Time series datasets tracking the fate of specific households over a number of years would enable better insights into the accumulation dynamics of households with different starting conditions (e.g. Coomes et al. 2011), and how the use of fishing and seaweed farming changes with changes in household status. This would help to test predictions about the contribution of seaweed farming to “stepping out” and “hanging in” strategies for households of different wealth categories. Combined with monitoring of the resource condition, this could also provide a valuable insight into the interaction between resource condition and fishing effort into the medium term for households with different asset categories and livelihood portfolios.

As with many similar studies, there are issues with assessing the impact of seaweed farming on livelihoods and resource use against the counterfactual (Barrett et al. 2011). Given the lack of information for “before” seaweed farming, and the difficulty of finding similar sites without seaweed farming for comparison, this would not be an easy task. Some indication of the counterfactual was provided with regards to perceived changes in fisher numbers in Chapter 3, with recall information on the situation before seaweed farming started, and information from two villages where seaweed farming had not properly started. However, there was no counterfactual for changes in welfare or fishing effort, or for population growth. Some key questions remain to be answered that could be addressed through research focused specifically on these issues. For example, whether seaweed farming has influenced emigration and immigration in these villages. Immigration as a result of the increased economic opportunities provided by alternative occupations is sometimes cited as a reason for failure of these schemes (Oates 1995; Noss 1997; Sievanen et al. 2005). However, on Danajon Bank the issue may be one of emigration rather than immigration. Recent generations of islanders on Danajon Bank have increasingly been providing the labour requirements of towns, cities and the shipping industry in the Philippines and abroad (Guieb 2008). This labour force has primarily come from new generations rather than household heads (Guieb 2008). It would be interesting to know whether this trend has been driven by decreasing fish catches, and if so, whether the opportunities provided by seaweed farming influenced this trend, and encouraged more young people to remain in their villages as fisher-seaweed farmers. If so it would be informative to know if this has influenced trajectories of change, or exacerbated the situation by maintaining higher numbers of fishers than may otherwise have remained.

The 24-hr recall surveys provided some insights into income patterns associated with fishing and seaweed farming, and relative income levels for the households concerned. However, it was not possible to link specific inputs to returns from seaweed farming because it is primarily a delayed return occupation. Therefore, the effects of different seaweed farming strategies on profitability could not be examined, and the levels of risk could not be fully quantified. Household diaries have been tried on Danajon Bank before, with very limited success due to high rates of non-completion and apparently missing information that made it difficult to determine cash flow (Barbon 2007). However, working closely with a small number of seaweed farmers it may be possible to establish a system to collect daily information on their activities, methods and species used, and link those inputs to returns. This would help to give a better idea of the risks involved, how the risks associated with different species are traded-off, and the profitability of different seaweed farming regimes (Chapter 4).

Finally, key area of further research will be to examine in more detail why different villages had such different responses to seaweed farming. Some hypotheses have been derived from the work conducted as part of this thesis, including the socioeconomic status of these villages (Chapter 3), the accessibility of these villages to wild/washout seaweed as a strategy to reduce risk (Chapter 4), and the possibility that social learning influenced outcomes following the development of (perceived) successful strategies by some individuals (Chapter 6). However, further research will be required to more closely examine the reasons for households self-defining as fishers or seaweed farmers.

Policy implications

The primary policy implications of this thesis are that in order to improve the chances that seaweed farming leads to a reduction in fishing effort, interventions should focus on providing the ‘ingredients’ to ensure success in seaweed farming. Simply helping fishers to get started with seaweed farming and allowing the development of seaweed farming to occur passively is not sufficient to reduce pressure on marine resources, especially given the context of pressure on Danajon Bank (Armada et al. 2009). Those key ingredients to ensure success include building people’s experience in seaweed farming, possibly encouraging exchanges of key individuals to villages where seaweed farming has reduced fisher numbers. Additionally, interventions have to be designed to effectively tackle risk and increase confidence in seaweed farming. The development of insurance schemes may be an important component of this (e.g. Chantarat et al. 2011), but strategies that more directly address risk will also be important. For example, the development of cooperatives to improve the negotiating powers of seaweed farmers would help to ensure seaweed farmers acquire more transparent information on prices, and could help them negotiate more stable prices. Also, assistance with construction of guardhouses for groups of seaweed farmers will help to reduce risks associated with theft. The placement of these guardhouses on remote areas of Danajon Bank would also provide access to wild seaweed growth that can act as a form of natural insurance (Chapter 4). This would also require an improved understanding of the ecological effects of seaweed farming, and how these ecological effects compare with those of current fishing practices in these areas.

Seaweed farming in these remote areas may help to provide *de facto* marine protected areas against illegal and destructive fishing practices (Sievanen et al. 2005). But they may also change benthic habitat and fish communities (Eklöf et al. 2006; Mandal et al. 2010), and given the concerns with predation of seaweed by fish (Chapter 4) and efforts that seaweed farmers may therefore take to limit predation, it remains to be seen whether fish would benefit from seaweed farming. Some of these questions are being tackled in a linked PhD study by James Hehre, working with Project Seahorse and based at the University of British Columbia, Vancouver, Canada.

Interventions to reduce risk and increase confidence in seaweed farming will help to improve the attractiveness of seaweed farming to fishers. However, there is also the potential for perverse incentives and unintended consequences with these programmes, such as initial reinvestment of increased incomes into improved fishing capital as households move towards “stepping out” of fishing (Chapter 5). Therefore, interventions involving alternative occupations should be closely tied to more direct forms of resource management, such as the establishment of marine protected areas, gear restrictions or gear exchanges. In effect, this would move alternative occupations from schemes that seek solely to raise the opportunity costs of fishing to schemes that seek to raise the opportunity costs of fishing by way of “compensation” for forgoing fishing opportunities (Chapter 1). However, these restrictions on effort should be carefully designed to avoid inadvertently increasing the vulnerability of the poorest households with the highest dependence on fishing (Chapter 5; Chapter 6). Additionally, explicit links between these direct resource management measures and seaweed farming development should be made clear to local communities, and any assistance provided in the form of ongoing financial or technical assistance made contingent upon meeting objectives of reduced exploitation. In return for help with accessing improved alternative occupations, direct conservation actions may receive increased support from local communities (Pollnac et al. 2001a; Torell et al. 2010).

An example of one way in which direct restrictions could be combined with the promotion of seaweed farming on Danajon Bank would be to use seaweed farming to buffer marine protected areas. In return for assistance with the construction of guardhouses on remote areas of reef, seaweed farmers could be required to maintain a core zone where no fishing or seaweed farming is permitted. The presence of seaweed farmers and their farms would help to deter poachers, both from the physical barriers to navigation posed by seaweed farms, and by increased ‘numbers of eyes’. This is already being trialled by PSF in the new multi-use Minantaw reserve. It will be important to monitor the effects of this set up, both on the behaviours of the benefactors, and on the marine resources within and around the core no-take zone.

Finally, the conservation benefits of even the most well designed interventions to improve the attractiveness of seaweed farming can be reduced if not offset entirely by rising human populations (Chapter 3). Without tackling human population growth these interventions may be considered at best to be ‘treading water’ and only delaying inevitable human and environmental crises. The integration of human population management with coastal resource management and alternative occupations can lead to “added value” for all stakeholders (D’Agnes et al. 2010) by resulting in greater community buy-in and acceptance of interventions (D’Agnes & Margoluis 2007). Such an integrated approach constitutes a vitally important strategy for achieving both human development and conservation objectives, and should become commonplace within the planning processes of conservation organisations and resource managers alike.

Conclusion

This thesis demonstrates that livelihoods-based approaches to the conservation of exploited species are unlikely to benefit all people engaged in the exploitation of those species all of the time. Although this thesis only examines one particular aspect of this approach, raising the opportunity costs of exploitation, the general principles can be applied to any application whereby resource managers aim to substitute for the exploitation of species, whether through incentives, compensation or alternatives. The complexity of livelihoods necessitates the consideration of reasons for engaging in the exploitation of species and how these reasons vary along a range of different dimensions. Well researched and well designed livelihoods-based interventions can make an important contribution towards conservation activities under the right circumstances and if they are adequately tailored to local needs and aspirations. Within this context, this thesis found that the frequency and timing of income from alternative occupations, together with risks associated with those occupations, are essential considerations in determining whether they meet people’s needs.

Livelihoods-based approaches can also help to safeguard or possibly improve the welfare of people engaged in the unsustainable exploitation of species. However, it should not be assumed that they will have the desired effect of substituting for the exploitation of these species. Even if they do partially substitute for this exploitation, it should not be assumed that the aggregate effect will be sufficient to achieve a level of exploitation that will ensure the persistence of target species. Thus, they are neither a quick nor easy fix, and should be combined with direct forms of resource management such as effort and spatial restrictions.

It is clear that solely introducing alternative occupations and passively allowing their development will be insufficient to change behaviours on the scale that is required for conservation, especially in the context of increasing human populations and other increasing environmental pressures such as climate change. Therefore, livelihoods-based approaches should be focused on providing the 'enabling environment' required to actively encourage and attract people to those alternative occupations. In the case of Danajon Bank, this involves building experience in seaweed farming and addressing issues of risk. In other contexts, the creation of enabling environments may involve other features. The more effort that managers and policy-makers put into understanding what is required to provide those enabling environments in the specific context that livelihoods-based interventions are being designed for, the more both biodiversity conservation and human development stands to gain.

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APPENDIX S2

Supporting Information for Chapter 2

S2.1. Survey instruments – Datasheets for the questionnaire used for the extensive surveys (Chapter 2 section 2.5).

Barangay: ________________________Date: _____________________ Interviewer: GS / LM / NH

Head of household: ______________________ Purok: _______ Respondent(s): ________________________

INTRODUCTION

CONFIDENTIALITY

PERMISSION – does the respondent(s) give his/her permission to conduct this interview?

Yes / No

Signature of respondent:

1. List household (HH) members and their details:

Name:	Sex:	Age:	Education level:	Occupation:	Any official position (e.g. village police):	Heads of HH (tick)	Living outside?
							Y / N
							Y / N
							Y / N
							Y / N
							Y / N

							Y / N
							Y / N
							Y / N
							Y / N
							Y / N
							Y / N
							Y / N
							Y / N
							Y / N
							Y / N

2. Timeline of fisher numbers (these are described in Chapter 3, and images of example timelines are provided in Appendix S3):

3. What are the existing sources of income for your household, and what is the current monthly income for your household from these sources?

a. Fishing □ Specify: _____________ Monthly income: ______________

i. Fish trading □ Specify: _____________ Monthly income: ______________

b. Seaweed farming □ Monthly income: ______________

i. Seaweed trading □ Monthly income: ______________

c. Sari-sari store / ministore □ Monthly income: ______________

d. Water selling □ Monthly income: ______________

e. Other trading □ Specify: _____________ Monthly income: ______________

f. Handicraft □ Specify: _____________ Monthly income: ______________

g. Hired labour □ Specify (e.g. carpenter, mechanic, fishpond worker):_____________________ Monthly income: ___________________

h. Self labour □ Specify: _____________ Monthly income: ______________

i. Professional with salary □ Specify (e.g. teacher, councillor, police):_____________________ Monthly income: _________________

j. Remittances □ Monthly income: _____________

k. Other □ Specify: _____________ Monthly income: ______________

4. Information for material style of life:

a. How many bedrooms (separate to living space) does the respondent's household contain?

- 1 room only □
- 2 rooms □
- 3 rooms □
- More than 3 rooms □ Number: _______________

b. What are walls of respondent's house made of?

- Native □
- Non-native □
- Mixture □

c. What is the roof of respondent's house made of?

- Native □
- Non-native □
- Mixture □

d. What is the floor of respondent's house made of?

- Native □
- Non-native □
- Mixture □

e. Does the respondent's household have a flush toilet? Yes / No

f. How many of each of the following appliances does the household have that are *currently functional*?

Television ____
DVD / VCD ____
Sound system ____
Radio ____
Videoke ____
Electric fan ____
Iron ____
Generator ____

g. How many of the following boats does the household own that are *currently functional*?

Baroto _____
Pumpboat _____

5. Is the respondent a fisher? Yes / No

If yes:

a. Why do you fish? (Please score, 0=no importance, 1=low importance, 3=high importance)

Lack of other options: 0__1__2__3 Details: ________________

Because it provides income: 0__1__2__3 Details: ________________

Because it provides food: 0__1__2__3

Because you own the gear: 0__1__2__3

Because it is reliable: 0__1__2__3

Because you enjoy it: 0__1__2__3

Traditional: 0__1__2__3

Possible to get jackpot: 0__1__2__3

Other ______________: 0__1__2__3 Details: ________________

Other ______________: 0__1__2__3 Details: ________________

If no, has the respondent ever been involved in fishing in the past: Yes / No

b. What fishing did you used to do? ______________________________

c. When did you give up fishing? ______________________________

d. Why did you give up fishing? (Please score, 0=no importance, 1=low importance, 3=high importance)

Old age / health: 0__1__2__3

Regulations / enforcement: 0__1__2__3 Details: ________________

Declining catches: 0__1__2__3 Details: ________________

Lack of gear: 0__1__2__3 Details (stolen / lost / broken / no money): _____

Income is not reliable: 0__1__2__3

Seaweed farming: 0__1__2__3

Other livelihood: 0__1__2__3 Details: ________________

Other ________________: 0__1__2__3 Details: ________________

Other ________________: 0__1__2__3 Details: ________________

6. Is the respondent a seaweed farmer? Yes / No

If yes:

a. Do you own your seaweed farming area? Yes / No

If yes: How big is your seaweed farming area? ________________________

Units: _______________

b. How important are these risks and constraints to seaweed farming? (Please score, 0=no importance, 1=low importance, 3=high importance)

Stealing. 0__1__2__3

Disease. 0__1__2__3

Eating by fish 0__1__2__3

Marketing problems 0__1__2__3 Details: __________________

Poor / lack of technology 0__1__2__3 Details: __________________

Unstable price 0__1__2__3

Weather / natural disaster 0__1__2__3

Lack of area for expansion 0__1__2__3

Lack of capital for expansion 0__1__2__3

Access to seedlings 0__1__2__3

Other__________________: 0__1__2__3 Details: __________________

Other_________________: 0__1__2__3 Details: _________________

c. Have you had any training in seaweed farming techniques or management, or had access to any seaweed farming technicians that can provide training? Yes / No

If yes, who from? _____________________________

d. What / who are your sources of financial capital for seaweed farming?

Personal savings □

BFAR / other agency □ Details: ______________________

Industry □ Details: ______________________

Individual / investor □ Details: ______________________

Bank (e.g. LandBank, TSKI, FCB) □ Details: ______________________

Araw-araw □ Details: ______________________

Other__________________: □ Details: ______________________

e. Are you a member of a People's Organisation relevant to seaweed farming? Yes / No

If yes, name of organisation: ____

S2.2. Survey instruments – screen shots for datasheets for the intensive 24-hr recall surveys (Chapter 2 section 2.6).

Project Seahorse Foundation for Marine Conservation HH2v3

Date: Day of the week: Time: Interviewer(s): Sign and date:

Barangay: Household: Purok: Interviewees

Fishing activities:

Fishing activity	HH members	No. hours	Owner	Income method	Number of shares	INCOME / PRODUCTION			EXPENSES			NET INCOME for HH	FOOD		GIFTS	
						Item / qty	Price	Total income	Item / qty	Price	Total expense		Item / qty	Price	Item / Qty	Price
Fishing ______________																
Fishing ______________																
Fishing ______________																
Gear maintenance ______________																
Balansi / Sale of Kept Fish. ______________																

Seaweed Activities:

	HH members	No. hours	Owner	Income method	Number of shares	Species	INCOME / PRODUCTION		EXPENSES		NET INCOME for Household
							Unit Price	Total Income	Item and unit price	Total Expenses	
Preparing softie											
Seaweed split											
Seaweed planting											
Seaweed tending / guarding											
Seaweed harvesting											
Seaweed drying / sacking											
Seaweed sales						(wet/dry)					
Seaweed buying											
Washout collecting											
Seaweed transport											

	HH members	No. hours	Owner	Income method	Number of shares	Income / production	Expenses	TOTAL NET income for the Household
Sari-sari store								
Water Selling								
Other sales ________________								
Buying __________________								
Firewood making __________________								
Handicraft / mat making __________________								
Livestock keeping __________________								
Hired labour (eg fishpond) __________________								
Hired labour (eg carpenter) __________________								
Barangay official work __________________								
Other activity __________________								

REMITTANCES, LOANS, PAYMENT FOR OTHER WORK

Income type	Date	Details		Total income	Purpose
When was the last time you sold seaweed?		Species	Unit price		
When was the 2nd last time you sold seaweed?		Species	Unit price		

What were other HH members doing?

APPENDIX S3

Supporting Information for Chapter 3

S3.1 Key informant estimates of fisher numbers before and after seaweed farming started.

Methods – further information

Key informants included people who had been village health workers, village secretaries (who were responsible for maintaining census lists and recording information such as occupations), People's Organisation (community groups specific to each village) leaders, fishers and seaweed farmers during the year of interest. Normally, key informants held more than one of these posts (i.e. the village secretary was also a fisher and/or seaweed farmer). If key informants were uncertain of household's occupations, they were asked to recommend other key informants that did know of them. Perhaps due to the relatively small geographical area of these villages and the interrelatedness of people from different households, we generally found people to have good knowledge of other households in the village, or at least of the households nearby to them.

Large villages were divided into their respective *puroks* or *sitios* (subdivisions of Filipino villages) and appropriate key informants found for each subdivision. The number of households validated or recalled by key informants varied depending on their knowledge of village members and the level and accuracy (i.e. proximity to the year of interest) of information already available from census lists.

These lists were analysed by calculating the changes in: proportion of households involved in fishing; actual number of households involved in fishing; and total number of households. The number of years since seaweed farming started varied substantially between villages, so all results were standardised per year to enable comparison. Changes in absolute numbers were expressed as compound annual change rates (CACR; Equation 1).

$$(1)\ \text{CACR} = ((\text{Value After} / \text{Value Before})\ ^\wedge\ (1 / \text{No. years})) - 1$$

Results- further information

Key informant estimates demonstrate that the proportion of fishers fell substantially in three of the villages were respondents had perceived that number of fishers had decreased (see main text): Alumar (before, 85% of households; after, 56%), Hingutanan East (before, 70%; after, 6%) and Mahanay (before, 68%; after, 32%). In those villages where number of fishers were perceived to have increased (see main text: Handumon, Cuaming, Hambungan and Guindacpan), proportions of households fishing had decreased slightly, but by only 7.9-8.2% (range of starting values; Handumon, 55.6% of households - Cuaming, 88.2%). After controlling for the amount of time since seaweed farming started, Alumar, Hingutanan East and Mahanay showed faster rates of decline in proportion of fishers than villages where number of fishers were perceived to have increased (Fig. S3.1). In Bilangbilangan East the proportion of households fishing had actually increased slightly (before, 63.8%; after, 65.1%), perhaps primarily as a result of a return to fishing that respondents had perceived (see main text) in 2008.

Since seaweed farming started in each village, the total number of households increased between 115% (Guindacpan) and 733% (Hingutanan East). This represents a cumulative annual growth rate of over 2% for all villages except Guindacpan (Fig. S3.1). Population growth rate was highest in Alumar and Hingutanan East. Anecdotal reports in Alumar (the highest population growth rate) and Mahanay indicated some residents that had left to pursue work outside these villages had returned, sometimes because of the opportunities of seaweed farming and the way of life. In Hingutanan East, anecdotal reports indicated immigration from terrestrial farmland areas on Bohol was becoming increasingly common.

Despite substantial declines in the proportion of fishing households in Alumar, Hingutanan East and Mahanay, actual fisher numbers only declined overall in Hingutanan East (before, 38; after, 24) and Mahanay (before, 163; after, 107). Controlling for time since seaweed farming started, Mahanay had the fastest decline in fisher numbers (Fig. S3.1). Alumar showed an increase in fisher numbers (before, 68; after, 98) (Fig. S3.1).

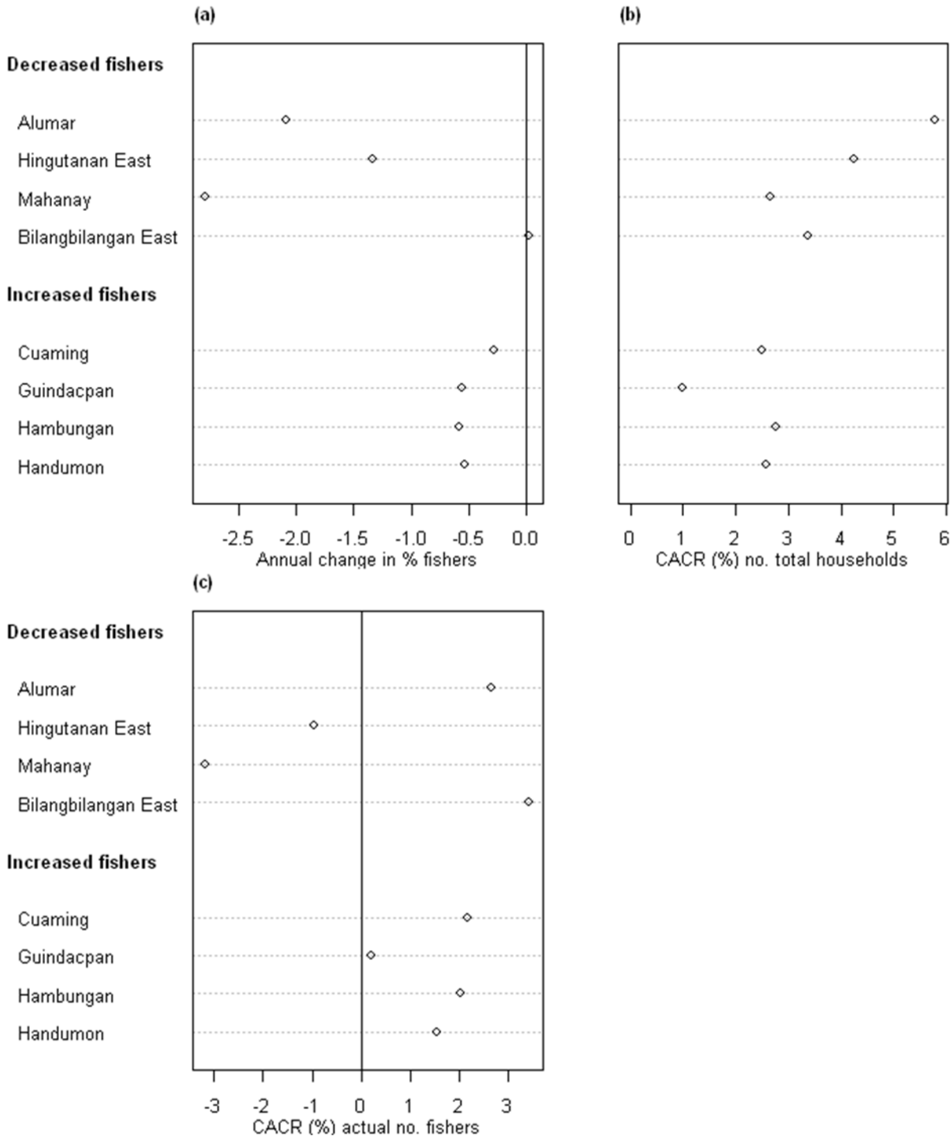


Figure S3.1 Results of key informant estimates. (a) Annual change in proportion of fishers; (b) annual rate of change of total number of households; (c) annual rate of change of actual number of fishing households. (b) and (c) are expressed as compound annual change rates (CACR). Results are shown for the four villages where respondents perceived decreases in number of fishers, and for the four villages where respondents perceived increases in number of fishers.

S3.2. Socioeconomic and seaweed farming attributes of households from each village, and village-level statistics.

Socioeconomic attributes collected for all interviewed households included the number of other income sources, wealth score, education, household size and monthly income:

- The number of other income sources was based on occupational categories, and was calculated as the total number of occupational categories outside of fishing (including gleaning) and seaweed farming. Occupational categories included trading of fish/shellfish products; trading of seaweed; agriculture (including livestock, coconuts and arable); salaried employment (e.g. village official or teacher); business (e.g. selling of food or water); casual labouring; handicraft; housemaid; trade of other products (e.g. firewood); independent trade work (e.g. carpentry or mechanical), and; remittances sent by family members living elsewhere.

- Wealth score was based on material style of life scores and ranged from -2.91 (poorest) to 7.33 (wealthiest) (Chapter 2, section 2.5).

- Education was calculated for the heads of households only, and was calculated as the mean number of years that the heads of household had spent in education.

- Household size was the total number of people that live within the household and share their incomes and regularly take meals together.

- Monthly income was the sum of monthly income from all sources of income, estimated for the month prior to the interview. Incomes were recorded in Philippine Pesos (P) and converted to US$ using the 2009 average exchange rate of P47.64 to US$1.

Seaweed farming attributes were collected for all interviewed households that were engaged in seaweed farming, and included size of seaweed farm, whether the household privately owned a seaweed farm, whether any members of the household were a member of a People's Organisation (a community Organisation), whether the household had used their own savings or financial assets to finance the start-up costs of seaweed farming, whether household members were satisfied with seaweed farming production, and whether any members of the household had received any technical assistance or training for seaweed farming. Seaweed farm size was measured in local units (*dupa*, which is equivalent to a fathom), and later converted to hectares. Finance was considered personal if the households own financial capital was used to finance the start-up of seaweed farming, and external if they obtained a loan or government assistance. Satisfaction with seaweed farming was used as a proxy for biological productivity (dissatisfaction indicating that a household's seaweed farming area may not be as suitable for seaweed growth), as time constraints meant we could not measure the growth rate of seaweed in all sites.

Village-level attributes collected included the number of households in the village for the year before seaweed farming started and for 2008 (based on key informant estimates, Appendix S3), population size in 2007 (based on national census data; NSO 2007), and population density, and distance to markets. Population density was calculated from area estimates for each island from village profiles held by village officials and estimation from maps where this was not available. Population densities were placed into categories because multiple and different area estimates were available for each island. The range of population densities estimated fell completely within the category that they were assigned to (1,000-2,000 people km^{-2}, >10,000 people km^{-2}). Distance to market included the distance to the municipal centre where weekly fish markets are held, and distance to Cebu City where the carrageenan producers that buy dried seaweed are based. Straight-line distances were calculated in Google Earth.

Results are presented in Table S3.2.

Table S3.2 Socioeconomic (mean (SE), unless otherwise stated) and seaweed farming attributes (counts) of systematically sampled households in each village (n=30 per village), and village level statistics (largest and smallest values within each characteristic highlighted).

	Decreased fishers				*Increased fishers*				*Other*	
	Alumar	*Hingutanan East*	*Mahanay*	*Bilangbilangan East*	*Cuaming*	*Guindacpan*	*Hambungan*	*Handuman*	*Batasan*	*Bilangbilangan Tub*
Socioeconomic										
Other incomes	0.70 (0.15)	0.47 (0.15)	0.57 (0.14)	**0.97** (0.19)	**0.30** (0.09)	0.67 (0.17)	0.90 (0.17)	0.63 (0.14)	0.60 (0.15)	0.47 (0.11)
Wealth score[a]	**-1.02** (0.29)	**1.32** (0.44)	-0.45 (0.26)	0.37 (0.41)	-0.24 (0.17)	-0.17 (0.27)	0.14 (0.29)	0.55 (0.35)	0.08 (0.28)	-0.58 (0.24)
Education; yrs	4.55 (0.39)	**8.25** (0.68)	4.58 (0.34)	6.58 (0.43)	**4.30** (0.31)	4.37 (0.33)	5.38 (0.47)	5.10 (0.39)	6.83 (0.44)	5.43 (0.45)
Household size	**4.70** (0.37)	5.17 (0.46)	4.83 (0.44)	5.63 (0.41)	5.00 (0.34)	**6.00** (0.49)	5.77 (0.41)	5.07 (0.34)	5.03 (0.33)	5.47 (0.29)
Monthly incomes; US$[b] median (range)	136 (19-596)	**176** (32-630)	126 (57-199)	144 (21-504)	**90** (19-220)	126 (42-420)	133 (38-735)	143 (38-924)	126 (63-399)	94 (5-163)
Seaweed farming										
Yr seaweed farming started	1996	1962	1997	1971	1980	1996	1996	1995	2008	NA
n[c]	30	26	30	14	17	17	29	27	13	NA
Size of seaweed farm; ln(ha)	-1.28 (0.18)	**-0.02** (0.13)	-0.60 (0.20)	-0.54 (0.21)	-1.59 (0.26)	-1.48 (0.40)	-2.19 (0.16)	-1.37 (0.27)	**-2.92** (0.40)	NA
Owner of seaweed farm?	27	21	29	2	16	15	27	22	10	NA
Member of People's Organisation?	10	3	3	4	3	4	23	9	3	NA
Personal finance?	16	20	28	11	8	11	12	13	1	NA
Satisfied with seaweed production?	29	24	26	14	16	16	28	24	13	NA
Receipt of training?	3	4	4	5	5	2	16	5	1	NA
Village-level										
# households before seaweed farming	80	54	239	47	289	343	75	133	256	NA
# households after	176	396	336	172	605	394	110	195	262	134
Population 2007	768	1,756	1,919	563	2,848	2,204	568	1,012	959	635
Pop density (km^{-2})	<2,000	>10,000	<2,000	<2,000	>10,000	>10,000	>10,000	<2,000	>10,000	>10,000
Seaweed market (km)	35	63	39	61	22	42	28	33	32	26
Market town (km)	7	16	10	15	12	10	6	4	8	13

[a] Wealth scores are based on material style of life scores (see Appendix S2).

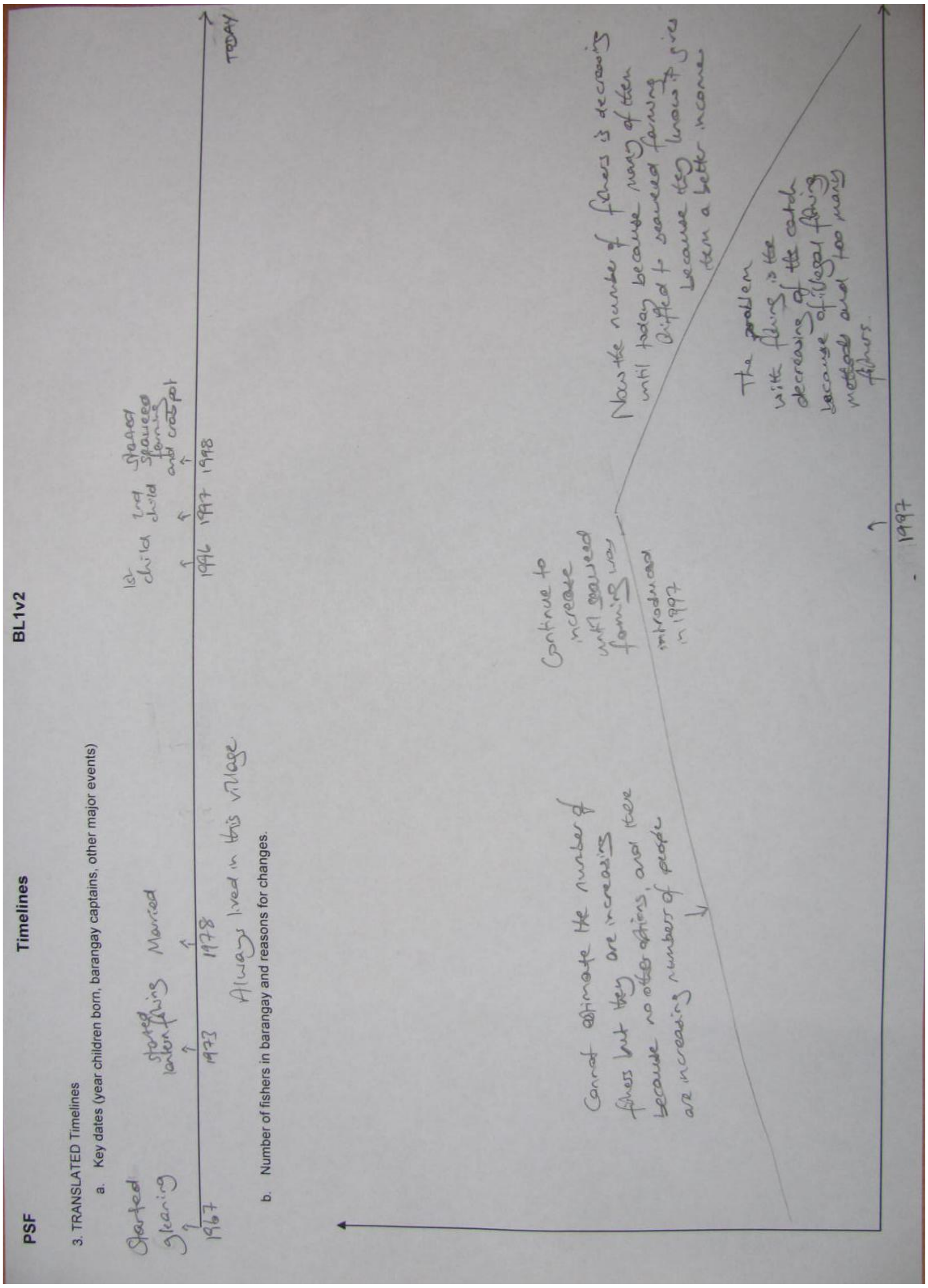
[b] US$ equivalents based on the 2009 average exchange rate of Philippine Peso (PhP) 47.64 to US$1.

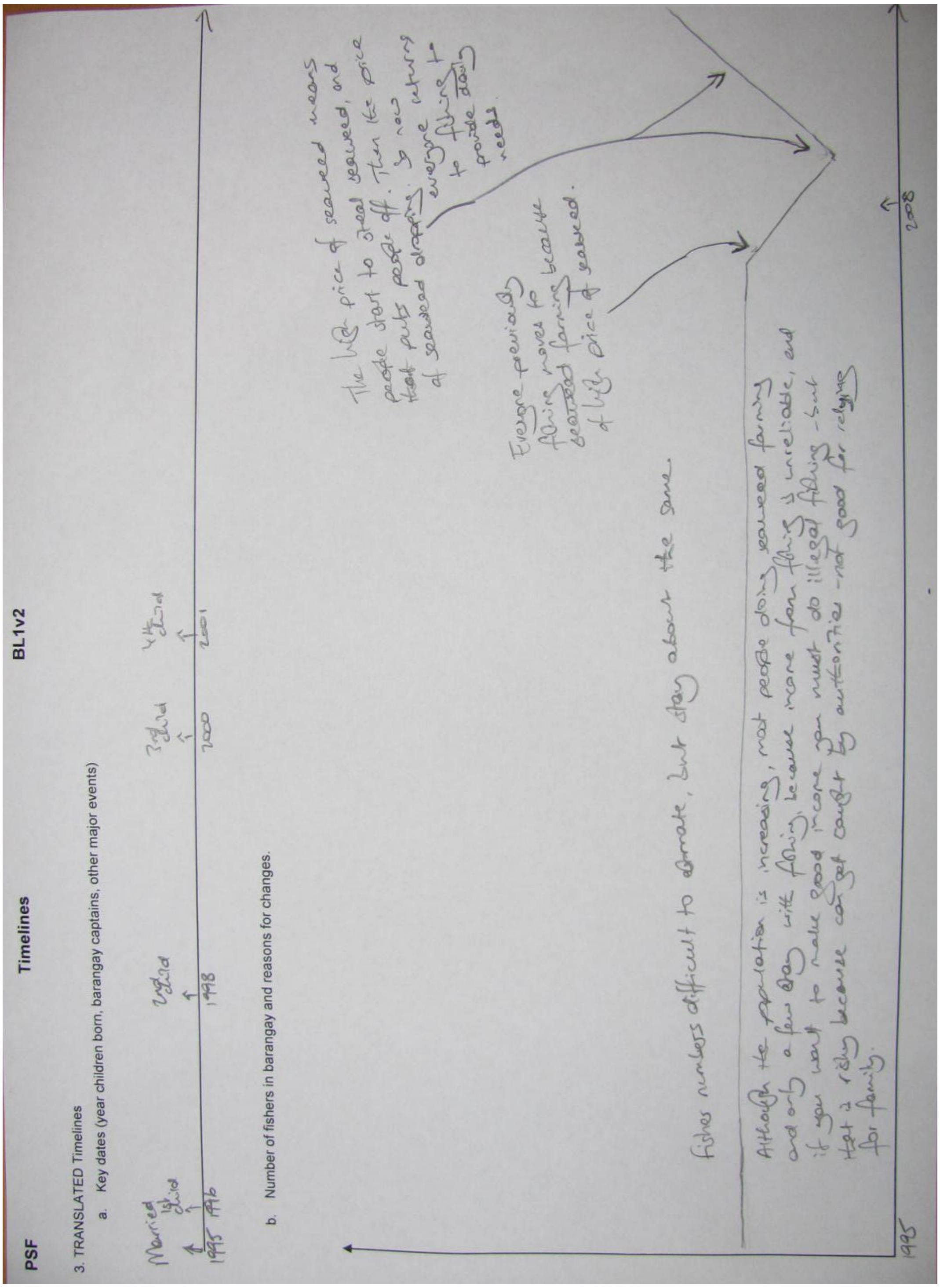
[c] Number of systematically sampled households (n=30 per village) that were currently involved in seaweed farming, and for which seaweed farming characteristics were measured.

References cited for Appendix S3.2

NSO (National Statistics Office of the Philippines). 2007. 2007 Census of Population. Available from http://www.nscb.gov.ph/activestats/psgc/province.asp?regName=REGION+VII+%28Central+Visayas%29&regCode=07&provCode=071200000&provName=BOHOL accessed 2nd September 2011.

S3.3. Two examples of timelines used to collect information on perceived changes in fisher numbers.





PSF Timelines BL1v2

3. TRANSLATED Timelines

a. Key dates (year children born, barangay captains, other major events)

Married – 1995
1st child – 1996
2nd child – 1998
3rd child – 2000
4th child – 2001

b. Number of fishers in barangay and reasons for changes.

The high price of seaweed means people start to steal seaweed, and that puts people off. Then the price of seaweed dropping. So now everyone returns to fishing to provide daily needs.

Everyone previously fishing moves to seaweed farming because of high price of seaweed.

fishers numbers difficult to estimate, but stay about the same.

Although the population is increasing, most people doing seaweed farming and only a few stay with fishing, because income from fishing is unreliable, and if you want to make good income you must do illegal fishing - but that is risky because can get caught by authorities - not good for relying for family.

1995

2008

APPENDIX S4

Supporting Information for Chapter 4

Appendix S4.1. Correlations between measures of effort for fishing, seaweed farming and informal sector occupations.

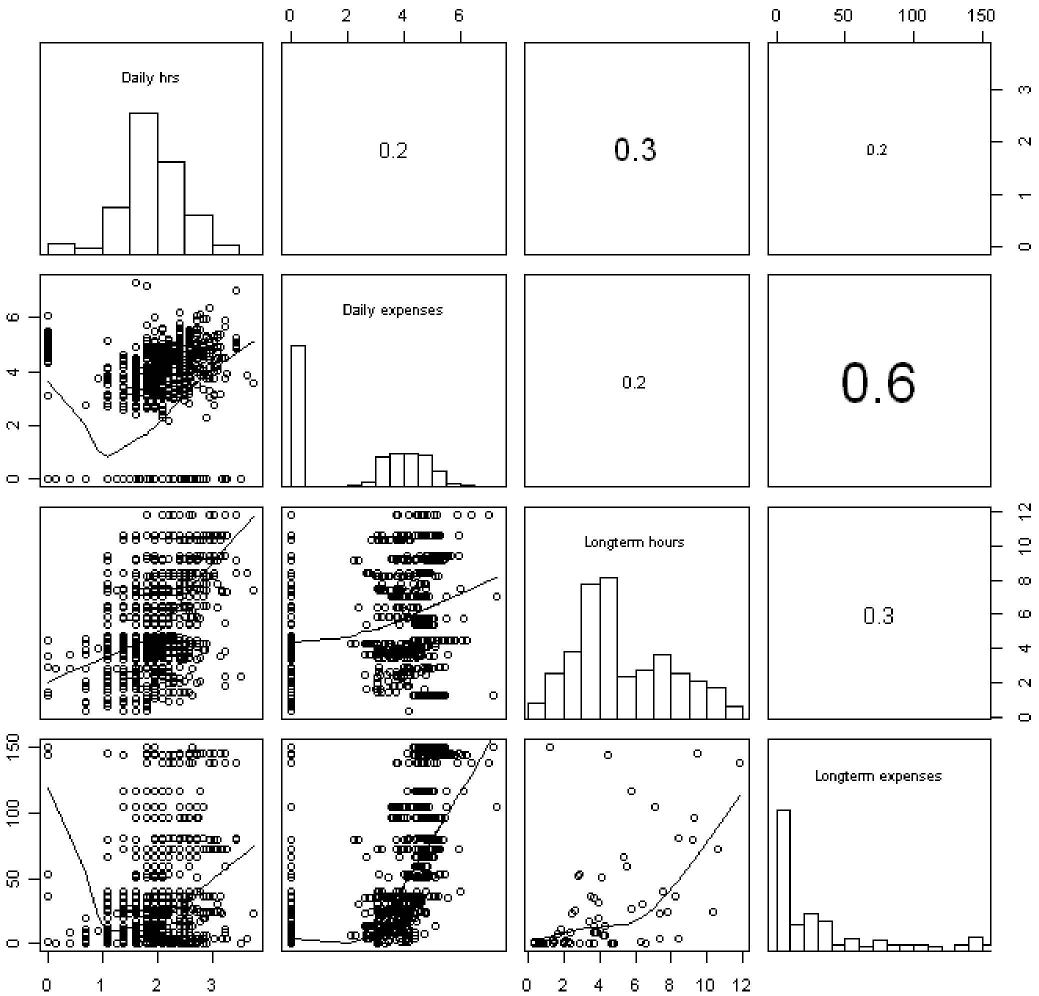


Figure S4.1.1 Histograms and pairwise plots of short-term and long-term measures of fishing effort with LOESS smoother, and Kendall correlation coefficients.

Table S4.1.1 Variance inflation factors for short-term and long-term measures of fishing effort (all values less than 3 indicates no problem with collinearity).

Explanatory variable	GVIF
Same-day time	1.47
Same-day expenses	2.00
Long-term time	1.63
Long-term expenses	2.19

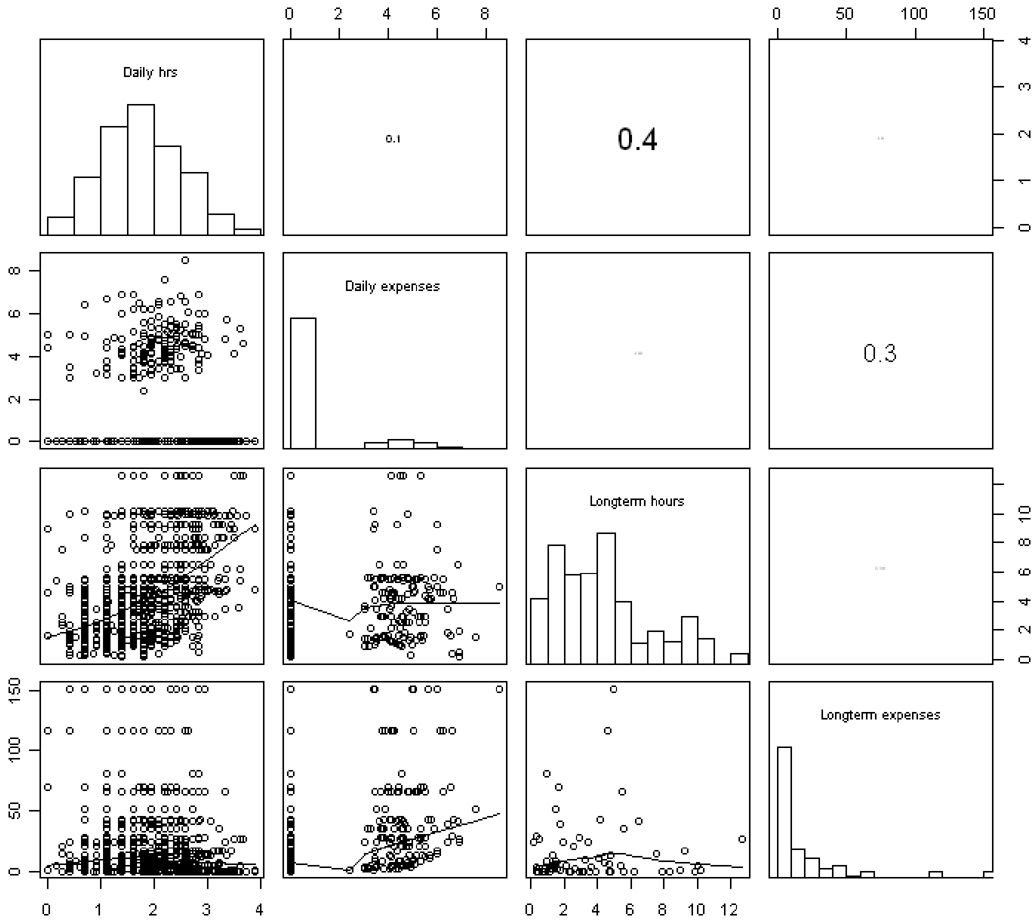


Figure S4.1.2 Histograms and pairwise plots of short-term and long-term measures of seaweed farming effort with LOESS smoother, and Kendall correlation coefficients.

Table S4.1.2 Variance inflation factors for short-term and long-term measures seaweed farming effort (all values less than 3 indicates no problem with collinearity).

Explanatory variable	GVIF
Same-day time	1.37
Same-day expenses	1.18
Long-term time	1.34
Long-term expenses	1.14

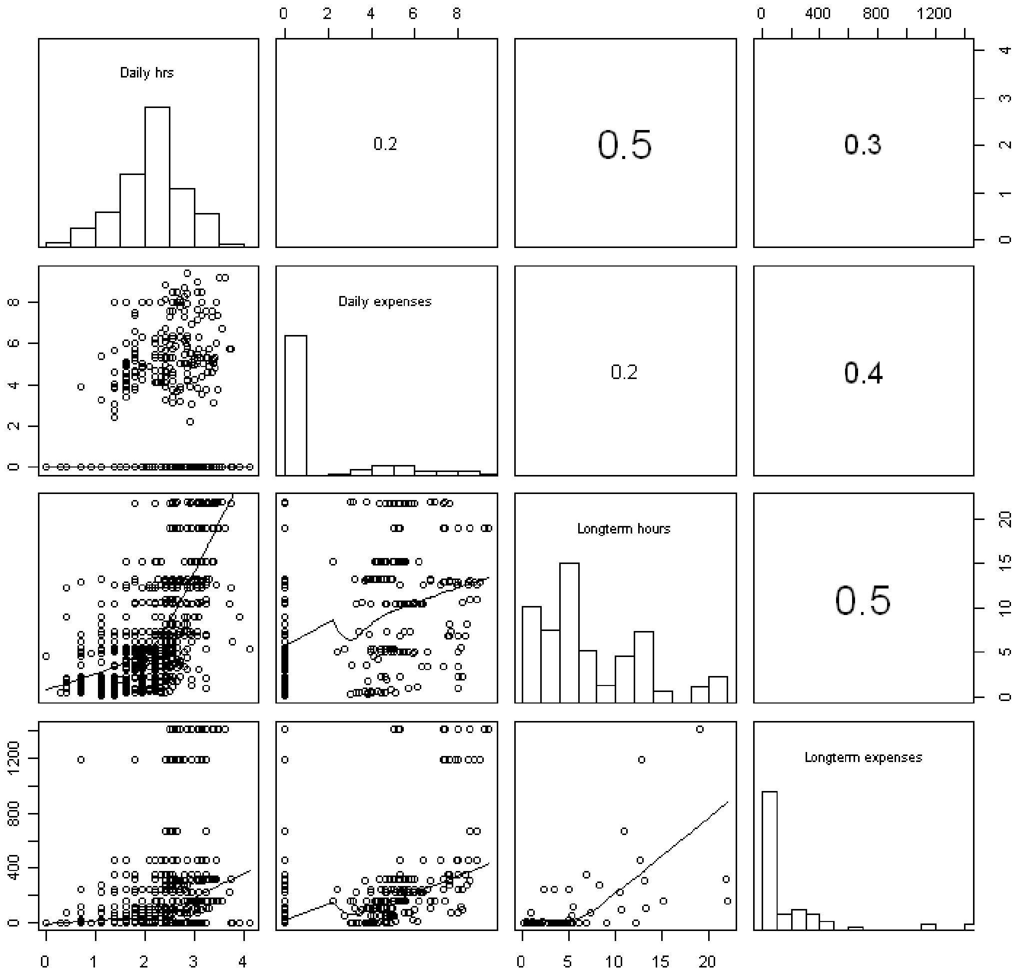


Figure S4.1.3 Histograms and pairwise plots of short-term and long-term measures of informal sector effort with LOESS smoother, and Kendall correlation coefficients.

Table S4.1.3 Variance inflation factors for short-term and long-term measures informal sector effort (all values less than 3 indicates no problem with collinearity).

Explanatory variable	GVIF
Same-day time	1.66
Same-day expenses	1.14
Long-term time	2.26
Long-term expenses	1.58

Appendix S4.2. Model averaging procedure for linear mixed effects models

For linear mixed effects models (LMMs), to select the 95% confidence set of models all possible combinations of explanatory variables (excluding interactions) were fitted using Maximum Likelihood (ML) estimation procedures in order to accurately estimate Akaike's Information Criterion (AIC) and Akaike weights (w_i) for each model. These Akaike weights were used to select the 95% confidence set. However, Restricted Maximum Likelihood (REML) estimation methods were required for parameter estimation (Zuur et al. 2009). Therefore, the 95% confidence set were re-run using REML estimation procedures. The model averaging procedure then used the parameter estimates from the REML fitting procedure and the rescored Akaike weights for the top models based on the AIC values from the ML fitting procedure to calculate weighted averages of parameter estimates. Example code is provided below, including the code for the modified model averaging procedure.

Run the full model using the ML fitting procedure (using lme4 package; Bates et al. 2011). This uses an example where random slopes are only included for same-day time within each household (HouseholdID). In this model, each income event is modelled (IncomeMagnitude).

```
full.mod <- lmer (IncomeMagnitude ~ 1 + Village + Season +
      SameDayTime + SameDayExpenses + LongTermTime +
      LongTermExpenses + Respondent + (1 +
      SameDayTime|HouseholdID), REML = FALSE, data = mydata)
```

Run all possible combinations of fixed effects (using MuMIn package; Barton et al. 2011).

```
all.combinations <- dredge (global.model = full.mod)
```

Determine the sum of Akaike weights closest to 0.95.

```
sum (subset (all.combinations, cumsum (weight) <= .95,
      recalc.weights = F)$weight)
```

at this stage, the ".95" is increased to check whether the closest value over 0.95 is closer to 0.95 than the closest value under it. Assume in this example that the closest value to 0.95 is 0.96.

Refit the top models with REML.

```
top.mods <- get.models (all.combinations, subset = cumsum
        (weight) <= .96, REML = TRUE)
```
the top models can be accessed from this object in order to run model validation plots.

Weighted model averaging procedure, using the REML parameter estimates and ML Akaike weights. The code for this function was modified from code kindly provided by Kamil Barton (via email), the author of the MuMIn package. It is inefficient because it requires the models to be refit again using ML, but it produces the desired result.

```
AICc_ML <- function (object) AICc (update (object, REML =
FALSE))
```

```
mod.average <- model.avg (top.mods, rank = AICc_ML)
```
the object created at this stage contains both the weighted average parameter estimates and the Relative Importance values for each variable.

Appendix S4.3. Model tables for Chapter 4 Table 4.1. See main text for details of the variables and responses, including units and transformations, and the modelling approach.

Table S4.3.1 Model selection table for the probability of obtaining income from a seaweed farming day in Guindacpan, with the models from the 95% confidence set of models. Each row represents a model, and the ticks indicate which variables were included in each model. PoOD=Proportion of Occupation Days. k = number of parameters in the model. Akaike weights (w_i) were calculated based on the full set of models, so add up to the nearest possible value to 0.95. Variables are ordered in the same sequence as in the main text.

Model #	Same day time	Same day expenses	Long-term time	Long-term expenses	Season	PoOD	Respondent	k	Δ	w_i
1	✔	✔		✔	✔		✔	8	0.000	0.246
2	✔	✔	✔	✔	✔		✔	9	0.550	0.187
3	✔	✔		✔			✔	6	1.449	0.119
4	✔	✔		✔	✔	✔	✔	9	1.455	0.119
5	✔	✔	✔	✔			✔	7	2.354	0.076
6	✔	✔	✔	✔	✔	✔	✔	10	2.617	0.066
7	✔	✔		✔		✔	✔	7	3.025	0.054
8	✔			✔	✔		✔	7	4.321	0.028
9	✔	✔	✔	✔		✔	✔	8	4.408	0.027
10	✔		✔	✔	✔		✔	8	5.299	0.017
11	✔			✔			✔	5	5.587	0.015

Table S4.3.2. Model estimates for the probability of obtaining income from a seaweed farming day in Guindacpan, based on the model average of the 95% confidence set of models. Relative importance for each variable is based on the sum of the recalculated w_i for each model in which the variable appears. PoOD=Proportion of Occupation Days. Variables are ordered in the same sequence as in the main text.

Variable	Coefficient	SE	Relative importance
(Intercept)	1.256	0.498	
Same day time	-0.644	0.172	1.000
Same day expenses	0.651	0.316	0.936
Long-term expenses	-0.026	0.005	1.000
Long-term time	0.037	0.071	0.391
Season: Habagat	-0.369	0.323	0.695
Season: Hot	-0.329	0.299	0.695
PoOD	0.103	0.514	0.279
Respondent	1.178	0.340	1.000

Table S4.3.3. Model selection table for the probability of obtaining income from a seaweed farming day in Handumon, with the models from the 95% confidence set of models. Each row represents a model, and the ticks indicate which variables were included in each model. PoOD=Proportion of Occupation Days. k = number of parameters in the model. Akaike weights (w_i) were calculated based on the full set of models, so add up to the nearest possible value to 0.95. Variables are ordered in the same sequence as in the main text.

Model #	Same day time	Same day expenses	Long-term time	Long-term expenses	Season	PoOD	Respondent	k	Δ	w_i
1				✔				3	0.000	0.101
2			✔	✔				4	1.356	0.051
3				✔			✔	4	1.434	0.049
4				✔	✔			4	1.490	0.048
5				✔		✔		4	1.604	0.045
6		✔		✔				4	1.959	0.038
7	✔			✔				4	2.034	0.036
8			✔	✔			✔	5	2.897	0.024
9				✔	✔		✔	5	2.903	0.024
10			✔	✔	✔			5	2.919	0.023
11				✔	✔	✔		5	3.182	0.021
12				✔		✔	✔	5	3.189	0.020
13	✔		✔	✔				5	3.325	0.019
14		✔	✔	✔				5	3.334	0.019
15		✔		✔			✔	5	3.357	0.019
16			✔	✔		✔		5	3.395	0.018
17	✔			✔			✔	5	3.455	0.018
18		✔		✔	✔			5	3.458	0.018
19	✔			✔	✔			5	3.532	0.017
20		✔		✔		✔		5	3.589	0.017
21	✔			✔		✔		5	3.634	0.016
22								2	3.720	0.016
23	✔	✔		✔				5	4.004	0.014
24			✔	✔	✔		✔	6	4.441	0.011
25				✔	✔	✔	✔	6	4.738	0.009
26	✔		✔	✔			✔	6	4.811	0.009
27		✔		✔	✔		✔	6	4.833	0.009
28		✔	✔	✔			✔	6	4.844	0.009
29		✔	✔	✔	✔			6	4.904	0.009
30	✔		✔	✔	✔			6	4.942	0.009
31			✔	✔		✔	✔	6	4.951	0.008
32	✔			✔	✔		✔	6	4.954	0.008
33			✔	✔	✔	✔		6	4.972	0.008
34					✔			3	5.143	0.008
35		✔		✔		✔	✔	6	5.144	0.008
36		✔		✔	✔	✔		6	5.174	0.008
37	✔			✔		✔	✔	6	5.197	0.007
38	✔			✔	✔	✔		6	5.235	0.007
39		✔						3	5.277	0.007
40							✔	3	5.298	0.007
41	✔	✔	✔	✔				6	5.333	0.007
42	✔		✔	✔		✔		6	5.377	0.007
43		✔	✔	✔		✔		6	5.383	0.007
44	✔	✔		✔			✔	6	5.400	0.007
45	✔	✔		✔	✔			6	5.502	0.006
46	✔	✔		✔		✔		6	5.637	0.006
47	✔							3	5.690	0.006
48			✔					3	5.691	0.006
49						✔		3	5.692	0.006
50		✔	✔	✔	✔		✔	7	6.394	0.004
51	✔		✔	✔	✔		✔	7	6.430	0.004
52			✔	✔	✔	✔	✔	7	6.498	0.004
53		✔		✔	✔	✔	✔	7	6.697	0.004
54					✔		✔	4	6.710	0.004
55		✔			✔			4	6.720	0.003
56		✔					✔	4	6.757	0.003
57	✔			✔	✔	✔	✔	7	6.787	0.003
58	✔	✔	✔	✔			✔	7	6.802	0.003
59	✔		✔	✔		✔	✔	7	6.868	0.003
60	✔	✔		✔	✔		✔	7	6.897	0.003
61		✔	✔	✔		✔	✔	7	6.905	0.003
62	✔	✔	✔	✔	✔			7	6.950	0.003
63		✔	✔	✔	✔	✔		7	6.967	0.003
64	✔		✔	✔	✔	✔		7	7.005	0.003
65			✔		✔			4	7.139	0.003
66					✔	✔		4	7.150	0.003
67	✔				✔			4	7.159	0.003
68	✔	✔		✔		✔	✔	7	7.180	0.003
69	✔						✔	4	7.212	0.003
70	✔	✔		✔	✔	✔		7	7.237	0.003
71		✔	✔					4	7.252	0.003
72		✔				✔		4	7.266	0.003
73	✔	✔						4	7.301	0.003
74			✔				✔	4	7.301	0.003
75						✔	✔	4	7.316	0.003

Table S4.3.5. Model selection table for the magnitude of seaweed farming income on days when income received in Guindacpan, with the models from the 95% confidence set of models. Each row represents a model, and the ticks indicate which variables were included in each model. PoOD=Proportion of Occupation Days. k = number of parameters in the model. Akaike weights (w_i) were calculated based on the full set of models, so add up to the nearest possible value to 0.95. Variables are ordered in the same sequence as in the main text.

Model #	Same day time	Same day expenses	Long-term time	Long-term expenses	Season	PoOD with income	Respondent	k	Δ	w_i
1	✔	✔		✔	✔		✔	11	0.000	0.216
2	✔			✔	✔		✔	10	0.848	0.142
3	✔	✔		✔	✔			10	1.475	0.104
4	✔	✔	✔	✔	✔		✔	12	1.870	0.085
5	✔			✔	✔			9	2.382	0.066
6	✔	✔		✔	✔	✔	✔	12	2.681	0.057
7	✔		✔	✔	✔		✔	11	2.705	0.056
8	✔			✔	✔	✔	✔	11	2.884	0.051
9	✔	✔		✔	✔	✔		11	3.429	0.039
10	✔	✔	✔	✔	✔			11	3.569	0.036
11	✔	✔	✔	✔	✔	✔	✔	13	4.037	0.029
12	✔		✔	✔	✔			10	4.292	0.025
13	✔			✔	✔	✔		10	4.363	0.024
14	✔		✔	✔	✔	✔	✔	12	4.762	0.020

Table S4.3.6. Model estimates for the magnitude of seaweed farming income on days when income received in Guindacpan, based on the model average of the 95% confidence set of models. Relative importance for each variable is based on the sum of the recalculated w_i for each model in which the variable appears. PoOD=Proportion of Occupation Days. Variables are ordered in the same sequence as in the main text.

	Coefficient	SE	Relative importance
(Intercept)	3.948	0.370	
Same day time	0.456	0.114	1.000
Same day expense	0.120	0.135	0.595
Long-term time	-0.005	0.023	0.265
Long-term expens	0.011	0.003	1.000
Season: Habagat	0.490	0.109	1.000
Season: Hot	-0.234	0.101	1.000
PoOD with income	0.037	0.292	0.232
Respondent	0.230	0.211	0.690

Table S4.3.7. Model selection table for the magnitude of seaweed farming income on days when income received in Handumon, with the models from the 95% confidence set of models. Each row represents a model, and the ticks indicate which variables were included in each model. PoOD=Proportion of Occupation Days. k = number of parameters in the model. Akaike weights (w_i) were calculated based on the full set of models, so add up to the nearest possible value to 0.95. Variables are ordered in the same sequence as in the main text.

Model #	Same day time	Long-term time	Long-term expenses	Season	PoOD with income	Respondent	k	Δ	w_i
1	✔	✔	✔			✔	7	0.000	0.086
2	✔	✔	✔				6	0.234	0.076
3		✔	✔				5	0.300	0.074
4		✔	✔			✔	6	0.649	0.062
5		✔	✔		✔		6	1.078	0.050
6			✔				4	1.162	0.048
7			✔			✔	5	1.320	0.044
8	✔	✔	✔		✔		7	1.498	0.041
9			✔		✔		5	1.586	0.039
10		✔	✔	✔			6	1.744	0.036
11	✔	✔	✔		✔	✔	8	1.968	0.032
12		✔	✔	✔		✔	7	2.063	0.031
13		✔	✔		✔	✔	7	2.109	0.030
14	✔	✔	✔	✔		✔	8	2.177	0.029
15	✔		✔			✔	6	2.266	0.028
16			✔		✔	✔	6	2.315	0.027
17	✔	✔	✔	✔			7	2.336	0.027
18	✔		✔				5	2.501	0.025
19		✔	✔	✔	✔		7	2.656	0.023
20			✔	✔			5	2.862	0.021
21			✔	✔		✔	6	2.989	0.019
22	✔		✔		✔		6	3.203	0.017
23			✔	✔	✔		6	3.333	0.016
24		✔	✔	✔	✔	✔	8	3.648	0.014
25	✔	✔	✔	✔	✔		8	3.649	0.014
26	✔		✔		✔	✔	7	3.667	0.014
27			✔	✔	✔	✔	7	4.098	0.011
28	✔	✔	✔	✔	✔	✔	9	4.190	0.011
29	✔		✔	✔		✔	7	4.410	0.009

Table S4.3.8. Model estimates for the magnitude of seaweed farming income on days when income received in Handumon, based on the model average of the 95% confidence set of models. Relative importance for each variable is based on the sum of the recalculated w_i for each model in which the variable appears. PoOD=Proportion of Occupation Days. Variables are ordered in the same sequence as in the main text.

	Coefficient	SE	Relative importance
(Intercept)	4.759	0.556	
Same day time	-0.098	0.159	0.428
Long-term time	0.074	0.071	0.666
Long-term expenses	0.081	0.025	1.000
Season: Hot	0.044	0.146	0.273
PoOD with income	-0.239	0.528	0.355
Respondent	0.221	0.323	0.469

Table S4.3.9. Model selection table for the magnitude of fishing income on days when income received, with the models from the 95% confidence set of models. Each row represents a model, and the ticks indicate which variables were included in each model. PoOD=Proportion of Occupation Days. k = number of parameters in the model. Akaike weights (w_i) were calculated based on the full set of models, so add up to the nearest possible value to 0.95. Variables are ordered in the same sequence as in the main text.

Model #	Same day time	Same day expenses	Long-term time	Long-term expenses	Barangay	Season	Respondent	k	delta	weight
1	✔	✔		✔		✔	✔	16	0.000	0.277
2	✔	✔				✔	✔	15	0.699	0.196
3	✔	✔	✔	✔		✔	✔	17	1.940	0.105
4	✔	✔		✔	✔	✔	✔	17	1.982	0.103
5	✔	✔	✔			✔	✔	16	2.417	0.083
6	✔	✔			✔	✔	✔	16	2.547	0.078
7	✔	✔	✔	✔	✔	✔	✔	18	3.894	0.040
8	✔	✔	✔		✔	✔	✔	17	4.351	0.031
9	✔	✔		✔			✔	14	4.700	0.026
10	✔	✔					✔	13	5.447	0.018

Table S4.3.10. Model estimates for the magnitude of fishing income on days when income received, based on the model average of the 95% confidence set of models. Relative importance for each variable is based on the sum of the recalculated w_i for each model in which the variable appears. PoOD=Proportion of Occupation Days. Variables are ordered in the same sequence as in the main text. Note the dummy variables for same day time and same day expenses, for when either of these values were zero (see main text for details). These dummy variables only occurred in the models in which their paired variable occurred.

Variable	Coefficient	SE	Relative importance
(Intercept)	3.197	0.224	
Same day time	0.539	0.057	1.000
Dummy: Zero same day time	1.582	0.336	1.000
Same day expenses	0.232	0.053	1.000
Dummy: Zero same day expenses	0.374	0.197	1.000
Long-term expenses	0.001	0.002	0.576
Long-term time	0.000	0.012	0.271
Barangay: Handumon	-0.012	0.059	0.263
Season: Habagat	-0.134	0.060	0.953
Season: Hot	-0.093	0.047	0.953
Respondent	0.229	0.059	1.000

Table S4.3.11. Model selection table for the magnitude of informal sector income on days when income received, with the models from the 95% confidence set of models. Each row represents a model, and the ticks indicate which variables were included in each model. PoOD=Proportion of Occupation Days. k = number of parameters in the model. Akaike weights (w_i) were calculated based on the full set of models, so add up to the nearest possible value to 0.95. Variables are ordered in the same sequence as in the main text.

Model #	Same day time	Same day expenses	Long-term expenses	Long-term time	Village	Season	PoOD with income	Respondent	k	delta	weight
1	✔	✔	✔			✔			11	0.000	0.236
2	✔	✔	✔			✔		✔	12	1.236	0.127
3	✔	✔	✔			✔	✔		12	1.761	0.098
4	✔	✔	✔		✔	✔			12	2.049	0.085
5	✔	✔	✔	✔		✔			12	2.067	0.084
6	✔	✔	✔			✔	✔	✔	13	3.014	0.052
7	✔	✔	✔		✔	✔		✔	13	3.268	0.046
8	✔	✔	✔	✔		✔		✔	13	3.310	0.045
9	✔	✔	✔		✔	✔	✔		13	3.750	0.036
10	✔	✔	✔	✔		✔	✔		13	3.807	0.035
11	✔	✔	✔	✔	✔	✔			13	4.125	0.030
12	✔	✔	✔		✔	✔	✔	✔	14	4.967	0.020
13	✔	✔	✔	✔		✔	✔	✔	14	5.068	0.019
14	✔	✔	✔	✔	✔	✔		✔	14	5.350	0.016
15	✔	✔	✔	✔	✔	✔	✔		14	5.744	0.013
16	✔		✔			✔			9	5.857	0.013

Table S4.3.12. Model estimates for the magnitude of informal sector income on days when income received, based on the model average of the 95% confidence set of models. Relative importance for each variable is based on the sum of the recalculated w_i for each model in which the variable appears. PoOD=Proportion of Occupation Days. Variables are ordered in the same sequence as in the main text. Note the dummy variables for same day expenses, for when this value was zero (see main text for details). This dummy variable only occurs in the models in which same day expenses occurred (they are tied).

Variable	Coefficient	SE	Relative importance
(Intercept)	3.453	0.381	
Same day time	0.605	0.114	1.000
Same day expenses	0.091	0.034	0.987
Dummy: Zero same day expenses	0.453	0.212	0.987
Long-term time	0.000	0.009	0.254
Long-term expenses	0.001	0.000	1.000
Village: Handumon	0.009	0.088	0.258
Season: Habagat	0.268	0.075	1.000
Season: Hot	-0.074	0.054	1.000
PoOD with income	0.050	0.190	0.286
Respondent: 1	0.018	0.042	0.341

Appendix S4.4. Fluctuations in price of relevant materials and marine products.

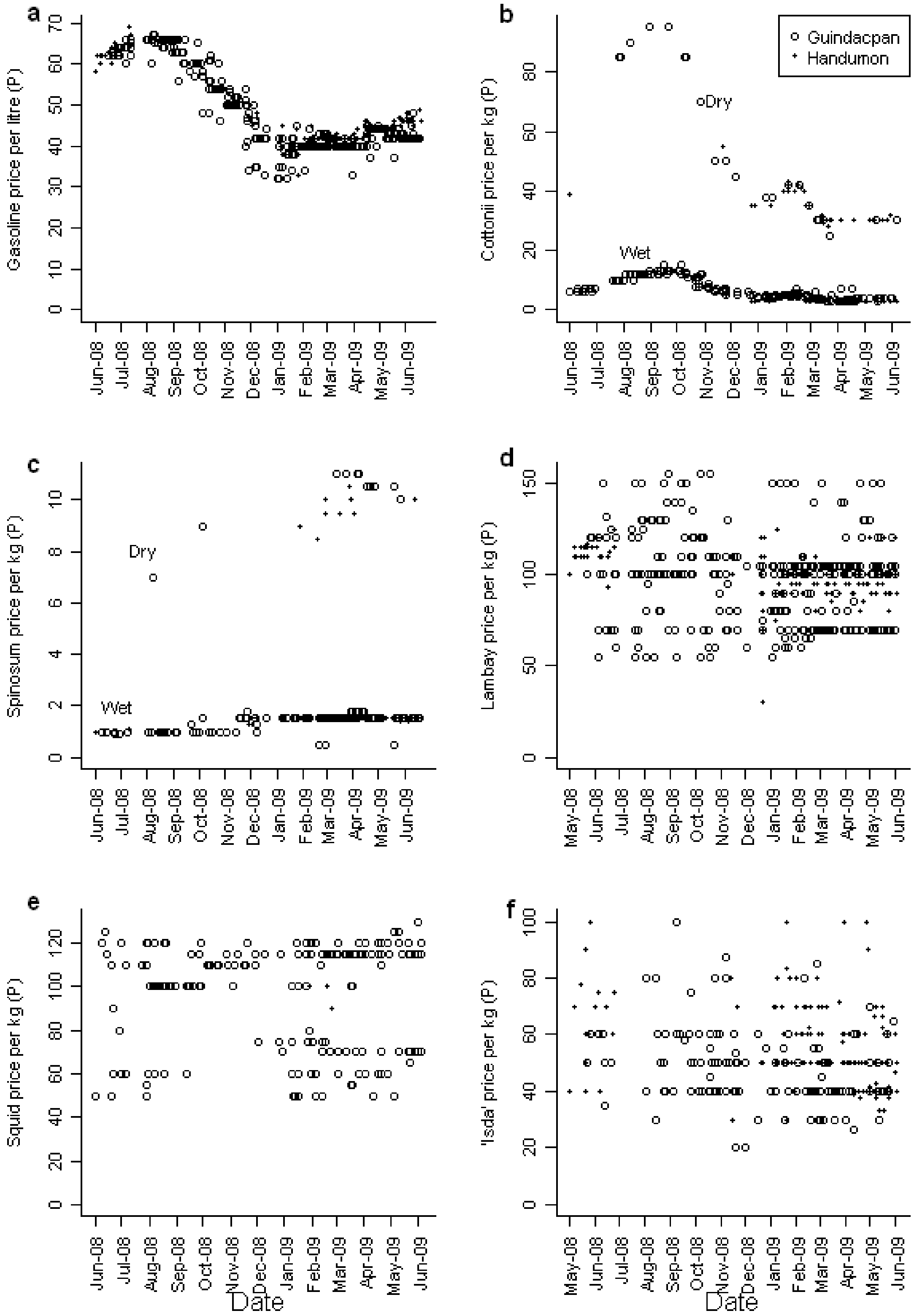


Figure S4.4.1 Prices in Guindacpan and Handumon for (a) gasoline, (b) cottonii (*Kappaphycus alvarezzi*) – wet and dry, (c) spinosum (*Eucheuma denticulatum*) – wet and dry, (d) blue crab ("lambay"), (e) squid, and (f) "isda"; a general term for fish that is used for mixed species sold together. Prices are in Philippine Pesos (P) and are the prices reported during 24-hr recall surveys for individual transactions.

Appendix S4.5. Access to loans and credit

Methods

Information on access to loans and credit was recorded during the 24-hr recall surveys, and after the final set of 24-hr recall surveys the heads of household were asked to recall the loans they had received during the previous year, including details of the size of those loans, the source of the loan, and the purposes to which they were put. Although details of interest rates and repayment schedules were sometimes not divulged, general discussions with respondents and with other village members were used to determine the range of different types of loans, and other sources of funding and credit that were commonly available within these villages.

Results

There were high-cost lending facilities available to households from both villages. In Guindacpan, 26 of the 40 households took out at least one loan from micro-credit facilities (based on mainland Bohol) during the year of the study, and one household borrowed money from a local lender (termed *araw-araw*). In Handumon, 14 of the 43 households took out at least one loan from micro-credit facilities, and 20 households borrowed money from local lenders (*araw-araw*). Loans varied in size from P1,000 to P25,000, and were used for a variety of purposes, from paying off previous loans, buying a pig for the next fiesta, paying for education, house improvements or medical expenses, to purchasing productive assets such as boats, engines and fishing or seaweed farming equipment. The interest rates varied from 10%-30% of the amount loaned over the course of a 2-3 month loan. Micro-credit loans had weekly repayment schedules, whereas *araw-araw* set minimum daily repayment limits, enabling some flexibility to repayment. Respondents indicated that they were keen to meet their repayment schedules so that they could continue to access further funds in the future, sometimes harvesting seaweed early or even stealing seaweed in order to be able to meet micro-credit repayments. Financial arrangements between fishers or seaweed farmers and intermediary traders were reportedly widespread. In exchange for loans for emergency purposes (e.g. health) or to buy fishing or seaweed farming capital, they would agree to sell all or part of their produce to this intermediary, normally for below-market prices. Credit was available from local food kiosks or grocery stalls, but such credit was generally short-term (a day or two).

APPENDIX S5

Supporting Information for Chapter 5

S5.1. Demographic life-cycle of households; Households start as young couples with few young children, and as they age the number of children increases and children age. At intermediary stages in the life cycle the number of children are large and some of them are old enough to contribute labour to the household. Eventually the children start to leave and establish their own households. This cycle is represented by the inverted U-shaped relationship between household size and age of heads of household (Fig. S5.1a). The number of adults in the household increases in subsequent years as well before declining (with the exception of two older households which still have a large number of adults; Fig. S5.1b). Household size is closely related to the number of dependents (age<18 years; Fig. S5.1c), but not the number of adults (age 18-65 years; Fig. S5.1d).

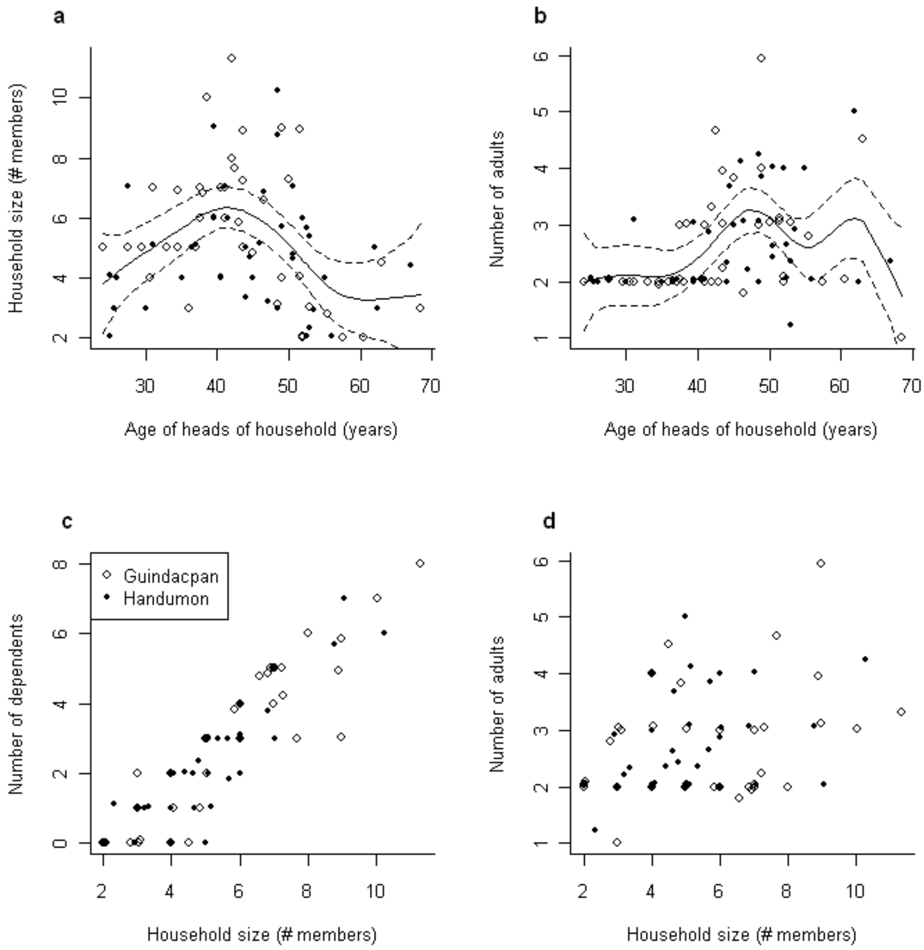


Figure S5.1. The relationships between household age and size for the household demographic life-cycle: (a) relationship between the age of heads of household and household size, with lines showing the smooth estimates and their standard error from a generalized additive model with thin plates regression spline (using R package mgcv, significance of smooth term: edf=4.044, F=5.02, p<0.001, r^2=0.26, n=83); (b) relationship between the age of heads of household and number of adults in the household, with lines showing the smooth estimates and their standard error from a generalized additive model with thin plates regression spline (significance of smooth term: edf=6.596, F=3.62, p<0.01, r^2=0.22, n=83); (c) relationship between household size and number of dependents, and; (d) relationship between household size and number of adults.

S5.2. Occupational diversity; relationship between revealed occupational diversity (from 24-hr recall) and reported occupational diversity (based on the number of occupations reported during the household profile questionnaires conducted in June 2009; see Chapter 2). A positive relationship was found between the two measures, although the relationship did not explain much of the variance (linear regression, df=1, t=2.71, p<0.01, r^2=0.076).

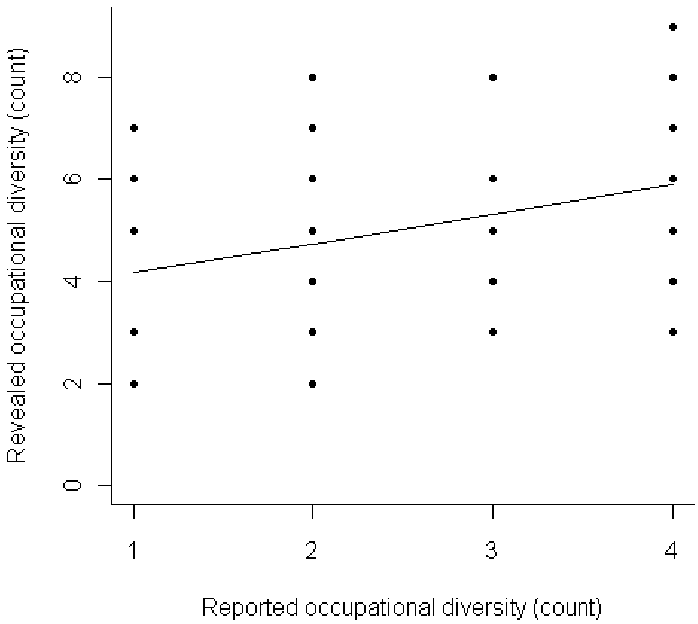


Figure S5.2. Relationship between reported occupational diversity (from household profile) and revealed occupational diversity (from 24-hr recall).

S5.3. Checking for collinearity between explanatory variables.

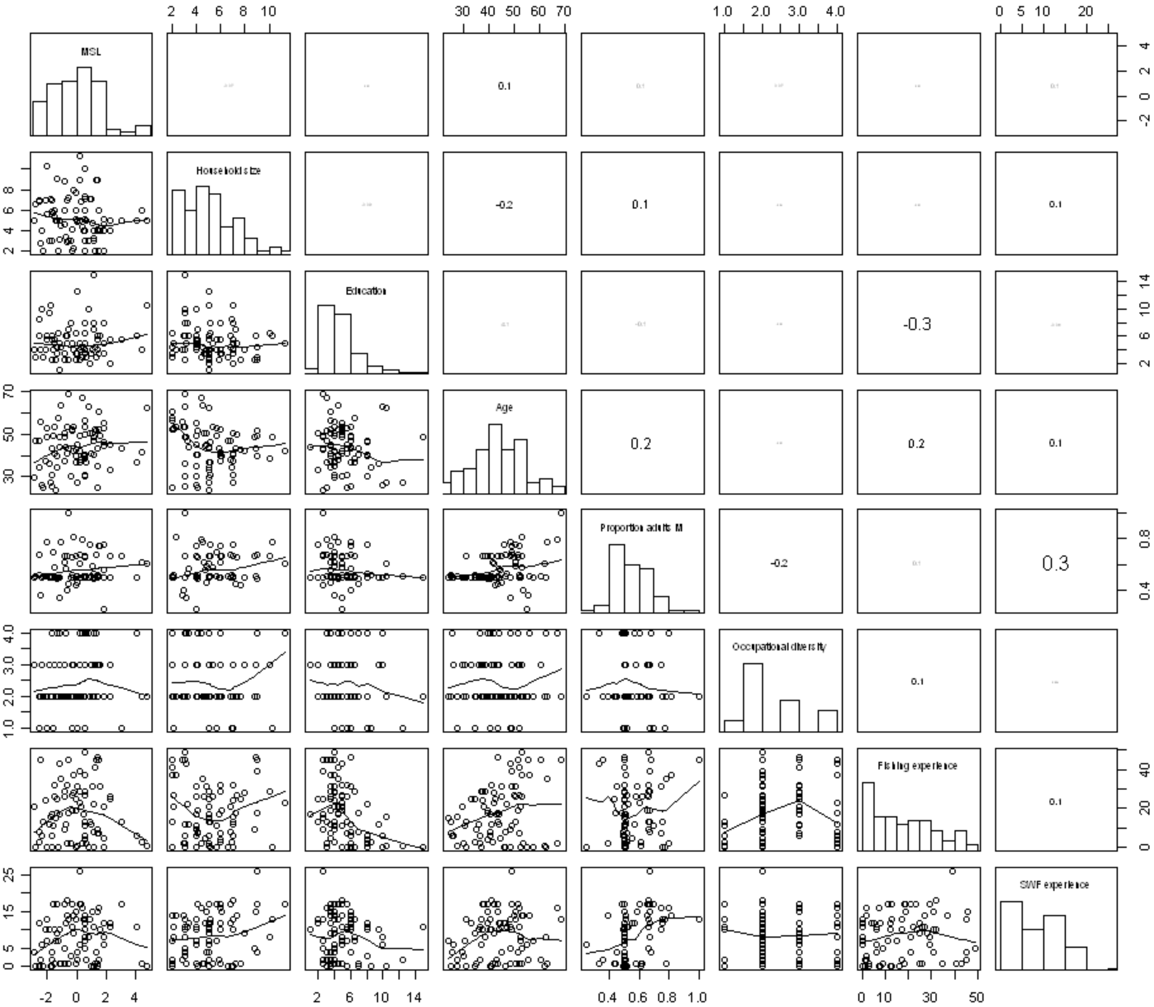


Figure S5.3. Histograms and pairwise plots of all non-categorical household-level explanatory variables with LOESS smoother, and Kendall correlation coefficients (SWF=seaweed farming, MSL=Material Style of Life).

Table S5.3. Variance inflation factors for non-categorical household-level explanatory variables (all values less than 3 indicates no problem with collinearity). MSL=Material Style of Life.

Household-level explanatory variable	**GVIF**
MSL	1.08
Household size	1.17
Education	1.27
Age	1.34
Proportion of adults M	1.42
Occupational diversity	1.06
Fishing experience	1.33
Seaweed farming experience	1.24

S5.4. Model selection tables, showing the fixed effects structures of the top 20 models for each analysis (Chapter 5, Table 5.2).

Table S5.4.1. Fixed effects structures of the top 20 models for the analysis of fishing income. Model averages of the 95% confidence set are presented in Chapter 5, Table 5.2.

Model #	Age of head of household	Village	Remittance	Season	Education	Gender ratio	Household size	MSL	Occupational diversity	Experience	k	AICc	Δ	w_i
1	✔				✔		✔	✔		✔	8	683.806	0.000	0.041
2	✔				✔		✔	✔	✔	✔	9	684.407	0.601	0.030
3	✔						✔	✔		✔	7	684.487	0.681	0.029
4	✔		✔		✔		✔	✔		✔	9	684.899	1.092	0.024
5	✔						✔	✔	✔	✔	8	684.957	1.151	0.023
6	✔				✔		✔		✔	✔	8	685.258	1.451	0.020
7	✔		✔		✔		✔	✔	✔	✔	10	685.363	1.557	0.019
8	✔	✔			✔		✔	✔		✔	9	685.492	1.686	0.018
9	✔				✔		✔			✔	7	685.626	1.819	0.017
10	✔	✔					✔	✔		✔	8	685.703	1.897	0.016
11	✔			✔	✔		✔	✔		✔	10	685.807	2.001	0.015
12	✔		✔				✔	✔		✔	8	685.838	2.032	0.015
13	✔						✔		✔	✔	7	685.841	2.035	0.015
14	✔	✔			✔		✔	✔	✔	✔	10	685.872	2.066	0.015
15	✔	✔					✔	✔	✔	✔	9	685.874	2.067	0.015
16	✔	✔	✔		✔		✔	✔		✔	10	685.953	2.146	0.014
17	✔				✔	✔	✔	✔		✔	9	685.958	2.151	0.014
18	✔	✔	✔		✔		✔	✔	✔	✔	11	685.968	2.161	0.014
19	✔	✔	✔				✔	✔	✔	✔	10	686.081	2.274	0.013
20	✔		✔				✔	✔	✔	✔	9	686.183	2.377	0.013

Table S5.4.2. Fixed effects structures of the top 20 models for the analysis of time spent fishing. Model averages of the 95% confidence set are presented in Chapter 5, Table 5.2.

Model #	Age of head of household	Village	Remittance	Season	Education	Gender ratio	Household size	MSL	Occupational diversity	Experience	k	AICc	Δ	w_i
1	✓			✓	✓		✓	✓	✓	✓	11	305.281	0.000	0.068
2	✓			✓	✓		✓	✓		✓	10	305.692	0.411	0.056
3	✓			✓			✓	✓	✓	✓	10	306.032	0.751	0.047
4	✓			✓			✓	✓		✓	9	306.590	1.308	0.035
5	✓		✓	✓	✓		✓	✓	✓	✓	12	306.722	1.441	0.033
6	✓			✓	✓	✓	✓	✓		✓	11	306.799	1.518	0.032
7	✓			✓	✓	✓	✓	✓	✓	✓	12	307.025	1.743	0.029
8	✓		✓	✓	✓		✓	✓		✓	11	307.277	1.995	0.025
9	✓			✓		✓	✓	✓		✓	10	307.352	2.071	0.024
10			✓	✓	✓		✓	✓	✓	✓	11	307.444	2.163	0.023
11	✓	✓		✓	✓		✓	✓	✓	✓	12	307.456	2.174	0.023
12	✓			✓		✓	✓	✓	✓	✓	11	307.536	2.255	0.022
13	✓		✓	✓			✓	✓	✓	✓	11	307.683	2.401	0.021
14	✓	✓		✓	✓		✓	✓		✓	11	307.919	2.638	0.018
15	✓	✓		✓			✓	✓	✓	✓	11	307.928	2.647	0.018
16				✓	✓		✓	✓	✓	✓	10	307.947	2.666	0.018
17			✓	✓			✓	✓	✓	✓	10	308.222	2.941	0.016
18				✓			✓	✓	✓	✓	9	308.234	2.952	0.016
19	✓		✓	✓			✓	✓		✓	10	308.363	3.082	0.015
20	✓			✓	✓		✓		✓	✓	10	308.406	3.125	0.014

Table S5.4.3. Fixed effects structures of the top 20 models for the analysis of seaweed farming income. Model averages of the 95% confidence set are presented in Chapter 5, Table 5.2.

Model #	Age heads of household	Village	Remittance	Season	Education	Gender ratio	Household size	MSL	Occupational diversity	Experience	k	AICc	Δ	w_i
1			✓			✓			✓	✓	7	752.299	0.000	0.047
2		✓				✓			✓	✓	7	752.533	0.233	0.042
3						✓			✓	✓	6	752.911	0.611	0.035
4			✓			✓		✓	✓	✓	8	753.336	1.037	0.028
5		✓	✓			✓			✓	✓	8	753.395	1.096	0.027
6			✓		✓	✓			✓	✓	8	753.451	1.152	0.027
7						✓		✓	✓	✓	7	753.747	1.448	0.023
8		✓				✓		✓	✓	✓	8	753.814	1.515	0.022
9					✓	✓			✓	✓	7	754.031	1.731	0.020
10		✓			✓	✓			✓	✓	8	754.069	1.769	0.020
11		✓				✓	✓		✓	✓	8	754.449	2.149	0.016
12	✓		✓			✓			✓	✓	8	754.474	2.175	0.016
13			✓			✓	✓		✓	✓	8	754.477	2.178	0.016
14		✓		✓		✓			✓	✓	9	754.509	2.210	0.016
15	✓	✓				✓			✓	✓	8	754.606	2.306	0.015
16			✓	✓		✓			✓	✓	9	754.641	2.342	0.015
17			✓		✓	✓		✓	✓	✓	9	754.643	2.344	0.015
18		✓	✓			✓		✓	✓	✓	9	754.699	2.399	0.014
19		✓	✓		✓	✓			✓	✓	9	754.848	2.549	0.013
20	✓					✓			✓	✓	7	754.950	2.651	0.013

Table S5.4.4. Fixed effects structures of the top 20 models for the analysis of time spent seaweed farming. Model averages of the 95% confidence set are presented in Chapter 5, Table 5.2.

Model #	Age heads of household	Village	Remittance	Season	Education	Gender ratio	Household size	MSL	Occupational diversity	Experience	k	AICc	Δ	w_i
1		✔		✔	✔	✔			✔	✔	10	341.634	0.000	0.096
2		✔		✔		✔			✔	✔	9	342.074	0.440	0.077
3		✔	✔	✔	✔	✔			✔	✔	11	342.696	1.063	0.057
4		✔	✔	✔		✔			✔	✔	10	342.970	1.336	0.049
5	✔	✔		✔	✔	✔			✔	✔	11	343.221	1.588	0.044
6		✔		✔	✔	✔		✔	✔	✔	11	343.251	1.618	0.043
7	✔	✔		✔		✔			✔	✔	10	343.478	1.844	0.038
8		✔		✔		✔		✔	✔	✔	10	343.550	1.916	0.037
9		✔		✔	✔	✔	✔		✔	✔	11	343.832	2.199	0.032
10		✔		✔		✔	✔		✔	✔	10	344.225	2.591	0.026
11		✔	✔	✔	✔	✔		✔	✔	✔	12	344.319	2.686	0.025
12			✔	✔		✔			✔	✔	9	344.324	2.690	0.025
13		✔	✔	✔		✔		✔	✔	✔	11	344.451	2.818	0.024
14	✔	✔		✔	✔	✔		✔	✔	✔	12	344.526	2.893	0.023
15	✔	✔		✔		✔		✔	✔	✔	11	344.577	2.943	0.022
16	✔	✔	✔	✔	✔	✔			✔	✔	12	344.675	3.041	0.021
17	✔	✔	✔	✔		✔			✔	✔	11	344.834	3.200	0.019
18		✔	✔	✔	✔	✔	✔		✔	✔	12	344.977	3.343	0.018
19			✔	✔	✔	✔			✔	✔	10	345.016	3.383	0.018
20		✔	✔	✔		✔	✔		✔	✔	11	345.226	3.592	0.016

Table S5.4.5. Fixed effects structures of the top 20 models for the analysis of informal sector income. Model averages of the 95% confidence set are presented in Chapter 5, Table 5.2.

Model #	Age of heads of household	Village	Remittance	Season	Education	Gender ratio	Household size	MSL	Occupational diversity	k	AICc	Δ	w_i
1					✓		✓	✓		6	825.847	0.000	0.039
2				✓	✓		✓	✓		8	825.928	0.082	0.037
3					✓		✓	✓	✓	7	825.938	0.091	0.037
4				✓	✓		✓	✓	✓	9	826.029	0.182	0.036
5			✓		✓		✓	✓		7	826.865	1.019	0.023
6			✓	✓	✓		✓	✓		9	827.107	1.260	0.021
7			✓		✓		✓	✓	✓	8	827.287	1.441	0.019
8					✓	✓	✓	✓		7	827.321	1.474	0.019
9					✓	✓	✓	✓	✓	8	827.412	1.566	0.018
10				✓	✓	✓	✓	✓		9	827.416	1.569	0.018
11		✓			✓		✓	✓	✓	8	827.438	1.592	0.018
12				✓	✓	✓	✓	✓	✓	10	827.516	1.669	0.017
13			✓	✓	✓		✓	✓	✓	10	827.528	1.682	0.017
14		✓			✓		✓	✓		7	827.533	1.686	0.017
15	✓				✓		✓	✓		7	827.708	1.861	0.015
16		✓		✓	✓		✓	✓	✓	10	827.753	1.907	0.015
17		✓		✓	✓		✓	✓		9	827.802	1.955	0.015
18	✓			✓	✓		✓	✓		9	827.825	1.979	0.015
19	✓				✓		✓	✓	✓	8	827.865	2.018	0.014
20	✓			✓	✓		✓	✓	✓	10	827.993	2.146	0.013

Table S5.4.6. Fixed effects structures of the top 20 models for the analysis of time spent in informal sector occupations. Model averages of the 95% confidence set are presented in Chapter 5, Table 5.2.

Model #	Age head of household	Village	Remittance	Season	Education	Gender ratio	Household size	MSL	Occupational diversity	k	AICc	Δ	w_i
1	✔	✔		✔	✔		✔	✔	✔	11	384.746	0.000	0.043
2	✔	✔		✔	✔	✔	✔	✔	✔	12	385.116	0.370	0.036
3	✔	✔		✔	✔		✔	✔		10	385.630	0.883	0.028
4	✔	✔		✔		✔	✔	✔	✔	11	385.756	1.010	0.026
5	✔	✔		✔			✔	✔	✔	10	385.866	1.120	0.025
6		✔		✔	✔		✔	✔	✔	10	385.975	1.229	0.023
7	✔	✔		✔	✔	✔	✔	✔		11	386.029	1.283	0.023
8		✔		✔			✔	✔	✔	9	386.095	1.348	0.022
9		✔		✔	✔		✔	✔		9	386.967	2.221	0.014
10	✔	✔	✔	✔	✔		✔	✔	✔	12	386.983	2.236	0.014
11	✔	✔			✔		✔	✔	✔	9	386.983	2.237	0.014
12	✔	✔			✔	✔	✔	✔	✔	10	387.240	2.493	0.012
13	✔	✔	✔	✔	✔	✔	✔	✔	✔	13	387.403	2.657	0.011
14		✔		✔		✔	✔	✔	✔	10	387.427	2.681	0.011
15		✔	✔	✔	✔		✔	✔	✔	11	387.635	2.888	0.010
16	✔	✔	✔	✔	✔		✔	✔		11	387.665	2.918	0.010
17		✔		✔	✔	✔	✔	✔	✔	11	387.680	2.933	0.010
18	✔			✔	✔		✔	✔	✔	10	387.744	2.998	0.010
19		✔		✔				✔	✔	8	387.778	3.032	0.009
20		✔	✔	✔			✔	✔	✔	10	387.868	3.121	0.009

S5.5. Model results run on only those households that engage in the relevant occupation

Table S5.5. Relationship between socioeconomic variables and seasonal measures of income (ln(income + 1)) and labour time (ln(hrs + 1)) of fishing, seaweed farming and informal sector occupations for households engaged in these occupations, showing the model average coefficient estimates (SE) for variables where the relative importance (RI) is greater than 0.5 (and in bold where RI is greater than 0.8) from the top 95% confidence set of linear mixed effects models based on AICc. Household is included as a grouping factor in the random effects. Experience was not included in the informal sector analyses (see text for details). Where a variable's RI is less than 0.5, only the direction of the effect is indicated (+ positive, - negative). This table is directly comparable with Table 5.2 in Chapter 5. MSL=material style of life; a proxy for wealth. Random effects estimates of variance [standard deviation] are for the global model in each case.

	Fishing				Seaweed farming				Informal sector occupations			
	Income		Hrs		Income		Hrs		Income		Hrs	
	Coef (SE)	RI	Coef (SE)	RI	Coef (SE)	RI	Coef (SE)	RI	Coef (SE)	RI	Coef (SE)	RI
(Intercept)	5.260 (0.996)		1.296 (0.500)		4.527 (1.238)		1.945 (0.408)		2.804 (1.832)		1.021 (0.830)	
Experience	**0.079 (0.015)**	**1.00**	**0.023 (0.006)**	**1.00**	**0.123 (0.036)**	**1.00**	**0.049 (0.012)**	**1.00**	NA		NA	
Age head of household	**-0.056 (0.017)**	**1.00**	-0.010 (0.009)	0.71	-	0.31	+	0.24	+	0.25	0.010 (0.012)	0.59
MSL^2	-	0.38	-0.052 (0.052)	0.66	-	0.35	-	0.27	**0.520 (0.156)**	**1.00**	**0.157 (0.069)**	**0.96**
Household size	0.057 (0.073)	0.54	0.044 (0.037)	0.74	-	0.25	+	0.26	**0.216 (0.139)**	**0.85**	0.070 (0.056)	0.76
Proportion of adults M	-	0.24	+	0.29	-2.657 (1.953)	0.79	**-1.285 (0.597)**	**0.94**	-1.774 (2.105)	0.58	-	0.37
Barangay: Handumon	+	0.49	+	0.26	-	0.39	**0.268 (0.172)**	**0.91**	+	0.26	0.326 (0.256)	0.76
Education head of household	-	0.35	-	0.42	-	0.29	-	0.46	0.108 (0.116)	0.62	0.043 (0.046)	0.63
Season:		0.25		**0.998**		0.23		**1.00**		0.41		0.79
Habagat	+		**0.146 (0.079)**		-		**-0.584 (0.103)**		+		-0.096 (0.086)	
Hot	+		**0.210 (0.061)**		-		**-0.388 (0.079)**		+		0.065 (0.062)	
Remittances: Y	-	0.25	-	0.26	-	0.35	0.176 (0.186)	0.63	+	0.27	+	0.35
Occupational diversity	**-0.328 (0.228)**	**0.82**	**-0.147 (0.106)**	**0.81**	**-0.511 (0.254)**	**0.93**	**-0.231 (0.074)**	**0.998**	-0.312 (0.380)	0.56	-0.151 (0.160)	0.63
# models in 95% confidence set	184		171		287		61		188		236	
# observations	178		178		172		172		171		171	

# households	71	71	68	68	71	71
Random effects						
Household	0.860 [0.927]	0.193 [0.440]	1.200 [1.096]	0.135 [0.367]	2.679 [1.637]	0.472 [0.687]
Residual	0.878 [0.937]	0.125 [0.354]	2.086 [1.444]	0.209 [0.457]	1.884 [1.372]	0.159 [0.399]

S5.6. Engagement in fishing, seaweed farming and informal sector occupations by gender and age.

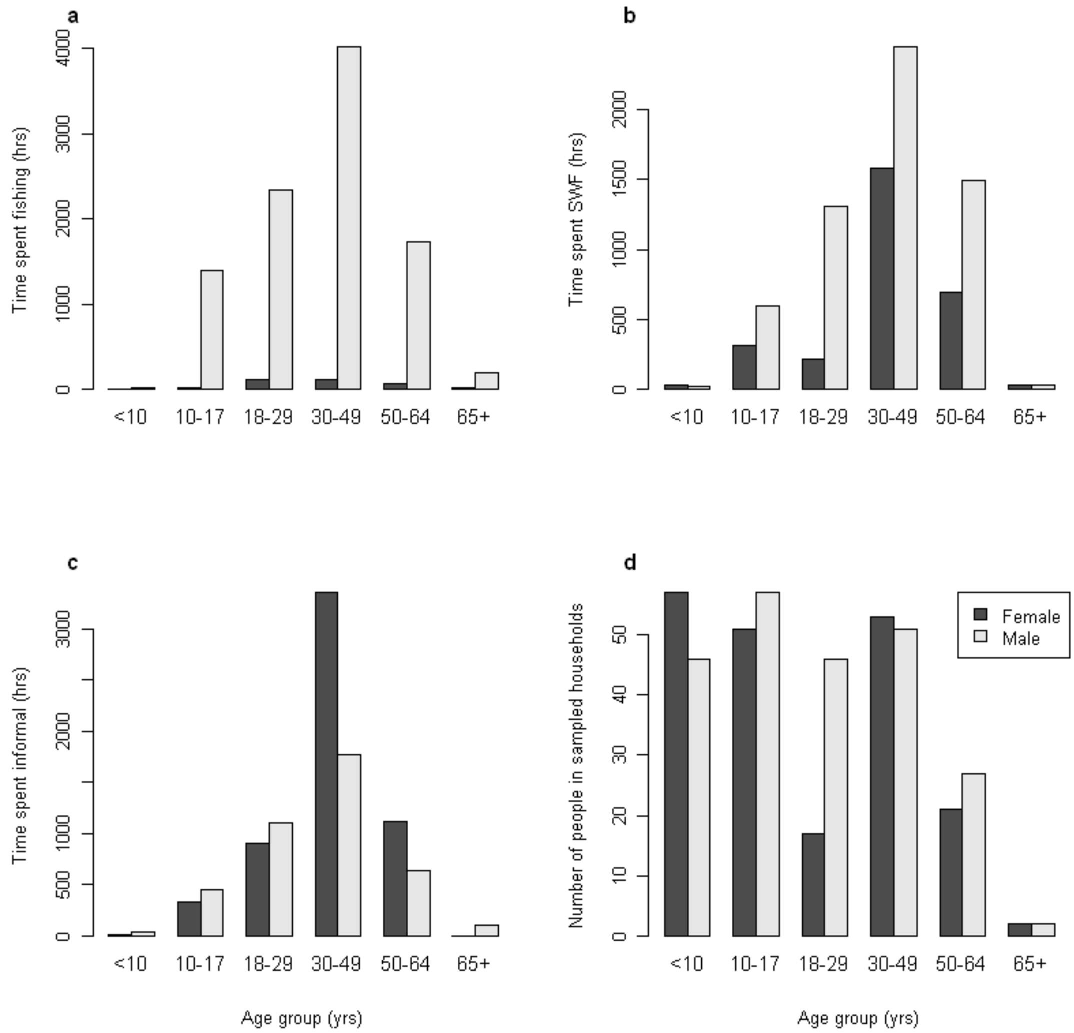


Figure S5.6.1. Engagement (sum of labour time across all households) in (a) fishing, (b) seaweed farming (SWF) and, (c) informal sector occupations by age and gender, and (d) number of people by age and gender in all sampled households.

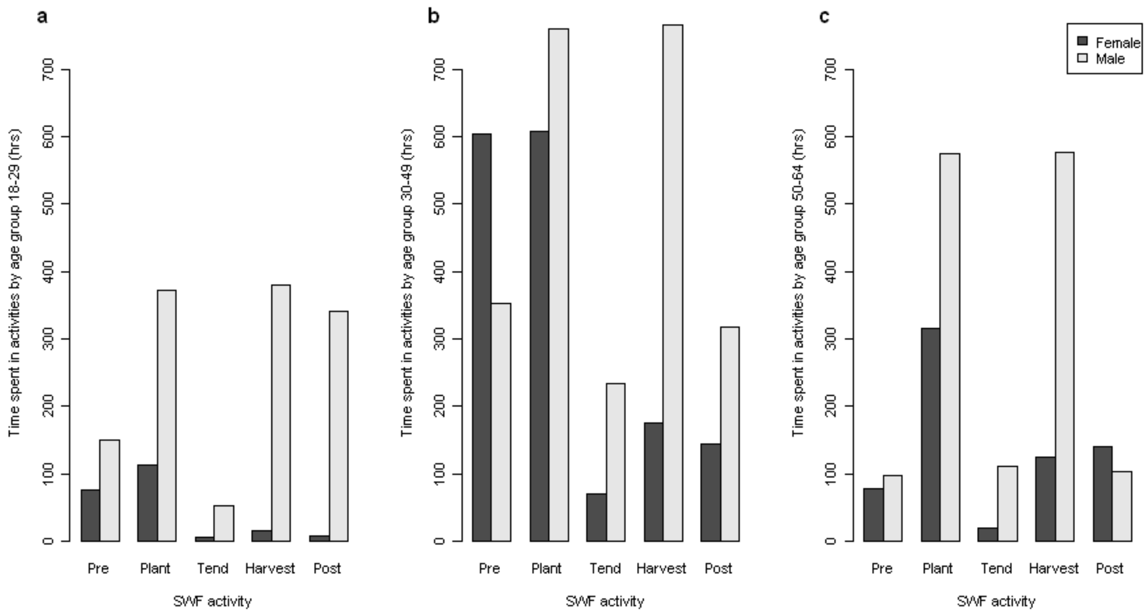


Figure S5.6.2. The cumulative number of hours spent in the different stages/activities of seaweed farming (SWF) by gender and age for the age groups that engage the most in seaweed farming: (a) 18-29 years old, (b) 30-49 years old, (c) 50-64 years old. “Pre” is the pre-planting stage, and involves preparing monolines on-shore. “Plant” is the planting stage, and involves tying seaweed to monolines (in the case of cottonii) which can be done on-shore, and planting at sea. “Tend” is the tending phase, which is at-sea and involves guarding the seaweed farm and removing rubbish and algae from lines and seaweed, and retying lines that have come loose (occasionally accompanied with some collection of washout seaweed). “Harvest” involves the harvest of seaweed at sea. “Post” involves primarily on-shore activities including drying and selling, but also transport for sale.

APPENDIX S6

Supporting Information for Chapter 6

S6.1. Number of occupations per household

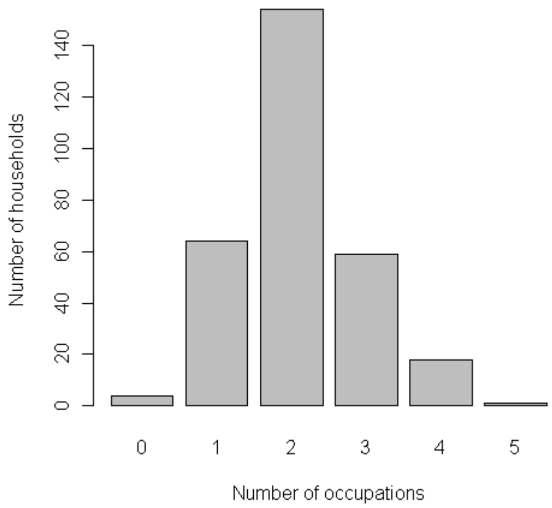


Figure S6.1. Histogram of the number of occupations per household.

S6.2. Wealth (material style of life scores) per household

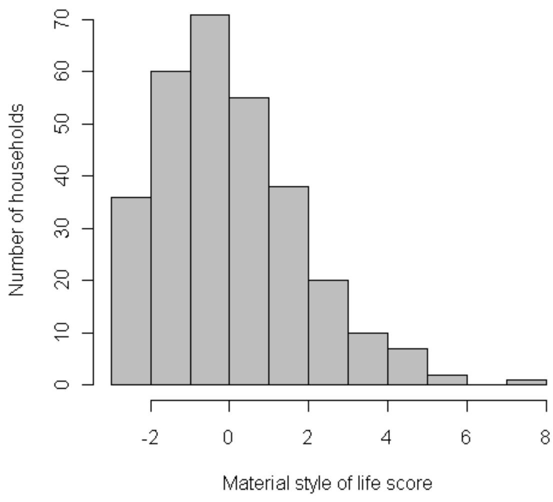


Figure S6.2. Histogram of material style of life scores for sampled households.

S6.3. Summary of household characteristics per wealth quartile.

Table S6.3. Demographic and socioeconomic characteristics of households in each wealth quartile, and distribution of households by village across wealth quartiles (mean (SE)). Significance of differences among wealth groups for demographic and socioeconomic characteristics are indicated based on Kruskal-Wallis rank sum test (*** *p*<0.001, ** *p*<0.01, * *p*<0.05, ns not significant).

	Wealthiest	*2nd*	*3rd*	*Poorest*	
Age	46.81 (1.38)	41.26 (1.26)	42.01 (1.34)	37.24 (1.39)	***
Household size	5.39 (0.24)	5.40 (0.24)	5.43 (0.25)	4.96 (0.26)	ns
Education	6.81 (0.35)	5.46 (0.33)	5.13 (0.22)	4.81 (0.27)	***
Proportion of adults male	0.545 (0.023)	0.501 (0.016)	0.547 (0.020)	0.502 (0.022)	ns
Occupational diversity	2.52 (0.10)	2.04 (0.09)	1.91 (0.08)	1.99 (0.09)	***
Fishing experience	21.41 (1.75)	21.33 (1.58)	23.76 (1.48)	19.22 (1.44)	ns
# households per village:					
Alumar	4	4	4	18	
Batasan	7	7	11	4	
Bilangbilangan East	13	3	5	9	
Bilangbilangan Tubigon	4	7	10	9	
Cuaming	3	10	12	3	
Guindacpan	8	7	7	8	
Hambungan	7	10	8	5	
Handumon	11	7	6	5	
Hingutanan East	13	10	4	3	
Mahanay	5	7	8	10	

S6.4. Checking for collinearity among explanatory variables for the linear mixed effects models of fishing income (Chapter 6, Table 6.3).

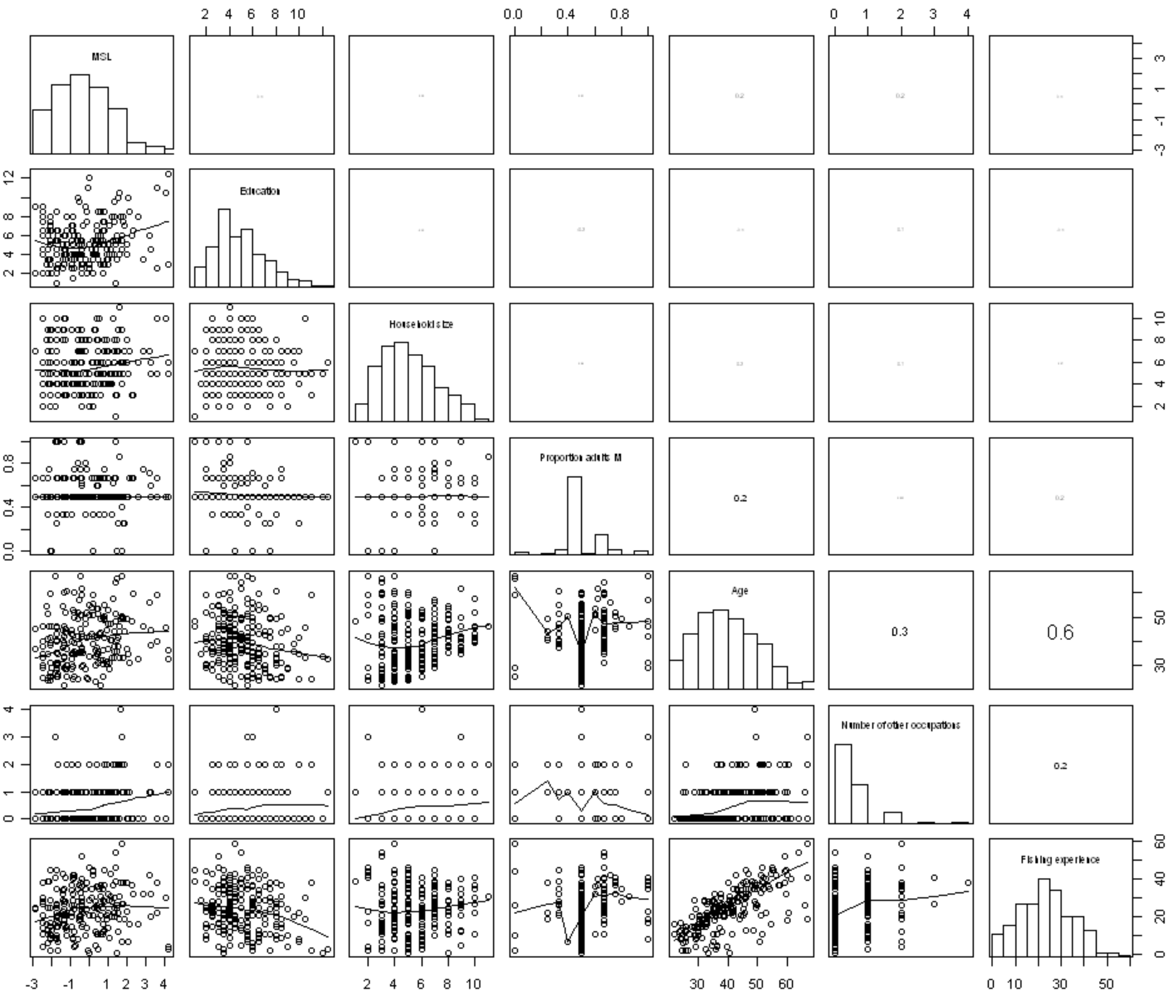


Figure S6.4. Histograms and pairwise plots of all non-categorical explanatory variables with LOESS smoother, and Kendall correlation coefficients (SWF=seaweed farming, MSL=Material Style of Life). The largest pairwise correlation was between age and fishing experience (0.6), but this was not sufficiently high to cause problems with the modelling, and all the variance inflation factors were less than 3 (see Table S6.4).

Table S6.4. Variance inflation factors for non-categorical household-level explanatory variables (all values less than 3 indicates no problem with collinearity). MSL=Material Style of Life.

Explanatory variables	GVIF
MSL	1.18
Household size	1.04
Education	1.21
Age	2.30
Proportion of adults M	1.07
Number of other occupations	1.28
Fishing experience	2.15

S6.5. Model selection tables for the 95% confidence set of linear mixed effects models

Table S6.5. Fixed effects structures of the 95% confidence set of models for the analysis of square-root transformed monthly fishing income. Model averages of the 95% confidence set are presented in Chapter 6, Table 6.3.

Model #	Age of head of household	Relative importance of fishing in relation to seaweed farming	Education	Household size	MSL	Number of other occupations	Gender ratio	Fishing experience	k	AICc	Δ	w_i
1	✔	✔			✔				7	1957.752	0.000	0.093
2		✔			✔			✔	7	1958.319	0.567	0.070
3		✔			✔				6	1958.926	1.173	0.052
4	✔	✔			✔	✔			8	1959.411	1.658	0.041
5	✔	✔		✔	✔				8	1959.457	1.705	0.040
6	✔	✔			✔		✔		8	1959.602	1.850	0.037
7	✔	✔			✔			✔	8	1959.637	1.885	0.036
8		✔			✔	✔			7	1959.667	1.915	0.036
9	✔	✔	✔		✔				8	1959.762	2.010	0.034
10		✔			✔	✔		✔	8	1959.828	2.076	0.033
11		✔		✔	✔			✔	8	1960.173	2.421	0.028
12		✔			✔		✔	✔	8	1960.237	2.484	0.027
13		✔	✔		✔			✔	8	1960.379	2.627	0.025
14		✔		✔	✔				7	1960.831	3.078	0.020
15		✔			✔		✔		7	1960.991	3.239	0.018
16		✔	✔		✔				7	1960.999	3.247	0.018
17	✔	✔		✔	✔	✔			9	1961.046	3.294	0.018
18	✔	✔			✔	✔	✔		9	1961.348	3.595	0.015
19	✔	✔			✔	✔		✔	9	1961.363	3.610	0.015
20	✔	✔		✔	✔		✔		9	1961.374	3.622	0.015
21	✔	✔		✔	✔			✔	9	1961.394	3.642	0.015
22		✔		✔	✔	✔			8	1961.440	3.688	0.015
23	✔	✔			✔		✔	✔	9	1961.488	3.736	0.014
24	✔	✔	✔	✔	✔				9	1961.497	3.744	0.014
25	✔	✔	✔		✔	✔			9	1961.517	3.765	0.014
26		✔		✔	✔	✔		✔	9	1961.597	3.845	0.014
27	✔	✔	✔		✔			✔	9	1961.605	3.853	0.014
28	✔	✔	✔		✔		✔		9	1961.713	3.961	0.013
29		✔	✔		✔	✔			8	1961.718	3.966	0.013
30		✔			✔	✔	✔		8	1961.777	4.025	0.012
31		✔			✔	✔	✔	✔	9	1961.823	4.071	0.012
32		✔	✔		✔	✔		✔	9	1961.970	4.218	0.011
33		✔		✔	✔		✔	✔	9	1962.149	4.397	0.010
34		✔	✔	✔	✔			✔	9	1962.267	4.515	0.010
35		✔	✔		✔		✔	✔	9	1962.375	4.623	0.009
36		✔	✔	✔	✔				8	1962.912	5.159	0.007
37		✔		✔	✔		✔		8	1962.935	5.183	0.007
38		✔	✔		✔		✔		8	1963.036	5.283	0.007
39	✔	✔		✔	✔	✔		✔	10	1963.054	5.302	0.007
40	✔	✔		✔	✔	✔	✔		10	1963.054	5.302	0.007
41	✔	✔	✔	✔	✔	✔			10	1963.186	5.434	0.006
42	✔	✔			✔	✔	✔	✔	10	1963.301	5.549	0.006
43	✔	✔		✔	✔		✔	✔	10	1963.313	5.561	0.006
44	✔	✔	✔	✔	✔			✔	10	1963.397	5.645	0.006
45	✔	✔	✔		✔	✔		✔	10	1963.445	5.693	0.005
46		✔	✔	✔	✔	✔			9	1963.486	5.734	0.005
47	✔	✔	✔	✔	✔		✔		10	1963.507	5.755	0.005
48	✔	✔	✔		✔	✔	✔		10	1963.520	5.768	0.005
49	✔	✔	✔		✔		✔	✔	10	1963.576	5.824	0.005
50		✔		✔	✔	✔	✔		9	1963.591	5.839	0.005

S6.6. Checking for collinearity among explanatory variables for the binomial generalized linear models of probability of seaweed farming households engaging in seaweed farming as a primary occupation (Chapter 6, Table 6.4).

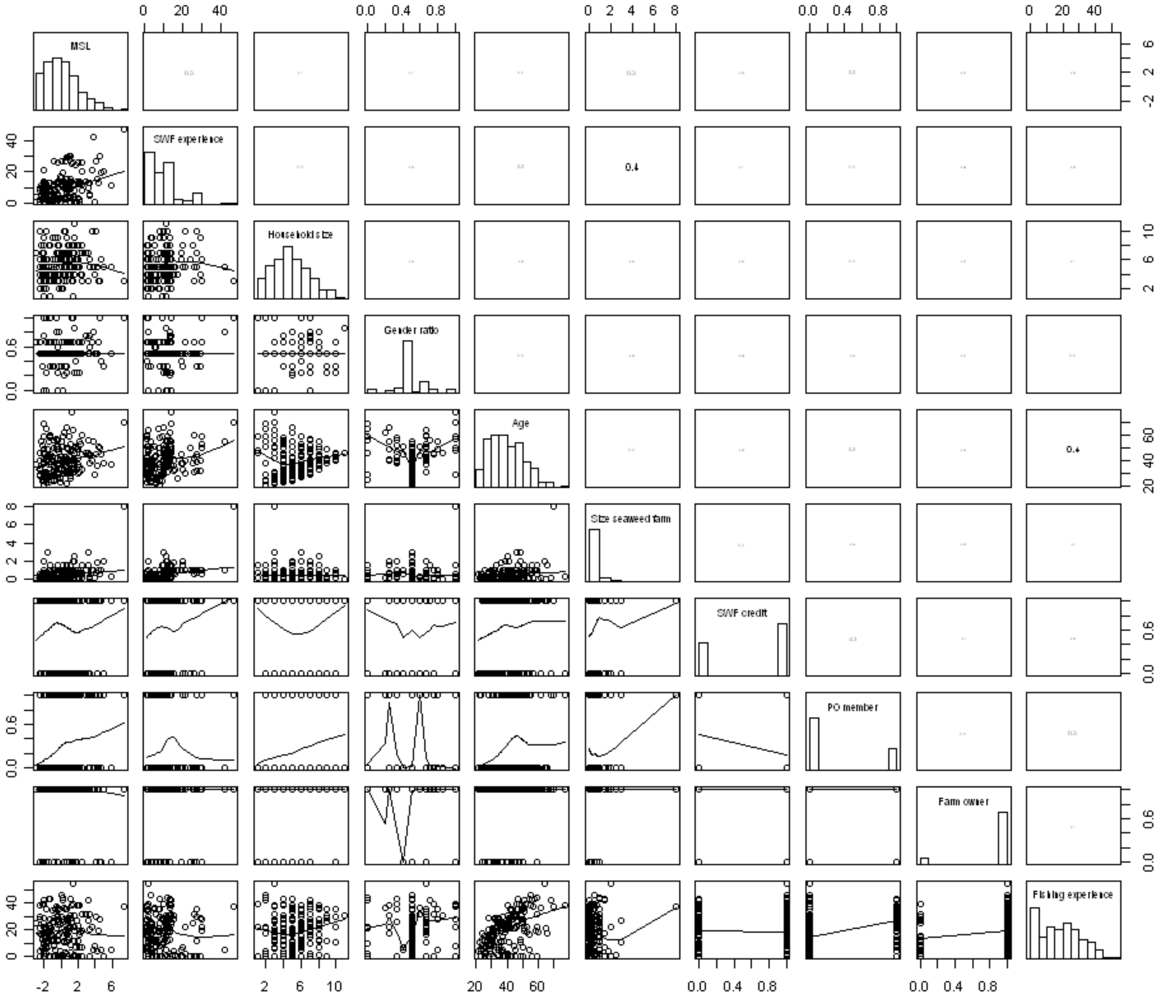


Figure S6.6. Histograms and pairwise plots of all non-categorical explanatory variables with LOESS smoother, and Kendall correlation coefficients (SWF=seaweed farming, MSL=Material Style of Life, PO=People's Organisation). There were no issues of collinearity (see Table S6.4).

Table S6.6. Variance inflation factors for non-categorical explanatory variables (all values less than 3 indicates no problem with collinearity). MSL=Material Style of Life, SWF=Seaweed farming, PO=People's Organistion.

Explanatory variables	GVIF
MSL	1.51
Seaweed farming experience	1.73
Fishing experience	1.60
Household size	1.13
Gender ratio	1.07
Age	1.67
Size of seaweed farm	1.65
SWF credit	1.17
PO membership	1.41
Ownership of farm	1.10