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Socioeconomic and ecological implications of special management areas (SMAs) regime in the Kingdom of Tonga

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Socioeconomic and Ecological Implications of Special Management Areas (SMAs) Regime in the Kingdom of Tonga.

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By

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Summary

The present study investigated aspects of establishment of the Special Management Area (SMA) regime as a conservation and fisheries management tool of the inshore waters in Tonga. The SMA regime is a fisheries management system that was adopted in 2002 in Tonga. SMA was established since 2006 after coastal communities who were interested in managing the fisheries resources within the adjacent fishing waters of their communities.

The result of this present study suggested there was significantly higher perceived support towards the establishment of SMAs from SMA households compared with comparator households. Subsequently, the perceived costs and benefits accruing from the establishment of the SMAs had a significant influence on perceived attitudes towards supporting the establishment of SMAs. The main differences in attitudes among fishers were related to the household livelihoods, fishing activities and seafood consumption pattern being the most important.

In addition, the abundance, biomass, diversity and percentage covers of fish, invertebrate and habitat structure were variable, however, there were significant increases in species richness, evenness, abundance and biomass of the major exploited fish families. The results also suggest that the response to protection vary with intensity of exploitation and body size and may be spatially idiosyncratic, as a function of local factors such as life histories, trophic groups, protection age and size, and geographical location.

Furthermore, the present study through local knowledge presents evidence for shifting baselines in fishers’ perception of declines of exploited fish species in inshore fisheries in Tonga. This will

also provide significant insights into the duration of “fisher’s memory” of depleted species, which is of fundamental importance for SMA network development in Tonga.

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Chapter 1

General Introduction

Introduction

It has been estimated that the global production of fishery products from wild capture fisheries continues to remain stable at about 90 million tonnes since 2006. During the same time period, it was estimated that the global human population increased from 6.6 billion to 7 billion, whilst the average consumption of fish increased from 17.4 kg to 18.8 kg per capita food fish supply (FAO, 2012). The demand for fishery products has increased disproportionately to growth in the human population despite that the global human population is predicted to increase still further, and may reach 8.9 billion by 2050 (www.fao.org/sd/wpdirect/wpan0040.htm). It therefore seems likely that there will be greater demand for fishery products in the future and hence increases in the amount of fishing effort exerted (FAO, 2008).

Many of the world's monitored fish stocks have been over-fished, and many fisheries catches have been in a state of decline (Watson & Pauly, 2001; Hutching, 2000; and Pauly *et a*l., 2002). In addition, overfishing has had the greatest impact on high trophic level groups such as sharks and groupers, leading to large reductions in their biomass and abundance (Myers & Worm, 2003). Subsequently, fishers have targeted less valuable species at lower trophic levels in order to maintain yields (Pauly *et al*., 1998).

The fisheries resources of the world have a limited potential as illustrated by catchs declines and collapses in many fisheries. Not only that, the inappropriateness of the fisheries management approaches has also contributed to the problems facing the fisheries (Beddington *et al.,* 2007; FAO, 2008). Fisheries management has been based largely on the concept of maximum sustainable yield (MSY) derived from population dynamic models (Beddington *et al*., 2007). However, the main problem has been the difficultly in controlling fishing pressure, resulting in many fisheries being overexploited.

Historically, humans have exploited marine resources without the implementation of adequate management strategies that aimed to ensure the long term sustainability of these systems and their associated benefits. This lack of adequate management has led in many instances to the degradation of marine ecosystems with global consequences such as the collapse or decline of some major fish stocks (Roberts, 2007). Existing management mechanisms have proven unable to stem resource degradation in many systems, leading to reduced productivity and prompting the need for a shift in policy (Pascoe, 2006).

Hence there is a need to manage fisheries more carefully to reverse the current downward trend and to sustain fish production into the future. Fish populations are less resilient than we once imagined, and the recovery of populations once overfished can be much slower than expected (e.g. Hutchings *et al*., 2000).

Many fisheries appear to be managed with short-term economic and social goals as the top priority with the result that these fisheries are at serious risk of losing the many benefits they should provide. In managing a fishery sustainably, ecological, social and economic factors that impact upon the fishery need to be considered such that management measures are proportionate and aimed at achieving specific objectives. Each of these factors must complement each other for the system as a whole to be sustainable.

The lack of fishery management successes may, in part, be attributed to the practice of discounting the future, whereby individuals prefer to collect benefits immediately, but defray the costs until a later date (Price, 1993). For fishers, these benefits and costs may be considered in terms of catches and profits (Hart, 1998). Typically, the interest rate levied on capital investment is higher than the rate at which biological resources increase naturally (Turner, Pearce &

Bateman, 1994). Hence, waiting until the future to harvest may lead to a smaller monetary gain overall than if the harvest was taken now, and short-term wealth is thereby pursued at the expense of long-term sustainability[1]. However, this prognosis is based upon assumptions about commercial interest rates levied on loans at any one point in time.

In addition, the lack of adequate management strategies that ensure the sustainable use of the marine environment is partly related to the open-access nature of the goods and services provided by the oceans. In the marine environment the lack of property rights for most goods, and the public nature of marine benefits, have led to what has been described as the "tragedy of the commons"[2] . The evidence of stock collapses across the world seas suggest that until discounting the future is fully recognised and accounted for in management regimes, fisheries may continue to decline (Knudson & MacDonald, 2000; Li, 2000, Sumaila *et al*., 2002).

How to manage fisheries

To address the critical need for a more effective and holistic management approach, fisheries managers should consider the ecosystem within which the fishery exists (Hofmann & Powell, 1998; Pitcher & Pauly, 1998; Pitcher, 2000). The ecosystem approach to fisheries management (EAFM) has been advocated in the Pacific region for coastal fisheries management (FAO, 2010). Despite this fundamental understanding of fisheries as part of the ecosystem, it has remained challenging to manage fish harvests while simultaneously sustaining the ecosystem. The

[1] Sustainability is define here as ' the pattern of social and structural economic transformations which optimise economic and other societal benefits available in the present, without jeopardising the likely potential for similar benefits in the future' (Goodland, Ledec & Webb 1989)

[2] Tragedy of the common refers to the conflicts associated to open access or free resources in which multiple individuals acting individually and for their own self-interest will ultimately deplete a shared resource (Hardin 1968).

establishment of Marine Protected Areas (MPAs)[3] can contribute to the adoption of a more holistic approach towards the management of marine ecosystems and which is an approach currently advocated as the way forward to achieve the sustainable management of the oceans (World Summit on Sustainable Development, 2002). For example, fishing activities have a range of direct and indirect impacts upon the marine environment (Kaiser & Groot, 2000), which can be mitigated by spatial restrictions. However, MPAs should not be considered the single solution to marine resource management issues, but rather one of the tools for an ecosystem approach (Shipp, 2003: Kaiser, 2005).

The use of MPAs has been proposed as a means to provide insurance against the uncertainty that is inherent in the management of exploited marine species. MPAs are designed to: (i) maintain essential ecological processes and life support systems; (ii) preserve genetic diversity; and (iii) ensure the sustainable utilization of species and ecosystems (IUCN, 1994).

MPAs are often implemented to conserve or restore species, fisheries, habitats, ecosystems, and ecological functions (NRC 2001). MPAs also are increasingly seen to have a role in poverty alleviation (Gjertsen 2005) and for climate change mitigation and adaptation (McLeod *et al*., 2009).

MPAs as a coral reef fisheries management tool

The use of MPAs as a traditional management tool for coral reefs has been long practice in the Pacific region (Johannes, 1998) and their use is increasing in many areas (Johannes, 2002). However, resource users may not accept them (Christie 2004; McClanahan et al. 2005), and many have failed to produce tangible conservation benefits (McClanahan, 1999). Some studies

[3] The term MPA is used here to refer to a marine management area in which usage is regulated by zoning for different activities (fishing), including marine reserves, which are no-take areas where human activities, especially fishing, are restricted or banned (Agardy et al. 2003; Hilborn *et al.* 2004).

suggest that MPAs are frequently unsuccessful as a reef conservation strategy, particularly in developing countries, where socio-economic factors such as poverty can drive resource abuse, and capacity for enforcement is often lacking (McClanahan, 1999; Christie *et al*. 2003; Christie, 2004). However, Russ *et al*., (2004) claimed that if MPAs are used wisely, they have the potential to simultaneously improve coral reef ecological condition as well as improve the lives of dependent people. However, few studies have objectively and simultaneously examined the type of MPAs that are most effective in conserving reef resources and the socioeconomic factors responsible for effective conservation (McClanahan *et al*., 2006).

Ecological and socioeconomic impacts of MPAs

A number of review studies have examined the ecological impacts of MPAs. No-take zones (NTZs)[4] typically result in increases in organism size, density, biomass, and species richness within MPA boundaries (Lester *et al*., 2009). These effects vary by taxa, with species targeted by fishing showing the most dramatic effects (Lester *et al*., 2009). Direct effects (i.e benefits to species targeted by fishing) are often detectable over a relatively short time frame (Babcock *et al.*, 2010), although this varies based upon species' population growth rates. Indirect effects, such as those resulting from trophic interactions, tend to accrue more slowly, sometimes taking decades (Edgar *et al*., 2009; *Babcock et al*., 2010). Top predators may take longer to respond to MPA protection, because these species are often particularly slow growing and long lived (DeMartini *et al*., 2008). MPAs also have been shown to benefit habitats, for example with MPAs preventing coral loss compared to unprotected areas (Selig & Bruno, 2010).

[4] The term No-take zones (NTZ) is used here to mean areas of the marine environment in which all forms of extraction by humans primarily fisheries, are banned permanently (Roberts and Polunin 1991; Roberts and Hawkins 2000; Gell and Roberts 2002).

Scientific understanding of the ecological impacts of MPAs outside their boundaries, as well as the impacts of ecologically interconnected networks of MPAs, is limited (Lowry *et al*., 2009), but modelling research and a growing number of empirical studies indicate a net movement of fish from No-take MPAs (Goni *et al*., 2010).

MPAs may have a substantial socioeconomic impact about which very little is currently known and few data are available on the socioeconomic consequences of MPAs in many places (Badalamenti *et al*., 2000). However, there is a relatively small but steadily growing body of literature that examines the economic and social impact of MPAs (Sanchirico *et al*., 2002; Foale and Manele, 2004, Christie and White, 2007, Cinner, 2007). These studies considered the various questions of how MPAs affect local, regional, and national stakeholders that depend on the oceans for their livelihood and well-being. It is also to understand the means by which households adapt to reduce their risks, the incentives that drive the decisions of resource users, and the sources of vulnerability to stresses and shocks (Pomeroy *et al.*, 2006). These studies also suggest that socioeconomic factors such as local resource use patterns, *de facto* governance institutions, market force, and poverty need to be considered in MPA planning and management. Findings indicate that food security generally increases, following MPA establishment, though some fishing groups experience a relative decline in their catch per unit effort (Mascia *et al*., 2010). Evidence regarding impacts on community organization, employment, health, and income remain scarce (Mascia *et al*., 2010), although fishers may face costs with MPA establishment from lost access to fishing grounds (Smith *et al*., 2010). Livelihoods can shift and sometimes diversify within the vicinity of a MPA associated with tourism (Briad & Sanchirico, 2008).

The success of MPAs as a management tool will be greatest when communities collectively support the MPA and government agencies that provide the necessary financing, monitoring, and enforcement, and technical expertise to ensure that MPAs reach their management objectives (Jameson *et al*., 2002). They are often highly dependent on factors such as the MPAs quality of design and management processes (Grafton *et al*., 2004). However, MPAs also present problems under a number of circumstances including (1) effects of spatial shifts in fishing effort as a consequence of closing an area to fishing where fishing effort moves elsewhere (Kaiser, 2005; Hutton *et al.*, 2008); (2) the stock of highly mobile organisms would not be protected; (3) hardship to fishing communities by shortening their fishing seasons, forcing them to travel much further to fishing grounds which increases risks to fishers (Hannesson, 1998).

Introducing the Tongan case study

Tonga is similar to many island economies in the south Pacific where fisheries provide a valuable resource base and many communities depend on fish for their basic livelihood, social and economic development (Bell *et al*., 1994; Govan *et a*l., 2009; Friedman *et al*., 2009 Kronen, 2004). Tongan fisheries include both commercial and subsistence sectors in which they target reef-lagoon, pelagic and deep-slope species. Gillet (2009) estimated that the contribution of the subsistence sector to Tonga's gross domestic production (GDP) to be roughly 3%, while the commercial sector contributes roughly 6%. The subsistence sector accounts for a substantial portion of total marine fisheries removals and draws mainly from nearshore reef resources (Sun *et al*., 2011).

In Tonga fisheries resources are critically important as a source of food and employment, a generator of government revenue and foundation for economic development. A knowledge of these fishery resources is required for an understanding of many aspects of the communities of the country, including their economies, nutrition, political relationships and development aspirations.

In concert with the importance of fisheries to the economies of Tonga, there has been a call for additional attention to be focused on the management of coastal/inshore fisheries to support food security, sustainable livelihoods and economic growth for current and future generations of Tongan people.

Coral reefs in Tonga are threatened by a rise in the human population, an increase in fishing effort, and more effective fishing methods which have led to overfishing in many of the inshore waters (Friedman et al., 2008; FAO, 2010). The reef fishery is under considerable pressure and is now considered to be overexploited (Petelo *et al*., 1995; Friedman *et al*., 2008). The reefs provide a vital source of food which is why the decline in fish stock is of huge concern to the Tongans (Bell *et al*., 1994; Kronen, 1994; Friedman *et al*., 2008).

It is evident that the carrying capacity of Tonga's inshore resources has been reached, and the "open access" approach to resource use may have worked well in the past when subsistence fisheries were more abundant but now fisheries in Tonga are commercially based, the open access approach is causing problems (Petelo *et al*., 1995). One of the main concerns regarding the open access approach is that Tongans from any island could harvest resources that were adjacent to other communities, who were heavily reliant upon those resources (Petelo *et al*., 1995).

Despite the rapid and continued development of fisheries in Tonga, knowledge of the status of the inshore resources is still poor. While information on catches and status of stocks is poor and highly uncertain, there is some good evidence that major declines in fish productivity have taken place and that these add to the impacts of other land-based activities (FAO, 2011). Tonga is becoming increasingly aware of the need for sustainable management of their marine resources. However, considerable effort is still required to implement appropriate management regimes. The most common management measures for inshore fisheries in Tonga include closed seasons, closed areas, gear restrictions and minimum landing sizes.

A fishery management system known as Special Management Areas (SMAs) has been established in Tonga since 2006. The SMA regime has functioned as a form of Community-Based Marine Protected Area (CB-MPA) where the community took the leading role in management of the fisheries resources within the SMA boundary for the purposes of coastal community management, application of certain conservation and management measures, subsistence fishing operations or other specified purposes (Tonga Fisheries Management Act, 2002). Among other fisheries measures, a no-take zone (NTZ) area known as Fish Habitat Reserves (FHR) must be established as a component of each established SMA. The SMA is therefore worthy of scientific attention because it offers a unique insight into the potential long-term outcomes associated with the implementation of SMA regime as a fisheries management tool in Tonga.

SMA communities are small island communities spread out through the Tonga archipelago. These include Átata and Éueiki in the Tongatapu group at the South, Haáfeva, Óúa and Felemea in the Haápai group to the North of Tongatapu, and Ovaka in the Vavaú group to the North of the Haápai group. The people in these islands live a simple Tongan way of life. The island inhabitats have limited means of subsistence from the land and struggle to produce and support enough food crops, so people are heavily dependent on coastal fisheries resources. With over harvesting of marine resources, population increase, and the emerging threats of climate change such as sea level rise, there has been a growing interest among the coastal communities to manage the marine resources better and specifically to adopt the SMA regime.

Aims and thesis structure

The aim of this thesis was to investigate the biological and socioeconomic impacts of the Special Management Areas (SMAs) regime on the reef communities and resources users in Tonga. The work detailed within this thesis may be divided into three major research components. All research work was carried out in Tonga, which provided sufficient information for the purposes of this study. Initially an analysis of the attitudes, perceptions and opinions of the communities was investigated to determine any impacts of the establishment of the SMAs on behaviour and the manner in which people engage with and perceive SMAs (Chapter 2). An investigation of the responses of the coral reef communities at the back reef zone within no-take zones, within SMAs and comparator treatment was also carried out, which focused on the differences in responses of the finfish, invertebrates and substrates to different levels of protection, and the degree to which changes/responses in biological parameters could be used as a surrogate for biological recovery (Chapter 3). Chapter 4 includes a detailed analysis of the fishers' ecological knowledge of the status of inshore fisheries. This chapter focused on the importance of local ecological knowledge of fishers in determining the shifting baseline in exploited species within island reef fisheries contexts. The general discussion (Chapter 5) summarizes the findings of this thesis and discussed providing suggestions for future work.

This information will be used to improve various scenarios for the implementation of SMAs. Hence, this study thus represents a unique opportunity to progress inshore fisheries management in Tonga and to further the development of marine spatial planning for marine resource management.

The thesis is presented in the form of papers prepared for scientific publication. As such, while every effort has been made to avoid repetition between the chapters, some overlap is inevitable when common methodologies or the same sites have been used for different components of the present study.

Chapter 2

Socioeconomic implication of the Special Management Areas in Tonga

2.1 Abstract

Marine protected areas (MPAs) may be important for protecting the marine environment, but they may also have substantial socio-cultural impacts about which very little are currently known, or acknowledged. In Tonga, few data are available on the socioeconomic consequences of MPAs. This study examines the impacts of SMA establishment by comparing households in the SMA with comparative communities adjacent to the SMAs based on the perceived attitudes, opinions and perceptions of households and fishers within these communities in Tonga. A questionnaire survey was undertaken to evaluate the demographic characteristics, households' and fishers' activity and behaviour, together with their perception of the SMA regime. Exploring these impacts will help better understand how future socioeconomic factors may influence the development of the SMA network. The result of this present study suggested that household demographic and characteristics were homogenous across the study sites. In addition, household and fishers' attitudes, opinions and perceptions towards the impact of the establishment of SMA varied across the study sites. However, there was significantly higher perceived support towards the establishment of SMAs from SMA households compared with comparator households. Subsequently, the present study revealed that perceived costs and benefits accruing from the establishment of the SMAs had a significant influence on perceived attitudes towards supporting the establishment of SMAs. The main differences in attitudes among fishers were related to household livelihoods, fishing activities and seafood consumption patterns. The heterogeneity among fishers' attitudes has important implications for the success of SMAs.

2.2 INTRODUCTION

Coral reefs provide ecosystem goods and services to millions of people around the world (Mascia 2003). Coastal communities are often highly dependent on marine resource for their livelihoods and food security (Malleret-King *et al*., 2003). The long-term sustainability of these benefits is threatened as increasing evidence suggests that coral reef ecosystems are currently under extreme pressure from the threats of climate change, pollution, disease and over-fishing (McClanahan *et al*., 2002; Hughes *et al*., 2003; Bellwood *et al*., 2004; Wilkinson, 2008; Hughes *et al*., 2010). In addition, it is widely accepted that fisheries are in decline across the globe (FAO, 2000; Pauly *et al*., 2002; Myers & Worm, 2003). In this context, there is greater interest in an application of spatially explicit restrictions of fishing effort through the use of marine protected areas (MPAs) (Agardy *et al*., 2003; Gell & Roberts, 2003).

MPAs are increasingly used as tools for fishery management and marine ecosystem conservation particularly in tropical marine ecosystems (Gell & Roberts, 2003; Halpern, 2003; Russ *et al*., 2004; and Hughes *et al*., 2010). Nevertheless, some MPAs have been reported to be inadequate, as many are threatened from external impacts and hence many MPAs are not effective (Mascia 1999, McClanahan, 1999).

The Pacific island region has been identified as an area for expansion of the use of protected areas (Rodrigues *et al*., 2004), and is experiencing a renaissance of community-based marine management initiatives (Johannes, 2002; Berkes, 2009). However, marine protected area initiatives and their suitability for use in the Pacific region has been called into question (Ruddle and Hickey, 2008; Foale and Manele, 2004).

Most research on MPAs tends to focus on the ecological aspects of the MPAs while ignoring the social, economic, cultural political and institutional implications of their use. Past MPA failures have highlighted the need for socioeconomic considerations to facilitate successful outcomes (Agardy, 2003; Marcia, 2004; Pomeroy *et al*., 2007; Charles & Wilson, 2009; Hughes *et al*. 2010; Pollnac *et al*., 2010). To date, the social sciences have contributed to a small but growing body of literature that examines the economic and social implications of MPAs (Farrow, 1996; Sanchirico, 2002).

In the last decades, research has started to address the human dimensions of MPAs, covering socioeconomic and cultural aspects of MPAs as well as MPAs governance (Bunce *et al.*, 1999; Mascia, 1999, 2003; Cicin-Sain & Belfiore, 2005; Christie and White, 2007; Jentoft *et al.*, 2007; Pomeroy et al., 2007; Charles and Wilson 2009). Studies of attitudes, perceptions and beliefs related to MPAs have been identified as priority social science topics that need research in relation to the establishment of MPA (Whales *et al.*, 2003; Pomeroy *et al*., 2005; NOAA, 2005). For instance, an understanding of fishers' attitudes and the influences that act upon them is needed in order to understand their behaviour and therefore to help predict the likely responses to the implementation of new management strategies (Kaiser, 2005; Hanna, 2001). Pomeroy *et al.* (1996) also emphasized that socio-economic research has revealed that rural households' behaviour regarding natural resource management is influenced by demographic and socio-economic factors.

Background in Tonga

Tongan fishery resources are critically important as a source of food and employment, a generator of government revenue and as a foundation for economic development (Bell *et al*., 1994; Kronen, 2003, 2004; Sun *et al*., 2011). The high dependence on marine resources and the ever increasing population exerts increasing pressure on marine resources from competing users with various interests (Sun *et al*., 2011). To counter this increasing pressure, the concept of the use of MPAs has been introduced since the early 1970s (Lovell and Palaki, 2002). In Tonga, the Fisheries Act 2002 provided the first guidance on the establishment of community-based marine protected areas known as Special Management Areas (SMAs). Historically, very little of the Tongan waters were protected from exploitation. However, the Fisheries Management Act 2002 provided the provision for the SMA, a new approach, built on existing community strengths in traditional knowledge and governance, and using local awareness of the need for actions to enhance sustainability. Many island communities in Tonga have shown interest in establishing SMAs. To date, eight island communities have established SMAs (Fisheries annual report, 2011).

The role of SMAs is to ensure that fishery resources are sustainably exploited under proper community management, to support economics growth, human development, and employment, while maintaining a sound ecological balance in the marine ecosystem (Tonga Fisheries Management Act, 2002; Bell *et al*., 1994; Kronen, 2004).

The management of coastal fishery resources in Tonga is a mixture of central government management, and the use of the SMA regime. Many management measures exist with most methods requiring a combination of limits on the available area, seasonal closure, and gear type, size limit for retained species (Table 2.1).

Table 2.1: Fisheries Management measures in relation to inshore fisheries in Tonga.

Management measures	**Examples**
Spatial restriction (Technical measures)	• Marine Protected Areas and Parks where fishing is prohibited;
Temporal restriction	• Fishing seasons (Sea cucumber, and sea turtle fishing) •
Catch and size restriction (Catch control)	• Size restriction (Lobster, giant clams, Pearl oysters, sea Turtles, • Total allowable catch and quotas (Sea cucumber • Species restriction (sea Turtle, sea cucumber, Whales,)
Right/Incentive-adjusting restrictions (Effort control)	• Licenses (fish fence, export licence)
Gear restrictions (Effort control)	• Gear type (SCUBA gear, destructive methods (poisoning and dynamiting)) • Gear size (gill net mesh size,)

Compliance with these restrictions can vary for a variety of reasons that could lead to confusion, conflict, poor enforcement, and unsustainable use unless efforts are made to understand the implications of different types of possible management measures. Understanding and comparing the perceptions of resource users is expected to improve the possibility of arriving at a consensus on appropriate management (MaClanahan *et al*., 2005). The implementation of the SMAs was designed to protect the marine and coastal resources with the aim of ensuring not only their sustainability but also to improve life of the coastal communities.

In Tongan coastal communities, households have different views and react differently to the SMA regime, and the acceptance of the SMA regime by communities could be severely hindered if some understanding of key factors, such as perceived needs and benefits, are not realized. At present, studies that consider the social and economic characteristics of coastal communities and attitudinal surveys that might inform policy and management decision making are lacking for Tonga. Understanding the attitudes of stakeholders towards the establishment of SMAs is an important step in achieving successful implementation.

The socio-economic implication of the SMA regime is of particular interest in Tonga. Following the concerns about the decline in fishers' catches due to overexploitation and habitat degradation, and the lack of fisheries data on inshore fisheries, the Tongan fisheries division is working together with these coastal communities interested in establishing SMA as a new fisheries management and conservation approach.

As the SMA regime network is likely to be expanded in the future it is important to understand how SMAs will affect stakeholders that depend on the oceans for their livelihood. The present study examined the perceptions of resources users toward the SMA regime that was designed to protect long-term sustainability of the fisheries on which they depended. The study set out to examine differences in attitude and perception towards the SMAs among different communities of the resources-user communities. In addition, it is hoped that this study will help in understanding better how community involvement in the decision-making process can improve conservation outcomes when establishing SMAs in Tonga and elsewhere. We explored the potential differences in attitude in relation to demographic, economic and social characteristics between SMA and comparative communities. In doing so, our objectives were to:

1. To investigate the degree of acceptance and support by stakeholders of the establishment of SMAs;
2. To understand fishers' perceptions of the impact of establishing of the SMA regime with respect to (a) consumption patterns of seafood and other foods, (b) effects on fishing activities and livelihood, (d) compliance, enforcement and the occurrence of conflict.
3. To evaluate households' perceptions regarding biodiversity conservation associated with SMAs and their attitudes towards the current fisheries management regime.

This socio-economic assessment also provides a baseline regarding the establishment of the SMA regime in Tonga.

2.3 METHODOLOGY

Study sites

Special Management Areas (SMAs) have been introduced in Tonga since 2006. The SMA regimes have been introduced on six islands: ‘Atata, ‘Eueiki, Ha’afeva, ‘O’ua, Felemea and Ovaka from 2006 to 2008. These islands have a diverse range of coastal and marine habitats including fringing corals, seagrass beds and sheltered lagoons. Eight villages were selected for the socioeconomic survey (Figure 2.1). Study sites were selected to encompass a range of social, economic, demographic, and marine fisheries resource governance conditions (e.g., varying degree of remoteness, SMA regime, open-access, dependence on marine resources etc.). Four of these villages were chosen for their closeness, access and dependence on the four SMAs such that Kotu and Tungua were associated with the SMAs at Ha’afeva and ‘O’ua; ‘Uiha was associated with the SMA at Felemea, and Matamaka was associated with the SMA at Ovaka.

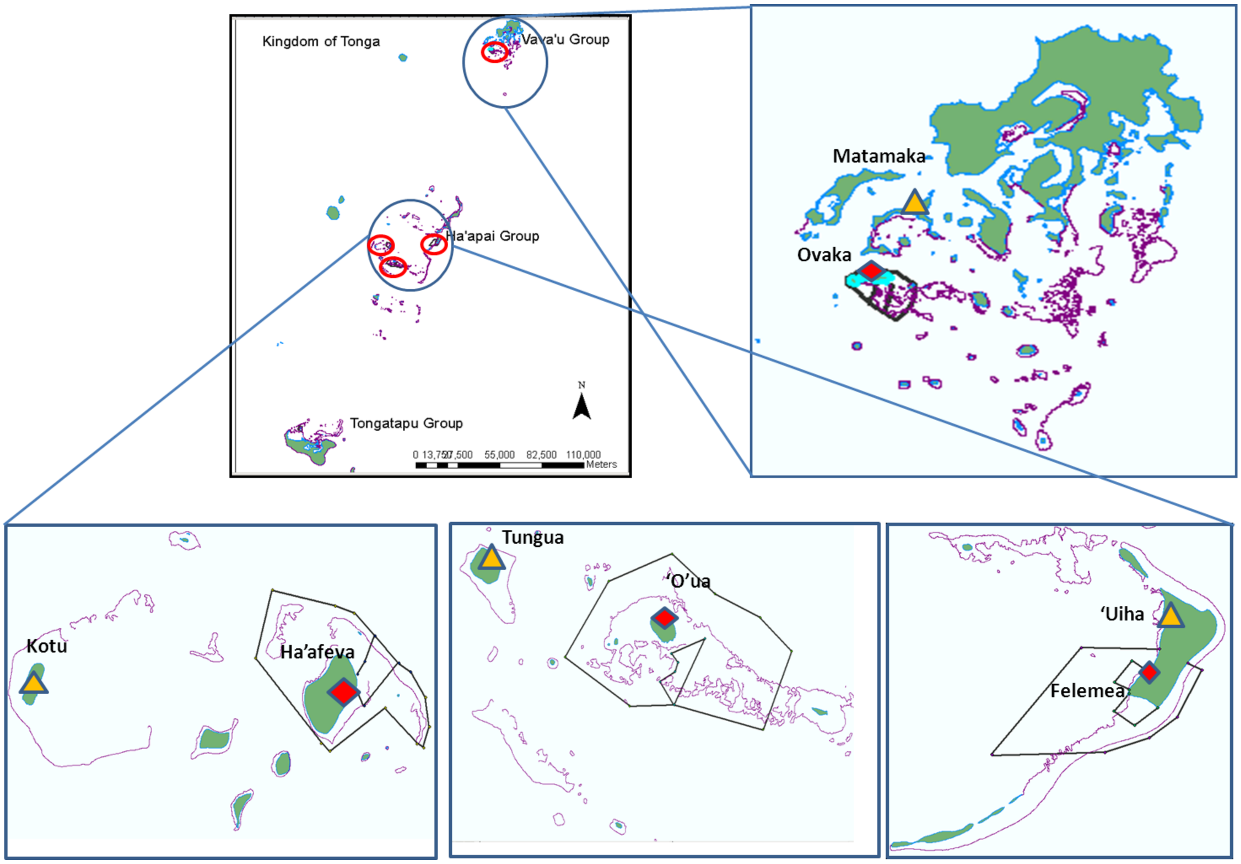

Figure 2.1. Map showing the study area, showing the Special Management Areas (SMAs) (with red diamond shape) and comparatives communities (with yellow triangle) in Ha'apai and Vava'u group in Tonga.

Sampling design and sampling

Primary data were obtained through a combination of household and fisher survey to examine the socioeconomic conditions in SMA communities and comparator communities from September 2010 to March 2011. A stratified sampling was used to select the study villages based on the SMA network and their neighbouring communities. Sampling within a community was based on a random sampling approach such that 191 households from the eight communities were surveyed. Random sampling is used to provide an average and representative picture of the household characteristics and fishery situation in each community, including those that do not fish, those engage in fishing activities for subsistence, and those engaged in fishing activities on a small-scale artisanal basis.

In each of the eight communities, household questionnaires were administered using face to face interviews. In order to gain in-depth information on topics relevant to fishing and tailored to the knowledge and concerns of each household, interviews were conducted with fishermen in their household. The percentages of surveys per community ranged from 31-92% (Table 2.2), and depended largely on the number of households in the communities and the available time per site (this was influenced by factors such as weather, the availability and frequency of transportation at certain sites, and budget constraints.

Table 2.2: Study sites summary

Village	SMA regime	Population	# of household	% of household surveys	# of fishers in household	% of fishers in household surveyed	% ranked fishing as primary occupation
Ha'afeva	yes	262	49	61	33	81.8	37
O'ua	yes	149	26	92	35	57.1	71
Felemea	yes	193	33	70	17	76.5	39
Ovaka	yes	72	22	68	18	55.6	67
Kotu	no	185	33	82	34	64.7	59
Tungua	no	231	42	74	33	93.9	71
Uiha	no	445	80	31	26	88.5	60
Matamaka	no	94	21	76	19	84.2	100

The head of the household was interviewed if available. In instances where it was appropriate, more than one member of the household was interviewed to obtain the most accurate information about specific subjects. For example, the wife or an elder female who was familiar with preparing the household food. Also, any fishers associated with the household were also interviewed regarding the household’s fishing activities and practices. Questionnaires were fully structured and closed, although open-ended questions were added on a case-by-case situation. Questionnaires were administered in Tongan in a face to face manner by the author and it took no more than 30 to 45 minutes to be administered and a total of 191 households, 162 fishers were interviewed (see Table 2.2).

The questionnaire was designed to evaluate the household's demographic characteristics, socioeconomic circumstances and fishing activity, together with their perceptions, attitudes, and opinions towards the benefits and effectiveness of the SMA regime. The questionnaires consisted of separate sections to solicit as much information as possible regarding the effectiveness of the SMA regime. These sections included household demographic structure and characteristics, household perceptions, attitude and opinions on willingness to accept SMAs, support of the establishment of SMAs, the most important occupation for their livelihood, household well-being status based on the material style of life, household food item and seafood consumption patterns, householdperceptions of fishing activities, attitude and opinion on compliance, enforcement and conflict, and household attitudes on benefit and knowledge towards management of coastal marine resources.

The questionnaire consisted of primarily multiple-choice questions with predefined answers and a mixture of closed and open-ended questions. The answers to the multiple-choice questions were based primarily on a 5-point Likert scale (Richardson *et al*., 2005), which ranged between 1 = strongly agree and 5 = strongly disagree, or 1 = increased greatly and 5 = decreased greatly, with the exception of a few yes/no/don't know questions. An open box enabled respondents to expand on the answers.

Data analysis

Quantitative and qualitative social data were grouped by community type and descriptive and statistical analysis carried out using the software Statistical Package for Social Sciences (SPSS v.

16.0). Comparisons among responses from the SMA and Comparatorcommunities were analysed using Kruskal-Wallis tests.

2.4 RESULTS

Household demographic characteristics

Table 2.3 shows the summary of the demographic characteristics of the households surveyed. Households were very homogenous with regards to their demographic characteristics across study sites. The majority of households at both the SMA and comparator communities had one member who was engaged in fishing. Most of the fishers were male while females made up a small proportion, and, among these most fished for both finfish and invertebrates. Spearfishing was the most common fishing method used across the study sites. Overall, no significant differences were found among household demographics and characteristics between the SMA and comparator communities.

Table 2.3: Mean (± SE) percentage of household characteristics for communities in the SMA and Comparator sites. Differences were tested for significance using Kruskal-Wallis tests (χ^2). SMA: Special Management Area communities, COM: Comparator communities.

Characteristics		**SMA**	**COM**	**χ^2**	**df**	**P**
Household size	No. of people per HH	5±0.2	5±0.2	0.5	1,6	0.5
	Male per HH	3±0.3	3±0.1	0	1,6	1.0
	Female per HH	3±0.1	3±0.2	0.5	1,6	0.5
	Male ≥ 15 years per HH	2±0.1	2±0.1	1	1,6	0.3
	Female ≥ 15 years per HH	2±0.1	2±0.1	0	1,6	1.0
Percentage of fishers per HH	One	65.1±9.2	68.9±7.1	0	1,6	1
	Two	9.6±3.8	17±2.3	0.1	1,6	0.8
	Three	9.4±4.3	3.6±2.6	0.8	1,6	0.4
Fishers gender (%)	Male	79.4±5.1	86.7±4.9	0.8	1,6	0.4
	Female	11.5±6.3	7.8±1.6	0.1	1,6	0.8
Most common fishing methods (%)	Hand line (shallow)	18.6±5.4	7.8±3.5	1.3	1,6	0.3
	Hand line(deep)	5±3.2	11.9±10.6	0	1,6	1
	Trolling	0±0	1±1	1	1,6	0.3
	Netting (gillnet)	4.6±0.7	2±2	1.4	1,6	0.2
	Casting net	1.7±1.7	0±0	1	1,6	0.3
	Spearfishing	54.9±7.5	65.9±7.5	2.1	1,6	0.2
	Gleaning	6.7±4.1	3.5±1.3	0.1	1,6	0.8
	Octopus fishing (iron bars)	2.7±1.6	0.9±0.9	1	1,6	0.3
Target catch (%)	Finfish	18.1±3.3	18.2±11.0	0.3	1,6	0.6
	Invertebrates	1±1.0	1.9±1.9	0.03	1,6	0.9
	Both	61.6±2.2	70.4±7.4	1.3	1,6	0.3

Household occupation structure

Weaving and handicraft were the highest primary livelihood occupation for 76% and 89% of SMA and comparator communities respectively (Figure 2.2a). About 88 % and 97% of the households were engaged in fishing and 53% and 73% of the respondents ranked it as their most important occupation in the SMA and comparator villages respectively, and another 22 % and 12 % as the secondary occupation in the SMA and comparator households respectively (Figure 2.2a,

Table 2.4). Farming had an important role with about 87% and 97 % of the households engaged in farming activities and 46 % and 62% of the respondents ranked it as their second most important occupation in the SMA and comparator communities respectively (Figure 2.2b, Table 2.4). Money contributed by relatives from overseas (remittance) also contributed to household for 91% and 98% of the households in the SMA and comparator communities respectively. However, about 70% and 76% of the respondents ranked it as their least important source of livelihood (Figure 2.2c). There are some involvement in salaried employment (i.e. government or non-government occupations) (Figure 2a, b, and c). Both the SMA and comparator communities have similar profiles of livelihood occupations.

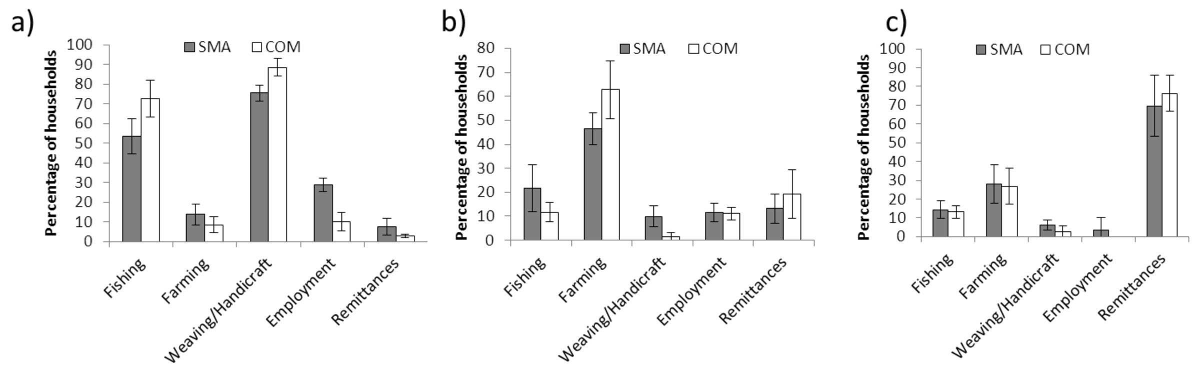

Figure 2.2: Mean (± SE) percentage of households in SMA and comparator communities involved in different occupational categories, highlighting the proportion of households that rank each occupation: a) Most important, b) second most important, c) least important, for the household All pairwise comparisons for each occupational category were non-significant (P >0.05) (Table 2.4).

Table 2.4: Mean (± SE) percentage of households in SMA and comparator communities in different occupational categories. Tests for significance were compared with the Kruskal-Wallis test.

Rank	**Occupations**	**SMA**	**COM**	**χ^2**	**df**	**P**
Most important	Fishing	53.3±9	72.6±9.5	1	1,6	0.3
	Farming	13.7±5.2	8.5±4	1.3	1,6	0.3
	Weaving/Handicraft	75.5±4	88.5±4.6	3	1,6	0.1
	Employment	28.7±3.3	10.2±4.7	4.1	1,6	0.1
	Remittances	7.5±4.4	2.7±0.9	0.1	1,6	0.8
Second important	Fishing	21.6±9.7	11.7±4.1	0.3	1,6	0.6
	Farming	46.6±6.6	62.8±12.1	1.4	1,6	0.3
	Weaving/Handicraft	9.9±4.3	1.6±1.6	2.9	1,6	0.1
	Employment	11.6±3.7	11.1±2.7	0.1	1,6	0.8
	Remittances	13.2±6	19.2±10.1	0.1	1,6	0.8
Least important	Fishing	14.3±4.6	13.1±3.3	0.1	1,6	0.8
	Farming	28.1±10.2	26.9±9.5	0	1,6	1
	Weaving/Handicraft	6.1±2.8	2.8±2.8	1.2	1,6	0.3
	Employment	3.3±6.7	0±0	1	1,6	0.3
	Remittances	69.7±16.4	76.4±9.7	0.02	1,6	0.9

Household spending structure

With regards to the household spending, family daily need spending (i.e. food, washing, etc.) was identified as the most common spending. Power (such as electricity, batteries, kerosene and solar) and water need was identified as the second common spending. The church obligation was identified as being the third common spending item while family and community obligations were the fourth most common spending (Figure 2.3). The allocation of financial resources for each household was ranked: Daily spending (i.e. food etc) > energy (electricity, batteries, kerosene and solar) and water > giving to the church > family and community obligations (Figure 2.3). There was no significant difference found in the proportion of these spending categories between SMA and comparator communities (Table 2.5).

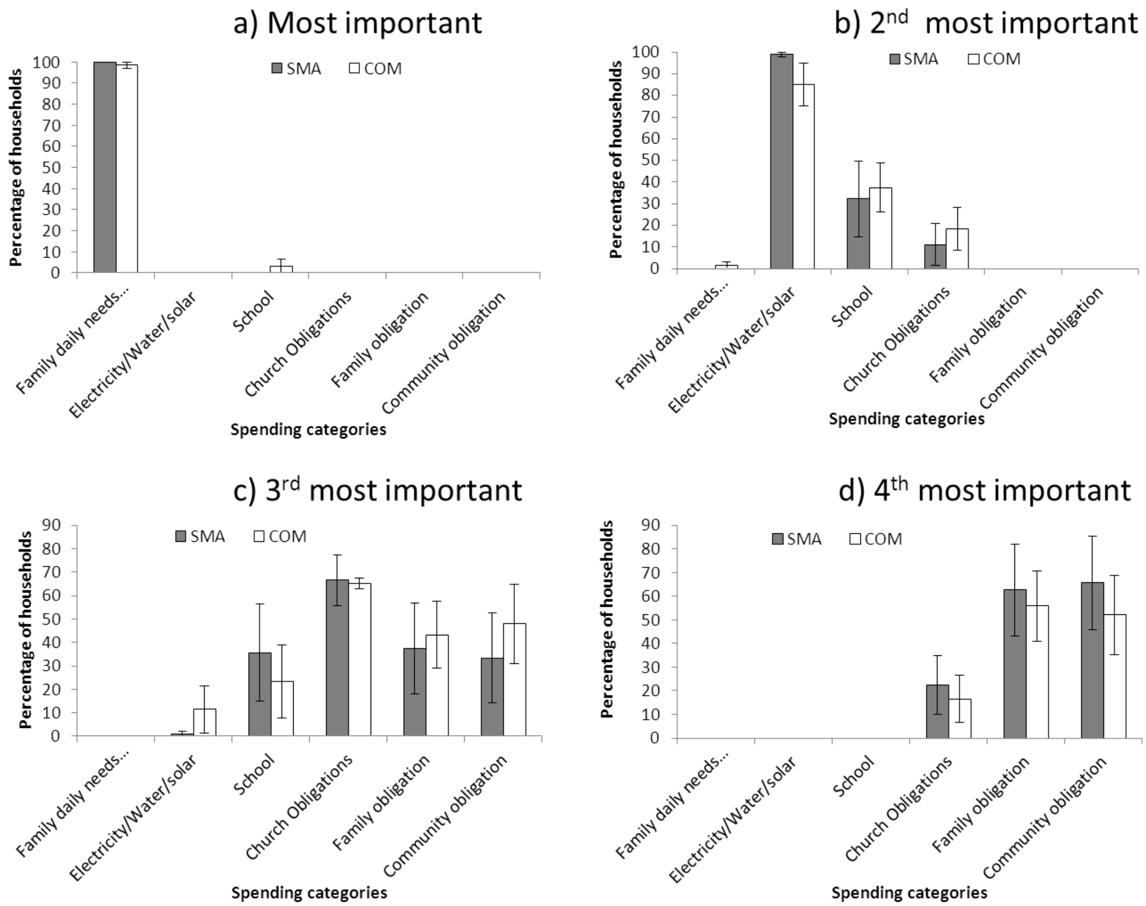

Figure 2.3: Mean (± SE) percentage of households in SMA and comparator communities that ranked different spending categories as the a) most important, b) second most important, c) third most and d) fourth most important for the household.

Table 2.5: Mean (± SE) percentage of households in SMA and comparator communities that ranked different spending categories. Differences were tested for significance using Kruskal-Wallis tests (χ^2). SMA: Special Management Area communities, COM: Comparator communities.

Rank	Spending categories	SMA	COM	χ^2	df	P
Most important	Family daily needs (food, others)	100±0	98.4±1.6	1	1,6	0.3
	Electricity/Water/solar	0±0	0±0	0	1,6	1
	School	0±0	3.2±3.2	1	1,6	0.3
	Church Obligations	0±0	0±0	0	1,6	1
	Family obligation	0±0	0±0	0	1,6	1
	Community obligation	0±0	0±0	0	1,6	1
2nd most important	Family daily needs (food, others)	0±0	1.6±1.6	1	1,6	0.3
	Electricity/Water/solar	98.9±1	84.9±9.9	0.98	1,6	0.3
	School	32.3±17.5	37.5±11.2	0.08	1,6	0.8
	Church Obligations	11.1±9.7	18.5±9.8	0.09	1,6	0.8
	Family obligation	0±0	0±0	0	1,6	1
	Community obligation	0±0	0±0	0	1,6	1
3rd most important	Family daily needs (food, others)	0±0	0±0	0	1,6	1
	Electricity/Water/solar	1±0	11.4±10.2	0.4	1,6	0.5
	School	35.7±20.6	23.4±15.7	0.09	1,6	0.8
	Church Obligations	66.5±10.9	65.1±2.4	0.09	1,6	0.8
	Family obligation	37.3±19.4	43.3±14.3	0.08	1,6	0.8
	Community obligation	33.3±19.2	48±16.9	0.09	1,6	0.8
4th most important	Family daily needs (food, others)	0±0	0±0	0	1,6	1
	Electricity/Water/solar	0±0	0±0	0	1,6	1
	School	0±0	0±0	0	1,6	1
	Church Obligations	22.4±12.4	16.5±9.9	0.4	1,6	0.6
	Family obligation	62.7±19.4	55.8±14.9	0.8	1,6	0.8
	Community obligation	65.6±19.9	52±16.9	0.09	1,6	0.8

Household social structure

Household social structure (well-being) was assessed in relation to their material life-style (i.e. housing materials, land ownership, livestock (type and number owned) private access to power, etc.). These items and their presence distribution in the households are provided in Table 2.6. Although the distribution of the material style of life items fluctuated among individual households, the differences were not statistically significant for SMA and comparator communities (Table 2.6).

Table 2.6: Mean (± SE) percentage of household responses in relation to ownership of material possessions as an indicator of social status at all study sites. Differences were tested using Kruskal-Wallis test. SMA: Special Management Area communities, COM: Comparator communities.

Characteristics	**HH wealth**	**SMA**	**COM**	**χ^2**	**df**	**P**
HH Livestock	Cattle	16.84±9.5	1.8±1.1	2.2	1,6	0.1
	Horses	3.0±2.1	1.8±1.1	0.02	1,6	0.9
	Pigs	96.7±1.9	97.5±1.7	0.4	1,6	0.5
	Goats	1.7±1.6	3.6±2.1	0.4	1,6	0.5
	Chickens	72.9±6.5	61.0±10.1	0.3	1,6	0.6
HH own land	Have land	54±4	58.3±8.5	0.3	1,6	0.6
	Have no land	45.2±3.8	41.7±8.5	0.1	1,6	0.8
HH dwelling	Tongan house	0±0	0±0	0	1,6	1
	Corrugated iron	2.1±2.1	4±2.4	0.4	1,6	0.5
	Timber	93.8±6.3	92.4±3.3	0.6	1,6	0.4
	Concrete	4.2±4.1	3.6±2.1	0.1	1,6	0.7
HH home furnishing	Radio	89.6±4.9	90.9±4	0.02	1,6	0.9
	Cd player	8.8±6.3	0±0	2.3	1,6	0.1
	Gas-Stove	81.3±7.1	72.7±8	0.3	1,6	0.6
	Video	52.9±11.7	59.6±9.7	0.1	1,6	0.8
	Generator	6.9±4.9	3.2±1.8	0.4	1,6	0.5
	Washing machine	20.9±7.7	16.5±13.2	0.2	1,6	0.7
	Refrigerator	33.9±13.1	20.2±14.6	0.8	1,6	0.4
HH Lighting system	Kerosene lamb	13.3±13.3	8.1±8	0.04	1,6	0.9
	Solar/Battery light	32.5±20.2	68.9±21.7	2.1	1,6	0.1
	Village electricity	51±28.3	23±23	1.9	1,6	0.2
	Own generator electricity	8.3±8.3	1.6±1.6	0.04	1,6	0.9
HH Water source	Rain water tank	100±0	98.4±1.6	1	1,6	0.3
	Village water	50±28.9	25.8±24.7	1	1,6	0.8
	Digging well	0±0	1.6±1.6	1	1,6	0.3
HH Toilet system	Pit hole	87.9±4.2	78.2±20.8	1.4	1,6	0.3
	Water system	12.1±4.2	21.8±20.8	1.4	1,6	0.3
Own a boat	Yes	29.3±1.9	29.7±9.2	0.3	1,6	0.6
	No	66.5±4.5	64.6±8.1	0.1	1,6	0.8

Perceived attitudes towards the establishment of SMAs and management opinions:

Although households from both community types had a strong awareness of the establishment of the SMAs, households from SMA communities reported a significantly greater level of satisfaction than households from comparator communities with regards to the establishment of the SMA and their respective boundaries (Table 2.7).

Nevertheless, 99% and 44% of the households in SMA and comparator communities respectively supported the establishment of SMA, while 53% of the comparator did not support the establishment of SMA (Table 2.7). The percentage of households that supported the establishment of SMA was significantly higher in SMA than comparator communities (Table 2.7). Accordingly, the percentage of households who did not support the establishment was significantly higher in comparator communities than the SMA communities.

Furthermore, the results showed that households that supported the establishment of SMAs attributed their support due to the perceived benefits that the SMA could realise (Table 2.7). These perceived benefits included “more fish in the future”, “stop outside fishers”, and “increase in fish catch” with a significantly higher proportion of responses from SMA respondents compared to comparator community respondents (Table 2.7). In contrast some households did not support the establishment of SMA due to perceived costs, such as “exclusion of fishers from other communities”, “limit access to fishing ground”, and “fishers from SMA communities fishing outside the SMA areas”. The percentage of households with the reasons of “limit access to fishing ground”, and “fishers from SMA villages fishing outside the SMA areas” were significantly higher in comparator rather than SMA communities (Table 2.7).

With regards to the fisheries management system, the perceived opinions of households on the current system (open access) included “lack of community involvement in fishery management”, “lack of management activities”, and “the current management system is fine”. However, only “lack of management activities” was found to have a significantly higher percentage of responses in the SMA compared to the comparator communities, while the preference of the current fisheries management system tended to be higher (though not significant) in the comparator communities (Table 2.7). On the other hand, perceived opinions on the SMA regime include “community empowerment”, “community sense of ownership”, “exclusion of outside fishers”, “community enforcement”, “an unfair system”, “limit access to fishing ground”, and “selfish system”. Only the perceived opinion on unfair system was found to be significantly higher for the comparator compared to the SMA communities (Table 2.7).

Table 2.7: Mean (± SE) percentage of household attitudes and opinions in respect of the awareness, satisfaction and support for the establishment of SMAs within the study area. Tests for significance were compared with the Kruskal-Wallis test. Shaded lines represent a significance difference found.

Statement	Attitude and comments	SMA	COM	χ^2	df	P
HH aware of SMA establishment	Agree	100±0	89.9±5.6	3.9	1,6	0.05
	Neutral	0±0	0±0	0	1,6	1
	Disagree	0±0	10.0±5.6	3.9	1,6	0.05
HH satisfy with SMA establishment	Disagree	3.2±2.0	24.4±7.8	2	1,6	0.15
	Neutral	0±0	17.2±10.3	5.5	1,6	1
	Agree	96.8±2.1	58.4±5.2	4.6	1,6	0.03
HH satisfy with the SMA boundaries	Disagree	8.4±7.4	44.2±17.9	2.2	1,6	0.14
	Neutral	5.2±5.2	17.32±12.9	1.2	1,6	0.3
	Agree	86.4±7.2	38.52±8.8	5.3	1,6	0.02
HH support the SMA establishment	Disagree	1±1.0	53.3±8.4	5.6	1,6	0.02
	Neutral	0±0	2.4±2.4	1	1,6	0.3
	Agree	99±1.0	44.3±8.9	5.6	1,6	0.02
Opinions for supporting SMA establishment	More fish in the future	66.8±7.8	26.5±4.3	5.3	1,6	0.02
	Stop outside fishers	73.8±6.3	31.3±3.5	5.3	1,6	0.02
	Community management	9.1±5.1	5.7±3.5	0.5	1,6	0.5
	Increase catch	68.4±8.2	26.8±1.9	5.3	1,6	0.02
Opinions for NOT supporting SMA establishment	Exclude outside fishers	0±0	7.7±4.5	2.3	1,6	0.1
	Limit access to fishing grounds	1±1.0	44.5±13.8	4.3	1,6	0.04
	SMA fishers fishing outside the SMA areas	0±0	46.3±7.0	6.1	1,6	0.01
Opinions on the current fisheries management (open access)	Lack of community involvement	28.8±15.5	19.1±11.1	0.34	1,6	0.6
	Lack of management activities	51.9±9.2	14.3±2.2	5.3	1,6	0.02
	Current system is fine	24.7±9.8	56.8±17.9	1.3	1,6	0.3
Opinion on the SMA regime	Community empowerment	56.8±14.5	15.6±7.2	3	1,6	0.08
	Community ownership	17.9±7.2	0.9±0.9	2.9	1,6	0.09
	Exclusion of outsiders	54.2±9.4	50.5±13.0	0.08	1,6	0.8
	Community enforcement	35.2±12.2	27.6±9.9	0.3	1,6	0.6
	Unfair system	0±0	47.6±9.4	6.1	1,6	0.01
	Limit access	0±0	12.9±10.3	3.9	1,6	0.05
	Selfish system	0±0	1.7±1.6	1	1,6	0.3

Perceived biological benefits of the SMA

Most of the SMA household respondents agreed (66%) that their household livelihood had been improved as a result of the establishment of the SMA. In contrast, 91% of the comparator households perceived no impact of the SMA on their household livelihood. Nevertheless, both SMA and comparator communities were aware of the biological value of the SMA. For instance, about 97% and 69% of SMA and comparator households respectively believed that SMA establishment is a better way to sustain fisheries in the community level. In addition, both SMA and comparator households (94 % and 83% respectively) believed that no-take zones benefit resources by protecting marine biodiversity and thereby enhance fish abundance. Furthermore, most household in both SMA (85%) and comparator communities (98%) agreed that the coral reef is valuable and an important focus for conservation (Table 2.8).

Table 2.8: Percentage (± SE) of household responses in relation to question about the benefits regarding the establishment of the SMAs. Tests for significance were compared with the Kruskal-Wallis test. Shaded line represent a significance difference found.

Statements	Perceptions	SMA	COM	χ^2	df	P
HH livelihood improve since the establishment of the SMA	Disagree	18.2±7.0	91.3±4.0	5.3	1,6	0.02
	Neutral	10.3±1.7	7.7±4.2	0.8	1,6	0.4
	Agree	66±7.7	0±0	6.1	1,6	0.01
Establishment of SMA is a good way to sustain fisheries in the community	Disagree	0±0	24.2±3.2	6.1	1,6	0.01
	Neutral	0.8±0.8	4.9±2.0	2.9	1,6	0.09
	Agree	96.9±2.1	68.9±5.8	5.4	1,6	0.02
Establishment of NTZ helps to protect marine biodiversity	Disagree	0±0	3.9±3.0	2.3	1,6	0.1
	Neutral	5.7±1.2	12.1±8.5	0.08	1,6	0.8
	Agree	94.3±1.2	83.2±6.8	4.1	1,6	0.04
Comments	Fishing is prohibited	28.1±7.4	21.9±13.3	0.3	1,6	0.6
	Depend on the Enforcement	36.7±3.5	22.8±4.8	3	1,6	0.08
	Fish population increases	5.8±3.9	0±0	2.3	1,6	0.1
	Fish are protected (NTZ)	58.9±16.0	80.2±12.0	1.3	1,6	0.2
	Only work with invertebrate	5.9±2.6	6.4±4.6	0.1	1,6	0.8
	Restocking activities	15.6±6.1	11.3±4.1	0.3	1,6	0.6
	Takes some time	21.7±1.5	22.5±3.0	0.1	1,6	0.8
Establishment of NTZ helps enhance fish abundance	Disagree	0±0	7.1±6.0	2.3	1,6	0.1
	Neutral	5.2±2.9	5.2±1.8	0.2	1,6	0.7
	Agree	92.6±2.3	87.8±6.7	0.1	1,6	0.8
Comments	Increase catch within the SMA	7.8±3.6	0.8±0.8	2.9	1,6	0.09
	More fish within the SMA	36.4±6.4	12.5±4.5	5.3	1,6	0.02
	Only with active enforcement	49.9±5.6	52.4±3.5	0.1	1,6	0.8
	Fish are protected	28±4.9	47.2±6.7	3	1,6	0.1
Marine environment and coral reef is valuable and important to be conserved	Disagree	0±0	0±0	0	1,6	1
	Neutral	2.5±2.5	0.8±0.8	1	1,6	0.3
	Agree	95.3±2.7	98.4±1.6	0.4	1,6	0.5
Comments	Source of living (food and income)	85.1±5.6	87.6±2.4	0.3	1,6	0.6
	Island Depend on for shelter	36.4±6.9	27.6±7.4	0.5	1,6	0.5
	For future generation	41.8±6.2	33.3±8.7	0.8	1,6	0.4

Perceived attitudes on the impact on food:

Finfish was the most common food item prepared by households across all the study sites (Figure 2.4 a). Tinfish (canned), chicken and invertebrates were ranked as the second most common food item prepared by households (Figure 2.4 b). Meat was rated as the least common food item prepared by households (Figure 2.4 c & d). There were no significant differences found for the common food items prepared in the households in SMA and comparator communities except for the second most common food item prepared, where households in the comparator communities reported the consumption of Tinfish was more common (Figure 2. 4 b).

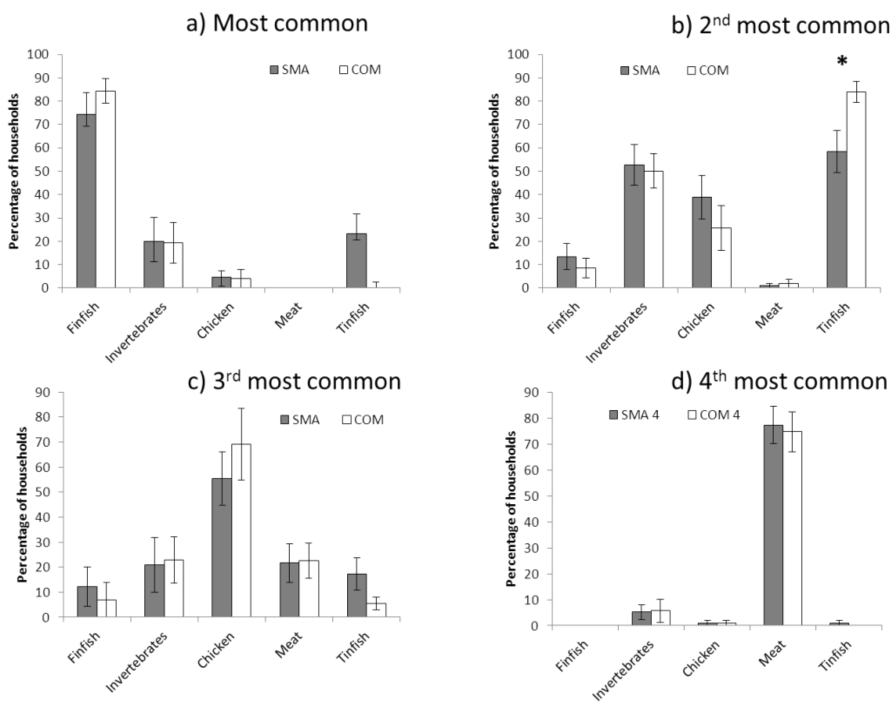

Figure 2.4: Mean (± SE) percentage of household responses in relation to the food type most commonly eaten in the household: (a) most commonly prepared food item, (b) 2nd common prepared food item, (c) 3rd common prepared food item, d) least common prepared food item. The symbol (*) indicates the occurrence of a significant difference when a Kruskal-Wallis test was applied (Table 2.9).

Regarding the factors that determined what food items were prepared, engaging in fishing was the most common factor that determined which food items were most likely to be prepared. Wealth (money) and the availability of the food items became the second common factors followed by the price of the food item (Figure 2.5 ai, ii & iii). The majority of the households held the opinion that the use of food items had changed with time (Figure 2.5 bi). When asked for the reasons behind these changes, the most frequent response was that "more shop-food" was available followed by "more seafood or less seafood" available (Figure 2.5bii). Households at SMA communities stated that their diet contained significantly more seafood whereas households at comparator villages said they included significantly less seafood in their diet. When asked if the changes to food items were related to the establishment of SMA, a significantly higher proportion of people agreed with this statement if they were from communities associated with the SMAs (Figure 2.5 biii). Seafood eaten in households was primarily derived from "own" caught seafood followed by gift of seafood and lastly seafood purchased from fishers (Figure 2.5c i, ii, & iiii). When asked if there had been any change in seafood consumption over time, most households from communities associated with SMAs felt that there has been a slight increase in consumption over time (Figure 2.6a).

Table 2.9: Mean (± SE) percentage of household responses in relation to the food type most commonly eaten in the household. Tests for significance were compared with the Kruskal-Wallis test. Shaded line represent a significance difference found.

Rank	**Food items**	**SMA**	**COM**	**χ^2**	**df**	**P**
1st most common	Finfish	74.3±9.4	84.4±5.2	0.5	1,6	0.5
	Invertebrates	20±10.1	19.4±8.7	0.1	1,6	0.8
	Chicken	4.7±2.7	4±4	0.1	1,6	0.8
	Meat	0±0	0±0	0	1,6	1
	Tinfish	23.2±8.4	10.6±2.5	1	1,6	0.3
2nd most common	Finfish	13.4±5.5	8.6±4.2	0.3	1,6	0.6
	Invertebrates	52.7±8.7	50.2±7.3	0.1	1,6	0.8
	Chicken	38.9±9.4	25.8±9.6	0.8	1,6	0.4
	Meat	1±1.0	1.9±1.9	0.04	1,6	0.9
	Tinfish	58.5±9.1	83.9±4.5	4.1	1,6	0.04
3rd most common	Finfish	12.2±7.8	7±7	1.2	1,6	0.3
	Invertebrates	20.9±10.9	22.9±9.3	0.1	1,6	0.8
	Chicken	55.4±10.7	69.2±14.3	0.3	1,6	0.6
	Meat	21.7±7.7	22.5±6.9	0	1,6	1
	Tinfish	17.3±6.5	5.5±2.5	2.1	1,6	0.2
4th most common	Finfish	0±0	0±0	0	1,6	1
	Invertebrates	5.3±2.8	5.7±4.5	0.1	1,6	0.8
	Chicken	1.03±1.0	1±1	0.04	1,6	0.9
	Meat	77.3±7.2	74.7±7.7	0.3	1,6	0.6
	Tinfish	1±1.0	0±0	1	1,6	0.3

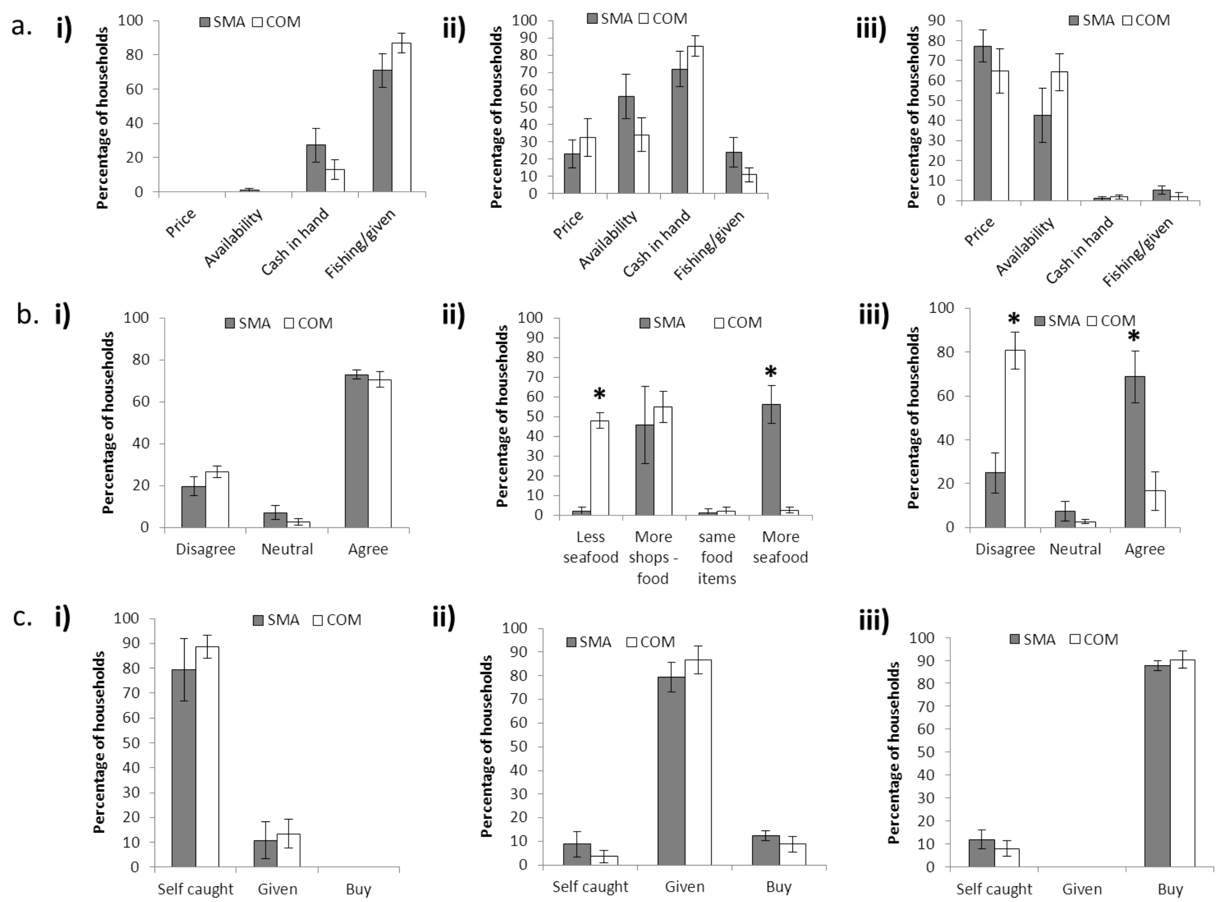

Figure 2.5: Mean (± SE) percentage of household responses to: a) questions in relation to what determined food items that are prepared in the household: i) most common factors, ii) second common factor, iii) Least common factor; b) Changes in relation to change on food items used: i) Have food items used changed over time, ii) Reasons for change in food items used, iii) change in food items related to SMA; c) Source of seafood: i) most common source of seafood, ii) second most source of seafood, iii) Least common source of seafood. The symbol (*) indicates the occurrence of a significant difference when a Kruskal-Wallis test was applied (Table 2.10 and 2.11).

Table 2.10: Mean (± SE) percentage of household responses to: a) questions in relation to what determines food items that are prepared in the household. Tests for significance were compared with the Kruskal-Wallis test.

Rank	**Factors**	**SMA**	**COM**	**χ^2**	**df**	**P**
Most common	Prize	0±0	0±0	0	1,6	1
	Availability	1±1.0	0±0	1	1,6	0.3
	Cash on hand	27.2±9.9	12.9±5.8	1.3	1,6	0.3
	Fishing/given	70.9±9.8	87.1±5.8	1.3	1,6	0.3
2nd most common	Prize	22.7±8.1	32.5±11.0	0.8	1,6	0.4
	Availability	56.3±12.8	33.9±9.7	1.3	1,6	0.3
	Cash on hand	71.9±10.2	85.3±6.1	1.3	1,6	0.3
	Fishing/given	23.9±8.7	10.9±4.1	1	1,6	0.3
Least most common	Prize	77.3±8.1	64.8±11.1	0.8	1,6	0.4
	Availability	42.6±13.7	64.3±9.2	1.3	1,6	0.3
	Cash on hand	0.8±0.8	1.8±1.1	0.4	1,6	0.5
	Fishing/given	5.1±2.1	2±2	1.9	1,6	0.2

Table 2.11: Mean (± SE) percentage of household responses to changes in relation to change on food items used: i) Have food items used changed over time, ii) Reasons for change in food items used, iii) Change in food items related to SMA. Tests for significance were compared with the Kruskal-Wallis test. Shaded lines represent a significance difference found.

Opinions	**SMA**	**COM**	**χ^2**	**df**	**P**
Disagree	19.8±4.4	26.7±2.8	3	1,6	0.1
Neutral	7.2±3.3	2.6±1.6	0.8	1,6	0.4
Agree	73.0±2.2	70.7±3.7	1.3	1,6	0.3
Reasons					
Less seafood	1.9±1.1	47.9±4.0	5.4	1,6	0.02
More shops -food	45.8±9.8	54.9±8.1	1.7	1,6	0.2
same food items	1±1.0	2±2	0.04	1,6	0.9
More seafood	56.3±4.8	2.5±1.5	5.4	1,6	0.02

Table 2.12: Mean (± SE) percentage of household responses to changes in food items related to the establishment of the SMA. Tests for significance were compared with the Kruskal-Wallis test. Shaded lines represent a significance difference found.

Opinions	SMA	COM	χ^2	df	P
Disagree	24.9±9.3	80.7±8.3	5.3	1,6	0.02
Don't know	7.5±4.4	2.7±0.9	0.1	1,6	0.8
Agree	68.7±11.8	16.6±8.7	5.3	1,6	0.02
Reasons					
Fishing catch decline	0±0	1.6±1.6	1	1,6	0.3
No change	1±1.0	2.4±2.4	0.04	1,6	0.9
Increase catch	63.2±9.3	0±0	6.1	1,6	0.01
More money	16.3±12.7	12.6±10.6	0.4	1,6	0.6
Don't know	19.9±10.7	7.8±7.8	1.2	1,6	0.3
Not related to SMA	1.9±1.1	54.5±22.8	5.4	1,6	0.02
Less fishing activities	5.3±2.1	13.9±13.8	0.6	1,6	0.4
Fish outside SMA	0±0	4.7±4.7	1	1,6	0.3
Establishment of NTZ	3.3±3.3	4±4.0	0.04	1,6	0.9
Close for fishing (SMA)	0±0	16.6±8.7	3.9	1,6	0.05

Table 2.13: Mean (± SE) percentage of household responses in related to their source of seafood. Tests for significance were compared with the Kruskal-Wallis test.

Rank	Sources	SMA	COM	χ^2	df	P
Most common	Self-caught	79.4±12.4	88.5±4.6	0.3	1,6	0.6
	Given	10.8±7.4	13.3±5.8	0.2	1,6	0.7
	Buy	0±0	0±0	0	1,6	1
2nd most common	Self-caught	8.8±5.3	3.6±2.6	0.4	1,6	0.5
	Given	79.4±6.2	86.7±5.8	0.3	1,6	0.6
	Buy	12.4±2.1	8.8±3.4	0.8	1,6	0.4
Least most common	Self-caught	11.9±4.1	7.9±3.3	1	1,6	0.3
	Given	0±0	0±0	0	1,6	1
	Buy	87.6±2.1	90.3±3.7	0.08	1,6	0.8

In contrast, the comparator households felt that they either have experienced a slight decrease or no change at all in the amount of seafood they consumed with significantly higher responses compared to SMA households (Figure 2.6a). When asked if the observed changes are related to the establishment of the SMA, a significantly higher percentage of the SMA households agreed than the comparator households and vice versa (Figure 2.6b). Household respondents were also asked to comment on the reasoning behind their response. The household respondents that disagreed with statement most frequently cited "being fishing outside the SMA", followed by "able to do less fishing" and "fishing catch decline" and "closed fishing grounds" to a lesser extent (Figure 2.6c). However, the reasons including "fishing outside the SMA", "less fishing" and "catch decline" were found to be significantly higher for the comparator than the SMA communities. The household respondents with an "agree" response most frequently cited "increased catch" as the most given reason followed by "closed fishing grounds" and "less fishing" to a lesser extent (Figure 2.6 d). Only the reason of "increase catch" was found to be significantly higher in SMA compared to comparative villages

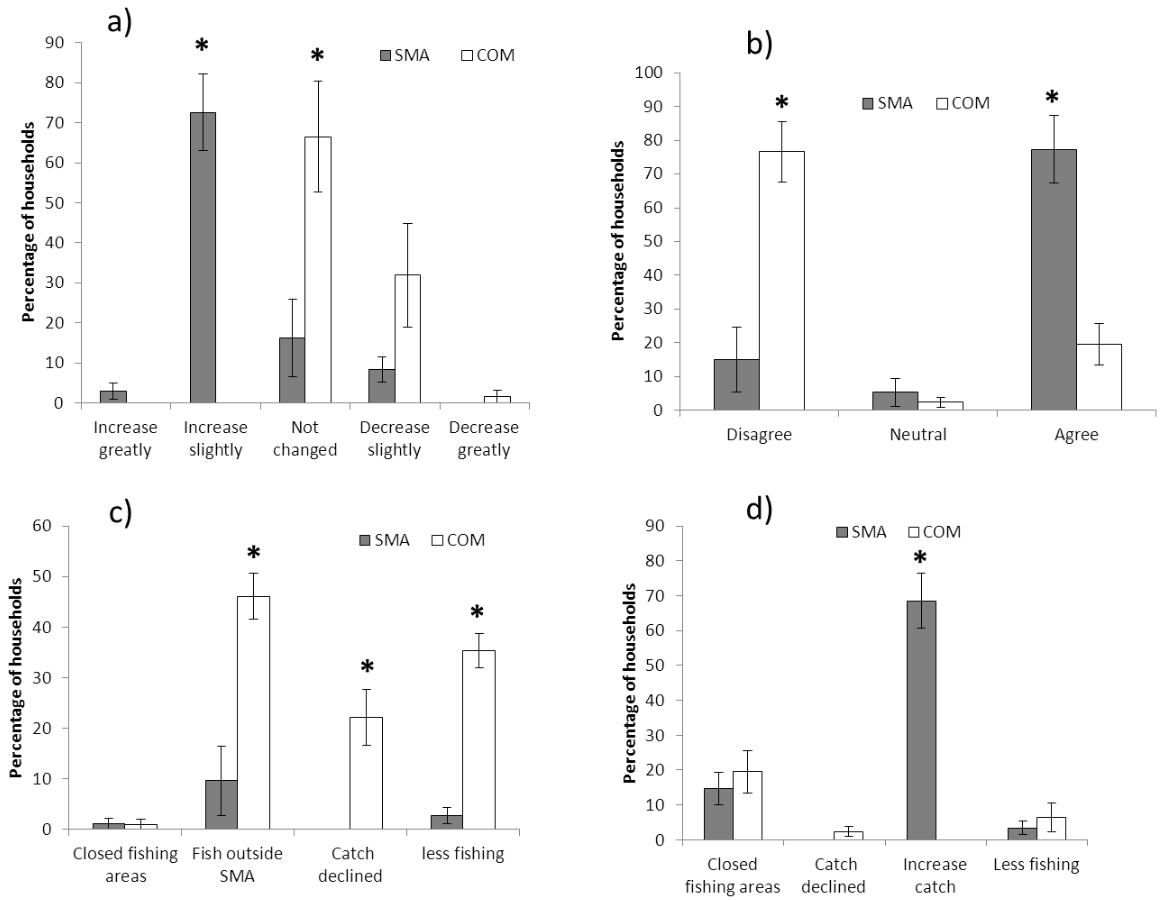

Figure 2.6: Mean (± SE) percentage of households' responses in relation to seafood consumption: a) Seafood consumption change over time, b) Seafood consumption change due to SMA, c) Reasons for disagrees that the change in seafood consumption is related to the establishment of the SMA, d) Reasons for agrees that the change in seafood consumption is related to the establishment of the SMA. The symbol (*) indicates the occurrence of a significant difference when a Kruskal-Wallis test was applied (Table 2.14).

Table 2.14: Mean (± SE) percentage of household responses to changes in seafood consumption related to the establishment of the SMA. Tests for significance were compared with the Kruskal-Wallis test. Shaded lines represent a significance difference found.

Opinions	**SMA**	**COM**	**χ^2**	**df**	**P**
Increase greatly	2.9±2.0	0±0	2.3	1,6	0.1
Increase slightly	72.6±9.6	0±0	6.1	1,6	0.01
Not changed	16.2±9.8	66.5±13.9	4.1	1,6	0.04
Decrease slightly	8.3±3.2	31.9±13.0	2.1	1,6	0.2
Decrease greatly	0±0	1.6±1.6	1	1,6	0.3
Disagree	15.1±9.6	76.6±8.9	5.3	1,6	0.02
Neutral	5.4±4.1	2.4±1.5	0.1	1,6	0.8
Agree	77.3±10.0	19.5±6.2	5.3	1,6	0.02
Comment					
Disagree					
Closed fishing areas	1.1±1.1	1±1	0.04	1,6	0.9
Fish outside SMA	9.6±6.9	46.1±4.6	5.3	1,6	0.02
Catch declined	0±0	22.1±5.6	6.1	1,6	0.01
Less fishing	2.7±1.6	35.3±3.4	5.4	1,6	0.02
Agree					
Closed fishing areas	14.7±4.5	19.5±6.2	0.3	1,6	0.6
Catch declined	0±0	2.4±1.5	2.3	1,6	0.1
increase catch	68.6±7.9	0±0	6.1	1,6	0.01
less fishing	3.3±1.9	6.4±4.2	0.1	1,6	0.8

Perceived attitudes on the impact on household fishing activities

Table 2.15 below summarised the household fishing profile. Fishermen's ages ranged from 18 to > 70 years old with the majority in the middle-aged (30 – 49). There was no significant difference between the aged-ranges of fishers from the SMA and comparator communities. The length of fishing careers ranged from < 5 to > 30 years with the majority in the 5 – 10 and 11 -20 year classes with no significant difference between the SMA and comparator communities.

A variety of fishing methods is practiced in both SMA and comparator communities. About 58 % and 68% of the household engaged with spearfishing and 55% and 66% ranked it as the most common fishing method used in both the SMA and comparator households respectively (Table 2.15). Other fishing methods included hand lining, netting, gleaning and octopus fishing but these comprised the minority of fishing activities. There was no significant difference in the fishing methods used between fishers from the SMA and comparator households.

Table 2.15: Mean (± SE) percentage of fishers regarding fishing characteristics in all study sites. Differences were tested using the Kruskal-Wallis test. SMA: Special Management Area communities, COM: Comparator communities.

Fishing characteristics		SMA	COM	χ²	df	P
Ages	18-29	13.1±5.1	15.6±5.3	0.2	1,6	0.7
	30-49	57.4±8.7	60.1±5.7	0.3	1,6	0.6
	50-70	29.5±6.9	24.3±5.2	0.3	1,6	0.6
Fishing life time	<5	15.4±1.8	14.9±5.1	0.3	1,6	0.6
	5_10	25.4±2.2	31.4±7.3	0.1	1,6	0.8
	11_20	34.4±7.1	25.9±3.4	1.3	1,6	0.2
	21_30	14.5±3.1	17.9±3.4	0.8	1,6	0.4
	>30	10.4±3.6	9.8±2.6	0.1	1,6	0.8
Most common fishing methods	Gleaning	6.7±4.1	3.5±1.3	0	1,6	1
	Octopus (Iron bars)	0±0	2.2±1.3	2.3	1,6	0.1
	Octopus lure	0±0	0±0	0	1,6	1
	Spearfishing	74.3±37.2	70.5±14.6	0	1,6	1
	Cast net	4.4±2.2	0±0	2.3	1,6	0.1
	Gillnet	1.9±1.0	2.2±1.3	0.1	1,6	0.7
	Hand line (shallow)	15.6±7.8	5.7±5.7	2.2	1,6	0.1
	Hand line (Deep)	3.7±1.9	18.3±16.9	0.4	1,6	0.5
	Trolling	0±0	1.1±1.1	1	1,6	0.3
Fishing catch target	Finfish	22.2±5.6	26.2±10.3	0	1,6	1
	Invertebrates	1.9±1.9	2.2±1.3	0.1	1,6	0.7
	Both	75.3±7.1	71.6±9.7	0.1	1,6	0.8
Most common fishing habitats	Sea grass	7.7±7.7	3.3±3.3	0.04	1,6	0.9
	Shallow lagoon	12.9±9.2	8.3±3.6	0.02	1,6	0.9
	Back reef	49.4±15.5	40.8±11.1	0.3	1,6	0.6
	Reef crest	32.6±9.7	24.8±6.1	0.3	1,6	0.6
	Reef front/Outer reef	83.8±6.0	74.2±14.6	0	1,6	1
	Lagoon	12.5±6.6	8.4±6.5	0.4	1,6	0.6
	Deep sea	8.7±5.1	19.4±16.6	0	1,6	1
Fishing time (2 - 6 hours)	Sea grass	12.7±6.5	4.1±1.8	1.7	1,6	0.1
	Back reef	43.7±13.7	34.5±11.9	0.3	1,6	0.6
	Reef crest	20.1±5.3	17.6±7.2	0.08	1,6	0.8
	Reef front/Outer reef	90±4.6	76.5±15.2	0.3	1,6	0.6
	Lagoon	15.9±2.2	6.8±5.4	1.3	1,6	0.3
	Deep sea	1.9±1.9	3.7±2.2	0.4	1,6	0.5
Fishing trips frequency (per week)	One	5.3±301	8.3±2.6	1.3	1,6	0.3

	Two	30.1±9.4	26.8±7.7	0.3	1,6	0.6
	Three	39.2±10.3	39.4±3.6	1.3	1,6	0.3
	Four	19.5±4.8	21.6±6.3	0	1,6	1
	Five	7.2±4.4	3.9±2.3	0.1	1,6	0.8
Most common fishing transport	Motorised boat	14.3±4.9	21±2.9	0.8	1,6	0.4
	Canoe	1±0.7	0.25±0.3	0.7	1,6	0.4
	Swimming/walking	1.5±1.0	1.5±1.2	0	1,6	1
Fishing period	Day	10.8±6.2	4.5±2.6	0.4	1,6	0.5
	Night	12.3±7.1	15.8±5.3	0.1	1,6	0.8
	Day & Night	78.9±8.0	79.8±7.4	0.02	1,6	0.9
Fishing season	All year	94.3±3.7	85.9±8.8	0.4	1,6	0.6
	summer season	5.7±3.7	12.9±7.7	0.4	1,6	0.6
	Winter season	0±0	1.1±1.1	1	1,6	0.3
	Never	32.9±4.6	18.9±10.8	1.3	1,6	0.3
What you mostly do with catch	Sell	62.4±13.3	89.4±4.9	2.1	1,6	0.2
	give away	0±0	0±0	0	1,6	1
	Family consumption	33.9±13.8	10.6±4.9	1.3	1,6	0.3

Fishers go out to fish 2 to 3 times per week regardless of which habitat or fishing ground they choose. An average fishing time spent targeting any habitat took from 2- 6 hours depending on what methods were used, the purpose of the fishing trip, and sometimes the target catch. The most common fishing habitat was the reef front or the outer reef followed by the back reef. However, the use of fishing habitats depended on the fishing methods used and the target catch as well. Mostly, fishers targeted both finfish and invertebrates despite in some cases where some fishers may target either finfish or invertebrate. Fishing activities are mostly carried out at both day and night throughout the year. The majority of fisher's catch is sold to generate income while a small portion is reserved for household consumption and as a gift.

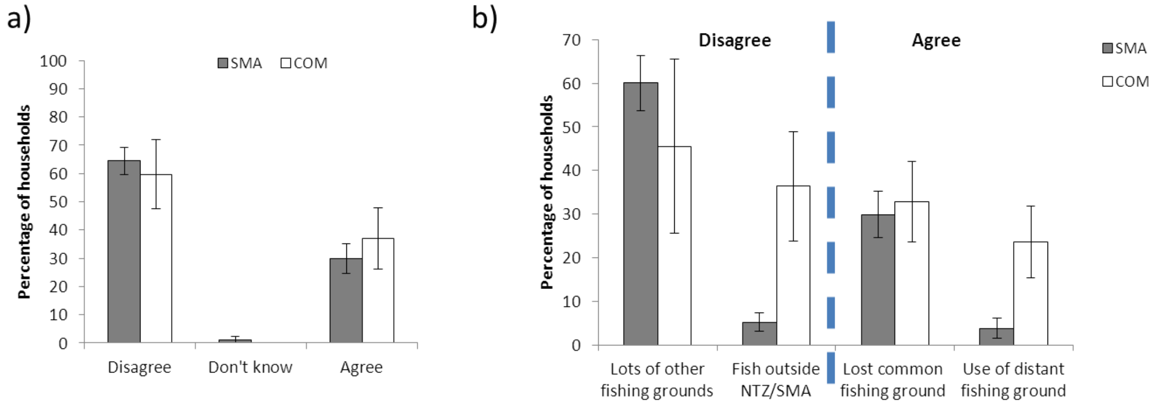

Figure 2.7: Mean (± SE) percentage of household‘s perception on household fishing catch: a) effect on fishing activities, b) Reasons for agree and disagree that there is an effect on their fishing activities related to the establishment of the SMA. SMA: Special Management Area villages, COM: comparator villages.

Table 2.16: Mean (± SE) percentage of fisher's perceptions of their change in catch as a result of the establishment of the SMAs. Tests for significance were compared with the Kruskal-Wallis test.

Responses	**SMA**	**COM**	**χ^2**	**df**	**P**
Disagree	64.5±4.8	59.8±12.2	0.3	1,6	0.6
Don't know	1.1±1.1	0±0	1	1,6	0.3
Agree	29.9±5.3	37±10.7	0.3	1,6	0.6

Table 2.17: Mean (± SE) percentage of fisher's opinions thatagreed or disagreed as a result of the establishment of the SMAs. Tests for significance were compared with the Kruskal-Wallis test.

Comments	SMA	COM	χ^2	df	P
Agree					
Lost common fishing ground	29.9±5.3	32.9±9.2	0.3	1,6	0.6
Use of distant fishing ground	3.8±2.3	23.6±8.2	2.2	1,6	0.1
Disagree					
Lots of other fishing grounds	60.1±6.3	45.6±20.0	0.3	1,6	0.6
Fish outside NTZ/SMA	5.3±2.1	36.4±12.5	2.1	1,6	0.2

When asking if establishment of SMA has had an effect on their fishing activities, the majority (65% and 60 %) of household respondents from SMA and comparator communities respectively disagreed. Accordingly, 30% and 37% of the respondent from SMA and comparator communities agreed that there are negative effects on their fishing activities in relation to the establishment of the SMAs (Figure 2.7a, Table 2.16). When asked the reasons for their perceptions, the most frequent response given by those that disagreed with the question was "lots of other fishing ground" is available for fishing followed by "fish outside the SMA/NTZ areas". On the other hand, the most frequent response given by those that agreed that the SMA had affected their fishing activities was "loss of their common fishing grounds" followed by use of "distant fishing grounds" that incur more expenses (Figure 2.7, Table 2.17).

In addition, when households were asked about the changes in their catch since the implementation of the SMA, about 60% of the SMA households cited a slight increase. In contrast, about 58% of the comparator communities' households cited a slight decrease in catch (Figure 2.8a). When asked if the changes were a result of the SMA establishment, SMA communities' households agreed with a significantly higher response than comparator communities, whereas the comparators communities' households disagreed significantly compared with the SMA communities (Figure 2.8 b, Table 2.18). When asked about the reasoning behind their opinions, those that agree felt that “less number of fishermen in the SMA”, “more fish around”, and “loss of common fishing ground” were the reasons for the observed changes, while those that disagree felt that “less fish around”, “fishing outside SMA”, and “depend on the status of fishing ground visited” were the reasons responsible for the observed changes (Figure 2.8c). Only the “less fish around the fishing ground” reason was found to be significantly higher responses in comparator than SMA communities, while the reasons of “less number of fishermen in the SMA” and “more fish around the SMA” were found to be significantly higher responses in the SMA than comparator communities (Table 2.18).

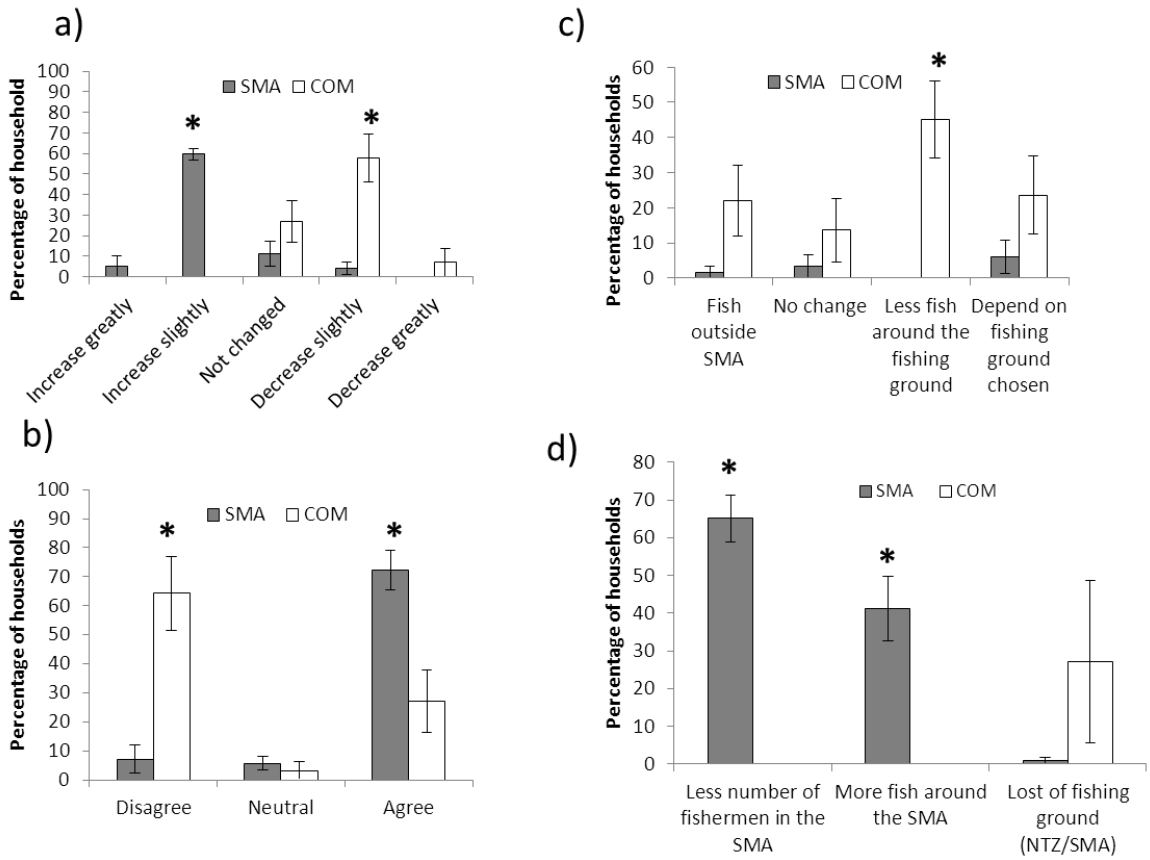

Figure 2.8: Mean (± SE) percentage of households' perceived attitude on status of fish catch: a) Changes in catch overtime, b) Changes in catch due to the establishment of the SMA, c) Reasons for being disagreed, d) Reasons for being agreed. The symbol (*) indicates the occurrence of a significant difference when a Kruskal-Wallis test was applied (Table 2.18).

Table 2.18: Mean (± SE) percentage of fisher's perceptions of their change in catch derived from fishing as a result of the establishment of the SMAs. Tests for significance were compared with the Kruskal-Wallis test.

Variables	**Effect and comments**	**SMA**	**COM**	χ^2	**df**	**p**
Changes in catches	Increase slightly	59.8±2.8	0±0	6.1	1,6	0.01
	Decrease slightly	4.2±3.2	57.7±11.7	5.4	1,6	0.02
Changes due to SMA	Disagree	7.2±4.7	64.3±12.7	5.4	1,6	0.02
	Agree	72.3±6.7	27.2±10.8	5.3	1,6	0.02
Disagree-reason	Less fish around fishing ground	0±0	45.1±11.1	6.1	1,6	0.01
Agree-reason	Less number of fishermen in the SMA	65.2±6.2	0±0	6.1	1,6	0.01
	More fish around SMA	41.1±8.6	0±0	6.1	1,6	0.01

When households were asked about the status of their income derived from fishing, the majority (56%) of the SMA households cited that a slight increase had occurred. In contrast, about 52% of the comparator households cited a slight decrease in their income (Figure 2.9, Table 2.19). When asked if the changes were a result of the SMA establishment, the SMA communities agreed with this proposition significantly more than the comparator communities (Figure 2.9 b, Table 2.19). The most common reasons given for the changes was that " increase catch" followed by "better price", and "less catch" and "increase expenses" to a lesser extent (Figure 2.9d). Both the reasons of "increase catch" and "better price" responses were significantly higher in the SMA than comparator communities. Those that had responses with disagreed with the statement felt that "less catch" was the main reason followed by "still the same catch", "better price" and "increase expenses" to a lesser extent (Figure 2.9c). Only the reason of "less catch" was found to be significantly higher in the comparative than SMA villages (Table 2.19).

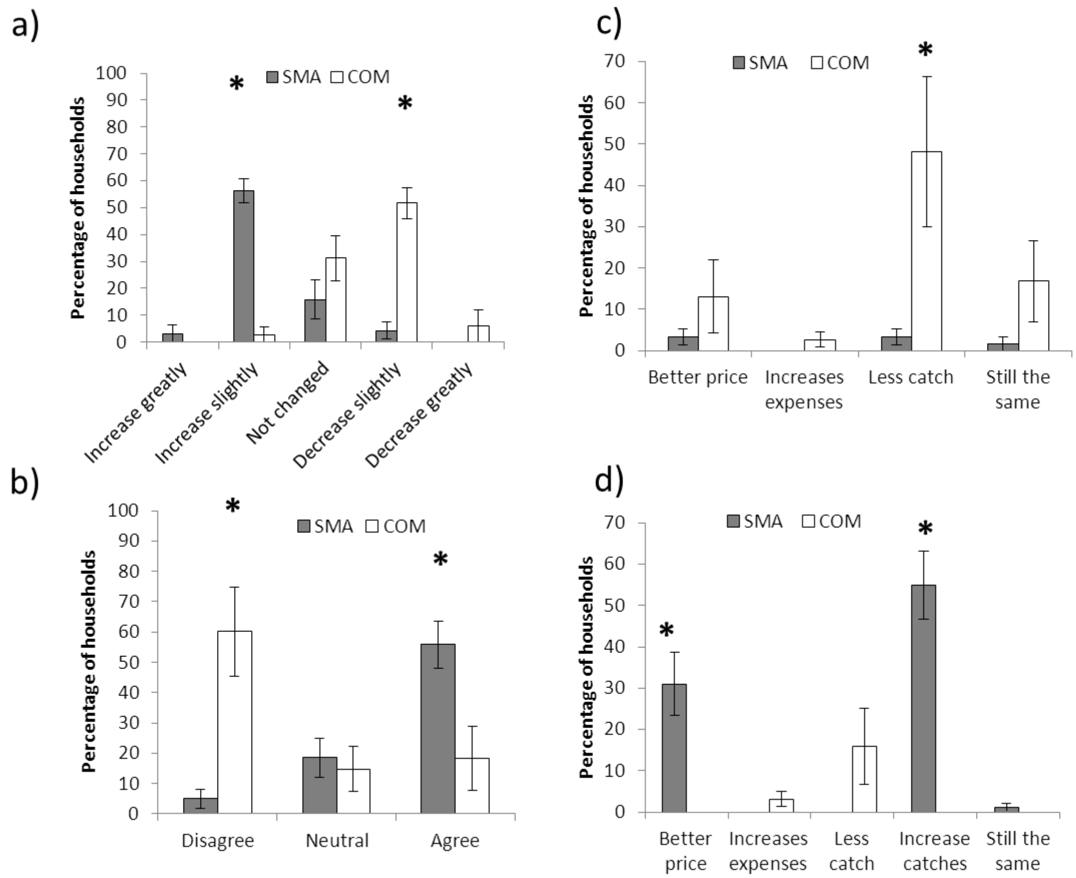

Figure 2.9: Mean (± SE) percentage of households perceived attitude on status of income from fishing: a) Changes in income overtime, b) Changes in income due to SMA establishment, c) Disagree, d) Agree. The symbol (*) indicates the occurrence of a significant difference when a Kruskal-Wallis test was applied (Table 2.19).

Table 2.19: Mean (± SE) percentage of fisher's opinions about change in their income derived from fishing as a result of the implementation of the SMAs. Test for significant differences were undertaken using a Kruskal-Wallis test (χ^2).

Variables	**Effects and comments**	**SMA**	**COM**	**χ^2**	**df**	**P**
Change in income	Increase slightly	56.4±4.4	2.8±2.8	5.6	1,6	0.02
	Decrease slightly	4.2±3.2	51.6±5.8	5.4	1,6	0.02
Changes due to SMA	Disagree	5±3.2	60.2±14.7	5.4	1,6	0.02
	Agree	55.9±7.8	18.3±10.5	5.4	1,6	0.02
Disagree-comments	Less catch	3.3±1.9	48.1±18.1	5.4	1,6	0.02
Agree-comments	Better price	31±7.6	0±0	6.1	1,6	0.01
	Increase catches	54.8±8.2	0±0	6.1	1,6	0.01

Fishers were also asked about perceived changes that had occurred with their actual fishing time in relation to the establishment of the SMA. The responses indicated that 64 % of the fishers from the SMA villages experienced a significantly shorter fishing time compared to the comparator communities. Sixty seven percent of the respondents from the comparator communities felt that there had been no change in their fishing time, while 33% felt that they spent significantly longer fishing than fishers from SMA communities. Only fishers from the comparator communities (43%) had to travel to distant fishing grounds (Figure 2.10b). Fishers were also asked about factors that influence their choice of fishing ground. Most of the respondents cited weather as the main factor, followed closely by availability of boat, fuel and SMA regulation. Of these factors, fishers from the comparator communities were more strongly influenced by the availability and price of fuel (Figure 2.10c, Table 2. 20) which reinforces the idea that they had to use distant fishing grounds more often than SMA communities.

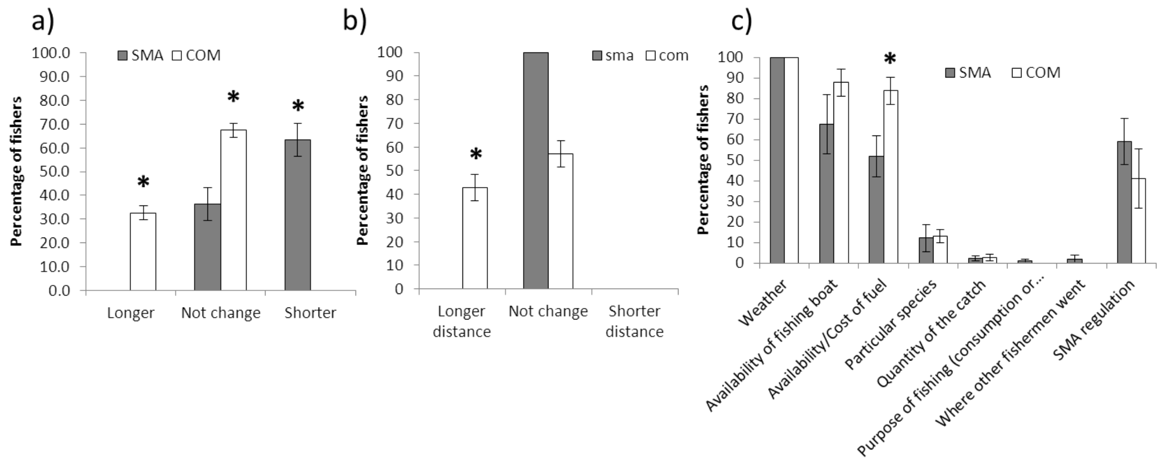

Figure 2.10: Mean (± SE) percentage of Fishers' perceptions of the impact of the SMAs on their practices: a) Fishing time change after establishment of the SMA, b) Distance travelled to fishing grounds after the establishment of the SMA, c) Factors influence the choice of fishing ground. The symbol (*) indicates the occurrence of a significant difference when a Kruskal-Wallis test was applied (Table 2.20).

Table 2.20: Mean (± SE) percentage of fisher's perceptions towards catches and other fishing activities regarding SMAs with test for significance using Kruskal-Wallis tests.

Variables	**Effects and comments**	**SMA**	**COM**	χ^2	**df**	**P**
Fishing time	Longer	0±0	32.6±2.9	6.1	1,6	0.01
	Not change	36.5±6.9	67.4±2.9	5.3	1,6	0.02
	Shorter	63.5±6.9	0±0	6.1	1,6	0.01
Fishing ground	Longer distance	0±0	42.9±11.3	6.1	1,6	0.01
Factors influence	Availability/Cost of fuel	51.8±10.1	83.8±6.6	4.1	1,6	0.04

Perception toward compliance, enforcement and conflict

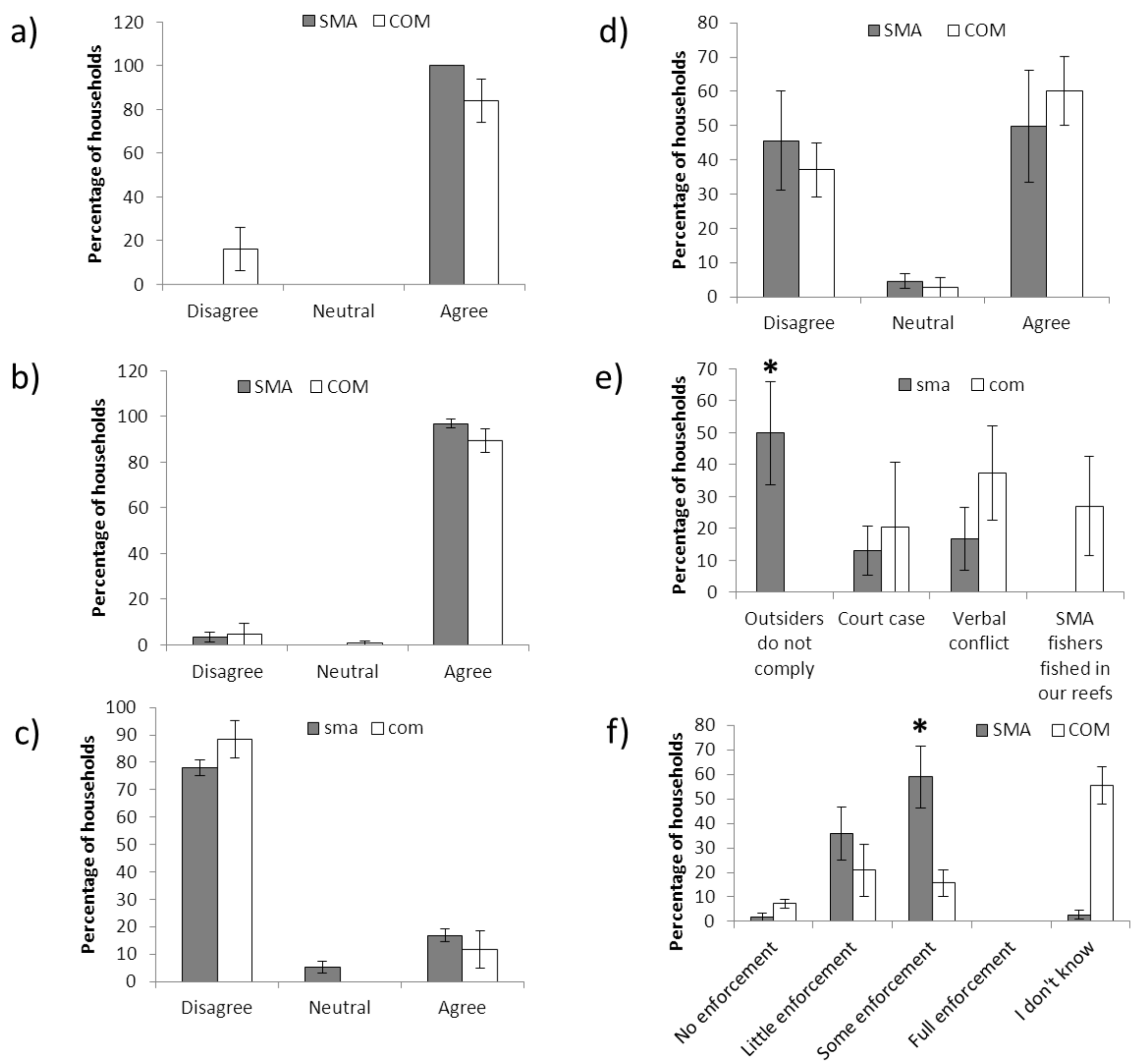

Figure 2.11: Mean (± SE) household perceptions of the compliance, enforcement and conflict regarding the establishment of the SMAs, a) awareness of SMA regulations, b) degree of compliance with SMA regulations, c) conflict exist over the use of marine resources, d) Existing of conflict between fishers form the SMA and comparator communities, e) Communities with evidence of conflict, f) degree of enforcement. The symbol (*) indicates the occurrence of a significant difference when a Kruskal-Wallis test was applied (Table 2.21).

Table 2.21: Mean (± SE) percentage of household perceptions towards the compliance, enforcement and conflict regarding SMAs with significant differences found (Shaded lines) when a Kruskal-Wallis test was applied.

Statement	Perceptions and opinions	SMA	COM	χ^2	df	P
a) HH aware of the SMA regulations	Agree	100±0	83.9±10.0	3.9	1,6	0.05
	Neutral	0±0	0±0	0	1,6	1
	Disagree	0±0	16.1±10.0	3.9	1,6	0.05
b) HH comply with the SMA regulations	Disagree	3.2±2.1	4.7±4.7	0.1	1,6	0.7
	Neutral	0±0	0.8±0.8	1	1,6	0.3
	Agree	96.8±2.1	89.5±5.2	0.8	1,6	0.4
c) Conflict over using of marine resources among users exists in this community?	Disagree	77.9±2.8	88.4±6.7	0.4	1,6	0.6
	Neutral	5.29±2.1	0±0	3.9	1,6	0.05
	Agree	16.9±2.3	11.6±6.7	0	1,6	1
d) Establishment of SMA create conflict among resources users inside and outside the SMA communities	Disagree	45.6±14.5	37.1±7.8	0.3	1,6	0.6
	Neutral	4.6±2.1	2.8±2.8	0.6	1,6	0.4
	Agree	49.7±16.4	60.2±10.1	0.3	1,6	0.6
e) Comments	Outsiders do not comply	49.8±16.1	0±0	6.1	1,6	0.01
	Court case	13.1±7.8	20.3±20.3	0.6	1,6	0.4
	Verbal conflict	16.7±9.9	37.3±14.7	0.8	1,6	0.4
	SMA fishers fished in our shore	0±0	27±15.5	3.9	1,6	0.05
f) What do you think of the SMA enforcement activities	No enforcement	1.7±1.7	7.2±1.8	3.2	1,6	0.08
	Little enforcement	35.9±10.9	20.8±10.8	1.3	1,6	0.3
	Some enforcement	58.9±12.5	15.7±504	5.3	1,6	0.02
	Full enforcement	0±0	0±0	0	1,6	1

About 100% and 84% of households in the SMA and comparative villages respectively were aware of the SMA regulations and claimed to comply with them (Figure 2.11 a, b). In addition, about 78% and 88% of households in the SMA and comparator communities respectively perceived that conflict did not exist among resource users with respect to use of fishing grounds, (Figure 2.11 c). Nevertheless, perceived attitude from both SMA and comparator communities households showed that some (50% and 60% respectively) believed that establishment of the SMAs has introduced conflict among fishers between communities while 46% and 37% disagreed respectively (Figure 2.11 d). There was no significant difference between SMA and comparator communities regarding the awareness of the SMA regulations, compliance and conflict among fishers. Nevertheless responses that provided evidence of the existence of conflict included “reported illegal fishing cases”, “reported court cases”, and the incident of verbal conflict among fishers (Figure 2.11 e). When the household’s respondents were asked about the enforcement activities within the SMAs, 58% and 36% of the respondents from SMA communities mentioned “some enforcement” and “little enforcement” activities respectively occurred (Figure 2.11 f). Comments from the SMA communities on “outsiders do not comply” and “some enforcement” were found to be significantly higher than for the comparator communities (Table 2.21).

Table 2.22: Short phrases used in figures and their meanings.

Short form responses (phrases)	Meaning
“more fish in the future”	There will be plenty of fish in the future as a result of the SMA establishment.
“increase in fish catch”	The fishers’ catch increased as a result of establishing of the SMAs.
“exclusion of fishers from other communities”	Only the residents of the SMA community are legally allow to fish inside their SMA area. Fishers from elsewhere (not a resident) is not allow to fish inside the SMA without permission from the SMA community.
“limit access to fishing grounds”	Respondents felt that their access to common fishing ground is limited by the establishment of the SMAs
“fishers from SMA communities fishing outside community SMA areas”	Fishers from the SMA communities are legally allowed to fish inside their SMA (except the no-take zones), and fishing grounds they wish outside their SMA areas.
“lack of community involvement in fishery management”	The community does not involve directly with fisheries management activities in the current fisheries management system.
“Lack of enforcement activities”	There are no fisheries enforcement activities at the community level, particularly outer islands.
“the current management is fine”	Some of the respondents prefer the current fisheries management system (open access).
“community empowerment”	The SMA communities felt that they are being given the power to manage the fisheries within their community.
“community sense of ownership”	The SMA communities have the feeling that they own the marine resources within their SMA boundary.
“community enforcement”	Community members involved in the enforcement activities within their SMA.
“an unfair system”	Some people felt that the SMA regime is an unfair system, by exclusion fishers from outside while SMA fishers allowed to fish anywhere.
“selfish system”	Some people think that the SMA regime only benefits the residents of the SMA community.
“Fishing is prohibited”	Any fishing activities are not allowed within the no-take zones.
“Depend on the enforcement”	Projected benefits due to the establishment of the SMA will depend on how well or bad is the enforcement activities.
“Fish population increases”	The number of fish will be increased as a result of having no-take zones.
“Fish are protected (NTZ)”	Fish are protected inside the no-take zones as fishing is prohibited.
“Only work with invertebrates”	Some people felt that only invertebrates will benefits from no-take zones but not with finfish.
“Restocking activities”	Collecting invertebrates (giant clams and snails) and release inside the no-take zone will enhance biodiversity.
“Takes some time”	It will take times (years –decades) before any change to fish population occurred as a result of no-take zones and SMA.
“increase catch within the SMA”	Some respondents within the SMA claimed that their fishing catch had increased inside the SMA.
“More fish within the SMA”	Some respondents claimed that there are more fish inside the SMA

	compared to the past years.
"Source of living"	Marine resources (coral reefs) are a source of food and income.
"Island depend on for shelter"	Coral reefs protect the land (island) from natural disasters (big waves, strong wind, etc)
"For future generation"	Protecting the marine resources is very important for the future generation.
"more or less seafood"	Household are either having more or less seafood items, consuming less or more seafood in relation to the establishment of the SMAs.
" fishing outside the SMA" "fish outside SMA/NTZ areas"	Fishers felt that establishment of the SMA does not have any effects on their fishing activities because they are commonly fished at fishing grounds outside the SMA (for comparator communities and outside the NTZ for the SMA communities.
"less fishing"	Some respondents claimed that they do less fishing activities.
"fishing catch decline"	Fishing catch has decline
"closed fishing ground", "loss of their common fishing grounds"	Some respondents felt that their common fishing have been closed due to the no-take zones or the establishment of the SMAs.
"lots of other fishing grounds"	Some responding claimed that SMA establishment has no effects because there are still plenty of fishing grounds outside the SMAs which are available for fishing.
"use of distant fishing ground"	Some fishers claimed that they travelled to further fishing ground (distance travelled) due to the establishment of the SMA and no-take zones.
"less fishermen"	Small numbers of fishermen are now fishing at the fishing grounds inside the SMA boundary.
"less fish around"	Less abundance of fish, or small number of fish, hard to find fish.
"Depend on fishing grounds chosen"	Sometimes fishing catch depends on the chosen fishing ground.
"less catch"	Small amount of catch or declined in the number of fish catch.
"still the same catch"	No change to the average amount of fish catch.
"better price"	Good or higher sales price for fish when selling in the market
"increase expenses"	Fishing expenses is increasing.

2.5 DISCUSSION

The aim of the present study was to determine the perceptions and attitudes of Tongan resource-users with respect to the establishment of SMAs as a new fisheries management tool in Tonga. This is the first study to quantitatively explore the relationships between socioeconomic factors and how they have responded to the SMA regime in Tonga. The perceived impact of the use of SMAs was achieved by comparing the experience of communities that benefited from a SMA with that of nearby comparator communities (with no SMA). Perceived attitudes towards the establishment of spatial management measures are crucial to the success of marine and resources conservation initiatives in coastal areas in developing countries. Understanding the underlying factors that influence the attitudes of coastal households is essential to achieve sustainable coastal ecosystems and thereby to promote economic development (Sesabo *et al*., 2006). Understanding the heterogeneity in fisher's attitudes toward management interventions is important to understand their impact on different stakeholders groups particularly when some stand to gain at the expense of others (Gelcich *et al*., 2005).

The results of the present study showed that the demographic characteristics for households (i.e. household size and fishing characteristics) were homogenous across the study sites. In addition, the households' social status and well-being was very similar among households across the study sites in respect to material possessions and life style coupled with land ownership (Table 2.3). Similarly, household occupations and their spending profile both within SMA and comparator communities were very similar (Table 2.4 and 2.5). Most households participate in more than one occupation which suggests that a diverse range of occupations are necessary to support households. Similar conditions were observed by Jennings and Polunin (1996) in Fiji where households tend to divide their daily activities (fishing, agricultural, other activities) between household members. Although, results from the present study showed that households in both the SMA and comparator communities engaged in a range of occupations, fishing activities were identified as one of the most important occupations. It is clear from this study that household are dependent upon marine resources for their livelihoods. In some cases, household had more than one important occupation and that was of equal importance like fishing and weaving for example. Hence males may fish as their primary occupation while farming is their secondary occupation, and similarly females may weave as their primary occupation while fishing is a secondary occupation.

Based on these findings, using social status as an indicator of the effect of the MPAs (Grawford *et al*., 2000), it is not possible to say that SMA households are significantly better off or worse off compared with comparator households. Although Tongan life is increasingly developing into a cash-based economy, coastal fishing activities generally reflect the need to satisfy subsistence-needs, social obligations and the choice of fishing as a traditional lifestyle (Kronen, 2004).

Perceived attitudes towards the establishment of SMAs

There was significantly higher level of support for the establishment of SMAs from SMA households compared to the comparator households. This suggested that the establishment of the SMA were accepted and preferred by the SMA households. In contrast, most of the comparator households did not favour the establishment of the SMAs in their neighbouring island. This difference in attitudes among households under the two management regimes is likely to be associated with the socioeconomic benefits and costs derived from the establishment of the SMA in terms of the impact upon their livelihoods. In general, most of the SMA households perceived more benefits for their livelihood, and therefore had positive attitudes towards the establishment of the SMA. Conversely, most of the households of the comparator communities perceived more costs to their livelihood, and therefore had a negative attitude towards the establishment of the SMA. Among the benefits perceived by SMA communities, the security of access to more fish in the future, exclusion of fishers from other communities, and increasing fishing catches were considered important. The SMA communities also felt that the SMA regimes conveyed a sense of ownership of the fishing grounds and therefore empowered them to manage the fisheries resources which included involvement with the enforcement activities. Conversely, the majority of the comparator households perceived costs that included access to fishing grounds that had become limited and that their current fishing grounds had shrunk due to the implementation of the SMAs. Consequently, they considered that there will be overcrowding and more pressure on the fishing grounds outside of the SMAs as more fishers, including SMA fishers, fish in a very limited area. In addition, fishers from the comparator communities argued that the system is unfair because they are prohibited from fishing at the SMA communities' fishing grounds while fishers from the SMA communities can fish in their communities' fishing ground. Thus, they believed that the current fisheries system (open access system) is better. Further, because fishers from comparator communities already experienced problems with decreasing fish stocks and catches, hence the SMA establishment is likely to create more difficulties for their livelihood. This divergence of opinions is consistent with findings reported in other socioeconomic studies regarding MPAs (Blyth *et al*., 2002; Himes 2003; Gelcich *et al.* 2005; McClanahan *et al*., 2005; Jones, 2008; Mangi & Austen, 2008; Dimech *et al*., 2009; Suuronen *et al*. 2010). The comparator communities did not perceive any benefits from this management regime. McClanahan *et al*. (2005) noted this same trend amongst Kenyan fishers that perceived more benefits from open access than from protected areas. Jones (2008) noted that fishers perceived that conservation MPAs are not the way forward, (see also Gelcich *et al.* (2005, 2009).

Despite the disparity with regards to benefits and costs, the results showed that both the SMA and comparator households had positive attitudes with regard to the value of SMAs. For instance, they both had positive attitudes towards fisheries sustainability and felt it is a better way to sustain fishery in the community and indicates the importance of community involvement in the management of fisheries (Petelo *et al*., 1995). In addition, they also had positive attitudes towards the establishment of no-take zones for marine conservation. There was a high level of understanding within households that NTZs can contribute to the improvement of the condition of fishery resources. Households believed that no-take zone areas benefit marine resources by protecting marine biodiversity and enhancing fish abundance. This is consistent with the finding by Jimenez-Badillo (2008) who reported that Mexican fishers had a positive attitude towards conservation and that they were conscious of the need to conserve resources. However, the results showed that households were aware that it will take some time for fisheries resources to build up and they emphasized that enforcement plays a critical role if the no-take zone is to be successful. Households from both types of communities had positive attitudes towards the value and importance of marine resources and coral reef communities and commented on their important functions and services such as coastal protection and as a source of food and income.

Perceived attitudes on impact on household livelihood

The results of the present study reveal that most of the SMA household respondents consider that their livelihood has been improved as a result of the establishment of the SMAs. With regards to livelihood security, household perceptions are that livelihoods have been enhanced due to the establishment of the SMA. It seems apparent that the exclusion of fishers from other villages, that then leads to increases in the catch of individuals, increase in fishing income, and hence enhanced household livelihood. In contrast, the majority of the households from the comparator communities strongly disagree that any aspect of their livelihood is linked to the establishment of the SMAs. However, they argued that SMAs have done nothing for the islands, SMAs limits where the fishers can work and extends the distance that the fishers need to travel to go fishing. SMAs impose costs for island households in the form of restrictions to access fishing grounds. Most households that did not support the establishment of SMAs indicated that SMAs caused them economic hardship. For instance, the households indicated that establishment of SMA limited fishing ground. This is a considerable economic obstacle, counting the higher fuel costs to access more distant fishing ground. Jimenez-Badillo (2008) argued that fishers are aware of depleting resources and that they understand their role in the degradation of fishery resources, but their attitudes will not change until they achieve a stable livelihood (Jimenez-Badillo, 2008).

Reliance on fish as a source of food

The SMA households believed that there has been change in their diet composition due to the establishment of the SMAs. In contrast, the comparator households did not perceive any change in their food consumption pattern as a result of the establishment of the SMAs. In general, a household's main food items consisted of finfish (seafood), and hence highlighted the importance of seafood for coastal communities in terms of food security. This is supported by Sun *et al.* (2011) who stated that fish was used as the main source of protein in Tonga. However, the present study also revealed that use of certain food items in the islands has started to change as more households indicated that they now consume more shop food than seafood. Various studies have reported that there has been a shift in dietary preferences from fish as a major source of protein to mutton flaps, chicken pieces, and corned beef, which have become cheap alternatives to traditional diets (Finau *et al*. 1994; Gillett, 2009). This is supported by Kronen *et al.* (2003), who found a decrease in fresh fish consumption with increasing urbanization. However, SMA households indicated that fish was more important in their diet than was the case for comparator households. The dietary importance of seafood may have an important influence on attitudes towards the establishment of the SMAs.

Perceived attitudes on the impact on household fishing activities

Fisheries have an important role in the livelihood of the households in the island communities in Tonga (Kronen, 2004). The results of the present study revealed that fishing is the most important occupation with regards to household livelihoods. The results showed that fishing activities and characteristics were very similar across all of the study sites. Nevertheless, the results revealed a disparity in the perceptions of the SMA and comparator communities regarding the impact of establishment of SMA on their activities. For instance, the majority of the households in both the SMA and comparator communities felt that the establishment of the SMA did not affect the overall amount of fishing activities, although some (30 and 37%) of the SMA and comparator communities respectively felt that establishment of the SMA had affected (decreased) their fishing activities.

Nevertheless, fishers who disagreed that SMAs affect the amount of their fishing activities claimed that there were still plenty of fishing grounds outside the SMA and no-take zones in which they can fish. Conversely, the loss of common access to a fishing ground and the need to travel to distant fishing grounds were identified as major problems that made fishing activities more difficult. The key complaint was that since access to the most common fishing grounds has been taken away from comparator communities (and SMA in the case of no-take zones); fishers are now fishing either for longer or same amount of time but catching substantially less. In addition, there is now more intense exploitation of resources by fishers from all over the region. In other words, displacement of fishers (from SMAs, comparator and other communities in the region) to other localities has increased overall effort in those localities.

Households noted changes in terms of their catches and related income. Most SMA households experienced increased fishing catches and income. Similarly, Cinner (2005) found that communities with exclusive marine tenure regimes in Papua New Guinea and Indonesia communities improved their livelihood security. Despite the impact felt by some of the SMA households with respect to loss of fishing ground due to NTZ, fishers remained financially secure implying that the loss of access to fishing grounds was compensated for by the exclusion of outsiders. The effect of the establishment of SMA on the comparator households either caused no change or a reduction in catch which suggested that catching fish became more difficult (Figure 2.10 and 2.11).

The inequality in the SMA and comparator household catches and income shaped the perceived attitude towards the establishment of SMAs. The finding that SMA households were more likely to have positive attitudes towards the establishment of SMAs than comparator households was expected, given the prominent role of fishing in household livelihoods. According to the results, SMA households were generally more supportive about SMAs because they have access to more fishing grounds, and less competition as most of fishers have been excluded from the fishing ground. These factors allow them to potentially increase their catch and their income. This means that SMA households can more easily adjust to the costs that result from the establishment of SMAs. In contrast the comparator communities' households were less likely to favour SMA establishment than SMA households. Coastal communities have been heavily reliant on marine resources and fishing due to lack of other viable alternatives for their livelihood (Kronen, 2004; Sun *et al*., 2011). Another explanation for the positive attitude towards the SMAs is that household wanted to have the ability to limit the high rate of exploitation of marine and coastal resources. According to a fisherman from the SMA communities

"…before the SMA established, too many fisher on our reef … fishers from everywhere comes to fish here...we have no control over them…"

This comment highlights the serious concern of coastal communities, that even if a community attempts to conserve and manage adjacent reef areas, it may be a useless exercise because outsiders can move in and over-harvest those common resources (Gillett *et al*. 1996). Fishers from other areas seem to create pressure on fisheries resources in the area, in addition to a lack of management initiatives for resource management. As a result, there is a need for increased control over local marine resources through the use of management tools such as SMAs.

Perception towards conflict, compliance and enforcement

There are several possible explanations for the relationship between the occurrence of conflicts and the SMA regime. The SMAs may have been developed to mitigate conflicts among fishers from different communities or the SMAs may have created conflicts among fishers by creating a situation of inequality. A historical lack of legal recognition of access rights to fishing grounds may have led to conflict. For example fishers from some communities were often challenged by others who claimed that they have the right to fish anywhere, and attempted to fish in some village's fishing grounds (reefs adjacent to their community). The latter resulted in verbal or physical conflict. Every community has had some degree of negative interaction with fishers from external communities. This has ranged from simple frustration over the inability to control overfishing by outsiders to physical confrontation (Gillett *et al*., 1996). Although no strong conflicts were detected among resource users in the present study, a general resentment against fishers associated with the SMAs was expressed by comparator households. The strongest negative feelings were felt by comparator community fishers that were excluded from SMAs and resentment towards fishers from SMA communities that fished elsewhere.

With regards to the level of compliance and enforcement with SMA regulations, the households' perception regarding compliance is perceived to be good. However, households believed that SMA regulations are not adequately enforced with little or only some enforcement of the system. A similar finding was reported by Gelcich *et al*., (2009) where Chilean fishers perceived compliance with policy requirements of the MPA were good; however, they perceived the lack of effective enforcement as a problem (Gelcich *et al*., 2009). Elsewhere, the lack of enforcement has been highlighted as one of the main causes of perceived management failure in MPAs (Himes, 2003; Jones, 2008). Hence, without enforcement, compliance will continue to remain low and expected benefits of the SMA will be difficult if not impossible to achieve.

In summary, households from SMA communities expressed strong support for the establishment of the SMA regime, whereas the comparator community household were strongly opposed to SMAs. The main source of attitudinal heterogeneity among households and fishers from different villages were related to their attitude toward the costs and benefits of SMA establishment. This suggested that households are willing to participate and support the SMA regime only if the perceived benefits outweigh the costs. The overall perceived benefits of SMAs were highest among the SMA households, and lowest among the comparator households. This imbalance in benefits is likely to explain why the relationship between SMA and comparator communities has been antagonistic. This points to the fact that fishers' attitudes and perceptions tend to reflect their personal interests and concerns. Fishers who generally benefit the most from the implementation of the SMAs or that are less affected by them tend to be more accepting and supportive of this management measure. In contrast, fishers expressed negative attitudes towards SMAs and tended to favour open access over SMA regime measures when those fishers are highly restricted by the management measure. Thus, it may be unreasonable to expect fishers to accept very restrictive measures when other fishery management measures are already in place and the effectiveness of SMA regime is still poorly understood.

In conclusion, the results of the present study indicate that the establishment of the SMA in Tonga has so far has had some impact with regards to fishing activities and food pattern. Most of the comparator households claimed that they were impacted by the establishment of the SMAs, but this may be resentment towards those that have privileged access to SMA.

Identification of differences in perceived attitudes towards the SMA regime offers a tool to better understand why and how members of local communities perceived the SMA regime. While the SMA regime is still in an infant stage in working towards true functionality, results indicated that the SMA could benefit from two main improvements:

- Increasing enforcement should decrease the number of violations because resource users will fear being caught. Consequently, compliance will increase and the objectives of the SMA will likely to be accomplished. The existing management institution and enforcement regime are inadequate to deal with the SMA needs in Tonga. By increasing enforcement, especially to catch illegal fishers, the majority of fishers would view the SMA much more positively, and illegal fishing activity occurring at the SMA would be substantially decreased.

- In coastal settings where fishing is the main livelihood, it is important to provide incentives in addition to the protection of marine and coastal resources; that the establishment of the SMAs must be accompanied by the development of additional income-generating activities in order to improve their socio-economic wellbeing, while at the same time allowing for the recovery of the coastal ecosystem. The future of the SMAs largely depends on the attitude and practices of today's coastal resource users. The SMA regime approach of prohibiting activities such as fishing for those communities without access to an SMA without the provision of alternatives may lead not only to bitterness, but also to conflicts.

Chapter 3

Biological assessment of reef community's assemblages in response to Special Management Area regime in Tonga

3.1 Abstract

The effect of the Special Management Area regime on coral reef resources was assessed on five existing Special Management Areas island communities in the island groups of Tonga. Between 2006 and 2008, in response to declining coral reef community resources, island residents and the fisheries division established Special Management Areas with small no-take zones on five islands throughout Tonga through a community-based process.

Control-impact experimental design was used to compare the abundance, biomass, diversity (species richness and evenness), and percentage cover of reef fish, invertebrates, and substrate composition in no-take zones, Special Management Area and adjacent fished (comparator) areas following a 1-3 year period of protection from fishing. Analysis were carried out in two levels, a national and island scale.

The abundance, biomass, diversity and percentage covers of fish, invertebrate and habitat structure were variable and no significant difference found between NTZ than fished areas (SMA and COM) at the national scale analysis.

In the island scale analysis, there were significant increases in species richness, evenness, abundance and biomass of the major exploited fish families (Acanthuridae, Serranidae, Scaridae) and also of the Nemipteridae and Pomacentridae. There were also significant increases in abundance of major exploited invertebrate species (*Holothuria coluber*, *Holothuria atra*, *Stichopus chlorontus*, and *Tridacna maxima*) and also of the *Echinometra* spp., *Heterocentrotus* spp., *Diadema* spp. and *Linckia laevigata*. There were also a significant increase in different substrate structures (Hard coral branching, encrusting, massive, sub-massive, macro algae, dead

coral with coralline algae and rocks) and also of hard corals (*Favite* spp., *Goniastrea* spp., *Porites* spp., *Isopora* spp., and *Acropora* spp.).

Abundance, biomass, species richness and evenness of large fish (Acanthuridae, Serranidae, Scaridae) and invertebrates (Tridacnidae and Holothuridae) targeted by fishing increased in no-take zones compared with SMA and COM sites.

The results also suggest that the response to protection varies with intensity of exploitation and body size and may be spatially idiosyncratic, as a function of local factors (life histories, trophic groups, protection age and size, and geographical location). The use of the SMA regime in Tonga as a fisheries management tool implies that they should ensure protection for a wide range of species and habitats.

3.2 INTRODUCTION

There is increasing global acceptance of the use of marine protected areas (MPAs) as conservation and fisheries management tools for the protection or restoration of marine biodiversity (Gell & Roberts, 2003; Russ, 2002; Halpern and Warner, 2002; Russ *et al*., 2005, Kaiser, 2005). However, the utility of MPAs as fishery management tools is highly context dependent (Gell & Roberts, 2003, Kaiser, 2005, Stuart *et a*l., 2009; Harmelin-Vivien *et al*., 2008, White *et al*., 2008). In theory, by protecting a portion of the exploited areas and restricting the extent of fishing activities, MPAs may lead to enhanced fishery yield by increasing the number and size of adults within the area. This increase in adult density and size should increase the production of eggs and larvae that originate from inside the MPA, leading to exporting of larvae and net emigration of adults outside the MPA boundaries (Roberts and Polunin, 1991; Roberts *et al*. 2001; Gell and Roberts, 2003; Alcala *et al*., 2005). MPAs are widely used as tools for the recovery of populations of coral reef fish (McClanahan and Kaunda-Arara, 1996, Halpern and Warner, 2002, Russ *et al*., 2005), although there remain debates over the mechanisms and speed of recovery of fish community (Walker *et al*., 2008). MPAs have been used as traditional management tools for coral reefs in the Pacific region (Johannes, 1998). In the Pacific, the use of MPAs has been increasing (Johannes, 2002), despite the fact that many resource users seldom accept them (Christie, 2004; McClanahan *et al*., 2005), and many MPAs have failed to produce tangible conservation benefits (McClanahan *et al*., 1999; Pollnac *et al*., 2001).

MPAs are reported to generate a number of biological benefits including; protection of slow growing species of fish and invertebrates that are susceptible to overfishing due to their life-history characteristics (Gell & Roberts, 2003; Kaiser, 2005), an increase in the abundance, size, and biomass of adults found within the MPA that lead to export of eggs, larvae, and net migration of adult outside the MPA boundary, and thereby enhancing adjacent fisheries (Russ, 2002; Gell & Roberts, 2003), maintenance and enhancement of species diversity, local ecosystem process, benthic habitat complexity and spawning habitat (Russ and Alcala, 1996; Garcia-Charton *et al*., 2000; Ward *et al*., 2001; Polunin, 2002; Pinnegar & Polunin, 2004;).

The performance of MPAs has been reported through a comparison of abundance, density, biomass, sizes of organisms, and diversity between protected and non-protected areas for a variety of marine species from many different locations (Russ & Alcala, 1989; Roberts *et al*., 2001; Halpern *et al*., 2003; Russ and Alcala, 2004; Harmelin-Vivien *et al*., 2008). These studies have shown that the abundance and biomass of some species is higher in reserves than adjacent fished areas, or that abundance in a reserve has increased following protection (Russ and Alcala, 1996, 1998 a,b; Wantiez *et al*., 1997; Mosquera *et al*., 2000). However, in those studies that compared abundance within and outside a reserve, it is not always easy to distinguish differences in biological responses due to various confounding factors including different geographical locations and different habitat effects (Stewart *et al.,* 2009), size and age of protection (Guidetti and Sala, 2007), species life histories traits (Stewart *et al*., 2009), trophic groups interactions (Micheli *et al*., 2004), fishing intensity (Halpern and Warner, 2002), and enforcement (Guidetti *et al*., 2008). Nevertheless, there exist a subset of studies that report on the outcome of using MPAs in a more robust analysis that has accounted for the many of the potentially confounding variables (Lester *et al*., 2009).

Whilst many of these studies have demonstrated a positive effect of MPAs on fish assemblages, others have found little, if any, observed differences in protected and unprotected areas (Guidetti, 2006), while still others have found a relatively balanced mixture of positive and negative impacts on individual species (Garcia-Rubies and Zabala, 1990; Stewart *et al*., 2009). Yet, a number of meta-analyses studies of the response of fish to MPAs have found that the common trend is for an overall positive effect of MPAs on fish abundance and biomass (Cote *et al*., 2001; Halpern, 2003; Botsford *et al*., 2003; Stewart *et al*., 2009).

MPAs have been used for conservation purposes in Tonga since the early 1970s (Lovell and Palaki, 2002). However, the enforcement of MPAs in Tonga was poor. Law enforcement for MPAs in Tonga has been weakened by traditional common property rights (Malm, 2001) such that it is usually difficult to get community agreement to set them up, and in areas where they do exist they are rarely respected (Lovell and Palaki, 2002).

In order to meet the need for effective governance of MPAs, a more community-based approach has been adopted as a fisheries management regime (Aswani, 2005; Aswani *et al*., 2007; Govan *et al*., 2009). Many case studies (Christie and White, 2000; White *et al*., 2002) have documented the success of this approach and its effects on marine resources and communities (Christie *et al*., 2002).

More recently, Tonga has implemented a community-based MPA regime, in which the community took the leading role in management of the fisheries resources within Special Management Areas (SMAs). Six SMAs were established between 2006 and 2008 in the Kingdom of Tonga (Table 3.1) following the approval of the Tongan 2002 Fisheries Management Act. The development of the SMAs was designed to address fishers' concerns about declines in fisheries catches and marine resource degradation, together with the need to encourage community management (Friedmen *et al*., 2008). The boundary of each SMA encloses the adjacent reefs and lagoon of a given island. Within each SMA, two distinct zones are defined: (1) a central zone that comprises shallow and deep waters where residents alone are allowed to fish legally, (2) a zone that is comprised of different fish habitats in which no fishing activities are permitted with the aim of providing a refuge habitat for fish and invertebrates that would normally be harvested outside this area (Community Special Management Area management plans, unpublished). The six established SMAs have common objectives including: exclusion of fishermen from outside the community (non-residents); to protect the adjacent coral reefs (and their associated fish and invertebrate communities); and to improve the livelihood opportunities available to communities through improvements in fish catches and alternative income generation from tourism and handicraft activities (Community Special Management Area management plans, unpublished).

The SMAs are spread across five islands (‘Atata, Ha’afeva, ‘O’ua, Felemea and Ovaka) and were established between year 2006 and 2008. These islands groups are remote (10 - 40 km between the small islands and the main island) and have small populations (range 70-270), and small-scale artisanal fisheries (Table 3.1). Each SMA boundary stretches for approximately 2500 m of coral reef and lagoon area from the shoreline of the island or extends out to the 50 m depth contour line.

Recent studies have been carried out on coral reef communities in Tonga (Lovell and Palaki, 2002, Friedmen *et al.*, 2008). However, no studies have looked at the effectiveness of the SMA regime in terms of the protection conferred on coral reef communities. The purpose of the present study was to assess the effectives of SMA regime through a spatial comparison of the effects of NTZ areas within the SMAs, the wider areas under SMA management regimes and the open access areas in Tonga. Understanding such a response would provide information to fill the important knowledge gaps in determining whether the existing SMAs are meeting their broader conservation and management objectives, and would provide important baseline information for the future monitoring and establishment of the SMA network in Tonga.

3.3 METHODOLOGY

Study sites

The present study was conducted in five island communities with Special Management Areas (SMAs) established in Tonga, hereafter referred to as the SMA location. ‘Atata island is located in the Tongatapu island group, Ha’afeva, ‘O’ua and Felemea islands are located in the Ha’apai island group, and Ovaka island is located in the Vava’u island group (Figure 3.1). These SMA locations are characterised by islands associated with fringing reef, barrier reef and lagoon sheltered reefs (Lovell and Palaki, 2002; Pakoa et *al.*, 2010), small population size, with subsistence and small-scale artisanal fisheries, multi-gear and multi-species fisheries (Kronen *et al*., 2006) (Table 3.1). Each SMA location encompasses the majority if not all of the island’s immediate reefs, within which is located a marine reserve referred to hereafter as a no-take zone (NTZ).

The study was carried out during the months of June to August, 2010 and focused on the back reef zone within the fringing or lagoon reef. This area of the reef was selected for study because (1) it was the most commonly accessed fishing area for most of the main fishing practices; (2) the shallow water enabled the survey snorkelling techniques to be used and thereby permitted a higher level of sampling that could be achieved using SCUBA.

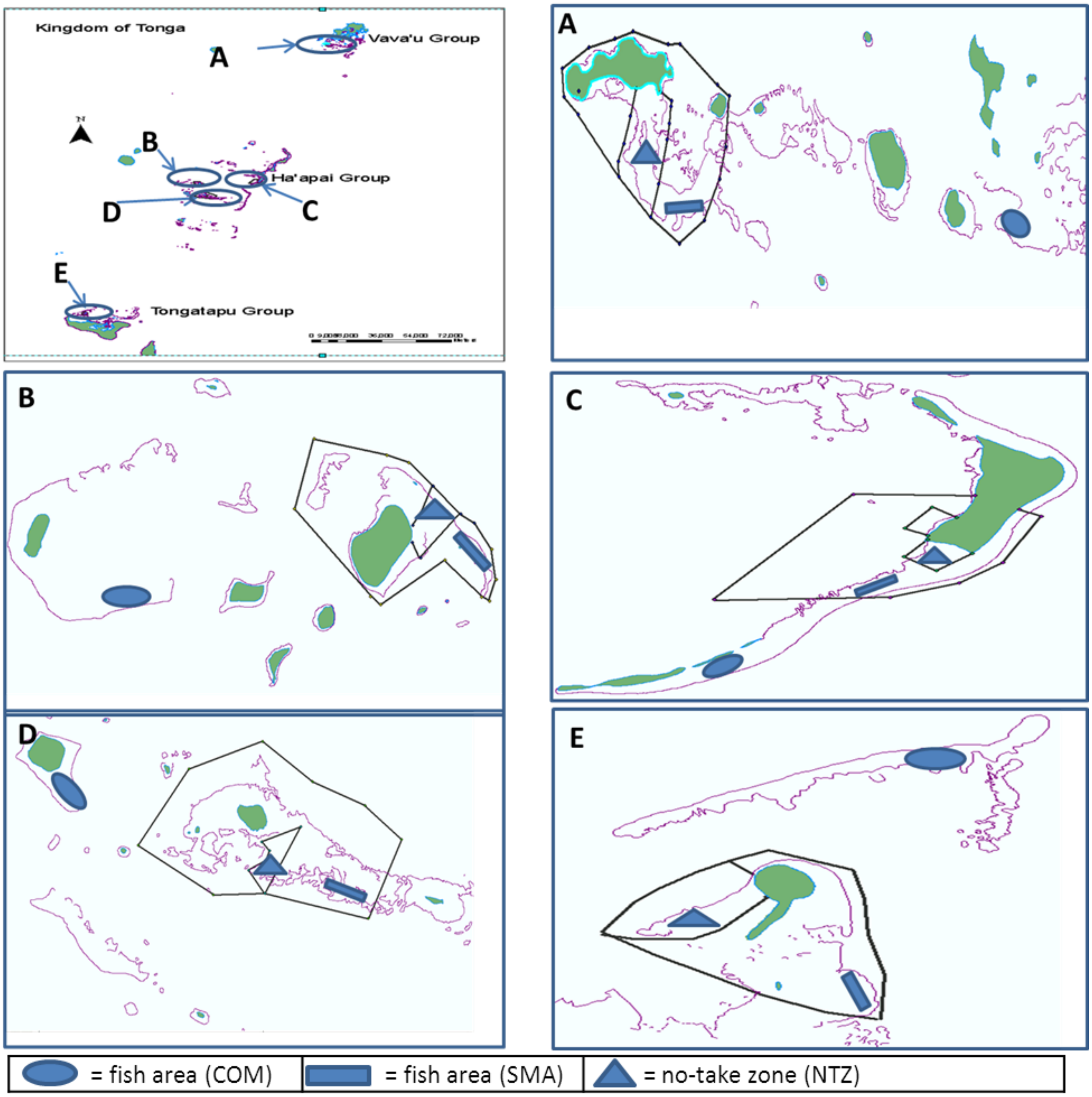

Figure 3.1: Location of the Special Management Areas (SMA) network in Tonga. Abbreviations represent sampling locations (A: Ovaka, B: Ha'afeva, C: Felemea, D: 'O'ua and E: 'Atata). Dark line outlines the SMA and NTZ boundaries.

Table 3. 1: Main characteristics of the five SMAs and island communities studied in Tonga.

Island group	SMA locations	Type of reef	Type of protected areas		Size (km^2)			Date of establishment	Population(number of household)	No. of active fishers
			Limit fishing access	Fishing prohibited	SMA	NTZ	Proportion protected			
Ha'apai	'O'ua	Fringing, lagoon, barrier reef	SMA	NTZ	47.4	2.0	0.04	2006	149(26)	18
	Ha'afeva	Fringing , lagoon, barrier reef	SMA	NTZ	11.3	1.5	0.13	2007	262(49)	9
	Felemea	Fringing, lagoon, barrier reef	SMA	NTZ	16.3	1.5	0.09	2008	193(33)	8
Vava'u	Ovaka	Fringing, lagoon, barrier reef	SMA	NTZ	8.5	2.9	0.34	2008	72(22)	5
Tongatapu	'Atata	Fringing, lagoon, barrier reef	SMA	NTZ	6.9	1.2	0.17	2008	250(38)	36

Survey method

To investigate the biological response to the implementation of Special Management Area (SMA) management regime in Tonga, we used a multiple control-impact comparison between NTZ and adjacent fishing areas (SMA and COM) design. Thus there were three treatment levels: NTZ = no fishing, SMA = fishing allowed but with restricted access, COM = comparator site with no management imposed. An underwater visual census (UVC) technique was employed to assess fish, macro-invertebrate assemblages and habitat structure (English et al., 1997; Samoilys and Carlos 2000; Wilkinson and Hill 2004). We surveyed three sites at each of the SMA locations; one inside the no-take zone (NTZ), one outside the NTZ but inside the Special Management area (SMA) and one outside the SMA in a fished area as a control, hereafter referred as Comparator (COM) site. These sites were chosen on the basis of similar habitat as possible in reef profile, current and exposures.

Within each site (SMA, NTZ and COM), we surveyed seven independent 50 m x 5 m replicate transects, haphazardly positioned close to the reef crest to reduce variance in the data due to increased reef patchiness and to avoid habitat overlap. The transect starting points were chosen at random and direction of the transect was laid parallel to the current to avoid the tape from being swept away during data recording. Sampling depth was between 0.5 and 3 m water depth. The overall analytical design was balanced with 21 replicate transects within each SMA location (SMA n=7, NTZ n=7, COM n=7).

Each transect was laid parallel to the current and marked with a marker buoy such that the position of each transect was recorded using a handheld GARMIN GPS 72 Geographical Positioning System (GPS). On each transect, we surveyed fish, macro-invertebrate and habitat structure. Potential bias by observers was eliminated by having one person observing fishes, a second observer for macro-invertebrates, and a third observer for substratum, and a fourth observer for reef complexity throughout the survey period (Bartlett *et al.*, 2009). The survey began after a training period to familiarize the surveyors with the coral reef community, species identification and size estimation. Photographs were also taken of different species for later identification and validation. Fish models were used to estimate size class where the observers estimated the length of each fish model from a distance of 5 m, and compared estimates to actual lengths. The training was also carried out for one day at each site prior to the beginning of each survey. The census began 15 minutes after transect was set to allow the fish to resume natural behaviour after any disturbance caused while the transect was set and the duration of the census for each transect was standardized to 15-20 minutes per transect for consistency (McCoy et al., 2009).

We sampled fish on a 50 m x 5 m belt transect along which all fishes encountered were recorded and identified to species level when possible. Fish total length (TL) was visually estimated to the nearest 1.0 cm to allow for more precise biomass estimation. Fish were subsequently allocated to 8 size classes in increments of 5 cm. Accuracy was maintained by frequently practicing with fish models of known length. Fish length (TL) was converted to biomass data (g 250 m^{-2}) using published length-weight relationships for the species or closely related species. These data were obtained from FishBase (Froese & Pauly, 2011). The midpoints of size classes were used in length data calculation (Cinner *et al*., 2005, McClanahan *et al*., 2009). Macro-invertebrates were surveyed on the same transect as for fish and individuals were identified to species level. The size of invertebrates that are target species for fishers were measured to the 1.0 cm and recorded in 8 size classes as for fish.

Habitat at each site was assessed by estimating substratum type, rugosity and coral cover using the Point Intercept Transect technique (PIT) (English *et al*., 1997) under 0.5 m intervals along the same transect. Seventeen substratum types were defined (English *et al*., 1997). A plumb line was used to determine the substrate type directly below the line when the transect tape lay above the substratum. An underwater Indo-pacific Coral Finder identification guide (Kelly, 2009) was used for standardized coral identification to genus level. Habitat complexity (rugosity) was measured using the chain and tape method (Knudby and LeDrew, 2007) using a 5 m long 0.02 m link steel chain laid to the reef surface. Measures were taken at 10 m intervals along the 50 m transect line.

Data analysis

We examined the response of abundance and biomass of fish to protection at the family level and at the species level for diversity (species richness, evenness), macro-invertebrate abundance and diversity was calculated using species level data. For benthic habitat structure and substratum percentage cover and hard coral percentage cover at genera level. Fish and macro-invertebrate were also categorized (Table 3.2) into target and non-target species (Bell *et al*., 1994; Vaikona *et al*., 1997; Gillet and Moy, 2006; Sun *et al*., 2011; Authors personal observations 2011); fish were assigned to trophic groups and life history information was sought using the available information in www.fishbase.org and through a review of the literature (Russ and Alcala, 1998; Halpern, 2003).

Table 3.2: List of the fish families that contributed most (SIMPER) to the similarity between different protection levels and their respective trophic groups. (HB: Herbivores, P: Planktivores, C: Carnivores (invertebrate and fish feeders); broad life history characteristics of coral reef fish (extracted from the literature (Russ & Alcala, 1998; McCoy *et al*., 2010; www.fishbase.org). Categories are body size (small, medium, large); potential longevity (short-lived, medium, long-lived); natural mortality rate (low, medium, high); growth rate (low, medium, high); recruitment rate (low, medium, high). Life history characteristics are used to make a qualitative assessment of the vulnerability of reef fish family to fishing. Target/ not target by subsistence or commercial fishing activities.

Vernacular name	**Common name**	**Family (number of species)**	**Trophic group**	**Body size**	**Potential longevity**	**Natural mortality rate**	**Growth rate**	**Recruitment rate**	**Life history vulnerable to fishing?**	**Target or Non-target**
Tukuku	Damselfish	Pomacentridae	HB	Small	Medium	High	High	High	No	N
Pone/Hapi/'Ume	Surgeonfish	Acanthuridae	HB	Medium	Long-lived	Medium/Low	Medium	Medium	Intermediate	T
Lalafi/Meai	Wrasses	Labridae	C	Medium	Medium	Medium	Medium	Medium	Intermediate	T
Hohomo	Parrotfish	Scaridae	HB	Medium	Medium	Medium	Medium	Medium	Intermediate	T
Sifisifi	Butterflyfish	Chaedodontidae	P/C	Medium	Medium	Medium	Medium	Medium	Intermediate	N
O/Ma'ava	Rabbitfish	Siganidae	HB	Medium	Medium	Medium	Medium	Medium	Intermediate	T
Tukuleia/Vete	Goatfish	Mullidae	P/C	Medium	Medium	Medium	Medium	Medium	Intermediate	T
Ngatala	Grouper	Serranidae	C	Large	Long-lived	Low	Low	Low	Yes	T
	Spinecheeks	Nemipteridae	P/C	Small	Medium	Low			No	N
Sifisifi	Angelfish	Pomacanthidae	P/C	Small	Medium	Low			No	N
	Filefish	Monacanthidae	P/C	Small	Medium	Low			No	N

We first considered in our analysis all protection level (national) where each SMA location was used as replicates (n = 5 per site, total n = 15) to look for possible general protection responses. Then we looked at individual SMA location level (island) in which the seven sample transects, were considered as replicate (n = 7 per site, total n = 21) were analysed separately to see if any clear pattern of the protection effect occurred.

Response measure and transformation. The magnitude of the response of fish species abundance to protection was calculated from the following equation, using the mean values for NTZ and fished (SMA and COM) areas.

$$\% \text{ difference } (X) = [(A_n - A_s)/ A_s] \times 100 \qquad (1)$$

where A_n is abundance in NTZ area and A_s is abundance in fished areas.

The use of percentage difference to standardise the responses of fish to protection can lead to a skewed distribution of the data as the response can be infinitely positive but is limited to a minimum value of -100%. The transformation described by Kaiser *et al*. (2006) was applied to these data which means that the data adequately met the assumption of equal variance and normality (Kaiser *et al*., 2006).

$$Y = \log_e (1+ [x/101]) \qquad (2)$$

The transformed percentage difference statistic (Y) was calculated for abundance of individual taxa. Thus the response of each variable to the protection levels is expressed on a log-scale, where values range from (-) values (decrease) through 0 (no response) to (+) values (increase).

Statistical analysis

Univariate statistical analyses of the biological data were carried out to determine differences in fish, macro-invertebrate and substrate composition abundance, biomass and diversity per transect (250 m^2) among the different protection levels. The effect of protection on fish, macro-invertebrates and substrate composition was analyzed on mean abundance, biomass and biodiversity indices per transect using ANOVA (Underwood, 1997, Dytham, 2003, Field, 2009). A One-way ANOVA test was used when the normality (Kolmogorov-Smirnov Test) and the homogeneity of variance (Levene's Test) assumptions were met. If the data did not meet the appropriate assumptions for normality and homogeneity of variance, square root or ln(x+1) transformation was to normalize distribution and homogenize variance (Pillans et al. 2007). When transformation did not remove heterogeneity, a non-parametric test (Kruskal-Wallis) test was used for the comparison for effects among the different treatments. In the case of ANOVA analysis, post hoc (Tukey) multiple comparison tests were undertaken when significant differences were found between protection levels to determine where the differences occurred. When it was necessary to use a Kruskal-Wallis test, Mann-Whitney pair-wise tests were applied. In the case of multiple comparison test, Bonferroni corrections were used with significant difference value of $p = 0.0015$. All univariate analyses were performed using the SPSS package (SPSS v. 16.0).

3.4 RESULTS

In this section, the results from the primary (national scale) and secondary (island scale) analyses are presented separately.

PRIMARY LEVEL ANALYSIS (NATIONAL SCALE)

Fish assemblage: abundance, biomass and diversity

A total of 20 460 individuals representing 96 species belonging to 23 families were recorded during this study. Of these, eight families: Pomacentridae, Acanthuridae, Labridae, Chaedodontidae, Scaridae, Mullidae, Siganidae and Nemipteridae were the most commonly encountered. Fish abundance and biomass were highly varied among different protection levels (SMA, NTZ and COM) and did not vary significantly (Table 3.3). Although the differences were not statistically significant, most of the common families (Scaridae, Siganidae, Mullidae, Nemipteridae, and Pomacanthidae) had higher values of abundance and biomass in the NTZs when compared to the SMA and COM sites. Similarly, species richness, and evenness varied among protection levels.

Table 3.3: Mean (± 2SE) fish abundance (AB), biomass (BIO), and diversity indices between Special Management Area (SMA), No-Take Zone (NTZ), and Comparator (COM) sites. Analyses were undertaken using either an ANOVA (F) or Kruskal-Wallis (χ) test depending on whether the data met the appropriate assumptions of normality and homogeneity of variance. Highest values highlighted. (AM = abundance, BIO = biomass, H=Herbivores, P/I=Planktivores/Invertebrate feeder, T = Fisheries targeted, N = Fisheries Non-target).

Biological parameters	**Family**	**SMA**	**NTZ**	**COM**	**F**	**χ**	**df**	**p**
Diversity	Richness (d)	7.08±1.44	7.91±0.84	7.57±1.56	0.40		2,12	0.68
	Evenness (J')	0.86±0.02	0.9±0.02	0.88±0.00	3.89		2,12	0.05
AB	Acanthuridae (H,T)	96.8±71.64	141.4±49.95	156±89.20	0.73		2,12	0.50
	Labridae (P/I,T)	107.6±55.33	78.6±33.67	65.2±11.44	1.30		2,12	0.31
	Siganidae (H,T)	16.4±10.76	30.2±36.38	4±3.16		4.89	2,12	0.28
	Chaetodontidae (P/I,N)	35±11.37	33.8±16.69	43.2±17.43	0.44		2,12	0.65
	Mullidae (P/I,T)	10.6±4.36	17.4±13.62	11.8±11.69	0.46		2,12	0.64
	Nemipterida (P/I,N)	4±4.52	9.6±11.84	4.4±3.50	0.68		2,12	0.53
	Pomacentridae (H/N)	823.2±249.41	546.4±371.10	466.6±63.78	2.06		2,12	0.17
BIO	Acanthuridae (H,T)	8045.9±7858.78	122.8±6268.1	15048.1±8962.3	0.82		2,12	0.46
	Scaridae (H,T)	1907.1±1950.3	4537.5±1874.3	3196.8±2103.1	1.79		2,12	0.21
	Labridae (P/I,T)	2410.7±1193.8	2295.7±542.9	1681.1±606.3	0.89		2,12	0.44
	Siganidae (H,T)	98.1±59.7	433.6±623.8	112.8±125.9	0.63		2,12	0.55
	Chaetodontidae (P/I,N)	1699.2±1041.5	1882.7±582.4	2527.4±884.1	1.03		2,12	0.38
	Mullidae (P/I,T)	372.3±322.9	1162.4±1346.4	671.1±943.0	0.68		2,12	0.53
	Nemipteridae (P/I,N)	505.6±633.3	1170.9±1376.1	758.2±1080.6	0.39		2,12	0.69
	Pomacentridae (H/N)	20388.5±12435.0	13874.2±15311.2	10344.1±8856.6	0.67		2,12	0.53

To try to explain the heterogeneity in the species response, the log percentage change response ratio (computed from the difference in abundance or biomass for a species in one treatment compared to another) in relation to species maximum length (Lmax). Fish were further grouped into 3 size categories on the basis of their Lmax (small (≤20 cm), medium (21-39 cm) and large (≥40 cm). Species were also grouped into species that are either target or non-target species, and trophic groups (herbivores, Planktivores/invertebrates feeder, Carnivores).

When the log response ratios were plotted against Lmax, points showed very broad variation indicating some species have greater values inside the NTZ, (points above log ratio line =0), no effect (points at zero line), and greater values outside NTZ (points below the zero line).

Furthermore, the slope of the regression lines are significantly different from zero (Figure 3.2a, Table 3.4), indicating that the Lmax showed different proportional differences to the different protection regimes, but this is strongly influenced by a limited number of fish with very high Lmax values and therefore this result should be treated with extreme caution.

When the species were further grouped into three size categories, where there are more larger fish inside NTZ compared to small size fish (Figure 3.2c) but no significant difference were found (ANOVA: NTZ/SMA, $F_{2,69} = 2.9$, $p = 0.06$; NTZ/COM, $F_{2,69} = 2.8$, $p = 0.07$) among the size groups.

When species were grouped into target and non-target groups, the target group showed positive responses to protection, suggesting that the abundance of target species was higher inside the NTZ relative to outside NTZ, while non-target groups responded negatively. However, only the response ratio of target-species group compared for NTZ/SMA was found to be significantly different. (ANOVA, $F_{1,74} = 6.7$, $p = 0.01$) (Figure 3.2b). When fish were grouped into trophic groups, no significant differences were found for either herbivores fish, planktivores /invertebrate feeder, or carnivores fish (ANOVA: NTZ/SMA, $F_{2,74} = 2.7$, $p = 0.07$; NTZ/COM, $F_{2,74} = 2.8$, $p = 0.06$) (Figure 3.2d).

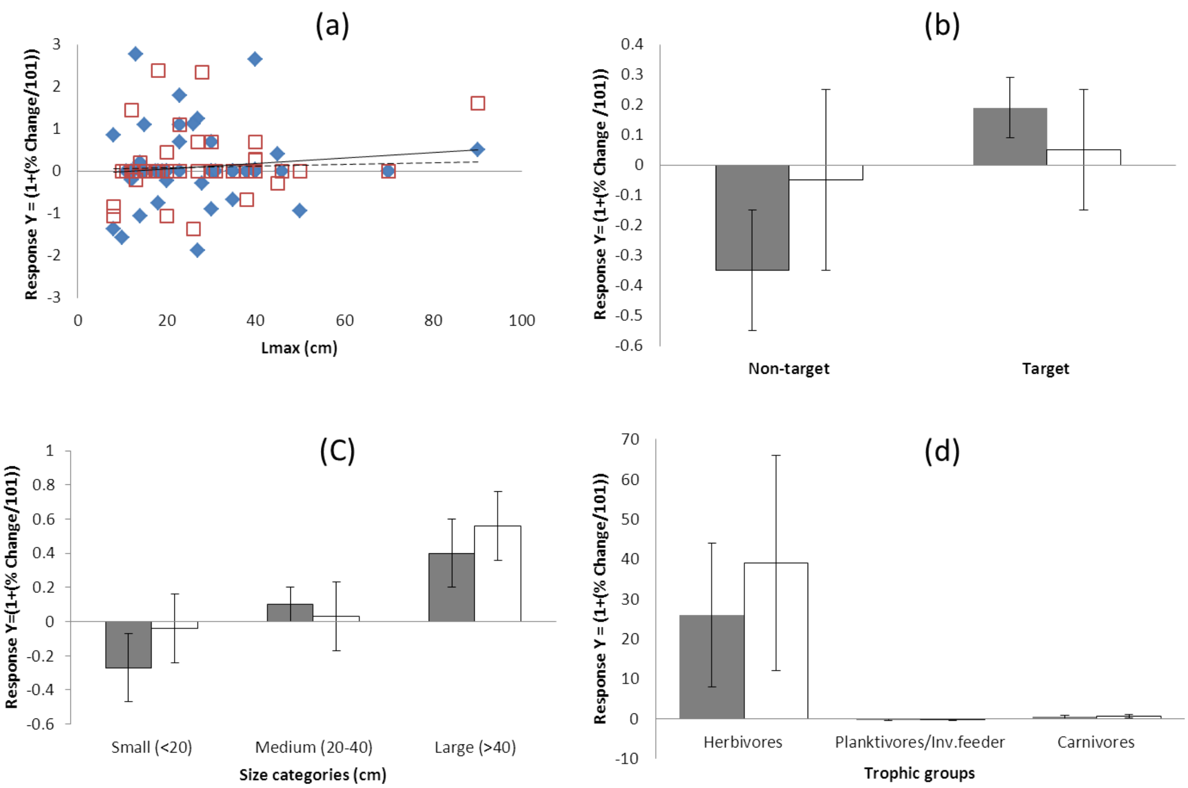

Figure 3.2: a) Linear regression of the response ratio of the abundance of all fish species in a comparison of the NTZ vs SMA (closed symbols) and the NTZ vs COMP (open symbols), b) mean (± S.E.) response ratio of the non-target and target species, c) mean response ratio of the small, medium and large body-sized species, and d) mean response ratio of the fish categorised by feeding groups. In b, c and d, the filled bars represent a comparison of the NTZ vs SMA and the open bars represent a comparison of the NTZ vs COMP. Because the ratio is log-transformed, line drawn at log ratio = 0 show where NTZ had no effect. Points above this line represent greater than zero; points below the line represent value less than zero.

Table 3.4: a) Linear regression of the response ratio of the abundance of all fish species, b) mean (± S.E.) response ratio of the non-target and target species, c) mean response ratio of the small, medium and large body-sized species, and d) mean response ratio of the fish categorised by feeding groups in a comparison of the NTZ vs SMA (NTZ/SMA) and the NTZ vs COMP (NTZ/COM).

(a)

	Mean	R Square	Constant	slope	F	df	p
NTZ/SMA	0.4±0.9	0.08	-0.4	0.2	5.7	1,70	0.02
NTZ/COM	0.2±0.9	0.13	-0.48	0.02	10.4	1,70	0.002

(b)

	Non-target	Target	F	df	p
NTZ/SMA	-0.35±0.2	0.19±0.1	6.7	1,74	0.01
NTZ/COM	-0.05±0.3	0.05±0.2	0.1	1,74	0.8

(c)

	Small (≤20)	Medium (21-39)	Large (≥40)	F	df	p
NTZ/SMA	-0.27±0.2	0.1±0.1	0.4±0.2	2.9	2,69	0.06
NTZ/COM	-0.04±0.2	0.03±0.2	0.56±0.2	2.8	2,69	0.07

(d)

	Herbivores	Planktivores/Inv.feeder	Carnivores	F	df	p
NTZ/SMA	26±18	-0.29±0.2	0.4±0.4	2.7	2,74	0.07
NTZ/COM	39±27	-0.28±0.2	0.65±0.4	2.8	2,74	0.06

Macro-invertebrate:

Abundance and diversity

A total of thirty seven species of macro-invertebrates were recorded during this survey in which fifteen species were those for which there are targeted fisheries. The macro-invertebrate assemblage was dominated in terms of abundance by eleven species (Table 3.5). All macro-invertebrate abundance and diversity (species richness and evenness) varied among protection levels but were not statistically significant (Table 3.5). With the exception of *Tridacna maxima*, most of the target invertebrate species had mean abundance values that were greater in the NTZ compared to SMA and COM sites, while the non-target species were varied considerably among protection levels. However, the lack of significant effects is related to high level of variance associated with the estimates of the means for all species.

Table 3.5: Mean (± 2SE) macro-invertebrate abundance (AB), and diversity indices (species richness (d) and evenness (J')) in Special Management Area (SMA), No-Take Zone (NTZ), and Comparator (COM) sites. Analyses were undertaken using either an ANOVA (F) or Kruskal-Wallis (χ) test depending on whether the data met the appropriate assumptions of normality and homogeneity of variance. (AM = abundance, BI = diversity indices, T = fisheries target species, N = non-target species).

Biological parameters	**Species**	**SMA**	**NTZ**	**COM**	**F**	**χ**	**df**	**p**
Diversity	Richness	3.9±0.3	3.2±0.6	3.3±0.3		2.87	2,12	0.096
	Evenness	0.88±0.06	0.77±0.3	0.86±0.07	1.378		2,12	0.142
AB	*Tridacna maxima* (T)	3.2±1.9	3.6±4.9	11±11.5		0.942	2,12	0.624
	Bohadschia argus (T)	2.2±2.9	4.6±5.7	1±1.2		0.112	2,12	0.946
	Holothuria atra (T)	106.2±126.2	849.4±139.8	37±45.1		1.503	2,12	0.472
	Holothuria coluber (T)	31±6	53.2±98.1	0±0		3.722	2,12	0.156
	Stichopus chloronotus (T)	7.4±11.9	36±43.7	2.4±2.1		0.144	2,12	0.93
	Diadema spp.(N)	6.6±10.2	3.2±2.6	6.4±7.0	0.271		2,12	0.767
	Linckia laevigata (N)	30.2±24.6	54.6±51.4	74.4±92.2	0.501		2,12	0.618
	Gasteropods spp.(N)	5.4±4.7	1±1.5	3±0.9	2.289		2,12	0.144
	Echinometra spp. (N)	79.8±154.1	4.4±6.8	6.4±6.5		1.331	2,12	0.514
	Heterocentrotus spp. (N)	1±0.9	1.2±1.5	47.8±94.1		0	2,12	1

Habitat structure

Substrate type and rugosity, hard coral cover, and diversity

Substrate type was dominated by eleven main substrate types, and percentage cover was highly varied among protection levels, and no significant differences were found among protection levels. A similar pattern was displayed for rugosity for which values were varied among protection levels such that no significant differences were found among the different protection levels (Table 3.6). A total of 25 coral genera, representing the live hard coral structure were identified during this survey. Hard coral was dominated by eight genera across the different protection levels. The hard coral percentage cover, and diversity (species richness and evenness) were varied among protection levels but the differences were not significant (Table 3.6).

Table 3.6: Mean (± 2SE) substrate cover, coral genera, species richness (d) and evenness (J’) within the Special Management Area (SMA), No-Take Zone (NTZ), and Comparator (COM) sites. Analyses were undertaken using either an ANOVA (F) or Kruskal-Wallis (χ) test depending on whether the data met the appropriate assumptions of normality and homogeneity of variance.

Biological parameters	**Substrate type**	**SMA**	**NTZ**	**COM**	**F**	**χ**	**df**	**p**
Substrate	Macro - algae (A)	2.46±2.23	1.90±2.28	5.04±6.63	0.615		2,12	0.557
	Dead coral with turf algae (DC/TA)	8.63±3.33	8.37±2.66	6.05±3.92	0.737		2,12	0.499
	Dead coral with coralline algae (DC/CA)	16.92±11.63	17.31±8.96	19.24±9.52	0.06		2,12	0.942
	Hard coral branching (HCB)	8.23±4.12	7.84±5.10	2.97±1.68	2.247		2,12	0.148
	Hard coral digitate (HCD)	1.07±0.90	3.20±4.03	2.18±2.26	0.609		2,12	0.56
	Hard coral encrusting (HCE)	1.13±0.75	1.07±0.64	2.49±1.82	1.79		2,12	0.209
	Hard coral massive (HCM)	1.41±1.03	1.44±1.64	3.20±2.64	1.168		2,12	0.344
	Hard coral sub-massive (HCSM)	2.46±2.16	2.01±1.68	2.91±2.98	0.15		2,12	0.086
	Rock (RC)	5.35±3.04	4.55±4.06	6.14±4.30	0.171		2,12	0.845
	Rubble (RB)	21.27±7.71	17.45±8.07	18.02±5.61	0.327		2,12	0.728
	Sand (SND)	23.31±6.95	32.16±15.95	28.49±11.45	0.547		2,12	0.592
	Rugosity index	0.22±0.07	0.23±0.06	0.23±0.08	0.015		2,12	0.985
Coral genera	*Acropora* spp.	7.86±3.96	9.9±9.21	5.86±4.46	0.41		2,12	0.672
	Montipora spp.	0.48±0.58	0.59±0.81	0.14±0.18	0.66		2,12	0.537
	Porites spp.	0.85±0.49	1.67±2.09	1.92±1.8	0.48		2,12	0.628
	Pocillopora spp.	1.39±1.15	1.36±0.6	1.22±1.12	0.03		2,12	0.967
	Platygyra spp.	0.45±0.55	0.25±0.44	0.93±0.6	1.72		2,12	0.221
	Favites spp.	0.34±0.34	0.06±0.11	0.4±0.35		2.14	2,12	0.343
	Goniastrea spp.	0.14±0.17	0.08±0.07	1.39±2.5		0.22	2,12	0.895
	Favia spp.	0.17±0.03	0.2±0.28	0.28±0.2	0.25		2,12	0.785
Diversity	Richness (d)	3.0±0.8	2.8±0.9	4.8±2.4	2.07		2,12	0.17
	Evenness (J’)	0.6±0.2	0.6±0.1	0.8±0.1	2.54		2,12	0.09

SECONDARY LEVEL ANALYSIS (ISLAND SCALE)

The measured biological parameters (abundance, biomass, species richness and evenness) were highly varied among different locations. For instance, considering all NTZs across the different islands, the fish families that showed significant variation in abundance and biomass among the protection levels were Pomacentridae, Acanthuridae, Scaridae, Serranidae, Nemipteridae (Table 3.7 and 3.9). Ovaka had the most families (Pomacentridae, Acanthuridae, Serranidae, Nemipteridae) that had significant variation in abundance and biomass in the NTZ relative to SMA and COM sites (Table 3.7 and 3.9). Species richness and evenness had significantly greater values in the NTZ in ‘O’ua compared to SMA and COM sites while only evenness had a significantly greater value in the NTZ compared to SMA and COM for Felemea (Table 3.8). With regards to trophic groups, the significant differences among the NTZ, SMA and COM sites in most cases were accounted for by herbivores fish. Similarly, those families targeted as commercial fisheries (Acanthuridae, Scaridae, Serranidae and Nemipteridae) had significantly higher abundance and biomass in the NTZ relative to SMA and COM sites at all locations except for Felemea and ‘O’ua where SMA and COM were higher than NTZ. Also, the abundance of non-target family (Pomacentridae) was varied among protection levels, and the direction of this response varied among locations.

Table 3.7: Mean (± 2SE) fish abundance between Special Management Areas (SMA), No-Take Zone (NTZ), and Comparator (COM) sites. Analyses were undertaken using either an ANOVA (F) or Kruskal-Wallis (χ) test depending on whether the data met the appropriate assumptions of normality and homogeneity of variance. Multiple comparison tests (mct) by Tukey test for ANOVA or Mann-Whitney test for Kruskal-Wallis when a significant difference ($p > 0.05$) was found (Shaded lines), and Bonferroni correction applied with significant difference at $p< 0.0015$ in all cases. Trophic groups: H=Herbivores, P/I = Planktivores and Invertebrate feeder, C = Carnivores; T= fisheries target species, N=non-target species.

Location	Family	SMA	NTZ	COM	F	χ	df	p	mct
Atata	Acanthuridae (H, T)	4.1±2.5	25.9±14.6	41.4±14.6	17.71		2,18	0.001	
	Pomacentridae (H,N)	134±59.3	51.57±23.9	80.9±22.9	4.51		2,18	0.025	
Ha'afeva	Scaridae (H,T)	0.1±0.3	3±1.5	5.1±3.22	13.01		2,18	0.011	
	Pomacentridae (H,N)	86.3±27.9	110.6±27.2	61.9±11.1	4.33		2,18	0.029	
O'ua	Acanthuridae (H,T)	4.9±5.5	26.6±14.6	16.7±8.1	6.12		2,18	0.009	
	Scaridae (H,T)	0±0.00	8±5.9	5.7±3.3		12.34	2,18	0.002	
	Siganidae (H,T)	3.9±1.92	2.1±1.1	0.6±0.7	6.88		2,18	0.006	
	Pomacentridae (H,N)	116.1±16.1	43.6±15.8	67.3±23.8	9.76		2,18	0.001	SMA > NTZ, COM
Felemea	Acanthuridae (H,T)	28.4±4.8	10.6±3.4	31±3.85	28.92		2,18	0.001	SMA > NTZ, COM > NTZ
	Scaridae (H,T)	5.9±2.7	10.4±5.6	1.4±1.06	7.29		2,18	0.005	
	Labridae (P/I,T)	17.9±3.3	12.4±3.4	12.3±1.49	4.93		2,18	0.02	
	Chaetodontidae (P/I,N)	7.3±2.4	2.0±1.1	5.7±3.11	5.73		2,18	0.015	
	Pomacentridae (H,N)	75.9±17.9	19.1±11.1	70±14.33	17.89		2,18	0.001	SMA > NTZ, COM > NTZ
Ovaka	Acanthuridae (H,T)	7.9±5.4	25.6±9.5	4.4±1.5	12.63		2,18	0.001	NTZ > SMA, COM
	Labridae (P/I,T)	29.9±7.2	20.1±7.4	9.7±5.7	8.75		2,18	0.002	
	Serranidae (C,T)	0.3±0.4	2±0.6	0±0.00		15.87	2,18	0.001	NTZ > SMA, COM
	Mullidae (P/I,T)	1.4±1.4	5.9±2.8	1±1.2		8.78	2,18	0.012	
	Nemipteridae (P/I,T)	0±0.00	4.6±3.1	0.1±0.3		13.81	2,18	0.001	NTZ > SMA, COM
	Monacanthidae (P/I,N)	3.6±1.5	0.7±1.4	0.6±0.7	7.09		2,18	0.005	
	Pomacentridae (H,N)	175.4±21.9	165.4±50.3	53.3±13.8	17.23		2,18	0.001	NTZ > COM

Table 3.8: Mean (± 2SE) diversity indices (species richness (d) and evenness (J')) between Special Management Area (SMA), No-Take Zone (NTZ), and Comparator (COM) sites for Ovaka. Analyses were undertaken using either an ANOVA (F) or Kruskal-Wallis (χ) test depending on whether the data met the appropriate assumptions of normality and homogeneity of variance. Multiple comparison tests (mct) by Tukey test for ANOVA or Mann-Whitney test for Kruskal-Wallis when a significant difference ($p > 0.05$) was found, and Bonferroni correction applied with significant difference at $p < 0.0015$ in all cases. (Trophic groups: H=Herbivores, P/I = Planktivores and Invertebrate feeder, T= fisheries target species, N= non-target species). Shaded lines represent a significance difference found.

Location	Diversity	SMA	NTZ	COM	F	df	p	mct
Atata	Richness (d)	4.20±0.64	5.0±0.59	4.74±0.66	1.663	2,18	0.217	
	Evenness (J')	0.91±0.02	0.95±0.01	0.91±0.01	9.109	2,18	0.002	
Ha'afeva	Richness (d)	3.3±0.7	4.0±0.8	3.4±0.7	1.12	2,18	0.347	
	Evenness (J')	0.9±0.03	0.9±0.02	0.9±0.02	4.93	2,18	0.02	
O'ua	Richness	2.5±0.4	402±0.6	3.3±0.5	11.12	2,18	0.001	NTZ > COM, SMA
	Evenness (J')	0.8±0.0	0.9±0.2	0.9±0.0	14.19	2,18	0.001	NTZ > SMA, COM > SMA
Felemea	Richness	4.3±0.6	3.9±0.4	4.6±0.4	2.61	2,18	0.1	
	Evenness	0.9±0.0	1.0±0.01	0.9±0.6	15.8	2,18	0.001	NTZ > SMA, COM
Ovaka	Richness (d)	4.3±1.0	5.2±0.3	3.0±0.9	6.87	2,18	0.006	
	Evenness (J')	0.9±0.0	0.9±0.0	0.9±0.03	4.32	2,18	0.029	

Table 3. 9: Mean (± 2SE) fish biomass within Special Management Area (SMA), No-Take Zone (NTZ), and Comparator (COM) sites. Analyses were undertaken using either an ANOVA (F) or Kruskal-Wallis (χ) test depending on whether the data met the appropriate assumptions of normality and homogeneity of variance. Multiple comparison tests (mct) by Tukey test for ANOVA or Mann-Whitney test for Kruskal-Wallis when a significant difference (p > 0.05) was found, and Bonferroni correction applied with significant difference at p< 0.0015 in all cases. (Trophic groups: H=Herbivores, P/I = Planktivores and Invertebrate feeder, C =Carnivores; T= fisheries target species, N= non-target species). Shaded lines represent a significant difference found

Location	Family	SMA	NTZ	COM	F	χ	df	p	mct
Atata	Acanthuridae (H,T)	179.5±173.2	1477.8±625.6	3836.1±1948.6	24.5		2,18	0.001	COM > NTZ, SMA
	Pomacentridae (H,T)	4664.1±2304.8	1582.9±825.3	1445.4±1103.5	5.5		2,18	0.014	
Ha'afeva	Scaridae (H,T)	76.6±153.2	805.9±317.0	506.6±473.9	14.7		2,18	0.001	NTZ > SMA
	Pomacentridae (H,N)	4976.91±3001.1	6266.5±2462.3	1129.8±677.8	11.4		2,18	0.001	NTZ > COM, SMA > COM
O'ua	Acanthuridae (H,T)	354.4578.7	3172.1±2677.3	1457.5±879.9	9.5		2,18	0.002	
	Scaridae (H,T)	0±0.00	604.4±366.2	516.1±317.4	29.3		2,18	0.001	NTZ > SMA
	Pomacentridae (H,N)	3049.1±477.1	833.2±284.9	3887.2±4231.1		8.9	2,18	0.012	
Felemea	Acanthuridae (H,T)	2494.3±712.5	508.2±233.8	2861.6±759.35	16.9		2,18	0.001	SMA > NTZ, COM > NTZ
	Scaridae (H,T)	604.6±282.1	503.1±181.1	207.9±147.5	3.8		2,18	0.042	
	Labridae (P/I,T)	640.5±199.4	245.9±115.7	344.3±126.8	7.3		2,18	0.005	
Ovaka	Acanthuridae (H,T)	169.6±98.5	1357.2±824.7	90.3±68.3	6.29		2,18	0.008	
	Serranidae (C,T)	22.9±32.6	155.3±88.0	0±0.00		14.1	2,18	0.001	NTZ > SMA, COM
	Mullidae (P/I,T)	7.6±8.8	107.0±61.8	19.6±24.9		10.7	2,18	0.005	
	Nemipteridae (P/I,T)	0±0.00	515.6±333.1	5.9±11.8	22.16		2,18	0.001	NTZ > SMA, COM
	Pomacanthidae (P/I,N)	0±0.00	24.1±14.3	0±0.00		12.3	2,18	0.002	
	Pomacentridae (H,N)	1493.8±292.8	1026.9±437.7	555.7±237.3	7.91		2,18	0.003	

Macro invertebrate abundance and diversity

Overall the macro-invertebrate communities showed very little response to the different protection levels. From the 37 species recorded only eight species showed significant differences in their abundance. Out of the eight species with significant difference, four were target species and four were non-target species. In most cases, the target species had significantly higher abundance in the NTZ compared to fished areas (SMA and COM), although there was some variability among the different protection levels as well as locations where these differences occurred (Table 3.10). For instance, sea cucumbers (Holothuria) had significantly greater abundance in the NTZ than SMA and COM sites, with the exception of *Holothuria atra* in Ovaka where the abundance of this species in the COM was significantly higher than NTZ and SMA. Similarly, giant clam species (*Tridacna maxima*) showed a significantly higher number in the NTZ compared to fished area in Ha'afeva, while in Felemea, it was significantly higher in the fish area (COM) than the NTZ. In contrast, all the non-target species abundance were significantly higher in the fished area (COM and SMA) compared to NTZ sites (Table 3.10).

Table 3.10: Mean (± 2SE) macro-invertebrate abundance and diversity (species richness (d) and evenness (J') within Special Management Area (SMA), No-Take Zone (NTZ), and Comparator (COM) sites among locations. Analyses were undertaken using either an ANOVA (F) or Kruskal-Wallis (χ) test depending on whether the data met the appropriate assumptions of normality and homogeneity of variance. Multiple comparison tests (mct) by Tukey test for ANOVA or Mann-Whitney test for Kruskal-Wallis when a significant difference (p > 0.05) was found, and Bonferroni correction applied with significant difference at p< 0.0015 in all cases. (T= fisheries target species, N= non-target species). Shaded lines represent a significant difference found.

Location	**Species**	**SMA**	**NTZ**	**COM**	**F**	**χ**	**df**	**p**	**mct**
Atata	*Holothuria coluber* (T)	21.9±12.7	35.6±15.2	0±0.0		14.9	2,18	0.001	NTZ > COM
	Holothuria edulis (N)	14.6±9.7	9.1±6.1	0.3±0.6		12.6	2,18	0.002	
	Echinometra spp. (N)	55.4±30.6	0.1±0.2	1.9±2.2		15.6	2,18	0.001	SMA > NTZ, COM
	Heterocentrotus spp.(N)	0.1±0.2	0.1±0.2	33.7±33.1		16.4	2,18	0.001	SMA > NTZ, COM
	Richness (d)	2.2±0.2	1.5±0.4	1.3±0.6		4.1	2,18	0.034	
Ha'afeva	*Tridacna maxima* (T)	0.4±0.4	1.9±0.9	4.0±1.8	12.9		2,18	0.001	NTZ > SMA
	Bohadschia argus (T)	0.0±0.0	0.0±0.0	0.4±0.4		6.7	2,18	0.036	
O'ua	*Holothuria atra* (T)	33.4±11.3	49±17.4	6.3±7.6		12.5	2,18	0.002	
	Stichopus chloronotus (T)	4.4±2.3	12.7±5.5	0±0.0		15.5	2,18	0.001	NTZ > SMA, COM
Felemea	*Tridacna maxima* (T)	0.9±1.2	0	3.7±1.7		13.7	2,18	0.001	COM >NTZ
	Holothuria atra (T)	0.3±0.4	518.9±113.7	0.4±0.4	681.4		2,18	0.001	NTZ > COM
	Stichopus chloronotus (T)	0±0.00	12.9±3.9	0±0.00		18.9	2,18	0.001	NTZ > COM
	Diadema spp. (N)	3.9±2.9	0±0.00	0.1±0.3		13.3	2,18	0.001	SMA > NTZ, COM
	Linckia laevigata (N)	2.9±4.4	8.4±2.1	2.4±2.9	4.2		2,18	0.032	
	Bohadschia argus (T)	1.0±0.0	1.4±1.1	0.0±0.0		7.2	2,18	0.028	
Ovaka	*Holothuria atra* (T)	0.9±0.8	1.6±1.2	17.7±7.1	33		2,18	0.001	COM > SMA,NTZ
	Linckia laevigata (N)	11.3±4.5	19.9±6.4	34.6±8.8	12.1		2,18	0.001	COM > SMA,NTZ

Substrate composition and live coral cover

Substrate cover, rugosity, hard coral cover, coral richness and diversity were highly varied among protection levels and study locations (Table 3.11 and 3.12). All locations with respected protection were characterised by dead coral with algae, live hard corals, macro algae, rubbles, rock and sand despite their high variability among protection levels and locations (Table 3.11). Only in ‘Atata, ‘O’ua and Ovaka locations showed a significant differences in substrate composition cover among treatments. In Atata, there was a significantly higher live coral cover in the SMA and COM site relative to the NTZ. SMA was dominated by hard coral branching where as hard coral encrusting and massive were dominated in the COM site. As for ‘O’ua, only hard coral sub-massive showed a significant difference and it was dominated in the COM site. For Ovaka, the SMA was dominated by rocks (RC) and hard coral branching, while the NTZ was dominated by dead coral with coralline algae (DC/CA) and COM was dominated by macro algae (A).

In addition, considering all the locations, live hard coral cover consist of various coral genera, but, the only coral genera that showed significantly higher cover were *Acropora*, *Pocillopora*, *Isopora*, *Porites*, *Millepora*, *Montipora*, *Platygyra*, *Stylophora*, *Favites* and *Goniastrea* species, despite their variability among protection level as well as locations (Table 3.12). Considering the NTZs, only in Felemea and Ovaka locations where *Porites* and *Isopora* species showed a significant difference relative to SMA and COM. In ‘Atata, *Favite* and *Goniastrea* species showed a significantly higher values in the COM compared to NTZ and SMA sites. In addition, coral diversity was also significantly higher values in the COM compared to SMA and NTZ sites. As for Ha’afeva, *Porites* species was significantly higher values in COM compared to SMA and NTZ sites. In Felemea, *Porite* species was significantly higher values in NTZ compared to SMA and COM sites, whereas *Isopora* species was significantly higher values in SMA compared to NTZ and COM sites. In Ovaka, *Acropora* species was significantly higher values in SMA compared to NTZ and COM sites, whereas *Isopora* species was significantly higher values in the NTZ compared to SMA and COM sites.

Table 3.11: Mean (± 2SE) percentage substrate cover within the Special Management Area (SMA), No-Take Zone (NTZ), and Comparator (COM) sites in Tonga. Analyses were undertaken using either an ANOVA (F) or Kruskal-Wallis (χ) test depending on whether the data met the appropriate assumptions of normality and homogeneity of variance. Multiple comparison tests (mct) by Post hoc for ANOVA or Mann-Whitney test for Kruskal-Wallis test were carried out if any significant differences (p > 0.05) was found, and Bonferroni correction applied with significant difference at p< 0.0015 in all cases. Shaded lines represent a significant difference found.

Location	**Substrate cover**	**SMA**	**NTZ**	**COM**	**F**	**χ**	**df**	**p**	**mct**
Atata	Dead coral with Turf algae (DC/TA)	1.6±4.9	1.6±3.2	0.5±2.5	4.09		2,18	0.034	
	Dead coral with coralline algae (DC/CA)	1.7±10.7	3.4±6.8	4.3±11.3	3.93		2,18	0.038	
	Hard coral branching (HCB)	2.1±3.5	2.6±5.1	0.6±2.2	14.7		2,18	<0.001	SMA> COM,NTZ> COM
	Hard coral encrusting (HCE)	0.1±0.7	0.3±0.6	0.8±1.6	21.86		2,18	<0.001	COM> SMA,COM > NTZ
	Hard coral massive (HCM)	0.1±0.4	0.04±0.1	1.1±2.4		14.82	2,18	0.001	COM> SMA,COM > NTZ
Ha'afeva	Dead coral with Turf algae (DC/TA)	5.4±3.5	8.9±3.3	4.0±1.5	3.73		2,18	0.04	
	Dead coral with coralline algae (DC/CA)	31.9±5.5	27.2±6.5	17.5±5.7	6.17		2,18	0.01	
	Rubbles (RB)	9.9±2.3	13.0±9.2	29±13.1	5.65		2,18	0.01	
O'ua	Macro algae (A)	4.8±1.64	1.6±1.1	2.1±1.6	5.59		2,18	0.013	
	Hard coral encrusting (HCE)	2.4±0.59	0.4±0.6	2.8±1.3	8.72		2,18	0.002	
	Hard coral sub-massive (HCSM)	1.3±1.41	0.3±0.6	7.6±3.9	16		2,18	0.001	COM> SMA,COM > NTZ
	Hard coral tabulate (HCT)	0.9±0.52	4.2±3.2	0±0.0		11.64	2,18	0.003	
	Soft coral (SC)	9.9±4.89	1.0±1.1	0.1±0.3		10.18	2,18	0.006	
Felemea	Macro algae (A)	0.3±0.4	0.7±0.7	2.7±1.3	5.71		2,18	0.01	
	Sand (SND)	34.9±6.5	86.3±53.	45.7±7.1	4.89		2,18	0.02	
Ovaka	Macro algae (A)	5.8±3.10	6.4±2.11	18.3±6.4	11.41		2,18	0.001	CO > SMA,COM> NTZ
	Dead coral with coralline algae (DC/CA)	4.±2.1	12.9±3.1	4.0±1.4	20.01		2,18	0.001	NTZ> SMA,NTZ > COM
	Hard coral branching (HCB)	11.6±3.3	5.4±2.3	1.0±1.1	23.28		2,18	0.001	SM > NTZ,SMA > COM
	Rocks (RC)	8.4±4.	0.9±0.9	12.5±5.5	19.01		2,18	0.001	SMA > NTZ,COM > NTZ

Table 3.12: Mean (± 2SE) percentage cover, richness (d) of coral genera within the Special Management Area (SMA), No-Take Zone (NTZ), and Comparator (COM) sites. Analyses were undertaken using either an ANOVA (F) or Kruskal-Wallis (χ) test depending on whether the data met the appropriate assumptions of normality and homogeneity of variance. Multiple comparison tests (mct) by Post hoc for ANOVA or Mann-Whitney test for Kruskal-Wallis test were carried out if any significant differences ($p > 0.05$) was found, and Bonferroni correction applied with significant difference at $p < 0.0015$ in all cases. Shaded lines represent a significant difference found.

Locations	**Coral genera**	**SMA**	**NTZ**	**COM**	**F**	**χ**	**df**	**p**	**mct**
Atata	*Acropora* spp.	1.9±3.75	3.8±7.23	1.7±4.67	9.39		2,18	0.002	
	Favite spp.	0±0.00	0±0.00	0.1±0.52		12.4	2,18	0.001	COM > SMA,COM > NTZ
	Goniastrea spp.	0.04±0.37	0.02±0.29	0.9±1.22		15.8	2,18	0.001	COM > SMA,COM > NTZ
	Australogyra spp.	0.04±0.37	0.2±104	0±0.00	4.47		2,18	0.027	
	Richness	1.0±0.4	0.8±0.3	1.9±0.5	8.43		2,18	0.003	
Ha'afeva	*Porites* spp.	0.9±0.43	0.6±0.85	4.7±3.02	10.4		2,18	0.001	COM > SMA,COM > NTZ
O'ua	*Stylophora* spp.	0±0.0	0±0.0	1.1±1.01		9.31	2,18	0.01	
Felemea	*Porites* spp.	0.1±0.28	5.8±3.39	1.1±0.8	14.57		2,18	0.001	NTZ > SMA,NTZ > COM
	Pocillopora spp.	1.1±0.8	2.4±1.49	0±0.0		12.6	2,18	0.002	
	Millepora spp.	0±0.0	0.77±0.83	0±0.0		6.63	2,18	0.036	
	Isopora spp.	3.7±3.61	0.17±0.28	0±0.0		13.2	2,18	0.001	SMA > COM,SMA > NTZ
Ovaka	*Acropora* spp.	11.7±3.33	4.57±2.02	0.6±0.4	38.52		2,18	0.001	SMA > NTZ,SMA > COM
	Pocillopora spp.	0±0.0	1.17±0.67	0.4±0.85		7.89	2,18	0.019	
	Isopora spp.	0.9±0.97	3.7±0.94	0.1±0.28		14.15	2,18	0.001	NTZ > SMA,NTZ > COM

3.5 DISCUSSION

The present study evaluated the effectiveness of the Tongan Special Management Area regime by examining the response of coral reef communities (fish, macro-invertebrate and substrate) to different protection levels (the no-take zone (NTZ), the special management area (SMA) with access only to the local fishing community, and the comparator (COM) with open access to all fishers).

National scale analysis

When the effects of the management regime were studied across all five island locations, the measured generic biological parameters (total abundance, biomass, and diversity indices) did not show a clear pattern of response to the protection afforded by the SMAs and there was considerable variability among individual taxa (Table 3.3). In the case of fish, the NTZs showed little change in species diversity (species richness and evenness), despite no significant differences found. The effect of NTZs on overall fish abundance and biomass were much more variable among protection levels and locations and showed few consistent patterns in response to protection. Similarly, for macro-invertebrates (abundance) and habitat structure (substrate and hard coral percentage cover), a similar pattern of variability among protection levels and locations was found. This result perhaps suggests that some of the NTZ sites were even more degraded than the SMA and comparator sites when originally implemented. Although there was no significant difference, the high variability in the biological parameters makes the detection of differences among protection levels difficult.

It was not possible to detect statistically significant differences in the measured generic biological parameters among protection levels across all study sites. This outcome is similar to the result reported in Vanuatu (Bartlett *et al*., 2009) where no significant difference found for fish abundance and biomass between permanent reserves and adjacent open fished areas. Also, Cinner *et al*., (2005) did not detect any differences in fish abundance between managed and control sites within which fish density was highly variable. Thus, from the results of the present study (national analysis) it appears that the biological parameters measured did not provide evidence of a positive response to protection within the 2 – 3 year timeframe since establishment. Therefore, this result appears to contradict with the finding of other marine reserves effects studies (Roberts, 1995; Russ & Alcala, 1998a; Halpern and Warner, 2002; Halpern, 2003; Russ and Alcala, 2004; Beenaerts and Berghe, 2005) where significantly higher values of fish abundance, biomass, and biodiversity were found inside reserves compared with fished areas.

There are a number of explanations for these findings. The implementation of NTZs are a prerequisite for a community to be granted a SMA which clearly empowers the local community to control who fishes within the SMA and how the fishing is undertaken. As the NTZs were chosen through a process of stakeholder engagement (Coastal community management plan, unpublished), it is possible that fishers offered a poor quality or previously over-exploited area of the reef to become the NTZ. As a result, any positive response to protection may take much longer than the 2-3 year timeframe of the present study, particularly if the original features of the NTZ area did not lend themselves to similar levels of production compared to the wider SMA. Other explanations are discussed later in this section.

Nevertheless, the response to protection showed some interesting trends when considering the log response ratio measured as change in species abundance plotted against species maximum length (Lmax), size categories, target and non-target species and trophic groups (Figure 2). The results from these analyses revealed that fish with very large Lmax values, and those targeted by fishers were significantly more abundant inside the NTZs compared to fished areas (SMA and

COM) sites. Although the trends were significant and positive, they were small in magnitude and strongly influenced by relatively few data-points. Small body-sized fishes did not show a response to protection because either they may be too small to be fished or they may be more resilient to fishing. Thus there is some evidence to suggest that the relative magnitude of the effect of NTZs on biological measures appears to be correlated with species maximum length and fisheries targeted species.

In contrast, trophic groups, herbivores, planktivores and carnivores did not show any evident of a response to protection, similar to the results of Guidetti and Sala (2007) and references therein. Also, there was no evidence of any trophic cascades involving prey fish. The present study result found that abundance of very small non-target species (Pomacentridae) was highly variable, and could reflect potential changes in predator-prey interactions at the different locations, with changes in the number of target fish species and hence competitive interactions, or localised spatial differences in habitat quality that were unrelated to the implementation of the NTZs.

Macro-invertebrate showed a variable response across study sites in term of abundance. The most notable response was that abundance of some of the heavily exploited species of the sea cucumber (Holothuria family) was higher in the NTZ compared with SMA and COM sites, despite that no significant difference was detected. Lincoin-Smith *et al*., (2006) reported a similar finding where sea cucumber (*Holothuria fuscogilva*) increased in the marine conservation area relative to fished areas.

Island scale analysis

When the response of biological communities to the implementation of the SMAs was examined at individual sites (island scale), the biological response of the fish families, macro-invertebrate and habitat structure were highly variable among protection levels and locations. In the case of fish assemblages, biological measures (abundance and biomass) for some families (Acanthuridae, Serranidae, Scaridae, Nemipteridae and Pomacentridae) were significantly higher in the NTZ than SMA and COM in some locations, but not at all locations. There is no clear mechanism for the differences; however, reasons that might attribute to the mentioned responses are discussed below in this section. Species richness and evenness were higher in NTZ compared to SMA and COM sites at two locations ('O'ua and Felemea) which showed significant differences. Such a response supports the expectation that species richness and evenness within a marine reserve is expected to increase due to the prohibition of fishing compared to fished areas (McClanahan, 1994; Jennings *et al*., 1996; Wantiez *et al*. 1997; Halpern, 2003; Worm *et al*., 2006; Tyler *et al*., 2011). However, in many situations, removal of fishing pressure may cause a decline in species richness because of unpredictable ecosystem changes or because particular species become dominant and exclude others (Edgar and Barrett, 1999; Ward *et al*., 2001).

The response of macro-invertebrates to the management system was variable among sites, and this is similar to trends reported in other studies (Russ and Alcala, 1998a, Dulvy *et al*., 2004, Cinner *et al*., 2005, Claudet *et al*. 2006). The abundance of sea cucumbers (Holothuridae) was consistently and significantly higher in NTZ in most cases except for Ovaka where *Holothuria atra* was significantly higher in the COM compared to SMA and NTZ sites. Edgar *et al*., (2004) reported that densities of the most valuable fishery resources, sea cucumbers, were higher in the fished areas compared to no-take zones in a study at the Galapagos marine reserve (Edgar *et al*., 2004). It is important to note that the survey was undertaken during the opening of the sea cucumber harvesting seasons (April –September). Also, *Holothuria atra* is the lowest value sea cucumber, despite that they are the most abundant sea cucumber species, and fishers ignore them and focus on the higher value species. Likewise, a similar pattern of variability was seen in the habitat structures. The substrate composition coverage showed no significant differences among protection levels and locations except for ‘Atata, ‘O’ua and Ovaka where some of the substrate (hard live corals, algae and dead coral with coralline algae) showed a significant difference, though they were highly variable among protection levels and locations. Habitat is an important predictor of fish abundance and species richness (Tyler et al. 2011), but there was no link between protection and habitat variables between NTZs and fished areas (SMA, COM) in the present study. The inability to detect an effect of protection on reef habitat is probably due to the long time scale needed for habitat recovery (Tyler *et al*., 2011) given the slow growth rates of many of the species.

Three main findings stand out from this study : first, the effect of the SMAs on fish and invertebrates depended on the degree of exploitation of that species. Halpern and Warner (2002) argued that heavily targeted species are more likely to respond quickly to the implementation of reserves because fishing has reduced their abundance to low levels (Halpern and Warner, 2002). The present study showed that most of the target species abundance and biomass were significantly higher in the NTZ than areas in which fishing was still permitted (SMA and COM). For example, targeted fish families (Scaridae, Acanthuridae, and Serranidae), and macro-invertebrates (*Holothuria coluber, Holothuria atra, Stichopus chlorontus, and Tridacna maxima)* had significantly higher abundance and biomass in NTZ relative to SMA and COM sites. This is consistent with what has been observed in other studies (Mosqueira *et al*. 2000; Guidetti *et al*., 2008; Garcia-Charton *et al*., 2004; Alcala *et al*., 2005; Evans *et al*., 2006; Claudet *et al*.,2006; Guidetti and Sala, 2007 Guidetti *et al*., 2008). A similar result reported by Evans *et al*. (2006) in a study of the Great Barrier Reef Marine Park in Australia. According to Evans *et al*. (2006), these results are commonly expected from the establishment of NTZs, in which reducing fishing mortality inside the NTZ is likely to increase abundance of species targeted by fishing.

Second, the analysis of mean response ratio against species Lmax reveals that the effect of protection for a particular species will certainly depend on their life-history characteristics. Various studies reported that the variability in life histories traits will have an influence on the response from particular species (Russ & Alcala, 1998b, Jenning *et al*. 1999a, b; Mapleston *et al*., 2009). For example, slow-growing, late-maturing species will probably respond quite slowly to reserve protection compared to a short-lived, fast growing species (Halpern and Warner, 2002). Maximum size (Lmax) has been demonstrated in the present study as a better indicator of the response to protection, species with larger Lmax (≥40 cm) exhibited a significant higher response to protection than species with a medium (21 – 30 cm) or small (≤ 20) Lmax.

In addition, families such as groupers (Serranidae) and parrotfish (Scaridae) responded positively to protection. These families typically have low natural mortality, late maturity, relatively long lifespan, slow to medium growth rates and large maximum size (Russ and Alcala, 1998). However, a similar response may also have been expected of wrasses fish (Labridae), that have similar life histories, but these did not respond significantly to protection. Again, there are also mixed result among small-sized families, damselfishes (Pomacentridae) and butterfly fishes (Chaetodontidae), fast growing species with relatively high rate of natural mortality and growth (Russ and Alcala, 1998), would be expected to benefit strongly from reserve protection.

Thirdly, the responses to protection were highly variable for biological parameters among protection levels and locations. It is likely that the high variation in response to protection could be partially explained by the differences in species life history. However, it is unclear why NTZs seemed to have small measurable impacts on biological parameters relative to fished areas. Although the response of some species to protection pattern appears to be predictable at the island scale, the national scale pattern appears to be unpredictable. This is consistent with the pattern observed in Guidetti and Sala (2007), a common pattern happened when other local factors associated with each locations need to be considered. A number of studies have suggested that there may be considerable heterogeneity in response to protection which may stem from different factors (Claudet *et al*., 2009).

The age and size of protection level is usually considered an important factor as it plays an important role for detecting changes in abundance and biomass in fish communities (Halpern and Warner, 2002). According to Guidetti and Sala (2007), the response to protection depends on the duration of protection. The five protection areas examined in this study were established at different time scale (2006, 2007 and 2008) and sizes, ranging from 1.5 to 2.9 km^2. Thus, variability in the response of biological measures could be attributed to their different reserve age and size. However, according to Halpern and Warner (2002), marine reserves appear to result in significant increase in average levels of density, biomass, and likely diversity within 1 – 3 years and Halpern (2003) found that reserve size did not affect the fish response to protection. Given the life histories of the fish target species, a change in abundance and biomass is surprising in less than 3 years of protection in this study. However, rapid responses to fishing closures have been reported in many studies (Evans *et al*., 2006; Halpern and Warner, 2002). This result may suggest that a pattern of build-up population or the beginning of a recovery process response to protection (Evans *et al*., 2006). It is also important to note that a rapid response undoubtedly requires an adequate supply of recruits and thus the slow or variable responses in the current system may reflect a lack of adequate recruitment from surrounding habitats.

Furthermore, the variability in responses may due to geographical and habitat heterogeneity for fish families that are related to a particular habitat type likes butterfly fishes with coral cover (Chapman & Kramer, 1999). The SMA sites in the present study were located at different geographical locations and as such each fished areas experienced different level of fishing pressure. The result of the present study indicates that different families respond to protection in a different way at different NTZ locations (an idiosyncratic response). The fact that biological responses were different for NTZs situated at relatively different locations suggests that the different biological conditions of these NTZs may cause different biological response to protection. In addition, SMA locations were located at different geographical locations (Figure 3.1), thus, habitat structure was likely to vary considerably. Variability in habitat structure is likely to drive spatial variability in the distribution and abundance of organisms (Garcia-Charton *et al*., 2000). The results showed that in some cases, biological parameters measured were significantly different among SMA locations, suggesting that spatial variability could be attributed to the high variability in the present study.

The trophic position of a species often correlates with its life-history traits and the degree of its exploitation (Halpern and Warner, 2002). Carnivores, which are most often the target of fisheries, are also generally long-lived, slow-growing species. Therefore, one might expect that carnivorous fishes would display different temporal responses to protection compared to herbivores or other trophic groups. However, Halpern and Warner (2002) noted no distinct differences in response to reserve protection showed by carnivores' fish. In fact, the present study result, showed an increase in the abundance of herbivores (e.g. families of Pomacentridae, Acanthuridae, and Scaridae) in NTZ, but not all families showed a significant change. Similarly, carnivorous fish (Serranidae and Nemipteridae) showed a significant higher abundance and biomass in NTZ than SMA and COM sites in only one location (Ovaka). This suggests that the fish assemblage response to protection appears to be clearer when trophic group and target species status are considered.

The results also revealed poor abundance and biomass of big carnivorous compared to herbivores and small carnivores fishes (planktivores/ invertebrate feeders). Herbivorous strongly dominated the fish community with three families, the Acanthuridae, Pomacentridae and Scaridae. The dominance of small-sized herbivores and low abundance of small-sized carnivore's species indicated that the fish community was strongly affected by fishing pressure. This is consistent with the results reported by Friedmen *et al.*, (2008) in a study in Tongan coral reef areas. They reported that fish abundance and biomass were lower in the back-reef zone, where most fishing takes place; Acanthuridae were the dominant family but were represented by small-size species; Scaridae were much less abundant and carnivores belonging to the family Serranidae were extremely rare (Friedmen *et al*., 2008).

In conclusion, in the short period of time since the implementation of the Special Management Area regime in Tonga:

- There have been variable responses in terms of the restoration of fish and invertebrates;
- There have been a positive response of the large target fish and invertebrate to protection (NTZs);

- NTZs are likely to still be on their trajectories of recovery and the protection needs sufficient time for the abundance and biomass of the biological communities to recover.
- The effectiveness of SMA depends on several factors (i.e. relative intensity of exploitation; age and size of NTZs; geographic location and habitat heterogeneity; life histories characteristics, and trophic levels).

Importantly, this study provides evidence that the SMA regime in Tonga is a success in that abundance, biomass and species diversity of large fisheries target organisms are higher within NTZs compared to fished areas. This information is crucial in developing and improving the current SMA regime given the current drive for using the SMA regime as conservation and fishery management tools in Tonga.

Chapter 4

Evidence of shifting baseline in fisher's perceptions of reef fisheries in Tonga

4.1 Abstract

This study investigated the current status of exploited inshore fish species through an extensive interview with fishers in communities across the three main island groups in Tonga.

Local ecological knowledge can provide a unique source of data for fisheries management, especially in efforts to investigate the status of inshore resources and possibly rare or extinct species, but it is unlikely to remain constant over time. Loss of perspective about past ecological conditions caused by lack of communication between generations may create "shifting baseline syndrome," in which younger generations are less aware of local species diversity or abundance in the recent past. This phenomenon has been widely discussed, but has rarely been examined quantitatively.

The present study demonstrated a perceived decline in the abundance of coral reef fisheries resources targeted by commercial and artisanal fisheries. The decline appeared ubiquitous among all exploited species and a clear trend emerged in which older fishers recall greater past abundance and size than younger fishers. This provides evidence for the shifting baseline syndrome, a dangerous cognitive condition in which each generation of fishers accepts a lower standard of resource abundance as normal. The interview information also suggested that some exploited species may have declined by as much as an order of magnitude between 1980s and 1990s.

Results from this present study provide evidence for shifting baselines in fishers' perception of declines of exploited fish species in inshore fisheries in Tonga. This will also provide significant insights into the duration of "fisher's memory" of depleted species, which is of fundamental importance for SMA network development in Tonga.

4.2 INTRODUCTION

Many of the fisheries in the developed world have sophisticated management regimes that are underpinned by long time-series of fisheries independent survey data collected by Government Agencies (e.g. Worm *et al*., 2009). For example, the International Council for the Exploration of the Seas has time-series that extend back to the beginning of the 20th Century. Such time-series provide an independent means to assess the status of fisheries at any point in time relative to the status of the fishery at the first point of sampling. However, for many of the world's fisheries, such time-series of data are lacking and it is thus difficult to assess the current status of a fishery or fish assemblage relative to historical levels. In the absence of such data it can be possible to use macro-ecological theory to try and reconstruct general community characteristics such as body-size spectra, but the details of changes in the status of individual species will be difficult to infer (Jennings & Blanchard, 2004).

In such circumstances, the use of traditional ecological knowledge can provide valuable insights into the historical changes that may have occurred in a fishery and thereby provide some reference point for the observed state of the present day fishery (e.g. Bunce *et al*., 2008). Such studies also provide some insight into the potential shift, from one generation to another, in fishers' perceptions of the relative change in their own fishery within the time-frame during which they have fished. This is the so-called 'shifting base-lines' syndrome (Papworth *et al*., 2009).

Fishers' perception of the status of their fisheries resources is important to provide the context for contemporary coral reef fishery management (Bunce *et al*., 2008). Depletion of fish populations and the degradation of fisheries dependent resources such as habitat, make coral reef systems vulnerable to the risk of unexpected phase shifts to less desirable states (Scheffer and Carpenter, 2003). Such changes can remove or limit the options for social and economic development in developing nations, deepening further their reliance on marine resources for survival.

Tonga is similar to many of the small island nations in the South Pacific where subsistence and artisanal fishing is regarded as one of the most important activities that underpin the livelihood of the local inhabitants (Kronen, 2004). Coastal fishing is of fundamental importance in Tonga and much of the country's opportunities for future development and food security are highly depend on coastal fisheries resources (Kronen, 2004; Gillett, 2011). Nevertheless, the inshore fishery resources in Tonga are under threat due to heavy exploitation and often show signs of overexploitation and habitat degradation such that there has been a large decline in the abundance of many species (Bell *et al*., 1994; Petelo *et al*., 1995; Gillett and Moy, 2006; Gillett, 2011). The current status of Tongan fisheries resources has reduced their capacity to provide food and livelihoods for fishers that rely on a healthy marine ecosystem (Gillett, 2011).

Despite the growing awareness of the declines in coral reef fish species through exploitation, very few data sources exist on the status of Tongan inshore marine resources (but see Bell *et al*., 1994). As for many tropical countries, a lack of good quality data impedes current efforts at effective regulation of Tongan fisheries (Johannes, 1998).

Spearfishing is a major component of the fishing effort on Tongan inshore marine resources. According to Halapua (1982), spearfishing in Tonga was already well established in the 1970s. Vaikona *et al*., (1997) and Lautaha and Cohen (2004) reported that most inshore fishery landings arose from spearfishing, although consistent landings data are lacking. Nevertheless, to enable the effective development of appropriate fisheries management it is necessary to utilise a combination of multiple sources of information to understand the past history and dynamics of the relevant fisheries (Godoy *et al*., 2010). Currently there are a growing number of scientific studies that have used multiple sources of information to understand resource collapse in data poor fisheries (Pauly, 1995; Saenza-Arroyo *et al*., 2006; Ainsworth *et al*., 2008, Godoy, 2008; Pinnegar and Engelhard, 2008; McClanahan, 2009). These studies have provided important evidence of depletion in terms of abundance and change in the size of reef fish (Baum and Myer,s 2004; Dulvy and Polunin, 2004; Saenz-Arroyo *et al*., 2005a; Ainsworth *et al*., 2008; Bunce *et al*., 2008).

Local Ecological Knowledge (LEK)

The use of the local ecological knowledge (LEK) of fishers and community members can be valuable in understanding the occurrence and magnitude of long-term changes in fish population structure and habitat quality (Johannes, 1998). Successful use of LEK often builds on existing community strengths in traditional knowledge and governance, and relies on a local awareness of the need for action, i.e. that there is a perceived problem with the current status of living resources (Gillett, 2010). The use of LEK is often the only feasible means of ascertaining the status of species that are rare and potentially extinct (Turvey *et al*., 2010).

LEK is defined as a body and/or a system of understanding and know-how that arises through time from individual and shared experiences (Davis & Wagner, 2003). The term LEK is used in the present study to refers to the traditional knowledge of Tongan communities in relation to their environment and that they use to sustain themselves.

Fishers and fishing communities often possess a high level of knowledge regarding fish populations and marine ecology, and so incorporating LEK into the fisheries management policy processes could be very helpful to corroborate scientific data and to fill in gaps in the scientifically generated data. For example, a large part of the literature about marine LEK has addressed the local knowledge of the environment or the taxonomy, biology and ecology of marine organisms (Aswani and Hamilton, 2004; Lauer and Aswani, 2008; Fraser *et al*.. 2006), as well as the sustainability of indigenous practices (Johannes, 2002; Lobes and Berkes, 2004). In addition, there is increasing evidence that LEK can improve the understanding of resource use patterns, monitoring and the adaptive management of coastal fisheries (Danielsen *et al*, 2005; Turner and Berkes, 2006b). Thus, LEK of artisanal fishers may be invaluable to inform management and research (Johannes, 1998; Saenz-Arroyo *et al*., 2005a, b). The greatest use of LEK within small island communities has traditionally been to manage and sustain local fisheries (UNEP, 2006). Knowledge of natural resources and ecosystem dynamics has traditionally existed within communities that have regularly and over long periods of time, utilized them for subsistence and income (Berkes *et al*., 2000). The United Nations Conference on Environment and Development (UNCED) in 1992 highlighted the use of LEK in producing innovative strategies for sustainable resources management (Veitayaki, 1997). LEK provides a key link between social and ecological systems that can be used to interpret and respond to signals of ecosystem change (Olsson and Folke, 2001).

Shifting baseline

Local perceptions about the status of species and other ecosystem resources are unlikely to remain constant over time if environmental systems experience biological change. In particular, a loss of perspective about past ecological conditions, caused by lack of communication between generations, creates a social phenomenon known as "shifting baseline syndrome" (Pauly, 1995), whereby age- or experience-related differences in perception of the state of the environment are present within communities (Turvey *et al*., 2009). For example, in a system that has experienced demonstrable biological change, younger generations may have less awareness of local species diversity or abundance from the recent past and interpret more degraded environmental conditions as the norm (Saenz-Arroyo *et al*., 2005*a*; Papworth *et al*., 2009). The phenomena of "shifting baselines" may be a contributory factor as it suggests successive generations of fishers adjust to the increasing scarcity of fish and fail to understand the extent to which human have modified their environment over the long term (Bunce, 2008).

The phenomenon of shifting baselines has received considerable recognition over the past decade (e.g., Sheppard, 1995; Roberts, 2003; Folke *et al*., 2004; Ainsworth et al., 2008), primarily in fisheries science but also increasingly in other areas of socioeconomic and conservation research across a range of global systems (Papworth *et al*., 2009). The term, however, is often used to refer to the primary ecological phenomenon of changing environmental conditions, and more importantly, the social phenomenon rarely has been quantitatively tested and its existence is based largely on anecdotal evidence (Pauly, 1995). However, more recently there has been an increase in the number of studies that have quantified shifting-baselines among fishers (Saenz-Arroyo *et al*., 2005; Bunce *et al*., 2008; Godoy *et al*., 2010). It is therefore important to recognise that this phenomenon can occur when collecting LEK and stratify sampling designs to account for the potential effect.

The aim of the present study was to investigate using LEK the current status and changes in that have occurred in exploited inshore fish species across Tonga. The results could provide insights into possible shifting baselines in fishers' perception of declines of exploited fish species in inshore fisheries in Tonga. This will also provide significant insights into the duration of "community memory" of depleted species. Understanding the latter would be important to be able to facilitate engagement with appropriate management regimes in Tonga.

4.3 METHODOLOGY

Between September 2010 and February 2011, 270 artisanal spearfishing fishermen from 35 communities in the three main island groups in Tonga were interviewed (Figure 4.1). Respondents were selected randomly and grouped into three age groups: young, (< 30 years old, N = 90); middle-aged (30 – 50 years old, N = 90; and old (> 50 years old, N = 90). Questionnaires were targeted at fishers engaged in small-scale artisanal spearfishing fisheries. Questionnaires were administered face to face through the medium of Tongan and followed the research approaches recommended in the context of coral reef management (Saenz-arroyo *et al*., 2005, Bunce *et al*., 2008 and Godoy *et al*., 2010).

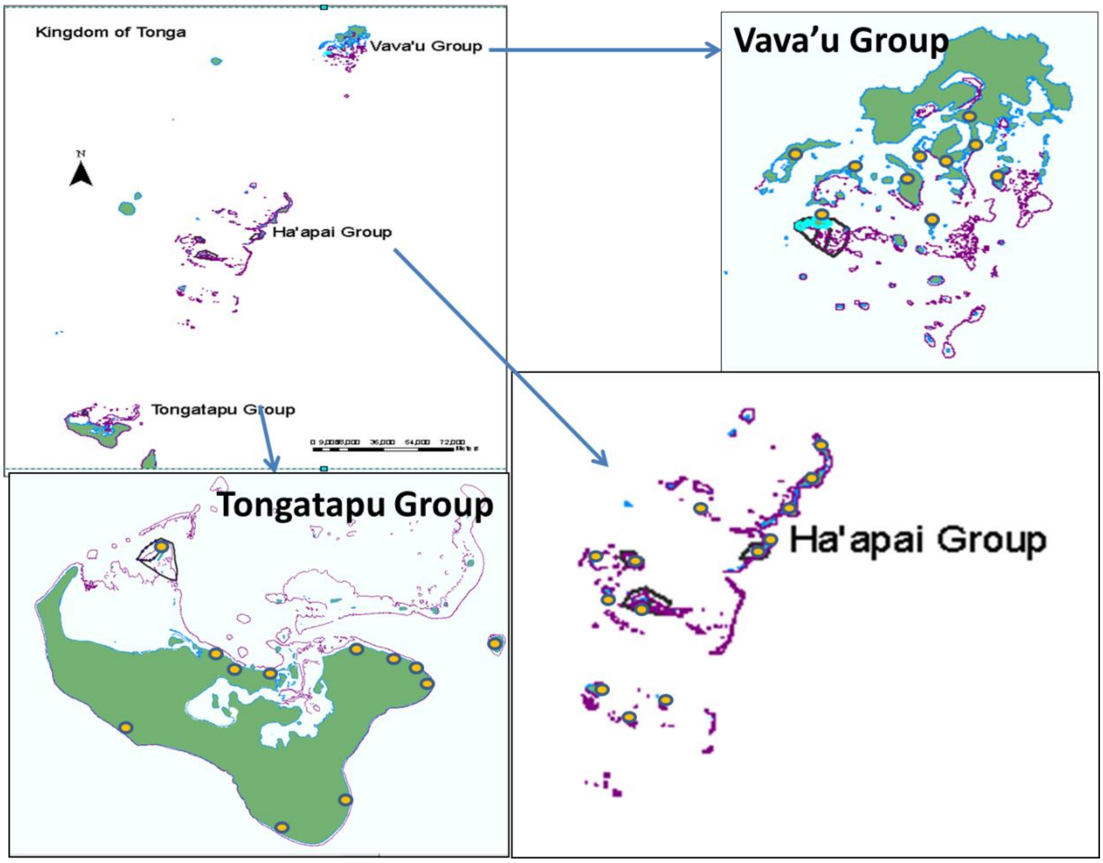

Figure 4.1: Map of Tonga showing the distribution of localities where the interviews occurred (Yellow circles).

The survey focussed on spear-fishers to ensure consistency in responses and because this is the main artisanal fishing technique used in Tonga to harvest fish in coral reef areas (Gillett and Moy, 2006). The questionnaires were answered by between 30% and 50% of the spear-fisher population in each of the communities visited. Names of the active spear-fishers were obtained from town officers (government representative at community level) as well as other community members in each community visited. In addition further contacts were also obtained from spear-fishers (snowballing) contacted at landing sites and fish markets. All interviews were conducted in private and took between 45 to 60 minutes for each interview.

To determine the extent to which fishers perceived change in the Tongan reef fishery, and to identify evidence for possible shifting baselines, respondents from the three age classes were asked to list the main reef commercial species they considered to have changed during their fishing career. We limited our investigation to those commercial fish species most likely to have been caught by spear-fishers. Fishers identified species using local Tongan names that were cross checked with a visual identification key used at all interviews. Fishers also gave the approximate date (years) for the onset of changes observed for each species that they perceived to have changed. Fishers were also asked to recall their best catch in a single day's fishing (in numbers) for each of the species, and the year in which these catches were made. Fishers were asked for their perception of changes in fish abundance and length (size) over time. For each species, fishers were asked to indicate the length of the largest individual fish that they had caught (cm), and the year that these catch were made. Fishers indicated the length of the largest fish they caught by showing a distance from their fingertips toward their shoulder (Bunce et al., 2008) and this was measured using a tape measure. Changes in fishing effort were recorded in terms of the distance of their fishing grounds from their home, the duration of each fishing trip (hours), and their average catch (estimate of wet weight [kg]), and how this varied across their fishing lifetime. Fishers were also asked to list the five fish species that they commonly catch today, 5, 10, 20 and 30 years ago.

Data analysis

Responses were grouped into the three age-classes before analysis. For all the depleted species reported, the mean percentage of fishers for the three age-classes were calculated and the mean of the means were reported. The questionnaire data was analysed using both multivariate and univariate approaches. A resemblance matrix was computed using the Bray-Curtis index of similarity. Differences in the responses by fishers from different age-groups were tested for significance with the ANOSIM procedure (one-way analysis of similarity) in relation to their observations of which species had declined in abundance across their fishing career. Univariate data were analysed using the non-parametric Kruskal-Wallis test as the data did not conform to the assumptions for parametric statistics. The PRIMER v6 (Clarke, 1993) and SPSS v16 software packages were used for statistical analyses.

4.4 RESULTS

Fisher's perceptions of fish species depletion and the year depletion noted

Altogether the 270 spear-fishers perceived that a total of 21 species had declined in abundance during their fishing career based on their own experience catching these species (Table 4.1). When these species were considered together in a multivariate analysis, differences in the perceptions which fish species had been depleted were found to relate to fisher age groups (generations) (ANOSIM, R = 0.175, P < 0.01).

Table 4.1: Mean percentage (± SE) of respondents from three age groups of fishers that considered different exploited species to have been depleted. For each age category n = 90. Maximum length is the L max from fish base.

Species	Maximum length (cm)	Old ≥50 years, (N=90)	Middle 30 – 49 years, (N=90)	Young < 30 year, (N=90)
Naso unicornis	70	81(±2)	63(±4)	43(±7)
Naso lituratus	60	50(±5)	41(±5)	29(±4)
Naso spp.	46	60(±10)	41(±6)	22(±3)
Ctenochaetus striatus	26	22(±3)	10(±3)	7(±3)
Acanthurus lineatus	38	44(±6)	32(±8)	27(±2)
Acanthurus xanthopterus	70	30(±4)	19(±3)	17(±4)
Cheilinus undulatus	229	49(±6)	14(±4)	0(±0)
Parupeneus barberinus	60	32(±6)	26(±6)	19(±4)
Mulloiddichthys vanicolensis	38	18(±5)	8(±3)	6(±3)
Scarus microrhinus	70	69(±4)	59(±4)	14(±1)
Scarus oviceps	35	53(±8)	51(±6)	33(±7)

Scarus ghobban	90	61(±4)	42(±9)	13(±4)
Bolbometopon muraticus	130	43(±3)	13(±5)	0(±0)
Siganus argentus	40	49(±9)	56(±1)	44(±1)
Siganus chrysospilos	40	24(±5)	14(±3)	13(±3)
Plectropomus leopardus	120	37(±4)	16(±4)	0(±0)
Epinephelus merra	31	10(±4)	13(±2)	4(±1)
Plectropomus spp.	120	60(±7)	21(±6)	0(±0)
Kyphosus cinerascans	50	26(±2)	10(±2)	4(±1)
Lethrinus harak	50	31(±5)	22(±4)	13(±10)
Plectorhinchus spp.	72	24(±3)	11(±3)	4(±1)

The old-aged group fishers reported significantly more species to have declined in their life-time than the youngest aged group (Fig. 4.2, Kruskal-Wallis test, χ^2 =6.9, p = <0.03). Since older fishers have had more opportunity to notice species that have depleted, for better comparison between generations, the species loss rate was calculated by dividing the number of depleted species observed by each fisher by the length of their fishing career (Saenz-Arroyo et al., 2005). There was a significant difference in the species loss rate between three age-groups (Kruskal-Wallis test, Chi-squared = 35.2, p = <0.001) (Table 4.2).

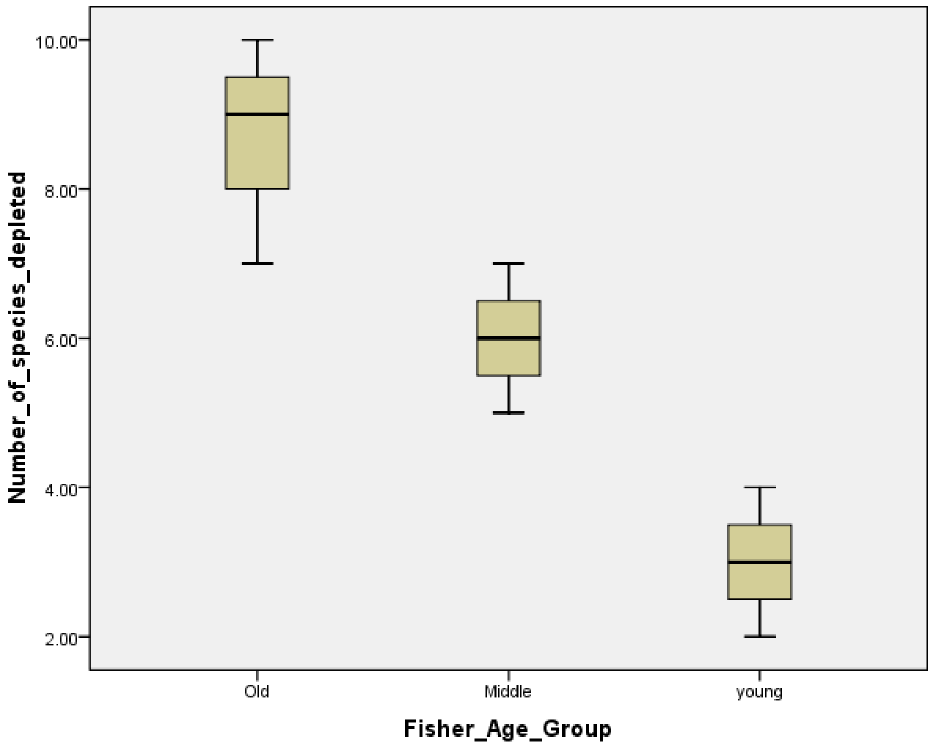

Figure 4.2: Number of species reported as depleted by three aged groups of fishers (Kruskal-Wallis test, $x^2 = 6.9$, p = <0.03).

Table 4.2: Mean (± SE) of species loss rate between three age-groups of fishers. (Kruskal-Wallis test with significant difference between three age-group, $p < 0.05$).

	Old	**Middle**	**Young**	χ^2	**df**	**p**
Species loss rate	0.26±0.01	0.48±0.05	0.81±0.09	35.2	2,267	<0.001

The older fishers perceived that noticeable species depletion had taken place during the year 1991, while middle-aged and young reported that noticeable depletion had occurred during years 2001 and 2011 respectively (Figure 4.3). In addition, there were significant differences found between the time periods (years) when species depletion was first noticed within each age-groups. The old fishers perceived that noticeable periods of depletion had occurred in 1982, 1991 and 2001, however, depletion in 1991 was mentioned by more fishers compared to year 1982 and 2001 (Chi-square = 97.8, df = 5, $p < 0.001$). The middle-aged fishers perceived the key years of depletion to include 2001, 2006, 2009 and 2011, with the change in 2001 mentioned by significantly more fishers than for the other years (Chi-square = 81, df = 5, $p < 0.001$). The young fishers perceived that the key depletion years were 2001, 2006, 2009 and 2011, however, 2009 and 2011 were mentioned by a significantly higher number of fishers than the other years (Chi-square = 54.5, df = 5, $p < 0.001$). Interestingly, twenty seven fishers (30%) from the young-aged group stated that there had been no depletion of species. Also, four species (*Cheilinus undulates, Bolbometopon muraticus, Plectropomus leopardus* and *Plectropomus* spp.) were cited as depleted by middle aged and older fishers whereas the younger fishers were not aware that these species had been common at some point in time (highlighted in Table 4.1).

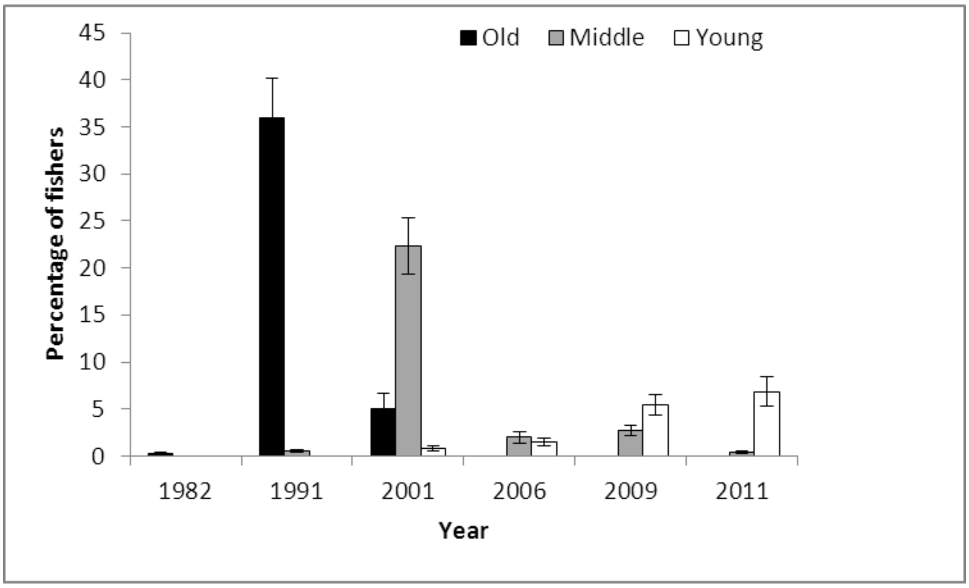

Figure 4.3: Mean (± SE) percentage of individual fishers that mentioned specific years when they first noticed a depletion in the number of fish species caught.

Fisher's perceptions of the best catch in a day (number of fish).

The perceived best catch per day remembered by fishers were pooled into six categories (5 = ≤10, 20 = 11 – 30, 40 = 31 – 50, 60 = 51 – 70, 80 = 71 – 90, 100 = 91 - 100 +). When fishers were asked to state their best catch per day fishing trip, the highest value were reported by old fishers who remembered their best day's catch of between 80 and 100 fish, followed by the middle aged with an average of between 40 and 60, and the young fishers reported the least with an average of 20 individuals (Figure 4.3). There was a significant difference found between the best day catch within the aged groups (Table 4.4).

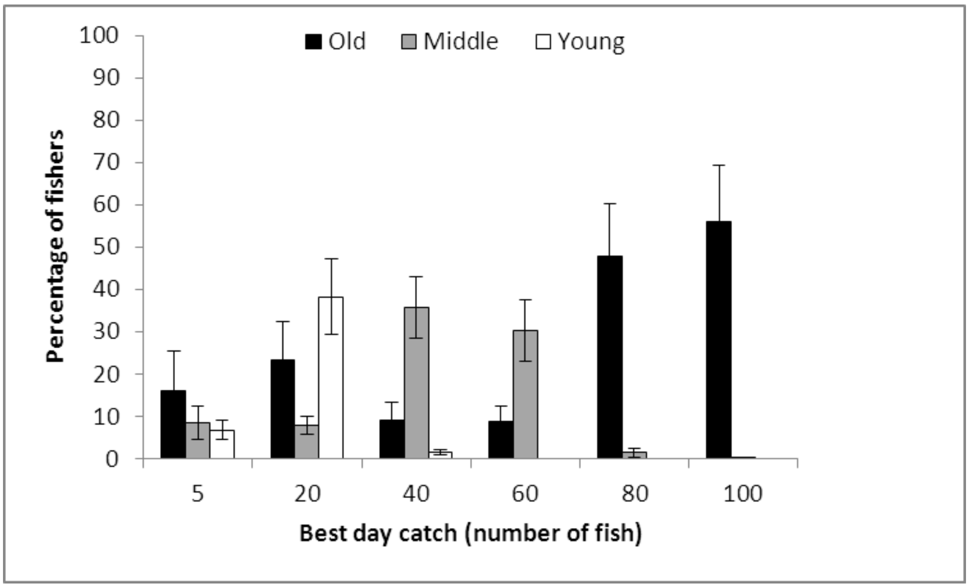

Figure 4.4: Mean (± SE) percentage of fishers with perceived best catch in a day (number of fish) for different fisher age group (old, middle and young). The values shown are midpoint values of the following categories (5 = ≤10, 20 = 11 – 30, 40 = 31 – 50, 60 = 51 – 70, 80 = 71 – 90, 100 = 91 - 100 +).

Table 4.3: Mean (± SE) percentage of fishers at different age group with perceived best day catch. Kruskal-Wallis test are shown for differences in the best day catch six categories.

Aged group	5	20	40	60	80	100	Chi-square	df	p
Old	4.1±3.1	7.8±3	3.0±1.4	3.0±1.4	16.0±4.1	18.6±4.5	14.2	5	0.01
Middle	2.9±1.3	2.7±0.7	11.9±2.4	10.1±2.4	0.5±0.4	0.5±0.5	42.1	5	<0.001
Young	2.3±0.8	12.8±3.0	0.5±0.2	0±0	0±0	0±0	58.7	5	<0.001

Fisher's perceptions of the year of best catch in a day

The best catch in a day was highest in 1982, followed by 1991, 2001, 2006, 2009 and 2011 (Figure 4.5). The highest values were cited by older fishers who remembered their best catch in a day to have occurred between 1982 and 1991; middle aged group remembered their best catch in a day to have occurred between 1991 and 2001, while most of the young aged group remembered their highest best day catch in between 2001 and 2011 (Figure 4.5, Table 4.4).

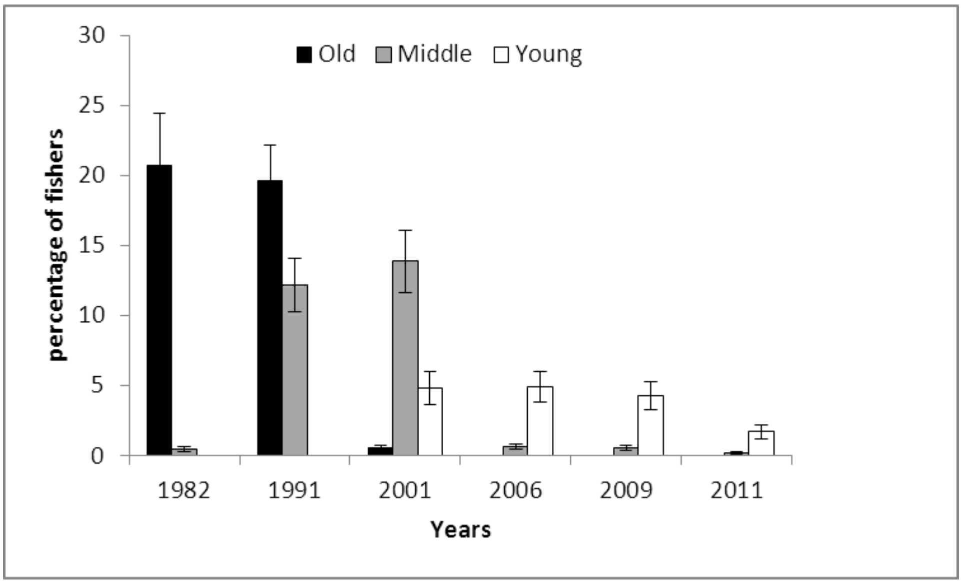

Figure 4.5: Mean (± SE) percentage of fishers noting the year in which their best day's catch occurred for each of the three age groups.

Table 4.4: Mean (± SE) percentage of fishers at different age group with perceived period of their best day catch. (Kruskal-Wallis test with significant difference between cited depletion years).

Aged group	1982	1991	2001	2006	2009	2011	Chi-square	df	p
Old	20.7±3.7	19.6±2.5	0.53±0.2	0±0	0±0	0±0	109.8	5	<0.001
Middle	0.5±0.2	12.2±1.9	13.9±2.2	0.6±0.2	0.6±0.2	0.16±0.1	94.4	5	<0.001
Young	0±0	0±0	4.8±1.1	4.9±1.1	4.3±1.0	1.7±0.5	51.8	5	<0.001

Fisher's perceptions of the period of last best catch in a day

Fisher's perceived period during which they attained their last best day's catch was 1991 for the old fishers, followed by 2001 for middle aged fisher and 2009 for the young aged fishers (Figure 4.6, Table 4.5).

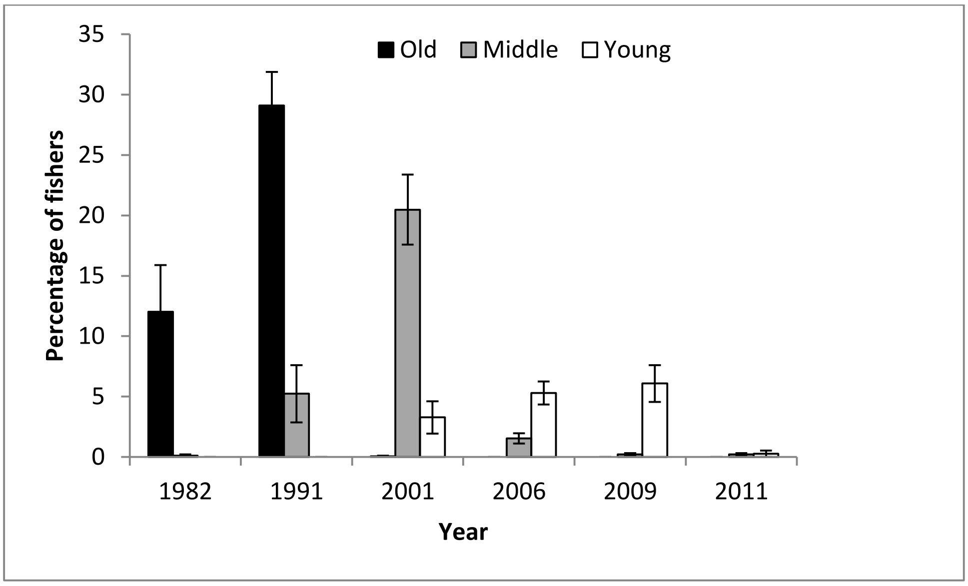

Figure 4.6: Mean (± SE) percentage of fishers stating the year in which their last best day's catch occurred for each of the three age groups.

Table 4.5: Mean (± SE) percentage of fishers in different age group stating the date of their last best day's catch. (Kruskal-Wallis test for significant differences between years).

Aged group	1982	1991	2001	2006	2009	2011	Chi-square	df	p
Old	12.0±3.9	29.1±2.8	0.1±0.1	0±0	0±0	0±0	102.9	5	<0.001
Middle	0.1±0.1	5.2±2.4	20.5±2.9	1.5±0.4	0.2±0.1	0.2±0.1	81.8	5	<0.001
Young	0±0	0±0	3.3±1.3	5.3±1.0	6.1±1.5	0.3±0.3	61.7	5	<0.001

Fisher's perceptions of depleted species abundance over time

Fishers were asked to identify the year in which the abundance of fish was the highest and those years in which fish abundance was considered to be lowest. It was clear that the greatest percentage of fishers considered high abundance to have occurred in the earliest time periods and the periods of low abundance to have occurred in more recent time periods. The year of highest perceived abundance varied among the different groups of fishers, with the oldest fishers stating that 1982 was the period with the highest abundance of fish (Figure 4.7a). In general, fishers agreed that the relative abundance of species is lowest for the most recent time periods (Figure 4.7b).

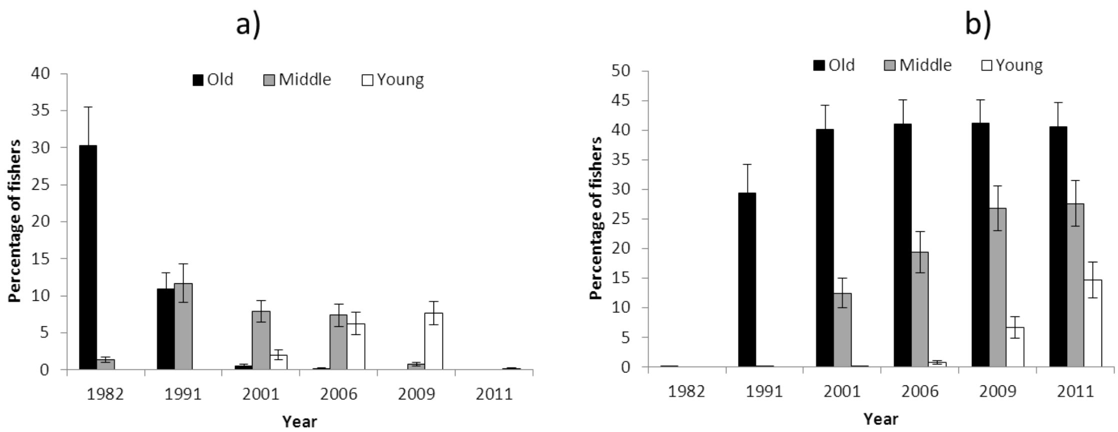

Figure 4.7: Mean (± SE) percentage of fishers that declared fish abundance to be either a) high or b) low for each time period (1982-2011).

Table 4.6: Mean (± SE) percentage of fishers from different age groups with perceived changes in fish species abundance (high or low) over time. (Kruskal-Wallis test with significant difference between years).

Abundance	Aged group	1982	1991	2001	2006	2009	2011	Chi-square	df	p
Higher	Old	30.3±5.1	11.0±2.2	0.5±0.3	0.1±0.1	0±0	0±0	107.8	5	<0.001
	Middle	1.4±0.3	11.7±2.6	7.9±1.5	7.4±1.5	0.7±0.2	0±0	74.5	5	<0.001
	Young	0±1	0±0	2.0±0.6	6.2±1.5	7.6±1.6	0.2±0.1	67.3	5	<0.001
Lower	Old	0.1±0.1	29.3±4.9	40.2±4.0	41.1±4.5	41.1±4.0	40.6±4.0	56.1	5	<0.001
	Middle	0±0	0.2±0.1	12.5±2.5	19.4±3.5	26.8±3.8	27.6±3.9	93.4	5	<0.001
	Young	0±0	0±0	0.1±0.1	0.8±0.3	6.7±1.8	14.7±3.0	73.4	5	<0.001

Fisher's perceptions of largest fish ever caught

For those of species of fish that were reported to have been depleted, fishers were asked to record the largest individual they had caught at any time in their career. The oldest fishers recorded the largest size categories of fish to have occurred in their catches, whereas the largest fish recorded by the youngest age-group of fishers were confined to the smallest size categories (Table 4.7).

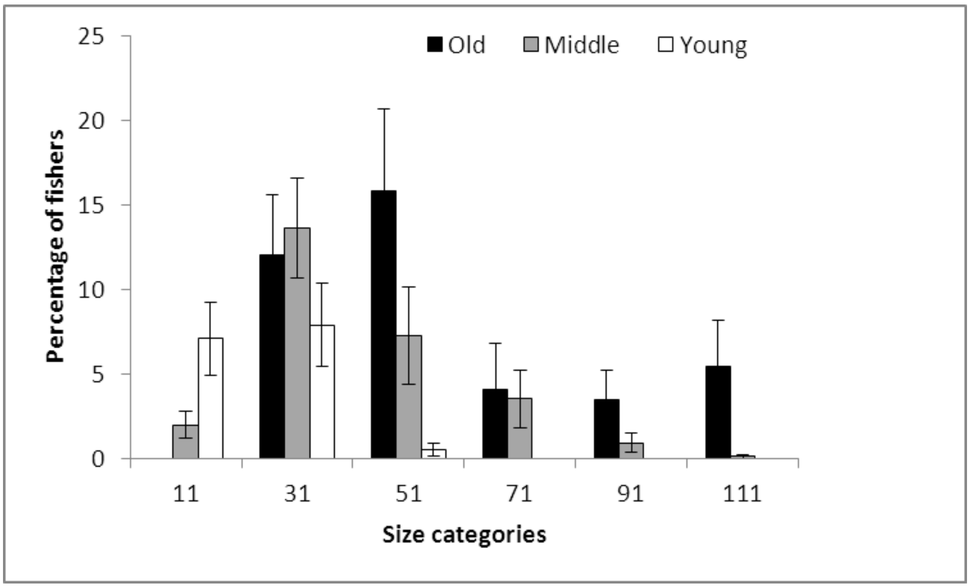

Figure 4.8: Mean (± SE) percentage of fishers in each of three age-groups that reported their largest fish that fell into each of the following size categories (11 (≤20cm); 31 (21-40cm); 51 (41-60cm); 71 (61-80cm); 91 (81-100cm) and 111 (>100cm).

Table 4.7: Mean (± SE) percentage of fishers in different age group with perceived largest fish (cm) ever caught. (Kruskal-Wallis test with significant difference between size categories, $p < 0.05$).

Aged group	11	31	51	71	91	111	Chi-square	df	p
Old	0±0	12.1±3.6	15.8±4.8	4.1±2.7	3.5±1.7	5.4±2.7	14.8	5	0.01
Middle	2±0.8	13.6±2.9	7.3±2.9	3.5±1.7	1±0.5	0.2±0.1	16.9	5	0.01
Young	7.1±2.2	7.9±2.5	0.5±0.4	0±0	0±0	0±0	14.8	5	0.01

Fisher's perceptions of the year when the largest fish were caught

Figure 4.9 shows the fisher's responses to the questions of the year when they caught the largest fish. The results present the average score among fishers for all of the species that were cited as depleted. The largest fish ever caught was in 1982 declining steadily to 2011. However, different age groups of fishers perceived that their largest fish was caught in different period. The majority of old fishers perceived that the largest size of fish caught was in 1982 while middle aged group perceived period was between 1991 and 2001 and young aged was 2001 to 2009 (Figure 4.9, Table 4.8). These responses indicate that fishers clearly perceive that fish caught today are much smaller than those caught 20-30 years ago.

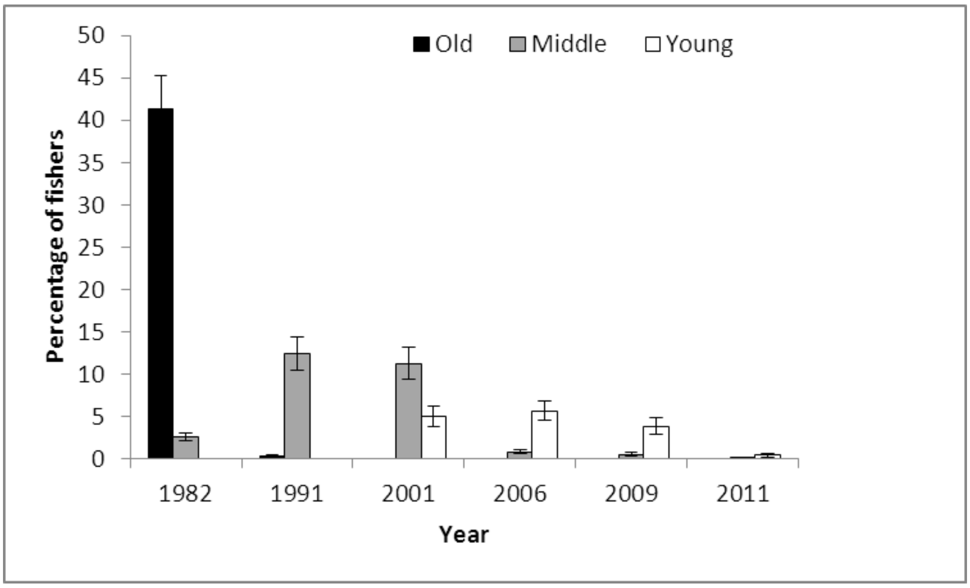

Figure 4.9: Mean (± SE) percentage of fishers that indicated the perceived year in which their largest fish (measured in terms of length) was ever caught for different fisher age group (old, middle and young).

Table 4.8: Mean (± SE) percentage of fishers in different age group with perceived period of their largest fish ever caught. (Kruskal-Wallis test with significant difference between cited depletion years).

Age group	1982	1991	2001	2006	2009	2011	Chi-square	df	p
Old	41.3±3.9	0.3±0.2	0±0	0±0	0±0	0±0	112.5	5	<0.001
Middle	2.6±0.5	12.5±2.0	11.3±1.9	0.9±0.2	0.5±0.2	0.2±0.1	87.7	5	<0.001
Young	0±0	0±0	5±1.2	5.7±1.2	3.9±1.0	0.4±0.2	61.2	5	<0.001

Fisher's perceptions of the year when the largest fish were last caught

Figure 4.10 showed fisher perceived period of last largest fish ever caught was 1991 for the old fishers, followed 2001 for middle aged fisher and 2009 for the young aged fishers. There was a significant different between these time periods within fisher's age groups (Table 4.9).

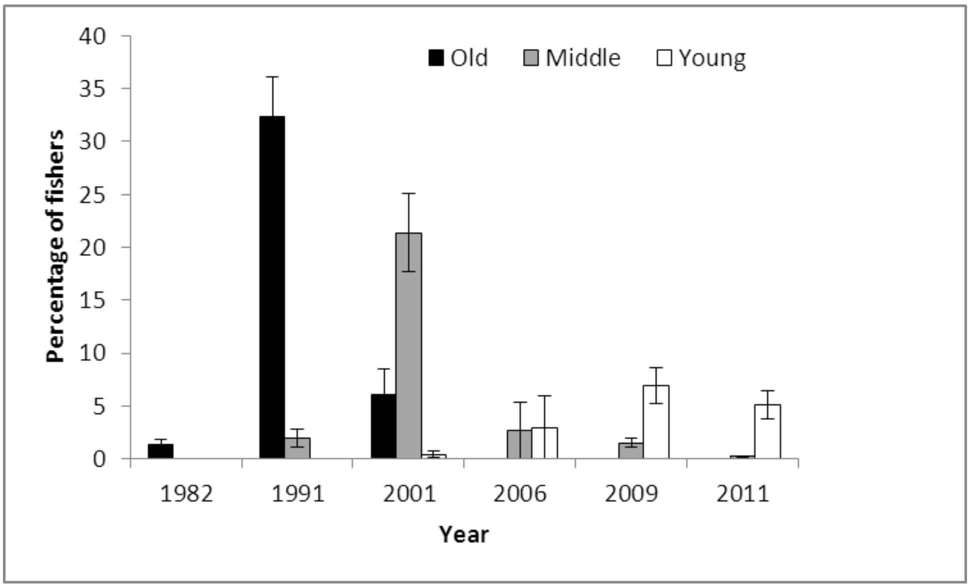

Figure 4.10: Mean (± SE) percentage of fishers that indicated the perceived year in which their largest fish (measured in terms of length) was last caught for different fisher age group (old, middle and young).

Table 4.9: Mean (± SE) percentage of fishers at different age group with perceived period of their last largest fish ever caught. (Kruskal-Wallis test with significant difference between cited depletion years, $p < 0.05$).

Age group	1982	1991	2001	2006	2009	2011	Chi-square	df	p
Old	1.3±.05	32.3±3.7	6.1±2.4	0±0	0±0	0±0	90.5	5	<0.001
Middle	0±0	2±0.9	21.3±3.7	2.7±2.7	1.5±0.4	0.2±0.1	73.4	5	<0.001
Young	0±0	0±0	0.4±0.3	3±3.0	6.9±1.7	5.1±1.3	57.7	5	<0.001

Fisher's perceptions of the changes in fish size over time

Figure 4.11 shows the fishers' responses to the rank size question, for which they scored the size of each species as bigger or smaller compared with the previous time period. The results show that initially <40% of fishers perceive that the size of fish has increased compared with the previous time period (Figure 4.11a) and this may relate to an increase in their ability to catch fish. However, in all cases, the mean percentage of fishers that report a decrease in the size of fish compared with the previous time period increased from 1991 to the present day (Figure 4.11b). The differences between these perceived periods were significantly different within each age group (Table 4.10).

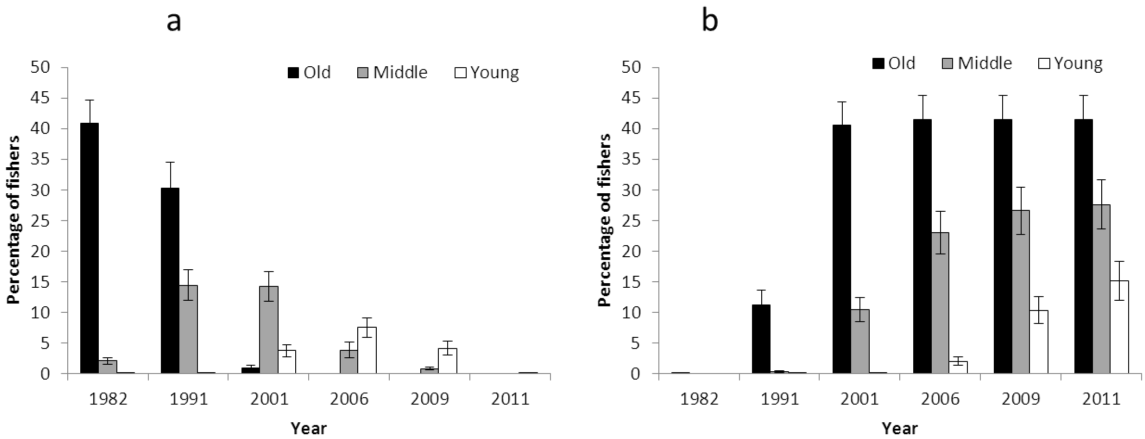

Figure 4.11: Mean (± SE) percentage of fishers that reported perceived changes in fish species size over time (1982-2011), a = perceived increase in fish sizes, b = perceived decrease in fish sizes.

Table 4.10: Mean (± SE) percentage of fishers in different age groups and their perceived changes in fish species size (increasing or decreasing) over time. (Kruskal-Wallis test with significant difference between cited depletion years).

Size		1982	1991	2001	2006	2009	2011	Chi-square	df	p
Increasing	Old	40.8±3.8	30.2±4.4	1±0.5	0±0	0±0	0±0	112.4	5	<0.001
	Middle	2.1±0.6	14.4±2.5	14.3±2.4	3.9±1.3	0.9±0.3	0±0	76.4	5	<0.001
	Young	0.05±0.1	0.1±0.1	3.8±1.0	7.5±1.6	4.2±1.1	0.1±0.1	59.3	5	<0.001
Decreasing	Old	0.1±0.1	11.3±2.3	40.5±3.8	41.5±4.0	41.5±4.0	41.5±4.0	75.9	5	<0.001
	Middle	0±0	0.3±0.2	10.5±2.0	23±3.4	26.6±3.8	27.6±4.0	92.6	5	<0.001
	Young	0±0	0.1±0.1	0.1±0.1	2±0.7	10.4±2.2	15.1±3.1	70.7	5	<0.001

Fisher's perceptions of the changes in fishing ground distance

Fishers' perceptions of the distance travelled to their fishing grounds over time showed that the distance travelled to fishing grounds on average was closer to their home between 1982 and 2001 and then increased to more distant fishing grounds in recent years (2006 to 2011). The majority of fishers agreed that the distance travelled to fishing grounds is currently far away. The difference between these perceived periods was significantly different within each age group (Table 4.11)

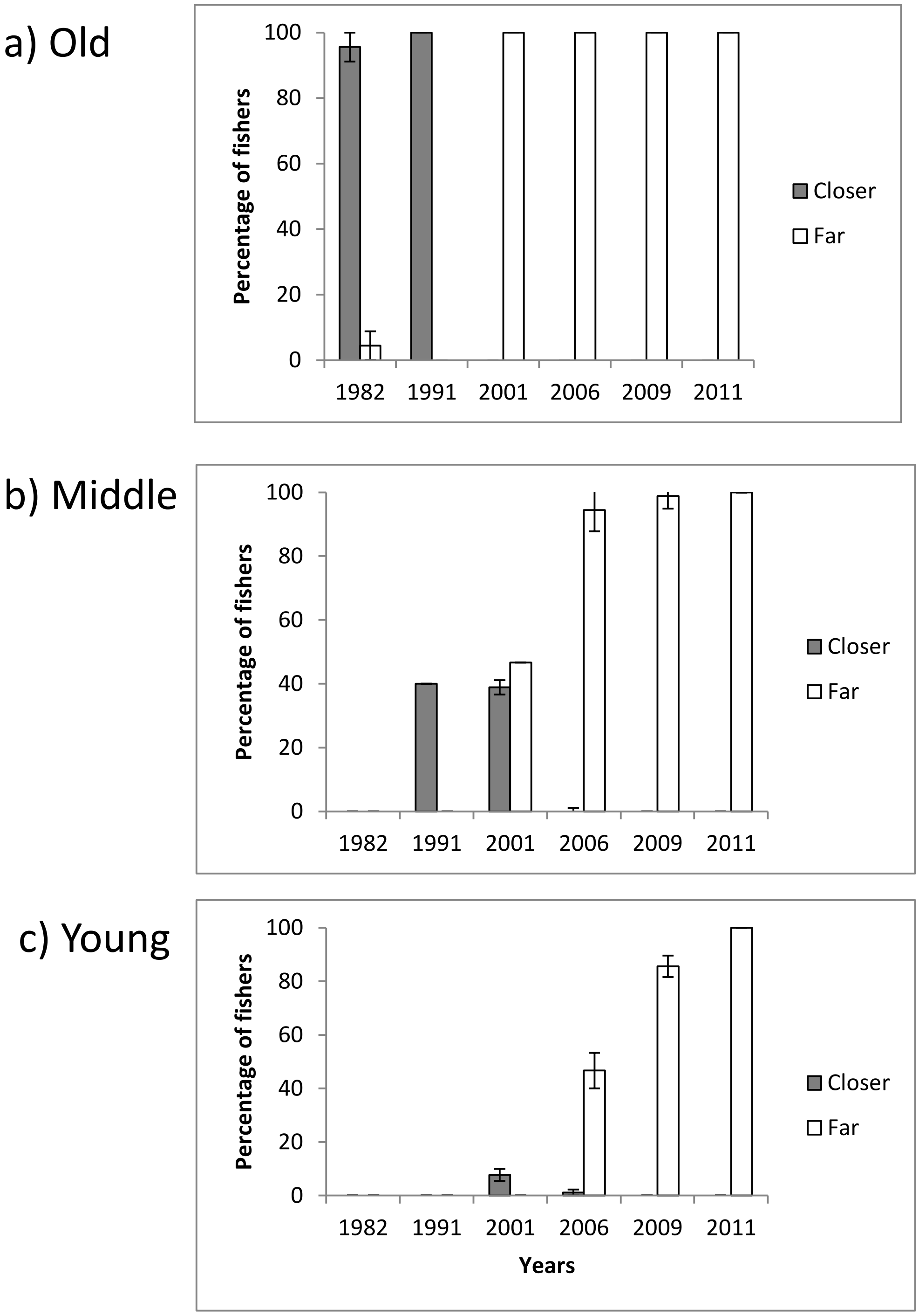

Figure 4.12: Mean (± SE) percentage of fishers in different age group with perceived changes in relative distance to fishing ground over time. Closed simple represent a closer distance, whereas open simple represent far away distance relative to fishing ground.

Table 4.11: Mean (± SE) percentage of fishers in different age group with perceived changes in distance (close or far) to fishing ground over time. (Kruskal-Wallis test with significant difference between years, $p < 0.05$).

Distance	**Age group**	**1982**	**1991**	**2001**	**2006**	**2009**	**2011**	**Chi-square**	**df**	**p**
Close	Old	95.6±4.4	100±0	0±0	0±0	0±0	0±0	16.7	5	0.01
	Middle	0±0	40±1.9	38.9±9.1	0±0	0±0	0±0	16.2	5	0.01
	Young	0±0	0±0	7.8±2.2	1.1±1.1	0±0	0±0	14	5	0.02
Far	Old	4.4±4.4	0±0	100±0	100±0	100±0	100±0	16.7	5	0.01
	Middle	0±0	0±0	46.7±8.8	94.4±1.1	98.9±1.1	100±0	16.5	5	0.01
	Young	0±0	0±0	0±0	46.7±6.7	85.6±4.0	100±0	19.9	5	0.01

Fisher's perceptions of the changes in fishing duration

When fishers were asked about their opinion regarding the amount of time spent fishing in the present compared to the past, the results showed that fishing time on average was shorter between 1982 and 1991 period and then changed to a longer time in more recent years (2001 to 2011) (Figure 4.13, Table 4.12). The perceived fishing time showed to be shifting between different age group. For instance, a higher proportion of older fishers agreed that fishing time to be longer in 2001.

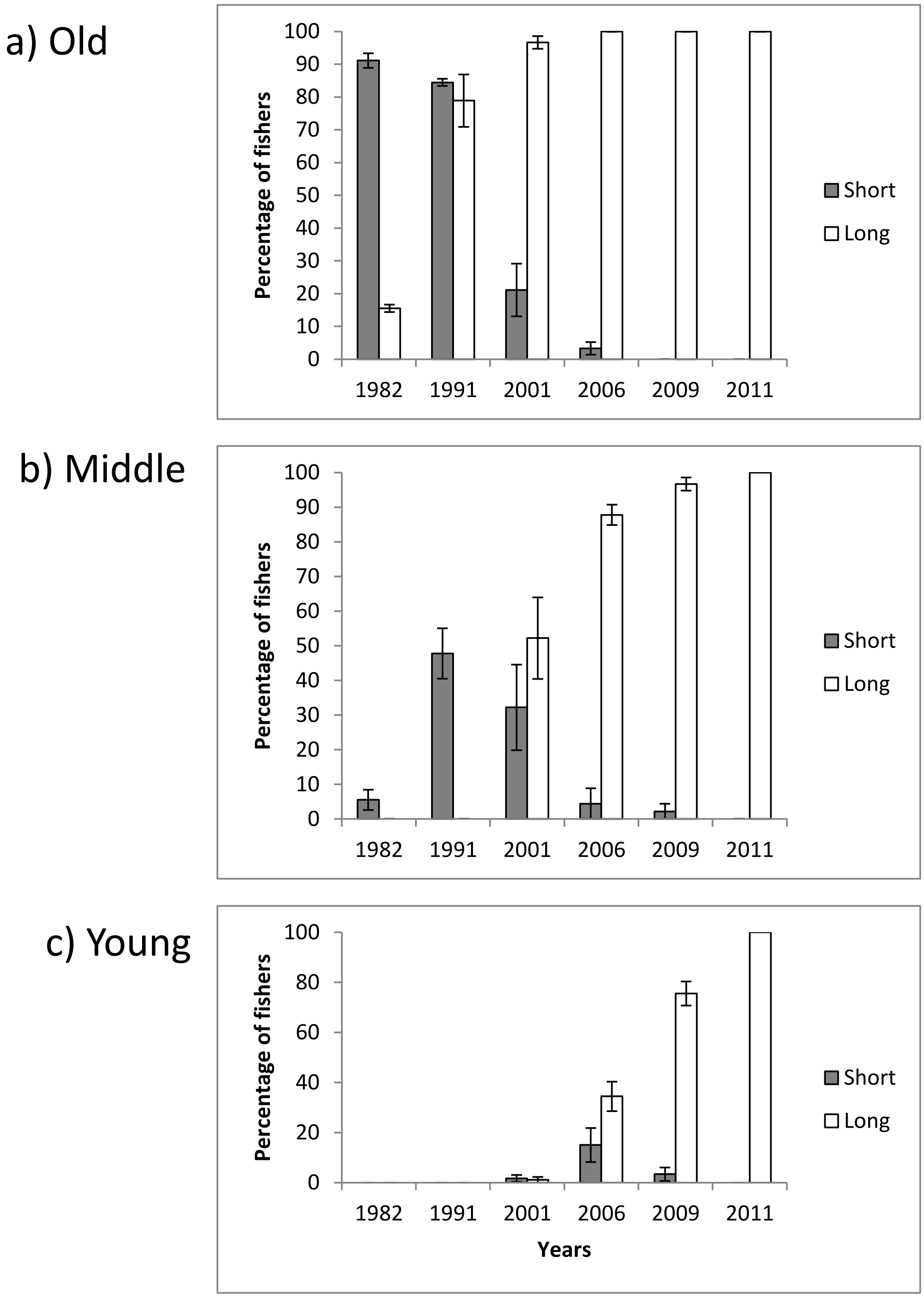

Figure 4.13: Mean (± SE) percentage of fishers at different age group with perceived changes in fishing duration (Hours) over time. Closed simple represent a short fishing time and open simple represent a longer fishing time.

Table 4.12: Mean (± SE) percentage of fishers at different age group with perceived changes in fishing duration (Hours) over time. (Kruskal-Wallis test with significant difference between time periods, $p < 0.05$).

Fishing duration	**Age group**	**1982**	**1991**	**2001**	**2006**	**2009**	**2011**	**Chi-square**	**df**	**p**
Shorter	Old	91.1±2.2	84.4±1.1	21.1±8.0	3.3±1.9	0±0	0±0	16.3	5	0.01
	Middle	5.6±2.9	47.8±7.3	32.2±12.4	4.4±4.4	2.2±2.2	0±0	13.5	5	0.02
	Young	0±0	0±0	6.7±5.1	14.4±4.8	2.2±2.2	0±0	11.8	5	0.04
Longer	Old	0±0	15.6±1.1	78.9±8.0	96.7±1.9	100±0	100±0	16.3	5	0.01
	Middle	0±0	0±0	52.2±11.8	87.8±2.9	96.7±1.9	100±0	16.5	5	0.01
	Young	0±0	0±0	1.1±1.1	34.4±	75.6±5.9	100±0	16.3	5	0.01

Fisher's perceptions of the changes in species composition

Figure 4.14 showed about 24 different species representing spearfishing fishers catch composition over time (last 30 years). The result revealed that there has been a significant change in the catch composition over time at the heavily exploited reef fishery in Tonga. The changes varied between periods and among species, some species that dominated the catch composition 30 years ago are not common now and some species which dominated the catch composition now were not very common in the past. The observed trend with catch composition is that the species that dominated fishers catch in the past now make up a very small proportion of the fishers' catches and vice-versa (Table 4.13).

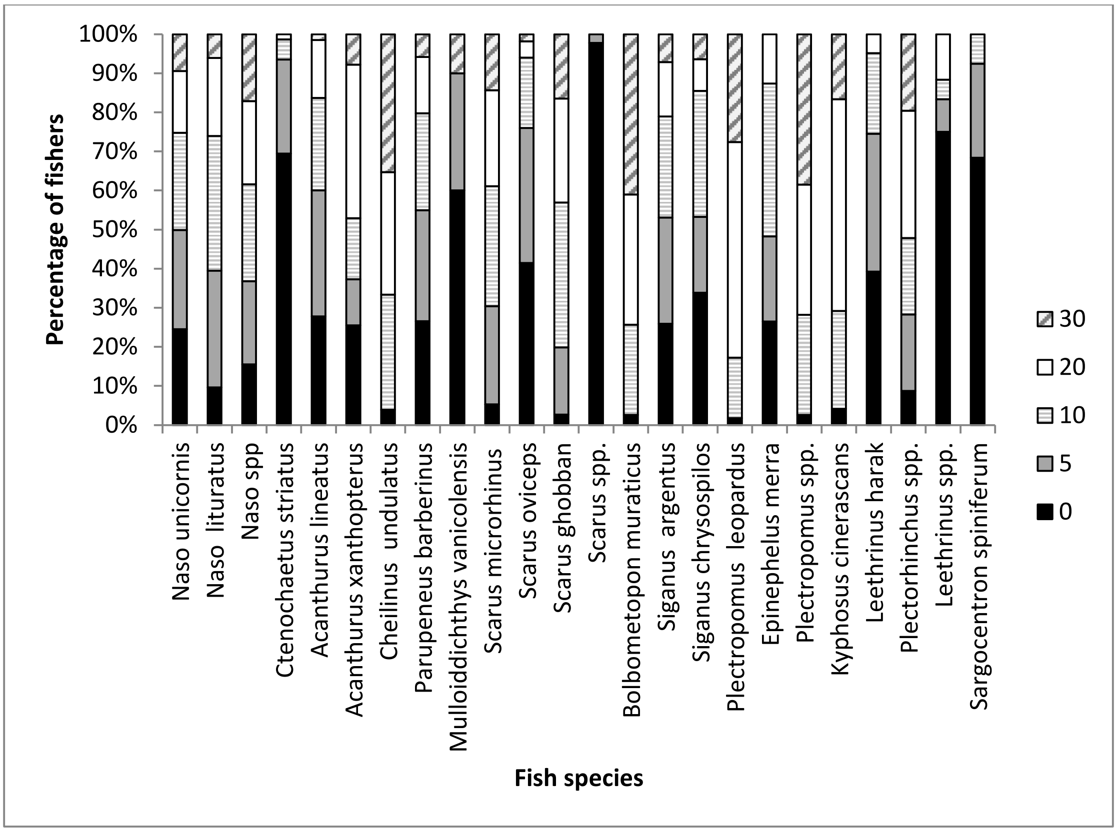

Figure 4.14: Mean (± SE) percentage of fishers with perceived species that commonly catches in different calendar year (0 = 2011, 5 = 2006, 10 = 2001, 20= 1991, and 30 = 1981).

Table 4.13: Mean (± SE) percentage of fishers with perceived species that commonly catches in different calendar year (0 = 2011, 5 = 2006, 10 = 2001, 20= 1991, and 30 = 1981). (Kruskal-Wallis test with significant difference between calendar year, $p < 0.005$, after Bonferroni correction of P value of 0.0015). The shaded lines represent a significant difference found.

Species	**0**	**5**	**10**	**20**	**30**	**Chi-square**	**df**	**p**	**mct**
Naso unicornis	88.5±3.9	91.5±5.3	90±1.3	57±29.1	34.1±8.8	9.8	4	0.04	
Naso lituratus	9.3±0.7	28.9±6.5	33.3±3.9	19.3±12.3	5.9±1.5	19.5	4	0.001	5>0,10>0,30
Naso spp	21.1±6.2	28.9±3.9	33.7±3.7	28.9±14.8	23.3±6.2	3.4	4	0.5	
Ctenochaetus striatus	55.6±4.5	19.3±8.0	4.1±3.5	1.1±1.1	0±0	33.7	4	<0.001	0>5,10,20,30,5>20,30
Acanthurus lineatus	27.8±2.9	32.2±7.6	23.7±2.6	14.8±8.1	1.5±0.3	21	4	<0.001	0>30
Acanthurus xanthopterus	4.8±2.3	2.2±0.6	3±0.4	7.4±4.9	1.5±0.4	7.9	4	0.1	
Cheilinus undulatus	0.7±0.7	0±0	5.6±5.6	5.9±5.9	6.7±1.8	4.6	4	0.3	
Parupeneus barberinus	21.9±4.3	23.3±3.3	20.4±2.4	11.9±6.5	4.8±1.4	15.3	4	0.004	0>30,5>30,10>30
Mulloiddichthys vanicolensis	2.2±0.6	1.1±1.1	0±0	0±0	0.4±0.1	16.1	4	0.003	0>10,20
Scarus microrhinus	11.1±1.3	52.6±6.5	64.1±1.0	51.5±26.3	30±7.5	10.2	4	0.04	
Scarus oviceps	84.4±5.0	70.4±2.6	36.7±6.3	8.5±4.8	3.7±1.1	37.5	4	<0.001	0>10,20,30,5>10,20,30,10>20,30
Scarus ghobban	4.1±2.0	26.3±7.7	56.7±7.8	40.7±20.4	25.2±6.3	16	4	0.003	5>0,10>0,5
Scarus spp.	15.9±1.0	0.4±0.4	0±0	0±0	0±0	40	4	<0.001	0>10,20,30
Bolbometopon muraticus	0.4±0.4	0±0	3.37±3.3	4.8±4.8	5.9±1.8	2.9	4	0.6	
Siganus argentus	81.9±3.5	85.9±3.8	81.9±6.2	44.1±22.0	22.6±5.5	24.1	4	<0.001	0>30,5>20,30,10>30
Siganus chrysospilos	7.8±1.3	4.4±0	7.4±0.7	1.9±1.9	1.5±0.4	14.7	4	0.01	
Plectropomus leopardus	0.4±0.4	0±0	3.3±2.8	11.9±6.0	5.9±1.6	13.3	4	0.01	
Epinephelus merra	8.5±1.5	7±0.4	12.6±1.5	4.1±4.1	0±0	18.1	4	0.001	0>30, 5>30,10>30
Plectropomus spp.	0.4±0.4	0±0	3.7±3.2	4.8±4.8	5.6±1.5	4.7	4	0.3	

Kyphosus cinerascans	0.4±0.4	0±0	2.2±1.1	4.8±4.8	1.5±0.4	6.4	4	0.2	
Leethrinus harak	14.8±5.5	13.3±6.5	7.8±3.3	1.9±1.9	0±0	13.4	4	0.01	
Plectorhinchus spp.	1.5±1.5	3.3±1.7	3.3±1.7	5.6±4.0	3.3±1.0	1.3	4	0.9	
Lethrinus spp.	16.7±3.3	1.9±1.0	1.1±0.6	2.6±1.6	0±0	27.3	4	<0.001	0>5,10,20,30
Sargocentron spiniferum	20±4.5	7±3.0	2.2±1.7	0±0	0±0	29.3	4	<0.001	0>10,20,30

4.5 DISCUSSION

The present study demonstrated that fishers' experience of past catches provide useful insights to reconstruct the history of the exploitation of the inshore resources, particularly in situations where fishing statistics are fragmented or have short time-scales. The present study revealed that the exploited species of the inshore fishery in Tonga were abundant and larger in terms of their body-size in the past. There appears to have been more pronounced depletion in the early 1990s. This is consistent with other observations (Bell *et al*., 1994) that the inshore reef fish resources could be over-exploited when the inshore fishery catches for 1987 were compared to those of 1993. A more recent study on fisheries catches in Tonga by Sun *et al*., (2010), however, reported that the artisanal and subsistence landings from coastal fisheries start to decline in the 1980s.

In general, older fishers perceived and remembered catching a higher abundance and larger body-sized reef fishes from the reefs adjacent to their island communities. This perception was different to that obtained when consulting middle-aged and younger fishers whose responses indicated that the current status of inshore fishery is dramatically different compared to the more distant past, with some species unknown to young fishers. For example, one young fisher stated:

> ".. Tenifa, Tangafa, and Menenga [*Plectropomus spp, Cheilinus undulates, and Bolbomentopon muricatum*] are fish I never caught ...however, I used to see them caught by my grandfather …my father sometimes caught one …"

A retired spearfisher in his early eighties remembered catching these species in the 1960s from the fringing reef surrounding his island. He also stated that these species were abundant and of a large body-size. From the retired fisher story, it is possible to understand that fish were plentiful and larger and resulted in shorter fishing times and shorter travel times to fishing grounds that were closer to home. A common response from fishers interviewed when asked "what do they think of the state of the fisheries" was that the fishery had declined and that the reefs that they used to fish had deteriorated, due to excessive fishing pressure from too many fishers.

Fisher's perceptions of fish species depletion and the year of depletion

The present study also revealed that there was a significant difference in the perceptions of the different age groups of fishers in relation to the number of exploited fish species that had been depleted. This observation perhaps suggests a shifting baseline syndrome (Pauly, 1995) evident in the memory of spearfishers with respect to the fish species that had been depleted (Table 4.1), and is similar to findings in other studies (Saenz-Arroya *et al*., 2005; Bunce *et al*., 2008). Spearfishers' perceptions of species depletion and especially the large body-sized species, including *Cheilinus undulates*, *Bolbometopon muraticus*, and *Plectropomus* species, are indicative of the inshore fisheries decline that appears to have occurred in Tonga. Similarly, Bunce *et al*., (2008) reported declines in the abundance of large fish predators, including groupers and sharks, which they interpreted to be an indicator of fishery decline and ecosystem impairment. The results from the present study also support the earlier reports of over-exploitation of the Tongan inshore fisheries (Gillet and Moy, 2010). Older fishers remembered that species depletion had taken place during 1991, while the middle-aged and young group perceived that depletion occurred in the years 2001 and 2011 respectively (Figure 4.3). The different perceived years of depletion among the different age groups of fishers further supports the idea of shifting baselines in the present study. Interestingly, it also seems that it takes about 10 years for fishers to perceive a change in fish populations.

Fisher's perceptions of best catch and fish abundance

Analysing fishers' memories of their best catch in a fishing day for the exploited species also provided a more complete picture of the past abundance of exploited species (Figure 4.4). While older fishers recalled large catches in 1982 and 1991 (Figure 4.5) of up to 80-100 fish in an average day, by 2001 this had dropped to 60 or even less (Figure 4.4 and table 4.3). This is consistent with the decline in the magnitude of coastal catches reported by Bell *et al*., (1994) that dropped from 823 to 386 metric tons in 1987 and 1993 respectively. A similar pattern was found among fishers in the Gulf of California (Saenz-Arroyo *et al*., 2005).

Although fishers' memories of the history of their reef fishery have not been used as an indirect index of population trends (Saenz-Arroyo *et al*., 2005), they provide support for the observations reported in other reports that focused on the historical characteristics of inshore fisheries in Tonga (Bell *et al*., 1994; Sun *et al*., 2010). However, the real scale of the species depletion is likely to be much greater as large catches can be prolonged due to the exploitation of new fishing grounds and the use of better technology (Pinnegar and Engelhard, 2008). It is evident that remote reefs have been targeted recently by spearfishers in Tonga (author's personal observations), resulting in higher numbers of fish and with a larger body-size compared to when they fish in the common fishing grounds. This use of remote fishing grounds may mask the true status of inshore fish stocks status and is perhaps reflected in the young fishers' perceptions of a lack of depleted species. This change in fishing grounds was also supported by the reported increase in time spent fishing and the distance travelled to fishing grounds (Figure 4.12). These lines of evidence show that exploited species were abundant in the past but that by the early 2000s much of the fish population biomass had been removed.

Fishers' perceptions of largest fish ever caught

The present study suggests that the largest fishes were caught from the beginning of the 1980s up to the end of 1990, from then on the average length of the largest fish declined which suggests that exploited species are currently smaller compared to 20 and 30 years ago such that there might have been a shift from large fish (carnivorous/omnivores) towards smaller sized omnivorous and herbivorous fish species. Similar findings were reported by Godoy *et al*., (2010) and Saenz-Arroyo *et al*., (2005) with the reef fisheries in Chile and Gulf of California respectively. One of the fishermen commented:

…" in the early 1990s we used to target large and good quality fish species like groupers, unicornfish, but now we catch any species we come across, mostly small parrotfish and surgeonfish…"

Furthermore, if these fish are protogynous hermaphrodites it is possible that the male breeding population size has been greatly reduced since the early 1990s, with potentially serious impacts on breeding success (Hawkins and Roberts, 2004).

Fishers' perceptions of the changes in species composition

There has been a significant change in the catch composition over time within the reef fisheries in Tonga, with species that were dominant in catches in the past now rare or absent. According to Bell *et al*., (1994) the species composition of catches in Tonga has changed, such that whereas in 1987, emperors were the main reef fish species caught in the artisanal fishery, by 1993 reef fish landings were predominately composed of parrotfishes as the major fish species landed. This change also coincided with a change in fishing techniques. In 1987, most of the catches were caught using gillnets, whereas in 1993 most of the fish landed were caught by night diving. The major reef-fish species landed at the domestic fish markets in Tongatapu in the 1990s included unicorn and surgeon fishes (Acanthuridae), squirrelfishes (Holocentridae), wrasses (Labridae), emperors and sea-breams (Lethrinidae), seaperches (Lutjanidae), goatfishes (Mullidae), sweetlips (Plectorhynchidae), parrotfishes (Scaridae), rabbitfishes (Siganidae), half-peak parrotfishes (Sparisomidae), sea-pikes (Sphyraenidae), drummerfishes (Kyphosidae), rock-cods (Epinephelidae), silver-biddy (Gerridae), trigerfishes (Balistidae), bullseyes (Priacanthidae), and majors (Abudefdufidae) (Bell *et al*., 1994). Although many of these families are represented in present day catches, some of the families reported by Bell *et al*., (1994) are now missing from the catch composition. A notable change has occurred in catch composition at the species level. The catch composition in the past was dominated by large-body sized (maximum length) species while the current catch composition consists mostly of smaller body-sized species.

Piecing together all the information in this present study reveals that shifting baseline could be evidenced in inshore (reef) fisheries in Tonga. Shifting baselines imply a reduction in what fishers expect of a fishery (Bunce *et al*., 2008). Understanding that a shifting baseline scenario exists is important information to support the development of the Special Management Areas network in the Tongan context. This has been achieved through the use of marine reserve establishment over a long period in the Philippines (Bunce *et al*., 2008). Fishers in Tonga already recognise the depletion of fisheries species, which indicates the status of ecosystem health, and hence it is useful for measuring the impact of Tongan SMAs and in particular of the no-take zones associated with them.

This study underlines the importance of understanding fishers' local knowledge in SMA contexts linking fisheries with wider development (Johhanes, 1989). MPAs are rarely built on scientific decisions alone (Alcala and Russ, 2006) and fishers' expectations need to be understood as they make the difficult transition from damaging traditional fishing livelihoods to economic alternatives linked to protected areas policy (Christie *et al*., 2007).

An increasing number of practical case studies illustrate ways to make use of local knowledge (Forke, 2004) and an exploration of fishers knowledge within adaptive management framework could help Tonga avoid repeating the failure of other island MPAs (Bunce *et al*., 2008). Also, key aspects of the islands' past inshore fisheries resources status, and showing how it had changed could be integrated into education and awareness program in order to increase acceptance of the SMAs regime. In the long term, fishers' perceptions of the fisheries resources recovery may need to be understood as much as their perceptions of decline. Further exploration of fishers' knowledge may help determine if the current SMA and no-take zones boundaries protect essential biodiversity and ecosystem functions at the island level. The presence and effects of removal of top predators around Tongan inshore waters need further study. Overall, there is a need for better information on the history and trajectories of state change in Tongas' social and ecological systems to cope with over-exploitation and impacts on land and sea amplified by climate change.

In conclusion, species such as the *Cheilinus undulates*, *Bolbometopon muraticus*, and *Plectropomus* species, may be at high risk of extinction without it being evident from current fishery statistics. This could be true for many other species exploited in multispecies inshore fisheries. Unless we recognize fisheries science as an historical science and start to use historical information as well as modern statistics, we are likely to overlook some marine species that are under threat (Saenz-Arroyo *et al*. 2005). Furthermore, this study presented the first quantified evidence of shifting baselines in fishers' perceptions of the status of inshore fishery in Tonga. Such evidence is a form of local ecological knowledge which is urgently needed for the successful establishment of SMA network in Tonga.

Chapter 5

General Discussion

5.1 INTRODUCTION

Although it has been widely acknowledged that the participation and integration of stakeholders in the design of conservation and fisheries management plans is fundamental to achieve successful outcomes (Leslie, 2005, Ritchie and Ellis, 2010), the views, values and perceptions of stakeholders are not always considered in the planning processes. Tonga is currently beginning to develop plans to establish a network of Special Management Areas (SMAs) as part of national and international conservation commitments. The Tongan fisheries division has undertaken that, in addition to biological aspects, it will consider the social and economic benefits to ensure that SMA sites are chosen to maximise ecological, social and economic benefits while minimising any unnecessary conflicts with the different uses of the area. However, there is very limited information on the status of inshore fisheries resources and the impacts of the SMA regime on the ecology of local reef systems. In the present study, a number of SMA sites were used as case studies to investigate the biological and socioeconomic implications of the SMA regime.

5.2 Socio-economic implications of SMA regime

Within a framework of SMA design, it has been widely recognised that in order to minimize socioeconomic impacts and achieve conservation and fisheries objectives effectively, the socioeconomic costs associated with the establishment of SMA should be integrated in the planning process (Carwardine *et al*., 2008). However, it is often the case that when socioeconomic aspects are incorporated in planning processes these aspects tend to be dominated by certain interested communities. The questionnaire study of SMA and comparator communities demonstrated that the latter tend to have different perceptions towards the SMA regime (Chapter 2).

Community support is an important aspect if newly established SMAs are to achieve their conservation and fisheries goals. The research herein has provided useful insights for the future establishment of SMA in Tonga. In the present study (Chapter 2) households from SMA communities expressed strong support for the establishment of the SMA regime, whereas the comparator community households were strongly opposed to SMAs. The main source of attitudinal heterogeneity among households and fishers from different villages were related to their attitudes toward the costs and benefits of SMA establishment (Table 2.7, 2.8, Figure 2.6, 2.7, 2.8, 2.9, 2.10 in chapter 2). This suggested that households are willing to participate and support the SMA regime only if the perceived benefits outweigh the costs. The overall perceived benefits of SMAs were highest among the SMA households, and lowest among the comparator households. This imbalance in benefits is likely to explain why the relationship between SMA and comparator communities has been antagonistic. This point to the fact that fishers' attitudes and perceptions tend to reflect their personal interests and concerns. Fishers who generally benefit the most from the implementation of the SMAs or that are less affected by them tend to be more accepting and supportive of this management measure. In contrast, fishers expressed negative attitudes towards SMAs and tended to favour open access over SMA regime measures when those fishers are highly restricted by the management measure. Thus, it may be unreasonable to expect fishers to accept very restrictive measures when other fishery management measures are already in place and the effectiveness of SMA regime is still poorly understood.

Furthermore, the results of the present study indicate that the establishment of the SMAs in Tonga has had some impact on fishing activities and patterns of food use. Most of the comparator households claimed that they were impacted by the establishment of the SMAs, but this may represent resentment towards those that have privileged access to SMA. Identification of differences in perceived attitudes towards the SMA regime offers a tool to better understand why and how members of local communities perceived the SMA regime.

Moreover, increasing enforcement should decrease the number of violations of fisheries regulations because resource users have an increased fear of being caught. Consequently, compliance will increase and the objectives of the SMA are more likely to be accomplished. By increasing enforcement, especially to catch illegal fishers, the majority of fishers would view the SMA much more positively, and illegal fishing activity occurring at the SMA would be substantially decreased.

In coastal settings where fishing is the main livelihood, it is important to provide incentives in addition to the protection of marine and coastal resources. This means that the establishment of the SMAs must be accompanied by the development of additional income-generating activities in order to improve people's socio-economic wellbeing, while at the same time allowing for the recovery of the coastal ecosystem. The future of the SMAs largely depends on the attitude and practices of today's coastal resource users.

The recognition of heterogeneous preferences will be fundamental for the monitoring and evaluation as well as the improvement of the SMA network development in Tonga, as it provides important information for the assessment of the level of support and commitment for potential fisheries and conservation policies. An increase in the level of support for the SMA regime may provide a useful indicator of the success of the management measure in additional to biological monitoring (author's personal observation).

5.3 Biological implication of the SMA regime

This study determined that there have been variable responses in terms of the restoration of fish and invertebrates (chapter 3). It may be argued that the most interesting result is that the NTZs appear to have positive responses of the large target fish and invertebrate to protection (NTZs). Furthermore, the no-take zone (NTZs) are likely to still be on trajectories of recovery and the protection afforded by the SMAs needs sufficient time for the abundance and biomass of the biological communities to recover.

In general, the results of this study may help to guide fishery managers in the event that proposed marine reserves or NTZs were established to allow coral reef communities to recover by prohibiting fishing activities in the areas. The results showed that whilst the effect of the NTZs on fish and invertebrates depended on the degree of exploitation of that species to some extent, the results presented here support claims that heavily targeted species are more likely to respond quickly to the implementation of NTZs (Halpern and Warner, 2002). This is consistent with what has been observed in other studies (Mosqueira *et al*., 2000; Guidetti *et al*., 2008; Garcia-Charton *et al*., 2004; Alcala *et al*., 2005; Evans *et al*., 2006; Claudet *et al*., 2006; Guidetti and Sala, 2007 Guidetti *et al*., 2008).

The present study also revealed that the effect of protection for a particular species will certainly depend on their life-history characteristics (e.g. Scaridae, Acanthuridae, and Serranidae fish). Various studies reported that the variability in life histories traits will have an influence on the response from particular species (Russ & Alcala, 1998b, Jennings *et al*., 1999a, b; Mapleston *et al*., 2009).

In addition, the responses to protection were highly variable for biological parameters among protection levels and locations. It is likely that the high variation in response to protection could be partially explained by the differences in species life history.

The age and size of protection level is usually considered an important factor as it plays an important role for detecting changes in abundance and biomass in fish communities (Halpern and Warner, 2002). Thus, variability in the response of biological measures could be attributed to the differences that exist in reserve age and size. However, there were too few case study sites to be able to explore this in a meaningful manner in the present study. Furthermore, the variability in responses may due to geographical and habitat heterogeneity for fish families that are related to a particular habitat type. The result of the present study indicates that different families respond to protection in a different way at different NTZ locations (an idiosyncratic response). The fact that biological responses were different for NTZs situated at relatively different locations suggests that the different biological conditions of these NTZs may cause different biological response to protection.

5.4 Local ecological knowledge and shifting baseline

As inshore fisheries often compete for the same fisheries resources their relative merits are often compared in an attempt to allocate access to these resources for maximum societal benefits (Kearney, 2002). The study therefore highlighted the erroneous manner in which fishers are often perceived. The advertent misuse of available statistics and fishers knowledge has emphasized the different perceptions and attitude among fishers, which only serves to further polarise the inshore fisheries sector and impede fishery conservation and management efforts (Cooke & Cowx, 2006). Hence, without reliable, comparable and unbiased information, decision makers will be unable to effectively evaluate management alternatives.

The present study (Chapter 4) revealed that the exploited species of the inshore fishery in Tonga were abundant and larger in size in the past until they were depleted in the early 1990s. This is consistent with the report by Bell *et al*., (1994) in which they believed that the inshore reef fish resources could be over-exploited by comparison of the inshore fishery catch for 1987 and 1993. However, a recent study on fisheries catches in Tonga by Sun *et al*., (2010), reported that the artisanal and subsistence landings from coastal fisheries started to decline in the 1980s.

In general, older fishers perceived and remembered catching higher abundance and larger sized reef fishes at the adjacent reefs to their island communities. This perception changes when consulting middle-ages and younger fishers. This indicated that the current status of inshore fishery is dramatic and with some species being practically unknown to young fishers.

In addition, the result of the present study revealed that there was a significant difference in the perceptions of different age group fishers in relation to the number of exploited fish species that had been depleted. Similar responses were also expressed for the perceptions of the best catch and fish abundance, catch composition and fishing grounds. This suggests a shifting baseline syndrome (Pauly, 1995) evident in spearfishers' memories and perceptions in regards to those fish species that were depleted in the multi-species and multi-gear coral reef fishery in Tonga. This result also supports the earlier reports of over-exploitation of Tongan inshore fisheries (Gillet and Moy, 2010; Bell *et al*., 1994) in which the coastal fishing catch dropped from 823 to 386 metric tons in 1987 and 1993 respectively. A similar pattern was found among fishers of the Gulf of California in Saenz-Arroyo *et al*., (2005).

This present study reveals that shifting baseline could be evidenced in inshore (reef) fisheries in Tonga. The importance of shifting baseline regarding the need for conservation is referred to in other shifting baseline studies (Saenz-Arroyo *et al*., 2005, Bunce *et al*., 2008) and is relevant to inshore fisheries in Tonga. In addition, using shifting baseline information in support of SMA network development is crucial in a Tongan context. Fishers in Tonga already recognise the depletion of fisheries species, which indicates the status of ecosystem health, and hence fishers perceptions are useful for measuring the impact of SMA and in particular of the no-take zones in Tonga.

Without immediate action there is a risk of further marine fisheries resources degradation coupled with species depletion or even extinction in Tongan water. The inshore fisheries already proved to be in declined, while coral reefs face threats from human activities and climate changes.

This study highlighted the importance of understanding fishers' local knowledge in SMA contexts linking fisheries with wider development. Protected areas are rarely built on scientific decision alone (Alcala and Russ, 2006) and fishers expectation need to be understood as they make difficult shifts from damaging traditional fishing livelihoods to economic alternatives linked to a protected areas policy (Christie *et al*., 2007).

The methods in which local knowledge is employed are certainly not without limitation, but the outputs represent the best available information on certain aspects of the inshore fisheries from the past and at the present. Given the urgent need for inshore fisheries resources conservation and management, it is suggested that the best available information should be used, although this does not negate the need to fully acknowledge any limitations and uncertainties that persist.

An increasing number of practical case studies illustrate ways to make use of local knowledge (Forke, 2004) and an exploration of fishers' knowledge within adaptive management frameworks could help. In addition, key aspects of the islands' past inshore fisheries resources status, and showing how it had changed could be integrated into an education and awareness program in order to increase awareness and potential of the SMA regime. In the long-term, fishers' perceptions of the fisheries resources recovery may need to be understood as much as their perceptions of decline. Further exploration of fishers' knowledge may help determine if the current SMA and no-take zones boundaries protect essential biodiversity and ecosystem functions at the island level.

The interview surveys in particular were a successful tool to which household members and fishers responded well (author's personal observation). It is hard to see how much of the information could have been acquired without a face-to-face approach, which emphasises the value of an *in situ* survey of local knowledge (Watson *et al*., 2000). The techniques employed could certainly be developed as a mean of integrating stakeholders in the SMA establishment and management process.

Conducting the survey provided the author with unexpected personal insights into preconceptions about resource users and the value of the information they could provide for the SMA regime and management process. Initial expectations that fishers would be unwilling to cooperate, especially to give sensitive information about their fishing activities and livelihood was proven to be unfounded. Given that interviews were voluntarily and respondents could have easily refused to answer these questions, the author believes that most information obtain during the surveys was as reliable as possible in the circumstances. Moreover, the author was impressed with fishers' eagerness to make their own presentation about the SMA regime and fisheries in general and its management, as if they were pleased to have been given the opportunity to have their say.

On the other hand, some fishers expressed a reluctance to reveal certain information because they considered it might be used against them by fisheries managers. This attitude could have frustrated the process of SMA network development for the sustainable use of fisheries resources.

This thesis does not provide irrefutable evidence that the SMA regime has benefited the economy of Tonga. However, circumstantial evidence supports the suggestion that the SMA has allowed more coastal communities' households to benefits from the marine fisheries resources. In addition, this could be the start of a process which has given people the ability to influence their own future livelihoods and so we should expect that biological responses may take longer to occur. This study has shown that the SMA has allowed socioeconomic benefits to accrue to the SMA communities through providing greater opportunities for fishing. Approximately 22 coastal communities in Tonga have recently flagged their interest in establishing of SMA as fisheries and conservation tool .

5.5 The Ecosystem Approach for Fisheries Management (EAFM) approach

Implementing an ecosystem approach to fisheries management within the SMA regime is an complex process as all affected stakeholders should be comprehensively incorporated (Rosenberg & Mcleod, 2005). Additionally, it is acknowledged that the ecosystem approach may involve many different complementary management measures, of which marine reserve or no-take zone are but one example (Sissenwine & Murawski, 2004; Kaiser, 2005). Consequently the work presented in this thesis has developed certain aspects of the ecosystem approach, namely the detailed assessment and incorporation of stakeholders in the design of SMAs. The integration of survey methods, socioeconomic impact assessment and site-selection demonstrated herein should, however, provide a valuable technical basis for future application of the ecosystem approach.

The study also highlighted a number of opportunities for future work to address the data inadequacies identified. While improved information were collated in Chapter 2, 3 & 4 there remains much that could be done to improve estimates of the status of the inshore fisheries resources and the fishing impact further. Information would be more reliable if the various data collections were comprehensive, complementary and standardised. Assessment of the ecological impacts of fishing activities would be further improved if fishers' catches could be estimated better. Time constraints in the present study limited the level of detail of the information sought during the study, but the success of the study suggests that more focussed interviews may yield more detailed and useful information in the future. Furthermore, information about the organisation of the fisheries obtained in the present study will assist future work by enabling better stratification of future survey efforts.

The successful implementation of a SMA plan is a complex process where all affected stakeholders should be adequately incorporated (Leslie, 2005; Ritchie and Ellis, 2010). The work presented here has made use of different methodologies to perform a detailed assessment of some of the impacts associated with the establishment of the SMA regime and has demonstrated the potential application of these type of data into the efficient design of SMA network in Tonga.

5.6 CONCLUSION

It has been proposed that fishery managers should bridge the gap between fisheries science and socioeconomic discipline (Knudson & MacDonald, 2000). One of the critical aspects of this process is the identification and promotion of win-win scenarios for the societal socioeconomic and biological environment.

The SMA regime is an example of a fisheries management system that can provide win-win solutions to many of the problems of inshore fisheries resources facing fisheries managers in Tonga. These solutions include limiting coral reef degradation caused by fishing, ensuring equitable access to fisheries resources, and maximising opportunities for those who fish responsibly.

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Appendices

Appendix 1

Socioeconomic questionnaire

Savea ki he tu'unga fakasosiale mo 'ekonomika 'a e ngaahi 'api (SMA community)

Kolo/Feitu'u:	
Fika 'o e 'apinofo'anga.	
'Aho:	
Hingoa tokotaha savea	

Tokotaha 'oku faka'eke'eke ('Ulu 'o e family/fakafofonga, fakamatala fakapulipuli, pea 'ikai ngofua ke pulusi ha hingoa)			
Hingoa	**Ta'umotu'a (Ta'u)**		
		Tangata	**Fefine**

Fakamatala fakalukufua fekau'aki mo e 'api nofo'anga

1. Ko e tokofiha 'oku lolotonga nofo he 'api?

Tokotaha nofo he 'api*	Ta'u motu'a	Mali/te'e ki mali	Tangata/ Fefine	Tu'unga fakaako ma'olunga taha	Siasi

*identify all living in house by name or role (e.g. father, mother, or grandmother)

2. Kataki ‘o fakakakato ‘a e tepile ki he tokotaha ‘oku nofo he ‘api mo’enau ngaue takitaha mo hono mahu’inga takitaha ‘o fakatatau ki he faka pa’anga pe me’atokoni ki he ‘api. (Fakakalasi e mahu’inga (1= mahu’inga taha, 4= ‘ikai mahu’inga taha)

Tokotaha he ‘api/NGaue	**Toutai**	**Ngoue**	**Ngaue vahenga**	**Lalanga**	**Ngaue kehe (Specify)** ____________	**Li pa’anga mei tu’apule’anga**

3. Kataki ‘o lisi mai mei he ma’olunga taha ki he ma’ulalo taha ‘a e ngaahi me’a ‘oku fakamole ki ai ‘a e pa’anga humai ‘a e ‘api ni ‘ki he mahina (e.g. Ako, Siasi/Famili/Sosaieti/kolo, Faka’api, etc)

Hokohoko	**Me’a ‘oku fakamole ki ai**
Ma’olungataha 1	
2	
3	
4	
5	
Ma’ulalotaha 6	

4. Kataki ‘o hiki ‘a e fangamanu ‘a e ‘api

Fangamanu	**Tick(√) kapau ‘oku ‘iai**	**Tokolahi**
Pulu		
Hoosi		
Puaka		
Kosi		
Moa		
Me’a kehe		

5. ‘Oku ‘iai ha ‘api tukuhau ‘oku ma’u he ‘api ni, lisi, pe ngaue’aki ? (Siakale’i)

Koe ha hono mahu’inga (ki he ‘api nip e)?

- Ngoue tu’uma’u/ngoue fakataimi ☐ (unit)

6. Kataki ka ke fakapapau’I pe ‘oku ma’u ‘a e ngaahi koloa ko ‘eni he ‘api ni?

a. Fa’ahinga ‘o e fale**:** _____Fale tonga, _____Fale kapa, _____Falepapa, _____Fale piliki; _____makehe(specify)________________________

b. **Naunau fale:** _____Letio, _____Tepi, _____Sitou (Kasa pe Kalasini), _____Vitio, _____Me’akehe (specify)____________________.

c. **Ma’u’anga ‘uhila:** _____Maama kalasini, _____Maama sola, _____Misini ‘uhila taautaha, _____Misini ‘uhila fakakolo.

d. **Ma’u’anga vai:** _____Tangike vai (Sima, kapa, or Faipa,), _____Vai fakakolo, _____Vai keli,

e. **Falemalolo:** _____ Falemalolo ponu, _____Falemalolo vai,

c. ‘Oku ‘iai ha vaka ‘a e ‘api ni? (‘Io/’Ikai)

- Fa’ahinga ‘o e vaka (vaka papa, vaka faipa, pe vaka kapa)___________________________________
- Fa’ahinga ‘o e misini (Hp)___________________________________
- Popao___________________________________

7. Ko hai fua ‘oku toutai ‘i he ‘api ni ‘i he hakau mo e namo ma’upe?

Hingoa tokotaha toutai	**Tangata/Fefine**	**Mata’iika**	**Fingota**	**Fakatou’osi mata’iika moe Fingota**

(Ma’upe tatau ia moe lahi hake he tu’o taha he mahina)

Ma’u me’atokoni mo e me’atokoni

8. Ko e ha ‘a e fa’ahinga me’atokoni ‘oku angamaheni hono teuteu he ‘api ni ki he ma’ume’atokoni ‘a e family he uike? (1 = lahi taha hono teuteu’i, 5 = si’isi’itaha ke teuteu’i)

Fa’ahinga me’atokoni	**Rank**
Ika	
Fingota	
Moa	
Kakano’i manu	
Kapaika	
Me’a kehe	

(Kakano’i manu ‘uhinga ki he pulu, sipi, mo e puaka)

9. Koe ha e fa’ahinga me’atokoni ‘oku faka’amu ‘a e ‘api ni ken au ma’ume’atokoni ai? (1 = fiema’u lahitaha, 5 = Fiema’u si’isi’itaha)

Fa’ahinga me’atokoni	**Rank**
Ika	
Fingota	
Moa	
Kakano’i manu	
Kapaika	
Me’akehe	

(Kakano’imanu kau ki ai ‘a e pulu, Sipi, mo e puaka)

10. Ko e ha e me'a 'oku ne pule'I pe ko e ha e me'atokoni ke ngaohi ki he ma'ume'atokoni 'a e family ko 'eni?

a. Liliu 'I he mahu'inga 'o e fa'ahinga 'o e me'atokoni ____________________

b. Lahiange fiema'u/manako ki he fa'ahinga 'o e me'atokoni ko ia____________________

c. 'Uhinga kehe (specify)____________________

11. 'Ihe taimi 'oku mou ma'u me'atokoni ai mei he me'atahi:

		Tick √	Rank (1-3)
a. 'Oku ma'u mei fe 'a e ika pea ko e ha 'a e founga angamaheni? (Tick√ box and rank from 1 to 3) (1 = Angamaheni lahitaha; 2 = Angamaheni hoko; 3 = Angamaheni si'isi'itaha)	Toutai pe memipa 'o e 'api	☐	☐
	'Ofa mai pe mei ha tokotaha kehe ('Ikai fakatau)	☐	☐
	Fakatau; 'I fe 'ia …………………………….	☐	☐
b. 'Oku ma'u mei fe 'a e fingota pea ko e ha 'a e founga angamaheni? (Tick√ box and rank from 1 to 3) (1 = Angamaheni lahitaha; 2 = Angamaheni hoko; 3 = Angamaheni si'isi'itaha)	Toutai pe memipa 'o e 'api	☐	☐
	'Ofa mai mei ha tokotaha kehe ('Ikai fakatau)	☐	☐
	Fakatau; 'I fe 'ia …………………………….	☐	☐

Koe ha ‘a e Lau mo e Fakakaukau ki he fokotu’u ko ia ‘o e Feitu’u Pule’I Makehe

12. ‘Oku ‘ilo nai ‘e he kakai ‘o e ‘api ni ‘a e polokalama ki he Feitu’u Pule’I Makehe ‘oku fokotu’u he motu ni? (‘IO/’IKAI).

13. Kataki ‘o fakaha koe ha ho’o ongo’i fekau’aki mo e ngaahi fakamatala ko ‘eni (Tick √)

	Ta’efakafiemalie ‘aupito	Ta’efakafiem alie	‘Ikai keu ‘ilo	Fakafiemal ie	Fakafiemalie ‘aupito
(a) ‘Oku fiemalie pe ‘api ni moe fakakaukau ‘a e kolo ni ke fokotu’u ‘a e Feitu’u Pule’I Makehe.					
(e) ‘Oku fiemalie pe ‘api ni ki he tu’unga ‘o e fepotalanoa’aki kimu’a pea toki fokotu’u ‘a e Feitu’u Pule’I Makehe.					
(f) ‘Oku fiemalie ‘ae ‘api ni ki he ngaahi ngatangata’anga ‘o e FPM.					
(h) ‘Oku fiemalie ‘a e ‘api ni ki he fakakaukau ke ta’ofi e toutai he ‘elia tapu?					
(e) ‘Oku fiemalie pe ‘api ni ki he feitu’u ‘oku tapu ai e toutai.					
(f) ‘Oku fiemalie ‘a e ‘api ni ki he ngatangata’anga ‘o e feitu’u ‘oku tapu ai e toutai.					
(g) ‘Oku fiemalie pe ‘api ni mo hono fili ‘o e kau memipa ki he komiti pule ki he FPM.					

14. Kataki ka ke fakaha pe ‘oku ke tui ki he fakamatala ko ‘eni. (Tick √)

	Ta’etui ‘aupito	Ta’etui	‘Ikai keu ‘ilo	Tui ki ai	Tui ‘aupito
(a) ‘Oku poupou ‘i mo kau ‘a e ‘api ni ki hono fokotu’u ‘o e FPM.					
(b) ‘Oku poupou’I ‘e he ‘api ni ‘a e polokalama FPM.					

Uesia ‘i he me’atokoni mei tahi

15. Kataki ‘o fakaha pe ‘oku ke tui ki he ngaahi fakamatala ko’eni. (Tick √)

	‘Ikai ‘aupito k etui ki ai	‘Ikai tui ki ai	‘Ikai keu ‘ilo	Tui ki ai	Tui ‘aupito ki ai
(a) ‘Oku liliu ‘a e me’atokoni angamaheni ne fa’a ngaohi he ‘api ni ‘I he ngaahi ta’u mai ki mui ni (Ta’u ‘e 5 ki mui ni).					
(b) Ko e liliu ‘i he me’atokoni ‘oku fa’a ngaohi he ‘api ni ‘oku makatu’unga ‘i hono fokotu’u ‘o e FPM).					

16. ‘I ho’o fakakaukau ‘oku liliu e ma’ume’atokoni mei tahi ‘a e ‘api ni talu mei hono fokotu’u ko ia ‘o e FPM?

Liliu lahi ‘aupito	Lahi ange	‘Ikai ha liliu	Holo si’isi’i	Holo ‘aupito

Uesia ki he toutai

17. Kataki pe ko e ha ho'o lau ki he ngaahi fakamatala ko'eni (Tick √)

	'Ikai 'aupito tui ki ai	'Ikai tui ki ai	'Ikai keu 'ilo	Tui ki ai	Tui 'aupito ki ai
(a) 'Oku uesia 'a e toutai 'a e family ni talu hono fokotu'u 'o e FPM.					
(b) Na'e ngaue'aki 'e he famili ni 'a e Feitu'u tapu ki he fai'anga toutai ki mu'a pea toki fokotu'u 'a e FPM.					
© 'Oku uesia 'a e toutai 'a e family ni 'I hono ta'ofi ko ia 'a e toutai 'I he feitu'u tapu.					

18. 'I ho'o fakafuofua, 'oku liliu nai 'a e ola 'o e toutai 'a e kakai 'I he 'api ni talu mei hono fokotu'u 'o e FPM?

Lahi 'aupito	Lahi ange	'Ikai liliu	Holo si'isi'I pe	Holo 'aupito

19. 'I ho'o fakakaukau, 'oku ke pehe 'oku liliu 'a e tu'unga ma'u'anga pa'anga mei he toutai 'a e kakai 'I he 'api ni talu mei hono fokotu'u ko ia 'o e FPM.

Tupu Lahi 'aupito	Tupu Lahi ange	'Ikai liliu	Holo si'isi'I pe	Holo lahi 'aupito

Ngaahi lelei mo e mahino

20. Kataki pe ko e ha ho’o lau ki he ngaahi fakamatala ko ‘eni (Tick √)

	‘Ikai ‘aupito tui ki ai	‘Ikai tui ki ai	‘Ikai teu ‘ilo	Tui ki ai	Tui ‘aupito ki ai
(a) ‘Oku leleiange ‘a e ma’u’anga mo’ui ‘a e famili ni mei he fokotu’u ko ia ‘o e FPM.					
(b) ‘Oku kaunga lelei ‘a e fokotu’u ‘o e FPM ki he ‘ekonomika ‘a e famili ni.					
© ‘Oku hoko hono fokotu’u ko ia ‘o e FPM ko e founga lelei ke tu’uloa ‘a e toutai he kolo ni.					
(d) ‘Oku tokoni ‘a hono fokotu ‘o e FPM ke malu’i e fa’ahinga me’amo’ui kehekehe.					
(e) ‘Oku tokoni hono fokotu’u ‘o e feitu’u tapu ke fakatupulekina e lahi ‘o e ika ‘i he loto FPM.					
(f) ‘Oku hoko hono fokotu’u ‘o e FPM ke liliu ‘a e ‘ilo ‘a e kakai ‘o e ‘api ni felave’i mo e mahu’inga ‘o e hakau.					

Palopalema/Ke

21. ‘Oku ke ‘ilo nai pe ‘oku hoko ha maumau he vaha’a ‘o e kakai ‘o e kolo ni he ngaue’aki ‘o tahi? (‘Io/’Ikai)

Kapau ‘oku ‘ikai, hiki ki he fehu’i 22(b).

Kapau ‘oku ‘io, hoko ki he fehu’i 22.

22. Kataki ka ke fakaha pe ‘oku ke tui pe ta’etui ki he ngaahi fakamatala ko ‘eni. (Tick √)

	‘Ikai ‘aupito tui ki ai	‘Ikai tui ki ai	‘Ikai keu ‘ilo	Tui ki ai	Tui ‘aupito ki ai
(a) ‘Oku si’isi’I ‘a e conflict ‘I hono fokotu’u ‘o e FPM.					
(b) ‘Oku fakatupunga ‘a e conflict ‘i he vaha’a ‘o e kau toutai he kolo ‘I he fokotu’u ‘o e FPM.					
© ‘Oku fakatupunga ‘a e conflicts ‘i he vaha’a ‘o e kau toutai he kolo ni moe kau toutai he ngaahi kolo kehe ‘i he fokotu’u ‘o e FPM.					

Polisi’i mo hono tauhi ‘o e lao ki he FPM

23. ‘Oku ke ‘ilo ‘oku ‘iai ha lao/Tu’utu’uni ki he FPM? (Yes/No)

Kapau ‘oku ‘io, Koe ha e ‘uhinga?

Kapau ‘oku ‘io, hoko atu ki he fehu’i 24.

24. Kataki signify pe ko e ha ha’o lau ki he ngaahi fakamatala ni (Tick √)

	‘Ikai ‘aupito tui ki ai.	‘Ikai tui ki ai	‘Ikai teu ‘ilo	Tui ki ai	Tui ‘aipito ki ai
(a) ‘Oku kei toutai pe kakai he ‘api ni ‘i he ‘Elia tapu ‘aupito.					
(b) ‘Oku tauhi ‘e he memipa ‘o e ‘api ni ‘a e Lao/Tu’utu’u ni ki he FPM (kau ai mo e ‘Elia tapu ‘aupito).					
© ‘Oku kei toutai mai pe kakai mei he ngaahi kolo kehe ki he FPM.					

25. ‘Oku ke kau ki he ngaahi polokalama polisi’I ‘o e FPM ‘I he kolo ni.? (‘Io/’Ikai).

Ko e ha ‘a e ‘uhinga?

26. Ko e ha ho’o fakafuofua ki he tu’unga hono polisi’i/le’ohi ‘o e FPM ‘i he kolo ni?

‘ikai fakahoko ha lpolokalama le’o	Fakahoko pe polokalama le’o ka ‘oku si’isi’i	Lahi pe fakahoko e polokalama le’o	Kakato hono fakahoko ‘o e polokalama le’o	‘Ikai keu ‘ilo

Savea ki he tu'unga fakasosiale mo 'ekonomika 'a e ngaahi 'api (Comparator Community)

Kolo:	
Fika 'o e 'api.	
'Aho:	
Hingoa 'o e tokotaha savea	

Tokotaha 'oku faka'eke'eke			
Hingoa	**Ta'umotu'a (Ta'u)**	**Gender**	
		Tangata	**Fefine**

Fakamatala fakalukufua fekau'aki mo e 'api nofo'anga

1. Ko e tokofiha 'oku nofo 'i 'api ni?

Kakai 'oku nofo he 'api *	Ta'u motu'a	Mali/Ta'e mali	Tangata/ Fefine	Tu'ungafakaako ma'olungataha	Siasi

*identify all living in house by name or role (e.g. father, mother, or grandmother)

2. Kataki ‘o fakakakato ‘a e tepile ki he tokotaha ‘oku nofo he ‘api mo’enau ngaue takitaha mo hono mahu’inga takitaha ‘o fakatatau ki he faka pa’anga pe me’atokoni ki he ‘api. (Fakakalasi e mahu’inga (1= mahu’inga taha, 4= ‘ikai mahu’inga taha).

Tokotaha he ‘api	**Toutai**	**Ngoue**	**Vahenga**	**Lalanga**	**Ngaue kehe (ko e ha)** ____________	**Li pa’anga mei tu’apule’anga**

3. Kataki ‘o lisi mai mei he ma’olunga taha ki he ma’ulalo taha ‘a e ngaahi me’a ‘oku fakamole ki ai ‘a e pa’anga humai ‘a e ‘api ni ‘ki he mahina (e.g. Ako, Siasi/Famili/Sosaieti/kolo, Faka’api, etc)

Hokohoko	**Me’a ‘oku fakamole ki ai**
Ma’olunga taha 1	
2	
3	
4	
5	
Ma’ulalo taha 6	

4. Kataki ‘o hiki ‘a e fangamanu ‘a e ‘api

Fangamanu	**Tick(√) ‘I ai**	**Lahi**
Pulu		
Hoosi		
Puaka		
Kosi		
Moa		
Toe me’a kehe		

5. ‘Oku ‘iai ha ‘api tukuhau ‘oku ma’u he ‘api ni, lisi, pe ngaue’aki ? (Circle your choice)

Koe ha hono mahu’inga (ki he ‘api nip e)?

- Ngoue tu’uma’u/ngoue fakataimi ☐ (unit)

6. Kataki ka ke fakapapau’I pe ‘oku ma’u ‘a e ngaahi koloa ko ‘eni he ‘api ni?

a. Fa’ahinga ‘o e fale**:** ____Fale tonga, ____Fale kapa, ____Falepapa, ____Fale piliki; ____makehe(specify)______________________

f. **Naunau fale:** ____Letio, ____Tepi, ____Sitou (Kasa pe Kalasini), ____Vitio, ____Me’akehe (specify)___________________.

g. **Ma’u’anga ‘uhila:** ____Maama kalasini, ____Maama sola, ____Misini ‘uhila taautaha, ____Misini ‘uhila fakakolo.

h. **Ma’u’anga vai:** ____Tangike vai (Sima, kapa, or Faipa,), ____Vai fakakolo, ____Vai keli,

i. **Falemalolo:** ____ Falemalolo ponu, ____Falemalolo vai,

c. ‘Oku ‘iai ha vaka ‘a e ‘api ni? (‘Io/’Ikai)

- Fa’ahinga ‘o e vaka (vaka papa, vaka faipa, pe vaka kapa)________________________________
- Fa’ahinga ‘o e misini (Hp)__________________________________
- Popao________________________________

7. Ko hai fua ‘oku toutai ‘i he ‘api ni ‘i he hakau mo e namo ma’upe?

Hingoa tokotaha toutai	**Tangata/Fefine**	**Mata’iika**	**Fingota**	**Fakatou’osi**

(Regularly refers to more than one in a month)

Ma’u me’atokoni mo e me’atokoni

8. Ko e ha ‘a e fa’ahinga me’atokoni ‘oku angamaheni hono teuteu he ‘api ni ki he ma’ume’atokoni ‘a e family he uike? (1 = lahi taha hono teuteu’i, 5 = si’isi’itaha ke teuteu’i)

Fa’ahinga me’atokoni	**Hokohoko**
Mata’I ika	
Fingota	
Moa	
Sipi,pulu	
Kapaika	
Ki ki kehe	

(Meat included Beef, sheep, and pork)

9. Koe ha e fa’ahinga me’atokoni ‘oku faka’amu ‘a e ‘api ni ken au ma’ume’atokoni ai? (1 = fiema’u lahitaha, 5 = Fiema’u si’isi’itaha)

Fa’ahinga me’atokoni	**Hokohoko**
Mata’I ika	
Fingota	
Moa	
Sipi,pulu	
Kapaika	
Ki ki kehe	

(Meat included Beef, sheep, and pork)

10. Ko e ha e me'a 'oku ne pule'I pe ko e ha e me'atokoni ke ngaohi ki he ma'ume'atokoni 'a e family ko 'eni?

d. Liliu 'I he mahu'inga 'o e fa'ahinga 'o e me'atokoni ____________________

e. Lahiange fiema'u/manako ki he fa'ahinga 'o e me'atokoni ko ia____________________

f. 'Uhinga kehe (specify)____________________

11. 'Ihe taimi 'oku mou ma'u me'atokoni ai mei he me'atahi:

a. 'Oku ma'u mei fe 'a e ika pea ko e ha 'a e founga angamaheni? (Tick√ box and rank from 1 to 3) (1 = Angamaheni lahitaha; 2 = Angamaheni hoko; 3 = Angamaheni si'isi'itaha)		Tick √	Rank (1-3)
	Toutai pe memipa 'o e 'api	☐	☐
	'Ofa mai pe mei ha tokotaha kehe ('Ikai fakatau)	☐	☐
	Fakatau; 'I fe 'ia	☐	☐
b. 'Oku ma'u mei fe 'a e fingota pea ko e ha 'a e founga angamaheni? (Tick√ box and rank from 1 to 3) (1 = Angamaheni lahitaha; 2 = Angamaheni hoko; 3 = Angamaheni si'isi'itaha)		Tick √	Rank (1-3)
	Toutai pe memipa 'o e 'api	☐	☐
	'Ofa mai mei ha tokotaha kehe ('Ikai fakatau)	☐	☐
	Fakatau; 'I fe 'ia	☐	☐

Koe ha ‘a e Lau mo e Fakakaukau ki he fokotu’u ko ia ‘o e Feitu’u Pule’I Makehe

12. ‘Oku ‘ilo nai ‘a e ‘api ni ki he FPM ‘a ……………………………..Is this household aware of the establishment of the SMA program in X-community? (Io /’Ikai).

Kapau ‘oku ‘ikai, fakamatala ki he FPM ‘a ………………………..pea hoko atu ki he fehu’i 13 (d).

Kapau ‘oku ‘io, hoko atu ki he fehu’i 14.

13. Kataki pe ko e ha ha’o lau ki he ngaahi fakamatala ko’eni (Tick √)

	Ta’etui ‘aupito ki ai	Ta’etui ki ai	‘Ikai keu ‘ilo	Tui ki ai	Tui ‘aupito ki ai
(a). ‘Oku fiemalie pe ‘api ni mo e fokotu’u FPM ‘a ………………………..					
(b). ‘Oku fiemalie pe ‘api ni mo e tu’unga ‘o e fepotalanoa’aki ki mu’a pea fokotu’u ‘a e FPM ‘a ………..					
(c). ‘Oku fiemalie pe ‘api ni mo e ngaahi ngatangata’anga ‘o e FPM ‘a ……………………….					
(d). ‘E fiemalie pe ‘api ni kapau ‘e loto ‘a e kolo ni ke fokotu’u ha FPM.					

14. Kataki ‘o fakaha pe ‘oku ke tui pe ta’etui ki he ngaahi fakamatala ko’eni. (Tick √)

	Ta’etui ‘aupito ki ai	Ta’etui ki ai	‘Ikai keu ‘ilo	Tui ki ai	Tui ‘aupito ki ai
(a) ‘Oku totonu ke fokotu’u nai ke fokotu’u ha FPM he kolo ni.					
(b) ‘E poupou nai e kolo ki he fokotu’u ‘o e FPM.					
© ‘E poupou e ‘api ni kapau ‘e loto e kolo ke fokotu’u ha FPM.					

Uesia ‘I he me’atokoni mei tahi

15. Kataki ko e ha ho’o lau ki he ngaahi fakamatala ko ‘eni (Tick √)

	Ta’etui ‘aupitoki ai	Ta’etui ki ai	‘Ikai keu ‘ilo	Tui ki ai	Tui ‘aupito ki ai
(a) ‘Oku liliu ‘a e me’atokoni ‘oku ngaohi angamaheni he ‘api ni ‘I he ngaahi ta’u ki mui ni (last 5 years).					
(b) ‘E liliu ‘a e me’atokoni ‘oku angamaheni hono ngaohi he ‘api , kapau ‘e fokotu’u ha FPM he kolo ni.					

16. ‘Oku ‘iai ha liliu ‘I he kai me’atahi ‘a e ‘api ni talu hono fokotu’u ‘o e FPM ‘a…………………………?

Tupu lahi ‘aupito	**Tupu si’isi’I**	**‘Ikai ha liliu**	**Holo si’isi’I**	**Holo lahi ‘aupito**

Uesia ki he toutai

17. Kataki pe ko e ha ho'o lau ki he ngaahi fakamatala ko'eni (Tick √)

	Ta'etui 'aupito ki ai	Ta'etui ki ai	'Ikai keu 'ilo	Tui ki ai	Tui 'aupito ki ai
(a) 'E uesia 'a e toutai 'a e 'api ni kapau 'e fokotu'u ha FPM.					
(b) 'E uesia 'a e ma'u'angapa'anga mei he toutai 'a e 'api ni kapau 'e fokotu'u ha FPM					
© 'Oku uesia 'a e toutai 'a e 'api ni 'I he fokotu'u 'o e FPM 'a ……………………………					
(d) 'Oku fa'a toutai 'a e 'api ni he feitu'u 'oku hoko ko e FPM 'a ……………………………………………..					
(e) 'Oku 'I ai 'a e kaunga 'a e FPM 'a …………………..ki he fili ko ia 'a e feitu'u toutai'anga 'a e 'api ni.					

18. 'Oku liliu nai 'a e ola 'o e toutai 'I he fo'I folau toutai 'a e 'api ni talu ko ia hono fokotu'u 'o e FPM 'a ………………………..?

Tupu lahi 'aupito	Tupu si'isi'I pe	'Ikai ha liliu	Holo si'isi'I pe	Holo lahi 'aupito

19. 'I ho'o fakakaukau, 'oku liliu nai 'a e pa'anga hu mai mei he toutai 'a e 'api ni talu hono fokotu'u 'o e FPM 'a …………………………?

Tupu lahi 'aupito	Tupu si'isi'I	'Ikai ke liliu	Holo si'Isi'I pe	Holo lahi 'aupito

Ngaahi lelei mo e mahino

20. Kataki pe ko e ha ho'o lau ki he ngaahi fakamatala ko 'eni (Tick √)

	Ta'etui 'aupito ki ai	Ta'etui ki ai	'Ikai keu 'ilo	Tui ki ai	Tui 'aupito ki ai
(a) 'Oku fakalakalaka 'a e ma'u'angamo'ui 'a e 'api ni 'I he fokotu'u 'o e FPM 'a ……………………..					
(b) 'E fakalakalaka 'a e ma'u'angamo'ui 'a e 'api ni kapau 'e fokotu'u ha FPM he kolo ni.					
© 'E sai hono fokotu'u ha FPM ki he tu'unga faka'ekonomika 'a e 'api ni.					
(d) 'Ko e founga lelei ki hono pukepuke 'o e toutai he kolo ni 'a hono fokotu'u 'o ha FPM .					
(e) 'E tokoni 'a hono fokotu'u ha FPM ki hono malu'I 'o e kehekehe 'o e me'amo'ui 'o tahi .					
(f) 'E tokoni hono fokotu'u 'o e FPM ke toe lahi ange ika 'I he ngaahi feitu'u toutai'anga he kolo ni.					
(g) Kapau 'e fokotu'u ha FPM he kolo ni, 'e liliu 'a e 'ilo mo e mahino 'a e 'api ni ki he mahu'inga 'o e hakau.					

Palopalema/Ke

21. ‘Oku ke ‘ilo nai pe ‘oku hoko ha palopalema/ke ‘’I he va ‘o e kau toutai he kolo ni? (‘Io/’Ikai)

Kapu ‘oku ‘ikai, hoko ki he fehu’I 22(b).

Kapau ‘oku ‘io, hoko ki he fehu’I 22.

22. Kataki ka ke fakaha ‘a e tu’unga ho’o tui pe ta’etui ki he ngaahi fakamatala ko ‘eni. (Tick √)

	Ta’etui ‘aupito ki ai	Ta’etui ki ai	‘Ikai keu ‘ilo	Tui ki ai	Tui ‘aupito ki ai
(a)’E fakasi’I ‘a e palopalema/ke kapau ‘e fokotu’u ha FPM.					
(b) ‘Oku fakatupu e palopalema/ke ‘I he va ‘o e kau toutai he kolo no mo …………………’I hono fokotu’u ‘o e FPM.					

Tauhi Lao mo hono le’ohi

23. ‘Oku ke ‘ilo nai ki he Lao ‘o e FPM? (Yes/No)

Kapau ‘oku ‘ikai, ko e ha e ‘uhinhga?

Kapau ‘oku ‘io, hoko ki he fehu’i 24.

24. Kataki ko e ha ho’o lau ki he ngahi fakamatala ko ‘eni (Tick √)

	Ta’etui ‘aupito ki ai	Ta’etui ki ai	‘Ikai keu ‘ilo	Tui ki ai	Ta’etui ‘aupito ki ai
‘Oku kei toutai pe kakai he kolo he FPM ‘a ………………………..					

Fehu'i ki he kau Toutai 'i he FPM

Hingoa: ______________________ _ F ☐ M ☐

Kolo: ________________

Hingoa tokotaha savea: ________________________ 'Aho: ________________

Ngaahi fakamatala fakalukufua

1. Koe ha e fuoloa ho'o hoko ko e takotaha toutai?___________Ta'u

2. 'Oku ke toutai ki he:

mata'iika ☐ pe fingota ☐ pe fakatou'osi ☐

3. Ko fe feitu'u 'oku ke toutai ai?

Loto-hakau	Namo	Tu'a-hakau	Limu	Tahi lololoto
☐	☐	☐	☐	☐

4. 'Oku tu'ofiha ('Aho/uike) ho'o 'alu 'o toutai 'i he ngaahi feitu'u toutai'anga?

Loto-hakau	Tahi-lololoto	Limu	Tu'a-hakau	
☐	☐	☐	☐	____________/tu'ofiha he uike/mahina
☐	☐	☐	☐	____________/ tu'ofiha he uike/mahina
☐	☐	☐	☐	____________/tu'ofiha he uike/mahina

5. ‘Oku ke ngaue’aki ha vaka ki ho’o toutai?

	Taimi kotoa pe	Taimi pe ni’ihi	‘Ikai ‘aupito
Loto hakau	☐	☐	☐
Tahi-loloto	☐	☐	☐
Limu	☐	☐	☐
Tu’a-hakau	☐	☐	☐

6. Kapau ‘oku ke ngaue’aki ha vaka ki ho’o toutai ko e fa’ahinga fe?

- Popoao (‘a’alo) ☐ misini tu’uloto: ☐ Misini fakapipiki ☐

7. Ko e ha e loloa ho’o taimi toutai ‘i he feitu’u toutai’anga ki he fo’i folau toutai?

< 2 hrs	2-6 hrs	6-12 hrs	> 12 hrs
☐	☐	☐	☐

8. ‘Oku ke toutai he taimi fe? *(tick box)* ‘Aho ☐ Po’uli ☐ ‘Aho &Night ☐

9. ‘Oku ke toutai he ta’u katoa?

‘Io ☐ ‘Ikai ☐

10. Kapau ‘oku ‘ikai, ko fe mahina ‘oku ‘ikai keke toutai ai?

Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

11. Ko e ha e founga toutai ‘oku ke fakahoko?

☐ Taumata’u

☐ Kupenga sili ☐ Kupenga:

☐ Uku (dive)

☐ Fakatele ☐ Maka feke/A’a feke

☐ Taumata’u loloto ☐ Tufi he funga hakau (Fingota, Limu, etc.)

☐ Founga kehe, koe ha: ____

12. ‘Oku ke ngaue ‘aki ha ‘aisi ki ho’o toutai?

☐ Ma’u pe ☐ Taimi pe ni’ihi ☐ ‘ikai ‘aupito

☐ Ko e ngaahi pe ‘i ‘api ‘a e ‘aisipoloka ☐ Fakatau? ‘I fe______________

13. Ko e ha e faka’avalisi ‘a e ola ho’o toutai (kg) ki he fo’i folau toutai? ☐ kg

14. ‘Oku ke fakatau atu ho’o toutai? ‘Io ☐ ‘Ikai ☐

15. ‘Oku ke tufa ho’o toutai (for no money)? ‘Io ☐ ‘Ikai ☐

16. ‘Oku ke faka’aonga’I ho’o toutai ki he ma’ume’atokoni ho famili?

‘Io ☐ ‘Ikai ☐

17. ‘Oku ke fakatau ika ‘i fe:

☐ ‘I he kolo ☐ ‘I ha kolo kehe

Pea kia hai?

Maketi ☐ Kautaha ☐ Falekoloa ☐ Tokotaha kehe ☐

____

18a.. Ko e ha ‘a e ‘avalisi ‘o e fa’ahinga ika ‘oku ma’u ‘i ho’o toutai?

Hingoa	Rank (1= ma’u lahitaha ki he 5= si’i taha)

18b. Koe ha e fa’ahinga ‘oku ke faka’amu ke ke ma’u?

18c. Ko e ha e ‘uhinga

19. ‘I he ta’u ‘e 5 kuo hili, ‘oku ke pehe ‘oku ‘iai ha liliu ‘i he lahi ‘o e ola ho’o toutai ki he fo’i folau toutai angamaheni?

Holo lahi	Holo si’isi’i	Ikai ha liliu	Lahi	Lahi ange

20. ‘Oku ke fiema’u ke toe lahi ange ola ho’o toutai ‘i he kaha’u?

‘Ikai ‘aupito ke fiema’u	‘Ikai fiema’u	Neither	Fiema’u	Fiema’u ‘aupito

21a. . Kataki ‘o faka ha pe ko ha e lahi ‘o e ngaahi me’a ko ‘eni ‘oku ne kaunga ki he fili ‘o e feitu’u ‘oku ke fili keke ‘alu ‘o toutai ai?

	Ngaahi me’a	**Kaunga si’i si’i ‘aupito**	**Kaunga si’isi’i pe**	**Kaunga lahilahi pe**	**Kaunga lahi**	**Kaunga lahi ‘aupito**
a	Tu’unga ‘o e matangi					
b	‘I ai ha vaka					
c	Ngaahi fakamole					
d	Fa’ahinga ‘o e ika ‘oku fiema’u					
e	Lahi ‘o e ola ‘o e toutai					
f	Makatu’unga ho’o toutai (Kai pe fakatau)					

g	Feitu'u 'oku 'alu ki ai 'a e kau toutai kehe					
h	Ngaahi tu'utu'uni 'o e FPM					
f	Toe me'a kehe (ko e ha)					

21b. Koe ha 'a e Lau mo e Fakakaukau ki he fokotu'u ko ia 'o e Feitu'u Pule'I Makehe

22. 'Oku ke 'ilo pe ki he fokotu'u ko ia 'o e Feitu'u Pule'I Makehe 'I he kolo ni? ('Io/'Ikai).

23. Kataki 'o fakaha koe ha ho'o ongo'i fekau'aki mo e ngaahi fakamatala ko 'eni (Tick √)

	Ta'efakafiemalie 'aupito	Ta'efakafiemalie	'Ikai keu 'ilo	Fakafiemalie	Fakafiemalie 'aupito
(a) 'Oku ke fiemalie pe mo e fakakaukau 'a e kolo ki hono fokotu'u 'o e FPM					
(b) 'Oku ke fiemalie pe mo e ngaahi fepotalanoa'aki ki mu'a pea fokotu'u 'o e FPM					
© 'Oku ke fiemalie pe mo e ngaahi ngatangata'anga 'o e FPM					
(d) 'Oku ke fiemalie pe mo e fakakaukau ke ta'ofi 'a e toutai he FMI					
(e) 'Oku ke fiemalie					

pe mo e tu'u'anga 'o e FMI					
(f) 'Oku ke fiemalie pe ki he ngatangata'anga 'o e FMI					
(g) 'Oku ke fiemalie pe mo e fili 'o e kau memipa 'o e Komiti pule ki he FPM.					

24. Kataki ka ke fakaha pe 'oku ke tui ta'etui ki he ngaahi fakamatala ko 'eni. (Tick √)

	Ta'etui 'aupito	Ta'etui	'Ikai keu 'ilo	Tui ki ai	Tui 'aupito ki ai
(a) 'Oku ke poupou mo kau hono fokotu'u 'o e FPM					
(b) 'Oku poupou'I 'e he kolo ni 'a e polokalama FPM.					

Uesia 'i he ngaue fakatoutai

25. Kataki 'o fakaha pe ko e ha ha'o lau ki he ngaahi fakamatala ko 'eni. (Tick √)

	Ta'etui 'aupito ki ai	Ta'etui ki ai	'Ikai keu 'ilo	Tui ki ai	Tui 'aupito ki ai
(a) 'Oku uesia ho'o toutai talu mei hono fokotu'u 'o e FPM 'I he kolo ni.					
(b) Na'ake fa'a toutai he 'elia tapu, FMI ki mu'a hono fokotu'u 'o e FPM.					
© 'Oku uesia ho'o toutai hono tapui 'o e FMI .					

26. ‘I ho’o fakafuofua, ‘oku ke pehe ‘oku liliu ‘a e ola ho’o toutai ki he fo’i folau toutai talu ko ia hono fokotu’u ‘o e FPM.?

Tupu Lahi ‘aupito	Tupu si’isi’I pe	‘Ikai ha liliu	Holo si’isi’I pe	Holo lahi ‘aupito

27. ‘I ho’o fakakaukau, ‘oku liliu nai ho’o ma’u’anga pa’anga mei ho’o toutai talu hono fokotu’u ‘o e FPM?

Tupu lahi ‘aupito	Tupu si’isi’i pe	‘Ikai ke liliu	Ki’i holo si’isi’i	Holo lahi ‘aupito

Ngaahi lelei mo e mahino

28. Kataki ‘o fakaha pe ko e ha ha’o lau ki he ngaahi fakamatala ko ‘eni. (Tick √)

	Ta’etui ‘aupito	Ta’etui	‘Ikai keu ‘ilo	Tui ki ai	Tui ‘aupito ki ai
(a) ‘Oku fakalakalaka ho’o tu’unga ma’u’anga mo’ui mei tahi ‘i he fokotu’u ko ia ‘o e FPM ‘i he kolo ni.					
(b)Ko e fokotu’u ko ai ‘o e FPM ko e founga lelei ke ne pukepuke toutai ‘i ho kolo.					
©Ko e fokotu’u ko ia ‘o e FPM ‘oku sai ki he ‘ekonomika ‘a e kolo					
(d)The establishment of a No-fishing area will increase fish catch in the future.					
(e)’Oku tokoni hono fokotu’u ‘o e FMI ke malu’I e ngaahi me’amo’ui kehekehe ‘o ‘oseni.					
(f)’Oku tokoni hono fokotu’u ‘o e FPM ke fakatokolahi ‘a e ika ‘I he FPM.					
(g)’Oku liliu ho’o ‘ilo mo ho’o mahino felave’I mo e mahu’inga ‘o e hakau ‘i hono fokotu’u ‘o e FPM.					

Palopalema/Ke

29a. ‘Oku ke ‘ilo nai pe ‘oku hoko ha maumau he vaha’a ‘o e kakai ‘o e kolo ni he ngaue’aki ‘o tahi? (‘Io/’Ikai)

29b. Kapau ‘oku ‘ikai, hiki ki he fehu’i 30(b).

29c. Kapau ‘oku ‘io, hoko ki he fehu’i 30.

30. Please indicate the extent to which you agree or disagree with the following statements. (Tick √)

	Ta’etui ‘aupito ki ai	Ta’etui ki ai	‘Ikai keu ‘ilo	Tui ki ai	Tui ‘aupito ki ai
(a) ‘Oku si’isi’i e ke ‘i tahi hono fokotu’u ‘o e FPM.					
(b) ‘Oku fakatupunga ‘a e ke ‘i he vaha’a ‘o e kau toutai he kolo ni ‘i hono fokotu’u ‘o e FPM.					
© ‘Oku fakatupunga ‘a e ke ‘i he vaha’a ‘o e kau toutai ‘i he kolo ni mo e ngaahi kolo kehe ‘i hono fokotu’u ‘o e FPM.					

Tauhi mo e polisi’I e Lao

31a. ‘Oku ke ‘ilo pe ‘oku ‘iai e Lao ki he FPM? (‘Io/’Ikai)

31b. Kapau ‘oku ‘ikai, ko e ha e ‘uhinga?

31c. Kapau ‘oku ‘io, hook ki he fehu’i 32.

32. Kataki ‘o fakaha pe ko e ha ha’o lau ki he ngaahi fakamatala ko ‘eni (Tick √)

	Ta’e tui ‘aupito ki ai	Ta’etui	‘Ikai keu ‘ilo	Tui ki ai	Tui ‘aupito ki ai
(a) ‘Oku ke kei toutai pe he FMI.					
(b) ‘Oku tauhi nai ‘e he kolo ‘a e Lao ki he FPM (kau ai ‘a e FMI)					
© ‘Oku kai toutai nai ‘a e kakai mei he ngaahi kolo kehe ‘i ho mou FPM.					

33a. ‘Oku ke kau ‘i ha ngaue faka polisi’I ‘o e FPM ? (‘Io/’Ikai).

33b.Kapau ‘oku ‘ikai, ko e ha e ‘uhinga?

34. Ko e ha ha’o lau ki he tu’unga faka le’ohi/polisi’i ‘o e FPM he kolo ni?

‘Ikai ha le’o	Le’o si’isi’i pe	Le’o pe ka ‘oku ‘ikai mahohi	Malohi ‘aupito e polokalama le’o	‘Ikai keu ‘ilo

Appendix 2

GPS coordinates of the start and end points of 50 m transects in SMAs, NTZs and comparator sites

Appendix 2 GPS coordinates of the start and end points of 50 m transects in SMAs, NTZs and comparator sites, ‘Atata, Ha’afeva, ‘O’ua, Felemea and Ovaka, Kingdom of Tonga, July 2010.

‘ATATA, TONGATAPU	Transect No.		Latitude (S)	Longitude (W)
SMA	1	Start	21° 04’ 17.0”	175° 14’ 44.1”
		End	21° 04’ 15.4”	175° 14’ 43.5”
	2	Start	21° 04’ 14.5”	175° 14’ 42.3”
		End	21° 04’ 13.9”	175° 14’ 42.3”
	3	Start	21° 03’ 46.3”	175° 14’ 55.9”
		End	21° 03’ 45.4”	175° 14’ 56.3”
	4	Start	21° 03’ 47.5”	175° 14’ 54.8”
		End	21° 03’ 48.7”	175° 14’ 53.8”
	5	Start	21° 04’ 03.8”	175° 14’ 42.2”
		End	21° 04’ 02.6”	175° 14’ 41.0”
	6	Start	21° 04’ 01.0”	175° 14’ 41.8”
		End	21° 03’ 59.2”	175° 14’ 41.7”
	7	Start	21° 03’ 57.4”	175° 14’ 44.0”
		End	21° 03’ 56.9”	175° 14’ 45.7”
NTZ	1	Start	21° 02’ 56.9”	175° 15’ 30.9”
		End	21° 02’ 56.4”	175° 15’ 32.1”
	2	Start	21° 02’ 57.3”	175° 15’ 33.0”
		End	21° 02’ 58.4”	175° 15’ 34.3”
	3	Start	21° 02’ 59.4”	175° 15’ 33.1”
		End	21° 03’ 01.0”	175° 15’ 32.4”
	4	Start	21° 03’ 02.3”	175° 15’ 33.5”
		End	21° 03’ 03.6”	175° 15’ 34.7”
	5	Start	21° 03’ 04.6”	175° 15’ 36.0”
		End	21° 03’ 05.2”	175° 15’ 37.7”
	6	Start	21° 03’ 05.8”	175° 15 ‘39.4”
		End	21° 03’ 05.0”	175° 15’ 41.0”
	7	Start	21° 03’ 06.5”	175° 15’ 42.2”
		End	21° 03’ 08.1”	175° 15’ 42.7”
Comparator site	1	Start	21° 01’ 19.2”	175° 13’ 54.1”
		End	21° 01’ 20.8”	175° 13’ 52.9”
	2	Start	21° 01’ 18.1”	175° 13’ 54.6”
		End	21° 01’ 16.9”	175° 13’ 53.2”
	3	Start	21° 01’ 16.2”	175° 13’ 55.2”
		End	21° 01’ 14.5”	175° 13’ 56.1”
	4	Start	21° 01’ 15.9”	175° 13’ 51.6”
		End	21° 01’ 14.4”	175° 13’ 51.4”
	5	Start	21° 01’ 17.5”	175° 13’ 50.6”
		End	21° 01’ 18.8”	175° 13’ 49.8”
	6	Start	21° 01’ 14.3”	175° 13’ 59.5”
		End	21° 01’ 14.9”	175° 14’ 00.9”
	7	Start	21° 01’ 14.6”	175° 14’ 03.1”
		End	21° 01’ 14.3”	175° 14’ 05.0”

Appendix 2 Continued (Ha'afeva, Ha'apai island group).

HA'AFEVA, HA'APAI	Transect No.		Latitude (S)	Longitude (W)
SMA	1	Start	19° 57' 06.4"	174° 41' 14.6"
		End	19° 57' 05.6"	174° 41' 15.7"
	2	Start	19° 57' 05.0"	174° 41' 16.4"
		End	19° 57' 04.7"	174° 41' 16.1"
	3	Start	19° 57' 02.9"	174° 41' 17.3"
		End	19° 57' 02.3"	174° 41' 15.8"
	4	Start	19° 57' 01.9"	174° 41' 14.9"
		End	19° 57' 00.0"	174° 41' 14.7"
	5	Start	19° 56' 56.0"	174° 41' 16.6"
		End	19° 56' 57.8"	174° 41' 17.9"
	6	Start	19° 56' 48.2"	174° 41' 24.1"
		End	19° 56' 46.7"	174° 41' 25.3"
	7	Start	19° 56' 46.6"	174° 41' 26.2"
		End	19° 56' 46.0"	174° 41' 27.8"
NTZ	1	Start	19° 56' 36.0"	174° 41' 39.7"
		End	19° 56' 34.7"	174° 41' 40.9"
	2	Start	19° 56' 35.0"	174° 41' 42.7"
		End	19° 56' 33.5"	174° 41' 43.5"
	3	Start	19° 56' 33.1"	174° 41' 42.7"
		End	19° 56' 31.4"	174° 41' 42.3"
	4	Start	19° 56' 31.9"	174° 41' 43.9"
		End	19° 56' 31.4"	174° 41' 45.7"
	5	Start	19° 56' 30.8"	174° 41' 43.3"
		End	19° 56' 29.3"	174° 41' 44.1"
	6	Start	19° 56' 29.4"	174° 41' 44.8"
		End	19° 56' 29.5"	174° 41' 46.5"
	7	Start	19° 56' 28.4"	174° 41' 44.6"
		End	19° 56' 27.4"	174° 41' 44.6"
Comparator site	1	Start	19° 57' 39.7"	174° 46' 08.5"
		End	19° 57' 40.7"	174° 46' 09.8"
	2	Start	19° 57' 40.6"	174° 46' 10.6"
		End	19° 57' 40.7"	174° 46' 12.3"
	3	Start	19° 57' 41.7"	174° 46 '12.5"
		End	19° 57' 41.8"	174° 46' 10.7"
	4	Start	19° 57' 41.7"	174° 46' 15.1"
		End	19° 57' 42.1"	174° 46' 17.5"
	5	Start	19° 57' 42.7"	174° 46' 18.2"
		End	19° 57' 42.6"	174° 46' 19.8"
	6	Start	19° 57' 44.0"	174° 46' 21.2"
		End	19° 57' 44.0"	174° 46' 23.2"
	7	Start	19° 57' 44.1"	174° 46' 24.1"
		End	19° 57' 44.1"	174° 46' 26.1"

Appendix 2 Continued (‘O’ua, Ha’apai island group).

‘O’UA, HA’APAI	Transect No.		Latitude (S)	Longitude (W)
SMA	1	Start	20° 03’ 35.4”	174° 39’ 27.2”
		End	20° 03’.33.9”	174° 39’ 27.7”
	2	Start	20° 03’ 36.3”	174° 39’ 26.8”
		End	20° 03’ 36.7”	174° 39’ 25.1”
	3	Start	20° 03’ 36.8”	174° 39’ 24.4”
		End	20° 03’ 37.0”	174° 39’ 22.5”
	4	Start	20° 03’ 38.1”	174° 39’ 21.7”
		End	20° 03’ 38.1”	174° 39’ 19.9”
	5	Start	20° 03’ 39.0”	174° 39’ 18.5”
		End	20° 03’ 37.2”	174° 39’ 18.8”
	6	Start	20° 03’ 40.3”	174° 39’ 18.4”
		End	20° 03’ 41.4”	174° 39’ 17.2”
	7	Start	20° 03’ 41.3”	174° 39’ 15.9”
		End	20° 03’ 42.7”	174° 39’ 16.8”
NTZ	1	Start	20° 03’ 32.1”	174° 40’ 36.0”
		End	20° 03’.31.2”	174° 40’ 37.4”
	2	Start	20° 03’ 31.1”	174° 40’ 38.6”
		End	20° 03’ 32.3”	174° 40’ 39.7”
	3	Start	20° 03’ 26.0”	174° 40’ 39.1”
		End	20° 03’ 26.3”	174° 40‘ 40.9”
	4	Start	20° 03’ 25.4”	174° 40’ 41.4”
		End	20° 03’ 25.6”	174° 40’ 43.2”
	5	Start	20° 03’ 24.2”	174° 40’ 38.5”
		End	20° 03’ 22.6”	174° 40’ 38.8”
	6	Start	20° 03’ 20.9”	174° 40’ 37.9”
		End	20° 03’ 19.4”	174° 40’ 38.0”
	7	Start	20° 03’ 18.7”	174° 40’ 39.2”
		End	20° 03’ 18.3”	174° 40’ 41.1”
Comparator	1	Start	20° 02’ 05.1”	174° 45’ 20.4”
		End	20° 02’.04.5”	174° 45’ 18.8”
	2	Start	20° 02’ 04.5”	174° 45’ 17.8”
		End	20° 02’ 05.6”	174° 45’ 16.3”
	3	Start	20° 02’ 06.1”	174° 45’ 15.1”
		End	20° 02’ 07.6”	174° 45’ 16.6”
	4	Start	20° 02 ‘08.4”	174° 45’ 14.9”
		End	20° 02’ 09.8”	174° 45’ 15.9”
	5	Start	20° 02 ‘09.6”	174° 45’ 17.2”
		End	20° 02’ 08.8”	174° 45’ 18.7”
	6	Start	20° 02’ 08.5”	174° 45’ 19.5”
		End	20° 02’ 07.4”	174° 45’ 20.9”
	7	Start	20° 02’ 06.2”	174° 45’ 24.4”
		End	20° 02’ 04.9”	174° 45’ 24.6”

Appendix 2 Continued (Felemea, Ha'apai island group).

FELEMEA, HA'APAI	Transect No.		Latitude (S)	Longitude (W)
SMA	1	Start	19° 56' 09.7"	174° 26' 12.7"
		End	19° 56' 11.2"	174° 26' 11.7"
	2	Start	19° 56' 07.7"	174° 26' 12.7"
		End	19° 56' 09.4"	174° 26' 12.1"
	3	Start	19° 56' 08.4"	174° 26' 10.8"
		End	19° 56' 09.6"	174° 26' 09.5"
	4	Start	19° 56' 05.3"	174° 26' 09.6"
		End	19° 56' 06.7"	174° 26' 09.0"
	5	Start	19° 56' 05.6"	174° 26' 06.7"
		End	19° 56' 07.0"	174° 26' 05.4"
	6	Start	19° 56' 02.4"	174° 26' 07.3"
		End	19° 56' 03.6"	174° 26' 06.0"
	7	Start	19° 56' 03.3"	174° 26' 04.7"
		End	19° 56' 04.9"	174° 26' 04.1"
NTZ	1	Start	19° 55' 25.2"	174° 25' 16.6"
		End	19° 55' 26.5 "	174° 25' 15.2"
	2	Start	19° 55' 26.8"	174° 25' 14.2"
		End	19° 55' 27.8"	174° 25' 12.9"
	3	Start	19° 55' 27.2"	174° 25' 12.7"
		End	19° 55' 26.0"	174° 25' 11.3"
	4	Start	19° 55' 25.4"	174° 25' 10.1"
		End	19° 55' 26.2"	174° 25' 08.6"
	5	Start	19° 55' 23.5"	174° 25' 12.0"
		End	19° 55' 24.1"	174° 25' 10.1"
	6	Start	19° 55' 22.7"	174° 25' 08.7"
		End	19° 55' 21.6"	174° 25' 08.1"
	7	Start	19° 55' 19.7"	174° 25' 12.2"
		End	19° 55' 21.3"	174° 25' 11.2"
Comparator site	1	Start	19° 57' 50.8"	174° 28' 14.7"
		End	19° 57' 52.3"	174° 28' 14.0"
	2	Start	19° 57' 50.7"	174° 28' 12.9"
		End	19° 57' 52.2"	174° 28' 11.8"
	3	Start	19° 57' 52.8"	174° 28' 14.7"
		End	19° 57' 54.5"	174° 28' 14.8"
	4	Start	19° 57' 52.0"	174° 28' 10.7"
		End	19° 57' 52.8"	174° 28' 09.2"
	5	Start	19° 57' 36.8"	174° 27' 45.8"
		End	19° 57' 37.8"	174° 27' 44.5"
	6	Start	19° 57' 36.5"	174° 27' 43.3"
		End	19° 57' 38.0"	174° 27' 42.4"
	7	Start	19° 57' 35.3"	174° 27' 41.5"
		End	19° 57' 36.2"	174° 27' 40.0"

Appendix 2 Continued (Ovaka, Vava'u island group).

OVAKA, VAVA'U	Transect No.		Latitude (S)	Longitude (W)
SMA	1	Start	18° 46' 00.4"	174° 05' 08.8"
		End	18° 46' 02.0"	174° 05' 08.7"
	2	Start	18° 46' 00.0"	174° 05' 07.2"
		End	18° 46' 01.3"	174° 05' 06.1"
	3	Start	18° 45' 58.8"	174° 05' 05.7"
		End	18° 45' 58.8"	174° 05' 03.9"
	4	Start	18° 45' 56.9"	174° 05' 02.6"
		End	18° 45' 58.3"	174° 05' 01.7"
	5	Start	18° 45' 55.9"	174° 05' 00.8"
		End	18° 45' 57.1"	174° 04' 59.7"
	6	Start	18° 45' 55.5"	174° 04' 59.2"
		End	18° 45' 56.6"	174° 04' 57.8"
	7	Start	18° 45' 55.3"	174° 04' 56.7"
		End	18° 45' 55.7"	174° 04' 54.9"
NTZ	1	Start	18° 45' 42.5"	174° 05' 42.9"
		End	18° 45' 43.4"	174° 05' 44.2"
	2	Start	18° 45' 41.8"	174° 05' 42.4"
		End	18° 45' 41.4"	174° 05' 44.0"
	3	Start	18° 45' 39.6"	174° 05' 42.6"
		End	18° 45' 39.8"	174° 05' 43.9"
	4	Start	18° 45' 38.0"	174° 05' 45.8"
		End	18° 45' 38.4"	174° 05' 45.8"
	5	Start	18° 45' 36.8"	174° 05' 44.3"
		End	18° 45' 36.4"	174° 05' 46.1"
	6	Start	18° 45' 35.3"	174° 05' 45.0"
		End	18° 45' 34.5"	174° 05' 46.6"
	7	Start	18° 45' 34.2"	174° 05' 45.6"
		End	18° 45' 32.5"	174° 05' 46.5"
Comparator site	1	Start	18° 46' 06.4"	174° 00' 15.4"
		End	18° 46' 04.9"	174° 00' 14.4"
	2	Start	18° 46' 07.5"	174° 00' 14.1"
		End	18° 46' 06.2"	174° 00' 12.9"
	3	Start	18° 46' 06.4"	174° 00' 11.9"
		End	18° 46' 07.1"	174° 00' 10.2"
	4	Start	18° 46' 08.1"	174° 00' 08.8"
		End	18° 46' 09.7"	174° 00' 09.7"
	5	Start	18° 46' 10.2"	174° 00' 08.7"
		End	18° 46' 11.3"	174° 00' 07.0"
	6	Start	18° 46' 08.8"	174° 00' 07.8"
		End	18° 46' 07.7"	174° 00' 06.1"
	7	Start	18° 46' 10.3"	174° 00' 05.4"
		End	18° 46' 09.4"	174° 00' 03.8"

Appendix 3

Local fisher’s questionnaire

Liliu í he tuúnga ó e toutai í he tui á e kau toutai tahi í Tonga

Fehuí ki he kau toutai

Hingoa:	
Áho:	
Áho faéleí;	Taú naé kamata toutai ai:

Konga A – Tuúnga óku íai a'e e mahu ó e ika mamaha:

1. Kataki ó lisi mai á e faáhinga ika óku ke tui óku holo hono lahi, pea moe taú .oku ke fakafuofua naé kamata ai á e holo koéni?

Depleted	Hingoa é faáhinga ika	Taimi (ofitaha ki he taú é 5)
1.		
2.		
3.		
4.		
5.		
6.		
7		
8		
9		
10		
11		
12		
13		

* (Confirm the fish species name given with the card/picture.)

2. Fakapapauí óku tonu á e faáhinga ika óku holo (í ólunga) pea fehuí ki he tangata toutai á e ngaahi fehuí í lalo.

a. Ko e ha á e lahi taha kuo ke maú? (lahi ó e mataíika)? Ko e taú fe naáke maú ai éni?

b. Naáke maú fakamuimui taha áne fe á e ola ko éni?

c-g. Óku k etui (hingoa ó e faáhinga ika) óku, lahi, siísií, íkai ha liliu í he taimi ni fakahoa ki he taú é 40, 20, 10, 5, 2 kou hili? Tohií óku lahi, siísií pe íkai ha liliu í he lolotonga ni.

#	Faáhinga ika	a) Óla lahi taha	b)Faka muimu i taha	c)Lahi he loloton ga/40	d) Lahi he lolotong a/20	e) Lahi he lolotong a/10	f) Lahi he lolotong a/5	g) Lahi he loloton ga//2
1								
2								
3								
4								
5								
6								

3. Hoko atu mei ólunga, fehuí ki he tangata toutai á e lalahi ó e faáhinga ika pea hiki he tepile í lalo.

a. Koe ha á e mataíika Loloa taha kuo ne ósi maú? (ngaueáki ho nima pe tepi fua ke fakafuofuaí e Loloa ó e ika). Taú naáke maú ai?

b. Taú naáke maú fakamuimui taha ai á e kalasi koéni?

c-g. Óku k etui (hingoa ó e faáhinga ika), lalahi ange, iiki ange pe íkai ha liliu he lolotonga ni fakahoa ki he taú e 40, 20, 10, 5, 2 kuo hili? Tohií lalahi ange, iiki anga pe íkai liliu he lolotonga ni.

#	Hingoa	a) lalahi (cm)	b)maú fakamuimui (year)	c)lalahi he lolotonga/40 years	d) lalahi he lolotonga /20 years	e) lalahi he lolotonga/10 years	f) lalahi he lolotonga/5 years	g) lalahi he lolotonga /2 years
1								
2								
3								
4								
5								
6								

4. Fehuí felaveí mo e ivi toutai.

a) Óku k etui óku mamaó ange, ofi ange pe íkai ha liliu í he faiánga toutai he lolotonga ni fakahoa ki he taú é 40, 20, 10, 5, 2? Tohií mamaó ange, ofi ange pe íkai ha liliu he lolotonga ni?

	Íkai liliu	Mamaó he lolotonga ni/40 years	Mamaó he lolotonga ni /20 years	Mamaó he lolotonga ni /10 years	Mamaó he lolotonga ni /5 years	Mamaó he lolotonga ni /2 years
Faiánga toutai						

b) Óku ávalisi ki he tuófiha hoó toutai he uike he lolotonga ni fakahoa ki he taú é 40, 20, 10, 5, 2 kuo hili? Tohií á e lahi he uike.

	Íkai ha liliu	Tuófiha he uike /40 years	Tuófiha he uike /20 years	Tuófiha he uike /10 years	Tuófiha he uike /5 years	Tuófiha he uike /2 years
Tuófiha he uike						

c) Óku ke tui ko e ávalisi hoó taimi toutai (houa) óku Loloa ange, nounou ange pe íkai ha liliu he lolotonga ni fakahoa ki he taú é 40, 20, 10, 5, 2 kuo hili? Tohií Loloa ange, nounou ange pe íkai ha liliu he lolotonga ni?

	Íkai liliu	Taimi toutai /40 years	Taimi toutai /20 years	Taimi toutai /10 years	Taimi toutai /5 years	Taimi toutai /2 years
Ávalisi taimi toutai						

d) Ko e ha á e ávalisi ó e ola hoó toutai (kg) he foí folau toutai é taha he lolotonga ni fakahoa ki he taú 40, 20, 10, 5, 2 kuo hili? Tohií á e lahi ó e ola óe toutai (kg) he folau toutai é taha.

	Íkai ha liliu	Lahi ó e toutai /40 years	Lahi ó e toutai /20 years	Lahi ó e toutai /10 years	Lahi ó e toutai /5 years	Lahi ó e toutai /2 years
Ávalisi lahi e ola ó e toutai						

Konga B – Faáhinga ika óku toutai;I, mahuínga mo e lahi

5. Ko e ha á e faáhinga ika óku lahi taha hono mau í hoó toutai, mahuínga ki he tangata toutai, pea mo e lahi (mahu). Hiki fakatatau ki he lahitaha hono maú, mahuínga lahi taha, mo e tuúnga mahu.

#	Hingoa	Lahi hono maú (1=most common, 5 least common)	Mahuínga (1=Highest, 5 Lowest)	Tuúnga mahu (very rare, there are some, few, many
1				
2				
3				
4				
5				

6. Ko e ha á e faáhinga ikaé 5 óku lahi taha hoó maú í hoó toutai?

	Now	2 years ago	5 years ago	10 years ago	20 years ago	40 years ago
1						
2						
3						
4						
5						

7). a. Ko e ha hoó úhinga ki he liliu he tuúnga mahu ó e ika?

b. Ko e ha hoó úhinga ki he liliu í he ola hoó toutai?