Designing marine protected areas that are ecologically representative and socially equitable

by

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B.Sc., McGill University, 2010

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Supervisory Committee

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Abstract

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The overexploitation of coastal ecosystems continues to threaten global biodiversity and fisheries. This has prompted international conservation commitments, such as the Convention of Biological Diversity's Aichi Target 11, to improve the coverage and integrity of marine protected area (MPA) networks worldwide. As reflected in Target 11, MPA networks need to be both ecologically representative and socially equitable. Systematic conservation planning (SCP) is an effective and efficient process for designing MPA networks to achieve biodiversity targets at minimal impacts to society. However, SCP has rarely been used effectively to develop MPA networks in developing nations. Three key challenges contribute to this 'research-implementation' gap: (1) SCP research concepts and tools are biased towards developed countries, (2) complete and high-quality datasets are lacking in developing countries, and (3) socioeconomic complexities and needs of stakeholders tend to be oversimplified.

In working towards addressing these challenges, this thesis focuses on Sogod Bay as a Philippines case study to examine the following overarching research question "**How can systematic conservation planning be applied as a framework for designing MPAs to achieve national biodiversity objectives in a manner that is socially equitable and accommodating to the needs of coastal communities?"**. To help answer this question, the thesis addresses three research objectives:

1. Develop and document strategies for incorporating dimensions of equity (recognition, procedural, and distributive) for stakeholders and coastal communities in the planning stages of SCP.

2. Investigate how recognition and procedural equity can impact the systematic design of MPA plans in terms of biodiversity representation, spatial efficiency, and distributive equity for fisher stakeholder groups and communities.
3. Evaluate and compare MPAs designed using a SCP approach with more conventional planning approaches in terms of their impacts on representation and social equity.

Objective one and two were assessed in Chapter two of this thesis. The findings of this chapter demonstrate how equity considerations can be integrated in the planning stages of SCP though consulting with local partners; integrating science-driven and participatory approaches; recognizing the key stakeholder groups of MPAs (recognition equity); engaging with representatives of each stakeholder group and community to inform MPA planning processes (procedural equity), and distributing costs of MPAs fairly across all stakeholder groups and communities (distributive equity). Additionally, the chapter demonstrates how inadequate inclusion of stakeholders and/or the variations between communities can disproportionately impact some fishers and communities more than others.

Objective three was achieved through the findings of Chapter three, which investigated impacts on representation and equity from MPA plans derived under a SCP approach and two conventional planning approaches. MPAs planned and selected by communities resulted in inadequately representation and unfair distributions of costs across fisheries and community. A donor-assisted approach that used local knowledge to select MPAs resulted in a plan with near-optimal representation but was inequitable for fisheries and communities. The SCP approach was the only approach to produce a representative and equitable MPA plan, thus highlighting the utility of SCP for achieving the representation and equity aspects of Target 11.

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List of Common Acronyms

CBD	Convention of Biological Diversity
CCC	Coral Cay Conservation
CMFO	Comprehensive Municipal Fisheries Ordinance
CTI/CTI-CFF	The Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security
FARMC	Fisheries and Aquatic Resources Management Councils
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
KBA	Key biodiversity areas
LGU	Local government unit
MAO	Municipal Agricultural Office
MPA	Marine protected areas
MPDO	Municipal Planning and Development Office
NAMRIA	The Philippines' National Mapping and Resource Information Authority
NGO	Non-government organization
PAME	The Protected Area Management Enhancement Project
PENRMO	Provincial Environment & Natural Resources Management Office
PGIS	Participatory geographic information systems
SCP	Systematic conservation planning
SMSMMA	Sogod Bay Sustainable Marine Management Alliance

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Chapter 1 : Introduction

Coastal ecosystems and fisheries are in continuous decline worldwide due to an array of anthropogenic threats including overfishing, habitat degradation, population growth, and climate change. These threats will continue to perpetuate declines unless urgent actions are taken (Butchart et al., 2010; Halpern et al., 2015; Pauly and Zeller, 2016).

The establishment of effectively managed marine protected areas (MPAs) is a proven method for conserving biodiversity and safeguarding important ecosystem services. Consequently, the global expansion of MPAs is a primary focus of global conservation efforts (Watson et al., 2014). Most countries have committed through Aichi Target 11 of the Convention on Biological Diversity to conserve at least 10% of their coastal and marine areas in MPAs by 2020. In addition to the areal target, the Aichi target states that conserved areas must be "ecologically representative" (must contain adequate samples of a full range of ecosystems), "equitably managed" (effectively managed with the full participation of local communities and equitable distribution of costs and benefits) and should include areas of "particular importance for biodiversity and ecosystem services" (CBD, 2010). There has been some progress in the global drive to achieve the areal target of Target 11 (Butchart et al., 2015), although less is known on how national efforts and actions to expand and allocate MPAs will affect other elements of the target such as representation and equity (Rees et al., 2017).

The use of systematic conservation planning (SCP) is increasingly recognized as an effective strategy for planning MPAs that addresses multiple elements of Target 11 (Bicknell et al., 2017; CBD, 2012a). SCP can assess and address gaps in representation and support the development and implementation of new MPAs to meet conservation targets at potentially minimal costs to resource users (Margules and Pressey, 2000). However, there are unresolved issues and ongoing challenges associated with applying SCP in developing nations (Ban et al., 2011; Mills et al., 2010; Weeks et al., 2014b).

This introductory chapter is divided into eight sections. The first two sections review some of the benefits and challenges of MPAs, while highlighting the need to scale up current MPAs into networks that are ecologically representative and socially equitable. The next two sections set the context for the research by reviewing past and current trends in SCP while highlighting key limitations that will be addressed in this work. Section five outlines the overall research question, specific objectives, and section six describes the structure of the thesis. The following section describes the importance of this work in the study area and within the context of the Philippines. Finally, section eight introduces the methods and data used to address the research objectives.

1.1. Marine Protected Areas

Marine protected areas (MPAs) are employed worldwide as a management tool to conserve marine biodiversity and manage fisheries (Walton et al., 2014; White et al., 2014). MPAs include “any clearly defined geographical space, recognised, dedicated, and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values” (IUCN-WCPA 2008:3). Through conserving components of biodiversity (e.g., life stages, species, habitats) and providing refuges for overexploited and vulnerable species, MPAs increase species abundance, body size, life expectancy, and reproductive success (Claudet et al., 2008; Lester et al., 2009). MPAs range from highly protected no-take MPAs that prohibit all forms of extraction, to multi-use MPAs that include multiple zone uses (recreation, research, limited harvesting, etc.). Hence, the term “MPA” embraces a wide range of management objectives (six management categories recognized by the IUCN), governance systems (e.g., governance by government, or local communities), and management approaches (IUCN-WCPA 2008:3).

MPAs can have both positive and negative implications for resource users and communities (Gaines et al., 2010a). In addition to maintaining ecosystem services (e.g., coastal protection), MPAs can provide a range of benefits for fisheries. They can support the recovery of overharvested species by protecting important breeding, nursery, and feeding habitats (Gaines et al., 2010a; Russ et al., 2008). There is evidence that they may enhance fisheries productivity through the spillover of larvae and adults into unprotected areas (Russ and Alcala, 2004). However, the initial implementation of MPAs can cause negative impacts to fishers by limiting their access to coastal and marine areas (Christie, 2004). MPAs can have significant impacts (e.g., spatial restrictions on resources, loss of revenue, displacement effects) on local fishers (Christie, 2004; Mascia et al., 2010), although the significance of these impacts may not be uniform among individuals, stakeholder groups, and communities (e.g., Fabinyi et al., 2010).

The disproportionate distribution of costs and benefits of MPA establishment can cause issues with equity (Halpern et al., 2013). Equity concerns associated with MPAs may also arise when stakeholders are included and considered in planning and decision-making processes inadequately (Bennett and Dearden, 2014; Schreckenberg et al., 2016). Inequity has been shown to lead to conflict, noncompliance with MPA rules, and reduced local support towards MPAs, all of which can lead to MPA failure (e.g., Christie, 2004; Fabinyi et al., 2010). In contrast, MPA plans that are designed to address equity considerations explicitly, such as equitable division of costs and adequate inclusion and participation of all relevant stakeholders, are more likely to succeed (e.g., Bennett and Dearden, 2013; Guidetti and Claudet, 2010; Hill et al., 2016; Olsen et al., 2014).

1.2. Scaling Up to Representative and Equitable Networks

Current management systems, including the global coverage and distribution of MPAs, are failing to maintain the biological diversity and productivity of marine and coastal ecosystems. This is in large part due to impacts from overfishing by both commercial and small-scale fisheries (Butchart et al., 2010; Pauly and Zeller, 2016; Worm et al., 2006). Human population growth continues to fuel the global demands for seafood, despite continuous and widespread declines in fish catch and fishing productivity. In addition to other anthropogenic stressors (e.g., pollution, coastal development, climate change), overfishing poses a serious threat to the persistence of marine biodiversity and the sustainability of fisheries worldwide (Halpern et al., 2015).

In response to declines in biodiversity and fisheries, most countries have committed, through the Convention of Biological Diversity's (CBD) Aichi Target 11, to conserve at least 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, through "effectively and equitably managed, ecologically representative and well-connected systems of protected areas" (CBD, 2010). In contributing towards this target, countries signatory to the CBD have set their own national targets, with most adopting 10% or more (CBD, 2012a). Target 11 addresses multiple components of MPAs, including coverage, connectivity, representation, management, governance, and equity (Woodley et al., 2012). This research will focus on two key aspects of the Target: representation and equity.

Representation encompasses two fundamental principles of conservation planning: comprehensiveness and representativeness. MPAs are representative of biodiversity when they contain all biodiversity features that occur within a planning region (comprehensiveness), along with a range of variations within each feature (representativeness) (Margules and Pressey, 2000; Possingham et al., 2005). Representation can be measured in numerous ways, although it is often measured in terms of abundance, density, probability of occurrence, or habitat coverage (Kukkala and Moilanen, 2013). Ideally, MPAs would represent all biological compositions (genetic, species, and community diversity), structures (physical organisation), and functions (ecological and evolutionary processes) of ecosystems (Green et al., 2014). However, complete and good quality data on biodiversity is rare. In practice, designing representative MPAs is frequently conducted though representing adequate samples of certain natural features that can act as reasonable surrogates for biodiversity (Kukkala and Moilanen, 2013). For instance, setting quantitative targets for major habitat types (e.g., coral reefs, seagrass beds, mangroves) is often used to design MPAs, since it is generally assumed that protecting different types of habitats will also protect many species, communities, and biophysical features (Green et al., 2014).

The Aichi Target 11 calls for "effective and equitably managed" systems of protected areas, highlighting the importance of equity in MPA planning and management (Woodley et al., 2012). Woodley et al. (2012) state that this wording means that protected areas must include the needs and rights of stakeholders. Furthermore, the authors argue that "effectiveness and equity are both different and essential elements of protected area management, and as such, should be treated separately" (Woodley et al., 2012 p.30). Expanding the coverage and representation of global systems of MPAs in a socially equitable fashion will require sharing costs and benefits amongst marine users, along with greater engagement and participation of a wide range of stakeholders, including local communities, government agencies, non-government organizations, and private organizations (Hill et al., 2016; Rees et al., 2017; Schreckenberg et al., 2016; Woodley et al., 2012).

Distributive equity (fair distribution of costs and benefits amongst stakeholders) is commonly associated with the term equity in the MPA literature in recognition of how inequitable distributions of cost can impede the management effectiveness of MPAs. Furthermore, many authors have discussed the importance of stakeholder engagement and participation in the design, implementation, and management of MPAs (Hill et al., 2016; Rees et al., 2017; Schreckenberg et al., 2016), which relates to recognition equity (recognition of the rights, values, interests and priorities of different stakeholders) and procedural equity (full and effective participation of all relevant actors in decision-making processes) (Schreckenberg et al., 2016). Despite widespread recognition of equity, there are few studies that have investigated dimensions and considerations of equity in the planning phase of developing MPAs (Halpern et al., 2013).

Planning MPAs that achieve the representation and equity aspects of Aichi Target 11 will be a challenging process. It involves addressing a series of trade-offs that must be balanced to achieve adequate coverage, representation, and equity (Rees et al., 2017; Stewart and Possingham, 2005). Increasing the overall coverage and ecological representation of MPAs will inevitably increase the number of people and communities that interact with MPAs. The magnitude and extent of impacts on stakeholders can vary dramatically depending on the MPA planning process or strategy employed (Mascia et al., 2010; Mascia and Claus, 2009). For example, increasing the size of current MPAs to form large MPAs may be ecologically optimal, but economically or institutionally impractical. A more realistic alternative may be to increase the number of smaller MPAs to form representative networks, and where possible, increase the size of MPAs in areas with low socioeconomic costs (IUCN-WCPA 2008; Lowry et al., 2009).

MPA networks consist of collections of individual MPAs that operate cooperatively and synergistically, at various spatial scales, to broaden ecological and socioeconomic benefits beyond the limitations of individual MPAs (IUCN-WCPA, 2008: 12). Hence, scaling up existing MPAs into well-designed MPA networks is being widely promoted by academics, and resource managers alike (Almany et al., 2009; Grorud-Colvert et al., 2014; IUCN-WCPA 2008; McCook et al., 2009).

Designing MPA networks requires careful planning. In order to be ecologically effective, MPA networks need to incorporate ecological principles (e.g., representativeness, connectivity, resilience) into their design parameters (e.g., size, shape, and spacing) (see review by Green et al., 2014). At the same time, there is a need to design MPAs that reflect the local context and accommodate the needs of multiple users and communities (Lunn and Dearden, 2006).

Systematic and science-based approaches can facilitate the design of MPA networks to balance conflicting needs between conservation and society (Margules and Pressey, 2000; Pressey and Bottrill, 2009). The next section provides a brief introduction to these approaches.

1.3. Systematic Conservation Planning

Systematic conservation planning (SCP) is a science-driven process of locating, configuring, and designing protected area networks that represent the biodiversity of a particular region of interest comprehensively (Margules and Pressey, 2000). It is a major departure from conventional ad-hoc and site-by-site MPA planning approaches, which have often been applied to select conservation areas based on urgency, scenery, and ease of designation (Kukkala and Moilanen, 2013). In contrast, SCP is a field of conservation science to select and configure MPA networks strategically with the aim of achieving explicit and quantifiable biodiversity objectives with minimal resources and/or costs to society (Margules and Pressey, 2000). In recognition that social factors have a profound influence on the success of conservation actions (Hughes et al. 2005, Cinner et al. 2009), systematic planning has changed from a process that was initially ecologically-focused (Margules and Pressey 2000) to one that now incorporates social, economic, political, and governance considerations (Pressey and Bottrill 2009). These changes reflect a new paradigm in conservation science of recognizing MPAs as social-ecological systems, where interactions between human and natural systems are linked at various spatial,

1. Scoping and costing the planning process
2. Identifying and involving stakeholders
3. Describing the context for conservation areas,
4. Identifying conservation goals
5. Collecting data on socio-economic variables and threats
6. Collecting data on biodiversity and other natural features
7. Setting conservation objectives (spatially explicit targets)
8. Reviewing current achievement of objectives
9. Selecting additional conservation areas
10. Applying conservation actions to selected areas
11. Maintaining and monitoring conservation areas

Figure 1.1. Systematic conservation planning framework. The framework contains 11 stages outlining the main components of conservation planning (adapted from Pressey and Bottrill, 2009).

temporal, and organisational scales (Cinner et al., 2009). The modified SCP framework contains 11 stages that outline the main stages of designing, implementing, and monitoring protected areas (Figure 1.1).

This research will focus on the planning phases of SCP (stage 1-9), particularly regarding the selection of new MPAs to achieve conservation objectives (stage 9). Spatial conservation prioritisation (hereafter 'spatial prioritization') is a key component of SCP (Margules and Pressey, 2000). This 9th stage of SCP involves using spatial prioritization tools — such as Marxan (Ball et al., 2009), Zonation (Moilanen et al., 2005), and C-Plan (Pressey et al., 2009) — integrated with biological and socioeconomic data, to identify priority conservation areas that can achieve spatially explicit biodiversity objectives while minimizing costs to society (Margules and Pressey, 2000; Pressey and Bottrill, 2009). Consisting of a suite of spatial prioritization tools, Marxan is the most widely utilised spatial prioritization software in the world (Ball et al., 2009). As with other decision-support tools, Marxan is not intended to produce a "final" MPA network plan. Rather, it serves to produce transparent and repeatable results that provide multiple MPA configuration options. These outputs can serve to (1) evaluate and compare alternative MPA plan options for conservation, (2) highlight areas that occur in multiple network options, and (3) identify set priorities for future conservation initiatives (Ball et al., 2009). Furthermore, it can be used to incorporate core conservation planning concepts into the design of MPA networks, including complementarity and representativeness (Kukkala and Moilanen, 2013; Possingham et al., 2005).

Growing recognition of the influence of socioeconomic factors in MPA planning, management, and implementation has spurred several publications in the SCP literature advocating for the need to improve methods for incorporating socioeconomic factors into spatial prioritization. A notable contribution of these publications has been the shift from treating socioeconomic factors as a 'cost' to treating them as 'objectives'. To understand this shift, it is important to recognize that SCP concepts and tool have evolved from the natural sciences as a branch of conservation science. Consequently, early applications of SCP focused purely on nature conservation. Socioeconomic factors were typically viewed as 'costs' to minimize whilst achieving conservation objectives. Accordingly, many of the popular spatial prioritization tools (e.g., Marxan, C-Plan, Zonation) employed worldwide were specifically designed to minimize an index of cost whilst aiming to meet set conservation targets. The disadvantage of these tools is it only permitted a single layer of cost per assessment (Ban and Klein, 2009a).

There are two main ways that socioeconomic considerations have been addressed using a 'cost' approach. The first is based on minimizing socioeconomic costs associated with MPAs through minimizing area cost based on the assumption that MPA plans with the least total area set aside for conservation will be most feasible to implement. The second is through using a single cost layer to reflect one or more socioeconomic costs (e.g., acquisition costs, management costs, and opportunity costs). The assumption here is that plans with the least total socioeconomic cost will be have the least impacts on stakeholders. The assumptions of 'cost' approaches are clearly flawed because they: (1) fail to account for spatial variations in how resource users access, use, and depend on marine resources, and (2) are limited to using a single cost layer that is unlikely to reflect multiple stakeholders and socioeconomic factors (Ban and Klein, 2009a).

More recently, an advancement in spatial prioritization software (Marxan with Zones; Watts et al., 2009) has provided a means to design MPAs systematically based simultaneously on conservation and socioeconomic objectives. As demonstrated in recent studies, treating socioeconomic factors as 'objectives' rather than 'costs' results in more socially equitable MPA plans (Gurney et al., 2015a; Klein et al., 2010; Weeks et al., 2010b). However, there is still a need to investigate how different approaches for integrating socioeconomic information in spatial prioritization can impact different stakeholder groups and their communities, especially in developing countries where access to marine resources is critical for the food security and livelihoods of coastal communities (Ban et al., 2011). In sum, there remain gaps in research on how to apply SCP in the socioeconomic context of a developing nation, as will be discussed in the following section.

1.4. The Research-Implementation Gap

There is a commonly perceived disconnect between conservation science and practice (Knight et al., 2009; Weeks et al., 2014b). A decade ago, Knight et al. (2008) found that only 6% of spatial prioritization assessments in the peer-reviewed literature have informed on-the-ground conservation actions, highlighting a clear gap between conservation science and action. To determine whether progress has been made to bridge this gap, Sinclair et al. (n.d.) recently surveyed 161 individuals from 64 countries and 9 multinational areas who had conducted a spatial prioritization activity as of 2002. The authors found that 58% of spatial prioritizations (including peer-reviewed and grey literature) were intended for implementation, and that 74% of these implementation-focused prioritizations have translated to conservation action. Additionally, the authors highlight how approaches in implementation-focused prioritizations tend to align with recommendations in the literature that call for stakeholder involvement in the planning process, identification and collaboration with end users early in the process, and the production and delivery of supporting products in a user-useful format. These findings suggest that there has been considerable progress towards bridging the gap between conservation research and practice, whereby spatial prioritization tools embedded in the SCP framework are contributing towards guiding conservation decisions in various countries. However, most reported prioritizations covered terrestrial (57%) realms and were developed for areas within America (24%), Australia (10%), Canada (5%), and South Africa (5%) (Figure 1.2). The "research-implementation" gap remains readily apparent in the Coral Triangle (Weeks et al., 2014b), which is recognised as an epicentre for marine biodiversity and a global conservation priority (Allen, 2008). This region contains the waters of six developing countries: Indonesia, Timor-Leste, Solomon Islands, Malaysia, Papua New Guinea, and the Philippines.

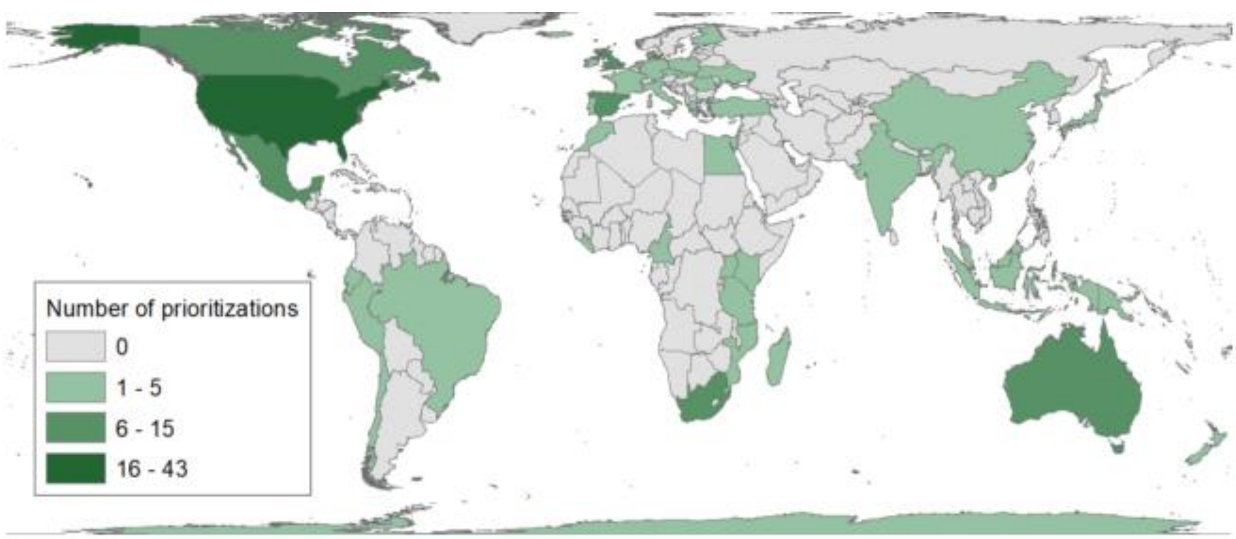

Figure 1.2. The global distribution of spatial prioritizations. The map by Sinclair et al. (n.d.) is based on survey responses of individuals (n=161) who have conducted prioritizations between 2002 and 2017. Most prioritizations were developed for areas within the USA (24%), Australia (10%), and South Africa (5%). Reported prioritizations covered terrestrial (57%), marine (16%), freshwater (16%) and coastal (11%) realms.

There are several factors contributing to the gap between SCP research and MPA implementation in the Coral Triangle, many of which are also present in other developing countries (Ban et al., 2011; Weeks et al., 2014a, 2014b). Three key challenges associated with the SCP planning stages are: (1) SCP research concepts and tools are biased towards developed countries, (2) complete and high-quality datasets are lacking in developing countries, (3) socioeconomic complexities and needs of stakeholders tend to be oversimplified.

1. **SCP research concepts and tools are biased towards developed countries.** The geographic origin of systematic planning concepts and tools originated from developing countries (i.e., North America, Europe, and Australia). Most studies relating to SCP assesments have focused on developed countries (Ban and Klein, 2009a; Kukkala and Moilanen, 2013; Sinclair et al., n.d.). This bias towards developed countries has limited the application of SCP approaches in developing nations with very different social, economic, governance, and political characteristics (Ban et al., 2011). Hence, future studies should aim to provide guidelines on how to adapt and apply SCP effectively to the context of developing nations (Knight et al., 2009, 2008; Weeks et al., 2014). For example, SCP has mainly been conducted at large scales (e.g., national or provincial level; bioregion) in developed countries to capture a full range of marine species, communities, ecological processes, and threats occurring across various spatial and temporal extents (Ban et al., 2011; CBD, 2012b; Mills et al., 2010). Regional MPA network plans in developed countries can be implemented through centralized means that typically involve one or a few governance authorities (CBD, 2012b). However, implementing regional plans in developing countries can be extremely difficult, particularly in countries in the Coral Triangle with decentralized governance systems (i.e., local tenure systems). The lack of scientific knowledge and guidance on how to adapt SCP approaches to the context of developing countries has been flagged as critically in need of research (Ban et al., 2011).

2. **Complete and high-quality datasets are lacking in developing countries.** Spatially explicit data on relevant biodiversity features (e.g., distribution of focal species, habitat types, and ecological processes) and socioeconomic features (e.g., tenure, use patterns of resource users, and existing conservation sites) are required in spatial prioritization to meet conservation objectives (Pressey and Bottrill, 2009). Thus, gaps in the quality, resolution,

and coverage of spatial data can compromise SCP (Ball et al., 2009; Mills et al., 2010). In general, large planning regions will have consistent data only at coarse resolution, while coverage of fine-resolution data will only be available at some locations and are generally patchy and incomplete over a planning region (Mills et al., 2010; Weeks et al., 2014b). While this issue is present in many countries, data gaps are especially prevalent in developing countries due to limited capacity and resources (Weeks et al., 2014b). Coarse data can fail to reflect the variability of natural and human attributes of a planning region (Weeks et al., 2014b), and incomplete datasets can introduce sampling bias in computing tools such as Marxan (i.e., they cause the algorithm to gravitate towards data-rich areas) (Grand et al., 2007). In the absence of empirical data, surrogates may be used as proxies for biodiversity (e.g., habitat types) and socioeconomic factors (e.g., number of boats), so long as they can reflect adequately the features they are meant to represent. Nonetheless, the use of untested surrogates in the absence of available data is prevalent in many SCP studies and applications. Untested surrogates add uncertainties in planning processes and can compromise the integrity of MPA plans and unforeseen consequences such as inequity issues (Ban and Klein, 2009b; Rodrigues and Brooks, 2007). The collection of new fine-resolution data could address gaps in available data, but this is often difficult due to resources (time, cost, expertise) and capacity limitations of many developing countries (Gill et al., 2017; Mills et al., 2010; Weeks et al., 2014b). Hence, the application of SCP in developing nations will largely depend on finding cost-efficient data collection methods and/or reliable surrogates for biodiversity and socioeconomic features.

3. **Socioeconomic complexities and stakeholders needs tend to be oversimplified.** As stated in the previous section, most studies to date have either assumed that socioeconomic factors are homogenous throughout the planning region or have only considered one or a few stakeholder groups (Ban et al., 2011). Recently, advancements in spatial prioritization tools have provided a means to produce more equitable plans that consider multiple stakeholders. While recent publications have demonstrated how Marxan with Zones can facilitate more equitable plans, their authors often state that the socioeconomic data used in their assessments cannot reliably reflect variations among marine users or communities. Insufficient consideration of the needs of different users and communities may result in MPA network plans that impact some people and groups disproportionately more than others

(Gurney et al., 2015a). This can be especially disastrous for poor and marginalized individuals and groups that are highly dependant on natural resources (Christie, 2004). Still, many studies have neglected to address these potential adverse outcomes and continue to oversimplify socioeconomic information or use untested surrogates in the absence of data (Ban et al., 2011; Weeks et al., 2010c). Hence, developing and testing methods for integrating socioeconomic features and equity considerations into SCP is essential to inform better decisions on how to reflect socioeconomic complexities adequately and realistically (Halpern et al., 2013; Rees et al., 2017).

1.5. The Research Question and Objectives

This thesis focuses on Sogod Bay as a Philippines case study to examine the following overarching question: **How can systematic conservation planning be applied as a framework for designing MPAs to achieve national biodiversity objectives in a manner that is socially equitable and accommodating to the needs of coastal communities?** In working towards answering this research question, this thesis set out to achieve three major research objectives. Together, the objectives address the knowledge gaps and three key challenges contributing to the 'research-implementation' in SCP as listed in the previous section. The objectives are:

1. Develop and document strategies for incorporating dimensions of equity (recognition, procedural, and distributive) for stakeholders and coastal communities in the planning stages of SCP.
2. Investigate how recognition and procedural equity can impact the systematic design of MPA plans in terms of biodiversity representation, spatial efficiency, and distributive equity for fisher stakeholder groups and communities.
3. Evaluate and compare MPAs designed using a SCP approach with more conventional planning approaches in terms of their impacts on representation and social equity.

As reflected in the above objectives, this thesis serves to improve our understanding on the ecological and socioeconomic implications of different MPA planning approaches, with a focus on biodiversity representation and social equity. Additionally, it provides important lessons on how SCP approaches should be applied in the context of developing nations. The following section provides background on marine conservation in the Philippines and on the study area in particular.

1.6. Study Area Context

The Philippines

The Philippines archipelago lies within the Coral Triangle making it an epicenter for marine biodiversity and a global priority region for conservation (Carpenter and Springer, 2005). The country is made up of over 7,100 islands with a coastline that has more than 26,000 km^2 of coral reefs (9% of global total), 2,500 km^2 of mangrove forests, and 1,000 km^2 of seagrass beds (Burke et al., 2012; Carpenter and Springer, 2005; White et al., 2014). These ecosystems support the highest concentration of marine shore fishes (approximately 1,700 species) on the planet, in addition to over 400 species of hard coral (Scleractinia), 40 species of mangroves, and 16 species of seagrass. Coastal ecosystems also provide important ecosystem services (e.g., coastal protection, food security, and employment) to millions of Filipinos, particularly small-scale fishers who depend directly on them for food security and income (Burke et al., 2012).

Despite over 30 years of practice, coastal resource management practices in the Philippines have not been able to keep up with increasing declines in fisheries and coastal habitat degradation, particularly coral reef and mangrove habitat (Burke et al., 2012). There are numerous anthropogenic threats contributing to these declines including rapid coastal development, poor land-use practices, various forms of pollution, illegal and destructive fishing practices, overfishing, and climate change (CTI-CFF, 2009a; Nanola et al., 2010; Wilkinson, 2008). The average daily catch of small-scale fishers has been declining continuously in the past 50 years despite improvements in fishing strategies (e.g., improvements in fishing gear technology), and increases in the number of small-scale fishers[1] (Muallil et al., 2014a). The fisheries decline has perpetuated poverty in coastal communities, which in turn, has intensified destructive fishing practices such as blast fishing and poison fishing. These practices provide short-term financial

[1] According to a study by Muallil *et al.* (2014a), the average daily catch rate (16.3 ± 39.8 kg/trip) of 20 coastal municipalities surveyed in the Philippines have declined in the last five decades. Relative to current catches, catches have decreased by 16 ± 14% from 2000–2010 and 24 ± 13–26 ±19% of catch rates in the preceding four decades. The authors suggest that the relatively more stable catches from 2000-2010 could be attributed to the improvement in fishing strategies and technologies employed by fishers to maximize catch rates even as the fish stocks continue to decline.

gains to fishers but they erode the health of coastal ecosystems and threaten the sustainability of future fisheries (Muallil et al., 2014b, 2013).

It is essential to address overfishing and destructive fishing practices to prevent collapses in fisheries and further destruction and degradation of marine ecosystems. However, addressing these issues through current management practices is extremely challenging in a developing country like the Philippines for reasons including rapid population growth, poverty, lack of incentive systems and alternative livelihoods, social complexities and divergent interests of stakeholders, weak governance capacity, lack of sustainable funding mechanisms to maintain management activities (e.g., enforcement and monitoring), and variable political will to address these problems (Campos and Aliño, 2008; Maypa et al., 2012; Muallil et al., 2014b; White et al., 2014).

MPAs are the most extensively implemented marine conservation and fisheries management tool employed in the Philippines (Cabral et al., 2014; White et al., 2014). There are four major categories of MPAs in the Philippines: 1) fish sanctuary, 2) reserve, 3) marine park, and 4) Protected Landscape and Seascape (Table 1.1) (Cabral et al., 2014). This research study focuses

Table 1.1. Types of MPAs in the Philippines.

Type of MPA	Description	IUCN Category
Fish Sanctuary	- A MPA that prohibits all extractive uses, and strictly regulates non-extractive uses - It may be located within a marine reserve/park	II, VI
Marine Reserve	- A MPA where access and uses (whether extractive or non-extractive) are regulated or controlled for specific uses or purposes - It may include a marine sanctuary within its boundaries	II
Marine Park	- A type of marine reserve, in which multiple uses may be allowed through zoning regulations, and where conservation-oriented recreation, education and research are emphasized	II, V
Protected Landscape and Seascape	- A national MPA designated under the National Integrated Protected Areas System (NIPAS) Act of 1992 - It often equates to a national park that includes marine and terrestrial areas	-

Adapted from Cabral et al. (2014)

solely on fish sanctuaries, or what is commonly referred to internationally as no-take MPAs. No-take MPAs prohibit extractive uses and may also restrict forms of human access (e.g., scuba diving or swimming) (Lowry et al., 2009).

The legal and policy framework to plan, establish, and manage MPAs in the Philippines is held in the National Integrated Protected Areas System (NIPAS) of 1992 (Republic Act 7586), the Local Government Code of 1991 (Republic Act 7160), and the Fisheries Code of 1998 (RA 8550). These Acts reflect the two main governance systems in the Philippines to plan, establish, and manage a MPA. The first is through the NIPAS Act that gives the national Department of Environmental and Natural Resources (DENR) the authority to designate MPAs at a national level (e.g., Tubbataha Reef National Marine Park and World Heritage Site). The second, and far more common approach, is through community initiatives at the barangay (analogous to village) level in collaboration with local governments (White et al., 2014, 2002). MPAs established under this co-management governance system will be referred to in this thesis as "community-based MPAs".

A major factor attributed with the proliferation of community-based MPAs in the Philippines is the Local Government Code. Enacted in 1991, the Act devolved the authority of natural resource management from the national government to the local government units (LGUs) which encompass provincial, municipal (including component cities), and barangay governments (smallest political unit in the Philippines). The Act gives extensive power, authority, and responsibilities to LGUs to manage the coastal and marine resources present within municipal waters[2] (marine tenure that extends 15 km shoreward from the coastline of a coastal municipality). This includes jurisdiction over the assessment, planning, regulation, legislation, enforcement, revenue generation, and monitoring of coastal and marine resources. The Act allows MPAs to be established at a municipal or barangay level through municipal ordinances without requiring national government approval (White et al., 2014, 2002).

The Fisheries Code of 1998 (RA 8550) supplements the mandates of the Local Government Code. It provides municipal LGUs jurisdiction over the management of fishery and aquatic

[2] Municipal waters typically extend 15km seaward from the shoreline of a municipality. In cases where municipal waters overlap, it is common for municipalities to divide the waters equally between them.

resources within their municipal waters. The Code supports the establishment of MPAs at local levels by giving LGUs the authority to declare and manage MPAs in municipal waters. It also gives LGUs the authority to regulate or limit fishing activities within municipal waters. These regulations are declared into law through municipal fisheries ordinances (White et al., 2014, 2002).

All fishery activities in municipal waters, as defined in the Fisheries Code, can only be utilized by registered "municipal fisherfolks". Municipal fisherfolks are small-scale fishers that are defined as any man or women who directly and physically engages in fishing practices using fishing vessels of three gross tons or less, or fishing not requiring the use of a fishing vessel (e.g., gleaning). Municipal fisheries ordinances often restrict all forms of active fishing characterized by gear movement, and/or the pursuit of the target species using methods such as towing, lifting, dredging, and scaring target species into nets or traps. Commercial fishing operations, defined as any operating using a fishing vessel greater that 3 gross tons, are prohibited from fishing in municipal waters nationwide (White et al., 2002). However, illegal commercial fishing in municipal waters remains largely unenforced in the country and posses a serious threat to the small-scale fisheries (Muallil et al., 2014b).

In addition to the Local Government Code and the Fisheries Code, the proliferation of community-based MPAs in the Philippines has been facilitated by external institutions such as NGOs, universities, and donor-assisted government programs and projects (White et al., 2002). The first sanctuary established in the Philippines in 1974 on Sumilon Island was under the guidance of the Silliman University[3] (Russ and Alcala, 2011, 1999). The unprecedented increases in coral cover and fisheries production of this community-based MPA were recognized nationally and internationally as a prime example of how community-based MPAs can provide both fisheries and conservation benefits (Russ and Alcala, 1996; White et al., 2002). This MPA promoted the development of numerous other MPAs, many of which have been implemented as part of coastal resource management projects facilitated by external institutions including NGOs,

[3] The community-based MPA on Sumilon Island was originally implemented to serve as an experimental case studies on the effects of MPAs on coral reefs and associated fisheries. After a 10-year closure, researcher discovered that the MPA caused the coral cover to double. More remarkably, it tripled the fish abundance (including commercially important species) and increased the yearly fish catches in surrounding areas from 14 tons/km^2 to nearly 36 tons/km^2 (Russ and Alcala, 2011, 1999).

universities, and development agencies (e.g., the World Bank, United States Agency for International Development (USAID), the United Nations Development Programme (UNDP) and the Asian Development Bank) (White et al., 2002). MPAs with external assistance are more likely to succeed and remain sustainable, however many fail when institutions stop providing support (Christie & White, 2007; Maypa et al., 2012).

In the Philippines' context, a growing body of research has shown that successful community-based MPAs (i.e. MPAs that have achieved their biological and/or fisheries objectives) are generally established and managed through (1) effective collaboration and participation of stakeholders and local community, (2) transparency and equitable sharing of costs and benefits, and (3) strong leadership, community support, and political will (Gutiérrez et al., 2011; Horigue et al., 2012).

While more than 1,600 community-based MPAs (covering approximately 240 km^2) have been established in the Philippines (White et al., 2014), there are concerns regarding their management status and poor design. Previous assessments on the conservation effectiveness of MPAs in the Philippines has shown mixed results (e.g., Hansen et al., 2011; Russ and Alcala, 2011; Weeks et al., 2010a). There are examples of "paper parks" (MPAs that exist only on paper) and internationally-renown MPAs (Lowry et al., 2009; World Bank, 2006). While most studies have been restricted to specific areas of the country, a few national assessments have found that the majority of MPAs in the Philippines are managed ineffectively (Maypa et al., 2012)[4], small in size (most less than 1 km^2), and biased towards areas that favor community stakeholders, rather than areas of high ecological importance (Agardy et al., 2011; Weeks et al., 2010a). A national assessment of "key biodiversity areas" (KBAs), areas with globally threatened species and geographically concentrated and restricted species, also found that the majority of marine KBAs are unprotected nationwide (Ambal et al., 2016).

The Philippines national government recognizes that addressing declines in fisheries and biodiversity will require improving the design and management status of existing MPAs and scaling up individual MPAs into ecologically representative MPA networks. The Philippines

[4] Maypa et al. (2012) estimated that approximately 70% of the community-based MPAs (n=425) surveyed across the Philippines were ineffectively managed or paper parks.

government has endorsed national, regional, and international conservation commitments to address this need. The Philippines is a signatory to the CBD and is one of the six countries in the Coral Triangle Initiative (CTI). Both initiatives have a target to increase the coverage, representation, and management effectiveness of MPAs (CBD, 2010; CTI-CFF, 2009a). Through the CTI, the Philippines has set a national target to protect at least 20% of each marine and coastal habitat type (e.g., coral reefs, seagrass beds, mangroves, beach forests, wetland areas and marine/offshore habitats) in no-take MPAs by 2020, which is 10% greater than that specified in the CBD Aichi Target 11 (CTI-CFF, 2009a).

The Philippines has employed various conservation strategies and actions at the sub-national level to achieve the national target, many of which are being supported by external institutions and government partnerships. The development of MPA networks will require identifying and improving existing functioning MPAs, selecting priority sites for new MPAs, and eventually linking these together with broader management frameworks to form ecologically representative networks (Lowry et al., 2009; Watson et al., 2014).

Planning and developing MPA networks in the Philippines to meet national targets will be a challenging process. It will require strategic approaches to balance conservation needs with socioeconomic constraints. SCP and spatial prioritization software (e.g., Marxan) can help achieve this balance, and is currently being applied in some parts of the country to scale up existing MPAs into ecologically representative MPA networks (Lowry et al., 2009; Watson et al., 2014; Weeks et al., 2014a). However, there are major ongoing challenges associated with using this approach in a developing country like the Philippines, as discussed previously. In the context of the Philippines, the major challenges of using SCP include 1) limitations in fine-resolution information on biodiversity and small-scale fisheries, 2) uncertainties on how to address the fine-scale of natural resource governance and marine tenure in larger scale MPA planning, and 3) unresolved issues on how to measure and incorporate small-scale fisheries and equity considerations in SPC (Ban et al., 2011; Mills et al., 2010; Weeks et al., 2014b).

Study Site: Sogod Bay

The study site is located in Sogod Bay in the Eastern Visayan region (Region VIII) of the Philippines. (Figure 1.3). Sogod Bay is surrounded by 131 km of coastline and is characterised by a narrow coastal shelf and a deep central channel (maximum depth of ~1,400 m) (Calumpong et al., 1994). The southern portion of the Bay is nationally recognized as a key biodiversity area (KBA) and is therefore a priority region for conservation (Ambal et al., 2016). It contains important feeding grounds and aggregation sites for marine megafauna, including pilot whales, manta rays, and whale sharks (Araujo et al., 2014; Calumpong et al., 1994). In addition, the Bay supports economically important species (e.g., tuna, mackerel, abalone) and a diverse collection of coastal habitats (e.g., coral reefs, seagrass beds, and mangrove areas) (Calumpong et al., 1994) including reefs in exceptionally good condition, such as Napantao reef with 100% coral cover (Longhurst and Ferguson, 2014).

The coastal habitats and fisheries in the Bay face many anthropogenic (e.g., illegal commercial fishing in municipal waters, destructive fishing practices, anchor damage) and natural stressors (e.g., crown of thorn starfish outbreaks, coral bleaching) (Calumpong et al., 1994; Longhurst and Ferguson, 2014). Reef surveys conducted by the NGO, Coral Cay Conservation (CCC), have revealed signs of overfishing and habitat degradation. For instance, commercially important species of groupers, sweetlips, giant clams, and Triton all occur in low numbers throughout the bay (Longhurst and Ferguson, 2014).

Sogod Bay encompasses the municipal waters of eleven municipalities in Southern Leyte province. This research focuses on coastal habitats and coastal barangays in six municipalities: Pintuyan, San Francisco, Liloan[5], Malitbog[6], Padre Burgos, and Limasawa. The municipal waters of these municipalities make up the southern portion of Sogod Bay and were chosen as a case study due to their rich biodiversity (i.e., KBA), similar demographics, and heavy reliance on coastal and marine resources for food and income (Araujo et al., 2014; Calumpong et al., 1994).

[5] The municipal waters of Liloan extend seaward into Sogod Bay and Surigao Strait. Only coastal barangays in Sogod Bay were included in this study. Those bordering Surigao Strait were excluded.

[6] Malitbog was excluded in paper 2.

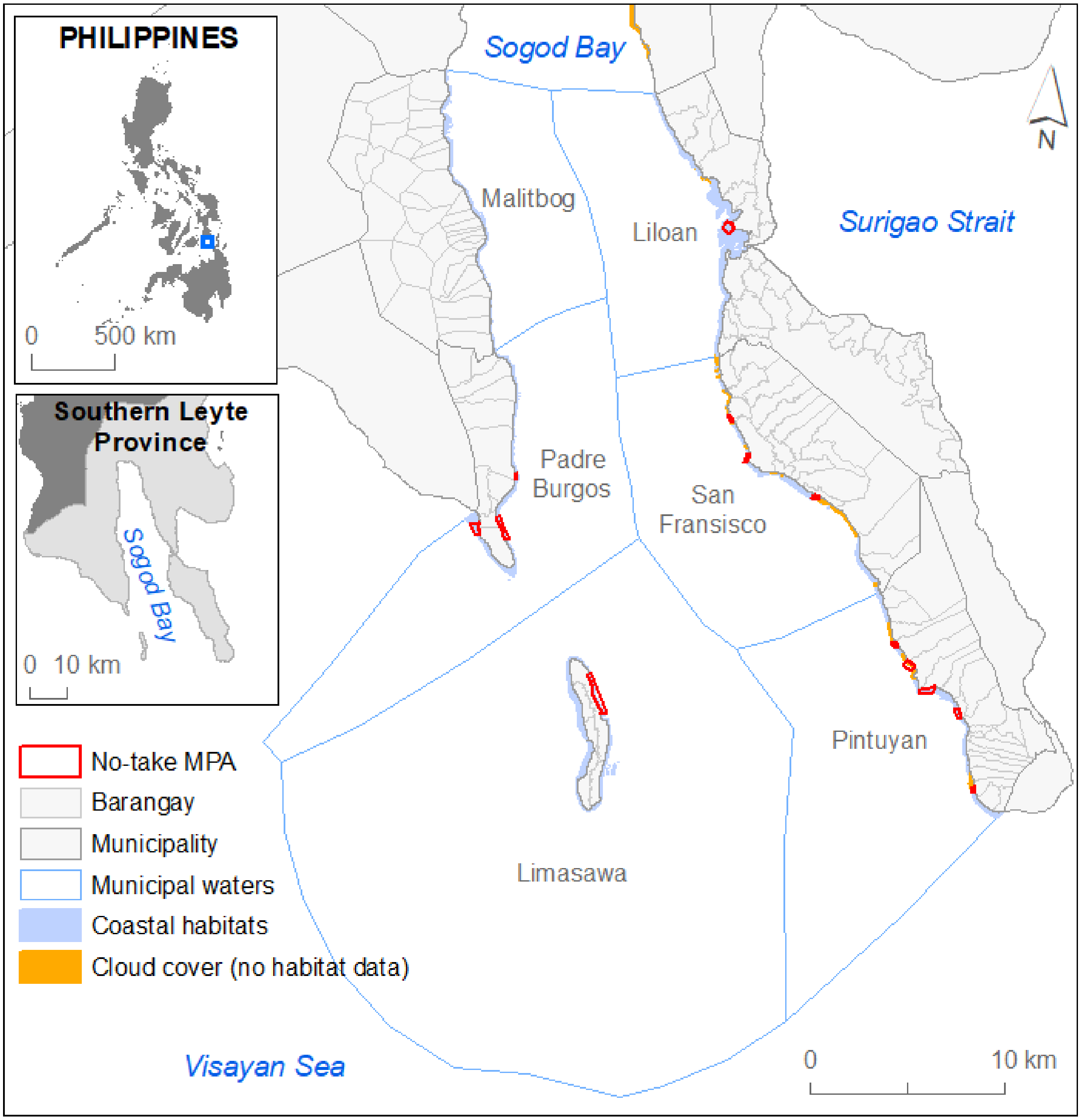

Figure 1.3. Map of study site in Sogod Bay in Southern Leyte, Philippines. The planning region encompasses the municipal waters of six municipalities. The map shows the existing MPAs in the Bay and the extent of coastal habitats derived from remote sensing imagery, including gaps in data due to cloud cover.

A total of 79 coastal barangays were included in this research. These coastal barangays represent more than 70% of municipal populations (total population of all six municipalities). They are predominantly rural (88%) and often rely on farming and fishing as the main sources of revenue (Philippine Statistics Authority, 2015).

Table 1.2. Population, number of (coastal) barangays, and MPAs by municipality.

Municipality	Population (2015 census)	N° of barangays	N° of coastal barangays	Existing MPAs			
				Total N°	Average size (km^2)	Size range (km^2)	Total area (km^2)
Pintuyan	9,826	23	19	5	0.11	0.04 - 0.18	0.54
San Francisco	13,402	22	13	3	0.06	0.04 - 0.07	0.18
Liloan*	23,981	24	9*	1	0.22	N/A	0.22
Malitbog	22,923	37	21	2	0.03	0.03	0.07
Padre Burgos	11,091	11	11	4	0.12	0.03 - 0.23	0.50
Limasawa	6,061	6	6	1	0.52	N/A	0.52
Total	87,284	123	79	16	0.13	0.03 - 0.52	2.02

*Liloan only includes MPAs and coastal barangays on Sogod Bay side (i.e., it excludes those in Surigao Strait).

When this research began in 2015, the study site contained 16 community-based MPAs[7] (Table 1.2). Most were established for fisheries purposes through community initiatives in partnership with LGUs and support institutions such as CCC, Project Seahorse, and Southern Leyte State

University. The MPAs are fish sanctuaries (no-take MPAs) and are mainly small in size (average size is 0.13km^2; size range is 0.03 to 0.52 km^2). They vary in age and management status. Some of the MPAs are actively managed (e.g., routine patrols, active guard stations, and high local compliance of rules) and have shown improvements in coral health and coral cover since their initial establishment. Others show signs of poor management (e.g., low local compliance of rules, lack of demarcation buoys or signage, and infrequent patrols) or inactivity (i.e., paper parks) (Longhurst and Ferguson, 2014).

In an effort to mitigate threats to natural resources, the municipalities of Sogod Bay created a unified resource management alliance in 1998, known as the Sogod Bay Sustainable Marine Management Alliance (SBSMMA). The Alliance members consist of municipal mayors, LGU officials, academics, and local NGOs that meet monthly to collaborate on shared management activities and issues. The alliance and individual municipalities have also formed partnerships

[7] The MPAs in the planning region 16 out of 28 MPAs found in Sogod Bay.

with various NGOs, academics, and donor-assisted and government programs in support of expanding the number, coverage, and management effectiveness of MPAs in Sogod Bay.

The research objectives of this study were presented and discussed with members of the Alliance prior to commencing the field season. Members of the Alliance were supportive of using a systematic process to prioritize MPA selection in Sogod Bay. Furthermore, they requested data sharing agreements and training workshops (e.g., Google Earth Pro and GPS training) with the research team to enhance governance capacity and support future conservation and management initiatives in the Bay.

1.7. Data, Methods, and Analysis

Data required for this thesis were collected through secondary data sources, remote sensing analysis, and participatory mapping methods, as outlined in Table 1.3. The following section introduces the methods used to collect biodiversity, fisheries, administrative (e.g., marine tenure), and existing MPA data required for MPA planning. Additionally, it describes the spatial prioritization tool utilised in this research. A more comprehensive description of the datasets, methods, and analyses are provided in chapters two and three, and supplemented through information provided in the appendices. As indicated in the Table 1.3, some datasets were used exclusively in Chapter two and three.

Secondary Data Sources

Secondary data sources were used to collect and compile data on mangroves, MPAs, administrative boundaries, and municipal waters (Table 1.3). Key government departments that acted as sources of data were the Municipal Planning and Development Office (MPDO), the Municipal Agricultural Office (MAO), and the Provincial Environment & Natural Resources Management Office (PENRMO). The Comprehensive Municipal Fisheries Ordinance (CMFO), a legal document outlining the fisheries laws in each municipality, was examined to obtain information on existing MPAs and municipal waters. In addition, the National Mapping and Research Information Authority (NAMRIA) supplemented information pertaining to municipal waters. The locations of MPAs (2016 to present) selected through the Protected Area Management Enhancement (PAME) project were required for Chapter three. This information was sourced by PENRMO with the permission of the Gesellschaft für Internationale

Zusammenarbeit (GIZ). The available datasets through secondary sources were often incomplete and outdated. The datasets were validated in collaboration with relevant LGUs and with the assistance of local experts. All MPA sites were compiled in a MPA database and validated in the field (Appendix A).

Table 1.3. Summary of data and methods used in this thesis.

Data type	Dataset	Description of data	Method	Notes
Biodiversity	*Coastal habitats*	Aerial extent of seven benthic habitat classes in the coastal waters (up to 25m) lining Sogod Bay	Remote sensing	Derived from WorldView-2 satellite images and video transects
	*Mangrove areas**	Aerial extent of mangrove stands and forests	Secondary data sources	Provided by MPDO, and PENRMO
Fisheries	*Small-scale fisheries*	Small-scale fisheries information by fishing method and barangay	Participatory mapping	Based on the local knowledge of small-scale fishers
MPA	*Existing MPA sites*	Existing MPAs (e.g., locations, delineations, age, size, and legislation)	Secondary data sources	Provided by MAOs and PENRMO, and documented in some CMFOs
	MPAs from the Protected Area Management Enhancement project (PAME)†	MPA network plan developed under the PAME project	Secondary data sources	Provided by PENRMO with permission of GIZ
	MPA sites proposed by fishers†	MPA sites proposed by fishers based on strong community support to develop a new MPA	Participatory mapping	Based on the local knowledge of small-scale fishers
Administrative boundaries	*Barangay and municipal boundaries*	Administrative boundaries of each municipality and barangay	Secondary data sources	Provided as paper maps or spatial files by MPDOs
	Municipal waters	Municipal marine tenure delineations	Secondary data sources	Provided by MPDO, MAOs, PENRMO, and/or NAMRIA

*Data used exclusively in Chapter two; † Data used exclusively in Chapter three

Remote Sensing

Remote sensing is a widely utilised and accepted method for mapping coastal marine environments (Green et al., 2000; Hedley et al., 2016; Yamano, 2013). Satellite sensors with moderate spatial resolution (pixel sizes 10 to 30 m), such as the Landsat series, have been frequently applied for mapping tropical coastal regions, including coral reef systems (Mumby et al., 1998; Yamano, 2013). Moderate spatial resolution imagery is often freely available, although the level of classification detail achievable is limited by the spectral resolution due to the high spectral heterogeneity of reef systems. For example, it is possible to derive geomorphic zonation of reef systems with a low-spectral resolution sensor like Landsat (Mumby et al., 2004), but not detailed coral type or changes to the reef over short time interval (Hedley et al., 2016). Recently, coastal habitat mapping has greatly benefited from advancements in remote sensing technology, especially from sensors with high spatial resolution (pixels less than 10m), and new spectral bands specifically designed for water resources and coastal zone assessments. High resolution imagery can be expensive, especially for large spatial extents. Still, habitat mapping by remote sensing is often more cost-effective than field sampling methods. Additionally, it provides complete aerial coverage of large-scale patterns of coastal areas. Hence, remote sensing using high spatial resolution imagery is increasingly advocated as a cost-effective method for producing habitat level maps (e.g., benthic cover type) suitable for MPA planning (Hedley et al., 2016; Roelfsema et al., 2013).

Remote sensing provided a practical solution for large-scale habitat mapping in Sogod Bay, since existing ecological data were sparse[8]. The remote sensing analysis used WorldView-2 satellite imagery (2m resolution) and underwater video transects to produce a fine-resolution benthic habitat map of the coastal areas in Sogod Bay. The analysis derived seven coastal habitat classes: rock/pebble/gravel, rocky reef, coral reef (high cover), coral reef (low cover), macroalgae, sandy, and seagrass. Appendix B provides a comprehensive overview of the remote sensing analysis and the definition of each habitat class.

[8] From September 2002 to July 2012, Coral Cay Conservation (CCC) conducted a over 2,000 ecological surveys throughout Sogod Bay (Longhurst and Ferguson 2014). The CCC Baseline Survey Technique (Raines et al., 1992) utilises a series of plot-less transects (5m x 10m), perpendicular to the coastline, starting from the 24m contour and terminating at the reef crest or in water too shallow to dive. While this information has supported the establishment of several MPAs, it has been labour intensive, and has resulted in a patchy datasets. Thus, the temporal and spatial distributions of the surveys were not suitable for systematic conservation planning.

Participatory Mapping

Participatory mapping workshops were used to document the local knowledge of small-scale fishers to collect small-scale fisheries data. This method represents one of the diverse uses and applications of participatory geographic information systems (PGIS), a methodology that seeks to emphasize community empowerment and stakeholder participation in the production, management, and/or use of geographic information (Dunn, 2007). PGIS generally involves the creation of maps by local people through documenting and translating local knowledge into spatial information. A growing number of studies have used PGIS to fill data gaps required for SCP, including information on the spatial use patterns and priorities of small-scale fisheries (e.g., Close and Hall, 2006; Levine and Feinholz, 2015; Wheeler et al., 2008; Yates and Schoeman, 2014).

This study chose to use a PGIS approach for the following reasons:

- It provides a cost-effective means for collecting fisheries data on different fishing methods and communities.
- It produces fisheries data that can be linked to place.
- It results in quantitative maps that can be incorporated into SCP.
- It promotes community engagement and participation, both of which play a vital role in the success of conservation and management initiatives.
- It documents rather than infers stakeholder needs and priorities.
- It can facilitate decision-making and action in support of communities, especially towards marginalized, unrepresented, resource-poor, and power-deficient populations.
- It creates opportunities for open discussion, information exchange, community empowerment, participatory learning, decision-making, and conservation action.

Participatory mapping workshops were conducted in 93 coastal barangays. A total of 79 and 58 coastal barangays were included in Chapter two and three, respectively[9]. Each workshop

[9] It was originally intended to include 93 coastal barangays in the study, including those situated on the Surigao Strait side of Liloan’s municipal waters. However, the mapping workshops revealed that the spatial extent of near-shore fisheries from barangays boarding Surigao Strait did not extend into Sogod Bay. Since the focus on the research is the coastal waters of Sogod Bay, these barangays were excluded from Chapter 2 and 3. Hence, a total of 79 coastal barangays were included in Chapter 2. Only 58 barangays were included in Chapter 3, because Malitbog was not considered in one of the MPA planning scenarios (MPA plan developed under the PAME project).

typically consisted of a focus group of six to twelve small-scale fisher representatives (men and women over 18 years of age). The participatory mapping method and the participant selection and recruitment process were approved by the Human Research Ethics Board at the University of Victoria (Appendix C). While the mapping procedures and protocols are described in Chapter two and three. Further, Appendix D provides a comprehensive review of the mapping workshops.

In line with the Philippines definition of “municipal fisherfolk” (local term to define a small-scale fisher), a small-scale fisher is defined as any man or woman who directly engages in the extraction of coastal resources in municipal waters. The definition includes fishing that do not use vessels (e.g., gleaning) or use vessels of 3 gross tons or less. It encompasses a wide range of fishing methods that may or may not involve the use of gear (e.g., gleaning, diving). It does not include commercial fishing, vessels larger than 3 gross tons, which are prohibited from fishing within municipal waters.

Marxan with Zones

Both of the studies applied, at least in part, the spatial prioritization tool ‘Marxan with Zones’ (MarZone) to develop MPA network plans (Watts et al., 2009). Unlike previous versions of the software Marxan, MarZone allows users to allocate different management zones, each of which can be assigned objectives and constraints as defined by the user. The functionality and flexibility of the tool can be used to address a range of complex spatial problems. Here, MarZone was used to developed MPA network plans in Sogod Bay that meet the Philippines national representation target, while minimising and distributing costs equitably among small-scale fisher groups. Furthermore, a series of gap analyses and spatial statistics were used to investigate MPA plans developed under different MPA planning scenarios. These will be discussed in greater detail in the following two chapters.

1.8. Thesis Structure

The research objectives of this thesis are addressed through Chapter two and three, which are presented as two manuscripts formatted for publication in peer-reviewed journals. A version of Chapter three has been submitted for publication in a peer-reviewed conservation journal. Since each chapter is intended as an individual publication, there may be some overlap between the two chapters, in addition to the methods section in this introductory chapter. This thesis consists of four chapters which are summarized below.

Chapter two achieves objectives one and two of this thesis. It describes a methodological and comparative study that examines different approaches for integrating small-scale fisheries information in the systematic design of an ecologically representative and socially equitable MPA network in Sogod Bay, Philippines. Furthermore, it investigates three dimensions of equity (recognition, procedural, and distributive) for small-scale fisheries, and the implications of including and excluding equity considerations and community needs in the planning stages of SCP.

Chapter three addresses objective three of this thesis. It presents a comparative study that compares the biodiversity representation and social equity implications of MPA plans developed using three different planning approaches: the first is an opportunistic approach, the second is through a donor-assisted provincial initiative, and the third is a SCP approach.

The concluding chapter (**Chapter four**) synthesizes key findings in relation to the research objectives. It outlines the main contributions of the research for addressing the three key challenges of the ‘research-implementation’ gap, and it discusses potential limitations in the thesis. Contributions for conservation in Sogod Bay are also provided. Finally, it highlights the needs for future research.

Chapter 2 : Coupling participatory and systematic conservation planning processes to design ecologically representative and socially equitable marine protected area networks

2.1. Abstract

Systematic conservation planning (SCP) is a science-driven process for designing marine protected areas (MPA) to achieve conservation objectives whilst minimizing costs to stakeholders. SCP research and tools are playing an increasingly important role in assisting nations to fulfil their commitments to international conservation treaties. In particular, the Convention of Biological Diversity's Aichi Target 11 commits most nations to conserve 10% of their marine and coastal waters in 'ecologically representative' and 'socially equitable' MPAs by 2020. However, SCP has rarely informed conservation action in tropical undeveloped countries, where coastal habitats are critically important for global biodiversity and local people.

Through a Philippines case study, we developed and compared MPA plans derived under three alternative planning scenarios, assessing their trade-offs in terms of biodiversity representation, spatial efficiency, and distributive equity. We show how adopting participatory and science-driven methods, with an emphasis on three dimensions of equity (recognition, procedural, and distributive), can facilitate the development of MPA plans that are socially equitable for a full range of fisheries and communities. In contrast, excluding minority fisheries was found to result in inequitable distributions of cost amongst fisheries and communities. The results show that failing to recognize and reflect the spatial variations among fishing communities in the design of MPAs can lead to inequitable plans. Hence, conservation planners must take precautionary steps to ensure that SCP approaches adequately recognize, include, and represent the needs of a full range of stakeholders and communities. This study highlights the utility of SCP to design representative and equitable plans. It provides guidance and lessons for employing this MPA planning strategy in the developing world, thus contributing towards bridging the gap between SCP research and conservation action.

2.2. Introduction

Tropical coastal ecosystems include a diverse set of habitat types, such as coral reefs, mangrove forests, and seagrass beds. They support a rich abundance of biodiversity (Martínez et al., 2007) and provide valuable services for humanity (e.g., food supply, livelihoods, coastal protection), which are vitally important to many of the world's poorest communities as a key source of protein and income (Sale et al., 2014; Worm et al., 2006). Despite their biological and social value, coastal ecosystems are being destroyed at alarming rates worldwide, in large part due to fishing pressures (Butchart et al., 2010; Halpern et al., 2015). Hence, there is a global need for improved management practices (Pauly and Zeller, 2016; Sale et al., 2014; Worm et al., 2006).

The establishment of marine protected areas (MPA) is widely acknowledged as a key management tool for mitigating fishing pressures and conserving coastal ecosystems and their biodiversity (Watson et al., 2014). Recently, there has been increased attention towards MPA networks, collections of individual MPAs operating cooperatively and synergistically at various spatial scales to meet objectives that an individual MPAs cannot (Butchart et al., 2015; Carwardine et al., 2010). Current national and international biodiversity conservation strategies are focused primarily on increasing the coverage and effectiveness of MPAs and MPA networks, supported by treaties such as the Convention on Biological Diversity (CBD) and the Coral Triangle Initiative (CTI) (CBD, 2010; CTI-CFF, 2009b). Through the CBD Aichi Target 11, most countries have committed to conserve at least 10% of their coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, within effectively and equitably managed, ecologically representative, and well-connected systems of MPAs by 2020 (CBD, 2010). This target extends beyond a simple aerial coverage goal, promoting strategies that include natural and human considerations and recognize MPAs as part of a complex and linked social-ecological system (Rees et al., 2017; Rochette et al., 2014; Woodley et al., 2012).

Countries signatory to the CBD recognize that to fulfil their commitment for Target 11, they must employ strategies that can produce 'ecologically representative' and 'socially equitable' MPAs. Representation is a key principle in conservation planning that aims to ensure that MPAs contains set portions of all known biodiversity features within a planning region (comprehensiveness), along with a range of variations within each feature (representativeness) (Margules and Pressey, 2000; Possingham et al., 2005). Another key element for consideration in MPA planning is equity (Hill et al., 2016; Woodley et al., 2012).

Equity is increasingly acknowledged in the literature as a major influencing factor in conservation success, although there are few cases where equity factors have been explicitly incorporated, measured, or assessed in the MPA planning process (see Halpern et al., 2013). In the context of MPA planning, equity can manifest itself in a number of ways. The term "recognition equity" refers to the recognition of all relevant stakeholders of MPAs, including their rights, interests, and needs of coastal resources. "Procedural equity" is closely linked to recognition equity but focuses on achieving adequate level of stakeholder engagement and inclusion in the MPA planning process. "Distributive equity", which is concerned with the fair distribution of costs and benefits of MPAs between stakeholders, is arguably the most common dimension of equity referred to in the MPA literature (Schreckenberg et al., 2016).

MPA research has demonstrated that while MPAs can provide significant benefits to local people (e.g., coastal protection, poverty alleviation, and recovery of overharvested fish stocks) (Gaines et al., 2010b; Russ and Alcala, 2004), their initial establishment may cause unintended consequences to stakeholders and communities (e.g., spatial restrictions on resources, loss of revenue, displacement effects) (e.g., Christie, 2004; Mascia et al., 2010). The significance of these impacts is heightened when costs impact marginalized and poor groups of people or communities disproportionally. Equity issues arising for disproportionate costs, inadequate recognition of all stakeholders, or insufficient stakeholder involvement or inclusion in MPA processes have led to conflict, noncompliance with MPA rules, and reduced local support towards MPAs (Bennett and Dearden, 2013; Christie, 2004; Fabinyi et al., 2010). Thus, inadequate consideration of various dimensions of equity increases the risk of MPA failure (Halpern et al., 2013).

Planning MPA networks that are both ecologically representative and socially equitable often requires maintaining a fine balance between the needs for conservation and the need of marine users (Klein et al., 2008; Stewart et al., 2007). One way to achieve this balance is systematic conservation planning (SCP) (Pressey and Bottrill, 2009; Stewart and Possingham, 2005). SCP is a branch of conservation science that is increasingly advocated by academics and international conservation agencies as an effective and efficient approach for scaling up existing MPAs into representative MPA networks whilst minimizing costs to society (Gibson et al., 2017; Lowry et al., 2009; Margules and Pressey, 2000; Pressey and Bottrill, 2009). The SCP process is typically facilitated by spatial prioritization software (e.g., Marxan, Zonation, C-Plan) that support decisions on how to select new MPA sites that meet a set of biodiversity targets for a minimum "cost", as specified by the user (Ball et al., 2009).

The majority of SCP studies have focused on reducing opportunity costs for fisheries, in recognition that they represent the group most at risk of incurring negative impacts for spatial restrictions of MPAs. In practice, most SCP assessments have been limited in scope because they have either treated fisheries as homogenous or have only considered one or a few stakeholder groups (Ban and Klein, 2009b). One reason for this limitation is due to the restricted functionality of early spatial prioritization software. For instance, the Marxan software (Ball et al., 2009), the most widely utilised decision-support tool in the world, only permits a single cost layer. Recently, advancements in conservation science and decision-support tools have provided new opportunities for incorporating multiple socioeconomic considerations within SCP.

Marxan with Zones software (MarZone; Watts et al., 2009), a new version of the Marxan software, is capable of addressing multiple objectives simultaneously. Klein et al. (Klein et al., 2010) demonstrated how this added functionality can be used to achieve more equitable impacts on different fishery sectors. Subsequent studies have shown that treating fisheries features as objectives rather than as a single cost result in more equitable plans (e.g., Gurney et al., 2015a; Mazor et al., 2014; Weeks et al., 2010b). While studies such as these illustrate the importance of including socioeconomic data in MPA planning, they remain limited in scope, because many have often employed data collection methods or have relied on existing data that does not capture the heterogeneity of different fisheries and communities. Oversimplified metrics for fisheries may lead to inequitable and negative situations (Carwardine et al., 2008; Kleiber et al., 2015; Weeks et al., 2010c), especially regarding diverse and complex small-scale fisheries in poor and marginalized communities.

SCP concepts, tools, and approaches will continue to evolve over time and are increasingly being used to inform management and conservation initiatives (CBD, 2012b; Fernandes et al., 2005). However, there are relatively few cases of SCP being applied successfully in developing countries (e.g., Agostini et al., 2010; Weeks et al., 2014a). Major challenges that restrict the applicability of SCP research in developing countries includes: (1) limited guidance on how to adapt western SCP concepts and tools to the context of developing countries (e.g., decentralized marine tenure system) (2) lack of fine-resolution spatial data, (3) uncertainties on how to address high local demands for resources, and (4) difficulties in representing the socioeconomic complexities of marine users such as small-scale fishers (Ban et al., 2011; Mills et al., 2010; Weeks et al., 2014b).

Through a Philippines case study, this study focuses on three dimensions of equity (recognition, procedure, and distributive) and on how these dimensions can be integrated adequately and realistically in the systematic design of representative MPA networks in the context of a developing country. The objectives of our study were two-fold. The first is to document strategies for incorporating dimensions of equity for stakeholders and communities in the planning stages of SCP. The second is to identify how recognition and procedural equity can impact the systematic design of MPA planning outputs. Specifically, it compared MPA plans developed under different planning scenarios to identify how (1) the inclusion or exclusion of minority fisher groups, and (2) the inclusion or exclusion of community variations in SCP may affect biodiversity representation, spatial efficiency, and distributive equity for small-scale fisheries and coastal communities.

2.3. Background

Our case study is in the Philippines, one of six countries in the Coral Triangle, an epicenter for marine biodiversity and a global conservation priority (Burke et al., 2012; Carpenter and Springer, 2005). The country comprises over 7,100 islands that contain biologically and socioeconomically important coastal habitats such as coral reefs (9% of global total), mangrove forests, and seagrass beds (Burke et al., 2012; Carpenter and Springer, 2005; White et al., 2014). These habitats support a rich abundance of biodiversity and provide important ecosystem services to local people (Burke et al., 2012). Most of the Philippines' population live in coastal areas and are heavily dependant on small-scale fisheries for their food security and livelihoods. Lamentably, coastal ecosystems and fisheries in the Philippines are in an increasingly declining state due to an array of threats such as illegal and destructive fishing practices, overfishing, coastal development, poor land-use practices, pollution, and climate change (CTI-CFF, 2009a; Foale et al., 2012; Nanola et al., 2010; Wilkinson, 2008). Malthusian overfishing from rapid population growth and a lack of alternative livelihood options has perpetuated poverty in coastal communities, resulting in further habitat degradation and fisheries declines (Muallil et al., 2014b, 2013).

MPAs are a primary management tool for conserving biodiversity and safeguarding fisheries in the Philippines (Cabral et al., 2014; White et al., 2014). The Local Government Code (LGC) of 1991 (Republic Act 7160) gives local government units (LGUs), which encompass provincial, municipal, and barangay (smallest political unit in the Philippines; analogous to a village community), the authority to establish MPAs at a municipal or barangay level. LGUs can declare MPAs through municipal ordinances without requiring national government approval. The Fisheries Code further supports the establishment of MPAs at local levels by providing LGUs the authority to declare and manage MPAs within their respective municipal waters (municipal waters typically extend 15 km seaward from the shoreline of a municipality). Given this decentralized governance system, most MPAs in the Philippines have been established at a barangay level in collaboration with municipal governments, and often with the assistance of support institutions (e.g., foreign donors, academics). These community-based MPAs have typically been planned and implemented in an *ad-hoc* manner, where sites have been selected based on management feasibility or local preferences, rather than biological importance (White et al., 2014, 2002). To date, most MPAs are less than 1 km^2 in size (Weeks et al., 2010a), ineffectively managed (approximately 70% of MPAs surveyed by Maypa et al., 2012), and not representative of critical habitats and key biodiversity areas (KBAs; areas with globally threatened and geographically concentrated species; Ambal et al., 2016).

The Philippine’s government recognizes the need to adopt strategies to improve the design, coverage, distribution, and management status of MPAs (Lowry et al., 2009; White et al., 2014). The country is a signatory of the CBD and the Coral Triangle Initiative (CTI) (CBD, 2010; CTI-CFF, 2009a). Under the CTI, the Philippines has committed to protect 20% of each major marine and coastal habitat type (e.g., coral reefs, seagrass beds, mangrove forests) in no-take MPA zones by 2020, which is 10% over the target specified in the CBD Aichi Target 11 (CTI-CFF, 2009a). Through both the CBD and CTI, the Philippines has endorsed conservation strategies that (1) prioritize KBAs, (2) include and engage stakeholders, (3) consider equity and socioeconomic considerations with an emphasis on poor and marginal communities, and (4) adopt methods and tools based on solid science and data (CBD, 2010; CTI-CFF, 2009a; Walton et al., 2014; Weeks et al., 2014a).

2.4. Methods

MPA Planning Region

Our study focuses on the southern portion of Sogod Bay in Southern Leyte province in the Eastern Visayan region of the Philippines (Figure 1.3). The planning region was defined by the municipal waters of six municipalities (Pintuyan, Liloan, San Francisco, Padre Burgos, Malitbog, and Pintuyan), which includes 79 coastal barangays. We selected the planning region as a suitable site for planning and implementing a representative and equitable MPA network for several reasons:

- it contains a diverse range of coastal habitats (e.g., fringing coral reefs, seagrass beds, and mangroves) that support a rich abundance of coastal and marine fauna, including large marine megafauna (e.g., whale sharks) and commercially important species (e.g., abalone, mackerel, tuna) (Araujo et al., 2014; Calumpong et al., 1994);
- the planning region is recognized as a marine KBA based on the presence of globally threatened and geographically concentrated species (Ambal et al., 2016);
- the LGUs in the region have a long history of planning and managing MPAs;
- our multi-disciplinary research team had previous experience working with LGUs, NGOs, and stakeholders in the planning region;
- key leaders and LGU officials strongly supported conservation initiatives to scale up existing community-based MPAs into a representative and equitable MPA network;
- local experts and key government departments were willing to assist the research team in the SCP process (e.g., field support, networking, data sharing);
- the coastal barangays lining the planning region had similar demographic characteristics; they were predominantly rural (88% of population), reliant on farming and fishing as the main source of revenue and had limited alternative livelihood options (Philippine Statistics Authority, 2015);
- the existing 16 no-take MPAs reflected most MPAs in the Philippines (Lowry et al., 2009; Weeks et al., 2010a); they are small (size range is 0.03 to 0.52 km^2), individually established

and managed at a barangay level, and under representative of a wide range of habitat types present in the planning region; and

- our research team had a strong network of contacts and a good understanding of the appropriate avenues for community and stakeholder engagement.

Recognizing Key Stakeholders

We carried out a series of activities to engage local governments, academics, NGOs, communities, and key stakeholders in Sogod Bay at each stage of the MPA planning process. The first step of the process was to identify and meet with appropriate departments and leaders of LGUs at all levels to determine their willingness to support the MPA planning process. We conducted informal interviews with government officials from three key government departments: The Provincial Environment & Natural Resources Management Office (PENRMO), the Municipal Agricultural Office (MAO), and the Municipal Planning and Development Office (MPDO). We also consulted with members of the Fisheries and Aquatic Resources Management Council (FARMC), dive operators from the private sector, academics from Southern Leyte State University (SLSU), and representatives from the non-government organization sector including Project Seahorse, Coral Cay Conservation (CCC), Ocean-Action Resource Center (ORC), and the Large Marine Vertebrates Research Institute Philippines (LAMAVE). The series of informal meetings with "local partners" (term used to refer to members of the government, academic, private, and NGO sector) served to collect existing information, recognize key stakeholders, identify data needs, and build local support for MPA networks. Some members of the local partners also acted as informal consultants throughout the planning process.

Tourism and small-scale fisheries were identified as non-extractive and extractive activities, respectively. The tourism sector consisted of six dive resorts and one community-led whale shark tourism operation (KASAKA). While this sector depends on coastal resources, we did not identify them as a stakeholder group at risk of potential negative impacts of MPA implementation. Through informal interviews, we found that dive operators were generally supportive of MPAs and were willing to support new community-based MPAs financially through diver fees. However, local partners identified small-scale fishers from coastal communities as the key stakeholders of MPAs. Hence, we chose to focus our study on these stakeholders that represented the sector of the population with (1) the highest reliance on coastal and marine resources for food and income, (2) the lowest monthly income, and (3) the highest risk of being negatively impacted by spatial restrictions imposed by MPAs. Commercial fishing (fishing with a vessel larger than 3 gross tons) is prohibited within municipal waters under the Philippines Fisheries Code and was therefore not considered in this study (White et al., 2002).

Developing a Spatially Explicit Database

Spatially explicit data on coastal habitats, small-scale fisheries, marine tenure, and existing MPAs were required to develop representative and equitable MPA network plans in Sogod Bay. Most of the available datasets in the region were too incomplete, sparse, or coarse to be useful for MPA planning. Consequently, we collected additional fine-resolution data through remote sensing, participatory mapping, and secondary sources. We chose data collection methods to meet as high scientific standards as possible, involve and engage stakeholders, and that would provide supplementary attribute data to identify conservation opportunities and challenges. Data collection occurred between June 2015 and April 2016.

Administrative Data and Existing MPAs

Administrative (barangay, municipal, and provincial) boundaries and municipal water delineations were obtained through the MPDO. Information gaps were supplemented through PENRMO and the National Mapping and Research Information Authority (NAMRIA). The location and supplementary information (e.g., age, year of establishment) of existing MPAs were provided by PENRMO and/or from examining the Comprehensive Municipal Fisheries Ordinance (CMFO) of each municipality. In collaboration with LGU officials, we validated the documented MPA delineations in the field using a GPS device. In several cases, the MPA coordinates were unknown or mapped incorrectly. In these cases, we defined the MPA coordinates based on the location of demarcation markers (e.g., marker buoys) and the recommendations of LGU officials and MPA guards (Appendix A).

Biodiversity Data

Available data from benthic habitat surveys in Sogod Bay were too sparse to be useful for SCP. Consequently, we used remote sensing to produce the first high-resolution (2m pixel resolution) benthic habitat map of coastal areas (less than 25m deep) in Sogod Bay. We collected data on benthic habitats using WorldView-2 satellite imagery (provided by the Digital Globe Foundation) in combination with field surveys (GPS-referenced video transects). Following standard methods used in nearshore habitats detection (O'Neill and Costa, 2013), the remote sensing analysis followed derived seven benthic habitat classes: rock/pebble/gravel, rocky reef, coral reef (high cover), coral reef (low cover), macroalgae, sand, and seagrass (Table 2.1). The user accuracy of identification of benthic habitat classes ranged from 20% to 90%. We were unable to include deep water marine habitats in waters deeper than 25m depth because of the limitation in using satellite remote sensing for substrate detection in deep waters (Appendix B).

Table 2.1. Coastal habitat classes targeted for inclusion in MPAs in Sogod Bay. The definitions were adapted from the IUCN Habitat Classification Scheme (2012).

Habitat class	Description	Data source*
Rock/ pebble/ gravel	Bottom habitat consisting predominantly (covers more than 70% of benthos) of unconsolidated cobbles rock or gravel (sediment size 64 to 256 mm diameter) and pebbles (sediment size 2 to 64 mm diameter).	RS
Rocky reef	Bottom habitat consisting predominantly (covers more than 70% of benthos) of consolidated rock or bedrock. May include small, sparse patches of coral or macroalgae.	RS
Coral reef (high cover)	Aggregated or fringing coral reefs: Massive limestone structure built up through the cementing and depositional activities of colonial stony corals, predominantly of the order Scleractinia, and other calcareous invertebrate and algal species. Living coral colonies cover more than 70% of the benthos.	RS
Coral reef (low cover)	Aggregated or fringing coral reefs: Massive limestone structure built up through the cementing and depositional activities of colonial stony corals, predominantly of the order Scleractinia, and other calcareous invertebrate and algal species. Living coral colonies cover 50 to 70% of the benthos.	RS
Macroalgae	Bottom habitat consisting predominantly (covers more than 70% of benthos) of large algae (typically brown algae, including green and red algae, and excluding blue-green algae or Cyanobacteria), which forms dense macroalgal beds.	RS
Sandy	Bottom habitat consisting predominantly (70 to 100% of benthos) of sand (loose particles of rock or mineral sediments ranging in size from 0.0625–2.0 mm in diameter).	RS
Seagrass	Bottom habitat consisting predominantly (70 to 100% of benthos) of seagrass (grass-like marine flowering plants that grow and reproduce while submerged in seawater).	RS
Mangrove	Isolated stands or forest of tropic mangrove species in the intertidal zone or above the high tide level	SS

*RS: Remote sensing, SS: Secondary data source

Coastal mangrove data was also included as biodiversity features. This dataset was provided by PENRMO, MAO, and MPDO, which was validated in consultation with local experts from SLSU. Given the governance system in the Philippines, we subdivided the full extent of the eight habitat classes into six municipal waters, resulting in 45 biodiversity features (not all habitat classes were present in each municipality). In addition, this served as a means to incorporate two key principles of conservation planning (comprehensiveness and representativeness) while targeting biodiversity features for inclusion in MPAs.

Fisheries Data

Small-scale fisheries data were generated though participatory mapping workshops with a total of 779 fishers (591 men and 192 women) from 79 coastal barangays in the six municipalities in the planning region. Each workshop (one per barangay) consisted of six to twelve small-scale fishers (both men and women over 18 years of age) nominated by their barangay LGU members (e.g., the elected barangay captain or FARMC) as individuals with extensive knowledge on the fishing practices in their barangay. To obtain a reasonably representative sample of fishers per barangay, we asked the LGU members to consider diverse sub-groups (e.g., age, gender) and types of fishers (fishers using different fishing methods) in their nominations. Participation was completely voluntary, and identities were kept confidential (i.e., no names recorded). We obtained verbal consent from workshop participants, in addition to written consent from municipal mayors and barangay captains, prior to each workshop (Appendix E). The recruitment process and mapping method were approved by the Human Research Ethics Board at the University of Victoria (Appendix C).

In accordance with the Philippines Fisheries Code, we defined a small-scale fisher as any man or women who directly and physically engages in fishing practices using a fishing vessel of three gross tons or less, or fishing not requiring the use of a fishing vessel (e.g., gleaning, diving). We aimed to achieve recognition equity through recognizing all small-scale fisher stakeholders in the planning process. To do this, we first reviewed the literature to compile a list of fisheries practices used in the Philippines (Christie et al., 2006; Dickson et al., 2003; Green et al., 2004; Kawamura and Bagarinao, 1980; Nédélec and Prado, 1990), and then identified the practices used in Sogod Bay with the help of local partners. With the assistance of local experts, we classified the fishing practices into 24 fishing methods (Table D1 in Appendix D) based on the gear type, main catch, and generalized spatial use patterns. The fishing methods and the mapping exercise procedures were tested prior to the field season via a series of “practice” workshops with volunteer small-scale fishers (all from barangays outside of the planning region), which were facilitated by the research team and ORC, a local NGO with extensive experience in working with fishing communities.

The mapping method employed in this study was adapted from the National Oceanic and Atmospheric Administration (NOAA, 2014) and Close and Hall (2006). The mapping workshops were conducted in the Filipino dialect of Visayan and facilitated by the lead researcher or the in-country research coordinator with the assistance of a research assistant (recorded attribute data), a local translators/ assistance (acted as both a translator and mapping facilitator), a GIS technician (digitized mapped data), and a data recorder (documented local knowledge and attribute data of mapped features), all of whom were trained in all procedures and protocols for mapping and documenting data.

The workshops generally lasted between three to six hours per barangay. In the first section of the workshop, we collected basic information on the fisheries profile of the barangay (e.g., total number of motor and non-motorized boats, total number of women and men fishers, alternative sources of livelihoods) based on the local knowledge of participants. The following section was used to map fishing sites per method used within the last 12 months by members of the barangay. To map fishing sites, we gave participants paper maps and access to a digital map of Google Earth Pro displayed on a 20-inch touch-screen tablet. The paper maps displayed Google Earth Pro images (scale of 1:20,000) and were laminated to allow fishers to draw directly onto the maps with markers. The touch-screen tablet acted as a digital mapping tool to assist fishers to measure distances from shore and describe mapped features with greater accuracy (e.g., zoom in and out to show fishing area extent). Additionally, the tablet was connected to a keyboard and a mouse to allow the GIS technician to digitize local knowledge *in situ* using Google Earth Pro. The facilitator explained the scale, direction, and features (e.g., landmarks, shoreline, and islands) of the paper and digital map to minimize map bias and facilitate mapping (many fishers had a limited understanding of maps). The comprehension of participants was tested by asking participants to locate certain map features.

For each fishing method, participants were first read the definition of the method and asked whether it had been used by any members of their barangay within the last 12 months. If so, the group was asked to provide general information on the seasonality, main catch, mode of transport, distances from shore, depth, and number of fishers in their barangay who engage in the fishing method. They then worked in groups of two or three to map the fishing sites of the method on a paper map. The fishing sites were drawn as closed polygons within the respective municipal waters extent. Participants were told to only map sites used by fishers from the barangay within the past 12 months, regardless of its frequency or intensity. They were asked not to include areas used exclusively for transit. The drawn maps were compared and discussed in a group to produce a final map. The GIS technician digitized (on site) the final map of each method based on participants' drawings, descriptions, and distance references (e.g., distance from shore, barangay limits). All sites were digitized within municipal waters in correspondence to the Philippines' Fisheries Code. Additional attribute information, such as importance value and number of fishers, were also documented but were not used in this study (Appendix D).

The spatial and attribute information obtained through the participatory mapping workshops were compiled in a GIS database in ArcGIS 10.2. The spatial data was used to examine the spatial patterns of small-scale fishers by barangay and fishing method, and to develop fishery features for spatial prioritization. We used the attribute data to (1) estimate the total number of fishers in each municipality and in the planning region, and (2) to create a small-scale fisheries profile per fishing method. We intended initially to use local census data to identify the number of fishers per barangay and municipality. However, this data source was incomplete or inconsistent among LGUs at a barangay and municipal level. For example, census data varied in how fishers were defined and grouped. Additionally, some LGUs chose to include women and/or other minority fishing groups in census counts, whereas others did not.

MPA Network Design

Spatial conservation prioritization is a key component of SCP, which typically involves the use of spatial prioritization software. This step in the SCP process requires identifying gaps in representation of existing MPAs and supplemental sites for new MPAs to achieve biodiversity targets (Margules and Pressey, 2000; Pressey and Bottrill, 2009). Marxan is the most widely used spatial prioritization software in the world. It employs an algorithm to produce multiple

MPA configuration options that meet spatially explicit biodiversity targets at a minimal cost, as defined by the user (Ball et al., 2009). In this study, we employed an advanced version of Marxan, called "Marxan with Zones" (MarZone), since it is designed to incorporate multiple objectives and management zones (Watts et al., 2009). This added functionality allowed us to produce solutions that addressed biodiversity and fishery targets simultaneously (Klein et al., 2010).

We divided the planning region into 0.04 km^2 hexagon cells or "planning units", which is required for MarZone. The size of one planning unit is comparable to the smallest no-take MPA in Southern Leyte province. Thus, MPAs selected in one or a few adjoining planning units would reflect a MPA size that could realistically be implemented in the planning region. We set MarZone to assign each planning unit in the planning region (see section 3.3.) as either a no-take MPA zone or an open zone available for fishing. In line with the Philippines national target, we set a biodiversity target to contain at least 20% of each biodiversity feature (i.e., habitat class per municipality) in the MPA zone. We assumed that conserving samples of each major habitat type would also conserve a wide range of species, life stages, and ecosystem functions and processes. We accounted for existing MPAs by locking them into the MPA zone. To minimise the spatial restrictions of MPAs on fishery features, we set the fishery target to maintain a minimal proportion of each fishery feature in the open zone. The amount of each biodiversity and fishery feature contained in each planning unit was calculated using QGIS 1.8. We defined the cost associated with the MPA zone as the total area of planning units, based on the assumption that spatially efficient solutions are easier to implement. There was no cost for the open zone.

We developed three MPA planning scenarios to investigate the implications of different methods for defining and including small-scale fisheries into SCP (Table 2.2). All scenarios contained the same biodiversity features but had different fishery features. The scenarios differed based on two factors: (1) the number of fishing methods considered, and (2) the scale for defining fishery features. **Scenario one** incorporated all fishery features at a community scale (apart from methods used exclusively offshore), where each fishery feature was itemized by method and barangay. **Scenario two** also incorporated fishery features at a community scale, but only included the five most used fishing methods at risk of coastal MPAs. In contrast, **scenario three** incorporated all fishing methods at a municipal scale (fishing methods grouped by municipality).

Table 2.2. Biodiversity and fishery features of MPA planning scenarios

	Biodiversity features			Fishery features		
	Data	Scale*	Total N°	Data	Scale*	Total N°
Scenario 1	8 coastal habitat classes	Municipal	45	16 fishing methods	Community	868
Scenario 2	8 coastal habitat classes	Municipal	45	5 most used fishing methods	Community	362
Scenario 3	8 coastal habitat classes	Municipal	45	16 fishing methods	Municipal	145

*Scale reflects whether the features are itemized by community or municipality.

We identified scenario one as our "equitable approach", since it recognized and included all types of fishers, along with the spatial variations of each barangay. We compared scenario one and two to analyse the benefits and trade-offs associated with considering all forms of fishing versus focusing solely on the most dominant methods. In contrast, scenario one was compared with scenario three to examine the impacts of using fine-resolution fishery data linked to community as opposed to coarse-scale resolution data that groups each method by municipality.

We first ran scenario one to identify the maximum fishery target that could be achieved while still meeting the biodiversity target. This was done by running Marxan iteratively with a constant biodiversity target and with a series of increasing fishery targets that varied by 1% increments. With each series, we calibrated the feature penalty factor (fpf) by increasing it until all biodiversity features met the biodiversity target (same fpf for each biodiversity feature). We then increased the fpf of each fishery feature (same for each fishery feature) until all fishery targets were achieved. We gave preference to achieving the fishery target by allowing biodiversity features to suffer the shortfall when both the biodiversity and fisheries targets could not be met simultaneously. Running the calibration with a series of increasing fishery targets allowed us to identify the highest fisheries target that could be achieved (all fishery features met targets) while simultaneously meeting all biodiversity targets. We then applied this target to run scenarios two and three, along with the above fpf calibration technique.

Each scenario was set to produce 100 solutions or MPA plans with 100 million iterations. We utilised the "best solution" and the "selection frequency" outputs of each MarZone analysis to analyse the scenarios. The “best solution” was used to identify the most efficient MPA plan (based on the lowest scoring of 100 output solutions), whereas the “selection frequency” illustrated the number of times each planning unit was selected in the MPA zone from all runs in a scenario.

We analysed the “best solution” of each scenario to determine the proportion of biodiversity and fishery features that achieved their targets. In all cases, we evaluated equity as a measure of the distribution of fishing area lost in MPAs among fishery features at a community scale, calculating the proportion of each fishery feature lost in the MPA zone under each scenario. We measured spatial efficiency by the total area of planning units in the MPA zones of the 100 solutions derived from each scenario.

2.4. Results

Fisheries Profile

The spatial use patterns of small-scale fishers varied by barangay and fishing method. For instance, gleaning (hand collection of prey in intertidal areas) and trap fishing (e.g., squid and fish traps) were typically practiced close to shore, whereas multiple handline and certain forms of squid fishing were exclusively used offshore (i.e., they did not overlap with coastal habitats).

Based on the local knowledge of fisher participants, we estimated that there are approximately 9000 small-scale fishers (6577 men and 2422 women) in the planning region (average of 114 fishers per barangay, range of 15 to 650 fishers per barangay). Fishers often employ more than one form of fishing, so the sum of fishers per method shown in Figure 2.1a does not equate to the total number of fishers in the planning region. We chose to exclude fishing methods used exclusively offshore (Figure 2.1a), because they would not be impacted by MPA planning in coastal areas. We thereby identified the following as the five most used methods at risk of MPA planning: gleaning, diving, spearfishing, simple handline 2 (handline with a vessel), and simple handline 1 (handline from shore). These methods were practiced by a high proportion (81 to 100%) of coastal barangays (n=79) (Figure 2.1b), although the methods used per barangay did vary.

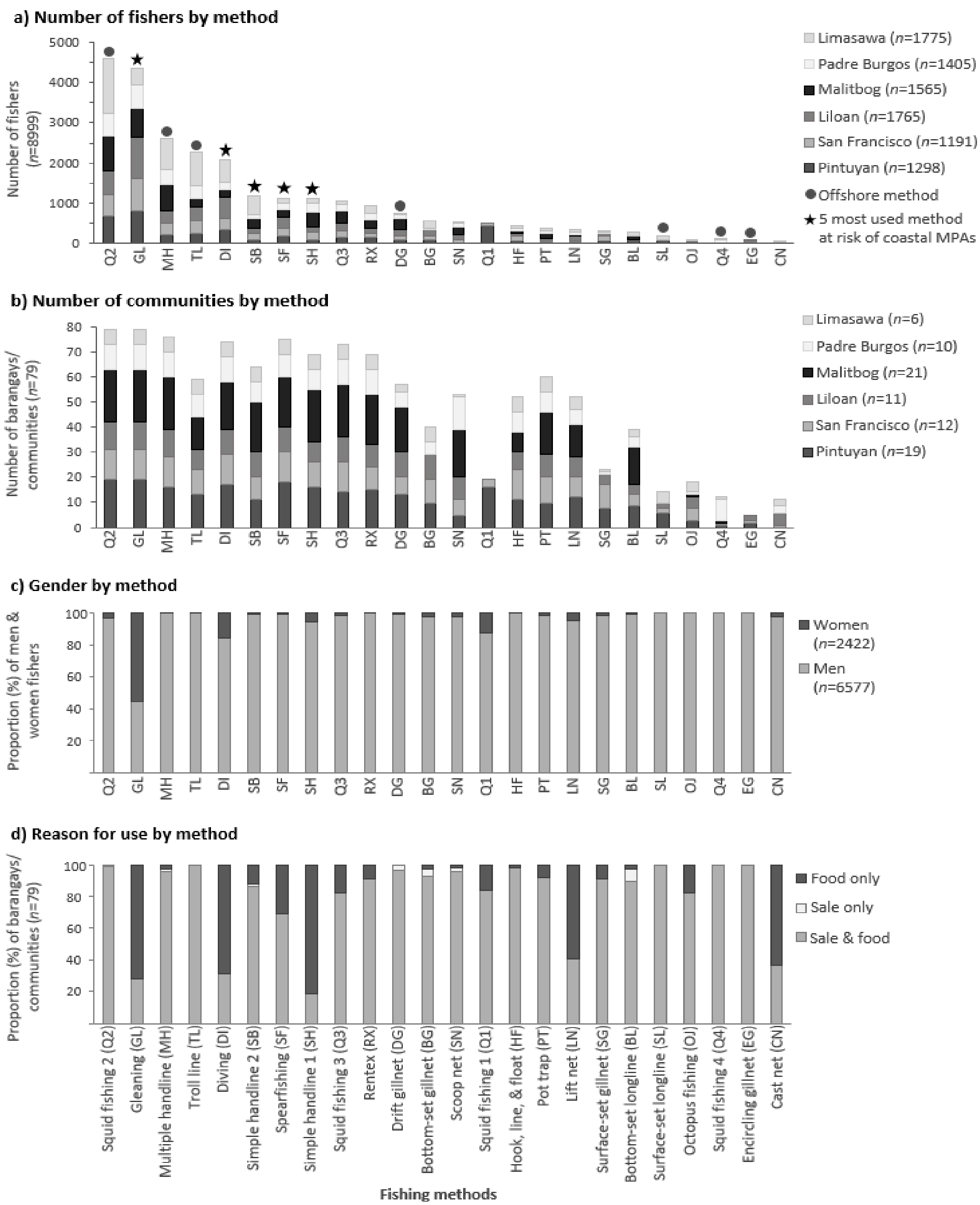

Figure 2.1. Small-scale fisheries profile per method: (a) number of fishers by method (the total number of fishers and the proportional contribution of each municipality per method); (b) number of communities by method (the total number of barangays/communities and the proportional contribution of each municipality per method); (c) gender by method (the proportional participation of men and women per method); and (d) reason for use by method (the proportional distribution of barangays/communities that described using a fishing method for food, sale, or both food and sale).

The number and proportion of fishers per method varied by barangays and municipality (Appendix D). All forms of fishing were practiced and dominated by male fishers, with the exception of gleaning that was predominantly carried out by women (Figure 2.1c). Most women fishers participated in gleaning, which was described by many participants as an important source of food for their family and community. A small portion of women also participated in near-shore fishing methods (e.g., diving, simple handline, and squid fishing 1), often in the company of male relatives. Most fishing methods were used to obtain food and income, although a few barangays employed certain methods just for food (e.g., gleaning, diving) or sale (e.g., bottom-set longline, drift gillnet) (Figure 2.1d).

MPA Network Plans

We identified the "best" solution (Figure 2.2) and the selection frequency (Figure 2.3) of each MPA planning scenario, all of which varied spatially. We ran scenario one first and found that the targets for each biodiversity and fishery features could be met up to a maximum fishery target of 75% (i.e., higher fishery targets could not achieve the biodiversity and fishery targets simultaneously). We subsequently ran each scenario with the same biodiversity target (conserve at least 20% of each biodiversity feature in MPAs) and fishery target (maintain at least 75% of each fishery feature open to fishing), which resulted in solutions that met both of these targets.

Biodiversity Representation

The best MPA plan of each scenario ensured that a minimum of 20% of each habitat class per municipality was conserved in MPAs (Figure 2.4 a,b,c). Hence, all scenarios were capable of achieving the same biodiversity representation target.

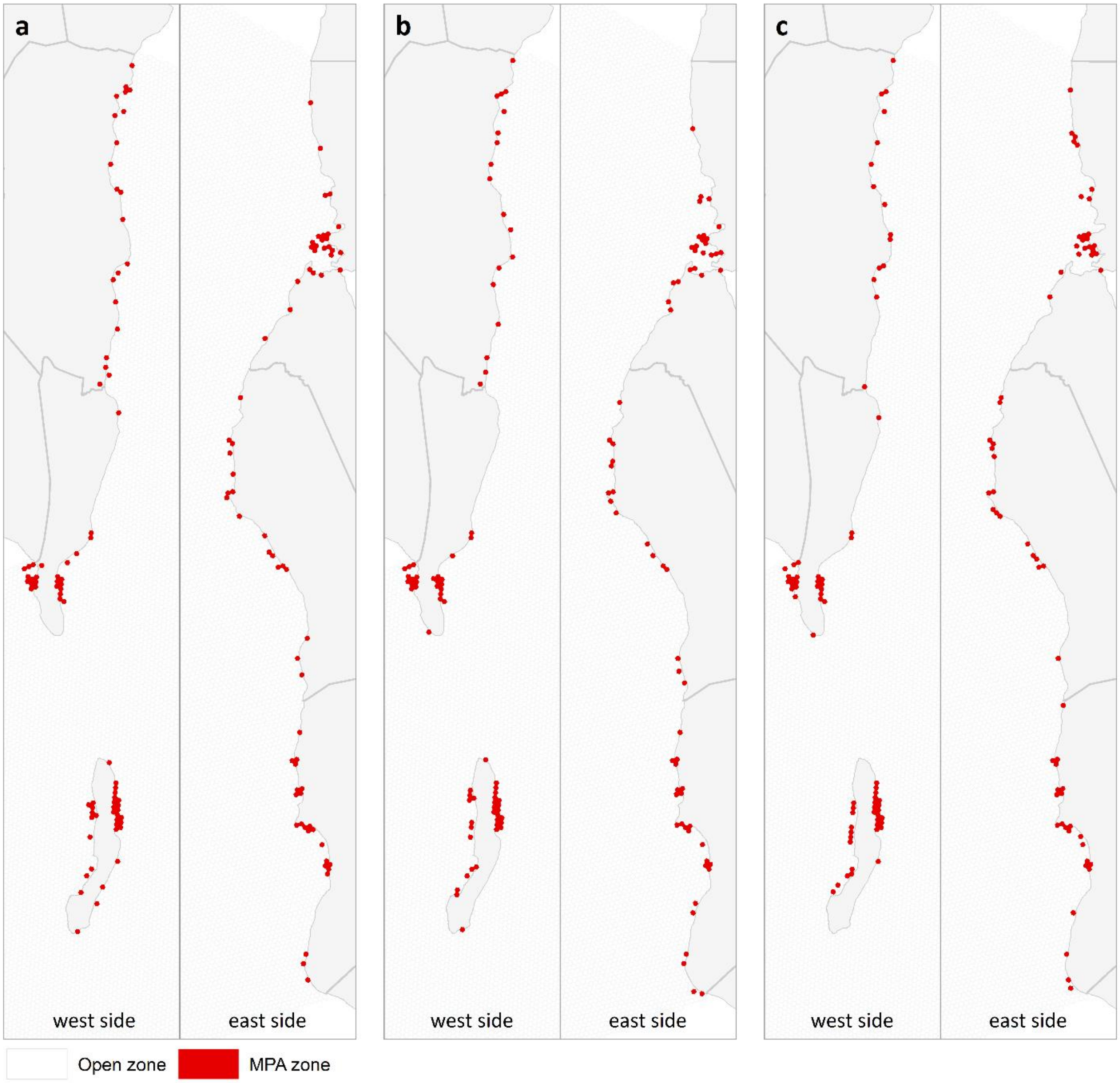

Figure 2.2. Best solution (lowest scoring) of MPA networks plans derived from each scenario: a) scenario one (fishery features grouped by community; including all forms of fishing), b) scenario two (fishery features grouped by community; only dominant fishing gear considered), and c) scenario three (fishery features grouped by municipality; including all forms of fishing).

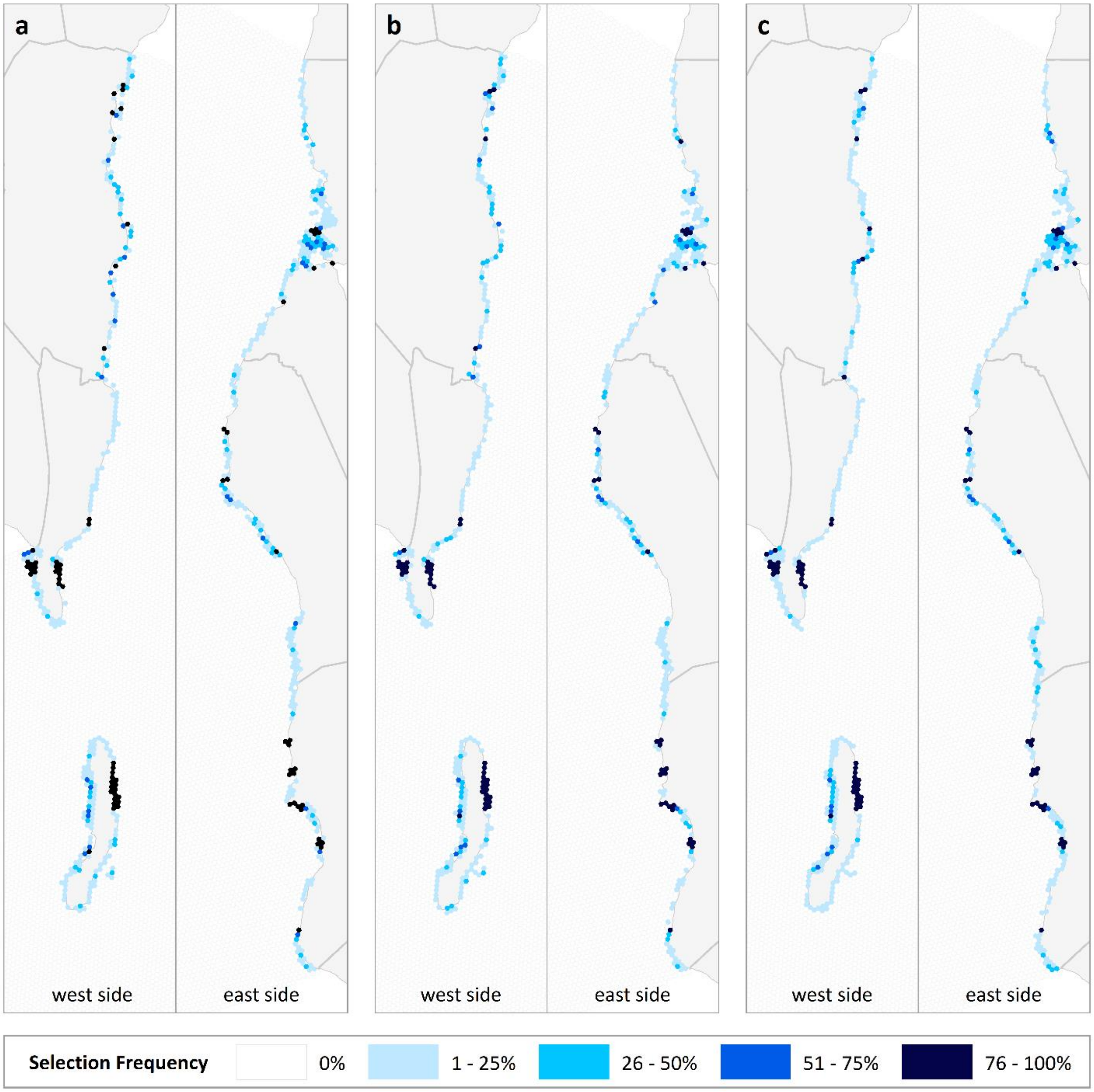

Figure 2.3. Planning unit selection frequencies for MPAs under each scenario: a) scenario one (fishery features grouped by community; includes all forms of fishing), b) scenario two (fishery features grouped by community; only dominant fishing gear considered), and c) scenario three (fishery features grouped by municipality; includes all forms of fishing).

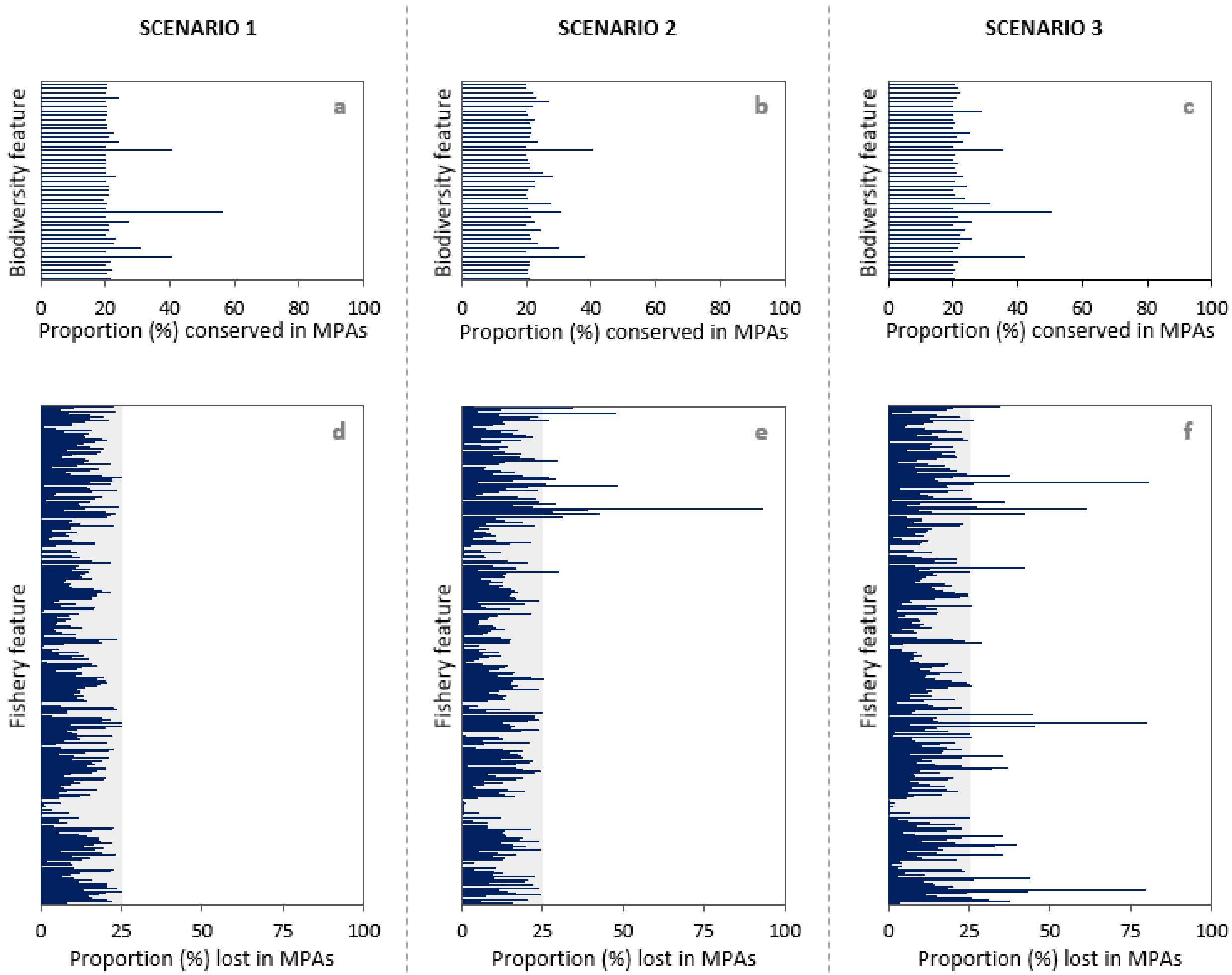

Figure 2.4. The proportion of biodiversity and fishery features in MPAs selected in the "best" MPA network plan of each scenario. The bars in the top graphs (a,b,c) represent biodiversity features (coastal habitat class per municipality). In all cases, the biodiversity features met their 20% representation target for inclusion in MPAs. Each bar in the bottom graphs (d,e,f) represent a fishery feature at a community scale (fishing method per barangay). Fishery features contained within the grey zone of each graph have maintained at least 75% of their fishing area in the open zone (i.e., they have not lost more than 25% of their entire fishing area in the MPA zone).

Equity

While each scenario met the fishery target successfully, they each had different fishery features. When we compared the best MPA plan of each scenario in terms of their impacts on all fisheries at a community scale (i.e., 863 features; each defined by method and barangay), we found that scenario one was the best at maintaining "distributive equity", followed by scenario two and three (Figure 2.4 d,e,f). Scenario one was the only scenario that considered all barangays and types of fishers in the MarZone analysis. In doing so, it resulted in a MPA plan that distributed costs equitably across all fishery features at a community scale (Figure 2.4 d), ensuring that all barangays maintained at least 75% of the fishing area of each method (Figure 2.5 a). In comparison, the best MPA plan from scenario two caused a few inequity concerns as it only considered the most popular methods in the planning region at a community scale (Figure 2.4 e). Still, 98% of fisheries features (8 of 863 features), including many of those associated with less popular methods (not considered explicitly in scenario two), maintained a minimum of 75% of their fishing areas (Figure 2.5 b). The remaining 2% were associated with less popular methods that lost more than 25% of their total fishing area. This included one barangay that would lose 93% of their pot trap fishing sites. In comparison to scenario one and two, we found that grouping fishers by methods and municipality in scenario three resulted in the most inequitable distributions of MPA costs for fisheries associated with different fishing methods and barangays (Figure 2.4 f). The best MPA plan of scenario three caused 5% of fisheries features at a community scale (42 out of 863) to lose more than 25% of their fishing grounds, including four features that suffered losses between 61 to 80% (Figure 2.5 c).

Spatial Efficiency

The average total area of MPA planning units selected in the MPA zone of 100 replicate MarZone solutions was highest for scenario one, followed by scenario two and three. Including all fishing methods at a community scale (scenario one) resulted in a total MPA zone area that was on average 4.7% larger than the scenario that included only the most used fishing methods at a community scale (scenario two), and 7.6% larger than the scenario that considered all fishing methods at a municipal scale (scenario three) (Figure 2.6).

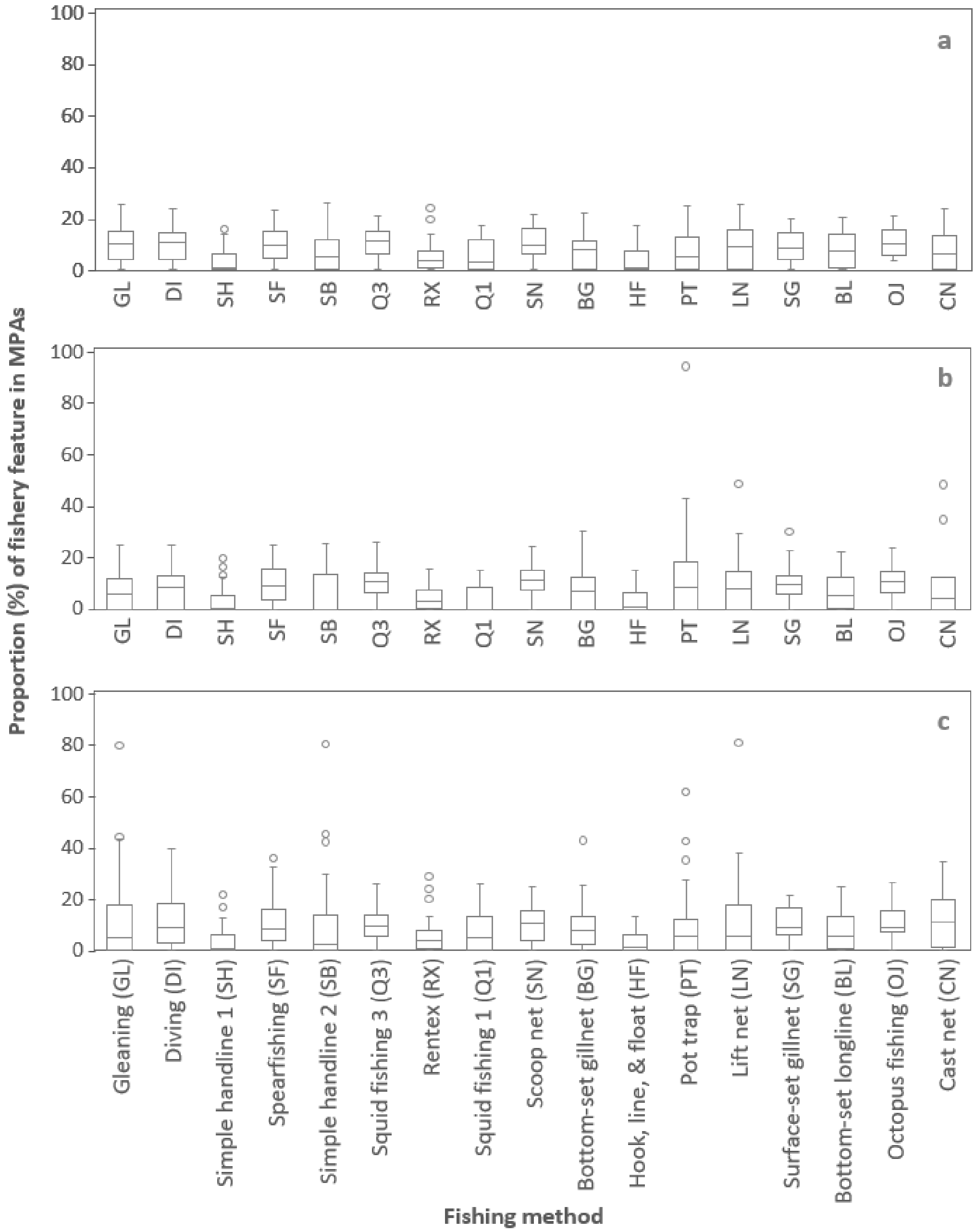

Figure 2.5. The proportion of each fisheries feature lost in MPAs identified in the best solution for (a) scenario one, (b) scenario two, and (c) scenario three. The fishery features are expressed at a community scale (method per barangay). Each boxplot shows the range, upper and lower quartiles, and the median values of fishery features by method. Outliers are shown as open circles.

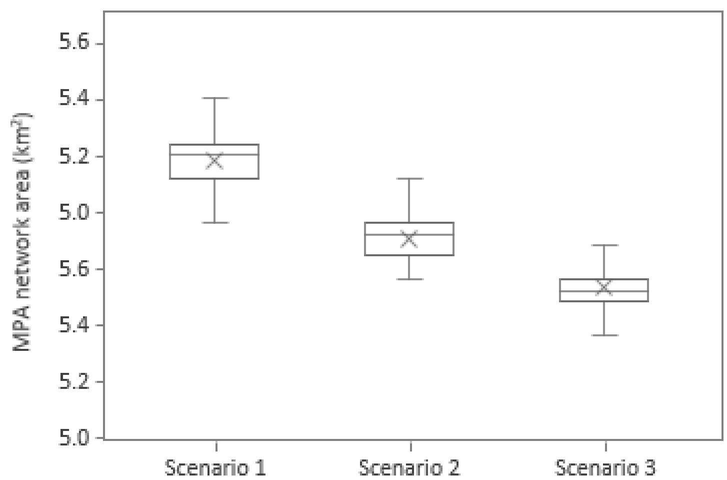

Figure 2.6. The total area of planning units contained in the MPA zone under different scenarios. Boxplots show the range, upper and lower quartiles, and median values of 100 replicate MarZone solutions. The mean is shown by an "x".

2.5. Discussion

SCP is a leading MPA planning strategy for designing and establishing representative MPAs and MPA networks that can accommodate the needs of local people (CBD, 2012b), yet, it has rarely been implemented in tropical, developing nations (Weeks et al., 2014b). Through a Philippines case study, we illustrate how coupling participatory approaches with science-driven methods (i.e., remote sensing, spatial conservation prioritization) in SCP can derive ecologically representative MPA plans that reflect the local context and needs of small-scale fishers and coastal communities. Most importantly, we show how employing a participatory and systematic MPA planning approach (scenario one) with an emphasis on recognition, procedural, and distributive equity (scenario one) can serve to secure important livelihoods and food securities in poor and marginalized fishing communities, without compromising the achievement of national representation target for the CBD and CTI (CBD, 2010; CTI-CFF, 2009a). Notably, the results highlighted how neglecting to include minority fisher groups and/or spatial variations between communities in the systematic design of MPAs can lead to inequitable outcomes.

In this study, we utilized a spatial prioritization tool, the MarZone software, to develop objective, transparent, and spatially efficient MPA options to address gaps in habitat representation in Sogod Bay in accordance with the Philippines' national target for the CTI (CTI-CFF, 2009a). Under the three MPA planning approaches investigated, MarZone was capable of finding solutions that satisfied the fishery targets, while at the same time, achieve representation targets of protecting at least 20% of each coastal habitat class per municipality in a MPA zone. This process for selecting MPAs based on spatially explicit targets and fine-resolution data is a major departure from more conventional approaches of selecting MPA sites in developing countries such as the Philippines (Margules and Pressey, 2000).

As seen in the case of Sogod Bay, most MPAs in the Philippines have been developed through community led initiatives that often prioritize selecting MPAs based on stakeholder preferences rather than biological importance. This has led to gaps in MPA coverage and habitat representation, especially in marine KBAs (Ambal et al., 2016; Weeks et al., 2010a). In response, the national government is currently employing strategies, often with the assistance of external agencies and donors, to scale up community-based MPAs into representative networks with a primary focus of conserving marine KBAs like Sogod Bay (Ambal et al., 2016; Lowry et al., 2009; White et al., 2014). Coral reef nations like the Philippines are of global concern for conservation because they are biologically significant, highly dependant on marine resources, and at increased risk of habitat degradation and fisheries declines from increasing fisher populations, poverty, and lack of alternative options (Allen, 2008; Burke et al., 2012; Foale et al., 2012; Mcclanahan et al., 2015). Hence, there is high demand for finding strategies to allocate and designate MPAs in a manner that can balance conservation and societal needs. As demonstrated through this study, SCP approaches coupled with remote sensing and participatory mapping can provide an efficient and effective means to achieve this balance in the context of a developing country.

While achieving representation targets is a key component of conservation planning, this study focuses primarily on equity. As emphasized in this study, equity can manifest itself in several ways and includes recognition, procedural and distributive equity. As shown through the findings of our study, these dimensions are interlinked and can influence each other and MPA planning outputs. While many academics advocate for careful consideration of equity factors in MPA planning (Hill et al., 2016), there are few studies that demonstrate how this should be achieved, and thus equity remains a poorly studied topic in conservation science (Halpern et al., 2013).

In the context of MPA planning, **recognition equity** relates to recognising and identifying all relevant stakeholders of MPAs, along with their rights, values, interests and priorities for using and accessing marine resources. In aiming to achieve recognition equity, we consulted with local partners and community representatives to gain a greater understanding on who the stakeholders are and how they should be considered within the MPA planning process. We identified a full range of small-scale fisher stakeholders, including women gleaners who have rarely been included in fisheries surveys and decision-making processes in the Philippines (Kleiber et al., 2015).

The premise of **procedural equity** is the engagement and inclusion of all relevant stakeholders in processes and decisions that may affect them. In working towards achieving procedural equity, we conducted participatory mapping workshops at each coastal community in the planning region, which allowed us to engage with fishers from different fisheries (i.e., fishers using different fishing methods) and communities (Schreckenberg et al., 2016). Employing a participatory mapping approach that included fisher representatives from each community facilitated the SCP process in two major ways. First, engaging with small-scale fishers from each coastal community provided an opportunity to explain the need for enhanced conservation actions early in the MPA planning process. It created a platform to build trust, promote open dialogue, facilitate conflict resolution, and enhance understanding amongst stakeholders. These factors can enhance local compliance and buy-in to MPA regulations, which are vital in coastal resource management (e.g., Levine and Feinholz, 2015; Mellado et al., 2014; Pomeroy and Douvere, 2008; Sullivan et al., 2015). Second, participatory mapping provided an efficient and effective means of collecting fisheries data in a data-poor context.

Fisher’s research knowledge has yet to become established in fisheries science (Hind, 2015), although it is being increasingly recognized as a viable source of data for SCP approaches that aim to design MPAs with minimal and equitable impacts on fishers (Grantham et al., 2013; Teh et al., 2013; Yates and Schoeman, 2014). As shown here, small-scale fishers can have considerable local experiential knowledge on the fishing practices and resource access needs of members of their community. Documenting this local knowledge provided a cost-effective and participatory means to obtain fine-scale spatial data on the use patterns of different fisheries and communities, in addition to rich attribute data such as number of fishers, gender profiles, and reasons for use.

While other studies have focused on the implications of stakeholder engagement, participation, and input in SCP (e.g., Game et al., 2011; Grantham et al., 2013; Teh et al., 2013), we provide the first comprehensive examination of how recognition and procedural equity may influence MPA planning outputs of SCP approaches in terms of **distribution equity** (benefits and costs shared equally between relevant stakeholders). Through investigating three alternative planning scenarios, we identified how (1) the inclusion or exclusion of minority fisher groups, and (2) the inclusion or exclusion of community variations in spatial prioritization affects MPA planning outputs in terms of representation, spatial efficiency, and distributive equity for small-scale fisheries and coastal communities.

Through comparing two planning scenarios that differed in whether they included or excluded minority fisher groups, we demonstrate how limited considerations of recognition and/or procedural equity may affect fisheries or communities disproportionately, thereby reducing distributive equity. In contrast, MPAs derived from recognizing and including all types of fisheries (scenario one) results in a more equitable distribution of costs amongst fisheries and communities. While MPAs derived from only considering the most dominant fisheries (scenario two) were less equitable, we found that the proportion of fisheries features that incurred high costs was unexpectedly low, even amongst minority fisheries that were not included as fishery features in spatial prioritization. One possible explanation is that the dominant fisheries in Sogod Bay included fishing methods (e.g., simple handline, gleaning, diving) that are typically practiced close to a fisher’s community and often restricted to narrow areas close to the coastline, which is a similar spatial pattern as some less dominant fishing methods (e.g., octopus fishing, bottom-set gillnets).

The functionality of MarZone allowed us to use a method to design MPA plans that can achieve biodiversity and fishery targets simultaneously. Studies that have utilised this same method have shown that treating fisheries as objectives to achieve, instead of a single index of cost, produce more equitable plans for multiple fisheries (e.g., Gurney et al., 2015a; Klein et al., 2010, 2008; Mazor et al., 2014; Weeks et al., 2010b). However, many of these studies have neglected to recognize or include the spatial variations among communities, often acknowledging this as a major limitation of their fisheries data and of their assessment of the fishing impacts of MPA plans. We investigated the potential consequences of this commonly stated limitation through comparing two scenarios that differed in whether or not they included the variations of communities in spatial prioritization. Our findings show that incorporating fishing data linked to communities produced more equitable plans for small-scale fishers from different fisheries and communities. In contrast, neglecting to integrate spatial differences between communities unfairly impacted certain communities. These results were expected given the diversity of methods and spatial patterns we observed amongst fishers and communities in Sogod Bay. To our knowledge, only a few SCP assessments in the literature have addressed distributive equity for small-scale fisheries at a community scale (e.g., Grantham et al., 2013; Teh et al., 2013).

We acknowledge that it may not be feasible or even necessary to include all fisheries or communities in spatial prioritization (e.g., fishers may only be interested in maintaining important fishing grounds). As shown in our results, one possible critique of including all fisheries and communities in spatial prioritization is that it can result in less spatially efficient plans. While the total area of planning units in MPAs under the two scenarios did not differ considerably, we do acknowledge that spatially efficient plans may be more feasible to implement, especially in nations with centralized governance systems. However, we agree with Game et al. (2011) that spatial inefficiency is probably a poor indicator of social acceptability in the context of developing countries, especially countries like the Philippines that have decentralized governance systems. Thus, we argue that spatial efficiency should not be favored over considerations of equity.

Regardless of the situation, we recommend paying special attention to marginalized fisher groups. For small-scale fisheries, this often includes women fishers who have often been excluded from fisheries surveys and decision-making processes (Hauzer et al., 2013; Kleiber et al., 2015). The importance of recognizing women and other minority groups in small-scale fishers is illustrate by Kleiber et al. (2014). Through a Philippines case study, they showed how narrow definitions of fishers that exclude women would neglect to recognize a substantial portion of local fisheries, since women surveyed in their study region accounted for more than 40% of the total fishing population. Similarly, we found that women represented more than a quarter of all fishers in our planning region in Sogod Bay. The impacts on women fishers could have been more inequitable had we neglected to include women fishers and/or gleaning from our planning scenarios.

As shown in our study, the results depicting estimated impacts on different fisher groups and communities are dependant on how fisher stakeholders are defined and grouped, and how fisheries data are collected. Another important factor involves the metric used to reflect the relative value of areas to each fisheries feature (Ban et al., 2009; Ban and Klein, 2009a; Carwardine et al., 2008). Here, we used area lost to each fishery feature the metric for fishing value. While this metric served to ensure that a minimum proportion of each fishery feature is kept open to fishing, it does not consider other factors (e.g., importance value, number of fishers per planning unit) that may be important for determining the actual impacts of different plans on fishers. Addressing these factors in an analysis may not require additional data collection, since we obtained supplementary data per fishing site (e.g., importance value, target catch, number of fishers) through our mapping workshops. Although, we found that integrating these factors within the input parameters of a MarZone analysis required making subjective decisions (e.g., how to set targets based on importance value, how to calibrate different metrics and targets simultaneously). Hence, we chose a simpler area-based metric to minimize uncertainties.

The primary intent of this study was to provide much needed guidance for developing countries interested in employing the SCP process to develop representative MPA networks in a manner that can accommodate the needs of local communities. MPAs designed using decision-support tools are not meant to reflect the final design of a network. They require fine-tuning to consider a wide range of ecological, political, socioeconomic, and practical factors (Ball et al., 2009). For instance, additional ecological information (e.g., species distributions, habitat quality, and bathymetry data) could supplement the remote sensing outputs and strengthen the analysis. It would also help address data gaps in regions under cloud cover that could not be derived from remote sensing techniques. Other important considerations that would need be considered include MPA design parameters (e.g., size, spacing, and connectivity)(Green et al., 2014; Kukkala and Moilanen, 2013), management effectiveness (Maypa et al., 2012), governance capacity (Gill et al., 2017), informed opportunities (e.g., LGUs in support of establishing MPAs; Game et al., 2011), and other types of marine users (e.g., tourism sector; Lopes et al., 2015).

2.4. Conclusion

Our study illustrates the utility of coupling science-driven and participatory methods in a SCP process to develop representative and equitable MPA plans that reflect the realities of developing countries. It contributes to the SCP literature by providing important insight on how to integrate equity considerations in the MPA planning process. It describes an approach to secure livelihoods and food securities in small-scale fishers and their communities, while aiming to fulfil national commitments to the CBD and CTI. By comparing different planning option, we highlighted the value and potential trade-offs of recognizing and including a full range of stakeholder in the SCP process. In addition, the findings highlight the importance of integrating fisheries data at a scale that reflects the heterogeneity of fishing communities. Finally, it highlights the benefits of gaining a good understanding of the fisheries in a planning region to inform better decisions on who the key stakeholders are, and how their needs should be included in the systematic planning of MPAs.

Chapter 3 : Evaluating approaches for scaling up community-based marine protected areas into socially equitable and ecologically representative networks

3.1. Abstract

Marine protected areas (MPAs) are vital to marine conservation, but their coverage is insufficient to address declines in global biodiversity. In response, many countries have committed through the Aichi Target 11 of the Convention of Biological Diversity to conserve 10% of the marine environment through 'ecologically representative' and 'effectively and equitably managed' MPAs by 2020. The rush to fulfill this commitment has raised concerns on how efforts to increase MPA coverage will impact other elements of Target 11, including representation and equity. We used a Philippines case study to assess and compare MPA planning approaches for biodiversity representation and equitable distribution of costs to small-scale fishers. We explored three approaches: (1) an opportunistic approach where MPAs were identified and supported by coastal communities, (2) a donor-assisted approach that utilised local knowledge to select MPAs through a national-scale and donor-assisted conservation project, and (3) a systematic conservation planning approach that identified MPA locations to achieve biodiversity objectives with minimal and equitable costs to fishers. The opportunistic approach was ineffective at representing biodiversity and resulted in inequitable costs to fishers. MPAs selected through the donor approach disproportionately impacted fishers, but provided near-optimal biodiversity representation of the study region. With approximately the same MPA coverage, the systematic approach was the only approach that achieved all representation targets with minimal and equitable costs to fishers. Our results demonstrate the utility of systematic conservation planning to address key elements of Target 11 and highlight opportunities and pitfalls for planning MPAs in similar contexts.

3.2. Introduction

Marine protected areas (MPAs) are one of the primary management tools employed worldwide to conserve biodiversity and sustain fisheries. Yet, their current coverage and distribution is insufficient to address the global declines in biodiversity and fisheries. This has led to several international agreements to increase global MPA coverage (Watson et al., 2014). In particular, the Convention on Biological Diversity's (CBD) Aichi Target 11 commits government signatories to conserve "10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, […] through effectively and equitably managed, ecologically representative and well connected systems of protected areas" by 2020 (CBD, 2010). While there has been progress in increasing the global coverage of MPAs, most countries are far from fulfilling Target 11 (Butchart et al., 2015; CBD, n.d.). Furthermore, Target 11 goes beyond a simple area-based target, recognizing MPAs as linked social-ecological systems (Ban et al., 2011), and encouraging MPA planning that addresses ecological and social considerations (Woodley et al., 2012). In this study, we focus on two elements of Target 11: ecological representation and social equity.

Ecological representation is a fundamental component of conservation planning. It aims to ensure that MPA systems contain all biodiversity features (comprehensiveness), as well as the range of variation within each feature (representativeness) (Margules and Pressey, 2000; Possingham et al., 2005). This is often accomplished through setting quantitative targets for habitat features (e.g., coral reefs, seagrass beds, mangroves), since it is generally assumed that protecting samples of different habitats will also capture a full scope of species, communities, and biophysical features (Green et al., 2014).

Calling for MPAs that are 'equitably managed', Aichi Target 11 emphasises the importance of equity in planning and managing (Hill et al., 2016; Woodley et al., 2012). Equity issues can arise when the benefits and costs of MPAs have a disproportionate impact on stakeholders and when stakeholders are not provided the opportunity to participate in MPA planning and decision-making processes. Social inequity can cause conflict, noncompliance to MPA rules, and reduce local support of MPAs (Bennett and Dearden, 2013; Christie, 2004; Halpern et al., 2013). In contrast, MPAs stand the greatest chance of success when local communities and stakeholders are considered and included in MPA planning processes (e.g., Guidetti and Claudet, 2010; Hill et al., 2016).

Various strategies and tools are being used to accelerate and improve the establishment of MPAs. Such efforts are often facilitated through the assistance of non-government organizations (NGO), academe, government, and development agencies (e.g., Hastings et al., 2012; White et al., 2014). The array of MPA planning approaches lies on a continuum between systematic conservation planning, with an emphasis on large scale (regional or national) and science-based approaches, and local conservation action, with an emphasis on community-based approaches (Ban et al., 2011). In a systematic conservation planning (SCP) approach, MPA configurations are selected to achieve explicit conservation objectives with limited costs, often through the support of spatial prioritization software. MPA plans developed through systematic approaches can support conservation initiatives to address a full range of species, processes, and threats (Margules and Pressey, 2000). However, they may also fail to inform conservation actions due to capacity, socioeconomic, governance, and political constraints (Knight et al., 2008; Mills et al., 2010). Instead, MPAs are often established through community or local initiatives in an ad-hoc fashion (i.e., MPAs established individually rather than as a collective network), particularly in developing countries. Community-based MPAs can provide local benefits, but often fall short of representing biodiveristy features and tend to be biased towards areas that favor stakeholders rather than biodiversity needs (e.g., Hansen et al., 2011; Weeks et al., 2010a).

While there are trade-offs with all MPA planning approaches, achieving Aichi Target 11 will require conservation strategies that integrate regional goals with local realities (Ban et al., 2011). This will require cost-effective and socially feasible approaches to scale up existing MPAs into ecologically representative networks (Ban et al., 2011; Lowry et al., 2009). Despite support to scale up to representative and equitable MPA networks, developing countries face significant challenges to meet Aichi Target 11, particularly in regard to governance capacity, data availability, and dependence on marine resources (Butchart et al., 2015; Gill et al., 2017; Solandt et al., 2014).

Evaluating the effectiveness of different strategies and actions at achieving biodiversity representation and social equity is critical to understand how increased MPA implementation will affect not only area coverage, but also impact biodiversity and society (Baylis et al., 2016). The purpose of this study is to investigate MPA planning approaches being applied at local to national scales in terms of their impacts on representation and social equity. Specifically, we focus on Sogod Bay in the Philippines as a case study to examine the following MPA planning approaches: (1) opportunistically placing MPAs in sites identified and supported by coastal communities, (2) using local knowledge to select MPAs as part of a national-scale and foreign donor-assisted conservation initiative; and (3) utilising a SCP approach to design a MPA network that achieves explicit conservation objectives with limited and equitable costs to small-scale fisher stakeholder groups. The MPA network plans produced by the three approaches were evaluated and compared based on total coverage, adequate representation of coastal habitats, and distribution of costs to small-scale fisher stakeholders. The comparison provides guidance on designing and implementing representative and equitable MPA networks, particularly in the context of achieving Target 11 in developing countries with community-based MPAs.

3.3. Methods

Study Region

We used Sogod Bay in Southern Leyte, Philippines (Figure 3.1) as a case study due to its rich biodiversity, reliance of local people on fisheries, long history of MPA establishment, and presence of government and external institutions in support of developing MPA networks. The Bay is characterised by a deep central channel (depth up to ~1400m) and a narrow coastal shelf with a mosaic of diverse habitats (e.g., coral reefs, rocky reefs, and seagrass beds).

The study region encompassed the marine tenure boundaries of five municipalities in the southern portion of Sogod Bay, which together consists of 58 coastal barangays (analogous to villages). Similar to elsewhere in the Philippines, MPAs in Sogod Bay are small in size (0.03 km^2 to 0.50 km^2) and have been established through community initiatives at a barangay level in collaboration with municipal governments, and local support institutions. Under the Local Government Code of 1991 (Republic Act No. 7160) and Fisheries Code of 1998 (Republic Act No. 8550), municipal governments have jurisdiction over MPAs in municipal waters (marine tenure boundary that extends ~15km offshore from the shoreline of a municipality), although barangays continue to play a pivotal role in MPA establishment and management. The Fisheries Code also permits registered small-scale fishers (or municipal fisherfolks) to fish anywhere within their municipal waters, with the exception of no-take MPAs (White et al., 2014, 2002).

The current distribution and coverage of MPAs in the Philippines is insufficient to mitigate growing threats such as destructive fishing practices, overharvesting, and climate change (Burke et al., 2012; Weeks et al., 2010a). Existing MPAs often fail to represent different habitat types that are necessary to maintain biodiversity and fisheries (Weeks et al., 2010a), including gaps in protection of Key Biodiversity Areas (KBAs), areas critical to the survival of globally endangered and geographically concentrated species (Ambal et al., 2016). In response, the Philippines government has endorsed international commitments to scale up MPAs into ecologically representative MPA networks. The country is a signatory to the CBD and the Coral Triangle Initiative (CTI), and has a national target to include at least 20% of each major marine and coastal habitat in no-take MPAs by 2020 (CBD, 2010; CTI-CFF, 2009a). The government, along with numerous support institutions, has employed various approaches to improve the ecological integrity of MPAs in the Philippines. Most effort has focused on improving the management effectiveness of existing MPAs and increasing the representation of coastal and marine habitats in MPA networks, with a focus on KBAs (Ambal et al., 2016; Horigue et al., 2012).

As a recognized KBA (Ambal et al., 2016), the Provincial Government of Southern Leyte requested and was granted financial support in 2015 to develop new MPAs in Sogod Bay through the Protected Area Management Enhancement (PAME) project (http://pame.denr.gov.ph/). PAME (2012-2017) was a national conservation initiative, implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). PAME worked in close collaboration with local government and communities to develop and improve management plans of MPAs located in KBAs in the Philippines. Specifically, the project aimed to improve the management effectiveness of 60 existing protected areas and support the designation of 100 new protected areas in KBAs by 2017, including the development of legal and financial frameworks. The project contributes to achieving aspects of Target 11, particularly regarding improved management and expansion of protected area systems with a focus on ‘areas of particular importance for biodiversity’.

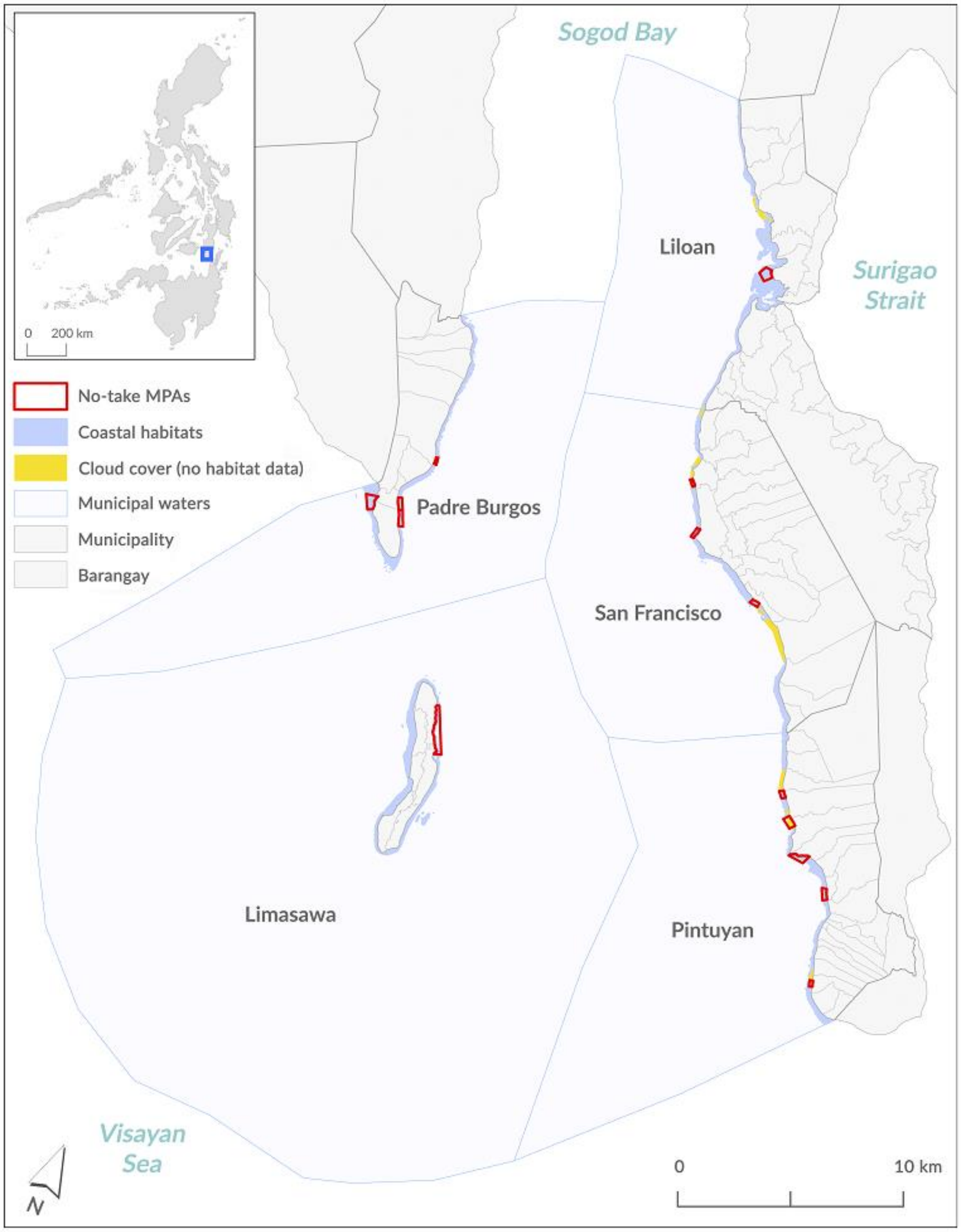

Figure 3.1. Map of study region for Chapter three. The study region is in the southern portion of Sogod Bay in Southern Leyte Province, Philippines. It shows existing MPAs, municipal water boundaries of municipalities included in the study, and the extent of coastal habitats derived from WorldView-2 images, including areas with missing data due to cloud cover.

Data

We collected biodiversity and small-scale fisheries data to compare and evaluate approaches for scaling up MPAs. The biodiversity features represented seven benthic habitat classes found in the coastal waters of each municipality (Appendix B, Table B1). The aerial extent of each habitat class was derived from remote sensing analysis of WorldView-2 satellite images, and field data collected using underwater video transects following standard methods used in nearshore habitats detection (O'Neill and Costa, 2013). The accuracy rate of identification of benthic habitat classes ranged from 20% to 90%. The full extent of each habitat was subdivided into five municipal waters, resulting in 35 biodiversity features. Due to the limitation in using satellite remote sensing for substrate detection in deep waters, we were unable to include deep water marine habitats (>25m depth) (Appendix B).

We collected data on small-scale fisheries because of the high reliance on access and use of coastal habitats for food and income. We conducted 58 participatory mapping exercises (one for each coastal barangay) with focus groups of six to twelve small-scale fishers (men and women over 18 years of age). Participants were asked to map the spatial use patterns of different fishing methods (each method mapped separately) used by members of their barangay. For the analysis, we focused on the five most dominant near-shore fishing methods: gleaning, diving, spearfishing, simple handline with a vessel, and simple handline from shore (Table D1 in Appendix D). We itemized the different fishing methods by barangay, resulting in 258 fishery features (not all fishing methods were practiced by each barangay).

The mapping exercises were also used to identify barangays in support of developing a new MPA. Participants were asked if their barangay had requested or expressed an interest in developing a no-take MPA by 2020, and if so, map the proposed MPA site. The proposed MPAs were then verified by barangay council members (Appendix D).

MPA Planning Scenarios

We investigated three planning scenarios for scaling up community-based MPAs in Sogod Bay into an ecologically representative and socially equitable MPA network. The scenarios differed in terms of the adopted MPA planning mechanism, type and source of data used to identify new MPAs, and the level of stakeholder participation (Table 3.1).

Table 3.1. MPA planning mechanisms and information used to select MPA locations in each planning scenario.

	Description of the MPA planning mechanism	**Information used to select MPA sites**				**Additional notes** (e.g., stakeholder inclusion and participation)
		Local support to develop MPA	Local ecological knowledge	Remote sensing data on coastal habitats	Spatial use patterns of small-scale fishers	
Scenario 1: Opportunistic approach	Barangays in support of establishing a MPA collaborated with their municipal government to implement and manage a MPA	✓	✓			▪ Prospective MPA sites identified during mapping exercises by small-scale fisher representatives ▪ Included fishers from <u>all</u> coastal barangays ▪ MPA sites verified by barangay council members ▪ Support for MPAs based on biodiversity and/or fisheries objectives
Scenario 2: Donor-assisted approach	The PAME project (implemented by the development agency, GIZ) collaborated with local governments to develop new MPAs in KBAs in the Philippines	✓	✓			▪ Workshop participants (government agencies, NGOs, academics, and stakeholder representatives) identified prospective MPA sites based on their local knowledge of coastal habitats and local support for MPAs ▪ Included fishers from <u>some</u> coastal barangays ▪ Biophysical assessments and follow-up meetings in selected municipalities and barangays held prior to MPA implementation
Scenario 3: Systematic approach	A systematic conservation planning tool was used to identify MPA configurations that meet explicit biodiversity targets with minimal and equitable costs to small-scale fishers			✓	✓	▪ Biodiversity targets based on the Philippines national target (include ≥20% of each habitat in no-take MPAs) ▪ Included fishers from <u>all</u> coastal barangays ▪ Included fishing data of top 5 near-shore fishing methods used in the study region

Scenario one (opportunistic approach) reflects a community-based approach to scaling up to networks, which is the most common mechanism employed in the Philippines to develop and manage MPAs (Horigue et al., 2012). In line with this approach, scenario one aims to predict the MPA network that would likely have been developed by 2020 through barangay initiatives without the influence of support institutions (e.g., donor agencies or academics). To design this MPA network, we assumed that MPAs would continue to be developed in Sogod Bay on an opportunistic basis, where barangays in support of MPAs would collaborate with their municipal government to develop new MPAs that over time may result in a more representative MPA network. We identified proposed MPAs with strong community support through participatory mapping exercises with small-scale fishers and used these MPAs as the opportunistic scenario.

We used scenario two (donor-assisted approach) as an example of a large-scale conservation initiative, supported by a foreign donor agency, to accelerate national efforts to identify and designate MPAs, and achieve Target 11. For this scenario, we used the MPA network plan developed through the PAME project where new MPA sites were selected through local knowledge coordinated through the provincial government of Southern Leyte with the support of the development agency, GIZ. The MPA selection process began with a workshop in March 2016 that included government employees (provincial, municipal, and barangay level), support institutions (NGOs and academics), and some stakeholder representatives (e.g., fishers from fisherfolk organizations) involved in coastal resource management. During this workshop, participants identified twelve MPA sites in Sogod Bay based on their local knowledge on coastal habitats, with an emphasis on conserving coral reefs. Community support to develop new MPAs was also considered. Ecological and fisheries data used in our analysis were not available at the time of this meeting. However, biophysical assessments and follow-up meetings at selected municipalities and barangays were conducted through the PAME project prior to finalising MPA plans. As of December 2017, four of the twelve MPAs supported by the PAME project have been officially implemented by law in Sogod Bay.

For scenario three (SCP approach), we employed a SCP approach using the spatial prioritization software, 'Marxan with Zones' (MarZone) to design a MPA network that could achieve set biodiversity targets at minimal costs to small-scale fishers (Watts et al., 2009). We used 35 biodiversity features (habitat class per municipality) and 258 fishery features (fishing method used by a barangay). We divided the study region into uniform hexagonal 'planning units' of 0.04 km^2, a scale comparable to the smallest no-take MPA in the province. We calculated the amount of each biodiversity and fishery feature found in each planning unit. We then used MarZone to identify solutions with two types of zones: a no-take MPA zone and an open zone available for fishing. We set a biodiversity target to include at least 20% of the total extent of each biodiversity feature in a MPA zone (the Philippines national target). Planning units with existing MPAs were designated in the MPA zone. To minimize and equitably distribute opportunity costs to small-scale fishers (costs associated with loss of fishing access), we set a fishery target to keep a minimum percentage of the total fishing ground of each fishery feature in an open zone. The cost associated with achieving the biodiversity target in the MPA zone was the total area of planning units. There was no cost for the open zone.

We applied MarZone iteratively to identify the maximum fishery target that could be achieved while still meeting the biodiversity target. To do this, we kept the biodiversity target constant, but ran the software with a series of increasing fishery targets that varied by 1% increments. With each series, we began by increasing the feature penalty factor (fpf) to first meet the biodiversity target (same fpf for each biodiversity feature). If the solution fell short of meeting the fishery target, the fpf of each fishery feature (same for each fishery feature) was increased until all fishery targets were achieved. When both the biodiversity and fisheries targets could not be met simultaneously, we let the biodiversity feature suffer the shortfall in preference to meeting the fishery target. Each of these analyses consisted of 100 runs of 10 million iterations. This process allowed us to identify the higher fisheries target that could be achieved (all fishery features met targets) while simultaneously meeting all biodiversity targets. We subsequently used the 'best' solution (solution with the lowest total cost of 100 runs) of this MarZone analysis as the MPA network plan for scenario three.

Analysis

We calculated the extent of MPA coverage and each biodiversity feature in each municipal water and in our study region using ArcGIS v10. We then performed a gap analysis to evaluate and compare the MPA network plan of each scenario in terms of area coverage, representation, and social equity. We measured equity as the distribution of costs amongst different small-scale stakeholder groups, calculating the proportion of each fishery feature that would be lost in new MPAs under the different scenarios.

3.4. Results

MPA Network Plans

The final MPA network plan derived from each MPA planning approach showed variable overlap with one another (Figure 3.2). Most MPA sites (eight of twelve) supported by barangays in the opportunistic approach (scenario one) overlapped with MPAs selected through the donor-assisted approach (scenario two). Of these, MPAs from the donor-assisted approach were 36% to 72% larger than those proposed by fishers in the opportunistic approach. MPAs selected in the SCP approach (scenario three) were more evenly distributed across the planning region and resulted in the greatest number of MPA sites.

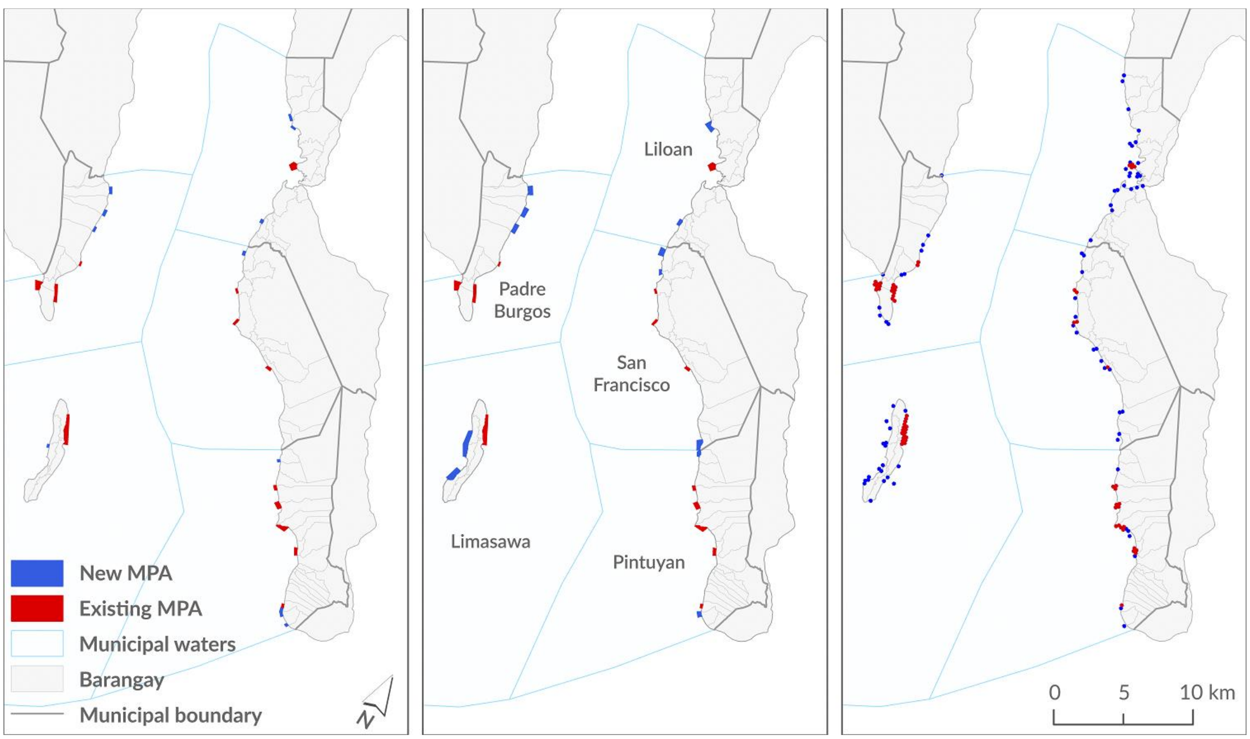

Figure 3.2. The final MPA network plans for each planning scenario: (a) scenario one used an opportunistic approach, (b) scenario two used a donor-assisted approach, and (c) scenario utilised a SCP approach.

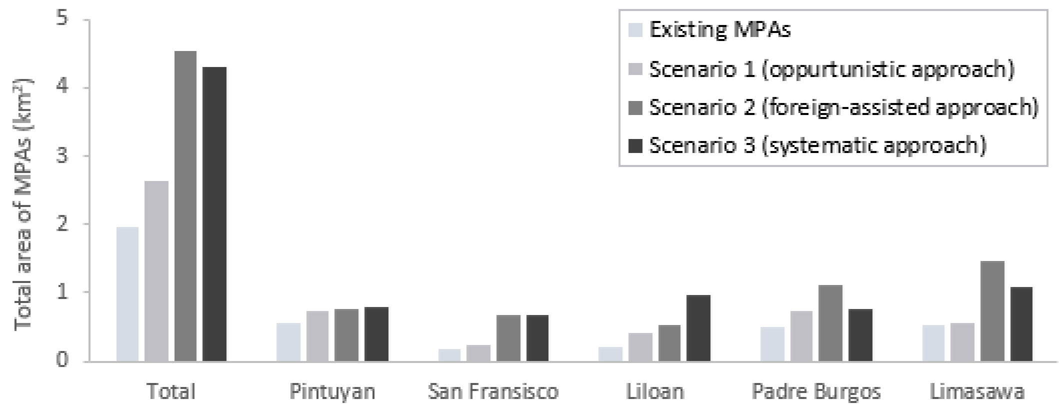

Figure 3.3. Total area coverage of MPAs (by municipality and study region) in the current MPA system and MPA networks developed under different scenarios.

The MPA network plan designed through the donor-assisted approach had the greatest total area of protection (4.6 km^2), while the opportunistic approach had the least (2.6 km^2). The total area coverage of existing MPAs (2.0 km^2) was increased by 26% with the opportunistic approach and was more than doubled for MPA networks developed through the donor-assisted approach and the SCP approach (Figure 3.3).

Representation

Representation varied by scenario (Figure 3.4). The current distribution of MPAs does not achieve the Philippines national target to protect at least 20% of each major habitat (Figure 3.4a). The MPA network systematically designed to achieve biodiversity and fishery targets resulted in the most ecologically representative MPA network plan (Figure 3.4d), representing at least 20% of the areal extent of each coastal habitat class in each municipal water and across the entire study region. In comparison, the opportunistic approach and the donor-assisted approach resulted in uneven representation of biodiversity features. The proportion of each biodiversity feature included in MPAs ranged from one to 35% for scenario one (Figure 3.4b) and 4 to 46% for scenario two (Figure 3.4c). The opportunistic approach had the lowest number of biodiversity targets met (ten out of 58 biodiversity features). The MPA network from the donor-assisted approach met less than 60% of all biodiversity targets, but at a regional scale represented more than 20% of the total area of six (out of seven) habitat classes (Appendix G).

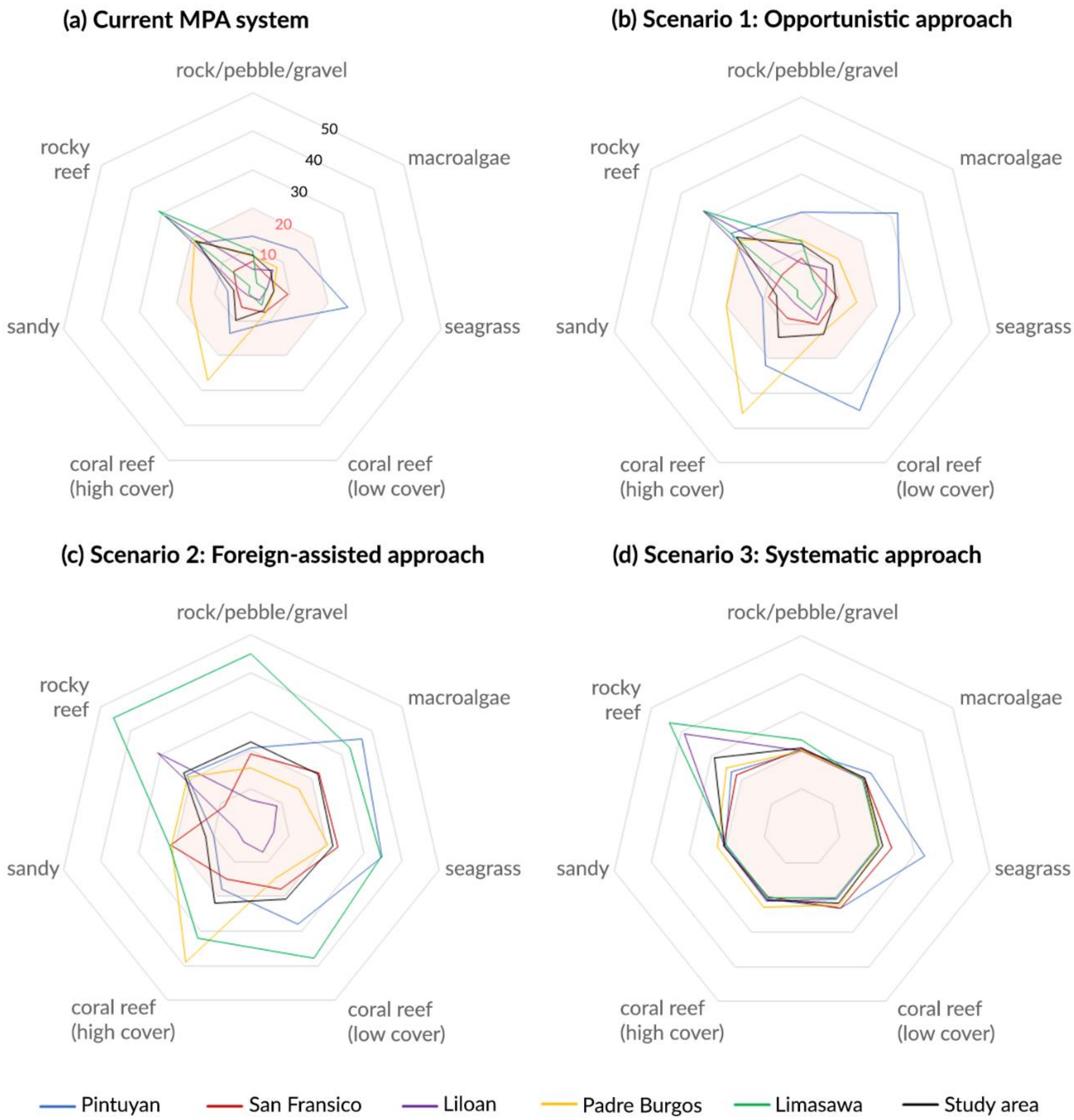

Figure 3.4. Proportion of biodiversity features included in (a) the current MPA system and in MPA network plans for (b-c) each planning scenario. The coloured lines show the proportion of each habitat class represented in MPAs within municipal waters and for the entire study area. Habitat features in the pink zone of the chart fall short of the Philippines national biodiversity target.

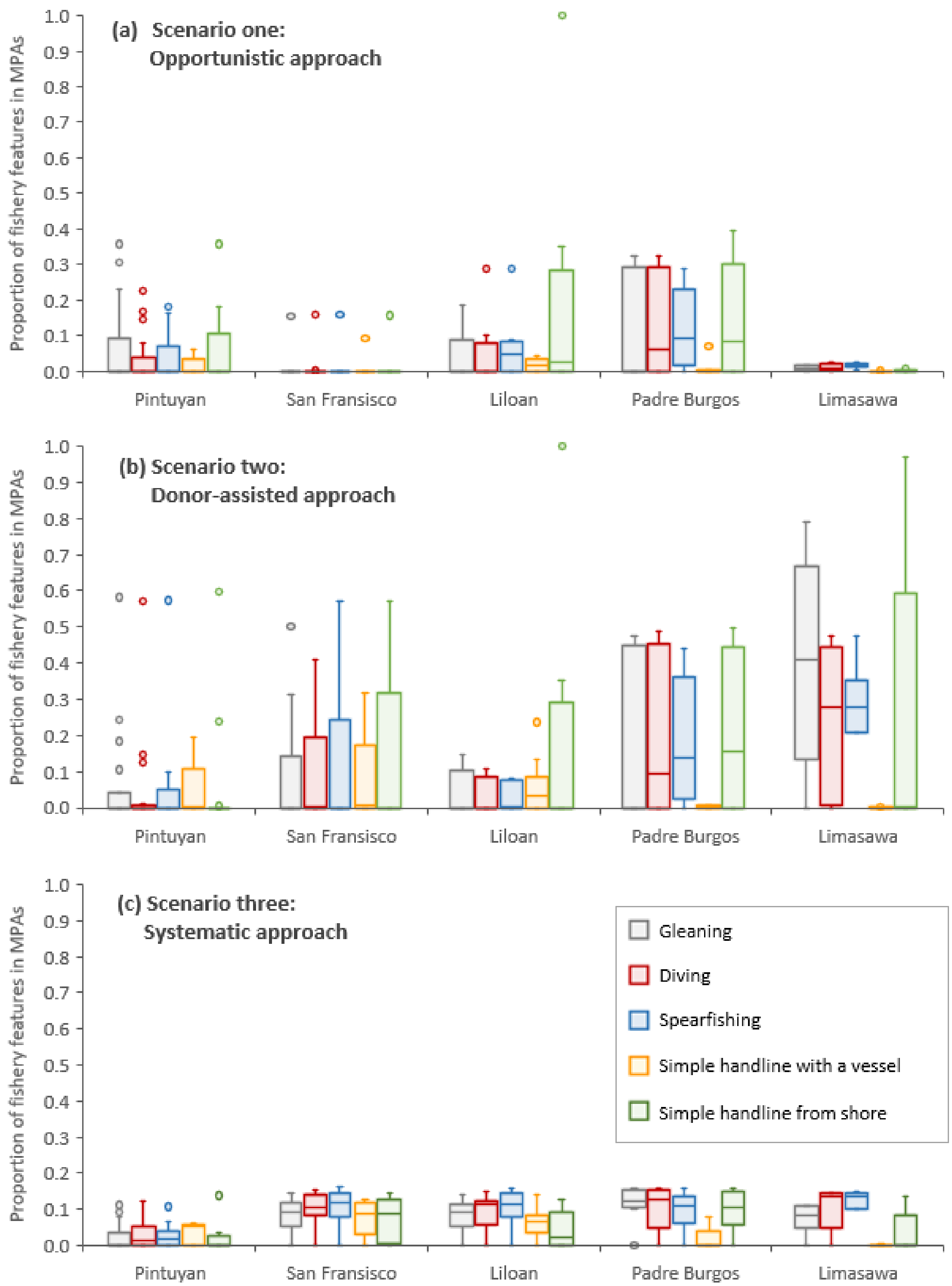

Figure 3.5. The proportion of each fishery features lost in no-take MPAs in each scenario (a-c). Equity was measured as the distribution of costs among fisheries features, where each feature represented the spatial use pattern of a fishing method used by a barangay. The boxplot shows the inter-quartile range, median, and outlier values of fisheries features by fishing method and municipality.

Social Equity

Social equity varied substantially by scenario (Figure 3.5). The systematic approach ensured that none of the fishing features lost more that 16% of their total fishing ground (Figure 3.5c). In comparison, placing MPAs opportunistically (scenario one) in areas with strong community support caused 11 of 258 (or 4%) fishery features to lose more that 30% of their fishing ground in MPAs. Fishery features in Padre Burgos, Liloan, and Pintuyan accounted for the greatest loss in fishing grounds, whereas those present in San Francisco and Limasawa were barely affected (Figure 3.5a). MPAs derived using the donor-assisted approach had the greatest impacts on small-scale fisheries. Out of the 258 fisheries features, 13% of fisheries features lost more than a third of their fishing ground in MPAs. This included two fisheries features that lost 97 to 100% of their entire fishing ground.

3.5. Discussion

Aichi Target 11 calls for representation and equity in recognition of the interconnections between humans and nature, and endorses conservation strategies that move beyond a simple area-based target (Spalding et al., 2016; Woodley et al., 2012). While these aspects of the target are widely acknowledged as key factors in MPA success (e.g., Green et al., 2014; Halpern et al., 2013), comprehensive social-ecological and comparative studies on the biological and social implications of MPA planning options are rare (Ban et al., 2011). Our assessment of the achievement of representation and equity under three MPA planning scenarios showed that planning MPAs was best achieved through SCP planning (scenario three). Our SCP approach employed a method that was holistic, transparent, inclusive of a range of stakeholders, and effective at addressing ecological gaps to develop a representative and equitable network. In comparison, the opportunistic approach (scenario one) and donor-assisted approach (scenario two) led to MPAs with variable representation and inequitable distributions of costs to stakeholders and communities.

Ecological representation is fundamental to the preservation of biodiversity, and is a critical component of conservation planning and international commitments. Existing MPAs throughout the world have variable representation of habitats and species (Butchart et al., 2015; Watson et al., 2014). Likewise, the current MPAs in Sogod Bay were insufficient at representing coastal habitats. This is typical for the Philippines (e.g., Weeks et al., 2010a), although comparisons among studies are limited due to differences in targets and biodiversity features. In accordance to the Philippines' national target for representation (CTI-CFF, 2009a), our results indicate that continuing to employ an opportunistic approach to select and establish MPAs is unlikely to produce a representative MPA network by 2020. Under-representation is a common pitfall of establishing community-based MPAs in an ad-hoc fashion. In contrast, SCP is specifically designed to identify and fill gaps in representation (Margules and Pressey, 2000). Our findings demonstrate this advantage, since the SCP approach was the only approach that produced a MPA network plan that fulfilled all representation targets. Interestingly, the MPA plan developed through the donor-assisted approach was close to achieving optimal representation, even though it did not consider representation as an explicit MPA selection criterion. Instead, representation was achieved inadvertently through the PAME project from using local knowledge to select MPAs with strong community buy-in and high coral cover. These results support studies such as Horigue et al. (2012) and Fox et al (2012) that advocate for strategic partnerships between governments and external support institutions to accelerate progress towards fulfilling conservation objectives.

Social equity in the context of MPA planning can take many forms. For example, procedural equity relates to inclusion and participation of all relevant stakeholders and individuals involved in planning processes. Distributive equity refers to the distribution of costs and benefits to those that would be affected by MPA implementation (Halpern et al., 2013; Schreckenberg et al., 2016). Our study focuses on the latter, although we do discuss the former in recognition of its considerable influence on MPA success. Through measuring the proportion of each fisheries feature (i.e., a fishing method and a barangay) lost in MPAs, we determined the SCP was most effective at minimizing and distributing costs equitably amongst stakeholder groups, without compromising the achievement of biodiversity targets. The method employed incorporated equity as an explicit planning objective, and contributes to emerging studies that address equity concerns by setting both biodiversity and fisheries objectives (e.g., Grantham et al., 2013; Gurney et al., 2015a; Klein et al., 2008). In contrast, the planning approaches that did not consider equity concerns explicitly (i.e., the opportunistic and donor-assisted approach) lead to inequitable distributions of costs to stakeholders. For the donor-assisted approach, this may be due to factors such as (1) inadequate inclusion of all relevant stakeholders, (2) power imbalance among participants in the MPA selection process, and/or (3) limited understanding of the complex spatial use patterns of small-scale fisheries (e.g., Halpern et al., 2013; Hill et al., 2016; Schreckenberg et al., 2016).

Our own observations from mapping exercises help explain inequity accrued through the opportunistic approach. We theorize that communities motivated to establish MPAs choose sites that could accommodate their resource access needs, but did not consider (deliberate or unintentional) possible implications of conservation actions on fishers from other barangays (marine tenure permits fishing at a municipal water extent). For example, in mapping exercises some fisher participants were vociferously opposed to MPAs being proposed by certain barangays, since implementation of these MPAs would impact them disproportionately. Several studies have shown that inadequate consideration of equity issues can lead to conflict, noncompliance, and destructive actions, which risk conservation failure. This is particularly problematic for poor and marginalized communities or stakeholder sub-groups (e.g., women gleaners), especially when socioeconomic factors limit spatial mobility and alternative livelihood options (e.g., Christie, 2004; Hauzer et al., 2013). Thus, MPA planning approaches that achieve procedural and distributive equity, as is largely the case for the SCP approach, should have a greatest chance of being accepted by stakeholders and at achieving long-term conservation success.

There were some limitations with our dataset. We were unable to represent a full scope of habitats, since our remote sensing analysis was only capable of deriving coastal habitat classes in shallow waters, and data were missing in patches under cloud cover (~9% in relation to the total possible mapped habitat area). For fisheries features, we only used the most dominant fishing methods and applied the same targets for all fisheries features to simplify our analysis. We recognize that the needs and preferences of different communities, sub-groups, and individuals may vary. Planning processes could be improved with more ecological (e.g. data on offshore benthic habitats, species distribution, larval dispersal) and fisheries (e.g., fisher priorities) information. In addition, MPA design parameters (e.g., size, spacing) would need be considered to fine-tune plans to maximize conservation benefits (Green et al., 2014). Despite these limitations, collecting the information provided additional benefits including: (1) the development of an up-to-date spatial database (MPA delineations, habitat maps, and spatial use patterns of fishers) that is now available to local governments, NGOs, and academics; (2) open dialogue with stakeholders from all coastal communities regarding their experiences, knowledge, and input on conservation and resource management practices; and (3) identification of opportunities and challenges for future conservation and research in Sogod Bay and regions with similar contextual settings.

The success of MPAs as conservation mechanisms is influenced strongly by the degree of support by local people (Bennett and Dearden, 2013). Like many developing countries, the Philippines has many “paper parks” that are legally designated on paper, but are poorly managed and ineffective at protecting biodiversity. Key reasons for ineffectiveness include limited governance capacity and lack of stakeholder support (Horigue et al., 2012; Lowry et al., 2009). Opportunistic and donor-assisted approaches provide a pragmatic means of selecting MPAs, because they are easier for communities to understand and often more feasible to implement due to strong community support. They require less technical knowledge and data, but come with significant costs to the achievement of equity. In contrast, the SCP requires a substantial amount of resources (time, cost, and level of expertise) to collect and incorporate data in a MarZone analysis. We recognize that this could be difficult to replicate at national scales, although remote sensing and participatory mapping can be highly cost-effective in comparison to field survey methods, especially for assessment at larger scale extents (Hedley et al., 2016). Additionally, support institutions can facilitate systematic conservation planning processes or other approaches to accelerate MPA planning and implementation processes. They can also strengthen governance capacity, finance management regimes, and establish mechanisms for stakeholder inclusion and participation, all of which can increase the likelihood of MPA success (Gill et al., 2017; Horigue et al., 2012; Lowry et al., 2009).

In future, the best approach likely lies in finding synergies between different planning approaches. Nonetheless, impact evaluation is imperative to inform planning and decision-making processes, can help allocate resources to conservation efforts that are most likely to succeed, and address uncertainties of existing and proposed conservation initiatives (Baylis et al., 2016). Furthermore, impact evaluation can measure progress towards achieving aspects of the Aichi Target beyond simplistic metrics of the number and coverage of MPAs (Spalding et al., 2016; Watson et al., 2014).

3.6. Conclusion

Understanding the trade-offs and synergies of different MPA planning approaches is fundamental to achieving all aspects of Aichi Target 11 and to encouraging the preservation of global biodiversity. This case study assessed the implications of three MPA planning approaches for achieving representation and equity, two aspects of Target 11. We found that a systematic approach was most suitable at developing a MPA network plan that simultaneously achieved representation and equity objectives. In comparison, an opportunistic and donor-assisted approach led to variable representation and inequitable costs to stakeholders and communities. While there is uncertainty regarding the feasibility of implementation of systematically designed MPAs (Knight et al., 2008), we contribute to studies that demonstrate how incorporating equity considerations in systematic planning processes can produce MPA network plans that are both biologically viable and socioeconomically feasible (Klein et al., 2008).

Chapter 4 : Conclusion

This concluding chapter consists of five sections. The first section outlines the objectives of the thesis, which were achieved through chapters two and three. The second section discusses the main contributions of this research in relation to four key limitations associated with the research-implementation gap of SCP in the context of developing nations. The third section outlines the main contributions of the research for the study area in Sogod Bay, highlighting how the research will inform ongoing and future resource management and conservation initiatives in the Bay. This section also provides an opportunity to reflect on some of the key challenges of conducting the research in this region. Section four points to some of the limitations of the research. Finally, the fifth section outlines some suggestions for future research.

4.1. Achievement of the Research Objectives

This thesis answers the overarching research question: **How can systematic conservation planning be applied as a framework for designing MPAs to achieve national biodiversity objectives in a manner that is socially equitable and accommodating to the needs of coastal communities?** In answering this question, three major research objectives were addressed:

1. Develop and document strategies for incorporating dimensions of equity (recognition, procedural, and distributive) for stakeholders and coastal communities in the planning stages of SCP.
2. Investigate how recognition and procedural equity can impact the systematic design of MPA plans in terms of biodiversity representation, spatial efficiency, and distributive equity for fisher stakeholder groups and communities.
3. Evaluate and compare MPAs designed using a SCP approach with more conventional planning approaches in terms of their impacts on representation and social equity.

The following section syntheses the key findings of each chapter and how they address the above-listed objectives.

Objective 1: Develop and document strategies for incorporating dimensions of equity (recognition, procedural, and distributive) for stakeholders and communities in the planning stages of SCP.

Chapter two serves to address objective one of this thesis. Through a Philippines case study, the chapter focuses on three dimensions of equity (recognition, procedure, and distributive) and on how these dimensions can be integrated adequately and realistically within the planning stages of the SCP process. This chapter documents the utility of adopting participatory approaches in SCP to promote the recognition, inclusion, and effective participation of all relevant stakeholders and communities in the design of ecologically representative and socially equitable MPA plans. Additionally, it encourages holistic approaches to SCP that recognize and include diverse sources of knowledge. **Recognition equity** relates to acknowledging and accepting the legitimacy of rights, values, interests and priorities of all relevant stakeholders of conservation activities (Schreckenberg et al., 2016). As demonstrated in Chapter two, this dimension of equity must be considered early in the SCP process and involves identifying all stakeholders who may be affected by MPAs (Hill et al., 2016; Rees et al., 2017; Schreckenberg et al., 2016). Furthermore, it requires setting criteria for defining each stakeholder group (e.g., how to categorize fishing methods practiced by fishers). The chapter illustrates how identifying and defining stakeholder groups can be achieved successfully and efficiently through engaging with individuals and groups that have local knowledge of the marine users and practices of the planning region, and/or people who can influence decision-making processes relating to marine management and conservation practices.

Through identifying and engaging with local partners (individuals from NGOs, LGUs, and academic institutes) and community representatives, this research identified small-scale fishers as the primary stakeholders of MPAs in Sogod Bay. The engagement process, along with a review of the scientific literature, provided a means to identify various types of small-scale fishers, including fishing practices employed by women. One notable finding was that the criteria used for defining small-scale fishers in fisheries surveys or census data varied between LGUs at all levels. For instance, many LGUs did not recognize women as “fishers” despite their known role in extracting coastal resource. One reason for this neglect is that fisheries management is often biased towards fisheries used for sale in local markets, rather than for food security. Even women who were included in this research did not always identify as “fishers”. This is not unique to Sogod Bay, as women and other minority groups have often been marginalized and neglected in fisheries studies (Hauzer et al., 2013; Kleiber et al., 2015). Hence, this research emphasises the need to address recognition equity in stakeholder identification and selecting to avoid further marginalization of certain groups.

In conservation planning, **procedural equity** is built on the inclusive and effective participation of all relevant stakeholders in affairs that concern them (Schreckenberg et al., 2016). This dimension of equity is addressed in Chapter two, and partly in Chapter three (the SCP approach) through the engagement and inclusion of small-scale fisher representatives of each coastal communities through a series of participatory mapping workshops (one workshop per barangay). The fisher participants involved in mapping workshops had extensive knowledge of the various fishing practices employed by members of their community and translate this knowledge onto maps. The collective knowledge of small-scale fishers from each community provided a means to document all the types of fishing methods practiced in all the coastal communities included in the planning region. In contrast, the PAME project described in Chapter three only included small-scale fisher representatives from a few communities. While Chapter three did not explicitly seek to address objective one of this thesis, it does illustrate how the level of stakeholder participation can influence MPA planning output, even among planning strategies that are participatory and reliant on local knowledge.

The premise of **distributive equity** is a fair distribution of costs and benefits between individuals, stakeholder groups, and communities (Schreckenberg et al., 2016). This form of equity may be relative, perceived, or actual, making it difficult to incorporate and evaluate in MPA planning and management (Fabinyi et al., 2010; Halpern et al., 2013; Schreckenberg et al., 2016). However, the negative impacts of spatial restriction of MPAs on small-scale fisheries are well documented (Christie, 2004; Mascia et al., 2010; Stevenson et al., 2013). Spatial restrictions can limit or even end an individuals’ or community’s ability to use or access marine resources, which is especially problematic for people and groups who are dependant on access for their livelihood and/or food security (Mascia et al., 2010; Mascia and Claus, 2009). Furthermore, equity issues among stakeholders and communities can easily arise when spatial restrictions affect marine users disproportionately (Christie, 2004; Fabinyi et al., 2015, 2010). Therefore, limiting the impacts of spatial restrictions and distributing costs fairly amongst stakeholders can promote conservation success (Halpern et al., 2013; Hill et al., 2016).

As illustrated in Chapter two, the use patterns and needs of different fisheries and communities vary spatially. Reflecting these variations within spatial prioritization tools can produce more equitable plans that distribute costs evenly across fisheries and communities, as demonstrated in Chapter two and three. Using a method developed by Klein et al. (2009), the spatial prioritization approach used in each chapter involved treating fisheries' features as objectives to achieve simultaneously with biodiversity objectives. This involved itemizing fishery features by fisheries (based on fishing method) and community, and then assigning each feature a fishery target to maintain a minimum area on their fishing grounds accessible within an open fishing zone. This 'objective' approach has been demonstrated to be much more effective at promoting distributive equity in comparison to more traditional 'cost' approaches that have either treated fishers as homogenous or have only considered one or a few stakeholder groups (Gurney et al., 2015b; Klein et al., 2010; Weeks et al., 2010b).

Objective 2: Investigate how recognition and procedural equity can impact the systematic design of MPA plans in terms of biodiversity representation, spatial efficiency, and distributive equity for small-scale fisheries and communities.

Dimensions of equity can influence intended conservation outcome (Christie, 2004). Despite widespread recognition of this, equity remain a subject that is rarely assessed in MPA planning (Halpern et al., 2013; Rees et al., 2017). Both Chapters two and three involve an assessment of distributive equity to investigate the impacts and trade-offs of different planning approaches. Chapter two addresses objective two explicitly. Specifically, it assesses the MPA outputs of three alternative planning scenarios in terms of their impacts on biodiversity representation, spatial efficiency, and distributive equity for small-scale fisheries and communities. While the MPA plans derived from each approach did not differ significantly regarding representation (all scenarios met the representation target) and spatial efficiency, they did influence distributive equity.

A key finding of Chapter two is that recognizing and including all types of fisheries in spatial prioritization (i.e., recognition and procedural equity), including minority fisher groups, results in more equitable plans for all fisheries and communities. In contrast, only including dominant fisheries (i.e., the most dominant types of fishing methods employed by fishers) can result in some inequity situations because some fishers and communities will incur greater losses associated with spatial restrictions of MPAs. Hence, studies like Hamel et al. (2013) that only considered a few dominant fisheries in a developing country are unlikely to derive socially viable plans. Again, this points to the importance of considering impacts of protected areas on a full range of stakeholders, especially for poor and marginalized fishers and communities in developing countries that are highly dependant on coastal resources and have limited livelihood options. Furthermore, this research emphasises the inaccuracies of many SCP assessments that have treated stakeholders as a homogenous group or have only considers one or a few stakeholders (Ban and Klein, 2009a).

A major advancement in SCP research and tools is the shift from treating socioeconomic factors as ‘objectives’ rather than ‘costs’ (Ban and Klein, 2009a). Recent studies have demonstrated how treating socioeconomic factors as objectives results in more equitable plans in comparison to treating them as a cost (Gurney et al., 2015b; Klein et al., 2010; Weeks et al., 2010b). As demonstrated through the findings in Chapter two, the resulting plans derived through these studies may not be as equitable as advertised because they tend to neglect variations between communities. This is problematic for representing the needs of small-scale fishers who vary not only by gear type and fishing method, but also by community. As shown in both Chapter two and three, failing to consider and include community variations in MPA planning can result in inequitable distributions of costs for different fisheries and communities. Hence, this research encourages careful planning to choose data collection techniques and/or spatial prioritization approaches that can reflect the diverse needs and complexities of stakeholders and their communities adequately and realistically, especially if the aim is to minimize impacts on small-scale fishers.

The findings of this thesis emphasize the role and importance of considering recognition, procedural, and distributive equity simultaneously in conservation planning. Notably, the results presented in Chapter two provide new insight on how (1) the inclusion or exclusion of minority fisher groups, and (2) the inclusion or exclusion of community variations in spatial prioritization affects MPA planning outputs in terms of representation, spatial efficiency, and distributive equity for small-scale fisheries and coastal communities. Furthermore, the findings show how dimensions of equity are intrinsically-linked, where failure to address one form of equity can impact another. More broadly, this research illustrates the benefits of addressing recognition, procedural, and distributive equity in MPA planning, along with the pitfalls of neglecting to consider the major influencing role of social equity on conservation success.

Objective 3: Evaluate and compare MPAs designed using a SCP approach with more conventional planning approaches in terms of their impacts on representation and social equity.

Objective two is addressed exclusively through the findings of Chapter three. This chapter focuses on three MPA planning approaches: (1) opportunistically placing MPAs in sites identified and supported by coastal communities, (2) using local knowledge to select MPAs as part of a national-scale and foreign donor-assisted conservation initiative; and (3) utilising a systematic planning approach to design a MPA network that achieves explicit conservation objectives with limited and equitable costs to small-scale fisher stakeholder groups. To achieve objective three, the MPA network plans derived from the three planning approaches were assessed and compared based on their impacts on spatial efficiency, biodiversity representation, and distributive equity.

The **opportunistic approach** that selected MPA sites, based solely on community willingness to implement MPAs, produced a network plan that was under representative of habitat biodiversity and disproportionately impacted certain stakeholders. While this approach emphasises conservation opportunities, the results of Chapter two indicate that continuing to develop MPAs using ad-hoc and community-led approaches is unlikely to produce representative and equitable MPA networks. Hence, Chapter two highlights the inadequacies of relying on conventional approaches for allocating and designating MPAs to fulfill international conservation targets.

The **donor-assisted approach** involved a national scale and donor-assisted project that utilised the local knowledge held by local partners (e.g., NGOs, academics, government officials) and fisher representatives to prioritize MPA selection in areas of high biological importance (mainly coral reef areas) and areas with known local support to implement new MPAs. The resulting MPA plan of this approach was representative of most habitat classes in the planning region but had the greatest inequitable impacts for fisheries. These results do not discredit the local knowledge of local partners and fisher representatives or discourage international donor agencies from assisting national efforts to expand the coverage of MPAs in developing countries. Rather, these finding should encourage coastal resource management programs that take the appropriate steps to recognize and include representatives of each community. Furthermore, these findings promote investing resources to collect spatially explicit data to inform better decisions in area-based conservation initiatives. This includes both biological and socioeconomic information that can influence conservation outcomes. Moreover, this research stresses the need to include evaluation and monitoring programs in conservation initiatives. In conservation planning, this involves evaluating alternative conservation options to inform better decisions and to avoid costly mistakes.

The findings of Chapter three demonstrate that planning MPA networks that aim to represent coastal habitats adequately, while minimizing and equitably distributing costs to small-scale fisher stakeholders, is best achieved through a SCP approach. Both chapters illustrate the utility of SCP approaches for planning MPA networks to achieve the representation and equity components of the Aichi Target 11. Thus, this research can conclude that participatory SCP approaches can serve to facilitate national efforts of developing countries to fulfil their commitments to multi- and international treaties including the CTI and CBD. Although, the applicability of this approach will depend on available datasets and adequate consideration of socioeconomic complexities, aspects of equity, and the local context for conservation.

4.2. Research Contributions

SCP is playing an increasingly important role in marine management and conservation (Kukkala and Moilanen, 2013), most notably in regard to developing MPAs that can fulfill the multiple elements of the CBD’s Aichi Target 11 (CBD, 2012b). Yet, SCP has rarely informed conservation actions in the developing world (Knight et al., 2008), including countries in the Coral Triangle that are globally important for the persistence of marine biodiversity (Weeks et al., 2014b). Three key challenges contributing to this ‘research-implementation’ gap are:

1. SCP research concepts and tools are biased towards developed countries.
2. Complete and high-quality datasets are lacking in developing countries.

3. Socioeconomic complexities and stakeholders needs tend to be oversimplified.

The following section discusses the main contributions of this thesis and how they address the above-listed challenges of applying SCP approaches in developing countries.

Challenge 1: SCP research concepts and tools are biased towards developed countries

A major reason for the gap between SCP research and successful implementation of MPA network plans in developing countries is the geographic origin of SCP concepts and tools. As with the majority of published literature providing guidelines for designing MPA networks (Ban et al., 2011), most SCP publications originates from developed countries (Ban and Klein, 2009a). These countries have very different social, economic, and political considerations in comparison to developing nations. Thus, applying the same SCP approaches from developed countries to developing countries has inevitably led to a disconnect between research and implementation (Ban et al., 2011; Ban and Klein, 2009a). Another reason for the ‘research-implementation’ gap (Knight et al., 2008) that relates to this limitation is the mismatch in spatial scale issue that occurs between the regional scale (e.g., bioregion, national, or provincial scale) at which systematic planning is generally undertaken, and the local scale (e.g., community level) of conservation action (Mills et al., 2010).

In stark contrast to most developed nations that implement MPAs through centralized approaches, resource management in most Coral Triangle countries (with the exception of East Timor and Malaysia) and certain developing countries has been decentralized to local governments (White et al., 2014, 2002). Consequently, the vast majority of MPAs in the Coral Triangle have been achieved through fine-scale community initiatives (Lowry et al., 2009). MPAs developed through community initiatives can provide local ecological and fisheries benefits (Alcala and Russ, 2006; Magdaong et al., 2013) and promote stakeholder engagement (Beger et al., 2004; Brody, 2003). Although, the resulting MPAs rarely work collectively as ecological networks and are unlikely to maintain regional scale ecological processes and biodiversity (Weeks et al., 2010a).

Applying SCP approaches at regional scales can address a full range of spatial and temporal natural processes and human threats (Margules and Pressey, 2000; Poiani et al., 2000; Sanderson et al., 2002). On the other hand, there are major concerns with regional planning that can be particularly problematic for developing countries. These include (1) increased transaction costs (time, and money) to coordinate conservation efforts across multiple jurisdictional boundaries (McDonald, 2009); (2) inequitable distribution of costs and benefits among resource users from inadequate considerations of stakeholders (Weeks et al., 2010b), and (3) reduced stakeholder participation, acceptance, and compliance (Lowry et al., 2009; Mascia et al., 2010). Only a few studies have attempted to address these potential adverse outcomes in the context of developing countries (e.g., Game et al., 2011; Teh et al., 2013; Weeks et al., 2014b).

Establishing functional MPA networks in the developing countries like the Philippines will require both scaling up governance and scaling down regional plans (Ban et al., 2011; Mills et al., 2010; Weeks et al., 2014a). Despite some progress in developing cohesive social and governance networks through the CBD, CTI, and other conservation initiatives, efforts to scale up governance in developing countries has been limited or short-lived owing to political instability, corruption, lack of sustainable financing, and low governance capacity (Christie et al., 2009; Gill et al., 2017; Lowry et al., 2009). A more feasible solution would be to develop innovative strategies to scale down regional planning processes to accommodate localised governance system (local marine tenure) (e.g., Weeks et al., 2010b) and socioeconomic constraints (e.g., Klein et al., 2010).

Chapters two and three of this thesis illustrate how adopting a participatory approach to the SCP, informed by scientific and local knowledge, and supported by recent advancements in spatial prioritization software can produce MPA network options that (1) reflect the local scale of resource management (e.g., MPA size, marine tenure), (2) recognize the needs of different stakeholders through the production of equitable plans, and (3) promote stakeholder engagement and participation from the onset of the SCP process. In doing so, this thesis provides a method for addressing many of the critiques related to the mismatch scale issue. Most importantly, it provides much-needed guidance on how to adapt SCP to the context of a developing country. As such, our work shows the relevance of using SCP to design MPA networks to translate national conservation commitments into action.

Challenge 2: Complete and high-quality datasets are lacking in developing countries.

Although spatial prioritization tools represent significant improvement over conventional and ad-hoc selection methods for identifying conservation areas, they are data-intensive and most countries, especially in the developing world, lack the resources (time, expertise, money) to collect and compile complete and high-quality spatial datasets on ecological and human factors (Ban et al., 2011; Gill et al., 2017). As a consequence, conservation planners must often rely on incomplete data or the use of surrogates despite their potential limitations (Ban, 2009; Mills et al., 2010).

This thesis contributes to addressing this limitation in three ways: (1) it demonstrates how remote sensing coupled with participatory mapping can derive high quality datasets that are suitable for planning MPA networks in an efficient and cost-effective manner, and (2) it enhances current understanding of how data limitations can impact the achievement of biodiversity and socioeconomic objectives in SCP, (3) it improves our understanding on the use patterns and resource access needs of small-scale fisheries. All of these contributions can help inform better practices in the selection of conservation priorities and guide future data collection efforts.

Habitat types are often used as surrogates for conservation planning, especially when using spatial prioritization tools (Kukkala and Moilanen, 2013). The remote sensing analysis provided a means of collecting fine-scale resolution data on habitat benthic classes in the coastal waters of Sogod Bay. Unlike field surveys that require considerable resources to collect fine-resolution data at larger scale extents, the remote sensing methodology provided a practical and cost-effective alternative for habitat assessments at a Bay-wide scale (Hedley et al., 2016). Furthermore, the available data of field surveys conducted in Sogod bay were scattered and inconsistent in space and time. In comparison, the remote sensing was capable of inferring large scale patterns with complete areal coverage, highlighting a major benefit of remote sensing applications (Hedley et al., 2016).

The Philippines is currently applying remote sensing applications at sub-national scale with the intent of scaling up to a national level. As described by Tamondong et al. (2016), the national government has embarked in a program to gather LiDAR data for the entire county. The goal of the program is to map high valued coastal resources, including benthic habitats and mangrove forests, to serve as baseline data for resource management. Despite progress, the program is lacking in capacity, highlighting a need to transfer the knowledge of remote sensing technology to undeveloped countries. Given that the Philippines consists of 36,000 km of coastline and is both vitally important for global biodiversity and local people, remote sensing is an optimal choice for coastal habitat mapping for SCP (Tamondong et al., 2016).

Another major accomplishment of this research was the production of a comprehensive spatial database on small-scale fisheries using the local knowledge of small-scale fishers. Small-scale fisheries form a substantial portion of the global fishery, representing 90% of all people employed in capture fisheries (FAO, 2016). Nevertheless, these types of fishers (including artisanal and subsistence) remain understudied and poorly represented in planning and decision-making processes that affect their lives (Schuhbauer and Sumaila, 2016). Furthermore, spatial information on small-scale fishers is rarely mapped, so few academics have been able to represent them adequately in area-based conservation assessments (Ban and Klein, 2009a). Even the most comprehensive assessment of small-scale fisheries in the Philippines has treated the entire fishing grounds as homogenous. This is problematic for a developing nation like the Philippines where fishers face high levels of poverty, increasing competition with other fishers, lack of alternative livelihoods, and extremely high dependence on limited natural resources (Muallil et al., 2014b).

The participatory mapping exercise provided a cost-effective means to generate spatial data (along with corresponding attribute data) on the fishing patterns of small-scale fishers. It was able to capture a high diversity of gear types and fishing practices employed by both men and women fishers from close to 100 coastal communities, thus highlighting the utility of participatory mapping methods as a data collection tool in a data-poor context.

Challenge 3: Socioeconomic complexities and stakeholders needs tend to be oversimplified.

There has been increasing emphasis on designing MPA networks that integrate socioeconomic and biological factors in MPA planning to increase the effectiveness and efficiency of MPA implementation and management (Horigue et al., 2012). However, there have been issues with equity and unintended socioeconomic consequences in MPA establishment, since emphasis is often placed on nature conservation and less on socioeconomic complexities and stakeholder needs, particularly for poor and marginalized fishers (Mascia et al., 2010; Schuhbauer and Sumaila, 2016).

Recognizing MPAs as complex and linked social-ecological systems (Cinner et al., 2009) has changed perspectives in SCP from a framework that was initially biologically focused (Margules and Pressey, 2000) to one that now incorporate the socioeconomic factors (Pressey and Bottrill, 2009) that shape society's use, value, and management of marine resources (Cinner et al., 2009; Hughes et al., 2005). Incorporating multiple socioeconomic dimensions in SCP has been facilitated through spatial prioritization software (Pressey and Bottrill, 2009). However, as highlighted throughout this conclusion, the real-world practicality of spatial prioritization software will ultimately depend on whether the data used reflects reality.

While several SCP studies have tested the application of Marxan and a range of similar spatial prioritization tools to theoretical problems, relatively few have tested these techniques in designing and implementing MPA networks under real-world conservation problems (Ban et al., 2011; Knight et al., 2008). A reason for the lack of applied studies, especially in developing countries, is due to limited resources and data coupled with challenges of trying to apply ecological guidelines into practice while minimizing socio-economic costs to multiple types of marine users. As documented in Chapter two, these constraints can be addressed through integrating natural and human dimensions, scientific and local knowledge, and stakeholder participation and engagement, with SCP approaches. In sum, this thesis illustrates how the design of ecologically representative and socioeconomically viable MPA networks in the context or the Philippines, or regions with similar contexts, can be derived through SCP approaches.

Most importantly, this research highlights the importance of recognizing socioeconomic complexities and stakeholder needs in MPA planning, and points to the potential pitfalls of oversimplifying socioeconomic factors. In the context of SCP, this includes the need to move beyond flawed approaches that rely on untested surrogates for fisheries (Rodrigues and Brooks, 2007; Weeks et al., 2010c) and only consider one or a few types of fisheries (Ban and Klein, 2009a). Even methods that treat fisheries as 'objectives' (e.g., Gurney et al., 2015a; Klein et al., 2010) may be flawed if they do not recognize or understand how individuals, fisheries, and communities vary in terms of how they use, access, need, and value coastal and marine resources (Fabinyi et al., 2010; Gurney et al., 2015b; Sullivan et al., 2015). While small-scale fisheries data may be rare, it is not necessarily difficult to acquire, especially when fishers are willing to share their knowledge. As shown through this thesis, small-scale fishers may be willing to share their local knowledge to inform MPA planning, especially when they understand how the information will be used to reduce impacts of MPAs to their community.

4.3. Contributions for Conservation Practices in Sogod Bay

The outputs of the SCP process have helped address opportunities and limitations for conservation and fisheries management in Sogod Bay. A major contribution of this research for Sogod Bay was the development of a comprehensive and up-to-date spatial database. There were several issues with existing datasets. Apart from bathymetric data that was not made available by a local academic institute, NGOs and LGUs were willing to share available datasets, although most were inaccurate or insufficient for systematic planning purposes. Validating existing datasets (administrative boundaries, municipal waters, and MPA delineations) required a substantial investment of time and energy from both international and local volunteers. In addition to collecting fine-scale resolution data on benthic habitats and small-scale fishers at a relatively large-scale, validation of existing datasets has produced a comprehensive baseline dataset in Sogod Bay for future research and conservation initiatives. All spatial data on habitat classifications, MPAs, and administrative boundaries were provided to NGO, academic, and LGU members during a third field season of this study. Additionally, the datasets are available as shapefiles and Google Earth files (.kml) on an online database upon request, thus contributing to free and open source data.

The work of this thesis would not have been possible without the participation of small-scale fishers and local partners, including LGUs, academics, NGOs, and coastal barangays. All municipalities and coastal barangays in the study area voluntarily participated in this study. Many fishers were very willing to participate in the research without any form of compensation. They were often eager to share their local knowledge and opinions on fishing practices and MPAs. At times, this even included sensitive topics such as illegal fishing and corruption. It was common for participants to express their gratitude for participating in the research, particularly in regard to being able to share their concerns on environment and fisheries issues. Many explained that they often feel ignored in the decision-making processes that impact their livelihood. On several occasions, the research team (e.g., the lead researcher, GIS assistant, local translator) was invited to meals, barangay council meetings, and community events to discuss topics relating to the research in greater detail. At times, the team was asked to provide recommendations and further information. For instance, a dozen barangays requested to view underwater videos taken near their barangays. Through viewing these videos with researchers, local people learned how to identify signs of habitat degradation and recognize important habitats for biodiversity and fisheries. For many people, this was the first time they had ever seen the state of underwater habitats surrounding their barangay.

In addition to small-scale fishers, this study received the support and guidance of various government, academic, NGO, and community members. LGU officials at all levels of government assisted the research team to compile and validate existing data and address data gaps. They helped coordinate interviews and disseminate results as well as other logistic aspects such as transportation, accommodation, and community outreach events.

The research team held several meetings with government members and attended monthly SBSMMA meetings. The Alliance meetings focused on marine management activities and issues in Sogod Bay, but also provided an opportunity to identify and address knowledge gaps and training needs. In partnership with the SBSMMA, the research team conducted Google Earth Pro workshops, GPS training workshops, beach clean-ups, and information, education, and communication (IEC) campaigns. Training workshops in Google Earth and GPS devices with police, MPA guards (*bantay dagat*) and resource managers were particularly helpful in building governance capacity. These workshops helped build basic GIS skills to facilitate MPA management and enforcement. They also taught participants how to access and use spatial data derived from this study using free and open source software.

Local NGOs, particularly LAMAVE, CCC, and ORC, were invaluable in assisting our team in project logistics, networking, and adapting participatory mapping techniques appropriate for small-scale fishers in the Philippines. Local academics and students from SLSU also volunteered their time to assist the research team in developing and testing field protocols, along with translation services. Fishers affiliated with KASAKA (Son-Ok, Pintuyan) and ORC (Balagawan, Silago) were instrumental in developing a complete list of fishing methods and in piloting the participatory mapping exercises.

A major focus of the third field season was to assist the provincial government with the Protected Area Management Enhancement (PAME) project supported through GIZ. The findings of Chapter three would not have been possible without the willingness of GIZ and the provincial members of PENRMO, who were willing to discuss the MPA selection process of the PAME project, along with their shortcomings. The remote sensing outputs of this thesis continue to be used by PENRMO to fine-tune the MPA sites selected through the PAME project. Additionally, they will serve to prioritize mitigation efforts for small-scale fisher stakeholders and communities most at risk of MPA implementation. The research has also highlighted issues in conducting small-scale fisheries surveys, including standardizing definitions for small-scale fishers (i.e., the need to include women and gleaning practices) and small-scale fisheries surveys, including the need for proper training for collecting and compiling data. Yet, it remains to be seen how this information will influence on-the-ground conservation action.

The research results were disseminated to the public, along with small-scale fishers, via a short documentary film. The film was developed to facilitate access and utilization of knowledge to stakeholders, organizations, and institutions outside of academia. It summarizes the goals, research process, methodology, and key research findings. The film included interviews with fishers, researchers, and MPA managers, along with animations to describe what MPAs are and how they work. The documentary was part of an undergraduate directed study course and is available in English[10] and Visayan. Film nights were held in several barangays in Sogod Bay and open to the public. The film was always followed by an open forum, which allowed the public to provide feedback and ask questions to researchers. The film showing at municipal halls were often attended by government members (including mayors and other elected officials), NGO members, academics, and small-scale fishers. This provided a rare opportunity for decision-makers, support institutes, and stakeholders to discuss openly topics related to fisheries and MPAs. Common topics discussed included threats to local fisheries, strengths and weaknesses of MPAs, MPA management and enforcement practices, and future conservation initiatives.

[10] The English version of the film can be viewed at http://www.alessiakockel.com/masters-project.html.

4.4. Research Limitations

There are several ways that this research could have been strengthened. The limitations of this thesis are discussed in three parts: research focus, data collection, and MPA design.

Research Focus

Aichi Target 11 commits government signatories of the CBD to conserve "10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, […] through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape"(CBD, 2010). While this thesis provides new insight for addressing the representation and equity elements of Target 11 in the context of developing countries, it remains limited in scope due to its lack of consideration of other essential elements. It did not address elements of the Target that call to conserve at least 10% of coastal and marine environments in effectively managed and well-connected systems of MPAs. Improving management effectiveness is of particular concern, especially in developing countries with limited capacity (Gill et al., 2017). A significant proportion of MPAs, including areas with high biodiversity, are not properly managed and enforced. These "paper parks" means that the current number and area coverage of MPAs globally are misleading indicators of effective conservation (Butchart et al., 2015; Mora et al., 2006). For example, Lowry et al. (2009) warns that despite the proliferation of MPAs in the Philippines, less than 20% of them are considered effectively managed. Hence, scaling up existing MPAs into representative networks can fail to achieve conservation objectives unless management practices are improved (Horigue et al., 2014; Lowry et al., 2009). Nonetheless, this thesis shows how adopting a SCP approach that includes participatory processes can highlight key management issues and prioritize management and conservation efforts.

Additional aspects of Target 11 that were not considered are "other effective area-based conservation measures" and the integration of MPAs into "the wider landscape and seascape". The patterns and processes occurring outside of MPAs will affect the functionality and integrity of coastal and marine systems contained within MPAs. Thus, MPAs need to be considered within a wider seascape (Rees et al., 2017; Woodley et al., 2012). This may be difficult to address within the scope of SCP assessments, although the process of collecting and compiling ecological and socioeconomic information relevant from conservation and resource management could support other resource management practices, such as fisheries management.

A major emphasis of this thesis is equity. In particular, Chapter two explores three important dimensions of equity in MPA planning. There are however other forms of equity that can play a vital role in conservation and resource management practices, including equity issues perceived by local people (Fabinyi et al., 2015; Halpern et al., 2013; Hill et al., 2016). For instance, fishers in Sogod Bay were extremely concerned with illegal commercial fishing operations in their municipal waters, including in no-take MPAs. Fishers argued that commercial fishers were benefiting from political corruption and poor enforcement, while they are left to suffer in poverty and from the negative impacts imposed by destructive commercial fishing practices (e.g., habitat degradation and fisheries declines). This equity concern highlights a challenging but important dimension of equity that warrants further study (Fabinyi et al., 2015). Additional knowledge gaps include investigating how various dimensions of equity could be measured and assessed in the later stages of the SCP processes, such as MPA implementation and evaluation.

Data Collection

SCP requires biodiversity and socioeconomic data in the planning region that is continuous and at a resolution that is suitable for conservation planning (Mills et al., 2010; Pressey and Bottrill, 2009). The dataset derived through remote sensing and participatory mapping methods strengthened this thesis, yet it is also a limitation.

Classification of the benthic habitats in Sogod Bay using remote sensing was challenging given the highly heterogeneric nature of coral reefs in the Bay and the need to conduct a full analysis on three separate satellite images (no image was available that covered the full extent of Sogod Bay). Furthermore, there was a four-year gap between the image acquisition date and the field surveys (i.e. collection of ground truth points). Benthic habitats such as macroalgae, seagrass, and coral reefs could have changed over this time gap, especially since the Bay has incurred extreme weather (e.g., tropical typhoons), coral bleaching events, and population explosions of crown-of-thorn starfish (a species that eats coral) in recent years. This temporal discrepancy reduced the overall accuracy rating for detecting certain habitat classes through remote sensing techniques. Other sources of error, as discussed in Appendix B, that resulted in lower accuracy rating of certain benthic classes were spectral similarities between habitat classes (e.g., spectral confusion between seagrass and macroalgae), frequent co-existing and mixing of classes (e.g., coral patches mixed with sand), and limitations of field surveys (e.g., camera tilt, low number of ground-truth points for some classes). Due to these limitations, the accuracy rate for classification of different benthic habitats ranged widely from 20 to 90%. Furthermore, the remote sensing could not provide information of habitat classes below 25m depth, thus deep water marine habitats and their associated biodiversity could not be targeted for inclusion in MPAs. The accuracy of remote sensing analysis may be improved with more ground truth points or with more accurate bathymetric data. Fine-scale bathymetric data was present in the Bay but was not made available to the research team. This highlights ongoing issues in spatial data sharing that result in less accurate analyses or lost resources from needing to duplicate efforts in collecting spatial data (Nwilo et al., 2010). Additional spatial data on biodiversity that could have supplemented the remote sensing analysis includes the distribution of focal species, habitat types, and ecological processes (Pressey and Bottrill, 2009).

Due to cloud cover, there were some areas on the east side of the Bay that were missing data (8 to 9% of coastal areas of the planning region in Chapter two and three, respectively). Ideally, the planning region would have had consistent spatial data on coastal habitats. Methods were attempted to address these data gaps using video surveys, but the resulting data was coarse. Using this data in a MarZone analysis together with fine-scale remote sensing data could be problematic. For instance, planning units with coarse data may appear to have higher coverage of certain classes and may bias the algorithm in MarZone to select MPAs in these areas (Margules et al., 2002). This illustrates a common issue of conservation planning in the Coral Triangle where data are limited and highly fragmented (Weeks et al., 2014b). This thesis faced a trade-off: limit the planning region to the extent of available remote sensing data for unbiased selection of MPA areas, or combine coarse- and fine-resolution data and risk biased MPA selection (Mills et al., 2010). Since the data gaps were limited to a few areas of the coastline, this thesis chose to go with the former option.

The participatory mapping exercises were capable of documenting a wealth of local knowledge, including spatial information on small-scale fisheries occurring in Sogod Bay. The methods employed ensured that a representative sample of each fisheries was collected for each coastal community in the planning region. However, it did not include all types of stakeholders involved in small-scale fisheries, such as fish processors and fish vendors, who are included in the national definition of ‘fishers’ (known nationally as municipal fisherfolk). Furthermore, it did not consider fishers from neighbouring barangays who do not live on the coast. This included a few mountain barangays with indigenous people who are extremely isolated and marginalized from society, and reliant on natural resources from the terrestrial and marine environment. Divers from the tourism industry were also not considered in this study, limiting the potential of this research to investigate the potential for synergistic interactions between fisheries and tourism (e.g., Lopes et al., 2015).

A common critique of participatory mapping techniques is the extent to which local knowledge can be ‘objectified’ and spatially represented through the use of mapping (Dunn, 2007; Forrester et al., 2015; McCall, 2006; G. Rambaldi et al., 2006). As with all methodologies, the outputs of participatory mapping methodologies are only as good as the data used to generate them (McCall, 2006). This thesis recognizes the importance of remaining reflexive regarding precision and accuracy when integrating spatial local knowledge with scientific knowledge at different geographical scales (Dunn, 2007; Forrester et al., 2015; Giacomo Rambaldi et al., 2006; Tripathi, Nitesh and Bhattarya, 2004). To address this potential limitation, the mapping procedures underwent a vigorous systematic evaluation that involved several field tests (e.g., tracking fishers movement patterns in the field) and “mock interviews” (e.g., test mapping methods and fishing categories). In line with many participatory mapping advocates and fishers’ knowledge researchers (Hind, 2015; Yates and Schoeman, 2013), this thesis highlights the strength and legitimacy of local experiential knowledge of small-scale fishers.

MPA Design

There were biological and socioeconomic limitations with the MPA plans designed in this research. Advancements in biological and conservation science have provided MPA planners with ecological guidelines for designing MPA networks to simultaneously reduce local threats, meet fisheries and conservation objectives, and promote ecosystem resilience to climate change (Green et al., 2014; McLeod et al., 2009; Wilson et al., 2011). These guidelines include designs that protect ecologically significant or resilient areas, represent and replicate major habitat types, ensure ecological linkages and connectivity, minimize local threats, and promote ecosystem resilience (Green et al., 2014). However, applying all these design guidelines into practice is not always feasible due to information gaps, and socioeconomic, political, and governance constraints, as is the case in Sogod Bay. It is recommended that priority be given to ecological guidelines that address local threats and areas that represent different habitats, protect threatened species, and show high resilient or biological significance (Green et al., 2014; Walton et al., 2014).

Due to limited resource (time and funds) and incomplete available data, this thesis was only able to target different habitat classes derived from the remote sensing analysis. The ecological integrity of the designs could be strengthened as additional ecological data becomes available. Furthermore, this thesis did not address design guidelines such as minimum MPA spacing and size. While spacing is unlikely to be a problem due to the close proximity of MPAs (close MPAs can promote connectivity), the resulting MPAs were smaller than recommendations provided in the literature (Green et al., 2014) in favor of accommodating the local governance capacity and fisheries needs of each community. Establishing larger MPAs will require investing in long-term alternative livelihood and capacity building programs. Strategic partnership with NGOs and research institutes can therefore play a pivotal role in MPA design and implementation of MPA networks in the future (Weeks et al., 2014a).

Ongoing strategies for developing MPA networks in the Philippines and Coral Triangle involve selecting MPAs that can work collectively as an ecological network to maintain ecological processes and ecosystem functions, and then selecting additional sites to improve representation, connectivity, and resilience of a network (Walton et al., 2014). Incorporating existing MPAs into "ideal" ecological networks is a challenging process, because the current locations of MPAs are often poorly managed or situated in areas that were most feasible to implement and enforce, rather than biologically important. This means that many MPAs may not be in optimal locations which would fully contribute to an ecological network (Lowry et al., 2009). Lowry et al. (2009) suggest that removing existing MPAs is politically and socially unwise, thus efforts and resources should instead be focused on identifying new MPA sites than can act as links between existing MPAs (Lowry et al., 2009). This thesis followed this recommendation by locking existing MPAs into the MPA zone of all planning scenarios. The disadvantage is that this assumes that all current MPAs contribute to biodiversity conservation equally, which as discussed, is not the reality of community-based MPAs in Sogod Bay.

As demonstrated in this thesis, relevant spatial data on socioeconomic features required for SCP may include information on tenure (e.g., municipal water delineations), resource users (e.g., use patterns of fisheries), and existing conservation areas (Pressey and Bottrill, 2009). However, there are various additional information about human influences that may support or constrain conservation efforts and actions that were not considered, such as community priorities and informed opportunism. Previous studies have shown that incorporating data on community willingness to establish MPAs can increase support for identifying priority areas that translate into conservation actions (Game 2011, Guerrero et al. 2010). This was not done in this thesis but could have been possible given the fisheries dataset. For instance, plans could be designed to only consider communities who choose to engage in conservation prioritizations. However, as illustrated in Chapter three, relying on stakeholder preferences may lead to inequitable situations and result in inadequate representation in MPA plans if too few communities are willing to implement MPAs.

An additional human dimension that was not considered in this thesis was perceived value of fishing sites. Rather, the metric used to reflect socioeconomic needs in Chapter two and three was based on the spatial extent of each fisheries used by each community. The assumption underlying the use of this metric is that MPAs that maintain adequate portions of each fisheries per community are more equitable and socioeconomically viable. However, this metric does not account for the perceived value of different fishing grounds, that may be more important to local people.

During mapping exercise, perceived values of fishing sites were classified based on their importance for fisher participants. Participants were asked to assign mapped fishing grounds as ‘high’, ‘medium’, or ‘low’ importance, or as ‘no distinction’. As observed through the mapping exercises, some fishing areas and methods are perceived to be more important than others, although this varied amongst communities. However, as discussed previously, attempts to combine different metrics (importance value and area) was challenging (e.g., difficult to calibration), resulting in greater uncertainties. This was also the case for attempts to integrate number of fishers with area. One suggestion would be to have communities map only methods and fishing sites that reflect their priorities. For example, Yates and Schoeman (2013) asked fishers in Ireland to map their priority fishing areas based on whatever factor they deem to be important (e.g., distance from shore, presence of target catch). Fishers were explained that they could choose to include their entire fishing extend, although this would mean that the spatial prioritization tool would treat all sites equally. Similarly, the mapping exercise adapted for Sogod Bay did allow fishers to assign importance value based on their own criteria, which were also documented. However, studies by Yates and Schoeman (2014, 2013) used this information to create a single cost layer in Marxan, rather than using MarZone to treat fisheries as a objective simultaneously with biodiversity objectives. Thus, there is a need for more guidance on how this can be achieved in MarZone.

This research produced several MPA configuration options that were representative and socially equitable in terms of recognition, procedural, and distributive equity. This was largely based on the assumption that equitable plans will be more socially feasible to implement because they will be favored by small-scale fishers, communities, and even LGU officials. Recent cases have shown that these forms of equity do promote conservation benefits (e.g., Hill et al., 2016). Yet like many conservation studies, this major assumption of this thesis remains relatively untested in the field and highlights a need for further research.

4.5. Future Research

The following are suggestions for areas of future research:

1. Investigate approaches for addressing representative and equity targets in SCP together with other elements of the CBD’s Aichi Target 11 (e.g., connectivity, effective management) and/or design principles in conservation planning (e.g., size, spacing);
2. Identify the trade-offs, feasibility, and resources required to maintain recognition, procedural, and distributive equity in the SCP process at local, provincial, and national scales
3. Examine the trade-offs, feasibility, and resources required to maintain recognition, procedural, and distributive equity in the SCP process amongst a wider range of marine users;

4. Test whether equitably designed plans facilitate MPA implementation and whether they enhance stakeholder compliance and support, and most importantly, the achievement of conservation goals;
5. Compare biodiversity data derived from local experts, small-scale fishers, versus remote sensing techniques, and/or socioeconomic data derived fishers' knowledge versus mainstream fisheries science methods, to determine how these methods impact MPA planning outcomes;
6. Explore the implications and trade-offs of different indices (e.g., catch-per-unit effort, number of fishers, perceived priority areas) for reflecting the needs and values of small-scale fisheries in MPA planning; and
7. Investigate how different small-scale fishers, communities, and levels of governments perceive MPA network plans that differ in regard to the metric used to reflect stakeholder needs and/or the level of equity consideration.

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Appendices

Appendix A. MPA Database

Table A1. Database on existing MPAs in the planning region

Municipality	**Barangay(s)**	**MPA Type**	**Year***	**Age**	**Ordinance** (Updated version)	**Ordinance Area** (km^2)†	**GIS Area** (km^2)
Liloan	Tabugon	Fish sanctuary	1993	23	# 16 S. 1993	0.20	0.23
Limasawa	San Agustin/ Lugsungan	Fish sanctuary	2008	8	# 1 S. 2009	0.40	0.55
Malitbog	Timba & Sto.Niño	Fish sanctuary	1996	20	# 189-A S. 1996	0.03	0.03
Malitbog	Maujo/ Juangon	Fish sanctuary	1996	20	# 59 S. 1996	0.02	0.03
Padre Burgos	Buenavista	Fish sanctuary	2005	11	SB # 45 S. 2005	0.15	0.23
Padre Burgos	Sta. Sofia	Fish sanctuary	2005	11	SB # 45 S. 2005	0.04	0.10
Padre Burgos	Tangkaan	Fish sanctuary	2005	11	SB # 45 S. 2005	0.06	0.13
Padre Burgos	Lungsodaan	Fish sanctuary	2005	11	SB # 45 S. 2005	0.04	0.03
Pintuyan	Manglit	Fish sanctuary	1997	19	# 4 S. 1997 (# 50 S. 2014)	0.09	0.15
Pintuyan	Caubang	Reserve	2014	2	# 8 S. 2014 (# 50 S. 2014)	0.11	0.11
Pintuyan	Catbawan/ Dan-an	Fish sanctuary	1999	17	# 1 S. 1999 (# 50 S. 2014)	0.06	0.07
Pintuyan	Son-ok II	Fish sanctuary	1995	21	# 1 S. 1995 (# 50 S. 2014)	0.28	0.17
Pintuyan	Balong-balong	Fish sanctuary	2005	11	Original unknown (# 50 S. 2014)	0.03	0.04
San Francisco	Napantao	Fish sanctuary	1996	20	# 90 S. 1996 (CMFO #165 2014)	0.05	0.07
San Francisco	Punta	Fish sanctuary	2009	7	Original unknown (CMFO # 165 2014)	0.10	0.07
San Francisco	Sta. Paz Sur	Fish sanctuary	2010	6	Original unknown (CMFO # 165 2014)	0.10	0.04

*Year of MPA establishment; †MPA area documented in municipal ordinances

Appendix B. Remote Sensing

Authors: Jennifer O'Neill and Alessia Kockel

1. Background:

A key component of this research was to develop a fine-resolution benthic habitat map for coastal regions in Sogod Bay. Remote sensing provided a practical solution for large-scale habitat mapping, since existing ecological data was sparse in the region (see Longhurst and Ferguson, 2014). Remote sensing is a widely accepted approach for mapping coastal habitats and recent advancements in technology and sensor resolution have increased the habitat classification accuracy to scales suitable for MPA network planning (Green et al., 2000; Hoang et al., 2016; Yamano, 2013).

WorldView-2 images from the Digital Globe Foundation were used to derive the aerial extent of coastal benthic habitat classes. The habitat classes were validated with ground-truth data derived from underwater video surveys. The habitat classes were incorporated into the spatial planning software (Marxan with Zones) and were targeted for inclusion in MPAs to meet conservation targets at minimum opportunity costs to fisher stakeholder groups.

This appendix outlines the methodologies and results of the remote sensing analysis. The field surveys were conducted by the research team11 in June 2016, under the direct supervision of the remote sensing specialist, Jennifer O'Neill. The remote sensing analysis was independently performed by Jennifer O'Neill between June 2016 and August 2017. This work is not only relevant for marine conservation in Sogod Bay but also contributes to scientific research on evaluation and validation of WorldView-2 data for identifying and mapping benthic habitat classes in highly heterogenous tropical settings. As such, the remote sensing component of this thesis is being prepared for scientific publication. The work will serve as a case study to evaluate the utility of high resolution WorldView-2 satellite imagery and modern remote sensing techniques for mapping tropical coastal benthic habitats, which will include comparing two to three mapping methods.

2. Methodology

2.1. Study area: The study region included the coastal waters (up to 25 m depth) lining Sogod Bay (10°12'N, 125°12'E), located in the Southern Leyte province in the Philippines (Figure B1).

2.2. Ground truth data: Field data required for the analysis of remote sensing imagery was collected using underwater video transects. Transects were conducted in June 2016 from a paddle boat along freely planned tracks (1 to 25 m depth) at various locations in Sogod Bay. The method involved a geographic positioning system (GPS) device and an underwater video camera (GoPro attached to a stand). The camera was placed 0.5 m below the boat and set to continuously record the seafloor. GPS coordinates were collected at 10 m intervals. GPS waypoints were uploaded to ArcGIS and a benthic class variable was added to the spatial table. This variable was populated via visual classification of

[11] Members of the research team who participated in the field surveys were the lead researcher, the research coordinator, a local translator, a local fisher guide, and the remote sensing specialist, Jennifer O'Neill.

the video into the benthic classes shown in Table B1 at the video timestamps corresponding to the GPS waypoint time tags. When benthic cover was continuous between two GPS waypoints, points were added along the transect to reflect this class. The names and definitions of the habitat classes are adapted from the IUCN classification scheme (IUCN, 2012), and are comparable to those used in diver surveys (Longhurst and Ferguson, 2014) in the Bay that are being conducted by the non-government organization (NGO), Coral Cay Conservation (CCC).

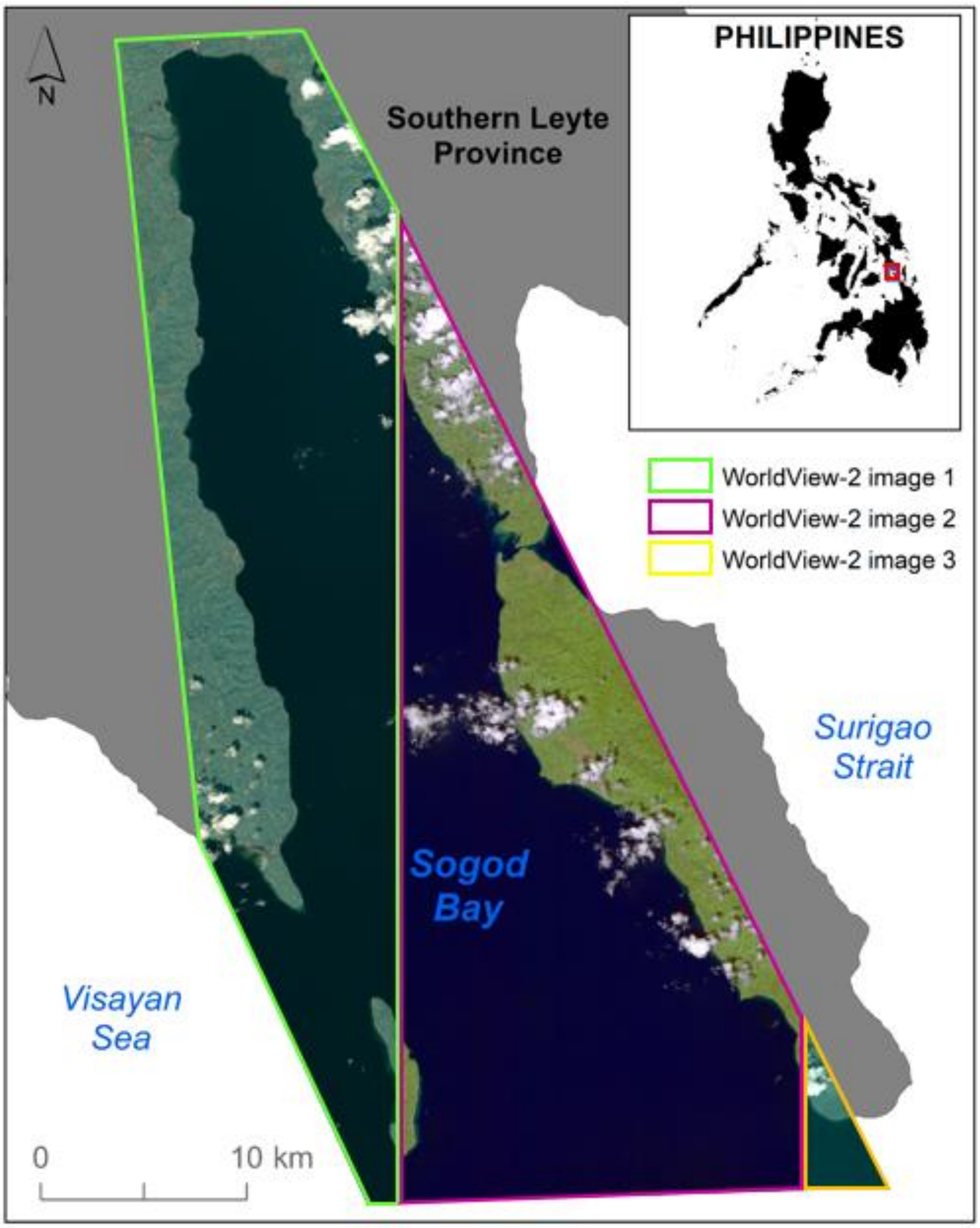
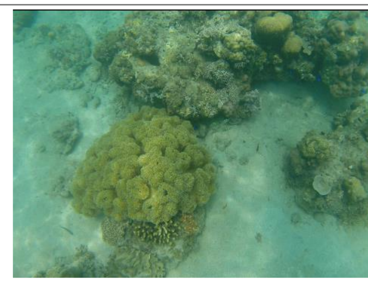
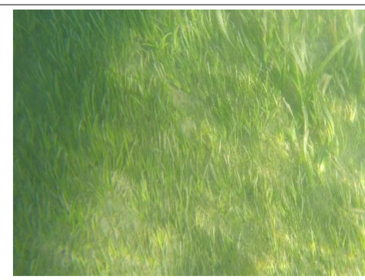


Figure B1. WorldView-2 images in Sogod Bay, Southern Leyte, Philippines

Table B1. Habitat classification from video transects

Class	Description	Example(s)
1) Coral reef (high cover)	Aggregated or fringing coral reefs (massive limestone structure built up through the cementing and depositional activities of colonial stony corals, predominantly of the order Scleractinia, and other calcareous invertebrate and algal species). Living coral colonies cover more than 70% of the benthos. May include patches of exposed bedrock (see **7**) or dead coral.	
2) Coral reef (low cover)	Aggregated or fringing coral reefs and bedrock (see **7**). Living coral colonies cover 50 to 70% of the benthos.	
3) Patch reef	Patches of coral reefs are separated by grooves (depressions) of sand (see **5**) or coral debris. Living coral colonies cover at least 50% of the benthos.	
4) Seagrass	Bottom habitat consisting predominantly (70 to 100% of benthos) of seagrass (grass-like marine flowering plants that grow and reproduce while submerged in seawater).	
5) Sand	Bottom habitat consisting predominantly (70 to 100% of benthos) of sand (loose particles of rock or mineral sediments ranging in size from 0.0625–2.0 mm in diameter).	

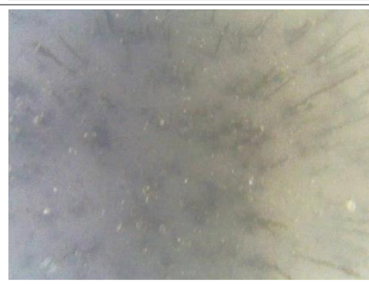
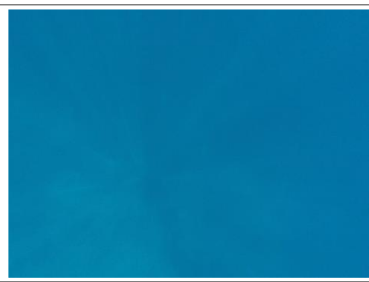
6) Rock/ pebble/ gravel	Bottom habitat consisting predominantly (covers more than 70% of benthos) of unconsolidated cobbles rock or gravel (sediment size 64 to 256 mm diameter) and pebbles (sediment size 2 to 64 mm diameter).	
7) Rocky reef	Bottom habitat consisting predominantly (covers more than 70% of benthos) of consolidated rock or bedrock. May include small, sparse patches of coral or macroalgae (see **10**).	
8) Mud	Bottom habitat consisting predominately (covers more than 70% of benthos) of wet clay (any particle smaller than 0.002mm in diameter) and silt-rich sediment (silt consists of loose participles or rock and mineral sediment that ranges in size from 0.002-0.0625mm in diameter). May include small, sparse patches of bedrock (see **7**), rock/pebble/gravel (see **6**), or seagrass (see **4**).	
9) Mangrove Roots	Bottom habitat where at least 50% of benthos contains submerged mangrove (tropical mangrove species that grow along coastlines in brackish and salt water) roots.	
10) Macro-algae	Bottom habitat consisting predominantly (covers more than 70% of benthos) of large algae (typically brown algae, including green and red algae, and excluding blue-green algae or Cyanobacteria), which forms dense macroalgal beds.	
11) Deep water	Water beyond the depth threshold of the sensor. At this depth, the sensor can not "see" the bottom.	

Table B2. WorldView-2 imagery information

Image code	Digital Globe Catalog ID	Acquisition Date	Acquisition Time (am)	Imaging Bands (Spatial resolution)	Area Max Off Nadir Angle	Total Cloud Cover	Tide
1	103001000EAF3900	21/10/2011	10:30	Pan_MS1_MS2 (0.5m)	27	19%	low (0.2-0.3m)
2	103001000D9E1E00	21/10/2011	10:30	Pan_MS1_MS2 (0.5m)	24	17%	low (0.2-0.3m)
3	1030010009C51300	09/02/2011	10:30	Pan_MS1_MS2 (0.5m)	27	2%	mid (0.5m)

2.3. **Image and bathymetry data:** WorldView-2 satellite images were granted by the Digital Globe Foundation. The images were composed of eight multi-spectral bands in the visible to near infrared spectral range (400–1040 nm) and 2-m spatial resolution. Three images (Table B2; Figure B1) were chosen with the lowest cloud cover possible and as close as possible to low tide at solar noon. The images were either acquired in February or October 2011.

2.4. **Bathymetry data**: Fine-resolution bathymetry data was present in the study region but was not made available to the research team. Bathymetry data were thereby derived from digitized nautical and topographic charts. Topographical charts (chart ID# 3951 II, 3950 I, 4050 IV, 3950 II, 4050 III, and 4049 IV) in a scale of 1:50,000 were provided by the Philippines National Mapping and Resource Information Authority NAMRIA. Depth curves on the charts (scale 1:50,000) are in fathoms and are sourced information obtained from the Bureau of Coast and Geodetic survey, and the US Army Map Series 711 compiled in 1956 from 1947-1953 photographs. Additionally, a nautical chart (Admiralty chart 4474) was provided by the United Kingdom Hydrographic Office. The chart has depth curves in meters that are sourced from Philippine Government charts of 1940 to 1994.

2.5. **Image pre-processing**: Image pre-processing techniques were applied to compensate for the attenuating effects of the atmosphere (scattering and absorption by haze, fog, and aerosols) and the interaction of light at the water surface. WorldView-2 images were geometrically corrected using GPS ground control points taken in the field. Raw digital numbers were converted to at-sensor radiance and then atmospherically corrected using the dark pixel subtraction and histogram shift methods. A low altitude cloud mask was defined similar to Montes et al. (2004). A land mask was defined using a combination of spectral thresholds and visual determination. A masks for lower depth limit was defined via a bathymetry threshold of 30 m. Surface glint correction was applied using methods of Hedley et al. (2005). Finally, water column correction were conducted using the methodology of Lyzenga (1978) and bathymetry data derived through digitized nautical and topographic charts. Different imagery processing techniques were applied to enhance the spectral separability of benthic classes. Principal component analysis (PCA) was used to help define image bands whose variance denotes the presence of different classes (Jolliffe, 1986).

2.6. **Spectral extraction:** The locations of each benthic cover class determined in the field via underwater videography were imported into ENVI software are ROI pixels. See Tables B3, B4, and B5 for the total number of pixels contained within each class[12]. The spectrum corresponding to each pixel was then extracted and examined in Excel software. Examination involved two steps:

1) Remove spectra with vastly different shape to the majority. This step was necessary due to the four-year interval between image and ground-truth acquisition and was class-specific. For instance, in regards seagrass, any spectra which was high in the blue and particularly red bands (representing sand) was removed. It is likely that these locations were sand in 2011, but had become seagrass by 2014.

2) Identify sub-classes within the larger benthic classes. When a marked gap was apparent in a group of spectra, this indicated a difference in spectral properties between shallow and deep class (e.g. shallow and deep rocky reef) and indicated that this class should be classified into subclasses. Other examples of subclasses are “clean” sand (green spectral peak) and sand with detritus coverage (red spectral peak).

2.7. **Spectral separability**: Optimal bands for the spectral separability of all benthic classes were determined via M-statistic analysis, visual analysis of overlaid class average standard deviation spectra and n-d visualizer of ENVI.

2.8. **Map classification:** A maximum likelihood supervised spectral classifier algorithm was applied to the image to derive the benthic cover map. 20% of ground-truth data points were used to train the classification of 12-14 benthic classes based on similar spectral reflectance signatures (Richards, 1999; Story and Congalton, 1986). In the case of benthic classes with very low sample numbers, the proportion of ground-truth data used for training was increased (Tables B3, B4, and B5). Classifications were carried out in this manner iteratively on various levels of pre-processing (radiance bands versus PCA bands and glint corrected versus glint and water column corrected) and various combinations of image bands from the list of optimal bands determined in the “spectral separability” section.

2.9. **Map validation:** All products were validated with the remaining 80% of ground truth data in standard confusion matrices to determine the user accuracies of each benthic class and the total accuracy of the entire map via a validation matrix (Story and Congalton, 1986). Before validation, all subclasses were merged into their base classes as confusion between deep and shallow subclasses of the same class (e.g. deep and shallow sand) is not considered to be an error.

[12] Some cover classes in image 3 had low sample numbers for ground truth points due to turbidity and thus limited visibility in the ground truth videos. Therefore, image 3 was mosaicked with image 2 to obtain additional training spectra from image 3 (i.e., the training data of image 3 was merged with the training data of image 2).

3. Results & Discussion

The best classification each image was yielded by the maximum likelihood classification on radiance bands 1–7 of the radiometric, atmospheric, and glint corrected image. Tables B3, B4, and B5 provides the image classification parameters for image 1 (north and west side of Sogod Bay), image 2 (east side of the bay), and image 3 (south west of Sogod Bay), respectively. Parameters include, for each benthic class: name and definition, total number of ground-truth pixels corresponding to the class, proportion of ground-truth dataset used for training and validation, user accuracy within the best derived classification, and primary source(s) of confusion with confusion severity rating and explanation. Figure B2 presents a subsection of the benthic cover class maps overlaid on the true colour WorldView-2 image.

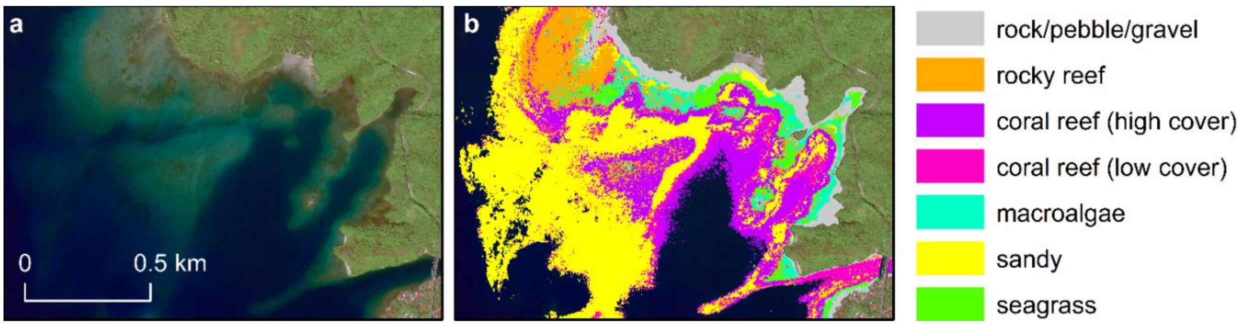


Figure B2. Subset of (a) WorldView-2 true colour image and (b) overlay of the final benthic classification map in coastal waters. Optically deep water or locations where the sensor could not detect the bottom are shown in dark blue.

Table B3. Classification parameters for image 1 (north and west side of Sogod Bay). Parameters per habitat class include: name and definition, total number of ground-truth pixels in the class, proportion of ground-truth data used for training and validation, user accuracy within the best derived classification, and primary source(s) of confusion with confusion severity rating and explanation.

Class	Class definition	Sub-Classes*	N° pixels total	N° pixels training	Training subsample % of total	N° pixels validation	User accuracy %	Primary confusion	Confusion level	Possible causes of confusion
Coral reef (high cover)	70-100% hard coral cover	shallow	25	13	48	29 (12+17)	50	coral reef (low cover)	med	*GPS/camera tilt error & degradation of the reef between 2011 & 2015.*
		deep	29	12	40					
Coral reef (low cover)	50-70% hard coral cover (incl. patch reef)	shallow	77	23	30	86 (54+32)	90	coral reef (high cover)	low	*GPS/camera tilt error & change in coral cover over time (reduced by time of ground-truth). Also, spectral confusion when c**oral reef (high cover)** is bright.*
		deep	46	14	30					
Seagrass	70-100% seagrass	shallow	225	46	20	179	83	macro-algae	low	*Commonly seen confusion with vegetation. These classes are spectrally similar due to green peak & blue/red absorption by Chlorophyll and NIR reflectance of vegetation.*
Sand	70-100% sand	"clean" (G) shallow	121	24	20	171 (97+42+32)	74	coral reef (low cover)	low	*Spectral confusion, especially for c**oral reef (low cover)** in the sand, or bright corals. Also, possibly degradation of coral between 2011 and 2015.*
		detritus (R) shallow	52	10	20					
		deep	40	8	20					
Rock/ Pebble/ Gravel	70-100% boulder	shallow	80	17	20	63	44	-	-	*Sample size for this class is too small and therefore accuracy assessment not robust enough to draw a conclusion on confusion.*
Rocky reef	70-100% bedrock	shallow deep	10	8	80	2	-	mud	med	*Spectral similarity of **rock/pebble/gravel** and **mud**, especially in areas that have muddy overlying water due to the river plumes.*

Macro-algae	70-100% macroalgae	shallow	34	10	30	24	20	seagrass	high	*Commonly seen confusion with vegetation. These classes are spectrally similar due to green peak & blue/red absorption by Chlorophyll and NIR reflectance of vegetation.*
Mud	70-100% mud	“clean” (Y) shallow	56	12	20	59 (44+15)	46	*rock/ pebble/ gravel*	med	***Mud** and **rock/pebble/ gravel** have fairly similar spectra, especially **mud** with high organics and **boulders** with thin films of microalgae.*
		high org. (G) shallow	19	4	20					
Mangrove roots	50-100% mangrove	shallow	13	8	60	5	-	-	-	***Mangrove roots** sample size is too small and therefore accuracy assessment not robust enough to draw a conclusion on confusion.*
Deep water	100% deep water (> 30m)	>30 m	279	56	20	223	100	none	-	-

* “Shallow” indicates <3m depth; “Deep” indicates >3m depth; Letters in brackets indicate a benthic cover class displaying a characteristic major peak in the green (G), red (R), or yellow (Y) spectral range.

Table B4. Classification parameters for image 2 (east side of Sogod Bay). Parameters per habitat class include: name and definition, total number of ground-truth pixels in the class, proportion of ground-truth data used for training and validation, user accuracy within the best derived classification, and primary source(s) of confusion with confusion severity rating and explanation.

Class	Class definition	Sub-Classes*	N° pixels total	N° pixels training	Training subsample % of total	N° pixels validation	User accuracy %	Primary confusion	Confusion level	Possible causes of confusion
Coral reef (high cover)	70-100% hard coral cover	shallow	194	39	20	297 *(155+142)*	41	coral reef (low cover) & rocky reef	med	*GPS/camera tilt error and degradation of the reef between 2011 and 2015.*
		deep	178	36	20					
Coral reef (low cover)	50-70% hard coral cover (incl. patch reef)	shallow	145	29	20	257 *(116+141)*	41	coral reef (high cover)	high	*GPS/camera tilt error & change in coral cover over time (reduced). Spectral confusion when **coral reef (high cover)** is bright.*
		deep	177	36	20					
Seagrass	70-100% seagrass	shallow	216	43	20	84 *(56+28)*	72	rocky reef	low	*Likely spectral confusion with turf algae on **rocky reefs**.*
Sand	70-100% sand	shallow	87	18	20	189 *(69+120)*	64	coral reef (low cover)	low	*Spectral confusion, especially for **coral reef (low cover)** with sand patches, or bright corals.*
		deep	151	31	20					
Rock/ Pebble/ Gravel	70-100% rock, pebble, or gravel	shallow	313	63	20	250	67	-	-	-
Rocky reef		shallow	148	30	20	393 *(118+275)*	57	coral reef (high & low cover)	med	*Variability of reefs temporally (new growth) & spatially (camera tilt). Also, spectral confusion with **most coral reef (low cover)** on bedrock.*
		deep	344	69	20					
Macro-algae	70-100% macroalgae	shallow	97	25	20	72	25	seagrass, coral reef (high cover), & rocky reef	med	*Bedrock and reefs have turf algae which is highly variable, especially over four years. Seagrass/Algae leads to spectral confusion.*

Deep water	100% deep water (> 30m)	>30 m	318	64	20	254	99	none	-	-

"Shallow" indicates <3m depth; "Deep" indicates >3m depth

Table B5. Classification parameters for image 3 (south west of Sogod Bay). Parameters per habitat class include: name and definition, total number of ground-truth pixels in the class, proportion of ground-truth data used for training and validation, user accuracy within the best derived classification, and primary source(s) of confusion with confusion severity rating and explanation.

Class	Class definition	Sub-Classes*	N° pixels total	N° pixels training*	Training subsample % of total	N° pixels validation	User accuracy %	Primary confusion	Confusion level	Possible causes of confusion
Coral reef (high cover)	70-100% hard coral cover	shallow	-	39	-	346	61	rocky reef & coral reef (low cover)	med	*Variability of reefs temporally (new growth) & spatially (camera tilt). Also, spectral confusion with coral on bedrock.*
		deep	-	159	-					
Coral reef (low cover)	50-70% hard coral cover (incl. patch reef)	shallow	-	33	-	97	39	rocky reef	high	*Variability of reefs temporally (new growth) & spatially (camera tilt). Also, spectral confusion with coral on bedrock.*
		deep	-	59	-					
Seagrass	70-100% seagrass	shallow	-	43	-	0	-	-	-	*No seagrass was identified by the classification, which is in alignment with field observations.*
Sand	70-100% sand	shallow	-	36	-	339	84	coral reef (high cover)	low	*Spectral confusion, especially for **coral reef (high cover)** with sand patches, or bright corals.*
		deep	-	277	-					
Rock/ Pebble/ Gravel	70-100% rock, pebble, or gravel	shallow	-	12	-	89	64	macroalgae	med	*Rock/pebble/gravel may have turf algae which is highly variable, especially over four years, leading to spectral confusion.*
		deep	-	88	-					

Rocky reef	70-100% bedrock	shallow	-	40	-	172	70	sand & coral reef (low cover)	med	*Variability of reefs temporally (new growth) & spatially (camera tilt). Also, spectral confusion with* ***coral reef (low cover)*** *on bedrock.*
		deep	-	103	-					
Macro-algae	70-100% macroalgae	shallow	-	53	-	30	83	sand	low	-
Deep water	100% deep water (> 30m)	>30 m	-	98	-	136	81	coral reef (high cover)	low	*Very high NIR haze in this image decreased accuracy of water pixels, which are usually identified via near-zero values in the NIR range.*

“Shallow” indicates <3m depth; “Deep” indicates >3m depth

*Some cover classes in this image had low sample numbers for ground truth points due to turbidity and thus limited visibility in the ground truth videos. Therefore, image 3 was mosaicked with image 2 to obtain additional training spectra from image 3. Validation was then carried out using only the image 3 ground truth data (the remaining 80%).

Table B6. Area coverage per habitat class in Sogod Bay and each municipality and study area.

Location	Area coverage (km^2) per habitat class						
	Coral reef (high cover)	Coral reef (low cover)	Seagrass	Sand	Rock/ Pebble/ Gravel	Rocky reef	Macro-algae
Pintuyan	0.35	0.28	0.05	0.30	0.42	0.36	0.09
San Francisco	0.43	0.34	0.05	0.29	0.44	0.37	0.11
Liloan	0.51	0.36	0.25	1.26	0.47	0.35	0.21
Malitbog	0.27	0.47	0.14	0.27	0.13	0.06	0.14
Padre Burgos	0.48	0.69	0.12	0.33	0.15	0.13	0.19
Limasawa	0.55	0.49	0.28	0.55	0.44	0.12	0.25
Study area in Chapter 2*	2.59	2.63	0.89	3.00	2.05	1.39	0.99
Study area in Chapter 3**	2.32	2.16	0.75	2.73	1.92	1.33	0.85
Sogod Bay	4.73	3.58	1.90	4.37	3.32	1.62	1.66

* All 6 municipalities, **5 municipalities (excludes Malitbog)

Table B7. Area coverage of coastal habitats and cloud cover.

Location	Area coverage of coastal habitats (km^2)		Cloud cover	
	Including cloud cover	Excluding cloud cover	Amount (km^2)	% of total coastal areas
Pintuyan	2.23	0.38	0.38	17.0
San Francisco	2.6	0.57	0.57	21.9
Liloan	3.7	0.29	0.29	7.8
Malitbog	1.48	0.00	0.00	0.0
Padre Burgos	2.09	0.00	0.00	0.0
Limasawa	2.68	0.00	0.00	0.0
Study area in Chapter 2*	14.78	1.24	1.24	8.4
Study area in Chapter 3**	13.3	1.24	1.24	9.3
Sogod Bay	4.73	3.58	1.90	4.37

* All 6 municipalities, **5 municipalities (excludes Malitbog)

For this thesis, the aerial extent of 7 benthic habitat classes within the coastal waters (up to 25m depth) of five or six municipalities (Chapter 2 includes Malitbog, Chapter 3 excludes Malitbog) in the southern portion of Sogod Bay were targeted for inclusion in MPAs. The habitat classes considered were coral reef (high cover), coral reef (low cover), seagrass, sand, rock/pebble/gravel, rocky reef, and macroalgae. Table B6 contains the total area coverage of each benthic habitat class. There was no mud in these municipalities. Mangroves were excluded because the accuracy assessment for this class was not robust enough to draw a conclusion on confusion. Sand was identified as the dominant habitat class in the study area for Chapter 2, followed by coral reef with low coral cover and coral reef with high cover. The study area in Chapter 3 was dominated by sand, coral reef with high cover, and coral reef with low cover, respectively. The most dominant habitat class for the full extent of Sogod Bay was coral reef with high coral cover, followed by sand and coral reefs with low coral cover.

Coastal habitat data could not be derived from areas under cloud cover, although this issue was limited to the east side of the bay (Table B7). This included an estimated 8% and 9% of the coastal areas in the study area in Chapter 2 and 3 respectively.

Overall classification accuracy was measured in units of percent; calculated by dividing the total number of pixels by the total error pixel in the classification process. In particular, the user's accuracy was used to determine the accuracy of each benthic classification. The results of the classification accuracy differed by benthic class and image. The highest accuracy for benthic classification (excluding deep water) was 90% for coral reefs with high cover in image 1 and 72% for seagrass in image 2. The lowest overall accuracy found was macroalgae with a value of 20 and 25 for image 1 and 2, respectively. Therefore, the overall accuracy rate for classification of different benthic habitats for all images ranged from 20 to 90%.

As outlined in Tables B3, B4, and B5, the low accuracy rating of certain benthic habitat classes can be attributed to:

1) **Temporal changes between the image acquisition date and field surveys:** There was a four-year gap between the image acquisition date and the field surveys (i.e. collection of ground truth points). Benthic habitats are subject to change overtime, which is likely the case in Sogod Bay that has incurred extreme weather (e.g., tropical typhoons), coral bleaching events, and population explosions of crown-of-thorn starfish (a species that eats coral) in recent years. This means that many of the pixels labelled as "incorrect" during validation are actually correct for the time the image was taken. This is particularly prevalent in cases of macroalgae, seagrass, and coral (e.g., coral degradation, new growth). Thus, the true accuracy of the final map of benthic habitat classes is actually much higher than the validation exercise indicates.

2) **Spectral similarities between classes:** The spectral confusion between certain classes (e.g., hard coral and low coral cover) is likely due to their spectral similarities. For instance, spectral classifications could not consistently differentiate bedrock in rocky reefs and mud in areas that have muddy overlaying waters near river plumes, because the spectral signatures are similar. Another example is the confusion between seagrass and macroalgae. Problems differentiating these two classes is owed to their biological characteristics, which are spectrally similar due to green peak and blue/red absorption by Chlorophyll and NIR reflectance. To improve classification of spectrally similar classes, environmental predictors of habitat presence (e.g., depth and distance from shoreline) could be used to inform final classification of certain classes (e.g., seagrass), as has been demonstrated by Baumstark et al. (2016). However, the coarse bathymetry dataset available in Sogod Bay restricted this possibility.

3) **Frequent co-existence and mixing of classes:** The coral reefs lining Sogod Bay are highly heterogeneous. Through examining all of the pixels labelled as classification errors, it was apparent that the vast majority of them were on the boundaries of a class (just on the outside edge

of a cluster of coral for example). Furthermore, errors occurred in areas where there was frequent co-existence and mixing of classes, which were often present at fine spatial scales. For instance, differentiations between low coral cover and sand in the study was problematic due to frequent co-existence of both sand and colonized hard coral on patches of bedrock or boulders. Classification preference towards the dominant biological cover, in addition to difficulty in delineating these gradual transitions, resulted in classification errors in areas where sand and coral co-exist.

4) **Limitations of field data:** Some cover classes in image 3 had low sample numbers for ground truth points due to turbidity, which limited visibility in the ground truth videos. To account for this low sample number, image 3 was mosaicked with image 2 to obtain additional training spectra from image 3 as the next-best solution. Additionally, the numbers of ground-truth points were too low to offer a robust analysis for two habitat classes in image one; rock/ pebble/ gravel and mangrove roots. This is due to inadequate sampling in shallow waters (<1m depth) which were difficult to sample from a boat. While a few samples were collected on foot, the field crew did not collect enough from a robust analysis. Field data collection in this study area was also limited by weather. The field surveys required waiting for days with calm water and clear visibility, which were rare given that the field surveys took place during the monsoon season or *habagat* (i.e., a season with frequent storms and high waves). Accuracy assessment was also complicated by differences in sampling and mapping scale. For example, interpretation of percent biological cover with the *in situ* videos images occurred at different depths since the camera was mounted at a set distance below a paddle boat rather than at a set distance from the seafloor. While the research team attempted to compensate for this by visually classifying images within a 2-m plot at the centre of a video image, their interpretations of percentage coverage of video may not adequately correspond to the percent biological cover of each 2 m pixel in a WorldView-2 image, especially in deep waters. This sampling-mapping scale discrepancies could have impacted the mapping and accuracy assessment results. Furthermore, camera tilt could have lead to sampling and interpretation errors (e.g., if the camera is at tilted when viewing, it might be viewing the neighbouring pixel). The sampling method could have been improved by setting the camera at a set distance from the bottom of the seafloor, although this would have required a more complex field sampling method that could is more costly and difficult to operator without risking damage to delicate benthos, such as coral reefs.

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Appendix C. Human Ethics Approval Form

University of Victoria

Office of Research Services | Human Research Ethics Board
Administrative Services Building Rm B202 PO Box 1700 STN CSC Victoria BC V8W 2Y2 Canada
T 250-472-4545 | F 250-721-8960 | uvic.ca/research | ethics@uvic.ca

Certificate of Approval

PRINCIPAL INVESTIGATOR:	**Alessia Kockel**	**ETHICS PROTOCOL NUMBER** Minimal Risk - Delegated	**15-140**
UVic STATUS:	**Master's Student**	ORIGINAL APPROVAL DATE:	01-Jun-15
UVic DEPARTMENT:	**GEOG**	APPROVED ON:	01-Jun-15
SUPERVISOR:	**Dr. Philip Dearden**	APPROVAL EXPIRY DATE:	31-May-16

PROJECT TITLE: **Evaluating the trade-offs between biodiversity conservation and socioeconomic viability in systematic marine conservation planning**

RESEARCH TEAM MEMBERS: Co-principal Investigator: Dr. Philip Dearden (UVic)

DECLARED PROJECT FUNDING: **CAPI Student Fellowship; Robin Rigby Trust; NSERC (pending); Bourses d'etudes de cycles superieurs en ercherche Fonds de recherche nature et technologies - Quebec (FRQNT); SSHRC (under Dr. Dearden)**

CONDITIONS OF APPROVAL

This Certificate of Approval is valid for the above term provided there is no change in the protocol.

Modifications
To make any changes to the approved research procedures in your study, please submit a "Request for Modification" form. You must receive ethics approval before proceeding with your modified protocol.

Renewals
Your ethics approval must be current for the period during which you are recruiting participants or collecting data. To renew your protocol, please submit a "Request for Renewal" form before the expiry date on your certificate. You will be sent an emailed reminder prompting you to renew your protocol about six weeks before your expiry date.

Project Closures
When you have completed all data collection activities and will have no further contact with participants, please notify the Human Research Ethics Board by submitting a "Notice of Project Completion" form.

Certification

This certifies that the UVic Human Research Ethics Board has examined this research protocol and concluded that, in all respects, the proposed research meets the appropriate standards of ethics as outlined by the University of Victoria Research Regulations Involving Human Participants.

[redacted]

Dr. Rachael Scarth
Acting Associate Vice-President, Research

15-140 Kockel, Alessia

Certificate Issued On: 01-Jun-15

Appendix D. Participatory Mapping

Objectives of the mapping workshop

The participatory mapping workshop consisted of six main parts to:

1. outline the context and objectives of the research to participants and obtain verbal consent,
2. collect basic information on the fishery profile of the barangay,
3. map fishing sites per fishing method,
4. map and document the local knowledge on the location and quality of coastal habitats adjacent to the barangay,
5. determine if the barangay had requested or expressed an interest in developing a no-take MPA in the near-future (by 2020) and map the proposed site(s), and
6. provide an open forum to give participants the opportunity to share and discuss topics pertaining to conservation and/or fisheries management.

Workshop participants

Research team: The workshops were facilitated by the lead researcher, with the assistance of a translator, in the Filipino dialect of Visayan. A research assistant and a GIS technician were also present to record spatial and attribute data. All members of the research team were properly trained in the mapping procedures and protocols.

Small-scale fisher participants: Small-scale fishers were defined as any person who directly engages in the extraction of coastal resources in municipal waters. The definition includes fishers who do not use vessels (e.g., gleaning) or use vessels of 3 gross tons or less. It also encompasses a wide range of fishing methods that may or may not involve the use of gear (e.g., gleaning, diving). Both men and women participants over the age of 18 were included in this study. Each workshop consisted of 6-12 participants.

Participant selection and recruitment

Participants were identified through purposeful sampling. Barangay captain or barangay council members were asked to nominate individuals who have extensive knowledge on the fishing practices in their barangay. They were asked to consider diverse sub-groups (e.g., age, gender) and types of fishers (based on the primary fishing method used by fishers) in their nominations. Participation was completely voluntary, and identities were kept confidential (i.e., no names recorded).

Prior informed consent

Verbal consent was obtained by fisher participants prior to commencing the mapping exercise. Additionally, written consent was also provided at a municipal level by the mayor and at a barangay level by the barangay captain prior to all mapping workshops (Appendix E).

Duration

The mapping workshops generally took between three to four hours per barangay.

Materials

Data sheets: Data sheets were used to record the local knowledge of participants.

Paper maps: Paper maps displaying Google Earth Pro images (scale of 1:20,000 with a grid reference overlay) were provided to each participant. The maps were laminated to allow fishers to draw directly on the maps with markers. The map showed the locations of existing MPAs, the municipal water extent, and the boundaries of barangays and municipalities.

Digital mapping tool: Fishers were also given access to a digital map. The digital map displayed Google Earth Pro on a 20-inch touch-screen tablet. The map included layers on the locations of existing MPAs, the municipal water extent, and the boundaries of barangays and municipalities. The digital mapping tool was used to assist fishers to measure distances from shore and describe mapped features with greater accuracy (e.g., zoom in and out to show fishing area extent). It was also used by the GIS technician to digitize the fishing sites on site.

Mapping procedures and protocols

The mapping procedures and protocols were adapted from the National Oceanic and Atmospheric Administration (NOAA, 2014) and Close and Hall (2006), and approved by the Human Research Ethics Board at the University of Victoria (Appendix C).

As is customary in the Philippines, each workshop began with a prayer. Members of the research team introduced themselves and thanked the volunteer participants for their time and participation. The translator provided a short (~10 minute) presentation to describe the context and objectives of the research to participants. Participants were provided the opportunity to ask questions or raise any concerns throughout the workshop. As described above, prior informed constant was obtained verbally.

After obtaining consent, participants were asked to provide an estimate on the number of boats and small-scale fishers in their barangay. This was followed by introducing the digital map and paper maps to the workshop. With the assistance of the local translator, the facilitator explained the scale, distances, directions, and features on the maps. The comprehension of participants was tested by asking participants to locate certain map features. In addition, participants were provided an example of how to map a fishing method on the paper maps and shown how their drawn maps would be digitized in the mapping tool.

Following the map orientation, the workshops proceeded to mapping fishing areas per fishing method. Fishers were first read a definition of the fishing method (Table D1) and asked whether it had been used by any members of their barangay within the last 12 months. If the method was used, the group was asked to provide general information on the seasonality, main catch, mode of transport, distances from shore, depth, and number of fishers who engage in the fishing method. Participants were then asked to work in groups of 2 or 3 to map the general fishing areas on a paper map. The “general fishing area” includes any area (closed polygon) within municipal waters where the fishing method is known to be used by fishers from the barangay, within the past 12 months, regardless of its frequency or intensity. It does not include areas used exclusively for transit. Drawn maps were compared and discussed in a group to produce one final map. The final map was then digitized on site by a GIS technician based on participants drawings, descriptions, and distance references (e.g., distance from shore, barangay limits).

Once consensus was reached, fishers were asked to assign different levels of importance to areas in the general fishing area using a scale of high, medium, low, or no distinction. Fishers were told that they could assign the same value to the whole "general fishing area" or break the "general fishing areas" into different sections (closed polygons). It was explained that they could base their choice on various reasons (e.g., presence of target species, regulations, fisher's experience, accessibility/proximity to barangay, proximity to a marine protected area) and their reasons were documented by the research team. Special attention was placed on selecting "priority areas", or high importance areas. Fishers were subsequently asked to record the number of fishers that use each area. The importance values and number of fishers were recorded by the research assistant and later included as attribute information to corresponding digitized fishing sites.

The next section of the mapping exercise asked participants to map the coastal habitats bordering their barangay with a focus on mangroves, seagrasses, and coral reefs. These were mapped directly on the digital map. Participants were then asked if their barangay had requested or expressed an interest in developing a no-take MPA in the near-future (by 2020). If so, they were asked to map the proposed MPA site. The proposed MPAs were verified by barangay council members. Additionally, fishers were asked to identify prospective MPA sites that they would support within their municipal waters.

Each mapping workshops concluded with an open forum. This gave participants the option to share any additional information pertaining to conservation and/or fisheries. Topics discussed included challenges facing MPAs and fisheries (e.g., corruption, conflicts between divers and fishers, illegal fishing practices, illegal commercial fishing within municipal waters), prospective new MPA sites, and potential solutions to enhance MPA effectiveness (e.g., salary for MPA guards, greater police enforcement, and community consultation).

The spatial and attribute data obtained through participatory mapping workshops were compiled within a GIS database in ArcGIS 10.2.

Summary of results

A total of 914 small-scale fishers (691 men and 227 women) from 79 coastal communities participated in a mapping workshop. Table D2 shows the duration and number of participants per barangay. It also shows the estimated number of boats and fishers by barangay and municipality, based on the local knowledge of fisher participants. In total, there are approximately 9000 fishers in the planning region. The estimated number of male and female fishers per fishing method and municipality are summarized in Table D3.

Table D1. Description of fishing methods used in the planning region.

Fishing class	Fishing method	Code	Visayan name (s)	Description
Glean	Gleaning*	GL	*Panginhas, Pantama Panglapas* (abalone), *Panuyom* (urchin), *Pangswaki* (urchin)	Gleaners walk in intertidal areas and collet marine animals by hand or with the assistance of hand tools (e.g., knife, machete, or spear). This method includes the collection of abalone, urchins, and octopus in intertidal areas with or without the use of a mask.
Dive	Diving*	DI	*Panawom, Panuyom, Panawom, Panginhas*	Fishers free dive to collect prey by hand or with the assistance of hand tools (e.g. knife, gaff hook).
	Spearfishing*	SF	*Pana*	Spear fishers use a firing device to shoot and propel a spear to strike and impel prey.
	Octopus fishing	OJ	*Pangugita*	Octopus fishers target octopus while free diving. This method can involve the use of hand tools or accessories to lure and catch octopus (e.g., octopus lure, knife).
Trap	Pot trap	PT	*Bubo, Pangaw, Panggal, Bantak*	Fishers use stationary trap to passively trap target prey (e.g., fish, crab, lobster, and shrimp) and prevent escape.
Hook & line	Squid fishing 1	Q1	*Pamoko bukoay*	Fishers use a line with a jig designed to catch small pencil squid (*Loliginidae*). The jig is moved by hand in a jerking action to attract squid at sunset and sunrise.
	Squid fishing 2†	Q2	*Pangnokus, Sarangat Kawil pangnokus,* Squid: *barawan, nokos sa lawod, and bulingit*	Fishers use a line with a jig designed to catch Flying Squids (*Ommastrephidae)*. This method is typically used at night in offshore areas.
	Squid fishing 3	Q3	*Subid-subid, Nokos sa piliw* (squid)	Fishers use a line with a jig designed to catch Bigfin Reef Squid (*Sepioteuthis lessoniana*). The method is typically used in shallow areas at sunset, sunrise, and/or during a full moon.
	Squid fishing 4†	Q4	*Pang koli-papa, Koli-papa* (squid)	Fishers use a line with baited jig designed to catch large Flying Squid species (*Ommastrephidae)*. This method is typically used in the morning in deep offshore waters.
	Simple handline 1 * (from shore)	SH	*Labyog*	Fishers use a handline that consists of a line with a single hook. This method is operated by hand from the shore and can include accessories (e.g., weight, spool, or rode).
	Simple handline 2 * (from vessel)	SB	*Pauro, Pamasol, Mingwit*	Fishers use a handline that consists of a line with a single hook. This method is operated by hand while on a vessel (without being dragged behind a boat). It can include accessories (e.g., weight, spool, or rode).
	Multiple handline†	MH	*Ontog, Bira-bira, Unda*	Fishers use a handline with multiple hooks suspended on a mainline. It can include accessories (e.g., weight, spool, or rode).
	Rentex	RX	*Rentex, Pambawo, Spirikitik*	Fishers use a synthetic fibre (known as 'Rentex') designed to catch needlefish and sailfish (with no hooks). The fibres are typically tied to a line and towed behind a boat. The line can be fitted with hooks to catch other types of fish (e.g., tuna).

* Top 5 most used fishing methods, excluding †methods used exclusively offshore

Table D1 (*continued*)

Fishing class	Fishing method	Code	Visayan name (s)	Description
Hook & line *(cont.)*	Bottom-set longline	BL	*Palangre, Panlahoy*	Fishers use a longline that is anchored and set vertically in shallow bottom areas to catch fish. The mainline has multiple branch lines with hooks.
	Surface-set longline†	SL	*Palangre* *Palotaw*	Fishers use a longline in open water to catch large pelagic species. The mainline is set near the surface with floats and has multiple branch lines with hooks. It could be anchored or left to drift.
	Troll line†	TL	*Lambo*	Fishers tow multiple hook and lines behind a boat to catch fish.
	Hook, line, and float	HF	*Palotaw, Pataw-pataw, Tawa-tawa*	Fishers use a line with multiple hooks attached to a float. The float is left to drift with the current.
Net	Surface-set gillnet	SG	*Lamba, Pamasayan Bungkol, Kayagkag Pangisaw, Patulay*	Fishers use a gillnet in shallow areas to catch schools of fish. The top of the net is set at the surface with floats, while the net is held at the bottom with weights.
	Bottom-set gillnet	BG	*Sedewe, Pantaan Palubog, Patugkad Palunod*	Gill net set on or near sea floor to catch bottom-dwelling fish.
	Drift gillnet†	DG	*Paanod, Palaran*	Fishers use a surface gill designed to drift with the current. The top of the net is set at the surface with floats. The net could be attached (not dragged) to a boat.
	Encircling gillnet†	EG	*Likos, Panglihos, Kayagkag, Lambat*	Fishers use a gillnet to surround and capture schooling fish within a 'wall' of netting. This method often involves two boats.
	Cast net	CN	*Laya*	Fishers throw a circular or conical weighted net over target prey. The net is hauled in to capture fish.
	Lift net	LN	*Skylab*	Fishers submerge a lift net and then haul it upwards out of the water to capture prey. This method can be operated by hand or with the use of boats, pulleys, and/or levers.
	Scoop net	SN	*Sikpaw, Sibot, Kandos* (tool), *Mamolinao, Pangbolinao, Pangtognos*	Fishers employ a small to medium sized meshed net to scoop prey from the water. This method excludes cases where gear is only used as a fishing accessory (e.g., used to remove fish from nets).

†Method used exclusively offshore

Table D2. Information on workshop participants, workshop duration, and estimated (by fishers) number of fishers and boats per barangay (brgy.) and municipality (mun.)

Mun./ Brgy. code*	**Workshop duration** (hr:min)	**N° of workshop participants** Male	Female	Total	**N° of boats** (estimate by participants) Motor	Paddle	Total	**N° of fishers** (estimate by participants) Male	Female	Total
A01	3:15	9	3	11	12	15	27	80	50	130
A02	3:50	5	4	9	30	5	35	80	20	100
A03	3:30	9	2	11	35	7	42	100	30	130
A04	3:35	8	1	9	25	10	35	50	20	70
A05	3:25	4	2	6	23	35	58	150	20	170
A06	5:00	6	1	7	10	9	19	21	10	31
A07	5:00	7	1	8	12	15	27	60	10	70
A08	3:56	5	4	9	15	8	23	30	50	80
A09	3:45	6	3	9	5	26	31	50	20	70
A10	3:15	4	2	6	4	13	17	30	15	45
A11	2:05	2	5	7	2	10	12	10	5	15
A12	2:35	7	1	8	4	25	29	45	20	65
A13	3:00	5	2	7	3	8	11	40	10	50
A14	4:00	5	2	7	3	9	12	20	15	35
A15	3:40	5	3	8	1	5	6	25	5	30
A16	3:55	4	5	9	5	17	22	39	25	64
A17	3:35	7	1	8	5	6	11	15	10	25
A18	3:45	7	2	9	4	10	14	60	25	85
A19	2:50	8	4	8	0	8	8	21	12	33
A total	N/A	113	48	156	198	241	439	926	372	1298
B01	3:45	6	2	8	12	10	22	70	140	210
B02	3:15	10	2	12	4	20	24	30	25	55
B03	3:35	9	3	12	6	15	21	50	30	80
B04	4:00	8	1	9	15	30	45	80	30	110
B05	4:00	6	2	8	10	20	30	30	20	50
B06	3:30	6	2	8	2	5	7	25	10	35
B07	3:30	7	2	9	0	20	20	40	15	55
B08	3:30	3	6	9	4	30	34	70	60	130
B09	3:30	6	4	10	5	30	35	80	40	120
B10	4:00	5	3	8	5	30	35	120	50	170
B11	4:00	9	1	10	5	25	30	40	30	70
B12	4:25	6	4	11	4	14	18	76	30	106
B total	N/A	81	32	114	72	249	321	711	480	1191
C01	2:25	10	2	12	6	30	36	100	20	120
C02	2:20	8	2	10	40	20	60	100	20	120
C03	4:00	10	2	12	8	20	28	50	30	80
C04	3:30	8	2	10	60	20	80	100	100	200
C05	3:00	8	3	11	5	15	20	50	35	85
C06	4:00	8	2	10	10	20	30	170	50	220
C07	3:45	10	1	11	25	100	125	200	30	230
C08	5:30	11	1	12	25	8	33	80	20	100
C09	5:00	11	1	12	4	20	24	45	15	60
C10	4:10	7	1	8	16	20	36	100	50	150

*Municipal codes: A=Pintuyan, B=San Francisco, C=Liloan, D=Malitbog, E=Padre Burgos, and F= Limasawa; Barangay codes are used to protect the confidentiality agreement.

Table D2. *(cont.)*

Mun./ Brgy. code*	**Workshop duration** (hr:min)	**N° of workshop participants**			**N° of boats** (estimate by participants)			**N° of fishers** (estimate by participants)		
		Male	Female	Total	Motor	Paddle	Total	Male	Female	Total
C11	3:45	6	3	9	25	50	75	300	100	400
C total	N/A	97	20	117	224	323	547	1295	470	1765
D01	3:15	9	3	12	40	15	55	150	30	180
D02	2:45	10	2	12	5	15	20	50	20	70
D03	3:15	6	3	9	10	15	25	50	20	70
D04	2:50	10	2	12	7	10	17	50	30	80
D05	3:25	7	2	9	15	10	25	50	40	90
D06	3:30	6	4	10	4	10	14	30	15	45
D07	2:55	9	3	12	60	23	83	90	30	120
D08	2:55	7	1	8	0	0	0	80	15	95
D09	3:00	9	3	12	7	17	24	40	20	60
D10	2:48	8	2	10	8	15	23	30	15	45
D11	2:45	9	1	10	4	5	9	25	10	35
D12	2:55	6	4	10	5	4	9	30	20	50
D13	3:22	9	3	12	6	18	24	50	10	60
D14	2:35	6	3	9	7	12	19	35	15	50
D15	2:35	8	1	9	9	30	39	70	20	90
D16	2:40	7	1	8	10	20	30	70	25	95
D17	2:40	6	2	8	6	25	31	60	10	70
D18	3:20	7	5	12	4	6	10	20	20	40
D19	2:55	9	3	12	3	12	15	20	10	30
D20	2.45	8	1	9	4	30	34	100	20	120
D21	2:50	10	2	12	4	13	17	60	10	70
D total	N/A	166	51	217	218	305	523	1160	405	1565
E01	3:15	11	1	12	16	30	46	80	30	110
E02	3:45	7	3	10	20	30	50	60	50	110
E03	3:35	7	1	8	10	30	40	100	20	120
E04	0.15	9	2	11	12	50	62	80	50	130
E05	3:50	9	0	9	4	60	64	200	30	230
E06	3:15	7	0	7	2	15	17	50	30	80
E07	3:15	9	2	11	6	8	14	65	50	115
E08	3:15	10	2	12	40	20	60	130	50	180
E09	3:35	7	4	11	20	10	30	170	60	230
E10	3:50	8	4	12	24	15	39	50	50	100
E total	N/A	84	19	103	154	268	422	985	420	1405
F01	5:20	9	3	12	60	20	80	200	50	250
F02	5:00	8	4	12	200	20	220	300	20	320
F03	5:00	7	5	12	320	10	330	600	50	650
F04	6:25	9	3	12	60	20	80	200	100	300
F05	4:25	10	2	12	85	22	107	140	30	170
F06	4:35	7	5	12	20	15	35	60	25	85
F total	N/A	50	22	72	745	107	852	1500	275	1775
TOTAL	N/A	591	192	779	1611	1493	3104	6577	2422	8999

*Municipal codes: A=Pintuyan, B=San Francisco, C=Liloan, D=Malitbog, E=Padre Burgos, and F= Limasawa; Barangay codes are used to protect the confidentiality agreement.

Table D3. Estimated number of male and female fishers by municipality and fishing method

		Municipality																				
		Pintuyan			San Francisco			Liloan			Malitbog			Padre Burgos			Limasawa			All municipalities		
		M	W	T	M	W	T	M	W	T	M	W	T	M	W	T	M	W	T	M	W	T
Fishing Methods	GL	448	361	809	370	450	820	543	470	1013	276	430	706	190	420	610	115	275	390	1942	2406	4348
	DI	275	58	333	210	69	279	505	42	547	149	17	166	195	15	210	420	130	550	1754	331	2085
	SF	192	0	192	185	0	185	275	0	275	171	1	172	156	0	156	144	5	149	1123	6	1129
	OJ	17	0	17	6	0	6	30	0	30	10	0	10	6	0	6	27	0	27	96	0	96
	PT	30	0	30	33	3	36	65	0	65	111	1	112	82	0	82	36	0	36	357	4	361
	Q1	387	61	448	40	0	40	0	0	0	0	0	0	0	0	0	0	0	0	427	61	488
	Q2	629	60	689	485	26	511	575	12	587	889	10	899	527	4	531	1365	15	1380	4470	127	4597
	Q3	133	9	142	177	7	184	181	2	183	308	0	308	155	2	157	95	0	95	1049	20	1069
	Q4	2	0	2	0	0	0	5	0	5	1	0	1	85	0	85	2	0	2	95	0	95
	SH	107	1	108	146	11	157	134	11	145	350	19	369	211	13	224	118	2	120	1066	57	1123
	SB	89	2	91	150	1	151	132	1	133	244	1	245	96	0	96	460	0	460	1171	5	1176
	MH	214	0	214	294	3	297	301	0	301	662	1	663	369	0	369	760	0	760	2600	4	2604
	HF	62	1	63	133	0	133	54	0	54	55	0	55	58	0	58	64	0	64	426	1	427
	TL	253	0	253	315	1	316	320	2	322	225	1	226	312	0	312	825	0	825	2250	4	2254
	RX	164	0	164	99	0	99	118	1	119	218	0	218	142	0	142	189	0	189	930	1	931
	BL	48	0	48	42	0	42	11	0	11	74	2	76	20	1	21	92	0	92	287	3	290
	SL	55	0	55	11	0	11	21	0	21	0	0	0	0	0	0	115	0	115	202	0	202
	SG	75	1	76	106	2	108	73	1	74	0	0	0	15	0	15	15	0	15	284	4	288
	BG	91	0	91	79	7	86	160	4	164	0	0	0	36	0	36	169	2	171	535	13	548
	DG	98	0	98	77	4	81	151	2	153	304	1	305	76	1	77	40	0	40	746	8	754
	EG	36	0	36	12	0	12	30	0	30	0	0	0	0	0	0	0	0	0	78	0	78
	CN	0	0	0	1	0	1	30	1	31	0	0	0	5	0	5	2	0	2	38	1	39
	LN	39	3	42	30	1	31	93	6	99	50	0	50	47	2	49	69	3	72	328	15	343
	SC	15	0	15	87	0	87	109	0	109	186	4	190	99	6	105	4	0	4	500	10	510

M: Number of men, W: Number of women, T: Total number of men and women

Appendix E. Prior Informed Consent Forms

Appendix E1. Written consent form for municipal mayors

Department of Geography, University of Victoria
PO Box 1700 STN CSC, Victoria, British Columbia, V8W 2Y2, Canada
Tel: 1-250-721-7327
Email: geoginfo@uvic.ca
Website: www.uvic.ca/socialsciences/geography/

July 8th, 2015

To the Attention of Hon. ________
Mayor, Municipality of ________

Re: Research evaluating the trade-offs of systematic conservation planning approaches for designing networks of marine protected areas in the Philippines

Dear Mayor ________,

In partnership with the Large Marine Vertebrate Research Institute Philippines (LAMAVE), I would like to extend this letter to invite you and members of your municipality to participate in a Masters research study on planning a marine protected area (MPA) network in Sogod Bay. This research is part of my Masters of Science degree requirement with the Department of Geography at the University of Victoria in British Columbia, Canada. It is being conducted under the supervision of Dr. Philip Dearden (pdearden@mail.geog.uvic.ca). The documents attached include a brief outline of the research study, a Prior Informed Consent (PIC) form, and a copy of the Certificate of Approval from the Human Research Ethics Board at the University of Victoria. I am more than happy to provide more information if needed.

The objectives of the research study are two-fold and will be conducted over two phases.

(1) The objective of the first phase is to develop and evaluate three planning scenarios for designing a marine protected area (MPA) network in Sogod Bay. The scenarios will incorporate varying complexities of social and governance considerations that are relevant to MPA implementation in the Philippines. The ecological and socioeconomic implications of each scenarios will be analyzed and compared.

(2) The objective of the second phase is to present a MPA network plan of each scenario to decision-makers and small-scale fishers to evaluate their feasibility for implementation and assess how preferences vary between different fishers, communities, and levels of government.

Local government unit (LGU) officials, barangay leaders, and small-scale fishers from municipalities surrounding Sogod Bay will be invited to participate in interviews regarding MPAs and small-scale fishing. Participation is this research is completely voluntary and the identity of all participants will remain confidential.

The results of this study will provide valuable information for decision-makers and local communities seeking to enhance conservation and fisheries benefits of MPAs in Sogod Bay and other regions in the Philippines. Furthermore, it addressed the need for more guidance for planning MPA networks that incorporate conservation goals with local community needs.

Please sign the Prior Informed Consent (PIC) for 2015 if you consent to this research study being conducted in the Municipality of ________. If you have any further questions, please feel free to contact me at any time by phone (09052738740) or email (akockel@uvic.ca).

On behalf of myself and my team, we thank you for your time and look forward to collarborating with you.

Sincerely,

Alessia Kockel
(Primary Researcher)

University of Victoria Geography

Department of Geography, University of Victoria
PO Box 1700 STN CSC, Victoria, British Columbia, V8W 2Y2, Canada
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Prior Informed Consent- Municipality of _____

Title: *Evaluating the trade-offs of systematic conservation planning approaches for designing networks of marine protected areas in the Philippines*

Your municipality is invited to participate in a Masters research study on planning a marine protected area (MPA) network in Sogod Bay conducted by Alessia Kockel. Alessia is a Graduate Student in the Department of Geography at the University of Victoria and you may contact her if you have further questions at akockel@uvic.ca. As a Graduate student, Alessia is required to conduct research as part of her Masters of Science degree. The research study is being conducted under the supervision of Dr. Philip Dearden (pdearden@mail.geog.uvic.ca) and has received a Certificate of Approval from the Human Research Ethics Board at the University of Victoria. It is being funded by the Social Sciences and Humanities Research Council (SSHRC) and the Robin Rigby Trust.

Purpose and Objectives

The objectives of this research study are two-fold and will be conducted over two phases/field seasons. This PIC form is for **phase one** of this study.

1. **The objective of phase one is to develop and evaluate three planning scenarios for designing a marine protected area (MPA) network in Sogod Bay. The scenarios will incorporate varying complexities of social and governance considerations that are relevant to MPA implementation in the Philippines. The ecological and socioeconomic implications of each scenario will be analyzed and compared.**
2. The objective of phase two is to present a MPA network plan of each scenario to decision-makers and small-scale fishers to evaluate their feasibility for implementation and assess how preferences vary between different fishers, communities, and levels of government.

Importance of this Research

Research of this type is important as it addresses the need for more guidance from the scientific literature to design MPA networks that incorporate regional conservation targets with local community needs. The results of this study will provide valuable information for decision-makers and local communities seeking to enhance conservation and fisheries benefits of MPAs in Sogod Bay and other regions in the Philippines.

What is involved

The first phase of this research study will involve collecting ecological and socioeconomic data required to develop, compare, and analyze three MPA network planning scenarios. Ecological data will be collected using benthic survey data from Coral Cay Conservation and WorldView-2 satellite imagery. Socioeconomic data will be collected using secondary data sources, semi-structured interviews, and participatory mapping.

You are being asked to grant the research team permission to contact/recruit barangay leaders, Local Government Unit (LGU) officials, Barangay Fishery and Aquatic Resource Management Council (BFARMC) members, and small-scale fishers from your municipality. These individuals will be invited to participate in interviews regarding MPAs and small-scale fishing. Furthermore, LGU officials may be asked to share spatial data (e.g., administrative boundaries, MPA locations, and municipal water boundaries) files and datasets with researchers.

Voluntary Participation, Anonymity, and Confidentiality

Participation in this study is completely voluntary. Individuals who decide to participate may withdraw at any time without any consequences or any explanation. The identity of all participants will remain confidential. No names will be collected.

The confidentiality of the data will be protected and saved in a locked and secure location. However, there are some limits to the researcher's ability to protect confidentiality, since responses will be linked to place (i.e. your municipality). Participation in this study should not cause participants any inconvenience, other than donating their time. There are no known or anticipated risks in participating in this study.

Dissemination of Results

It is anticipated that the results of this study will be shared with others through a thesis paper, defense presentation, public community and partner presentations, academic and media presentations, and published scholarly articles. Your municipality will receive a written report of the results upon the completion of this study. Presentations of results can be scheduled by contacting the primary researcher.

Contacts

Individuals that may be contacted regarding this study include:

- Primary Researcher: Alessia Kockel, akockel@uvic.ca
- Supervisor: Dr. Philip Dearden, pdearden@mail.geog.uvic.ca

In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or ethics@uvic.ca).

Signature

Your signature below indicates that you understand the above conditions of participation in this study, that you have had the opportunity to have your questions answered by the researcher, and that you grant the research team permission to contact/recruit Local Government Unit (LGU) officials, barangay leaders, Barangay Fishery and Aquatic Resource Management Council (BFARMC) members, and small-scale fishers from your municipality for the purpose of this study.

______________________	______________________	____________
Name of Mayor	*Signature*	*Date*

A copy of this consent will be left with you, and a copy will be taken by the researcher.

Appendix E2. Written consent form for barangay captains (English version)

University of Victoria Geography

Department of Geography
University of Victoria
PO Box 1700 STN CSC
Victoria, British Columbia, V8W 2Y2, Canada
Tel: 1-250-721-7327
Email: geoginfo@uvic.ca.
Website: www.uvic.ca/socialsciences/geography/

Participant Consent Form
Phase 1: Group 2

Evaluating the trade-offs of systematic conservation planning approaches for designing networks of marine protected areas in the Philippines

You are invited to participate in a study on designing marine protected area networks in Sogod Bay conducted by Alessia Kockel. Alessia is a Graduate Student in the Department of Geography at the University of Victoria and you may contact her if you have further questions at akockel@uvic.ca. As a Graduate student, Alessia is required to conduct research as part of her Masters of Science degree. The research study is being conducted under the supervision of Dr. Philip Dearden. You may contact her supervisor at pdearden@mail.geog.uvic.ca. The research is being funded by the Social Sciences and Humanities Research Council (SSHRC) and the Robin Rigby Trust.

Purpose and Objectives
The objectives of this research study are two-fold and will be conducted over two phases/field seasons. You are being asked to participate in phase one of this study.

(1) **The objective of phase one is to develop and evaluate three planning scenarios for designing a marine protected area (MPA) network in Sogod Bay. The scenarios will incorporate varying complexities of social and governance considerations that are relevant to MPA implementation in the Philippines. The ecological and socioeconomic implications of each scenario will be analyzed and compared.**
(2) The objective of phase two is to present a MPA network plan of each scenario to decision-makers and small-scale fishers to evaluate their feasibility for implementation and assess how preferences vary between different fishers, communities, and levels of government.

Importance of this Research
Research of this type is important as it addresses the need for more guidance from the scientific literature to design MPA networks that incorporate regional conservation targets with local community needs. The results of this study will provide valuable information for decision-makers and local communities seeking to enhance conservation and fisheries benefits of MPAs in Sogod Bay and other regions in the Philippines.

Participants Selection
You are being asked to participate in this study because you are a barangay leader or a Barangay Fishery and Aquatic Resource Management Council (BFARMC) member that has influence over the management and conservation of fishery and aquatic resources within your barangay. If you are a barangay leader, you will be asked to grant the research team permission to contact/recruit small-scale fishers from your municipality. You will be asked to identify 6-8 individuals who have expensive knowledge on the fishing practices in your barangay.

What is Involved
If you consent to voluntarily participate in this study, your participation will include participating in a group interview that will take approximately one hour of your time and be scheduled at your convenience. The group interview will consist of the barangay leader and a BFARMC member from your barangay. A transcription will be made of your answers as written notes. With your consent, interviews will be audio recorded and visually recorded (videos or photographs).

Inconvenience and Risks
Participation in this study should not cause you any inconvenience, other than donating your time. There are no known or anticipated risks to you by participating in this study.

Benefits
Participation in this study could enhance your level of marine conservation knowledge and provide useful information to inform marine management and conservation practices.

Revised April 2015

Voluntary Participation
Your participation in this study must be completely voluntary. If you do decide to participate, you may withdraw at any time without any consequences or any explanation. If you withdraw part-way through the completion of the group interview, any answers identified as your own will not be used in the analysis. Due to the nature of the group interview, data linked to group discussions will need to be summarized. Additionally, it will not be logistically possible to withdrawn your responses or audio recordings after the interview has been completed. If you have given consent to take pictures and/or videos of you, but later wish to withdraw these images, please contact the primary researcher within one month of the interview date.

Anonymity and Confidentiality
In terms of protecting your anonymity, your identity will be confidential. No names will be collected. The confidentiality of the data will be protected and saved in a locked and secure location. However, there are some limits to the researcher's ability to protect your confidentiality owing to your elected government statue (i.e. public figure in the community) and since responses will be linked to place (i.e. your municipality and barangay). If you consent to be visually recorded, you may be recognizable if visual images are used in municipal reports, public community and partner presentations, and academic and media presentations.

Dissemination of Results
It is anticipated that the results of this study will be shared with others through a thesis paper, defense presentation, municipal reports, public community and partner presentations, academic and media presentations, and published scholarly articles.

Future Research
This data may be used by future researchers with your consent. Your identity will be anonymous.

Contacts
Individuals that may be contacted regarding this study include:

- Primary Researcher: Alessia Kockel, akockel@uvic.ca
- Supervisor: Dr. Philip Dearden, pdearden@mail.geog.uvic.ca

In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or ethics@uvic.ca).

Your signature below indicates that you understand the above conditions of participation in this study, that you have had the opportunity to have your questions answered by the researchers, and that you consent to participate in this research project.

_______________________	_______________________	_____________
Name of Participant	*Signature*	*Date*

Future Use of Data

- I consent to the use of my data in future research: __________ (Participant to provide initials)
- I do not consent to the use of my data in future research: _______________ (Participant to provide initials)

Audio Recorded and Visually Recorded Images
Participant to provide initials, only if you consent.

- Audio recording may be taken of me for: Analysis __________ (Participant to provide initials)
- Photos may be taken of me for: Dissemination __________ (Participant to provide initials)
- Videos may be taken of me for: Dissemination __________ (Participant to provide initials)

A copy of this consent will be left with you, and a copy will be taken by the researcher.

Revised April 2015

Appendix E3. Verbal consent for small-scale fisher participants

Department of Geography
University of Victoria
PO Box 1700 STN CSC
Victoria, British Columbia, V8W 2Y2, Canada
Tel: 1-250-721-7327
Email: geoginfo@uvic.ca
Website: www.uvic.ca/socialsciences/geography/

GROUP 3
Verbal Consent
English Translation

Evaluating the trade-offs of systematic conservation planning approaches for designing networks of marine protected areas in the Philippines

You are invited to participate in a study on designing marine protected area networks in Sogod Bay conducted by Alessia Kockel. Alessia is a Graduate Student in the Department of Geography at the University of Victoria and you may contact her if you have further questions at akockel@uvic.ca. As a Graduate student, Alessia is required to conduct research as part of her Masters of Science degree. The research study is being conducted under the supervision of Dr. Philip Dearden. You may contact her supervisor at pdearden@mail.geog.uvic.ca. The research is being funded by the Social Sciences and Humanities Research Council (SSHRC) and the Robin Rigby Trust.

Purpose and Objectives

The objectives of this research study are two-fold and will be conducted over two phases/field seasons. You are being asked to participate in phase one of this study.

(1) **The objective of phase one is to develop and evaluate three planning scenarios for designing a marine protected area (MPA) network in Sogod Bay. The scenarios will incorporate varying complexities of social and governance considerations that are relevant to MPA implementation in the Philippines. The ecological and socioeconomic implications of each scenario will be analyzed and compared.**

(2) The objective of phase two is to present a MPA network plan of each scenario to decision-makers and small-scale fishers to evaluate their feasibility for implementation and assess how preferences vary between different fishers, communities, and levels of government.

Importance of this Research

Research of this type is important as it addresses the need for more guidance from the scientific literature to design MPA networks that incorporate regional conservation targets with local community needs. The results of this study will provide valuable information for decision-makers and local communities seeking to enhance conservation and fisheries benefits of MPAs in Sogod Bay and other regions in the Philippines.

Participants Selection

You are being asked to participate in this study because you are a small-scale fisher from a coastal barangay in Sogod Bay. You have been nominated by your barangay leader and/or a Barangay Fishery and Aquatic Resource Management Council (BFARMC) member as an individual with extensive knowledge of the fishing practices within your barangay.

What is Involved

If you consent to voluntarily participate in this study, your participation will include a short preliminary interview and a group mapping exercise. The group interview will consist of six to eight other fishers from your barangay and may take up to three hours to complete. A transcription will be made of your answers as written notes. With your consent, interviews will be audio recorded and visually recorded (videos or photographs).

Inconvenience and Risks

Participation in this study should not cause you any inconvenience, other than donating your time. There are no known or anticipated risks to you by participating in this study.

Benefits

Participation in this study could enhance your level of marine conservation knowledge and provide useful information to inform marine management and conservation practices that incorporate the needs of small-scale fishers.

Voluntary Participation

Your participation in this study must be completely voluntary. If you do decide to participate, you may withdraw at any time without any consequences or any explanation. If you choose to withdraw part-way through the preliminary interview, your responses will not be used in the analysis and will be destroyed. However, since your responses will be recorded anonymously, it will not be possible to withdraw your responses after completing the interview. If you withdraw part-way through the completion of the group mapping exercise, data linked to group discussions or maps will be summarized. Additionally, it will not be logistically possible to withdrawn your responses or audio recordings after the interview and mapping exercise has been completed. If you have given consent to take pictures and/or videos of you, but later wish to withdraw these images, please contact the primary researcher within one month of the interview date.

Anonymity and Confidentiality

In terms of protecting your anonymity, your identity will be confidential. No names will be collected. The confidentiality of the data will be protected and saved in a locked and secure location. However, there are some limits to the researcher's ability to protect your confidentiality since you were nominated by your barangay leader and participated in a group exercise with other members of your barangay. Additionally, your responses will be linked to place (i.e. your municipality and barangay). If you consent to be visually recorded, you may be recognizable if visual images are used in municipal reports, public community and partner presentations, and academic and media presentations.

Dissemination of Results

It is anticipated that the results of this study will be shared with others through a thesis paper, defense presentation, municipal reports, public community and partner presentations, academic and media presentations, and published scholarly articles.

Future Research

This data may be used by future researchers with your consent. Your identity will be anonymous.

Contacts

Individuals that may be contacted regarding this study include:

- Primary Researcher: Alessia Kockel, akockel@uvic.ca
- Supervisor: Dr. Philip Dearden, pdearden@mail.geog.uvic.ca

In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or ethics@uvic.ca).

Your signature below indicates that you understand the above conditions of participation in this study, that you have had the opportunity to have your questions answered by the researchers, and that you consent to participate in this research project.

______________________	______________________	____________
Name of Participant	*Signature*	*Date*

Future Use of Data

- I consent to the use of my data in future research: _________ (Participant to provide initials)
- I do not consent to the use of my data in future research: _____________ (Participant to provide initials)

Audio Recorded and Visually Recorded Images

Participant to provide initials, only if you consent.

- Audio recording may be taken of me for: Analysis _________ (Participant to provide initials)
- Photos may be taken of me for: Dissemination _________ (Participant to provide initials)
- Videos may be taken of me for: Dissemination _________ (Participant to provide initials)

A copy of this consent will be left with you, and a copy will be taken by the researcher.

Revised April 2015

Appendix F. Data Sheets for Mapping Workshop

Appendix E1. Data sheet on general information of fishing, number of boats, number of fishers, coastal habitats, and proposed MPA sites

SHEET 1: INTERVIEW SUMMARY

1) GENERAL INFORMATION

Location	*Code:*	*Municipality:*	*Barangay:*
Date (dd/mm/yyyy)			
Duration (hh:mm)	*Start time:*	*End time:*	*Duration:*
Total number of participants	*Total:*	*Male participants:*	*Female participants:*
Team	*Facilitator:*	*Spatial recorder:*	*Digitizer:*

2) MPAS IDENTIFIED BY PARTICIPANTS

Fish Sanctuaries	Reserves

3) NUMBER OF BOATS

No. of motorized boats	No. of non-motorized boats	Total No. of boats

4) NUMBER OF FISHERFOLKS

	Total	Fishing Method						
		Walking	Diving	Traps	Hook & line		Gill nets	Misc.
					Total	*Squid*		
No. of male fisherfolks								
No. of female fisherfolks								
Total number fo fisherfolks								

5) COASTAL HABITATS

Habitat	Polygon #	Distance from shore (m)		Condition	Threats	Comments
		min	max			

Data entered on computer by:_______________ *on (dd/mm/yy)*____/____/____, ***Verified by:*** ____________________

6) MPAs: Did participants identify any areas they think should be protected within MPAs? ___ Yes ___No

Polygon #	Location (barangays)	Reserve (R) or sanctuary (FS)	Comments

7) OPEN DISCUSSION

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8) NOTES

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Data entered on computer by: ________________ *on (dd/mm/yy)* ____/____/____, ***Verified by:*** ____________________

Appendix F2. Data sheet on general fishing information per fishing method

Barangay code: ____________, *Facilitator:* ________________, *Date (dd/mm/yy):* ___/___/___,

SHEET 2: GENERAL FISHING INFORMATION

GLEANING

Code	Fishing Method	Present (Y/N)	# of fishers		Habitat Type*	Main catch	Depth (m)		Distance from shore (m)		Use (✓)		Transport (✓)				Seasonality **	Comments
			Male	Female			Min	Max	Min	Max	Food	Sale	Motor	Paddle	Walk	Bike		
GL	Gleaning																	

DIVING

Code	Fishing Method	Present (Y/N)	# of fishers		Habitat Type*	Main catch	Depth (m)		Distance from shore (m)		Use (✓)		Transport (✓)				Seasonality **	Comments
			Male	Female			Min	Max	Min	Max	Food	Sale	Motor	Paddle	Walk	Bike		
DI	Diving																	
SF	Spear fishing																	
OJ	Octopus Fishing																	
		TOTAL:			*(total number of diving fisherfolks)*													

***Habitat type:** 1=coral reef, 2=mangroves, 3=seagrass, 4=sand, 5=rocky, 6=open ocean, 7=intertidal area, 8=other types of habitat, specify: ________________

****Seasonality:** 1=Habagat (June-Sept/Oct), 2=Amihan (Sept/Oct-Feb), 3=Tag-init (March-May), 4=other, specify: ________________

Data entered on computer by: _______________ *on (dd/mm/yy)* ___/___/___, ***Verified by:*** ___________________

1

Barangay code: ____________. *Facilitator: ________________.* *Date (dd/mm/yy): ____/____/____.*

TRAPS

Code	Fishing Method	Present (Y/N)	# of fishers		Habitat Type*	Main catch	Depth (m)		Distance from shore (m)		Use (✓)		Transport (✓)				Seasonality **	Comments
			Male	Female			Min	Max	Min	Max	Food	Sale	Motor	Paddle	Walk	Bike		
PT	Pot trap																	
FC	Fish corral																	
BN	Barrier net																	
FY	Fyke net																	
FN	Filter net																	
		TOTAL:			*(total number of trap fisherfolks)*													

***Habitat type:** 1=coral reef, 2=mangroves, 3=seagrass, 4=sand, 5=rocky, 6=open ocean, 7=intertidal area, 8=other types of habitat, specify: ________________

****Seasonality:** 1=Habagat (June-Sept/Oct), 2=Amihan (Sept/Oct-Feb), 3=Tag-init (March-May), 4=other, specify: ________________

Barangay code: ____________, *Facilitator:* _______________, *Date (dd/mm/yy):* ____/____/____,

HOOK AND LINE (SUBSET SQUID FISHING)

Code	Fishing Method	Present (Y/N)	# of fishers		Habitat Type*	Main catch	Depth (m)		Distance from shore (m)		Use (✓)		Transport (✓)				Seasonality **	Comments
			Male	Female			Min	Max	Min	Max	Food	Sale	Motor	Paddle	Walk	Bike		
Q1	Squid Fishing 1 (Buko-buko)																	
Q2	Squid Fishing 2 (Pangnokos, bulingit & barawan)																	
Q3	Squid Fishing 3 (Subid-subid, nokos sa piliw)																	
Q3	Squid Fishing 4 (Pang koli-papa)																	
		TOTAL:			*(total number of squid fisherfolks)*													

***Habitat type:** 1=coral reef, 2=mangroves, 3=seagrass, 4=sand, 5=rocky, 6=open ocean, 7=intertidal area, 8=other types of habitat, specify: ________________

****Seasonality:** 1=Habagat (June-Sept/Oct), 2=Amihan (Sept/Oct-Feb), 3=Tag-init (March-May), 4=other, specify: ________________

Barangay code: ____________, *Facilitator:* ________________, *Date (dd/mm/yy):* ___/___/___,

Hook and Line (Continued)

Code	Fishing Method	Present (Y/N)	# of fishers		Habitat Type*	Main catch	Depth (m)		Distance from shore (m)		Use (✓)		Transport (✓)				Seasonality **	Comments
			Male	Female			Min	Max	Min	Max	Food	Sale	Motor	Paddle	Walk	Bike		
SH	Simple handline (Shore)																	
SB	Simple handline (Boat)																	
MH	Multiple handline																	
HF	Hook & line with float																	
TL	Troll line																	Lambo Y / N Tapsay Y / N
RX	Rentex																	Hook or no hook
BL	Bottom-set longline																	
SL	Surface-set longline																	
		TOTAL:			*(total number of hook and line fisherfolks, including squid fisherfolks)*													

***Habitat type:** 1=coral reef, 2=mangroves, 3=seagrass, 4=sand, 5=rocky, 6=open ocean, 7=intertidal area, 8=other types of habitat, specify: ________________

****Seasonality:** 1=Habagat (June-Sept/Oct), 2=Amihan (Sept/Oct-Feb), 3=Tag-init (March-May), 4=other, specify: ________________

Barangay code: ____________, *Facilitator:* ________________, *Date (dd/mm/yy):* ____/____/____,

GILL NETS

Code	Fishing Method	Present (Y/N)	# of fishers		Habitat Type*	Main catch	Depth (m)		Distance from shore (m)		Use (✓)		Transport (✓)				Seasonality **	Comments
			Male	Female			Min	Max	Min	Max	Food	Sale	Motor	Paddle	Walk	Bike		
SG	Surface Set Gill Nets																	
BG	Bottom Set Gill Nets																	
DG	Drift Gill Nets																	
IG	Drive-In Gill Nets																	
EG	Encircling Gill Nets																	
FG	Fixed Gill Nets																	

Number of owners [ ] [ ] *(number of people who own a gillnet)*

Total number of participants [ ] [ ] *(total number of people who participate in gill net fishing)*

***Habitat type:** 1=coral reef, 2=mangroves, 3=seagrass, 4=sand, 5=rocky, 6=open ocean, 7=intertidal area, 8=other types of habitat, specify: ________________

****Seasonality:** 1=Habagat (June-Sept/Oct), 2=Amihan (Sept/Oct-Feb), 3=Tag-init (March-May), 4=other, specify: ________________

Barangay code: _____________, *Facilitator:* _________________, *Date (dd/mm/yy):* ____/____/____,

Miscellaneous

Code	Fishing Method	Present (Y/N)	# of fishers		Habitat Type*	Main catch	Depth (m)		Distance from shore (m)		Use (✓)		Transport (✓)				Seasonality **	Comments
			Male	Female			Min	Max	Min	Max	Food	Sale	Motor	Paddle	Walk	Bike		
BE	Beach Seine																	
DS	Danish Seine																	
CN	Cast Net																	
LN	Lift Net																	
PN	Push Net																	
SC	Scoop Net																	
MT	Municipal Trawl																	

***Habitat type:** 1=coral reef, 2=mangroves, 3=seagrass, 4=sand, 5=rocky, 6=open ocean, 7=intertidal area, 8=other types of habitat, specify: _________________
****Seasonality:** 1=Habagat (June-Sept/Oct), 2=Amihan (Sept/Oct-Feb), 3=Tag-init (March-May), 4=other, specify: _________________

Appendix F3. Data sheet on spatial fishing information

Barangay code: Date (dd/mm/yy): ____/____/____ **Recorder:**

SHEET 3: SPATIAL FISHING INFORMATION

Fishing Method	Polygon #	# of fishers		Distance from shore (m)		Importance (✓)				*Major factors that influence choice	Additional Comments
		Male	Female	Min	Max	H= high	M= medium	L= low	N= no distinction		

*Major factors that influenced choice: 1=abundance of prey, 2=weather condition, 3=proximity to barangay, 4=proximity to MPA, 5=other: ____________

Page ____ of ____

Data entered on computer by:________________ on (dd/mm/yy)____/____/____ Verified by: ____________________

Appendix F4. Data sheet on barangay demographics

Barangay code: **Date (dd/mm/yy): ____/____/____** **Recorder:**

SHEET 4: SECONDARY DATA (Barangay-level)

1. **Demographics:** Palihog kompletoha ang mga sumusunod nga demographic nga impormasyon sa inyong barangay.
   Demographics: *Please complete the following demographic information for your barangay.*

	Demographic Information	Source
Populasyon *Population*	Lalaki ug babaye *(Male & Female):* Lalaki *(Male):* Babaye *(Female):*	
Pusyento sa populasyon nga kada klase sa edad *Percentage of population by age classes*		
Gidaghanon sa panimalay *Number of households*		
3 ka mga unang gekuhaan ug panginabuhi *Three primary sources of income**	1. 2. 3.	

Panguhaan sa panginabuhi: 1=panagat, 2=pang-uma, 3= hayopan ug/o pamaligyag manok, 4=negosyo, 5= pasuhol or sweldo, 6=turismo, 7= uban, hinganli:____________
**Livelihood source: 1= fishing, 2=farming, 3=livestock and/or poultry sale, 4= business, 5=wages or salaries, 6=tourism, 7=other, specify: _______________*

2. ***Gidaghanun sa mananagat:*** Ang mananagat sa munisipalidad kung hain apil ang bisan kinsa nga lalaki o babaye nga direktang nakiglambigit ug pagpanguha sa mga isdaanan ug ubang kabtangan satong kabaybayonan sulod sa katubigan satong munisipalidad (sulod sa 15km gikan sa kabaybayonan) para sa pagkaon ug panginabuhi. Palihog kompletoha ang mga sumusunod nga impormasyon sa gidaghanun sa mananagat nga naa sa inyong barangay.
   Number of fisherfolk: *This study defines a municipal fisherfolk as "any man or women who directly engages in the taking of fishery and other coastal resources in municipal waters (within 15km from the shore) for food or income". Please complete the following information on the number of fisherfolk present in your barangay.*

	Total	Source
Gidaghanon sa lalaki nga mananagat (rehistrado ug dli-rehistrado). *Number of male fisherfolks (registered and non-registered).*		
Gidaghanon sa mga babaye nga mananagat (rehistrado ug dli-rehistrado). *Number of female fisherfolks (registered and non-registered).*		
Gidaghaghanon sa lalaki ug babaye nga mananagat (rehistrado ug dli-rehistrado). *Number of male and female fisherfolks (registered and non-registered).*		

3. ***Gidaghanun sa panagatan nga bangka:*** Palihug kompletoha ang mga sumusunod nga impormasyon mahitungod sa gidaghanun sa panagatan nga bangka nga naa karon sa inyong barangay.
   Number of fishing vessels: *Please complete the following information regarding the number of fishing vessels currently present in your barangay.*

	Total	Source
Gidaghanon sa mga bangka nga may makina (rehistrado ug dili-rehistrado). *Number of motorized fishing vessels (registered and non-registered).*		
Gidaghanon sa mga bangka nga walay makina (rehistrado ug dili-rehistrado). *Number of non-motorized fishing vessels (registered and non-registered).*		

Data entered on computer by:__________________on (dd/mm/yy)____/____/____, Verified by: ________________________

Appendix G. Gap Analysis

Table G1. Habitat representation in the current MPA system and MPA networks developed under different planning scenarios in Chapter 3.

	Habitat class	Total amount (m²)	MPA coverage target (m²)	Current MPA system		Scenario 1: Opportunistic approach		Scenario 2: Donor-assisted approach		Scenario 3: Systematic approach	
				Coverage (m²)	% protected	Coverage (m²)	% protected	Coverage (m²)	% protected	Coverage (m²)	% protected
Pintuyan	rock/pebble/gravel	419746	83949	54529	13	29164	20	31634	21	84279	20
	hard coral (low cover)	283722	56744	29191	10	69918	35	49874	28	65844	23
	sandy	303839	60768	20214	7	11112	10	9782	10	61767	20
	hard coral (high cover)	349618	69924	47034	13	29249	22	15199	18	71474	20
	rocky reef	359963	71993	63828	18	19570	23	13852	22	84279	23
	macroalgae	92626	18525	13608	15	15851	32	20445	37	21086	23
	seagrass	46375	9275	11672	25	478	26	4420	35	15101	33
San Francisco	rock/pebble/gravel	436453	87291	28279	6	6845	8	54227	19	90003	21
	hard coral (low cover)	336194	67239	25500	8	8402	10	34313	18	77318	23
	sandy	289228	57846	11922	4	13957	9	49823	21	60750	21
	hard coral (high cover)	429931	85986	26525	6	9937	8	37246	15	85673	20
	rocky reef	372732	74546	22725	6	920	6	10532	9	81649	22
	macroalgae	107113	21423	4833	5	1162	6	19204	22	22257	21
	seagrass	48181	9636	4531	9	80	10	6525	23	11482	24
Liloan	rock/pebble/gravel	475599	95120	20677	4	11362	7	12994	7	95324	20
	hard coral (low cover)	376209	75242	15198	4	18179	9	11609	7	77017	20
	sandy	1262029	252406	42851	3	12532	4	4609	4	259866	21
	hard coral (high cover)	517472	103494	13849	3	7515	4	8754	4	108707	21
	rocky reef	355000	71000	102190	29	13344	33	7521	31	138436	39
	macroalgae	215426	43085	14241	7	3813	8	4309	9	43844	20
	seagrass	251932	50386	9462	4	6755	6	5435	6	51669	21

Table G1. (*continued*)

	Habitat class	Total amount (m²)	MPA coverage target (m²)	Current MPA system		Scenario 1: Opportunistic approach		Scenario 2: Donor-assisted approach		Scenario 3: Systematic approach	
				Coverage (m²)	% protected	Coverage (m²)	% protected	Coverage (m²)	% protected	Coverage (m²)	% protected
Padre Burgos	rock/pebble/gravel	151085	30217	11491	8	7780	13	11907	15	30115	20
	hard coral (low cover)	692864	138573	54657	8	31418	12	46204	15	153970	22
	sandy	328903	65781	53692	16	12549	20	16055	21	74155	23
	hard coral (high cover)	484286	96857	130707	27	42002	36	57701	39	110955	23
	rocky reef	129170	25834	24567	19	1962	21	2574	21	32271	25
	macroalgae	191403	38281	15298	8	8364	12	14901	16	39643	21
	seagrass	122013	24403	6944	6	11027	15	18059	20	25111	21
Limasawa	rock/pebble/gravel	443264	88653	40358	9	14921	12	159439	45	101828	23
	hard coral (low cover)	494875	98975	27108	5	1139	6	159675	38	99240	20
	sandy	547663	109533	4096	1	1322	1	114923	22	109885	20
	hard coral (high cover)	548865	109773	12142	2	548	2	163414	32	110297	20
	rocky reef	116062	23212	36072	31	1433	32	16798	46	50998	44
	macroalgae	250110	50022	3172	1	6883	4	78908	33	50242	20
	seagrass	281175	56235	9588	3	6330	6	87193	34	57061	20
Study Area	rock/pebble/gravel	1926147	385229	155334	8	70072	12	270201	22	401549	21
	hard coral (low cover)	2183864	436773	151653	7	129056	13	301675	21	473389	22
	sandy	2731662	546332	132775	5	51473	7	195192	12	566423	21
	hard coral (high cover)	2330172	466034	230257	10	89251	14	282313	22	487106	21
	rocky reef	1332927	266585	249382	19	37229	22	51277	23	387633	29
	macroalgae	856678	171336	51152	6	36073	10	137767	22	177072	21
	seagrass	749676	149935	42197	6	24671	9	121632	22	160424	21