Avoiding and reversing "paper parks": integrating fishers' compliance into marine conservation efforts

PhD thesis submitted by

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MSc

September 2016

For the degree of Doctor of Philosophy

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Statement of Contribution of Others

Competitive research funding

AusAID Australian Development Scholarship and Australian Leadership Award (PhD scholarship, and supplementary award for leadership training, development and networks)	>AUD $280,000
PADI Foundation (Fieldwork grant)	USD$4,593
ARC Centre of Excellence for Coral Reef Studies Graduate Research Scheme (Fieldwork grant)	AUD$1,110
AusAID SAP Grant (Fieldwork grant)	AUD$4,600
AusAID Leadership Program Independent Opportunities (grant to attend IUCN World Parks Congress 2014)	AUD$1,700

Supervisory committee

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- Dr. Robert A. Birtles, College of Business, Law and Governance, James Cook University

Editorial support

Professor Robert L. Pressey

Professor Joshua E. Cinner

Dr. Jorge Álvarez Romero

Emeritus Professor Rhondda E. Jones

Brock J. Bergseth

Damian P. Weekers

Sam Ham

Anonymous reviewers and editors who handled my published chapters

Permits

Research associated with this thesis was approved by the James Cook University Human Research Ethics Committee (JCU Human Ethics H4804).

Acknowledgements

Special thanks to my supervisors for their invaluable guidance.

A big thank you to my mentors: Sam Ham and Jon Day

Thanks to my close collaborators: Rhondda Jones, Brock Bergseth, Reg Parsons, and Damian Weekers.

Data were provided to me by: interviewees, MarViva, SNG and ACMIC.

I received funding from: AusAID, Australian Research Council, and the PADI Foundation

Thanks to JCU and the ARC CoE CRS for institutional support, and Janet Swanson, Olga Bazaka, Rose-Marie Vasiljuk, David Yellowlees and Jenny Lappin for administrative support.

Thanks to my friends, family and colleagues: Adriana, Mom, Dad, Julian, Andres, Felipe, "Bob's mob", Cindy Huchery, Tessa Hempson, Chancey McDonald, Franz Tattenbach, Arturo Izurieta, Jessica Cramp, Chuck Fox, Ed Roberts, Tom Bridge, Alana Grech, Matt Young, Geoff Collins, Nina Kenny, Paul Markey, Kirsty Nash, Amy Diedrich, Fernando Quirós, Sirleny Vega, Mariamalia Rodríguez, Pepe Rodríguez, Yeudi Peraza, Jan Robinson, Nick Graham, Stefan Walker, Nathalie Walker, Sean Conolly, Anne Caillaud, James Moloney, Mel Cowlishaw, Darren Cameron, Jane Addison, Rachel Turner, Fanny Douvere, Matt Curnock, Leo Mata, Mariana Fuentes, Pete Waldie, Rossana Sanderson, Michael Rothschild, Natalia Andrade, Laura Richardson, Rose Basita, Zdenka Piskulich, Aung Myo Chit, Jacqueline Lau, Andrew Norton, Vanessa Messmer, Lisa Boström, Hugo Harrison, Coralie D'Lima, Pip Cohen, Jessica Blythe, Phil Blythe, Robert Puschendorf, Marie Roman, Chris Cleuger, Mel Hamel, Michelle Barnes, Emmanuel Mbaru, Julian Rinaudo, Justin Rizzari, Dave Mills, Georgina Gurney, Jodie Rummer, Kim Kamo, Cata Aguilar, Nick Graham, James Aumend, John Knott, Naama Blatman, Mark Thomas,

Tony Bligh, Conrad Hoskin, Megan Higgie, Steve Sutton, Nadine Marshall, Richard Quincey, Coral Sea OCC, Alex Salvador, Aaron MacNiel, Libby Pressey, Rebecca Weeks, Jackie Wolstenholme, and the reviewers who helped improve my work.

Abstract

Nature conservation is fundamentally about managing people. Consequently, the effectiveness of conservation interventions depends largely on people's compliance with regulations. However, noncompliance with environmental regulations is common, as illustrated by the following examples. In the worldwide timber trade, roughly 20% to 50% of all timber is of illegal origin (INTERPOL & The World Bank, 2010). Meanwhile, in the world's industrial fisheries, estimates of nearly 20% of reported catch being illegal are probably conservative (Agnew et al., 2009). Poaching has militarized the struggle between poachers and rangers (Kalron, 2013; Stiles, 2013) with deadly consequences: more than half of the world's ranger deaths can be attributed to poachers (IUCN, 2014). Financially, illegal wildlife trade, illegal, unreported and unregulated fishing, and illegal timber trade are amongst the largest illicit activities in the world (Haken, 2011). Noncompliance with environmental regulations is a critical problem to address because it threatens not only the environment, but also social and economic prosperity.

In this thesis I investigate compliance through the lens of fishers' compliance, particularly with marine protected areas (MPAs). MPAs are widely used tools for marine conservation and fisheries management (Lester & Halpern, 2008). Studies show that compliance can be a strong predictor of fish biomass within MPAs (Ayling & Choat, 2008; Cudney-Bueno & Basurto, 2009; Guidetti et al., 2008). Hence, fishers' compliance is critical for MPA effectiveness. However, although there is a growing interest on the topic, there currently few empirical studies looking into fishers' compliance with MPAs. Without such information, conservation practitioners[1] have limited opportunities to provide effective interventions. Through a series of studies, mostly in Costa Rica, I contribute theoretical

[1] "Practitioners are managers, researchers, and local stakeholders who are responsible for designing, managing, and monitoring conservation and development projects" (Margoluis & Salafsky, 1998, p. 7).

and practical advances in the field of compliance with nature conservation rules.

The overarching research questions of my thesis are: (1) How can we better understand fishers' compliance with MPAs? and (2) How can we better manage fishers' compliance with MPAs? As it will become apparent throughout my thesis, both questions could apply to other contexts, including terrestrial conservation. This thesis is composed of six core chapters, each with specific research questions or purposes (Table 1). My interest in the field of compliance led me to approach the research questions through multiple contexts and scales: from nature conservation in general (Chapter 2), coastal MPAs and artisanal fisheries (Chapters 4 and 6), offshore MPAs and longline fishing (Chapter 5), and industrial tuna fishing (Chapter 7). Throughout my PhD I have endeavoured to make my work relevant and useful for practitioners while maintaining scientific rigour and novelty. Below I describe the core chapters of this thesis.

Table 1. Thesis chapters and research questions or purpose for each.

Chapter	Name	Research questions/purpose
1	General introduction	- Introduce the thesis.
2	Understanding and managing compliance in the nature conservation context	- Review literature. - Propose framework for understanding and managing compliance.
3	Marine conservation and marine protected areas in Costa Rica	- Describe study region: Costa Rica.
4	Optimizing enforcement and compliance in offshore marine protected areas: A case study from Cocos Island, Costa Rica	- What factors constrain enforcement? - How can patrols be optimized to match the spatial and temporal distribution of illegal fishing?
5	Countering strategies used in small-scale fisheries to avoid patrol detection	- What strategies do fishers use to avoid detection? - How can detection-avoidance strategies be countered?
6	Combatting illegal, unreported, and unregulated fishing with information: a case of probable illegal fishing in the Tropical Eastern Pacific	- Expose a potential case of illegal fishing. - Recommend ideas for managing illegal, unreported and unregulated fishing.
7	Levels and drivers of fishers' compliance with marine protected areas	- What are the levels of fishers' compliance with MPAs? - What influences fishers' compliance?
8	General discussion	- Discuss and conclude thesis.

In Chapter 2 I review and integrate key concepts and tools about compliance from different fields in an effort to guide compliance management in the conservation context. First, I address the understanding of compliance by breaking it down into five key questions: who?, what?, when?, where?, and why? A special focus is given to 'why?' because understanding the reasons for compliance (and noncompliance) is critical for designing management interventions. Second, I review compliance management strategies, from voluntary compliance to coerced compliance. Finally, I suggest a system, adapted from research on tax compliance, to balance these multiple compliance management strategies. I provide a broad yet practical perspective on

theory and tools for understanding and managing compliance in the nature conservation context.

In Chapter 3 I condense relevant information about Costa Rica. I provide an overview of conservation and marine protected areas in Costa Rica with the objective of giving the reader contextual information to better understand the subsequent chapters. Costa Rica has been renowned for its rich biodiversity and for being a leader in nature conservation. Even though this might be true to some extent, here I argue that the country is currently lacking the strong leadership that it had decades ago, and that the marine realm in particular is in urgent need of attention. Costa Rica's marine area is almost 11 times larger than its land area, and marine resources and services are critical for the country's development and well-being. Nevertheless, the lack of policies and actions aimed at marine conservation is now evidenced by factors such as overfishing, poorly planned conservation initiatives, a neglected nautical sector, conflict between stakeholders, and as discussed in the following chapters, illegal fishing. I anticipate, however, that the perilous state of marine affairs has created a new wave of interest in Costa Ricans for marine conservation that will lead to positive changes, resembling the similar cycle experienced in the country during the 1970s and 1980s with rampant deforestation followed by energetic terrestrial conservation.

In Chapter 4 I look at enforcement in MPAs. Enforcement, although not the only tool for managing compliance, is common and usually necessary to ensure compliance. Enforcement, however, is expensive and must be optimized. In this Chapter I present a case study of how enforcement could be optimized in Cocos Island National Park, an offshore MPA and World Heritage Site. By analysing several years of patrol records I determined the spatial and temporal distribution of illegal fishing, and its relationship to patrol effort. Illegal fishing was concentrated on a seamount within the Park and peaked during the third year-quarter,

probably as a result of oceanographic conditions. The lunar cycle in conjunction with the time of year significantly influenced the occurrence of incursions. The predictability of illegal fishing in space and time facilitates the optimization of patrol effort. Repeat offenders are common in the Park and I suggest that unenforced regulations and weak governance are partly to blame. I provide recommendations for efficient distribution of patrol effort in space and time, establishing adequate governance and policy, and designing marine protected areas to improve compliance. My methods and recommendations from this Chapter could be applicable to other protected areas and managed natural resources.

In Chapter 5 I study strategies that illegal fishers use to avoid being detected by authorities, and I provide countermeasures that managers can use against these strategies. Detection-avoidance strategies are common in the context of nature conservation, yet they remain largely unstudied and are scarcely addressed in the peer-reviewed literature. Even though enforcement can be greatly improved (as discussed in Chapter 5), patrol effectiveness also depends on knowing and countering detection-avoidance strategies. First, I discuss detection-avoidance strategies in the nature conservation context. Second, by drawing on evidence collected in Costa Rica, I describe a series of detection-avoidance strategies used by small-scale fishers. And third, I provide countermeasures that can help prevent or neutralize these strategies.

Chapter 6 is a short account of how existing fisheries information collected by Regional Fisheries Management Organizations and coastal states can be used to expose illegal fishing. Here I draw on a little-known report, published in Spanish in Costa Rica, which reveals potential cases of illegal fishing from foreign tuna purse seiners. The cases, still pending action on behalf of the authorities, involve fishing without a licence, and the illegal use of fish aggregating devices. I discuss the broader

implications of these cases, and suggest recommendations that could be adopted by Regional Fisheries Management Organizations and coastal states.

In Chapter 7 I explore the levels and drivers of fishers' compliance with MPAs. By studying 12 coastal MPAs in Costa Rica, I investigate the roles of different variables in influencing fishers' compliance with MPAs. Particularly, I found that compliance levels perceived by resource users were higher in MPAs: (1) with multiple livelihoods, (2) where government efforts against illegal fishing were perceived to be effective, (3) where fishing was allowed but regulated, (4) where people were more involved in decisions, and (5) that were smaller. I also provide a novel and practical measure of compliance: a compound variable formed by the number of illegal fishers and their illegal fishing effort. This study underlines the centrality of people's behaviour in nature conservation, and the importance of grounding decision-making on the social and institutional realities of each location.

Overall, my thesis features the relevance of integrating compliance management into conservation interventions. Without compliance, conservation fails. Conservation interventions such as MPAs can be effective. However, many of them are failing (Jones et al., 2011; Mora et al., 2006), and the growing interest in creating more MPAs calls for a critical evaluation of planning and management strategies, giving special consideration to compliance. My thesis builds on previous work, offering new concepts, methods and results that can contribute to enhanced nature conservation through better compliance management.

Publications associated with this thesis

Peer reviewed papers

- Arias, A., Pressey, R. L., Jones, R. E., Álvarez-Romero, J., & Cinner, J. E. (2016). Optimizing enforcement and compliance in offshore marine protected areas: A case study from Cocos Island, Costa Rica. *Oryx*. doi: http://dx.doi.org/10.1017/S0030605314000337
- Arias, A. (2015). Understanding and managing compliance in the nature conservation context. *Journal of Environmental Management, 153*, 134-143. doi: http://dx.doi.org/10.1016/j.jenvman.2015.02.013
- Arias, A., Cinner, J., Jones, R. E., & Pressey, R. L. (2015). Levels and drivers of fishers' compliance with marine protected areas. *Ecology and Society*, 20 (4). doi: http://dx.doi.org/10.5751/ES-07999-200419
- Arias, A. & R.L. Pressey (2016). Combatting illegal, unreported, and unregulated fishing with information: a case of probable illegal fishing in the Tropical Eastern Pacific. *Frontiers in Marine Science*, 3. doi: http://dx.doi.org/10.3389/fmars.2016.00013
- Arias, A., et al. (in prep). Strategies used in small-scale fisheries to avoid patrol detection: a review and countermeasures. Target journal: *Maritime Studies*

Books

- Salas, E., Ross-Salazar, E., & Arias, A. (2012). Diagnosis of marine protected areas and responsible fishing areas in the Costa Rican Pacific [Translated Title]. *MarViva Foundation*. San José, Costa Rica. link: http://eprints.jcu.edu.au/23865/

Reports

- Arias, A. (2014). Optimizando la coacción y el cumplimiento en áreas marinas protegidas oceánicas: el caso del Parque Nacional Isla del Coco, Costa Rica. doi: http://dx.doi.org/10.13140/RG.2.1.1956.2400

Conference presentations

- Arias, A., & Sutton, S. G. (2012). Understanding recreational fishers' compliance with no-take zones in the Great Barrier Reef Marine Park. Poster presented at XII International Coral Reef Symposium. Cairns, Australia. doi: http://dx.doi.org/10.13140/RG.2.1.3938.1201

Workshops

- World Parks Congress parallel event (2014). *A structured approach to protected area compliance management*. Facilitator and presenter. Townsville, Australia. Four-day workshop with 36 participants from 15 countries, mostly World Heritage marine protected area managers.
- Eastern Tropical Pacific Seascape (2015). *Compliance Management in Protected Areas*. Facilitator and presenter. Galapagos, Ecuador. Five-day workshop with managers of four marine World Heritage Sites: Galapagos National Park (Ecuador), Cocos Island National Park (Costa Rica) and Malpelo Flora and Fauna Sanctuary (Colombia).

Other publications during my PhD candidature

- Arias, A., & Sutton, S. G. (2013). Understanding recreational fishers' compliance with no-take zones in the Great Barrier Reef Marine Park. *Ecology and Society, 18*(4). doi: http://dx.doi.org/10.5751/ES-05872-180418
- Turner, R.A., Addison, J., Arias, A., Bergseth, B.J., Marshall, N., Morrison, T., Tobin, R. (2016) Leveraging trust for effective natural resource governance. *Ecology and Society*, 21(3). doi: http://dx.doi.org/10.5751/ES-08542-210318

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Chapter 1: General introduction

Conservation is defined as the "protection, preservation, and careful management of natural resources and the environment" (Collins Online Dictionary). Conservation is multidisciplinary, adopting questions and methods from various fields such as ecology, fisheries, forestry, and social sciences (Soulé, 1985) and, more recently, spatial modelling and information technology. However, at its core, conservation is "…a human endeavour: initiated by humans, designed by humans, and intended to modify human behaviour" (Mascia et al., 2003, p. 650). In other words, "conservation can *only* be achieved by changing human behaviour" (Schultz, 2011, p. 1080). The vast majority of environmental problems, such as deforestation, pollution, poaching, overfishing, and climate change, have a common denominator: they are driven by humans. Human behaviour is critical for conservation.

Human behaviour is dictated by rules, formal and informal. Similarly, these rules can be reinforced through formal or informal institutions. For example, formal laws can be reinforced through courts and social ostracism (Colding & Folke, 2001). Rules regulate conservation; for instance, there can be laws against pollution, and pollution can be scorned by society. Nevertheless, the presence of rules does not mean that people will comply with them. On the contrary, noncompliance is common, and it carries serious social, environmental and economic consequences. For example, at least 7.4% of the African elephant population was illegally killed in 2013 (CITES et al., 2013); with wide-ranging repercussions, including the decimation of elephant populations to the point of driving local extinctions, large-scale corruption, the death of wardens and poachers, and funding of militias (Vira & Ewing, 2014). Conservation depends largely on compliance, or the adherence to rules related to natural resource use and conservation.

Problem statement

The success, or failure, of conservation often relies on people's compliance with the rules. Unfortunately, as I discuss in this thesis, noncompliance with conservation rules is frequently encountered.

Focus of my thesis

I focus on compliance through the lens of fishers' compliance with marine protected areas (hereafter: MPAs). MPAs are a response to anthropogenic degradation, such as overfishing, and they can be effective tools for conservation and fisheries management (Harrison et al., 2012; McClanahan et al., 2006). Nevertheless, when MPAs are poorly planned and managed, they become "paper parks". Paper parks are protected areas that exist only on the document that created them (Dudley & Stolton, 1999). Paper parks are common around the world, both in terrestrial and marine realms (Bonham et al., 2008; Mora et al., 2006; MPA news, 2001; Wood et al., 2008). Inadequate planning and management of protected areas is attributed to multiple variables, including limited funding (Balmford et al., 2004; Bruner et al., 2004), political instability (Terborgh, 2004; Wood et al., 2008), and lack of local support (Christie et al., 2003). These variables can lead to noncompliance, and consequently, environmental degradation.

The effectiveness of MPAs relies largely on users' compliance (Hockings et al., 2006), particularly from fishers, because fishing can profoundly degrade global marine biodiversity and ecosystems (Pauly et al., 2002). The mere presence of an MPA does not guarantee fishers' compliance, and its effectiveness can be eroded by illegal fishing. Indeed, the ecological performance of MPAs has been linked to fishers' compliance (Bergseth et al., 2015; Pollnac et al., 2010).

There is a growing interest in MPAs, with significant advances in their number and extent (Spalding et al., 2013). International commitments to

marine conservation aim to effectively conserve 10% of the world's coastal and marine areas by 2020 (CBD, 2010), although Devillers et al. (2015) and others have criticized broad-based percentage targets. Ensuring the effectiveness of existing and future MPAs will involve having a better understanding of fishers' compliance, and improving management strategies.

Research gaps

The topic of compliance with MPAs has gained momentum in the literature; nevertheless, most studies provide indirect and anecdotal information (Bergseth et al., 2015). A good understanding of fishers' compliance with MPAs can help improve management interventions. An advantage is that, because compliance is highly relevant in many domains of life and has been studied in several academic disciplines, there is a wealth of information that can be applied to MPAs. For instance, psychology has studied human behaviour exhaustively and has robust theories, such as the Reasoned Action Model (also known as the Theory of Planned Behaviour) (Fishbein & Ajzen, 2010), that can help explain compliance. Also, there are multiple methods that can be used to investigate sensitive behaviours (e.g., poaching), ranging from social survey techniques, to remote sensing and forensics (Arias, 2015). Most of this information and methods, however, were scattered in a wide array of literature before I embarked on my review.

Through a literature I found that there are basically two ways for dealing with compliance: coerced compliance and voluntary compliance. In Chapter 2 I elaborate on these, but, in a nutshell, the former occurs when people comply mostly because they fear the potential costs of "getting caught", and the latter occurs when people believe that complying is beneficial, personally and/or socially. While working on Chapter 2 (a literature review), I identified two general research gaps: how to A) optimize enforcement and B) foster voluntary

compliance. These gaps are tied to the two types of compliance mentioned above—coerced and voluntary compliance. Enforcement is an integral part of coerced compliance. Nevertheless, as discussed in Chapter 2, enforcement and voluntary compliance must be coupled. A one-sided compliance management strategy is likely to fail—not all people comply voluntarily and coercion alone can lead to noncompliance. I break down these two gaps in my chapters:

1. Optimizing enforcement

It is clear that enforcement is a necessary and widely used tool for managing compliance. Nonetheless, enforcement is very expensive in MPAs, particularly offshore, so it must be optimized to reduce costs and to increase effectiveness. There are multiple studies analysing this topic in the terrestrial realm, mostly in the African continent (Critchlow et al., 2015; Holmern et al., 2007; Jachmann, 2008; Jachmann & Billiouw, 1997; Plumptre et al., 2014). Even though there were a few studies addressing enforcement in MPAs (Davis et al., 2004; Smallwood & Beckley, 2012), I was unable to find studies that focused specifically on how to optimize this enforcement.

It is well-established that fishing is not random in space and time, yet I was not able to find studies emphasizing how the predictability of fishing effort can be used to optimize marine patrols. By optimizing patrols, managers can better allocate funds and staff, which are usually limited, and they can increase the likelihood of detecting illegal fishing and follow with other enforcement actions such as fines, arrests, and prosecutions.

Compliance, enforcement, and patrols are not interchangeable terms. Enforcement is just one tool to help leverage compliance, and patrols are a small part of enforcement. In my thesis, I clarify these distinctions, and I introduce the concept of the enforcement chain, which seemed to be missing from the MPA literature. The enforcement chain serves as a simple model that helps understand that enforcement is a

chain composed by four probabilities or links: the probability of detection, the probability of arrest, the probability of prosecution, and the probability of conviction (Figure 5). All links in the enforcement chain must be strong. Any weak link can drastically reduce the effectiveness of others in terms of the overall process of enforcement.

The effectiveness of enforcement, particularly the probability of detection, depends partly on wardens knowing and countering strategies that fishers use to avoid being detected. These detection-avoidance strategies are common in nature conservation, for example for smuggling illegal wildlife and wildlife by-products, but they are sparsely mentioned in the peer-reviewed literature. While doing fieldwork in Costa Rica I encountered multiple detection-avoidance strategies. In my thesis I discuss these strategies, and offer potential countermeasures.

2. Fostering voluntary compliance

Compliance does not depend only on enforcement, and voluntary compliance should be the main goal (Arias, 2015; Challender & MacMillan, 2014; Milner-Gulland & Rowcliffe, 2007). Voluntary compliance is critical because it shows that people approve the rules and institutions, and follow them purposefully. Fostering voluntary compliance typically requires information to explain why people behave the way they do (Ham, 2013). In other words, understanding what drives compliance can be very useful for managers because it can help them develop relevant strategies. Some studies have focused on measuring or understanding fishers' compliance in MPAs (Peterson & Stead, 2011; Read et al., 2011; Wood, 2004). However, the current literature and evidence base on compliance levels and, importantly, the factors that influence fishers' compliance with MPAs, remain limited (Bergseth et al., 2015; Peterson & Stead, 2011). Additionally, compliance with MPAs is typically linked to complex social and institutional interactions (e.g., perceptions, rules, socio-demographics, and enforcement) which are context-dependent

(Arias, 2015; Pollnac et al., 2010). Hence, the best way to design practical solutions for fostering compliance is by empirically answering questions in the sites of interest.

Overarching research questions

1. How can fishers' compliance with MPAs be better understood?
2. How can we better manage fishers' compliance?

Thesis structure

I present this thesis as a series of chapters. The chapters in this thesis are structured in a way that the focus is funnelled, from a broad perspective on compliance in conservation, to increasingly specific cases of how fishers' compliance can be understood and managed. This tapering, or zooming in, helps the reader realize that the subject matter has countless lines and intersections.

The core of the thesis starts with a literature review (Chapter 2), followed by a chapter detailing the social and environmental context of the study sites (Chapter 3). The two research gaps—1) optimizing enforcement, and 2) fostering voluntary compliance)—are addressed in four chapters. Chapters 4-6 provide a comprehensive assessment of how enforcement can be optimized in different contexts and using multiple tools. Chapter 7 offers information for measuring the levels of illegal fishing, and understating what influences compliance, helping achieve voluntary compliance by facilitating the selection of priorities, and management strategies. Figure 1 shows the overall structure of my thesis and is presented at the beginning of every chapter.

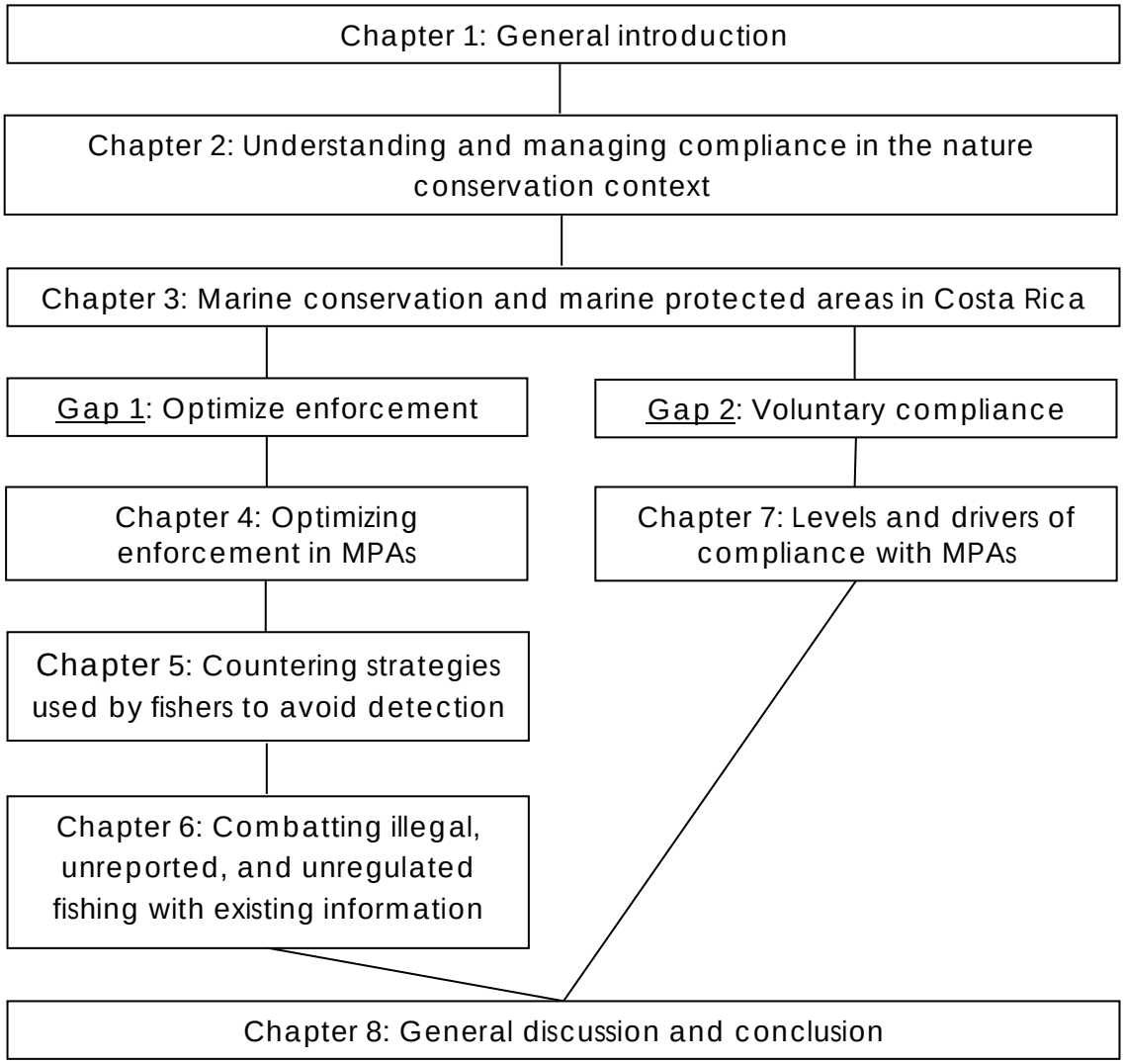

Figure 1. Chapter structure for this thesis

Chapters 2 and 4-7, the core chapters, were originally formatted for publication in peer-reviewed journals and have been slightly edited for this thesis.

Chapter 1 (this Chapter) provides a general introduction to my thesis; it presents the research gaps, the overarching research questions, and the structure of the thesis.

Chapter 2 is a literature review that condenses useful information from disciplines such as psychology and economics, and applies it to the

context of nature conservation. This review proposes a framework for comprehensively understanding compliance, and balancing the use of management strategies, from communication to coercion.

Associated publication:

Arias, A. (2015). Understanding and managing compliance in the nature conservation context. *Journal of Environmental Management, 153*, 134-143. doi: http://dx.doi.org/10.1016/j.jenvman.2015.02.013

Chapter 3 describes the social and environmental context of my broader study site: Costa Rica. This chapter gives the reader useful information for understanding the past, present, and perhaps the future of marine conservation in Costa Rica.

Associated publication:

Salas, E., Ross-Salazar, E., & Arias, A. (2012). *Diagnóstico de áreas marinas protegidas y áreas marinas para la pesca responsable en el Pacífico costarricense. Fundación MarViva*. San José, Costa Rica. link: http://eprints.jcu.edu.au/23865/

Chapter 4 discusses the importance of optimizing enforcement in MPAs, and provides an empirical study showing how enforcement can be optimized in an offshore MPA. Here I analyse patrol records and determine the spatial and temporal distribution of illegal fishing. Also, I discuss the concept of the enforcement chain.

Associated publication:

Arias, A., Pressey, R. L., Jones, R. E., Álvarez-Romero, J., & Cinner, J. E. (2016). Optimizing enforcement and compliance in offshore marine protected areas: A case study from Cocos Island, Costa Rica. *Oryx*, 50(01), 18-26. doi: http://dx.doi.org/10.1017/S0030605314000337

Chapter 5 is a qualitative study detailing strategies that illegal fishers use to avoid being detected, and countermeasures that managers can employ. I discuss the detection-avoidance strategies in the broader conservation context, and then describe a series of these strategies that I discovered in the field and how they could be countered.

Associated publication:
Arias, A., et al. (in prep). Strategies used in small-scale fisheries to avoid patrol detection: a review and countermeasures. Target journal: Maritime Studies

Chapter 6 discusses ways of using existing databases to detect cases of illegal, unreported, and unregulated fishing, this is done through a little-know case study that is pending action on behalf of the Costa Rican government.

Associated publication:
Arias, A. & R.L. Pressey (2016). Combatting illegal, unreported, and unregulated fishing with information: a case of probable illegal fishing in the Tropical Eastern Pacific. Frontiers in Marine Science, 3. doi: http://dx.doi.org/10.3389/fmars.2016.00013

Chapter 7 is an empirical study about the levels and drivers of fishers' compliance with MPAs. I determined the amount of illegal fishing in coastal MPAs in Costa Rica, and I analysed the effect that multiple variables had on compliance.

Associated publication:
Arias, A., Cinner, J., Jones, R. E., & Pressey, R. L. (2015). Levels and drivers of fishers' compliance with marine protected areas. *Ecology and Society,* *20*(4):19 doi: http://dx.doi.org/10.5751/ES-07999-200419

Chapter 8 provides a summary of the previous chapters. I highlight the contributions to science and practice, and I discuss the caveats and directions for future research.

Chapter 2: Understanding and managing compliance in the nature conservation context[2]

Abstract

Nature conservation relies largely on people adhering to rules. However, noncompliance in the conservation context is common: it is one of the largest illegal activities in the world, degrading societies, economies and the environment. Understanding and managing compliance is key for ensuring effective conservation, nevertheless crucial concepts and tools are scattered in a wide array of literature. Here I review and integrate these concepts and tools in an effort to guide compliance management in the conservation context. First, I address the understanding of compliance by breaking it down into five key questions: who?, what?, when?, where? and why?. A special focus is given to 'why?' because the answer to this question explains the reasons for compliance and noncompliance, providing critical information for management interventions. Second, I review compliance management strategies, from voluntary compliance to coerced compliance. Finally, I suggest a system, initially proposed for tax compliance, to balance these multiple compliance management strategies. I provide a broad yet practical scope on theory and tools for understanding and managing compliance in the nature conservation context.

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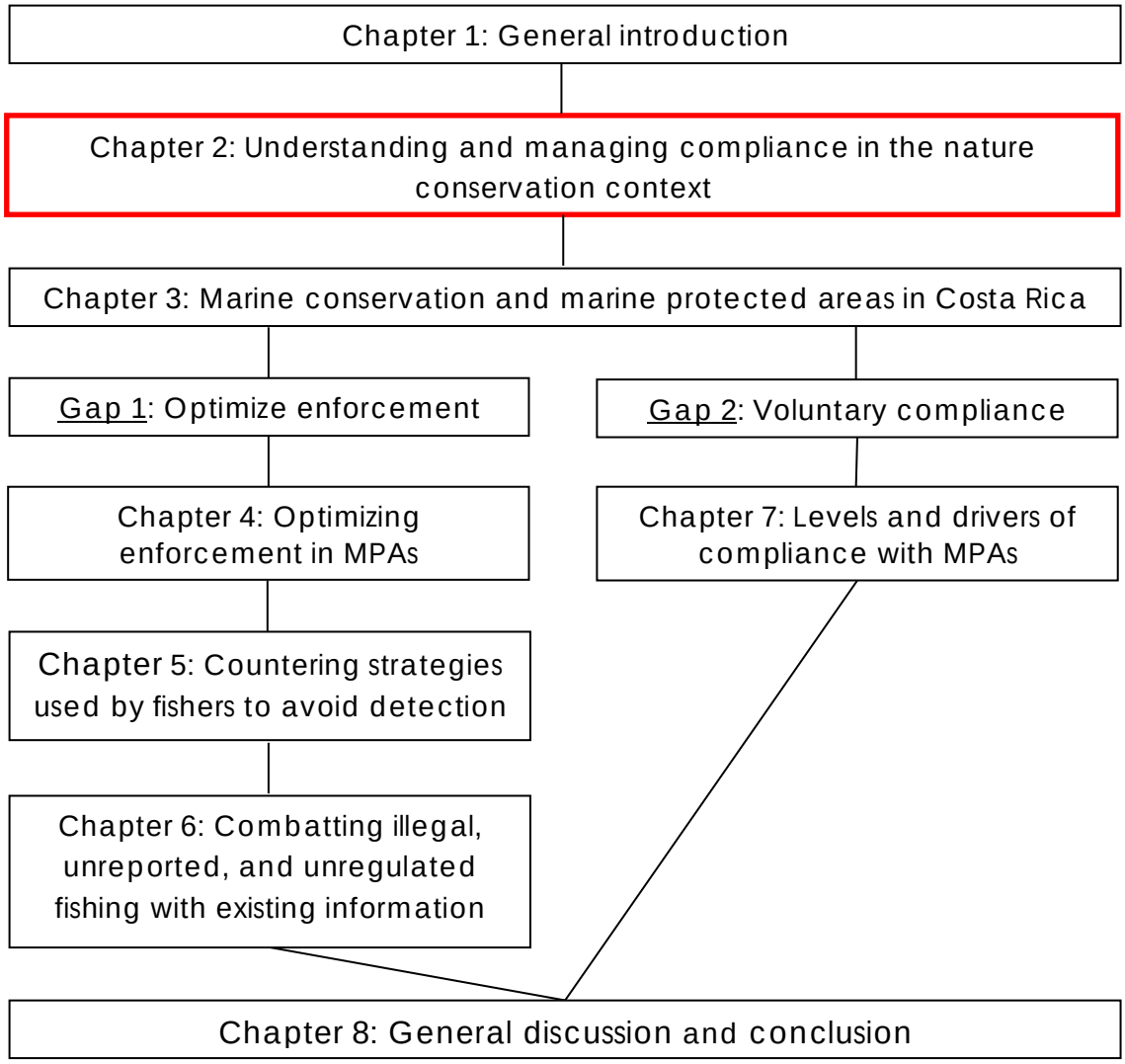
[2] This Chapter is published as: Arias, A. (2015). Understanding and managing compliance in the nature conservation context. *Journal of Environmental Management, 153*, 134-143. doi: http://dx.doi.org/10.1016/j.jenvman.2015.02.013 As the sole author of this Chapter, I developed the concept, conducted the research, constructed the tables and figures, and wrote the text. Three individuals deserve special recognition in this Chapter. My friend and mentor, Sam Ham, played an instrumental role by introducing me to the study of human behaviour and helping me understand its relevance for nature conservation. Joshua E. Cinner encouraged me to write this Chapter by myself. Robert L. Pressey provided some editorial advice, particularly helping me define my concept of compliance which I remember struggling to express in writing.


Chapter 1: General introduction
Chapter 2: Understanding and managing compliance in the nature conservation context
Chapter 3: Marine conservation and marine protected areas in Costa Rica
Gap 1: Optimize enforcement
Gap 2: Voluntary compliance
Chapter 4: Optimizing enforcement in MPAs
Chapter 7: Levels and drivers of compliance with MPAs
Chapter 5: Countering strategies used by fishers to avoid detection
Chapter 6: Combatting illegal, unreported, and unregulated fishing with existing information
Chapter 8: General discussion and conclusion

1. Introduction

Central to nature conservation, from species to ecosystem scales, is the regulation of human activities. Countless regulations are set toward nature conservation; however, noncompliance is common. Illegal wildlife trade; illegal, unreported and unregulated fishing; and illegal timber trade are amongst the largest illicit activities in the world (Haken, 2011). The impacts of noncompliance in the conservation context can be broad. Illegal fishing, for example, affects food security, causes the loss of millions of dollars of catch, and drives overexploitation and environmental degradation (MRAG, 2005). Impacts from noncompliance can be extreme, driving extinctions (Branch et al., 2013; Wilkie et al., 2011), and even the death of poachers and the murder of rangers (Dudley et al., 2013). Nevertheless, compliance receives relatively little focus in the conservation literature when compared to other aspects of conservation. Key concepts and tools that help understand and manage compliance are dispersed in a wide array of literature, including sociology and economics.

This review is aimed at conservation practitioners[3], it identifies relevant theories, methods and tools for understanding and managing compliance. This review builds on previous contributions by integrating key concepts and tools from other disciplines and relating them to the nature conservation context. Several theories, methods and tools that I discuss here are well-established in other fields (e.g., policing, psychology and taxation), so these can also become useful for conservation practitioners because they are ultimately aimed at understanding and managing human behaviour.

[3] "Practitioners are managers, researchers, and local stakeholders who are responsible for designing, managing, and monitoring conservation and development projects" (Margoluis & Salafsky, 1998, p. 7)

Here, compliance means adherence to rules related to natural resource use and conservation. Compliance can be interpreted as dichotomous or as a gradation of behaviour. As a dichotomy, the term compliance refers to whether a person or system adheres to rules or not. More realistically, as a gradation, compliance refers to the degree of adherence to rules, as when a person breaks some rules but not all, or respects rules most of the time, but not always. A gradation of compliance could be represented by continuous values or categories such as 'high', 'medium' or 'low'. So the words 'compliance' and 'noncompliance' are opposites that, as a dichotomy, allow only two values, or lie at either end of a gradation and allow intermediate values.

Compliance management is improved by understanding the factors describing and causing compliance. Here I explore compliance using the Kiping Method or 5W's (who?, what?, where?, when?, and—perhaps the most vital—why?). I consider each of the W's, focusing on 'why?', and then suggest a system for managing compliance (Figure 2). Because of the breadth of compliance in the nature conservation context this is not intended to be an exhaustive review, but rather one that enriches the literature, and facilitates discussion and most importantly—action.

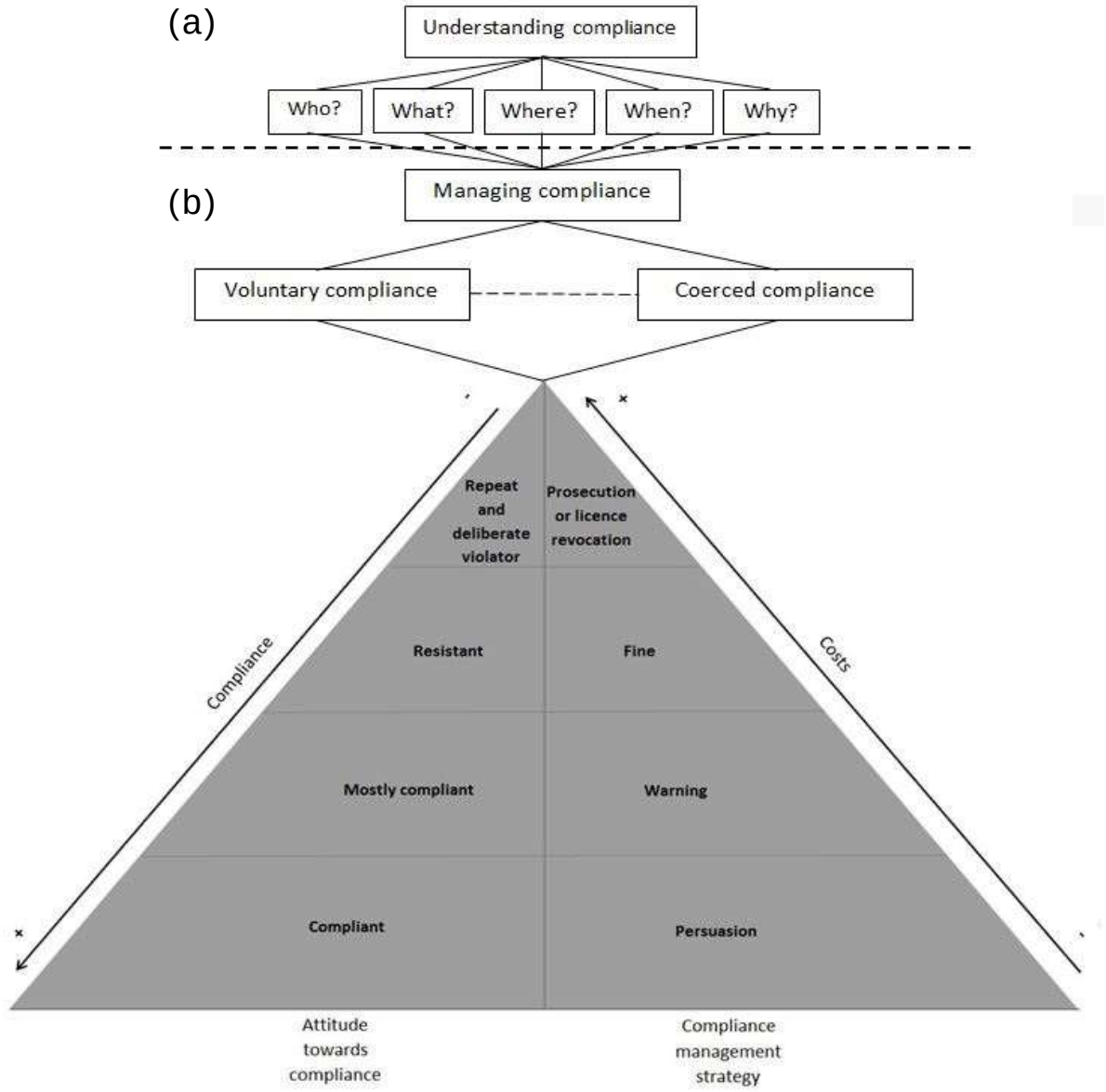


Figure 2. Heuristic of a system for (a) understanding and (b) managing compliance.

2. Understanding compliance

2.1. **The 5W's**

Journalists and law enforcement officers typically use the 5W's to gather a complete story. Here I use the same tool, breaking down compliance in the following questions, with no particular order: 1) Who complies (or not)?; 2) What is the noncompliance act?; 3) Where is noncompliance occurring?; 4) When is noncompliance occurring?; and 5) Why is compliance (or noncompliance) occurring?

2.1.1. Who complies or not

Management interventions can be focused when compliers or noncompliers are known. The answer to this question is usually multilayered. For example: Is it a particular community engaging in illegal activities or a particular group within the community? Several people or just one person? Are they male or female, young or old? Some studies have made these distinctions. In the Calamianes Islands, Philippines, Fabinyi (2007) found that local young males were more likely to fish illegally. Likewise, Cinner (2010) found that the poor were more likely to use illegal destructive fishing gear in Kenya and Tanzania. Noncompliance can also be driven by outsiders (Berkes et al., 2006; Leader-Williams et al., 1990), requiring special attention when designing interventions such as patrols, investigations and awareness campaigns.

Complicity can add layers to this question. Referring to the previous example from the Philippines, one might discover a bigger story when investigating who is an accomplice: who is providing the cyanide that the young illegal fishermen use? And who buys the illegal catch from them? These questions are relevant for compliance management. For instance, campaigns condemning the consumption of wildlife products such as shark fins (Dell'Apa et al., 2014) and ivory (Stiles, 2004) are common. Such campaigns appeal to consumers, raising awareness on facts such as

cruelty, and the social or environmental impacts of consuming these products. Similarly, knowing who deals illegal natural resources might be more effective than focusing on immediate noncompliers in the field. Clayton et al. (1997) explain how it can be easier to deter the illegal hunting of a wild pig in Indonesia by focusing on markets and road checks rather than by patrolling the forests for poachers. Additionally, by reducing demand, illegal hunting becomes less profitable for poachers. Unravelling the complicity chain can provide a complete notion of the situation and improve compliance management.

Knowing who complies can also be beneficial. Compliers can provide useful information and positively affect compliance by acting, consciously or not, as enforcers. In Zambia, Jachmann and Billiouw (1997) report the success of an enforcement system using investigations aided by cash rewards for information that led to arrests or confiscations. Using this system, arrests became four times more cost effective than foot patrols (Jachmann & Billiouw, 1997). In the Great Barrier Reef Marine Park, Australia, people can report illegal activities seen within the Park, such as littering and taking more than the approved number of tourists to an area (GBRMPA, 2014). Such reporting mechanisms provide a means of self-enforcement, urging some to comply. Understanding compliers, their traits and motivations, proves particularly useful when trying to answer 'Why is compliance occurring?'

2.1.2. What is the noncompliance act

The answer to this question should explain what is being done illegally and in what way (or how). In some cases this can be a simple question to answer. Imagine tourists walking off-track in a protected area. 'Tourists' is a broad description for 'who?', and should ideally be unpacked to provide more information (e.g., nationality and age), but the noncompliance act ('what?') is simple to describe (i.e., 'walking off-track') and cannot be unpacked. Nonetheless, sometimes the

noncompliance act can be further described. For example, if fishing is the noncompliance act an answer to this question should include the method or gear being used and the target species.

Knowing the methods used for noncompliance can be highly relevant. In case of extractive uses such as hunting and fishing, selectivity is commonly given by the methods used. Methods such as wire snares or nets can be set for targeting particular species, but their selectivity is low and can result in considerable levels of unintended catch. Becker et al. (2013) evaluated wire snare poaching in Zambia and concluded that snares increased the mortality of elephant, lion and wild dogs—all non-target threatened species. Knowledge of the methods used and the species being affected can help estimate the environmental impact of noncompliance and can inform interventions.

2.1.3. Where is the noncompliance act occurring?

Knowing the location of noncompliance can guide where interventions should be focused. The place where noncompliance occurs can be from geographically widespread (e.g., illegal logging (Laurance, 1998)) to localized (e.g., point pollution in a river). The location of noncompliance can correspond to factors such as features that concentrate flora or fauna (e.g., watering holes, seamounts), isolated places, places near communities or areas of high tourism visitation. Monitoring and the analysis of patrol records can help establish these locations. However, sometimes determining the source location of noncompliance could involve more complex investigations. An example is the illegal trade of plants, animals and their derivatives, where investigations can include intelligence and wildlife DNA forensics—a tool that can establish the species its geographical origin (Ogden et al., 2009). Illegal trade highlights the importance of monitoring and influencing markets, and having the legal tools to sanction those involved at various scales.

2.1.4. When is the noncompliance act occurring?

Knowing the time or frequency of noncompliance helps optimize interventions, particularly patrols. Noncompliance can be opportunistic (Eliason & Dodder, 1999; Milner-Gulland & Leader-Williams, 1992), but it can also respond to natural variables or management actions. When analysing illegal fishing in a marine protected area Arias et al. (2016) found that illegal fishing was more likely to occur around the new moon of the third quarter of the year. The combination of time of the year and lunar phase was likely to maximize illegal catch because of oceanographic and ecological reasons. By knowing what the noncompliance act is practitioners could elicit when these acts are occurring because of factors such as seasonality (e.g., vacations, migrations, aggregations) or diel patterns (e.g., nocturnal vs diurnal activity).

Noncompliers are likely to adopt strategies to evade detection, such as acting at night, or when patrols are limited or inexistent. This might have been the case with the previous example—the new moon involves darker nights, potentially reducing the probability of detecting incursions (Arias et al., 2016). Also, noncompliers can learn about the timing and location of patrols. A way to counter this problem is by integrating a degree of randomness in patrols and performing systematic and periodic analyses of patrol records.

2.1.5. Why is compliance or noncompliance occurring?

The previous points described compliance; this point focuses on explaining it. Prior W's clearly define the behaviour (Ajzen & Fishbein, 2005)—they define WHO is doing WHAT, WHEN and WHERE. Finally, 'why?' explains the behaviour.

Practitioners should identify and address the specific factors that are salient for maintaining or improving (hereafter: influencing) compliance (Ham, 2013; St. John et al., 2010). Practitioners will typically benefit more

when understanding what influences compliance rather than what influences noncompliance, because compliance is the desired behaviour. However, understanding why people break rules could also help contextualize the problem and design solutions. It is important to clarify that knowing why someone follows a rule is not necessarily the opposite of knowing why someone breaks it. For instance, if some people fish illegally in an area because they believe the area holds more fish, it would be invalid to assume that those who comply do so because they think that there are less fish in the closed area (Arias & Sutton, 2013). Management interventions can have better chances of being successful when the factors influencing compliance are understood.

Perhaps the main reason for why useful information about compliance is distributed so widely in the literature (e.g., sociology, criminology, anthropology, psychology, economics) is because compliance is highly relevant for many fields. Compliance is critical for a functional society. Consequently, there is a long history of trying to understand compliance. In 1775 Cesare Beccaria presented a theory that sparked the field of criminology. Beccaria's theory is that people take rational choices to maximize pleasure and reduce pain, and by doing so they can break rules (Cullen & Agnew, 2006). He proposed that sanctions are necessary, but to be effective these must be clear, well known, proportionate to the offense, quick, and certain. This theory stood alone for nearly a century, influencing reforms in Europe and USA, but was challenged in 1876 by Cesare Lombroso (Cullen & Agnew, 2006). Lombroso, a physician, believed that criminals could be identified by observable physical traits, a theory that was followed by others and later led to eugenics (Winfree & Abadinsky, 2009). Lombroso's theory was rejected, but he is credited for pioneering the use of the scientific method to explore crime. Some of Beccaria's ideas also persist, such as the responsibility that each person holds for their actions and how the certainty of sanctions reflects on crime (Cullen & Agnew, 2006). Recent theories suggest that compliance is

explained by a combination of factors such as economics and social norms (Cullen & Agnew, 2006; Tyler, 1990).

The factors influencing compliance have been widely studied in the behavioural sciences. Fishbein and Ajzen (2010) offer a highly popular model for predicting, explaining and changing behaviour: the Reasoned Action Model (also known as Theory of Planned Behaviour). The model suggests that three beliefs drive a person's intention to behave, in this case comply, or not. The three beliefs are behavioural beliefs, normative beliefs, and control beliefs. Behavioural beliefs relate to the positive or negative consequences associated to the behaviour (e.g., 'If I comply I will not get punished by the law'). Normative beliefs are the social pressures controlling a person's behaviour (e.g., 'Noncompliance is unacceptable in my social circles'). Control beliefs are factors that ease or hinder behaviour (e.g., 'I don't have the skill or resources to be noncompliant'). So if a person believes that it is easy to comply, that complying will have a positive outcome, and that compliance will be well received by others, there will be a strong intention to comply. There are other theories that can help explain compliance (see for example: Maslow, 1943; Rogers, 1975). However, here I focus on the Reasoned Action Model because it is simple and effective (Beck & Ajzen, 1991; Kaiser et al., 2005).

Behavioural beliefs are people's evaluation of the benefits vs. costs of a specific behaviour. For instance, if a hunter concludes that the consequences of complying with hunting regulations are mostly positive or beneficial (e.g., healthier game populations) the hunter's attitude toward that behaviour will be positive, and vice versa. Several practitioners focus on the behavioural component of compliance, particularly coercion (Becker, 1974; Hauck & Kroese, 2006; Kalron, 2013; Peluso, 1993). Coercion acts as a negative incentive, making actors evaluate the potential benefits and costs of noncompliance and

compliance. But positive incentives can also be used to strengthen compliance by influencing behavioural beliefs.

The normative component is particularly important for determining compliance (Tyler, 1990), and it deserves special attention considering that people typically behave in accordance to norms. Cialdini et al. (1991) distinguish three types of norms: personal, descriptive, and injunctive. Personal norms are the moral obligations for engaging or not in a behaviour, with internal sanctions and rewards for doing so (Schwartz, 1973). Descriptive and injunctive norms are social norms that rely on sensed external cues. Descriptive norms are what most others do, whereas injunctive norms are what most others approve or disapprove. So descriptive norms inform behaviours while injunctive norms prescribe and proscribe them (Cialdini et al., 1990).

Personal norms are not part of the Reasoned Action Model but some authors have integrated them into the Model (Harland et al., 1999), and into other, more complex, models (Klöckner, 2013). The Reasoned Action Model is a general model of human behaviour, and Fishbein and Ajzen (2010) suggest that, with some exceptions, personal norms do not add explanatory power to their Model. However, exceptions where personal norms help explain behaviour are proenvironmental and prosocial behaviour (Harland et al., 1999, 2007; Schwartz, 1977)—hence, personal norms are relevant for compliance. Feeling morally obliged to comply or regretting noncompliance are examples of how personal norms can influence compliance and how these norms can be measured in social surveys (Harland et al., 2007). Also, research shows that long lasting behavioural change can be achieved through personal norms (Matthies et al., 2006). Once personal norms are activated people are likely to engage in positive behaviours because 'it is the right thing to do'. While not all conservation behaviours are driven by morality and altruism some clearly is, therefore practitioners should consider personal norms when

trying to understand and influence compliance. Social norms are also highly relevant for compliance because people typically behave according to the behaviour of others (Schultz et al., 2007).

Social norms act as rules guiding behaviour. For instance, there are fishing communities in Indonesia where people do not fish on Fridays because of their religious beliefs (Cinner, Basurto, et al., 2012). Compliance with these rules can be enforced through social ostracism (Colding & Folke, 2001; Sumner, 1906). Social norms, however, are not necessarily weaker or less effective than formal rules. In fact, long-standing social norms regulating natural resource use can be weakened by the superimposition of formal laws, bringing negative social and environmental impacts. Jones et al. (2008) describe multiple social norms regulating terrestrial natural resource use in Madagascar, and mention that these social norms can be preferable to formal laws that can be poorly enforced by the state. Similarly, Gelcich et al. (2006) argue that the effectiveness of a system to manage kelp and mollusc extraction in Chile faded when it transitioned from a traditional access right system to a government-led co-management system. Compliance dwindled, and ecological resilience and social bonds were weakened. Informal rules and institutions can provide effective conservation and social outcomes.

The effect of social norms on pro-environmental behaviour and compliance is well-studied. Cialdini et al. (1990) assessed the impact that descriptive and injunctive norms have on littering in public spaces. Their results show that the presence of litter encourages further littering. This occurs because the presence of litter generates a descriptive norm of what most other people do, so a highly littered place translates to 'littering is normal'. To assess the effect of the injunctive norm, researchers placed handbills on car windshields, handbills had messages with varying degrees of proximity to the injunctive norm against littering (i.e., do not litter, recycle, turn out lights, vote, celebrate arts month). By surreptitiously

observing people's behaviour when they reached their cars, researchers noticed that littering of the handbills decreased as the message on the handbill got closer or was identical to the injunctive norm against littering. In other words, people who received handbills with the injunctive message against littering were the least likely to litter the handbill, while those who received the handbill with the message about celebrating arts months were most likely to litter the handbill. This result underlines the importance of delivering specific messages aimed at clearly defined behaviours. General messages (e.g., the typical 'Save the environment') are ineffective. Furthermore, poorly designed management interventions aimed at influencing norms can even be counterproductive. For example, signage at a beach with a descriptive statement that 'Tons of seashells are stolen every year…' tells visitors that 'everyone does it', and could actually increase seashell theft (Cialdini, 2003). These examples demonstrate the relevance of understanding what drives compliance for creating influential interventions.

Lastly, control beliefs—people's perceptions of what can ease or hinder a particular behaviour—can also influence compliance. Examples of control beliefs are knowledge, skills, time, money, weather and equipment. While some control beliefs cannot be managed by the governing institution (e.g., weather), others can be identified and addressed. Knowledge, for instance, is typically used to foster desirable behaviours. In a meta-analysis of recycling behaviour Hornik et al. (1995) found that consumer knowledge about recycling was the strongest predictor of recycling. Nevertheless, another control belief such as the lack of a recycling program can act as a strong barrier against recycling, even for a person with overall strong and positive beliefs about recycling. Thus, an institution that wants to foster a particular behaviour can provide knowledge on why and how to perform it, but should, if possible, also offer services or facilities to ease behaviour performance. Managing institutions can apply one or multiple interventions to either facilitate or obstruct

peoples' control over a particular behaviour. Interventions can have varying degrees of complexity and success. For instance, a managing institution can use brochures or signs to inform about the illegality of using particular gear; information can remove knowledge barriers (e.g., people not knowing about the regulation). Another intervention could be aimed at banning the possession and importation of particular gear (e.g., spearguns in Seychelles), obstructing access to that gear. However, in some cases illegal gear can be cheap and simple to build (e.g., wire snares). Interventions are context specific, just as the relative importance of control beliefs, normative beliefs and behavioural beliefs.

To answer 'why?' social surveys are required, although modelling can be used to understand the implications of different motivations for compliance or noncompliance (Table 1). The popularity of the Reasoned Action Model makes it easily accessible, and by including personal norms it is a powerful tool for understanding compliance. There are guides for the application of the Model and the subsequent crafting of interventions (Fishbein & Manfredo, 1992; Ham, 2013), including freely available material (Ajzen, 2013; Ham et al., 2009; Ham et al., 2008). The need for social sciences to understand and manage compliance stresses the fact that conservation is mainly about managing people—not plants, animals or landscapes (Balmford & Cowling, 2006; Schultz, 2011).

Table 1. Methods for studying compliance. Adapted from Bergseth et al. (2015) and Gavin et al. (2010).

Methods	Examples	Units	5 W's					References
			What	Why	When	Where	Who	
Social surveys	Expert elicitation, random response technique, perceived compliance, item count, self-reporting	proportions, likert scales, geographic, effort	✓	✓	✓	✓	✓	(Arias & Sutton, 2013; Cinner, McClanahan, et al., 2012; Nuno et al., 2013)
Modelling	predictions of illegal resource use and resource dynamics, spatiotemporal patterns	absolute measures (e.g., effort, biomass) and response ratios	✓	✓	✓	✓	✓	(Ainsworth et al., 2012; Jachmann & Billiouw, 1997; Keane et al., 2012)
Law enforcement records	Foot or vehicle based patrol records, legal proceedings	number of detections, arrests/citations, prosecutions, absolute measures (e.g. time and area)	✓	×	✓	✓	✓	(Akella & Cannon, 2004; Arias et al., 2016; Holmern et al., 2007)
Direct observation	Surreptitious or open observation	number or proportion of detections, absolute measures, effort	✓	×	✓	✓	✓	(Cialdini et al., 1990; Davis et al., 2004; Schill & Kline, 1995)
Indirect observation	Discarded or set gear (e.g., traps, bullet casings), carcasses, animal behaviour, markets	absolute measures, flight initiation distance	✓	×	✓	✓	×	(Clayton et al., 1997; Januchowski-Hartley et al., 2012)
Remote sensing	Forest cover, satellite tracking, drones	absolute measures	✓	×	✓	✓	✓	(Brooke et al., 2010; Kuemmerle et al., 2009; Lein, 2009)
Forensic studies	Genetic and chemical analysis	absolute measures	✓	×	✓	✓	✓	(Mak et al., 2005; Ogden et al., 2009)

- Additional considerations: Magnitude of compliance

Low compliance can render a rule ineffective, so high compliance is desired. However, the magnitude of compliance must be defined. It is simplistic to think that the magnitude of compliance is based on the number of people complying or not. For example, consider a forest that has two people logging illegally. The same two loggers can have very different impacts depending on factors such as the characteristics of the forest, whether they use axes or chainsaws, or if they log trees once a year or daily. In this case the number of people, frequency, gear and location are key when considering the magnitude of compliance. 'Who?', 'what?', 'when?' and 'where?' can provide a robust estimate of the magnitude of compliance. Answering 'who?' qualitatively or quantitatively establishes the amount of noncompliers; 'what?' describes the action; 'when' describes the frequency of noncompliance; and 'where' describes the location (e.g., area and sensitivity). These four factors should be considered when evaluating the magnitude of compliance. However, sometimes it is only necessary to confirm the presence or absence of compliance, for example to determine someone as guilty or innocent.

Rules are directed at targets (e.g., water, forests, and fish); therefore, the magnitude of compliance could be estimated indirectly through measurable traits on those targets (e.g., water quality, forest coverage, and fish biomass). The magnitude of compliance can also be estimated though methods such as social surveys. This means that the magnitude of compliance can be established in several ways and it can have a multiple units of measurement (Table 1). The magnitudes of compliance can be used to establish baselines to monitor and evaluate interventions.

An example that illustrates the importance of fully describing compliance and its magnitude is fishers' exploitation of fish spawning aggregations. Several coral reef fish, such as the Nassau grouper

(*Epinephelus striatus*), form large reproductive aggregations. These aggregations are predictable in space and time, and the species grows slowly and is late to mature. Hence, the Nassau grouper is highly vulnerable to overfishing. Noncompliance with conservation measures set for Nassau grouper have caused alarming population declines (Sadovy de Mitcheson et al., 2008). This species is typically spearfished by divers who know the time and place of these aggregations. Therefore, common methods for managing the Nassau grouper fishery are temporal and spatial closures, and speargun regulations.

2.2. Methods to study compliance

A particular obstacle exists when studying compliance with conservation regulations. Compliance is expected—morally, socially or legally. Hence, a high bias can result if inadequate methods are used to study compliance. When social surveys are used to gauge compliance, noncompliers could refuse to participate or provide deceitful responses. Nevertheless, several methods exist to circumvent these obstacles (Table 1). Practitioners can choose methods depending on which of the 5W's requires answers. Budget, labour demand and technological requirements also influence method selection (Gavin et al., 2010). Social surveys are typically the simplest method and can provide large amounts of information, but have the potential for response or non-response bias. However, they can be used in conjunction with additional elements that reduce bias (Jaccard & Blanton, 2005). Specialized questioning techniques (Table 1), ensuring confidentiality or anonymity, underlining the importance of accurate data, and using neutral interviewers (e.g., students instead of government staff) can all reduce bias in social surveys.

3. Managing compliance

Not all people comply, and not all of them comply for the same reasons. Hence there is a need for comprehensive compliance management strategies, even when compliance is prevalent.

Compliance can be voluntary or coerced, and each strategy should correspond to a particular type of individual: varying from the always compliant to the repeat and blatant offenders (Figure 2). Perverse outcomes can arise when a strategy is misapplied. For example, a hiker who unintentionally enters a closed area in a National Park by being unaware about the closure or unskilled at navigation would likely benefit from persuasive communication (e.g., signs, brochures or talks from rangers). However, a hunter who repeatedly and knowingly enters that same area would be more likely to comply if subjected with a punitive strategy (e.g., fine, gear confiscation, imprisonment). If these two strategies were applied inversely, the result would be business as usual for the illegal hunter, and an antagonized hiker. Understanding compliance helps the design and application of management strategies.

3.1. Voluntary compliance

Practitioners should aim for voluntary compliance. A high degree of voluntary compliance is preferred because it: 1) reflects that most users are assertive about the benefits of compliance, 2) provides a buffer when costly enforcement is paused (e.g., patrol unit breaks down) and 3) confirms effective governance and management. I define voluntary compliance as that which is performed purposefully as an act of approval with the rules or institutions, either when punishment is applicable or not. Levi (1989) uses the term 'quasi-voluntary compliance' when punishment is applicable to noncompliance, or as stated by Hart (1994, p. 198) 'voluntary cooperation in a coercive system'. The main tools used to promote voluntary compliance are legitimacy, incentives, alternatives, and persuasive communication.

3.1.1. Legitimacy

Voluntary compliance requires constant input from the regulating institution. Positive opinions about the regulating institution will generate a sense of legitimacy and in turn increase voluntary compliance (Tyler,

1990). Empirical studies in the conservation context support the value of legitimacy to influence compliance. McClanahan et al. (2006) mention the perception of legitimate regulations as the likely explanation for high compliance in the absence of regular enforcement in traditionally managed areas in Indonesia and Papua New Guinea. Hønneland (2000) reported similar conclusions when studying fishermen in the Barents Sea; some enforcement was necessary to ensure compliance, but it was not as significant as the perception of legitimate regulations, procedures and authorities.

A governing institution expects positive results on natural resources from rule compliance, for instance clean water and increased biomass. In exchange for their compliance, natural resource users will typically expect not only positive results on the natural resources, but also evidence of efforts on behalf of the governing institution to ensure those positive results. The perceived effectiveness and justness of the efforts done by the managing institution will dictate the degree of legitimacy granted to the institution (Levi et al., 2009). Regulating institutions can reduce or increase compliance through their actions. Some noncompliance for example can be explained as a response to what natural resource users believe is illegitimate (Stern, 2008). It is therefore the regulating institution's task to ensure legitimacy (Knopf & Dustin, 1992). This feedback loop calls for the inclusion of social, economic and political contexts in early stages of conservation initiatives (Ban et al., 2013).

3.1.2. Incentives

Incentives can take multiple forms, such as awards and public recognition, information and training, and monetary/financial incentives (Stonehouse, 1996). Incentives can be granted to regulators as well as natural resource users. Jachmann (2008) reports how rangers from different protected sites in Ghana improved work performance when they started competing against each other, and when information about their

performance was made public. In this case the incentive was recognition. Incentives can improve interventions; however, incentives can sometimes backfire (Fehr & Falk, 2002).

As discussed earlier, norms can have a strong effect on compliance. People can comply predominantly because they believe it is morally correct and because it is socially accepted. Nevertheless, the introduction of external incentives can change motivations to comply, giving dominance to behavioural (economic) beliefs over normative beliefs. So the motivation to comply can shift: from a positive moral stance, to the expectations of an economic transaction. This shift has been documented in psychology and economics (Deci et al., 1999; Frey & Jegen, 2001). An example of this effect (called 'hidden costs of reward' or 'crowding-out effect') in the conservation context is portrayed by tradable emission rights, where a company has a 'licence to pollute' and therefore the moral motivations to lessen pollution are greatly reduced because pollution is legitimized (Frey, 1999). In a small artisanal fishing community in Costa Rica fishermen receive money from a nongovernment organization to buy fuel for patrolling a fishing area; fishermen patrol voluntarily using their boats and they rotate shifts (A. Arias pers. obs.). Fishermen benefit from patrols because they deter the use of illegal nets within the fishing area, and the financial costs of buying the fuel themselves would be high. However, one must question whether fishers' motivation to patrol the area would remain if (or mostly likely 'when') this external incentive disappears. In fact, while some fishers mentioned increased catch as a result of patrols, several argued that they should receive a salary for patrolling (A. Arias pers. obs.). Despite good intentions from the organization providing the fuel, fishers' motivations seem to have been negatively affected. Practitioners should be cautious when applying incentives as these can have unaccounted consequences that can become difficult or impossible to reverse.

3.1.3. Persuasive communication

Undesired practices can be replaced by more desirable alternatives. Because this approach aims to draw people's attention from practices that are environmentally undesired, Franz Tattenbach suggested the term 'conservation by distraction' (Ferraro & Simpson, 2002). These distractions are typically introduced through alternative livelihoods and are central in integrated conservation and development projects. Introducing alternative goods, such as western synthetic medicine to replace traditional medicine, can also be considered within this approach (Milner-Gulland & Rowcliffe, 2007). There are successful examples of conservation by distraction, such as cases of ecotourism (Ferraro & Hanauer, 2014; Wunder, 2000). However, as with positive incentives, alternatives can bring damaging and unintended consequences if they are not well designed and managed. Sievanen et al. (2005) describe how seaweed farming projects were introduced in the Philippines, particularly to reduce fishing pressure. Seaweed farming offered benefits such as partially reducing fishing, some people earning more money and farms attracting fish. But seaweed farming also brought perverse outcomes such as attracting outsiders to the small villages where farming was taking place, people using mangrove wood to build farms, pollution from discarded materials, and boom and bust cycles caused by market fluctuations and disease outbreaks. Mixed results from the introduction of alternatives have been reported elsewhere (Baker et al., 2013; Gettleman, 2015), raising an important caveat when using alternatives to influence behaviour.

Through communication a person can be persuaded to comply voluntarily. Studies show that when persuasive communication successfully activates in a person's mind it can reinforce, change or create new beliefs (Ham, 2013). Hence, persuasive communication can significantly enhance the likelihood of voluntary compliance. Large scale communication efforts such as education and outreach campaigns can be expensive (Alder, 1996; McKenzie-Mohr, 2000), particularly in remote

areas with limited media resources such as radio and television, but compared to enforcement, they can offer broader benefits such as environmental knowledge and pro-environmental behaviour (Leisher et al., 2012). Note, however, that increased knowledge does not necessarily translate to behavioural change (Schultz, 2002).

As mentioned previously, understanding what drives compliance can help design communication strategies. By applying key knowledge on behavioural sciences, such as the Reasoned Action Model and personal norms, practitioners can strengthen their communication efforts. Using persuasive communication, informed through the Reasoned Action Model and personal norms, Brown et al. (2010) describe how visitors were influenced to pick up litter in a Tasmanian National Park. Practitioners created two signs with thought-provoking titles (‘‘What will you do when you see it?’’ and ‘‘If not you, who?’’) followed by short sentences related to the titles and the target behaviour (litter pick up in the Park). The signs increased litter pickup by 15-20%. Littering was considered to be the utmost visitor problem in the Park, so by increasing visitor litter pick up the Park possibly influenced a positive behaviour on visitors (i.e., litter pick up), improved its appearance by having less litter, and reduced management costs by having visitors, not staff, picking up litter (Brown et al., 2010).

Persuasive communication, however, is a tool that does not influence everyone. Persuasive communication is particularly effective for managing uninformed and inexperienced actions that result in noncompliance. But persuasive communication is ineffective for dealing with people who have ingrained beliefs resulting in deliberate and persistent noncompliance—these cases usually require coercion (Roggenbuck, 1992; Tyler, 1990).

3.2. Coerced compliance

Coercion can be an effective strategy to deter noncompliance and to ensure people that noncompliers will be penalized. Levi et al. (2012)

suggest that effective coercion can strengthen an institution's legitimacy by indicating competence. So although coercion forces compliance, it can be linked to legitimacy and, consequently, it can also be linked to voluntary compliance (Figure 2 b).

3.2.1. Enforcement

Enforcement is a tool that can help increase compliance. Effective enforcement is a chain with four links. First, the probability of detecting offenses; second, the probability of arrest or citation given detection; third, the probability of prosecution given arrest or citation; and fourth, the probability of conviction given prosecution (Akella & Cannon, 2004; Sutinen, 1987). Enforcement acts as a negative incentive, it makes people weigh economic decisions: the benefits of acting illegally vs. the chances and repercussions of getting caught doing so. Effective enforcement can be complex to manage because of the diverse steps or 'links' involved, requiring strong institutions to ensure deterrence. In developing countries enforcement is commonly weak (Akella & Cannon, 2004). But even in wealthy countries enforcement is only capable of detecting a small fraction of infringements (Stern, 2008; Sutinen & Kuperan, 1999). Additionally, enforcement is significantly expensive in both land and sea. In the Great Barrier Reef Marine Park, Australia, enforcement accounts for approximately 30% of the management costs (McCook et al., 2010). In India, approximately 60% of the forest department's budget is spent on enforcement (Robinson et al., 2010). Enforcement should therefore be used efficiently.

Enforcement should be targeted, and targets exist in space and time. For instance, Arias et al. (2016) determined the spatial and temporal distribution of illegal fishing in a marine protected area, helping to inform patrol effort. Enforcement can also become more efficient through investigations. As mentioned previously, markets can be good places to gather information about acts of noncompliance. In Costa Rica, a

manager reported seeing unusually large fish being sold in a market adjacent to a no-take marine protected area at a time when patrol boats were inoperative (M. Chavarría, pers. comm.). Larger fish are expected within no-take marine protected areas, so this observation suggested that illegal fishing was taking place. Investigative work is key for targeting offenders, including corrupt officers (Sundström, 2012). A major reform of South Africa's fisheries compliance system allowed solving high profile cases through investigative work and a specialized environmental court (Hauck & Kroese, 2006). However, Hauck and Kroese (2006) mention that this reform was focused on enforcement and, despite several benefits, there was a need to shift toward a system that prioritized voluntary compliance. Some enforcement is typically necessary, but it should be coupled with strategies that foster voluntary compliance.

3.3. Balancing compliance management strategies

Tax compliance has made considerable progress in managing compliance and can provide lessons for nature conservation. The Australian Taxation Office, applies a model which strives for voluntary compliance and relies on graduated sanctions (Braithwaite & Braithwaite, 2001). The model assumes that most people are compliant and applies a 'softer' approach, such as persuasion, then gradually increases sanctions according to the number and severity of violations (Ayres & Braithwaite, 1992). Costs can be reduced by directing expensive and resource intensive measures to the smaller proportion of noncompliers (Figure 2) who do the most damage. Furthermore, through graduated sanctions, the model is more likely to be deemed as legitimate. Applying strong sanctions at once can not only be seen as illegitimate, but can have adverse effects such as increasing the chances for bribery and violence, foster the investment in methods to avoid detection, stronger defences in court, and having a stronger effect on the poor (Keane et al., 2008; Robinson et al., 2010). Similar to how 'positive incentives' could legitimize environmental harms (e.g., tradable emission rights), negative incentives

such as sanctions can legitimise noncompliance (Gneezy & Rustichini, 2000), highlighting the importance of making the sanction proportional to the infraction to reduce this effect. Whilst some regulatory agencies possess the legal framework allowing graduated sanctions, others might have to undergo policy and legislation changes to allow it. Political will is crucial for effective compliance management (Gibson, 1999).

Conservation practitioners should focus on building and strengthening a wide base of voluntary compliance. People commonly follow the behaviour of others (Cialdini & Goldstein, 2004; Schultz et al., 2007), so compliance can become the norm, at least in the immediate time frame. However, the opposite also applies. Compliers are unlikely to indefinitely tolerate the burden of noncompliance (i.e., free riding and degraded goods), so compliance can progressively deteriorate as compliers defect (Levi, 1989). These thresholds can be difficult to locate because they depend on dynamic factors such as norms, punishment, and rewards (Fehr & Fischbacher, 2003; Ostrom, 2000). In practice, knowing that these thresholds exist is useful, acting as encouragement for staying away from them by striving for a strong base of voluntary compliance.

Despite the preference for a strong base of voluntary compliance in some cases noncompliance predominates (Arias et al., 2016; Laurance, 1998), requiring prompt action to stop further degradation of the environment and compliance. Cases with high noncompliance can resemble the pyramid in Figure 2 but with an inverted factor order. However, the relationship between attitudes toward compliance and compliance management strategies remains the same. Enforcement can offer fast results by disrupting the economic incentives that drive noncompliance, allowing time for other strategies to come into effect.

4. Conclusion

Noncompliance can render a rule ineffective—defeating the rule's purpose. Nature conservation requires compliance. The concepts and

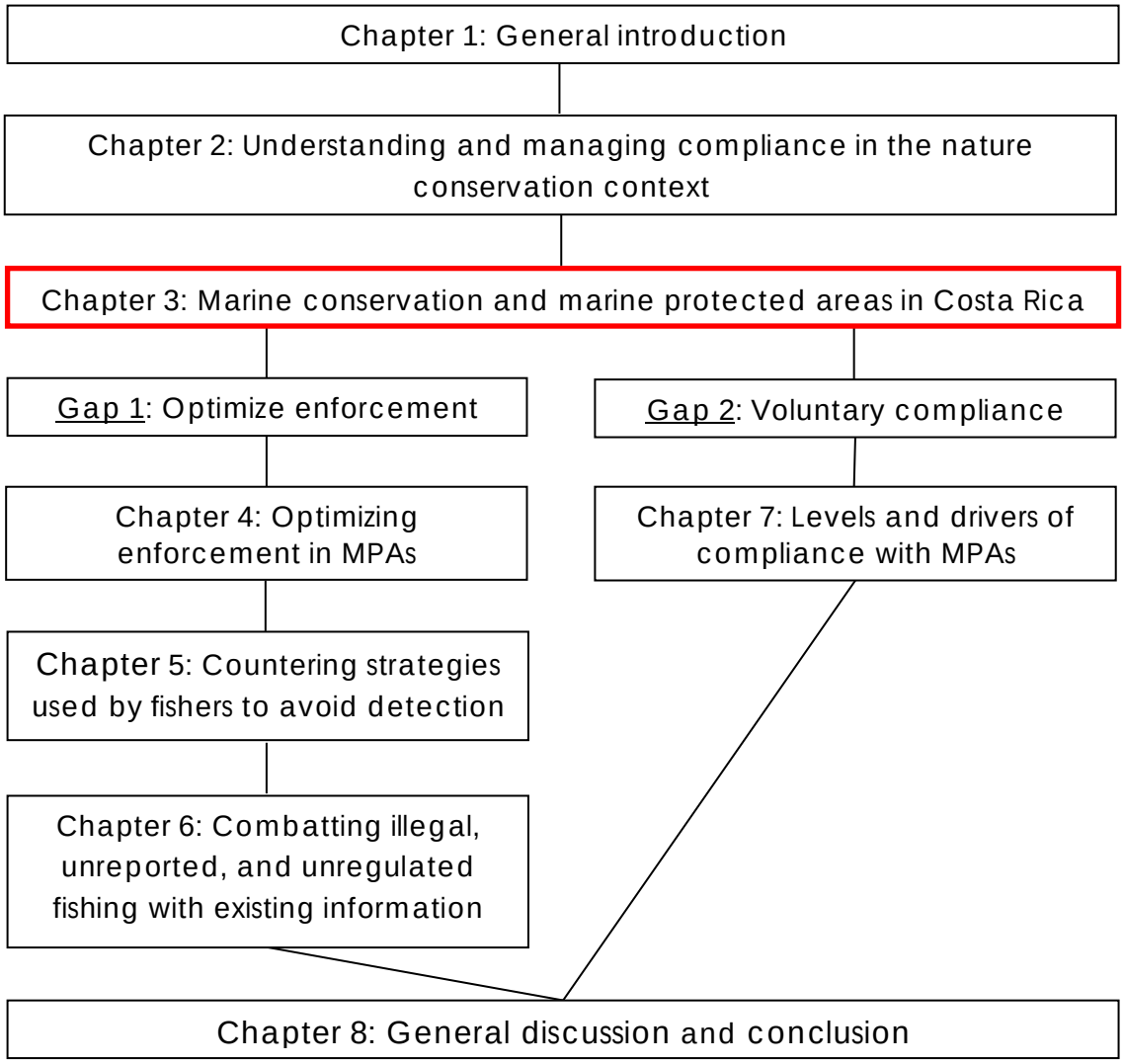
tools that I describe here provide solid foundations for compliance management in the nature conservation context. However, the operationalization of compliance management is context dependent and requires ongoing adaptation. The multiple examples provided in this review demonstrate the diversity of ways in which compliance managers can gather information and devise interventions. Interventions can work through coercive or voluntary compliance; with the ultimate goal of building and maintaining a wide base of voluntary compliance. The strong link between effective conservation and human behaviour highlights the need to eliminate barriers between disciplines. Compliance management in the nature conservation context has been gradually progressing toward the integration of knowledge and methods from different disciplines such as environmental, behavioural, and risk and decision sciences (Gibbs et al., 2010). As this transdisciplinary progress continues, the linkages between scholars and managers should be strengthened through the exchange of knowledge and needs. The difficulties that compliance managers face present abundant opportunities for problem-solving and for translating research into action.

Chapter 3: Marine conservation and marine protected areas in Costa Rica[4]

Abstract

The study area for this thesis was Costa Rica. Here I condense relevant information about the country and remove redundancy from the subsequent chapters which originally, in their published forms, repeated some of this information. I provide an overview of conservation and marine protected areas in Costa Rica with the objective of giving the reader contextual information to better understand the subsequent chapters. Costa Rica has been renowned for its rich biodiversity and for being a leader in nature conservation. Even though this might be true to some extent, here I argue that the country is currently lacking the strong leadership that it had decades ago, and that the marine realm in particular is in urgent need of attention. Costa Rica's marine jurisdiction is almost 11 times larger than its land area, and marine resources and services are critical for the country's development and well-being. Nevertheless, the lack of policies and actions aimed at marine conservation is now evidenced by factors such as overfishing, poorly planned conservation initiatives, a neglected nautical sector, conflict between stakeholders, and as discussed in the following chapters, illegal fishing. I anticipate, however, that the perilous state of marine affairs has created a new wave of interest among Costa Ricans for marine conservation that will lead to positive changes, resembling the cycle experienced in the country during the 1970s and 1980s with deforestation followed by terrestrial conservation.

[4] A small part of this Chapter is published as a book: Salas, E., Ross-Salazar, E., & Arias, A. (2012). *Diagnóstico de áreas marinas protegidas y áreas marinas para la pesca responsable en el Pacífico costarricense. Fundación MarViva*. San José, Costa Rica.
I developed the concept, conducted the research, constructed the tables and figures, and wrote the text.


Chapter 1: General introduction
Chapter 2: Understanding and managing compliance in the nature conservation context
Chapter 3: Marine conservation and marine protected areas in Costa Rica
Gap 1: Optimize enforcement
Gap 2: Voluntary compliance
Chapter 4: Optimizing enforcement in MPAs
Chapter 7: Levels and drivers of compliance with MPAs
Chapter 5: Countering strategies used by fishers to avoid detection
Chapter 6: Combatting illegal, unreported, and unregulated fishing with existing information
Chapter 8: General discussion and conclusion

1. Background

I selected Costa Rica as a study site for multiple reasons. First, fishers' noncompliance, the main theme of my thesis, is pervasive around the world and developing countries are the most vulnerable to fisheries noncompliance (Agnew et al., 2009). Second, there are significant levels of fisheries noncompliance reported in Latin America and the Caribbean (MRAG, 2005), including Costa Rica (Salas et al., 2012). Third, small-scale (artisanal) fisheries are very common in coastal developing countries, where they are key for livelihoods and food security; however, these fisheries urgently require science-based management (Oliveira Júnior et al., 2016). Fourth, tropical MPAs can host high levels of biomass and biodiversity; nevertheless, many tropical MPAs are threatened by fishers' noncompliance and require effective management to prevent it (Mora et al., 2006). Fifth, Costa Rica has a wide variety of MPAs that enriched the study (Table 6). And sixth, Costa Rica is my home country, so there were no language or cultural barriers, and I was able to use my existing contacts and relationships with various stakeholders.

Costa Rica´s marine surface is nearly 11 times larger than its land surface (51 100 km^2). Costa Rica's marine waters cover 589 683 km^2 (INCOPESCA, 2006); this large expanse is primarily explained by Cocos Island, off the Pacific coast, which significantly extends the Economic Exclusive Zone (Figure 3). This relatively large marine area is characterized by a high marine biodiversity (Wehrtmann et al., 2009). The closure of the Central American Isthmus approximately 3.5 million years ago generated strong biophysical shifts that led to high marine and terrestrial biodiversity (Haug & Tiedemann, 1998). Costa Rica translates to 'rich coast', a fitting name.

Unlike many coastal countries, Costa Rica's socioeconomic growth started in the central valley, later spreading toward the coasts which remained sparsely populated until the late 1970's (Mack et al., 1992).

Today, however, the socioeconomic importance of the coasts is critical for the country's development. A narrow country between two marine masses, Costa Rica is largely reliant on resources and ecosystem services provided by marine ecosystems, from fisheries to tourism and ports (Casa Presidencial, 2011; Comisión Presidencial para la Gobernanza Marina, 2012). While both coasts are important for Costa Rica's development, the Pacific coastline is six times longer than the Caribbean's (Cortés & Wehrtmann, 2009), the Pacific portion of the economic exclusive zone is much larger than that of the Caribbean (Figure 3), and the Pacific drainage basin supports most of the country's population (INEC, 2011).

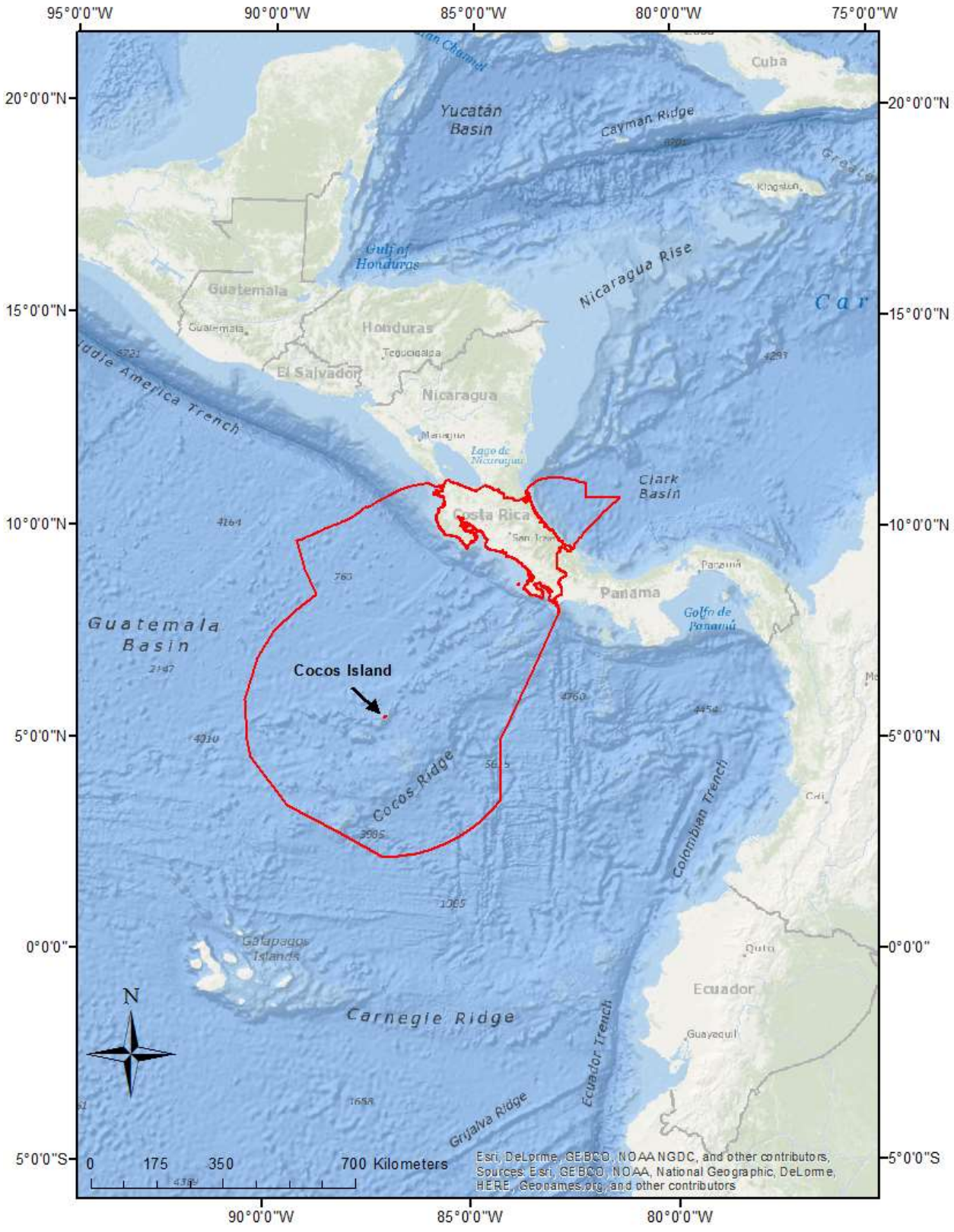


Figure 3. Map showing Costa Rica and its Exclusive Economic Zone in red. Cocos Island, near the 5˚0'0"N meridian, is labelled and marked with a black arrow.

Tourism is a main driver of coastal development in Costa Rica: 75% of foreign tourists visit the country for holidays (ICT, 2015b), and nearly 70% of them have coastal areas as their main destination (ICT, 2015a)—including several MPAs (ICT, 2015c). Tourism has caused rapid environmental and socioeconomic changes in many coastal areas, mainly in the Central and North Pacific. For instance, modifications in land tenure (e.g., from poor fishing villages to tourism destinations) have displaced some local people, creating social conflicts (Mack et al., 1992). Nevertheless, tourism has also created new livelihoods and expanded services and infrastructure in coastal areas. In Chapter 4 I discuss the potential role of tourism in influencing compliance within MPAs in Costa Rica.

The ports located on the Pacific and Caribbean coasts are highly relevant in terms of usage of the marine space, and for the country's economy. Ports in the Caribbean are busier than ports in the Pacific. For instance, in 2014, 667 vessels docked and nearly 4.5 million tons of cargo were imported and exported through the two main ports on the Pacific coast (INCOP, 2015). In contrast, for the same year in the Caribbean, it was almost 11 million tons of cargo and 2006 vessels (JAPDEVA, 2015). Despite the already high vessel traffic and the relevance of ports and navigation for national development, Costa Rica's maritime legislation and institutions require significant improvements to guarantee sustainability, safety and efficiency (Comisión Presidencial para la Gobernanza Marina, 2012). Evidence of this is a series of spills and fatal boating accidents that occurred in 2015 (Dyer, 2015; Fendt, 2015), and the fact that Costa Rica lacks laws to regulate navigation and has not signed key international conventions such as Safety of Life at Sea (SOLAS) and Prevention of Pollution from Ships (MARPOL). Fisheries, which are critical for many coastal communities in Costa Rica, and a central theme of my thesis, are also in urgent need of support by the state (Comisión

Presidencial para la Gobernanza Marina, 2012; Frente por Nuestros Mares, 2013b; Jimenez-Ramón, 2015).

The Pacific coast accounts for most of the country's fish catch, which is landed by domestic and foreign fleets. Costa Rica's fishery statistics, although outdated (CGR, 2014) and imprecise (Trujillo et al., 2012), suggest that most of the landings from the national fleet come from the pelagic longline fishery, and landings from the international fleet fishing in Costa Rica's waters are caught by tuna purse seiners and pelagic longliners. The international fleet catches more fish than the entire national fleet, and most of its catch is exported. The lack of adequate fisheries management, coupled with overcapitalization, subsidies, and illegal, unreported and unregulated fishing has resulted in resource overexploitation (Álvarez & Ross-Salazar, 2010; Trujillo et al., 2012; Wehrtmann & Nielsen-Muñoz, 2009).

The problem with fisheries management and other marine uses in Costa Rica was considered so serious that, in December 2011, ex-president Laura Chinchilla created a special Commission to "diagnose, assess and recommend the necessary adjustments for good marine governance in Costa Rica" (Casa Presidencial, 2011). One of the main results from this process was the recommendation to completely restructure the National Fishery and Aquaculture Institute (Instituto Nacional de Pesca y Acuicultura, or INCOPESCA) (Comisión Presidencial para la Gobernanza Marina, 2012). INCOPESCA's Board of Directors is mostly comprised by members with direct personal interests in commercial fishing and has no representatives from the sport fishing and artisanal fishing sectors, which are sizeable groups in socioeconomic terms. INCOPESCA does not guarantee the public interest (Comisión Presidencial para la Gobernanza Marina, 2012). The biased representation of stakeholders in INCOPESCA's Board creates strong cross-sectoral conflicts and endangers fisheries sustainability and marine

conservation in general (Frente por Nuestros Mares, 2013b; Quesada-Alpízar, 2006). Even though the ex-president's action of creating this Commission showed some political will to tackle these conflicts, INCOPESCA has not been restructured and continues to be highly criticized by local non-government organizations (Frente por Nuestros Mares, 2013b; Jimenez-Ramón, 2015), artisanal fishermen (Torres, 2015), and even the Comptrollers General's office (CGR, 2012, 2014). As a response to overexploitation, some believe that MPAs (discussed below) will provide a safeguard for marine resources.

2. Marine protected areas in Costa Rica

Costa Rica has 31 MPAs, only two of which are offshore in the Pacific. Three MPAs are in the Caribbean and the rest are in the Pacific. All MPAs are managed by the state. The Ministry of Environment manages 23 MPAs through an institution called National Protected Area System (Sistema Nacional de Áreas Conservación, or SINAC). INCOPESCA manages the remaining eight MPAs. In total, these MPAs cover an area of 15 377 km^2, of which approximately 93% is managed by SINAC and the remaining 7% is managed by INCOPESCA (Figure 4). The two offshore MPAs, Cocos Island National Park and Seamounts Marine Management Area, are very large compared to the coastal MPAs, which resulted in steep increments in MPA coverage in 1984 (i.e., Cocos Island National Park) and 2011 (i.e., Seamounts Marine Management Area) (Figure 4).

MPAs managed by SINAC are patrolled by the Coastguard and SINAC, and MPAs managed by INCOPESCA are patrolled by the Coastguard. INCOPESCA has no patrolling mandates but can sanction noncompliance administratively. However, INCOPESCA's fisheries management, including sanctioning processes, is weak. For example, audits done by the Comptroller General found that INCOPESCA has not implemented bag and size limits, and temporary and spatial closures are not science-based (CGR, 2012, 2014). INCOPESCA's mismanagement has

contributed to the impoverished state of fisheries and fishing communities in Costa Rica, sparking multiple calls for intervention and restructuring (Comisión Presidencial para la Gobernanza Marina, 2012; Frente por Nuestros Mares, 2013b).

SINAC's approach has historically been top-down and includes no-take management categories, leading to MPAs that can disenfranchise fishers (Agardy et al., 2003; Solis et al., 2012). Since the mid-1990s, SINAC opted to establish MPAs that would allow fishing and created new, more permissive, management categories in 2008 (Salas et al., 2012). Similarly, also in 2008, INCOPESCA created a type of MPA called 'responsible fishing area', the first of which was created in 2009 (Figure 4). Responsible fishing areas aim for fisheries sustainability and involve a bottom-up approach by which fishing communities propose an area and a management plan to INCOPESCA. Compared with top-down approaches, responsible fishing areas have been generally well-received by several artisanal fishing communities (Fargier et al., 2014). Recent marine conservation efforts in Costa Rica, both from SINAC and INCOPESCA, aim to involve stakeholders in decision-making.

The creation of MPAs began in 1970 and their number has followed a steady growth (Figure 4). Nearly every president has created an MPA or, more commonly, a protected area with marine and terrestrial components. Conversely, the total area covered by MPAs remained relatively constant for more than two decades because of the creation of small MPAs (or marine components of protected areas) (Figure 4). From 1970 to 1983 MPA coverage was below 2000 km^2, then doubled in 1984 and plateaued until 2009 (Figure 4). MPA coverage soared in 2010 and 2011, with the creation of the Golfo Dulce Responsible Fishing Area and the Seamounts Marine Management Area (Figure 4). MPA coverage is likely to increase further because: a) a recent initiative proposes to increase coverage to achieve the United Nations' Convention on

Biological Diversity (CBD) target of 10% (Forever Costa Rica, 2012)—current coverage is 2.6%; and b) responsible fishing areas are being called for by many coastal communities as a response to overexploitation. However, percentage-based conservation targets are inadequate and are criticized for protecting "residual" areas, or those that are politically and socially easy to conserve (Devillers et al., 2015). Additionally, as discussed with more detail in the following chapters, increasing the number and extent of MPAs will not be sufficient to achieve conservation goals if these are not adequately designed and managed (De Santo, 2013; Jameson et al., 2002).

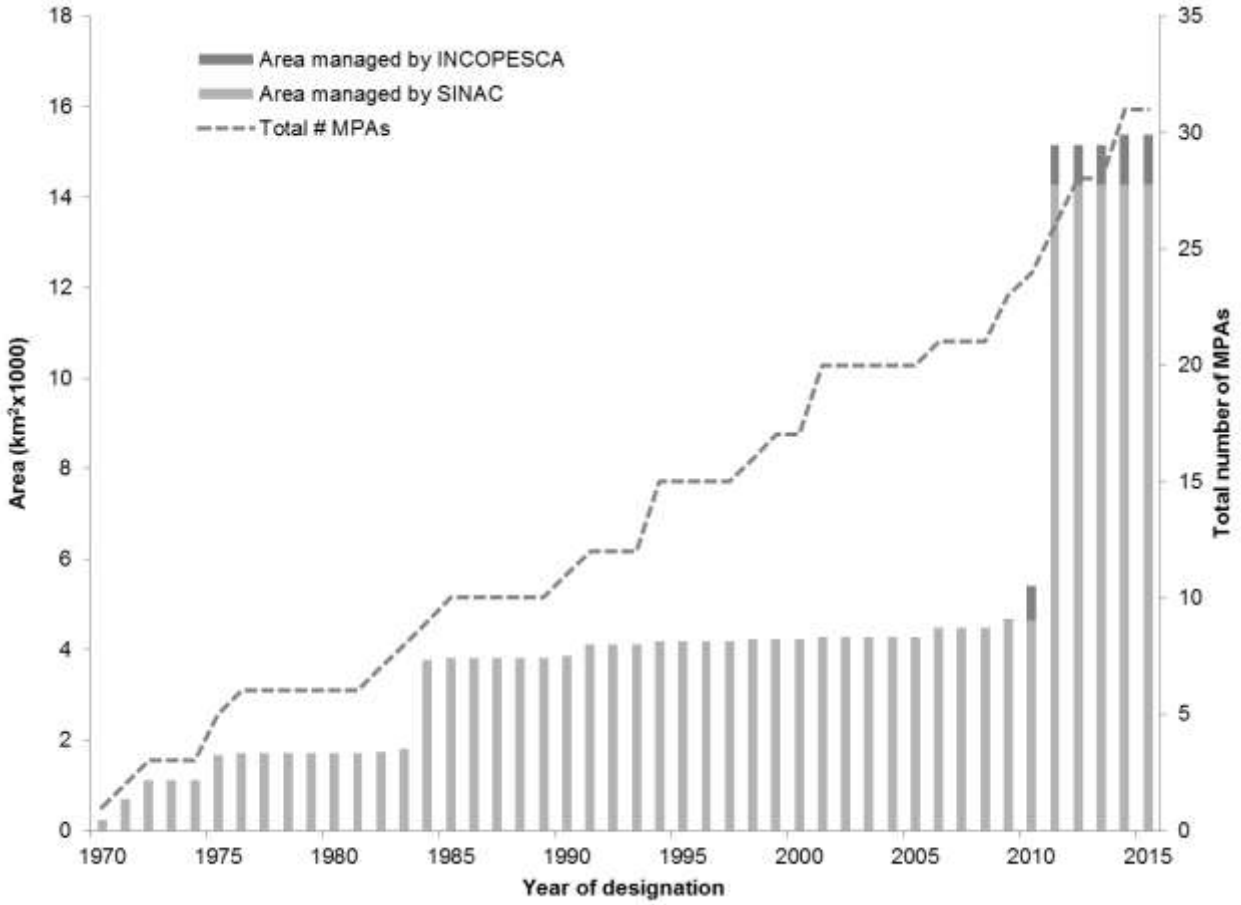


Figure 4. Cumulative growth in the area (bars) and number (dashed line) of MPAs in Costa Rica between 1970 and 2015. Several protected areas in Costa Rica have terrestrial and marine components. If the marine component was added after the terrestrial designation, the data shown here represents the date when the marine component was designated. For example, Cocos Island National Park started as a terrestrial protected area in 1978, and in 1984 it was expanded to include the marine component and hence 1984 is the date considered here. Also, some MPAs have undergone area expansions. The numbers used in this figure represent the current area for each MPA, counted on the date of designation, not at each expansion. The general trends shown here, however, are very similar to the trends that would be observed if the area were represented cumulatively per year of expansion because not all MPAs went through expansions and, when considered as a total, the expansions were not so large that they would alter the general trends shown here. More detailed information about MPA expansions is published in Salas et al. (2012) which I co-authored during my PhD candidature.

2.1 Planning and management of Costa Rican MPAs

The planning and management of terrestrial and marine protected areas in Costa Rica has been marked by a top-down approach—a potential originator of failed conservation efforts around the world (De Santo et al., 2011; Keppel et al., 2012). In Costa Rica, most MPAs entail no-take regimes, so they have displaced some locals by restricting access to marine resources, creating a degree of social antagonism toward the national protected area system (Weitzner & Fonseca-Borrás, 1999). The initial top-down approach and the focus on no-take regimes led to MPAs being seen as threats by some coastal communities and resource users, especially fishermen.

In response to the opposition against protected areas and the restrictions that they represented, the Ministry of Environment created two new MPA categories: "marine reserve" (a misnomer not equivalent to the usual definition) and "marine management area" (Poder Ejecutivo, 2008). The main motivation behind these two categories was that previous categories (e.g., national park and wildlife refuge) were only comparable to IUCN categories I-IV and not to the more permissive, multiple-use, IUCN categories V and VI. Also, unlike previous categories, these were created specifically for MPAs. The new categories allow for multiple-use and are expected to reduce rejection from users. However, the Seamounts Marine Management Area, so far the only MPA created under one of these categories, had no support from the national longliners (Chuprine et al., 2010) and still lacks a management plan because the longliners have blocked it, claiming that they were not included in the decision-making process (Soto, 2013).

The reasons for lack of support for MPAs from the fishing sector are similar to those in other countries, and relate mostly to inadequate stakeholder engagement (Agardy et al., 2011; Christie, 2004) and the economic self-interest of some stakeholders (Ostrom et al., 1999). Even

though some Costa Rican protected areas are known for having positive interactions with local communities (Ferraro & Hanauer, 2014), lack of support for MPAs seems to apply mostly to the fishing sector and areas without a developed tourism industry (Boza, 1993; Weitzner & Fonseca-Borrás, 1999). This problem calls for special attention because a sense of poor legitimacy can trigger noncompliance toward MPA regulations (Christie, 2004; Christie et al., 2002; Kuperan & Sutinen, 1998), which can lead to considerable detrimental effects on conservation efforts (Kritzer, 2004).

In 2009, the same year in which the Ministry of Environment decreed the aforementioned categories, INCOPESCA, after much lobbying from fishing communities, created the 'responsible fishing area' category (INCOPESCA, 2008). Small-scale fishing communities in the Pacific have been receptive of responsible fishing areas, which is reflected in the fast proliferation of this MPA category (compared to those promoted by the Ministry of Environment); there are currently eight responsible fishing areas on the Pacific coast. One of the main factors behind the interest in responsible fishing areas is their potential for dealing with conflict between fishers, specifically through gear restrictions. For example, Palito and Montero, two small fishing communities in Chira Island, had constant conflicts with gillnetters in "their"[5] fishing area. Many of the fishermen in these communities had traditionally used hook and line, whereas some community members and neighbours use gillnets. Gillnets are blamed for much of the overfishing in the Gulf of Nicoya, where this island is located (Marin-Alpizar et al., 2012). After much lobbying with INCOPESCA, Palito-Montero became a responsible fishing area where only handlines are permitted (INCOPESCA, 2009). Gillnets were excluded from the area and

[5] Marine areas in Costa Rica, including beaches, are public. Responsible fishing areas do not create property rights; any fisher who abides by the responsible fishing areas regulations is allowed to fish within these areas.

now fishermen report improved catches and high compliance (Chapter 7).

Responsible fishing areas are treating some conflicts between users (e.g., by legally excluding bottom trawlers and gillnets) and have received support from universities, NGOs and a growing market for sustainably caught fish. Palito-Montero has been widely considered a success and other communities took it as a precedent for starting their own areas. Nevertheless, the long-term sustainability, and 'responsibility', of these MPAs is uncertain because: (a) fisheries management is currently limited to gear regulations; (b) support from INCOPESCA and the Coast Guard is very limited; and (c) the extensive areas outside the MPAs lack management (Marin-Alpizar et al., 2012). Additionally, as revealed by my work, compliance with MPAs (including responsible fishing areas) in Costa Rica is highly variable, and unfortunately some of them are fished illegally nearly every day, likely impeding their effectiveness (Chapter 7).

MPAs require adequate planning and management in order to be effective. The planning of Costa Rican MPAs has been mostly opportunistic and unsystematic. Mario Boza, one of the 'fathers' of Costa Rica's protected area system, mentioned how opportunism reigned through the 1970s to mid-1980s for creating protected areas as a desperate effort for halting environmental degradation—at that time, mainly rampant deforestation (Boza, 1993). It is possible that this opportunism, usually characterised by *ad hoc* conservation actions (Pressey, 1994), has hindered the planning and management of MPAs in Costa Rica and is now a burden on conservation effectiveness. Some examples of this poor planning and management are:

- MPAs under the 'wetland' management category are defined by depth (six meters). This boundary is consistent with the 'wetland' definition given by the Ramsar Convention. However, boundaries given by depth are not fixed in space and time (e.g., tides and

periodic changes in sediment deposits such as sandbars) and pose significant difficulties for users, and managers alike.

- Some no-take MPAs were decreed for the protection of sea turtles (e.g., Marino Las Baulas MPA). These areas face resistance from fishers who, correctly, claim that: 1) not all fishing gear poses a significant threat to sea turtles, and 2) the presence of sea turtles is seasonal.
- The boundaries for several MPAs are not coordinate-based; hence it is difficult to establish their exact location. For example, some MPAs extend from the beach to 12 nautical miles offshore (i.e., territorial waters), forming long and narrow MPAs that do not respond to any social or ecological criteria and are difficult to locate accurately. Also, see Chapter 4 for a more detailed example.

Poorly planned conservation is especially counterproductive when it leads to lost opportunities for creating new MPAs because of an ineffective allocation of area dedicated to conservation (Agardy et al., 2003; Pressey, 1994; Pressey et al., 1993). This is particularly relevant because opportunistic MPAs created in the past may act as barriers for more relevant and better planned MPAs, for example through financial constraints, approaching or exceeding allocation of the total area perceived to be adequate for conservation, and social disapproval toward more area for conservation purposes.

However, not all the MPAs that were poorly planned are necessarily ineffective, and they could still benefit from information and improvement (Noss et al., 2002; Pressey & Bottrill, 2008). For instance, early reviews of MPA effectiveness (Dugan & Davis, 1993; Roberts & Polunin, 1991) showed MPAs providing significant biological responses to protection, although many—or most—of these MPAs were planned without the sound technical and scientific information being used more recently (Roberts,

2000). The use of adaptive management in MPAs has been effective in both developing (Cinner et al., 2006) and developed countries (McCook et al., 2010), and can improve MPAs (Ban et al., 2012). The planning and management of Costa Rica's MPAs has plenty of room to adapt by improving existing MPAs, and, if necessary, creating new and better-informed MPAs.

3. Conclusion

Costa Rica is often recognized for some exceptional accomplishments in its past. The country has a durable history of democracy and peace[6] despite being in a region that has been afflicted by tyranny and civil wars. On the environmental front, Costa Rica also has notable undertakings such as: its clean energy production in which most of the electricity comes from hydro and geothermal power stations; an innovative payment for forest ecosystem services, funded mainly by a 'carbon tax' on fossil fuels; and a comprehensive terrestrial protected area system. However, as described in this Chapter, conservation efforts and institutions are lagging, chiefly in the marine realm which has been historically neglected.

It is evident that the country requires clear policies and stronger institutions that can allow ample stakeholder participation, a balance between sustainable use and preservation, and significant improvements in ports and navigation (Comisión Presidencial para la Gobernanza Marina, 2012; Jimenez-Ramón, 2015; Solis et al., 2012). The current weak governance system can foster noncompliance—for instance through inadequate legislation and enforcement (Arias et al., 2016), or low perceived legitimacy toward management institutions (Levi et al., 2012)—which is very likely to impede conservation initiatives such as MPAs.

[6] Costa Rica is one of the few countries in the world with no army; the army was abolished in 1948 by ex-president José María Figueres Ferrer.

There is reason for optimism, however. Marine systems can be very resilient, failed planning and management actions can be corrected, and there is a clear idea of what needs to be done (Comisión Presidencial para la Gobernanza Marina, 2012; Frente por Nuestros Mares, 2013b). Perhaps a new cycle has started, similar to the one that Boza (1993) described from the early-1970s when rampant deforestation in Costa Rica forced conservationists to react and when later, in the mid-1970s to mid-1980s, conservationists were supported by an impetus of growing interest in conservation from the population and decision makers. Now it is time for Costa Ricans to face the sea. The years of neglect for the seas have taken a toll; it seems that people realize this, and I sense a growing interest in marine conservation amongst the younger generations. The ease of information access and communication are playing a critical role in factors such as awareness, scrutiny, and social protest. One of the overarching goals of the work I will present in the following chapters is to influence policy and stakeholders, with what I hope is relevant science and ideas that can add momentum to this new cycle of marine conservation in Costa Rica.

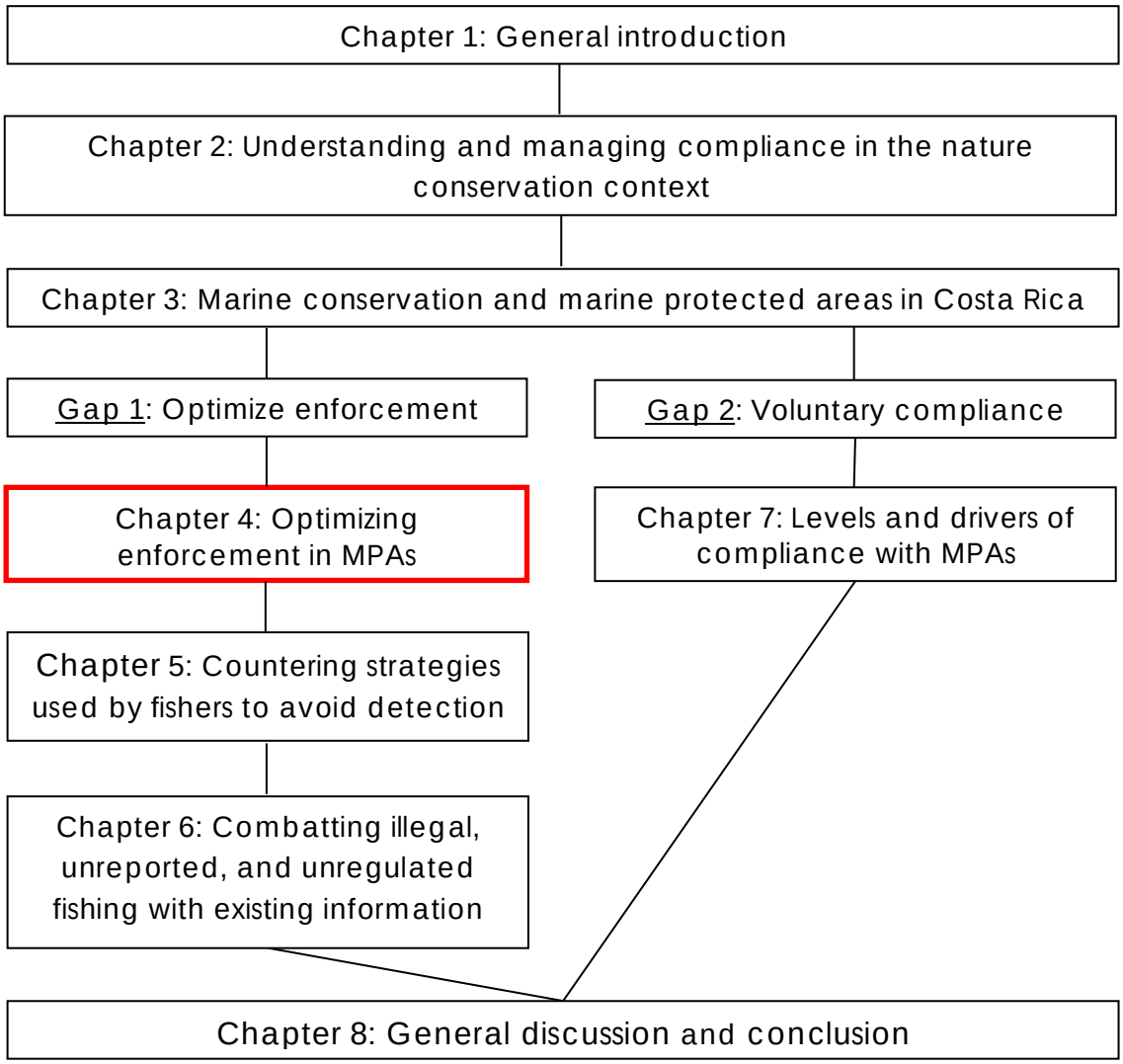
Chapter 4: Compliance with offshore marine protected areas—Optimizing enforcement and compliance in offshore marine protected areas: A case study from Cocos Island[7]

Abstract

Illegal resource exploitation is a cause of environmental degradation worldwide. The effectiveness of conservation initiatives such as marine protected areas relies on users' compliance with regulations. Even though compliance can be motivated by social norms (e.g., peer pressure and legitimacy), some enforcement is commonly necessary. Enforcement is expensive, particularly in areas far from land, but costs can be reduced by optimizing enforcement. I present a case study of Cocos Island National Park, Costa Rica, an offshore protected area and World Heritage Site confronting illegal fishing. By analysing patrol records, I determined the spatial and temporal distribution of illegal fishing and its relationship with patrol effort. Illegal fishing concentrated on a seamount within the Park and peaked during the third year-quarter, most likely due to oceanographic conditions. Additionally, the lunar cycle, in conjunction with time of the year, significantly influenced the occurrence of incursions. The predictability of illegal fishing in space and time allows for the optimization of patrol effort. Repeat offenders are common in the Park, and I suggest that unenforced regulations and weak governance are partially to blame. I provide a series of recommendations for efficiently distributing patrol effort in space and time, establishing adequate governance and policy, and designing marine protected areas to

[7] This Chapter is published as: Arias, A., Pressey, R. L., Jones, R. E., Álvarez-Romero, J., & Cinner, J. E. (2016). Optimizing enforcement and compliance in offshore marine protected areas: A case study from Cocos Island, Costa Rica. *Oryx, 50*(01), 18-26. doi: http://dx.doi.org/10.1017/S0030605314000337
For this Chapter I developed the research questions, obtained and analysed the data, and wrote the paper. Pressey, Cinner and Álvarez provided valuable insight and editorial support. Jones provided assistance with statistical analysis, interpretation of results and the concept for Figure 8. The data was kindly provided by the Cocos Island Marine Conservation Area, the National Coast Guard Service, and MARVIVA.

improve compliance. My methods and recommendations are applicable to a broad range of protected areas and managed natural resources.



1. Introduction

Offshore marine protected areas are an emerging frontier for marine conservation and fisheries management (Game et al., 2009; Graham & McClanahan, 2013). Their effectiveness, as for those near-shore, relies heavily on fishers' compliance (Campbell et al., 2012; Edgar et al., 2014). Even remote locations are not safeguarded from illegal fishing because fishermen can travel long distances to target commercially valuable species (Berkes et al., 2006). For example, Graham et al. (2010) deduced that illegal fishing accounted for the precipitous decrease in sharks around the Chagos Archipelago, a remote area in the Indian Ocean with few residents.

Ensuring compliance offshore is challenging. Patrolling large and distant tracts of ocean is logistically difficult and financially expensive, commonly translating into low detection rates. Additionally, important factors for compliance such as social norms (e.g., peer pressure and legitimacy), and legislation can be absent or lack support offshore. Whilst voluntary compliance is desirable (Arias & Sutton, 2013; Hønneland, 2000; Ostrom, 1990), not all people comply voluntarily. Hence, some degree of enforcement is typically necessary (Hønneland, 2000; Tyler, 1990). However, enforcement is perhaps the most expensive management activity in protected areas—terrestrial and marine (Ban, Adams, Pressey, et al., 2011; Robinson et al., 2010). With limited funds for conservation, optimizing enforcement can make management more cost-effective.

Enforcement is regularly mistaken as only patrolling, but actually encompases detection, arrest/citation, prosecution, and conviction (Akella & Cannon, 2004; Sutinen, 1987); it can be heuristically described as a four-link chain (

). The first link, probability of detection, is mainly technical and field based, relying on factors such as equipment, and number and skills of

wardens. The remaining links—probabilities of: arrest/citation, prosecution, and conviction— tend to rely progressively more on legal and political constructs. The probability of arrest depends partially on field equipment (e.g., a boat's capacity to pursue), but also on what legally constitutes noncompliance and evidence. The probability of prosecution involves the capacity of the legal and institutional system to undertake proceedings against noncompliance, underlining the importance of strong institutions and coordination between them. Conviction, and its associated penalties, rests on the judiciary, and its probability depends on the quality of evidence and the overall capacity of the enforcement system (Akella & Cannon, 2004). Ultimately, the effectiveness of all links is influenced by resources, legislation, and political will.

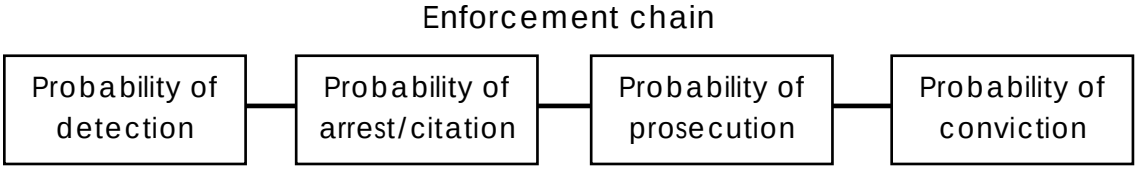


Figure 5. The enforcement chain with its four links (see Akella & Cannon, 2004; Sutinen, 1987)

Recognizing that all links in the chain must be strong for effective enforcement, in this study I focus on the probability of detection. The probability of detection is a key, yet largely unstudied, aspect of natural resource management. To increase the probability of detection, patrol effort must be efficiently distributed; for this, authorities need reliable data on illegal resource use. However, illegal resource use is typically clandestine, posing methodological challenges for data collection (Arias & Sutton, 2013; Gavin et al., 2010). Few methods are suitable to study illegal resource use offshore. Sparse populations and the presence of foreign boats reduce the practicality of social-survey techniques. Modelling, forensics, and remote surveillance are expensive and require high levels of technology and/or training, inhibiting their use in developing

countries. Indirect observations of illegal activity, such as derelict gear, are challenged by currents, depth and extent. However, protected areas typically have enforcement systems that use patrols to deal with illegal resource use, and these patrol records are one of the few options available for assessing illegal resource. This approach has been used in terrestrial protected areas to provide information on factors such as patrol allocation (Leader-Williams et al., 1990), enforcement funding (Hilborn et al., 2006), and levels of poaching (Knapp et al., 2010). Yet the analysis of patrol records remains largely unstudied in marine protected areas (but see: Davis et al., 2004; Mangubhai et al., 2011).

Here I present a case study of Cocos Island National Park (hereafter: Cocos), Costa Rica. I focus on the probability of detection and explore other options for optimizing enforcement and compliance. Cocos shares key characteristics with other offshore marine protected areas, including remoteness, presence of illegal fishing, and difficulty of enforcement. I analyse illegal fishing and patrol effort by using a multi-year data set of patrol records, expert consultation, and literature. I use the concept of the enforcement chain to guide two research questions: 1) How can patrol effort be optimized to match the spatial and temporal distribution of illegal fishing? and 2) What are the key constraints on the subsequent links of the enforcement chain: arrest/citation, prosecution, and conviction? My methodological developments and recommendations aim to contribute to the adaptive planning and management of Cocos and other offshore marine protected areas.

2. Methods

2.1. Study area

Cocos is nearly 500 km southwest of Costa Rica's Pacific Coast (Figure 6). It is a large no-take marine protected area (1989 km^2) created in 1984 (Salas et al., 2012). The only inhabitants of the Island are Park wardens and,

occasionally, Coast Guard staff, researchers and volunteers. The Park is a World Heritage Site and a Ramsar site. Cocos has among the highest fish biomass in the tropics (7.8 tonnes/hectare), notable endemism and globally threatened species (Friedlander et al., 2012). The Park is consequently recognized as a top international dive destination. However, it also attracts fishermen, mostly Costa Rican, targeting fish using surface longlines.

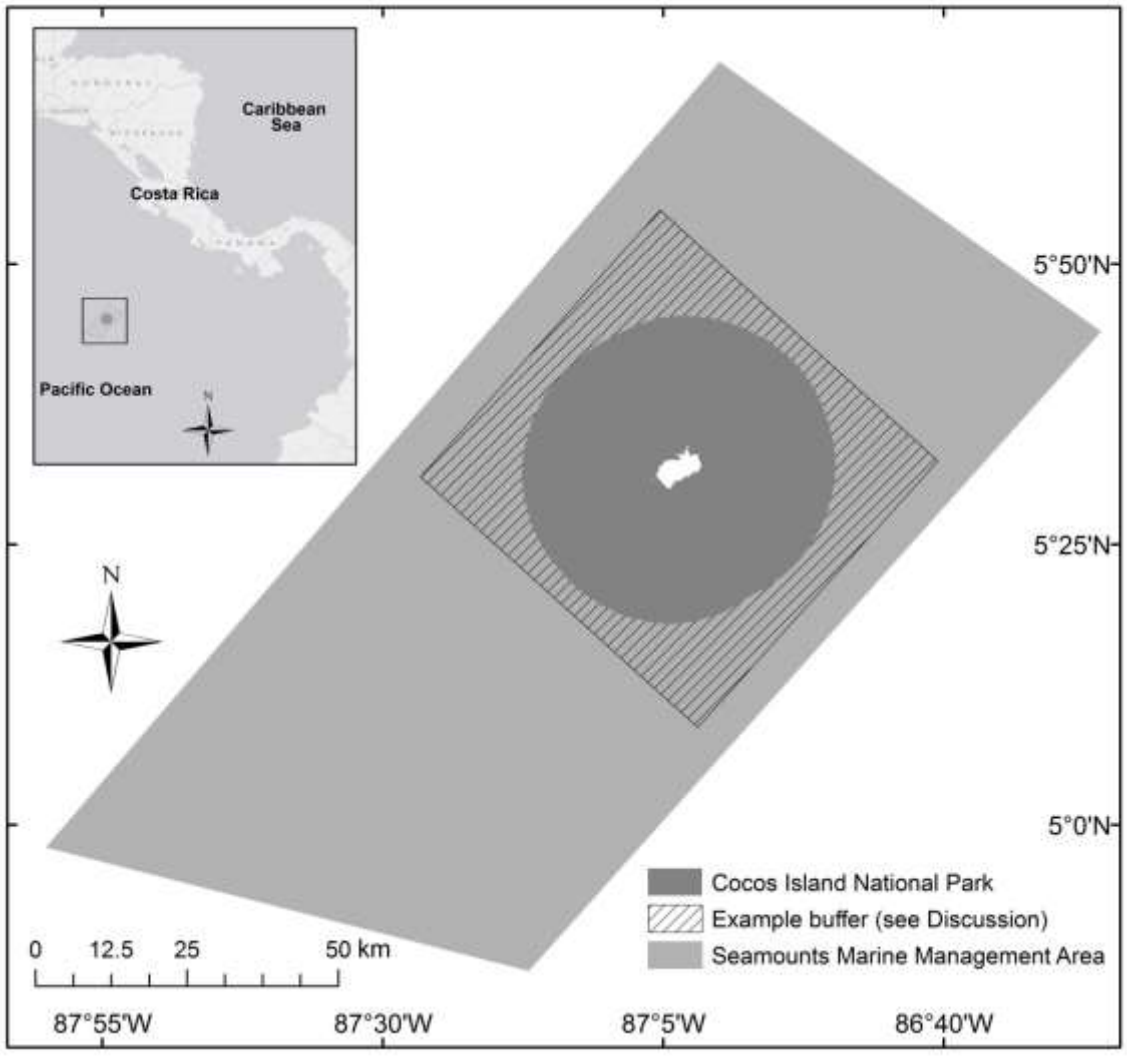


Figure 6. Cocos Island National Park, Costa Rica, and the surrounding Seamounts Marine Management Area. The rectangle on the inset shows location of the main map in relation to mainland Costa Rica.

In 2011 a multiple use marine protected area covering 9640km^2, named Las Gemelas Marine Management Area, was created surrounding Cocos (Figure 6). The main objective of Las Gemelas was to protect seamounts. Bottom trawling and purse seining are prohibited and

longlining is regulated. I focus on Cocos, but also provide recommendations that relate to Las Gemelas.

2.2. Data

I used a 5-year dataset (December 2005 to September 2010) of patrol records from Cocos. Records were taken by Park wardens, the Coast Guard, and MarViva, an NGO that assisted with patrols. The dataset contained information for 1501 patrols and was missing data for November 2007, and July and February 2008. Data were extracted from patrol logbooks detailing hours and nautical miles patrolled, and, if applicable, the confiscation of longlines. I mapped only the initial location of confiscated longlines in the National Park (hereafter: incursions) because final locations were not commonly given. I did not estimate catch per unit effort because soak time—the time a baited hook is available, and an integral component of catch per unit effort (Ward et al., 2004)—was unknown and assumed to be extremely variable.

2.3. Optimizing patrols

To analyse whether and how patrols could be optimized, I first examined illegal fishing in terms of catch, and the spatial and temporal distribution of incursions. I recorded: 1) which fish species were commonly caught; 2) whether incursions were concentrated on specific bathymetric features; and 3) whether incursions prevailed during specific months and lunar phases. The rationale for using months and lunar phases for the temporal analysis was because this data is freely accessible, relatively simple to analyse and the required information (date) was present in the dataset. Additionally, evidence suggests that seasonal variations and lunar cycles can influence fishing activity (Lowry et al., 2007).

Second, I examined the temporal distribution of patrol-days according to months and lunar phases. For these analyses, I grouped all patrols for each day, giving a total of 1078 patrol-days as input. These temporal

analyses made it unnecessary to distinguish between multiple patrols on the same days.

Third, I tested for correlations (r_s) between: 1) nautical miles and hours patrolled, 2) incursions and catch, and 3) hours patrolled and incursions. For the correlations, I used individual patrols, distinguishing between those occurring on the same day.

To explore bathymetry I used the GEBCO_08 Grid, version 20100927 (http://www.gebco.net) and created a three-dimensional chart using Surfer 11 (Golden Software Inc.). Incursions were mapped in ArcMap 10.1 (ESRI Inc.) and analysed for spatial patterns with a Moran's I spatial autocorrelation test (I). I used a 5km distance threshold (mean distance between incursions) within which to consider the spatial relationship between neighbouring records.

I used a logistic regression to examine the effects of time of year (i.e., year-quarters), lunar phases (i.e., lunar-quarters), and their interaction on the probability of a patrol detecting an incursion. Patrol effort was not included in the model because once an illegal incursion was detected, retrieving it considerably reduced further search effort on that day, and exploratory analyses revealed that including patrol effort did not significantly change the model's coefficients. The regressions; therefore examined variations between year- and lunar-quarters in the proportion of patrol-days on which incursions were detected. Because year-quarter and lunar-quarter were categorical variables, the model gave a perfect fit to the data and was used to provide estimates of detection probabilities for each combination of year-quarter and lunar-quarter. Data analysis used SPSS 20 (IBM Corp.) and SPLUS 8 (TIBCO Software Inc.).

To analyse data according to the lunar cycle, I counted the number of days after the new moon (day 0) when an incursion was detected, I refer to these as 'lunar days'. I used moon phase predictions by F. Espenak,

NASA/GSFC (http://eclipse.gsfc.nasa.gov/phase/phasecat.html). I converted lunar days to angles by multiplying each lunar day by 360 and then dividing by 29.53 (number of days in a lunar month). I refer to the phase from new moon to first quarter as 'first quarter', first quarter to full moon as 'second quarter', full moon to third quarter as 'third quarter' and third quarter to new moon as 'last quarter'. Circular histograms were created using Oriana 4 (Kovach Computing Services).

2.4. Constraints on the enforcement chain

To analyse key constraints on arrests/citations, prosecutions and convictions related to incursions in Cocos, I reviewed legislation, newspaper articles, and grey literature, and interviewed five key informants. Key informants had substantial legal and/or practical experience with enforcement in the Park. Interviews were conducted in Spanish; they consisted of open-ended questions about patrols and the legal mechanisms to control illegal fishing.

3. Results

3.1 General characteristics of patrol effort and incursions

Three hundred incursions were recorded within the Park, with nearly 34500 hooks. Approximately 2000 animals were hooked, of which 66% were tuna and 25% were sharks. The most commonly reported species were yellowfin tuna (*Thunnus albacares*) and silky shark (*Carcharhinus falciformis*). Less common species included marlin (Istiophoridae), turtles (Chelonioidea), rays (Batoidea) and dolphins (Delphinidae). Incursions were clustered non-randomly (I=0.301, z=75.18, $p < 0.0005$) northeast of the Park where there is a seamount (Figure 7 b). The seamount has a very steep wall and lies nearly 15 km from the island (Figure 7 b) (Lizano, 2012).

The percentage of patrol-days resulting in the detection of incursions was 20%. Patrols averaged 6.9 hours and 40.3 nautical miles. There was a

positive correlation between the total nautical miles and hours patrolled (r_s (1407) = 0.629, p < 0.0005), and between the total incursions and catch (total number of animals hooked) (r_s (1474) = 0.782, p < 0.0005). Although statistically significant, total hours patrolled were only weakly correlated with total incursions (r_s (1421) = 0.204, p < 0.0005).

Records revealed that illegal fishers used plastic containers and old tires as buoys. Some boats were seen breaching the Park's boundaries repeatedly—and this persisted until more recently (Salas, 2013; SINAC-MINAET, 2012). Using the patrol boat's radar, wardens frequently detected multiple fishing boats, some within the Park and others close to the boundary; those within the Park would flee when seeing the patrol boat. It was common for boats not to stop when requested, with insults and threats occasionally directed to wardens by radio. Threats have also been reported more recently (Rojas, 2013). Illegal fishers have reportedly been trolling (Salas, 2013), using currents to drift their gear in and out Cocos, fishing when dark, and painting buoys with low-contrast colours (SINAC-MINAET, 2012).

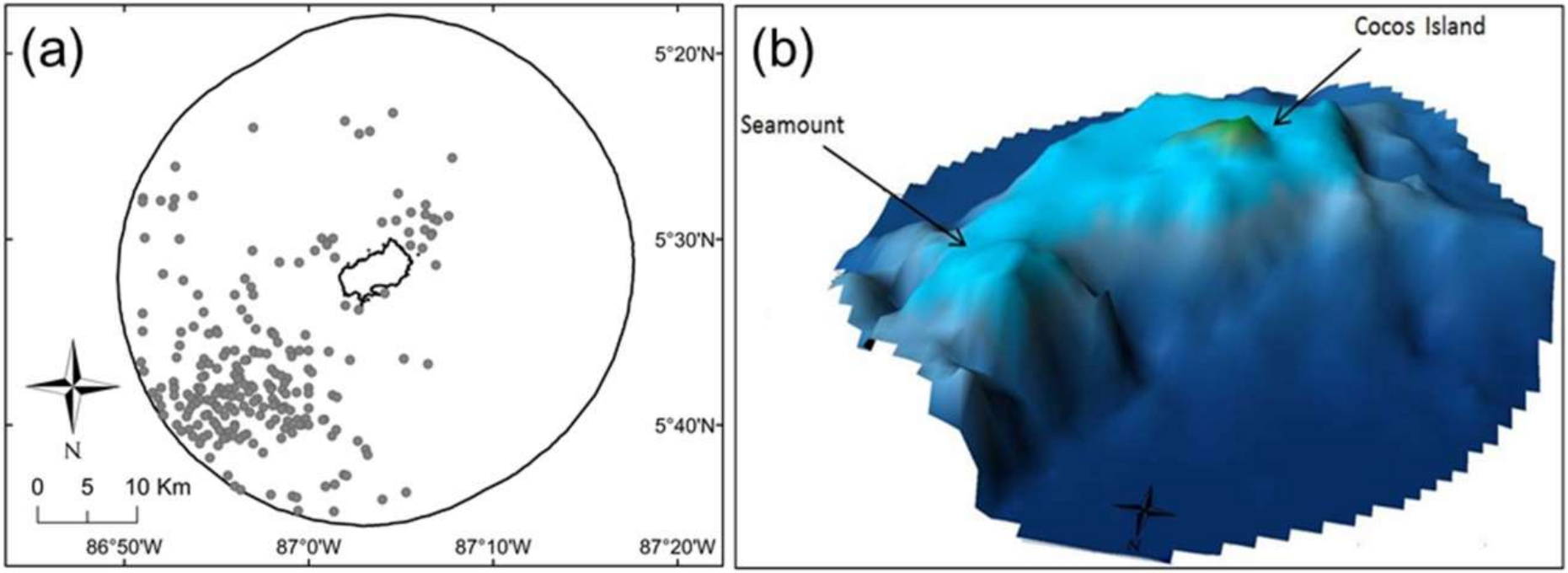


Figure 7. (a) Locations of recorded incursions in Cocos Island National Park, Costa Rica. (b) Bathymetric profile of the Park. The black circle in (a) and the 3D area in (b) represent the Park. Note that north–south orientation has been inverted in both (a) and (b) to show the steep walls of the seamount in (b).

3.2 Temporal distribution of patrol effort and incursions

Time of year and its interaction with lunar phase significantly influenced the probability of encountering incursions (Table 2). The probability of finding incursions increased during the third year-quarter, with higher probabilities during the first and last lunar-quarters at this time of year (Figure 8).

Table 2. Analysis of deviance for the binary logistic regression. Year quarter, lunar quarters and their interaction were tested as predictors of illegal incursions.

	Df	Deviance	Residual Df	Residual Deviance	Pr (Chi)
NULL			1077	1068.8	
Year quarter	3	20.9	1074	1047.8	0.0001
Lunar quarter	3	5.4	1071	1042.4	0.1416
Year quarter: Lunar quarter interaction	9	18.4	1062	1023.9	0.0305

Incursions peaked during the third year-quarter (Figure 8 and Figure 9 a), with the maximum in August (Figure 9 a). Patrols hours were more evenly distributed throughout the year than incursions (Figure 9 b). Incursions peaked during the first lunar-quarter (Figure 9 c). Patrol hours were higher during the second and third lunar-quarters (Figure 9 d).

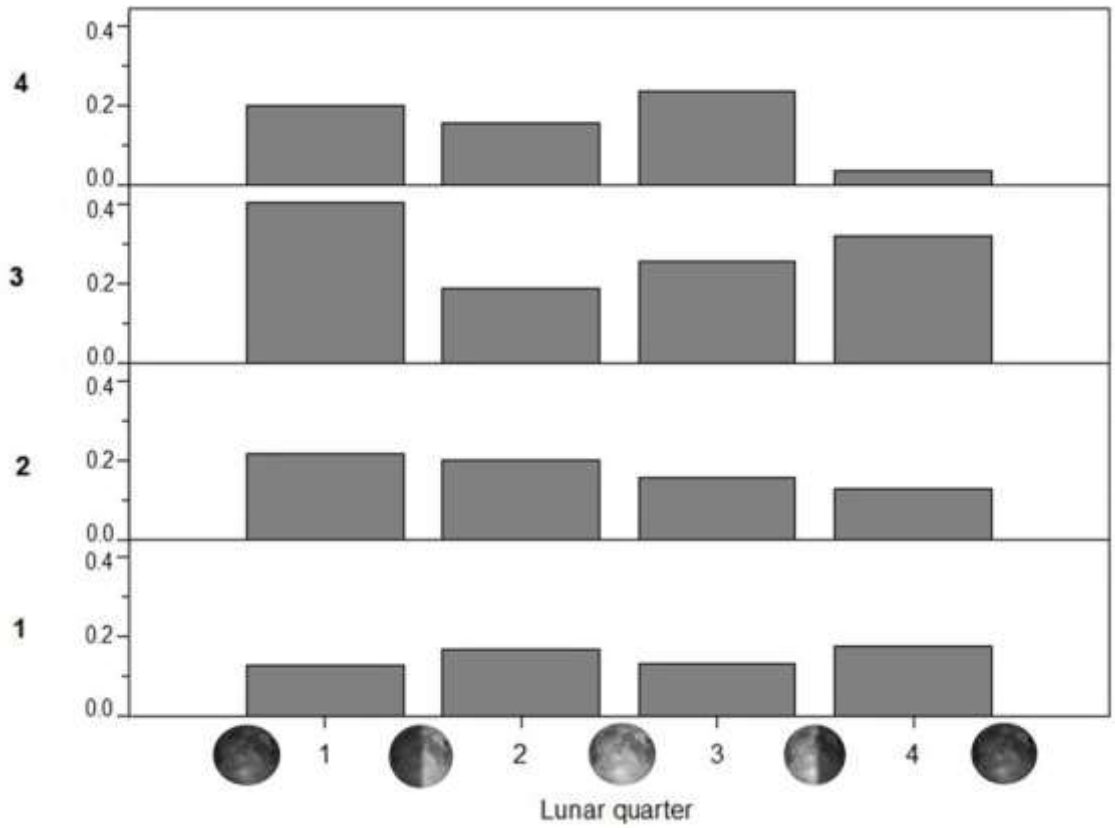


Figure 8. Predictions of probability of encountering incursions within Cocos Island National Park. Predictors are year-quarters (rows) and lunar-quarters (columns). Probabilities are given on the vertical axis.

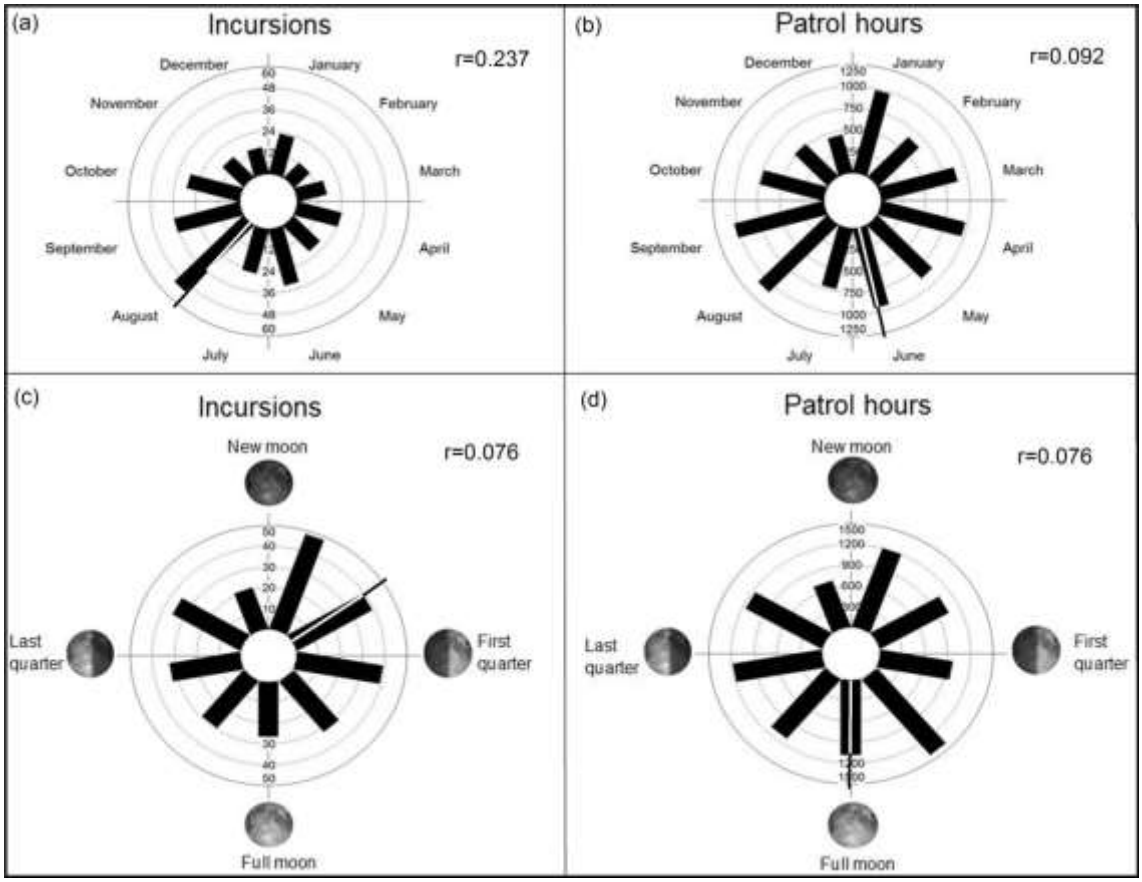


Figure 9. Temporal distribution of incursions and patrol effort in Cocos Island National Park. (a) Incursions by month; (b) patrol hours by month; (c) incursions by lunar cycle; (d) patrol hours by lunar cycle. Bars indicate frequencies. Labels on vertical lines represent number of recorded incursions or hours of enforcement. The radial line on each graph shows the location of the mean value. The length of the mean vector (r), a measure of variance (range 0–1), is given in the top right of each graph; larger values indicate that observations are grouped closer to the mean.

3.3 Key constraints on the probabilities of arrest/citation, prosecution and conviction

The management and conservation of marine resources in Costa Rica relies on the fisheries authority and the Environment Ministry. In 2011, the President created a commission to "diagnose, assess and recommend the necessary adjustments for good marine governance in Costa Rica" (Casa Presidencial, 2011). The Commission recommended a complete review and restructuring of the fisheries authority (Comisión Presidencial para la Gobernanza Marina, 2012), this was backed by environmental groups (Frente por Nuestros Mares, 2013a) and the Comptroller General

(CGR, 2012). There is a conflict of interests within the fisheries authority: most of the Board members are representatives of the fishing industry (Quesada-Alpízar, 2006).

Probabilities of arrest or citation are low. Although only authorized vessels are allowed to enter the Park (Poder Ejecutivo, 2012), this rule is commonly flouted and is difficult to enforce. When illegal boats are setting or retrieving gear and detect a patrol boat, they cut the line and flee to avoid charges of illegal fishing (Costa Rica does not mandate gear identification). Unless wardens can intercept fleeing boats, arrests/citations are impossible. Wardens then must remove the abandoned fishing gear from the Park. If a boat is intercepted, it is given a written and verbal notification stating the illegality of entering the Park. If the same boat is intercepted again within the Park, it is processed for "disobedience to authority" for which the captain could face a jail sentence.

Even after arrest or citation, the probability of prosecution is very limited. Most illegal fishing boats found in the Park lack the legal autonomy to travel safely further than 40 nautical miles (approximately 74km) from the coast. But noncompliance with this regulation goes unsanctioned. Actually, several illegal fishing boats receive subsidized fuel granted by the fisheries authority (Delgado, 2012), allowing them to reach these distant waters at a lower cost. To circumvent the limitations of administrative sanctions by the fisheries authority, the Park's management goes through the judicial system. Nonetheless, prosecutions can be delayed by more than eight years because of inefficiencies within the judicial system.

At the end of the enforcement chain, convictions are rare and faint. To date, no longline boat or captain has been convicted with severe sanctions (e.g., jail sentences or boat confiscations) for fishing illegally or entering the Park, although one boat has accumulated more than 10

lawsuits for "disobedience to authority". From December 2010 to March 2013, from six concluded prosecutions, three cases were dismissed and three ended in conviction. All convictions, however, ended in probation for the captains.

4. Discussion

In Cocos, illegal fishing is a considerable threat to some marine species, with a targeted location and time, and repeat offenders usually go unpunished. I use my findings to consider the following key factors for optimizing enforcement and compliance.

4.1 Increasing the probability of detection

Illegal fishers focused efforts on a seamount within the Park (Figure 6). The concentration of incursions on this seamount is consistent with the aggregations and elevated presence of predators expected on seamounts (Morato et al., 2010). Studies report derelict fishing gear and low densities of groupers at seamounts outside the Park (Starr et al., 2012), and declines in shark abundance inside the Park (Friedlander et al., 2012). Fishing pressure is significant around and within Cocos, and detracts from the Park's ecological integrity.

The higher incidence of illegal fishing during the third year-quarter (Figure 8 and Figure 9a) could be driven by oceanographic variables. For example, seasonal variations in mixed layer depth (Fiedler & Talley, 2006) can affect the distribution and catchability of yellowfin tuna (Song et al., 2008), potentially bringing fishermen further from the coast and closer to Cocos. Fishermen commonly benefit from finding oceanographic features such as upwellings with remote sensing technology (SPC, 2011), so managers could also exploit these tools to improve the probability of detection. Remotely-sensed data, however, also increases the technical difficulty of analyses—possibly hindering their usage where expertise and/or funding are limited. The lunar and bathymetric data that I used

are freely accessible and relatively easy to explore and analyse when compared to remotely-sensed data on dynamic oceanographic features. Simple and effective methods for analysing patrol records can foster replication.

An effect of lunar cycles on fish behaviour and catchability has long been known by fishermen (Parrish, 1999). The variability of illegal fishing activity around the lunar phases agrees with other studies. Lowry et al. (2007) reported peak catch of several predators, including yellowfin tuna, during the first lunar-quarter. Reduced light around the new moon could drive both prey and predator closer to the surface (Blaxter, 1974), potentially increasing catchability with surface longlines. Additionally, reduced light might favour illegal boats by lowering the probability of detection. Because time of the year and lunar cycle can affect fish catchability, and because incursions can be masked by lower visibility, it is reasonable to expect the observed temporal patterns of incursions.

My analysis of monthly trends and the lunar cycle suggests that patrols can be optimized by matching incursions more closely (Figure 9), thereby increasing deterrence when most needed and reducing management costs by cutting unnecessary effort. However, while natural variables can explain incursions fluctuating inter- and intra-monthly, fluctuations can also be influenced by patrol effort. If fishers believe that detection is unlikely at a given time, their motivations for noncompliance could increase then and vice versa. Managers can adapt to such variations by monitoring patrol records periodically and systematically to develop approaches that maximize the probability of detection.

4.2 The role of marine protected area design in compliance

The spatial design of marine protected areas plays an important role in compliance. An example of this is the Great Barrier Reef Marine Park, Australia, with simple and easily-identifiable boundaries to provide clarity

for both users and wardens (Day et al., 2012). In contrast, the boundary at Cocos is defined by 12 nautical mile radius (Figure 6). The boundary, represented by the territorial sea, poses problems for compliance and enforcement. The boundary is somewhat irregular because of the Island's shape, so it is difficult to identify accurately in the field. The boundary can therefore confuse fishermen and wardens. While it would be difficult politically to modify the Park's boundary, a feasible alternative would be to zone *Las Gemelas* to create a simple polygonal buffer zone around the Park (Figure 6). The buffer could serve three purposes: facilitating navigation; excluding longlining farther from the Park; and reducing the boundary effect. Fishing effort can concentrate on boundaries (Kellner et al., 2007) and illegal fishing is likely to occur near boundaries because of accidental incursions or deliberate ones facilitated by easier entry and exit (Gribble & Robertson, 1998). For a given shape, the boundary effect is amplified in smaller marine protected areas because of larger perimeter:area ratios (Kritzer, 2004), but buffers reduce this effect by reducing the perimeter per unit area. The hypothetical buffer in Figure 6 has, approximately, a 0.066:1 perimeter:area ratio, compared to 0.079:1 for the nearly-circular Park.

4.3 Constraints in subsequent links of the enforcement chain

For Cocos, the probability of detection, although needing improvement, is apparently stronger than the subsequent links of the enforcement chain. The main reason for weaknesses in the three subsequent parts of the chain is an ineffective legal and governance base. Boats continuously enter the Park, sometimes employing techniques to avoid detection. This suggests that some illegal fishing goes undetected and that the thousands of illegal hooks that I report are probably underestimates. When illegal fishers lose their gear to wardens, their economic losses are minimized by selecting cheap gear, and are potentially offset by the high market prices for tuna and shark fins [finning

has been reported in Cocos (Delgado, 2012)]. Seemingly, in Cocos the potential gains of illegal fishing surpass the potential costs of getting caught. This also applies internationally, particularly when dealing with high-valued catch (Sumaila et al., 2006).

By hypothesizing that the probabilities of detection, arrest, prosecution, and conviction were each 50%, the cumulative probability of being penalized would be 6.25% (Table 3, Case 1). Unfortunately the real values for each link at Cocos and other offshore marine protected areas are likely to be lower than 50%. With 20% of patrol-days resulting in detection of incursions in Cocos, it can be assumed that the overall probability of detecting incursions is lower. Some incursions are not detected because they go unseen during patrols and/or occur on days with no patrols. Importantly, as values for any one link approach zero, overall enforcement becomes practically ineffectual (Table 3, Case 2), and weak links undermine the investments in and success stronger ones (Table 3, Cases 2 and 3). Having accurate probabilities for such analysis requires systematic record keeping for each link and/or values estimated through social surveys (Akella & Cannon, 2004).

Table 3. Cumulative probability of illegal fishers in Cocos being penalized, given various hypothetical probabilities at each of the four links of the enforcement chain.

	Probability of detection	Probability of arrest/citation	Probability of prosecution	Probability of conviction	Cumulative probability of penalization
Case 1	50%	50%	50%	50%	6.25%
Case 2	90%	90%	5%	90%	3.65%
Case 3	90%	50%	50%	50%	11.25%

Perhaps the main gain from enforcement at Cocos has been avoiding rampant illegal fishing through the partial deterrence offered by patrols. Nevertheless, this is a limited approach that is failing to achieve strong compliance. Whilst technology (e.g., vessel monitoring systems and radar) can increase the probability of detection and reduce management costs

by directing patrols, deterrence remains low if other links are weak. Offshore marine protected areas require clear and enforceable regulations, applicable at sea and in ports (port state measures: inspections, vessel blacklists, etc.). Field staff, prosecutors and judges must be trained in environmental and marine law (Akella & Cannon, 2004). The institutions managing compliance must collaborate and adapt to change (Hauck & Kroese, 2006). Penalties must counter the illegal gains from highly valued catch and include loss of privileges (Robinson et al., 2010), such as loss of access to the *Las Gemelas* (Figure 6). A useful system in which to nest penalties is graduated sanctions (Ostrom, 1990), varying sanctions according to the number and/or severity of violations (for detail see Russell, 1990).

5. Conclusion

This study reflects on the enforcement challenges faced by offshore marine protected areas. While the enforcement system at Cocos has deficiencies, it still manages to fend off rampant noncompliance. The same, however, might not apply to other marine protected areas. A systematic and periodic analysis of patrol records, such as the one I presented, can help optimize enforcement. My case study highlights how clear and enforceable regulations, coupled with strong institutions can help optimize enforcement. This applies also for areas beyond national jurisdiction (high seas), where, because of legal and governance weaknesses, additional national, regional, and international efforts are needed to ensure adequate enforcement (Gjerde et al., 2013). Enforcement is a tool to encourage compliance, a means to an end; and other tools such as social norms should also be exploited. In the process of achieving international objectives for marine conservation [e.g., effectively conserve ≥10% of coastal and marine areas by 2020 (CBD, 2010)], and with increasing pressure on global marine resources, compliance is vital. Failing to maintain compliance seriously undermines

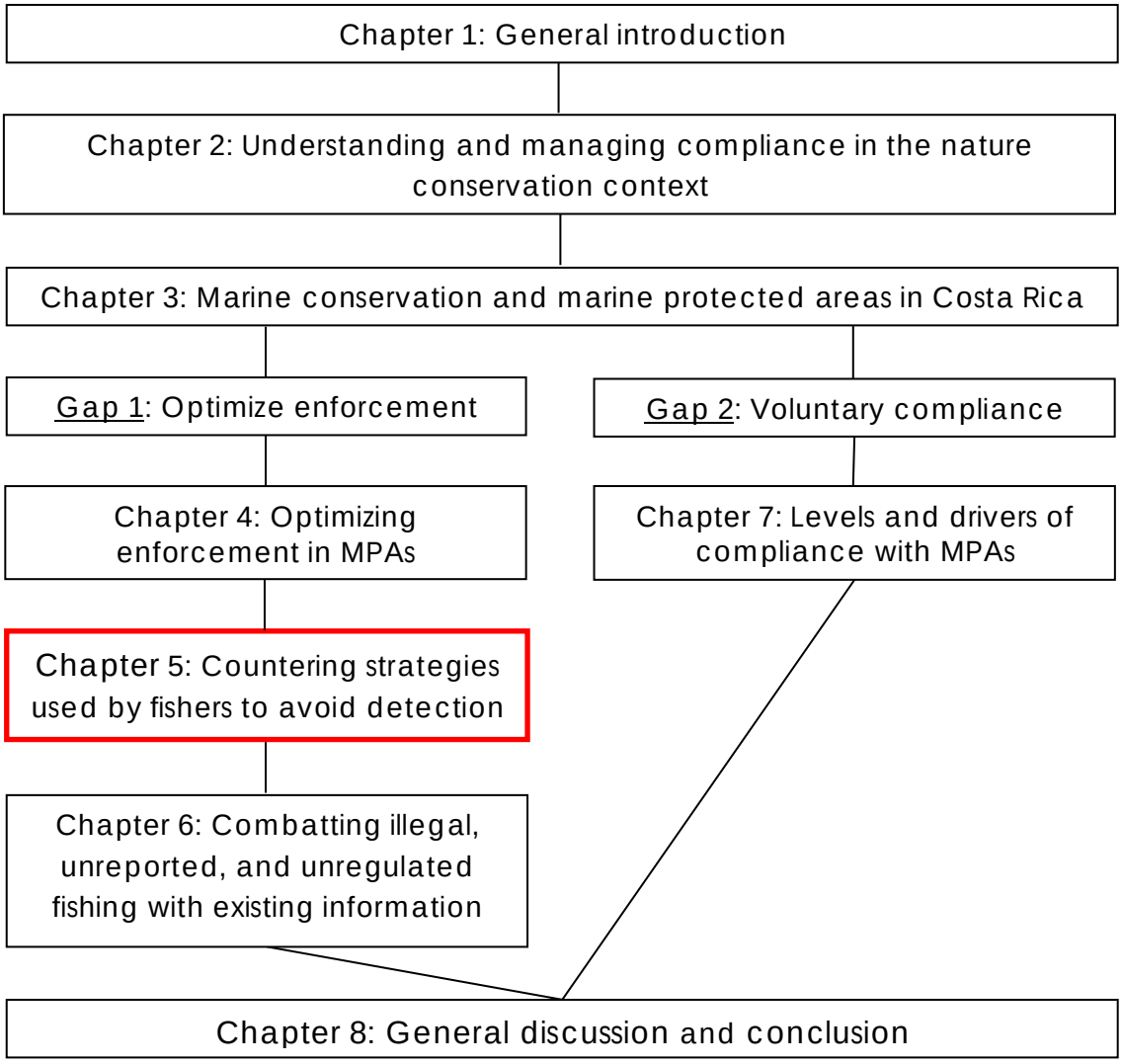
the conservation benefits expected from effective marine protected areas and leads to metrics, such as the extent of marine protected areas, not reflecting actual outcomes for marine conservation.

Chapter 5: Countering strategies used by fishers to avoid detection[8]

Abstract

Illegal fishing is challenging to enforce at sea, mainly because patrols are expensive, and the chances of detecting of illegal fishing are small. If noncompliant fishers avoid being detected by wardens, they can benefit from increased catch and income compared to compliant fishers. In order to reduce the likelihood of getting caught, noncompliant fishers can adopt detection-avoidance strategies (e.g., having secret compartments to hide illegal catch). Detection-avoidance strategies are common in nature conservation, yet they remain largely unstudied and are scarcely addressed in the peer-reviewed literature. This Chapter has three main sections. First, I discuss detection-avoidance strategies in the broader conservation context. In this first section I introduce detection-avoidance strategies, and I hypothesize the likelihood of their adoption by resource users. Second, I present and categorize a series of detection-avoidance strategies used by small-scale fishermen in Costa Rica. I categorize these strategies as, concealment, and information and communication. And third, I provide recommendations for countering detection-avoidance strategies. Countermeasures respond to particular contexts, and they should be informed through systematic processes for managing information such as the intelligence cycle. I emphasize enforcement activities can also help build a broad base of voluntary compliance, particularly through procedural justice, or behaving in a way that resource users perceive as fair and just.

[8] This Chapter is a work in progress and has not yet been submitted for peer-review. Brock Bergseth, Damian Weekers, and Robert Pressey are co-authors in this manuscript. For this Chapter I collected the information, I developed the concept, and wrote the manuscript. Bergseth, Weekers and Pressey have provided editorial support. Pressey suggested the development of Figure 10. Weekers made Figure 11.


Chapter 1: General introduction
Chapter 2: Understanding and managing compliance in the nature conservation context
Chapter 3: Marine conservation and marine protected areas in Costa Rica
Gap 1: Optimize enforcement
Gap 2: Voluntary compliance
Chapter 4: Optimizing enforcement in MPAs
Chapter 7: Levels and drivers of compliance with MPAs
Chapter 5: Countering strategies used by fishers to avoid detection
Chapter 6: Combatting illegal, unreported, and unregulated fishing with existing information
Chapter 8: General discussion and conclusion

1. Introduction

Coastal fisheries provide food and livelihoods that are vital to millions of people in many of the world's developing countries. More than 90% of the world's fishermen work in the small-scale sector, and most of their total catch comes from coasts (Mills et al., 2011). However, nearly 90% of the world's fisheries have been driven to or beyond their sustainable limits (FAO, 2014). Furthermore, fishers can also mask signals of exploitation by increasing fishing effort (Cinner, 2011), and shifting to new fishing grounds (Morato et al., 2006; Roberts, 2010). Thus, overexploitation is a vicious cycle that is often self-perpetuating. For example, when fishermen start catching less fish with hook and line, they can transition to nets, and when catch with those nets decreases, they can use nets with a smaller mesh. In each transition, fishermen can catch more fish, but also more species and smaller fish, including bycatch. These actions generally create negative ecological effects and ultimately result in fishers moving themselves further down the socioeconomic slope (Brashares et al., 2014; Cinner, 2011). In addition, fishers' efforts to maintain yields in the face of declining resources can also lead to illegal fishing (Brashares et al., 2014; Peterson & Stead, 2011). While the solutions to overexploitation and noncompliance are often very complex and require context specific management interventions (Arias et al., 2015; Petrossian, 2014), most approaches need rule enforcement.

It is well established that the management of compliance must not be solely dependent on enforcement. Research has increasingly documented the importance of diverse factors for rule compliance, which include the consideration of livelihoods, and norms, whether personal or social (Arias, 2015; Challender & MacMillan, 2014; Milner-Gulland & Rowcliffe, 2007; Peterson & Stead, 2011). Additionally, emphasis must be placed on achieving voluntary compliance, which I define as people complying as an act of approval with norms and institutions, rather

than to avoid the penalties associated with enforcement (Chapter 2). Whilst voluntary compliance is important, enforcement is necessary for dealing with people who knowingly or repeatedly break rules. This is because it demonstrates that noncompliance is punishable, and discourages further noncompliance while signalling administrative competence (Chapter 2). However, enforcement is often simplistically equated to the conduct of patrols. This is a simplistic explanation, because, as discussed in Chapter 4, enforcement is best described as a chain of four links: the probability of detection, the probability of arrest/citation given detection, the probability of prosecution given arrest/citation, and the probability of conviction given prosecution (Akella & Cannon, 2004; Arias et al., 2016; Sutinen, 1987). Effective enforcement therefore relies on strong links between the policies, processes, systems and people in each category, whereas weakness in any link can undermine the entire chain. In this Chapter, I focus on the probability of detection, and the techniques that small-scale fishers use to avoid being detected while fishing illegally.

The probability of detection has two aspects: perceived and real probabilities. The perceived probability of detection is that which actors believe to occur. This can be estimated through social surveys (Arias et al., 2015; Arias & Sutton, 2013; King & Sutinen, 2010). The real probability of detection is defined as the number of illegal acts detected compared to the total number of illegal acts. The real probability of detection is difficult to determine because of the clandestine nature of these illegal acts, and often leads to underestimations of the prevalence of illegal behaviours. For example, on land, authors have estimated very low probabilities of detecting poaching activities, below 4% (Eliason, 1999). In fisheries, the real probability of detection is considered to be extremely low, even below 1% (Kuperan & Sutinen, 1998; Sutinen et al., 1990). In some cases (e.g. exclusion areas), technology such as radar could allow detection of all incursions where it is illegal to even enter a closed area. However,

detecting illegal fishing is typically more complex than patrolling a no-go area, because illegal fishing can involve noncompliance with multiple factors such as quotas, size limits, zoning, and gear regulations. Hence, it is generally easier and more practical to estimate the perceived probability of detection than the real probability of detection.

Fishermen are usually more likely to comply if they perceive a high likelihood of getting caught while fishing illegally. Accordingly, a high perceived probability of detection, even if the real probability is low, can have a strong deterrent effect (Furlong, 1991; Leader-Williams & Milner-Gulland, 1993). There are numerous ways that managers can influence fishers' perceived probability of detection, such as publicizing enforcement actions such as arrests and prosecutions, and increasing the real probability of detection. The ability of managers to influence the probabilities of detection is also dependent on the availability of resources and their understanding of the compliance problem. An understanding of the compliance problem can better guide the decision-making process (Chapter 2), inform legislators, and help strengthen regulations that support the enforcement chain (Pires & Moreto, 2011).

Managers can increase the real probability of detection through patrol effort (e.g., distance and time covered) and patrol effectiveness. Fishing, for example, is unlikely to be random in space and time, so the chances of detecting noncompliance would increase if managers understand the spatial and temporal distribution of fishing effort. As discussed in Chapter 4, in Cocos Island National Park most illegal fishing occurred on a seamount within the Park during specific times (i.e., quarter of the year and lunar phase). However, fishers can also employ counter-surveillance strategies that reduce the probability of being detected by wardens (hereafter: detection-avoidance strategies). Again drawing on the Cocos case, fishermen can paint their buoys with low contrast colours, and fish mainly at night and when the moon is dark (Figure 9). Therefore,

the effectiveness of patrols, and hence the probability of detection, depends not only on allocating patrols adequately through space and time, but also on knowing and countering detection-avoidance strategies.

Effective enforcement planning grounded in data analysis and creative problem solving can address specific matters associated with illegal fishing (Petrossian, 2014; Wortley & Mazerolle, 2011). Enforcement planning can increase the effort and mitigate the risks associated with the illegal activity, potentially influencing the perceived probability of detection and ultimately the decisions of fishers to offend (Clarke, 2011). This is particularly so in the Great Barrier Reef Marine Park, Australia, where managers use intelligence to inform enforcement decisions for targeting illegal fishing. Intelligence refers to the "collation, analysis and dissemination of information" (ICCWC, 2012, p. 80). Thus, planned patrols consider the risk calculations made by fishers when presented with an opportunity to fish illegally (e.g., in a no-fishing zone). If fishers perceive that the risk of being detected in a no-fishing zone is low at first light, then managers conduct early morning patrol effort targeting specific areas and vessels. Regardless of the amount of noncompliance detected during such patrols, the presence of a patrol boat should alter fishers' future risk calculation as the perceived probability of detection increases. Importantly, such an approach relies on understanding fishers' actions. This understanding can be gained through intelligence, which, as I discuss below, can be applied to detection-avoidance strategies.

2. Detection-avoidance strategies

Detection-avoidance strategies are common in the context of nature conservation, yet they remain largely unstudied and are scarcely addressed in the peer-reviewed literature. In the illegal wildlife trade, smugglers conceal or disguise wildlife and wildlife by-products as inconspicuous objects (e.g., ivory worked to look as wood or marble)

(Rosen & Smith, 2010). In Australia, fisheries officers report that fishermen use numerous strategies to avoid detection, such as hidden compartments for illegal catch in boats and cars, employing lookouts, having some degree of knowledge of patrol movements, and mixing legal with illegal catch (Putt & Nelson, 2009). In larger scale fisheries, detection-avoidance has been well-documented. For example, under the United National Law of the Sea, Flag States must ensure that boats flying their flags comply with international regulations (particularly when they fish in areas beyond national jurisdiction or the high seas). However, there are "flags of convenience" which is when vessels boats pay a fee to fly a flag of a country that has very little to no control over its flagged boats. Some countries, such as Belize and Honduras, facilitate these flags in a way that noncompliant fishing boats can avoid detection by very quickly and frequently changing flags and therefore their identities (High Seas Task Force, 2006). Other detection-avoidance strategies used by the larger boats include changing names, providing false information and documents to authorities, having multiple log books, and changing the ownership structure of boats (High Seas Task Force, 2006). By avoiding detection, noncompliers evade costs, such as arrests and fines, and can therefore maximize their benefits. The level of organization and sophistication in detection-avoidance strategies is diverse, and expected to be proportionate to the perceived probability of detection; this determines the costs of each strategy.

Detection-avoidance strategies range from high cost, to being relatively inexpensive. An inexpensive strategy could be learning about patrol movements, whereas a costly strategy could be investing in or modifying gear (e.g., painting boats and gear with low contrast colors). If avoidance is costly, either because of the potential costs of being detected (e.g., fines) or by the cost of the strategy itself, the likelihood of fishers adopting detection-avoidance strategies is expected to decrease (Figure 10 a) (Anderson, 1989). Nevertheless, additional elements can also

influence the likelihood of fishers adopting detection-avoidance strategies. The cost of avoidance would likely be weighed against the profitability expected from using detection-avoidance strategies: the higher the profits expected from using detection-avoidance strategies, the higher the likelihood of adopting these strategies (Figure 10 b). The perceived probability of detection can also affect the likelihood of adopting detection-avoidance strategies (Figure 10 c). Fishers would be unlikely to adopt detection-avoidance strategies, especially high cost strategies, if the perceived probability of detection were extremely low or null. However, the adoption rate of avoidance strategies would likely increase rapidly with low perceived probabilities of detection, peak at intermediate to high perceived probabilities of detection, and then diminish with a perception of very high probabilities of detection (Figure 10 c). The overall level of illegal fishing would be expected to decrease as the perceived probabilities of detection increase (Figure 10 c). Therefore, the likelihood of fishers adopting detection-avoidance strategies could be expected to decrease when: a) the profits expected from using the detection–avoidance strategy are low, b) the costs of adopting the detection–avoidance strategy are high, and c) the perceived probability of detection is either extremely low or extremely high. I assume that the general trends shown in Figure 10 are true. However, I do not have the data to determine the shapes of the curves and, to my knowledge, these relationships have not been explored empirically in the conservation or fisheries literature.

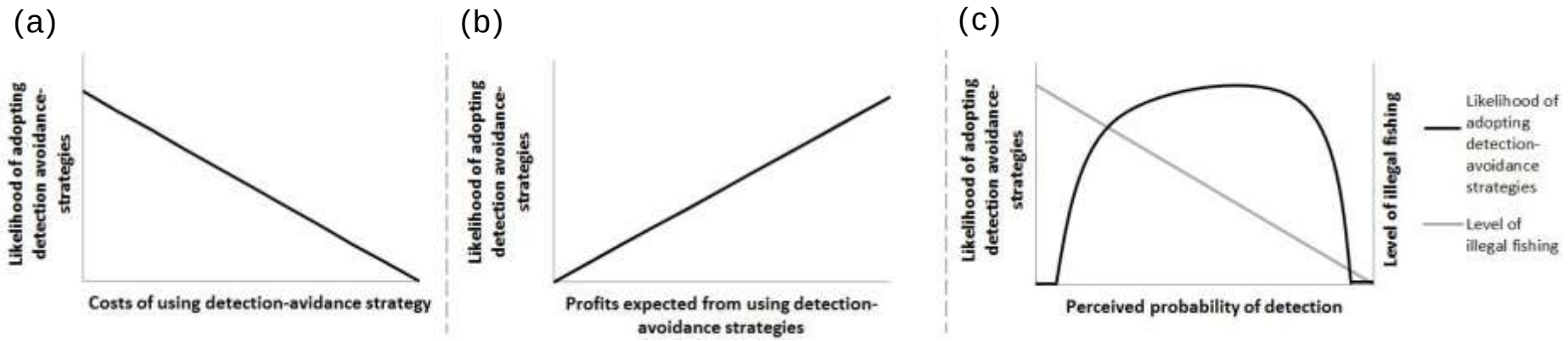


Figure 10. Hypothesized likelihoods of adopting detection-avoidance strategies, based on three key interacting factors: (a) the costs of using detection-avoidance strategies; (b) the profits expected from using detection-avoidance strategies; and (c) the perceived probability of detection. The level of illegal fishing is expected to decrease as the perceived probability of detection increases (c). To my knowledge, the shape of these interactions has not been tested empirically and is likely to be context dependent.

In the following sections I identify numerous detection-avoidance strategies used in the field by small-scale fishers, and offer possible countermeasures that could be employed by the authorities. The detection-avoidance strategies that I present here were collected in Costa Rica as part of Chapter 7 (a study of the levels and drives of fishers' compliance with MPAs). Although the aim of the study (i.e., Chapter 7) was not to collect information about detection-avoidance strategies, numerous interviewees discussed detection-avoidance strategies which were documented and further explored. This descriptive data on detection-avoidance strategies was therefore unanticipated and collected in an incidental fashion rather than via a systematic approach. As such, this is not intended as an inclusive list of avoidance strategies but rather as an opportunity to generate information and discussion on an important, yet rarely considered topic. Such information and discussion is particularly valuable for conservation managers and scholars.

The detection-avoidance strategies presented here were discovered during 140 anonymous interviews performed in Costa Rica from February to April 2014. However, not all interviewees provided information on detection-avoidance strategies, and the total number who provided this information was not recorded. Survey participants were small-scale fishermen, tourism operators, government staff (i.e., coastguard, fisheries, and conservation), community leaders, leaders of fishing associations, and researchers. I conducted all the interviews in person and in Spanish.

3. Detection avoidance strategies in Costa Rican small-scale fisheries

Small-scale fishermen can employ detection-avoidance strategies, which can be classified in two main categories: concealment, and information and communication (Table 4). Concealment strategies are typically aimed at modifying boats or fishing gear so they become difficult to detect by wardens. Information and communication varies in

sophistication, ranging from knowing where and when patrols are taking place, to using lookouts and spreading disinformation (i.e., deliberately false or inaccurate information).

3.1 Concealment

The concealment strategies presented in Table 4 are aimed at hiding the presence of fishermen or their gear. Fishing at night and painting boats with low-contrast colours, such as grey, makes visual detection at sea more challenging. However, most concealment strategies (Table 4) are directed at concealing illegal fishing gear. Fishers can decide on concealing their gear entirely or just an illegal portion. For example, if gillnets of a specific mesh size are permitted, fishermen can use two mesh sizes, a legal mesh for the upper or shallower portion of the net—which is the most likely to be checked by wardens when the net is set—and a smaller, illegal, mesh-size for a larger and deeper portion of the net. In this case, the gear itself is not concealed, only its illegal traits. If wardens are unaware of this detection-avoidance strategy, they are likely to raise and check only the small portion of the net made of legal mesh size while overlooking the majority of the net that uses an illegal mesh size.

In cases where noncompliant fishermen wish to avoid the detection of their entire gear, they can camouflage it by using inconspicuous floating materials as buoys (e.g., a coconut), or by completely immersing it at a known location and then extracting it using a reef (grapnel) anchor. It is worth noting that most of these detection-avoidance strategies involve a cost—an investment of time, resources, and effort. Therefore, these investments in detection-avoidance strategies imply that the economic gains from noncompliance outweigh their costs (Figure 10 a and Figure 10 b), and that some degree of enforcement exists that warrants the use of these strategies (Figure 10 c).

3.2 Information and communication

The widespread availability of mobile telephones and other communication devices enables noncompliant fishermen to share the location of patrol boats and thereby avoid detection. Also, noncompliant fishermen can avoid detection because patrol boats can be distinguished at a distance, thereby allowing them to cease illegal actions or flee. These same strategies have been reported elsewhere; commercial fishermen in the United States of America can detect patrol vessels at long distances via radar, and then communicate the presence and locations of patrols to other fishers by radio or mobile telephones (King et al., 2009).

Misleading communication from fishers to managing institutions can also be used to avoid detection. During this study, Costa Rican coastguard officers cited the use of false reports as an attempt to misdirect patrols. In these instances, the coastguard received fake calls about supposed illegal fishing or suspicious activities. These false reports caused negative repercussions which were perhaps unintended by those who used this strategy. When the coastguard noticed the deliberately false reports and suspected the intentions behind them (i.e., misdirecting patrols), they began asking for the identity of the person making the report, or paying less attention to reports. As a result, some fishermen complained that they lose anonymity when attempting to report authentic cases of illegal fishing, because they are asked to provide their names and other personal details which they do not wish to provide. This lack of anonymity when reporting offences can reduce or eliminate people's willingness to report offenders, particularly if retaliation is a possibility (Mesmer-Magnus & Viswesvaran, 2005). Some small-scale fishermen mentioned that they did not tend to report illegal fishing to avoid potential confrontations with other fishers, and because of inaction on behalf of the authorities. The reduction of an enforcement institution's attention toward reported cases of noncompliance can erode people's

sense of cooperation and public support for the institution. This simple and virtually cost-free strategy of false reporting by noncompliers thereby escalated into an intricate problem that affects conservation and governance, highlighting the need for an agile and adaptive approach from managers.

Table 4. Detection avoidance strategies and possible countermeasures.

Detection avoidance strategy	Countermeasures
Concealment	
Replace buoys with inconspicuous floating objects	Check that floating objects are unattached (e.g., flow with current, or closely inspect floating objects). Clear and enforceable regulations.
Fish at night	Perform night patrols and use technology (e.g., night-vision devices, radar). Undercover patrols.
Paint boats with low-contrast colours	Use of technology (e.g., binoculars, radar, thermal scopes, drones). Undercover patrols.
Sink gear entirely below water surface and mark location with GPS	Mandate use of standard buoys. High definition sonar. Intelligence and covert observation.
Use two mesh sizes on single net when there are mesh-size regulations	Inspect nets on boats and on the coast. On the water, lift nets from several points and check middle and bottom sections.
Information and communication	
Lookouts and mobile phones	Perform patrols with multiple vessels. Undercover patrols.
Knowledge about activity or inactivity of patrols	Introduce a degree of variability in planning patrol. Collaborate with other agencies. Use auxiliary vehicles. Eliminate possible information leaks.
Disinformation	Provide incentives for legitimate information. Improve reporting processes. Engagement to build trust and guardianship.
Detect patrol boats at a distance (visually or through radar)	Undercover or unmarked patrols. Use of technology when possible (e.g., Automatic Identification System and Vessel Monitoring Systems). Land-based patrols.

4 Countermeasures

Countermeasures are intended to prevent or neutralize detection-avoidance strategies. The countermeasures recommended in Table 4 can

reduce the opportunities for illegal fishing by increasing the risk of detection, the effort required, and the costs associated with illegal fishing. Effective countermeasures can be developed through an understanding of the specific crime types and the associated detection-avoidance strategies. Although context dependent, countermeasures can also address either a particular detection-avoidance strategy (e.g., mandating use of standard net buoy), while others can address multiple strategies (Table 4). For instance, land-based patrols can help counter concealment (e.g., illegal nets), and information and communication strategies (e.g., detection of patrol boats at a distance; Table 4). These countermeasures therefore reduce the opportunities for illegal fishing by creating unfavourable conditions for noncompliance, which can be strengthened if supported by legislation.

Fishing activities should be explicitly regulated because legal gaps or loopholes can prevent or encumber enforcement actions against detection-avoidance strategies. For instance, if the legislation does not describe the buoys that must be used to mark fishing gear, the use of an inconspicuous floating object as a buoy (Table 4) would be legal, and hence wardens would not be able to act against it. In Queensland, Australia, crab traps are required by law to have an identifying tag with the surname and address of the owner, and, when not attached to a fixed object (e.g. a tree above the high water mark), traps must have a "light coloured surface float" of "no less than 15cm in any dimension" (DAF, 2015). This legislation constrains the objects that can be used as buoys, allowing for enforcement actions such as penalties and confiscation in case of noncompliance. Clear regulations should also allow for enforcement actions on land and at sea. At the time of writing this thesis, a law was being debated in Costa Rica which would allow authorities to prohibit the importation, sale, possession, use, transport, storage, and fabrication of illegal fishing gear such as nets of a specific mesh size (Asamblea Legislativa, 2013). The current legislation only prohibits the use

of illegal gear, so fishers have to be caught in the act, and this presents obvious drawbacks for wardens. Legislation must give authorities the powers to fully deal with illegal fishing, because clear and enforceable rules are critical for tackling noncompliance.

4.1 Countering detection-avoidance in the field

There are multiple ways of countering detection-avoidance strategies in the field, namely technological tools, and field procedures. Modern technology is playing an increasingly important role in enforcement; the costs of technological devices such as night-vision, radar, and drones are decreasing and are thus being increasingly used to counter concealment strategies. For example, sunken fishing gear can be found using high-definition sonar that can accurately scan large areas. These devices can cost less than US$1000 and are currently being used by recreational fishermen to find fishing spots. However, the open availability of some of these technologies also implies that noncompliers can employ them to avoid detection. The use of GPS devices to mark sunken fishing gear (Table 4) exemplifies this point. In more extreme examples of noncompliance in the nature conservation context, such as rhino and elephant poaching in Africa, poachers use night-vision gear, silenced weapons, tranquilizers, and even helicopters (Vira & Ewing, 2014). Wardens therefore need to constantly adapt their field procedures.

Field procedures such as thorough inspections of set fishing gear, and gear inspections on land and sea can be effective against detection-avoidance strategies. As mentioned previously, authorities require legislation that allows them to act on detection-avoidance strategies. Once wardens know about the use of particular concealment strategies they are in a better position to find them. Field inspections are usually necessary. Nevertheless, field inspections can be ineffective in areas where there are repeat and deliberate noncompliers who are proficient at avoiding detection. In this case, mangers might require more

sophisticated countermeasures such as undercover operations. Undercover operations can range from tasks to collect quick evidence (e.g., take photos or buy illegal product), to complex and lengthy processes to infiltrate and dismantle organized criminal groups (Latham, 2012).

It is important to note that while field procedures can disrupt detection-avoidance strategies by influencing the perceived probability of detection, they can also play a critical role in influencing the perceptions of legitimacy through procedural justice. Procedural justice is the way in which authorities treat those being regulated, and the quality of the decisions made by the authorities (Tyler, 2003). Previous research has demonstrated the importance of procedural justice in increasing the legitimacy of authorities. People who are treated in a just and fair fashion are more likely to recognize the legitimacy of the authorities than those who experience injustice (Mazerolle et al., 2013). This is encouraging for managers looking to increase voluntary compliance and cooperation, because policies and training can guide enforcement officer's behaviours while interacting with the public.

Procedural justice and legitimacy are particularly relevant in the context of the disinformation strategy that I mentioned above (Table 4) and how it might have eroded cooperation. Some fishers mentioned that they did not report noncompliance because they felt that the authorities would not respond, or because the system was not anonymous. Procedural justice in the form of an effective reporting and response system can strengthen cooperation; this can then increase risks for noncompliers. Cooperation can be a cost-effective way of directing patrols and gathering intelligence (Glover, 1982; ICCWC, 2012). As mentioned previously, technology can increase cost-effectiveness; in this case it could be through commonly used communication tools such as social media and mobile phone applications. It is clear that institutions

should allow closer relationships with public (ICCWC, 2012), but these steps must be well-planned to avoid counterproductive actions (Chapter 2).

Field activities should be informed through a systematic process that allows adaptation. Undertaking patrols and having resources is not a panacea, adequate procedures and capacities are also critical components of effective enforcement.

4.2 Countering detection-avoidance with intelligence

The ability of management agencies to understand noncompliance is a key element in their capacity to deliver effective enforcement programs. Developing an understanding of noncompliance through the analysis of available information can assist decision-makers in prioritising problems and allocating appropriate resources. For example, understanding a detection-avoidance strategy in the context of its spatial and temporal characteristics can be used to design more targeted patrol strategies. To this end, the application of "intelligence-led" policing and crime analysis techniques can be equally used for developing a better understanding of compliance within the conservation context (Weekers, 2011). Indeed, an intelligence-led approach to compliance management in nature conservation is gaining momentum (Moreto, 2015; Pires & Moreto, 2011), especially through the increased availability of technology (SMART, 2015).

The primary function of an intelligence-led approach is to provide managers with appropriate levels of strategic knowledge to make effective planning and operational decisions. Intelligence-led enforcement is underpinned by information management, a processes which can be conceptualized through a model called the intelligence cycle (Ratcliffe, 2012) (Figure 11). In the context of nature conservation, the intelligence cycle has the advantage that it closely resembles the adaptive management cycle, a concept which many managers are

familiar with. Here I propose the application of intelligence-led enforcement through the intelligence cycle as a means to manage information that can be used to counter detection-avoidance strategies and noncompliance in general. The intelligence cycle offers a simple and potentially cost-effective measure for building enforcement capacity.

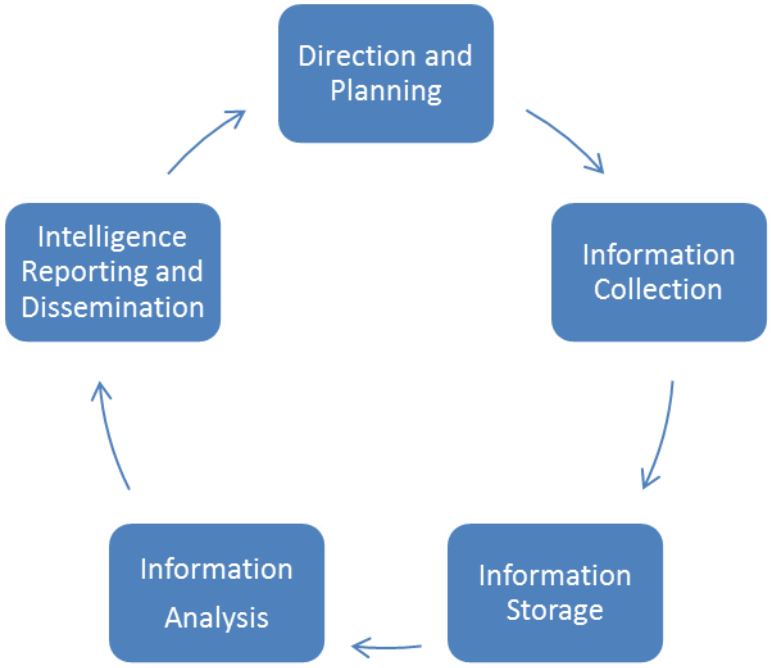


Figure 11. The intelligence cycle. This is one representation of the intelligence cycle, there are other versions; however, the process is inherently the same. It is important to note that the process is not always linear; there can be additional connections between nodes, for example, from analysis to the collection of additional data. This is a simplification of what can be an intricate process, I present it as a starting point which managers should mature and adapt to fit their needs.

The intelligence cycle begins and ends with direction and planning (Figure 11). In this stage, the decision-making group considers organisational priorities, based on established risks and existing intelligence, to direct the information collection requirements. Information collection methods can be either passive or targeted, and are based on the priorities set in the direction and planning stage. Passive collection refers to unsolicited information such as that provided by a third party (e.g., an anonymous report about a fisher using a detection-avoidance

strategy), while targeted collection refers to the purposeful collection of information on a priority identified in the previous stage. The standard of the information collected can be enhanced through the inclusion of specific characteristics that typically respond to five the key questions reviewed in Chapter 2: WHO, WHAT, WHEN, WHERE and WHY. For example, each piece of information received on detection-avoidance strategies can be categorised by type, location, time and date, moon phase, weather conditions, and so on. The inclusion of multiple variables can be used to develop a detailed understanding of problems; this helps improve enforcement effort through appropriately targeted patrols (Chapter 4). The ability to conduct such analyses, however, is conditional on effective information storage. While complex databases can represent a high cost for institutions, a primary concern for intelligence analysis is the identification of patterns, and a capacity to retain the information in a structured format. Unfortunately, information about illegal fishing and other cases of environmental noncompliance is not commonly unified in a single database or it is not recorded at all (ICCWC, 2012). With a structured database, information can be used to develop detailed characterisations of an illegal activity. The results of these analyses are then communicated through specific reports that address the original requirements of the cycle. The objective of the intelligence reports is to provide managers with enough knowledge about noncompliance to make effective planning and operational decisions.

The implementation of the intelligence cycle is not necessarily expensive or resource intensive. In fact, a structured approach to compliance management, such as the one offered by the intelligence cycle, is more cost-effective than improvised approaches because it optimizes activities and resource allocation through informed decision making. In many cases, a single person can execute the cycle, and popular spreadsheet (e.g., Microsoft Excel) and mapping software (e.g., Google Earth) can be used. There is also free and purpose-built software

for managing enforcement information in the nature conservation context (SMART, 2015). It is important that organizations become aware of the significance of structuring their approach to information management; focusing on developing strong processes that allow for accountability and the efficient use of resources.

5 Conclusion

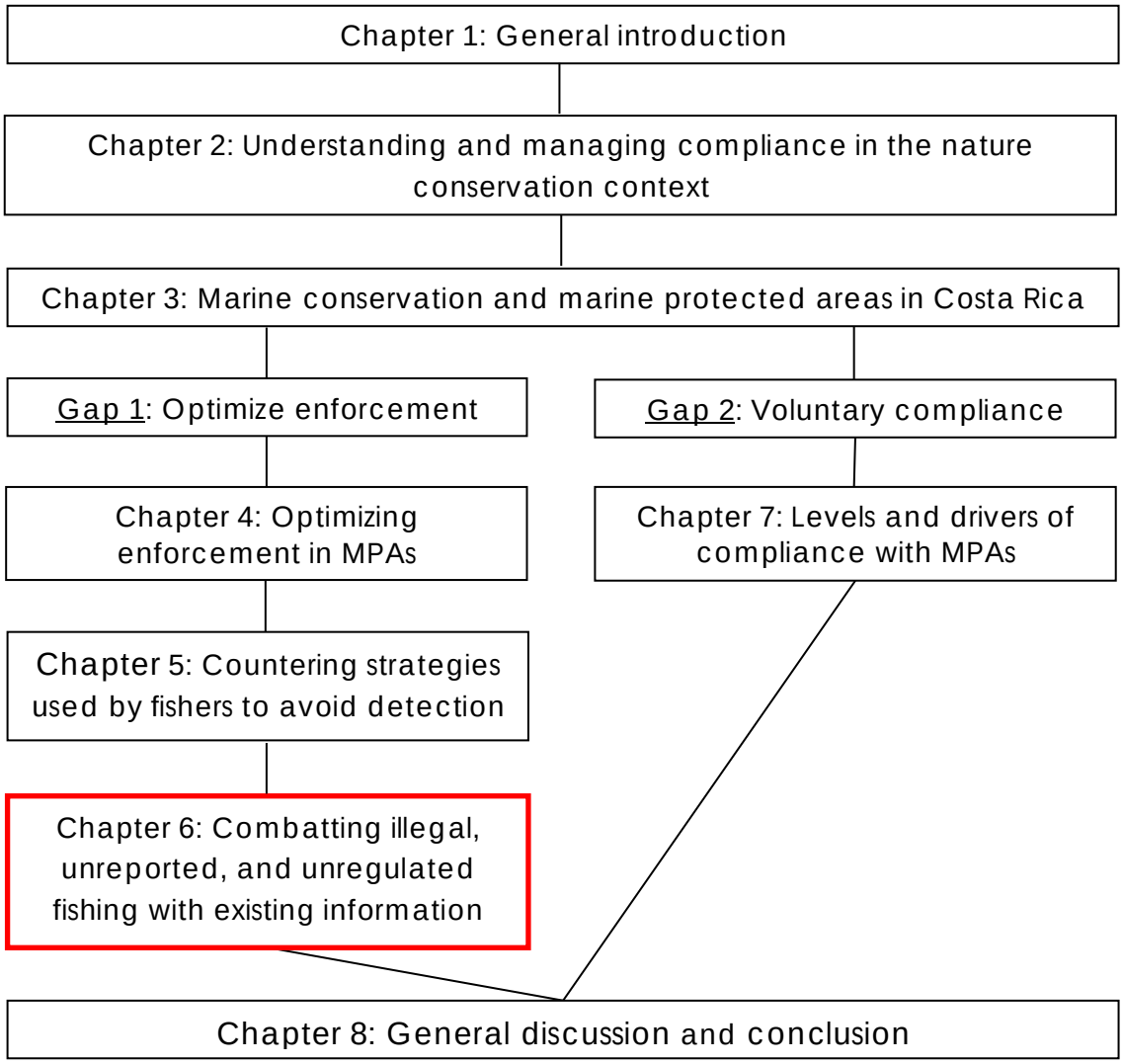
Effective patrols depend not only on allocating patrol effort in space and time, but also on countering detection-avoidance strategies. The likelihood of fishers adopting detection-avoidance strategies is likely to depend on the costs of adopting them, the profits expected from using them, and the perceived probability of detection. The latter, however, is typically the easiest for managers to influence. I proposed a series of tools and processes that managers can use to counter detection-avoidance strategies and increase the perceived probability of detection. Importantly, managers should improve their information management, with the intelligence cycle being a good and proven option for doing this. Also, I underline that enforcement practices should also be bolstered by additional management actions that aim to reduce noncompliance and increase both voluntary compliance and cooperation with the authorities. In this regard, procedural justice often demonstrates success in increasing the legitimacy of the authority or management agency, which normally results in higher voluntary compliance and cooperation.

Chapter 6: Combatting illegal, unreported, and unregulated fishing with existing information[9]

Abstract

In this Chapter I discuss how existing fisheries information can be used to detect illegal, unreported and unregulated (IUU) fishing. I do this through a case that was first documented by a nongovernment organization (NGO) in Costa Rica. The NGO used national and regional fisheries databases to find evidence suggesting that foreign purse seiners fished illegally in Costa Rican waters. Here, I intend to give this case more exposure, and to provide broad recommendations for tackling IUU fishing. Also, this *post facto* case shows how stakeholders, from enforcement agencies to members of the public, can use existing information to detect cases of fisheries noncompliance. This chapter highlights the importance of openly available information and the need for political will to act on IUU fishing.

[9] This Chapter has been published as a Comment: Arias, A. & Pressey, R. L. (2016). Combatting illegal, unreported, and unregulated fishing with existing information. *Frontiers in Marine Science*, 3. doi: http://dx.doi.org/10.3389/fmars.2016.00013
For this Chapter I developed the concept, performed informal interviews, made Figure 12, and wrote the paper. Pressey provided editorial support and suggested the addition of Figure 12 to address comments from one of the reviewers.


Chapter 1: General introduction
Chapter 2: Understanding and managing compliance in the nature conservation context
Chapter 3: Marine conservation and marine protected areas in Costa Rica
Gap 1: Optimize enforcement
Gap 2: Voluntary compliance
Chapter 4: Optimizing enforcement in MPAs
Chapter 7: Levels and drivers of compliance with MPAs
Chapter 5: Countering strategies used by fishers to avoid detection
Chapter 6: Combatting illegal, unreported, and unregulated fishing with existing information
Chapter 8: General discussion and conclusion

1 Introduction

Millions of people depend on marine fisheries for food and livelihoods. Unfortunately, global marine fisheries are severely degraded. The latest estimates from the Food and Agriculture Organization indicate that nearly 30% of assessed fish stocks are overfished (FAO, 2014). Overfishing threatens food security and livelihoods. Its negative effects go beyond the exploitation of fish stocks, and affect entire food webs and ecosystems (Scheffer et al., 2005).

Overfishing is exacerbated by IUU fishing. For example, illegal fishing is estimated to represent approximately 20% of the world's reported catch (Agnew et al., 2009). IUU fishing endangers the productivity of ecosystems (Agnew et al., 2009; Flothmann et al., 2010), and the socio-economic stability of fishing communities. Piracy off the Somali coast, for instance, is thought to have started when Somali fishermen began seizing boats that were fishing illegally in their waters (Bahadur, 2011). Fisheries overexploitation leads to vicious cycles that generate progressive environmental degradation and social conflict when people attempt to maintain or increase their catches as the yields of previous fishing methods decline (Brashares et al., 2014). It is therefore in the best interests of coastal states to prevent IUU fishing, but the capacity to do this is generally low, particularly in developing coastal states which are the most vulnerable to IUU fishing.

Regional fisheries management organizations (RFMOs) can play a decisive role in supporting coastal states to treat illegal fishing. RFMOs are institutions formed by countries with interests in fisheries within particular regions. RFMOs can play advisory or legally binding managerial roles. RFMOs integrate management across a number of countries, and are thus advantageous for managing highly mobile species, because their agreements and actions apply to all member states. Therefore, countries might be more likely to participate in multilateral agreements because

there are shared costs and opportunities across countries, compared to implementing actions as single countries (FAO, 2002). Accordingly, RFMOs have a broad spectrum of tools for addressing IUU fishing, many of which are outlined in the International Plan of Action to Prevent, Deter and Eliminate IUU Fishing (FAO, 2001) and its implementation guidelines (FAO, 2002). An applicable and valuable tool for fighting IUU fishing is the collection, analysis, and sharing of information about fishing vessels and their operations, inside and outside economic exclusive zones. Examples of this are the use of satellite data by initiatives such Global Fishing Watch and Project Eyes on the Sea. I present a case where RFMO and government information was obtained and used by a nongovernment organization (NGO) to discover possibly serious instances of illegal fishing that had not been detected by the RFMO or the government themselves. The case highlights the importance of openly available information and the need for political will—thus far not apparent—to act on IUU fishing when it is detected.

2 The case

The Costa Rican Fishing Federation, a NGO, published a report (Cubero-Pardo & Martínez-Cascante, 2013) that revealed probable noncompliance by foreign purse seiners within Costa Rica's exclusive economic zone. In this case, the apparent illegal fishing included: 1) the use of artificial fish aggregating devices (hereafter FADs), illegal in Costa Rica since 1999 (INCOPESCA, 1999), and 2) fishing without a license. More explicitly, the report stated that nearly 800 sets were on FADs between 2002 and 2011. Furthermore, the report estimated the extent of unlicensed fishing: 14 to 38 foreign purse seine vessels were recorded as fishing without a license each year between 2008 and 2011. Below I describe how the case unfolded.

The data used for these analyses came from the Inter-American Tropical Tuna Commission (IATTC), an RFMO of which Costa Rica is a

member, and the Costa Rican government. The Costa Rican Fishing Federation wanted to analyse national and regional fisheries data and, given the lack of open access to regional fisheries data, the Federation petitioned these data from the Costa Rican Ministry of Agriculture and Livestock. In the absence of shared databases, the Ministry had to petition the regional fisheries data from the IATTC, and then handed it to the Federation (Cubero-Pardo & Martínez-Cascante, 2013). Figure 12 a describes the flow of data and information.

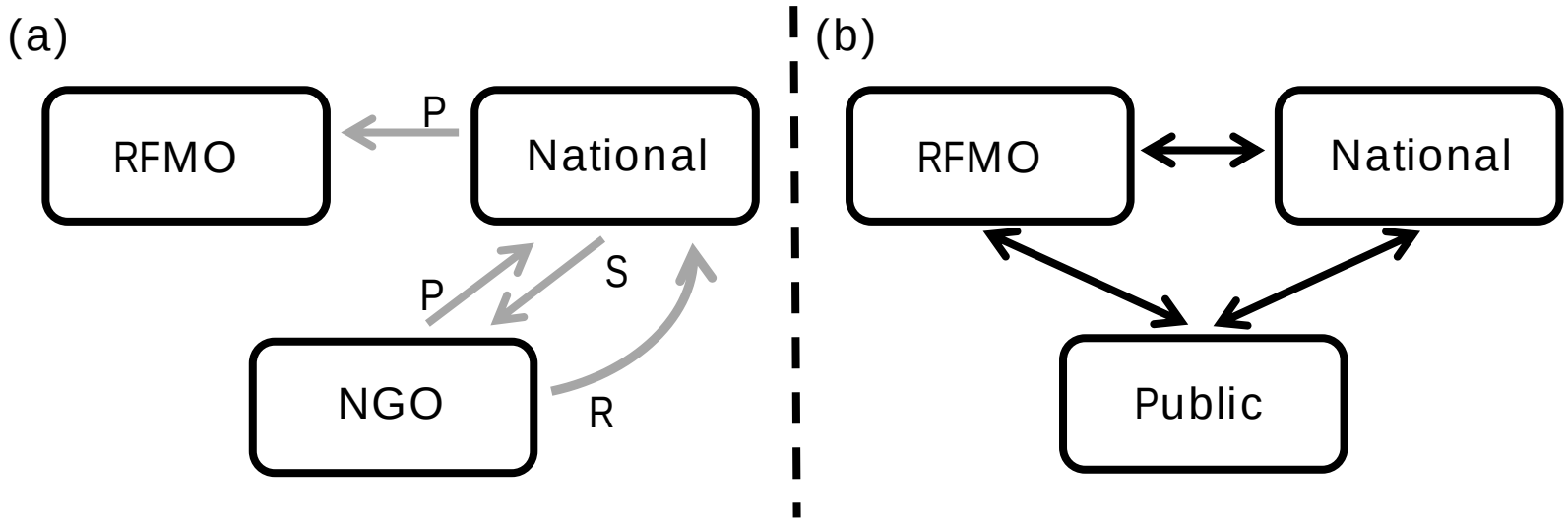


Figure 12. Flows of data to detect and deter illegal, unreported and unregulated fishing. (a) The petitions for and supply of data described in the main text and summarized here. Given the lack of open access to fishery databases, the Costa Rican Fishing Federation, a non-government organization (NGO), petitioned regional fisheries data from the Costa Rican Ministry of Agriculture and Livestock, a national institution. Again, given the lack of shared databases, the Ministry asked the Inter-American Tropical Tuna Commission, a Regional Fisheries Management Organization (RFMO), for the regional data, received them, and then passed them to the NGO. The NGO analysed the data and reported the potential cases of illegal fishing to the Ministry. However, the Ministry did not communicate the potential cases of illegal fishing back to the RFMO, and did not take action concerning the cases. (b) Preferable flow of data and information between RFMOs, national institutions, and the public (including NGOs, academia and civil society). Grey arrows in (a) represent deficient channels for sharing data (P indicates petition for data, S indicates supply of data, R indicates reporting on analysed data). Solid arrows in (b) represent the idealized situation of formal and automatic channels for sharing data.

The IATTC data contained information about purse seine sets, reported in geographic coordinates and stating the type of set (e.g., FAD, dolphin associated). The IATTC data did not include an identifier for each vessel, but it included the vessels' hold capacities. Cubero-Pardo and Martínez-Cascante (2013) estimated the number of vessels that fished in Costa Rica's exclusive economic zone using hold capacities, which are distinctive to individual vessels. Hence, the estimate of vessels that operated without a license was a comparison of the total number of vessels that had a fishing license (national data provided by the Costa Rican government) vs. the total number of vessels they estimated fished in Costa Rica (IATTC data).

The assertion by the Costa Rican Fishing Federation that FADs were used illegally seems well substantiated because the IATTC database explicitly mentioned their use, and sets were reported using geographic coordinates, not grids. There is less certainty regarding unlicensed fishing because the IATTC database did not identify vessels by name or number. However, the estimate of vessels that fished in Costa Rican waters without a license each year from 2008 to 2011 (i.e., 13 to 38) is large, and probably includes vessels that indeed fished without a license. Additionally, claims have been made that purse seiners in Costa Rica have used explosives during fishing activities (Staley, 2012), and harassed sport fishing boats to drive them off schools of tuna (McDonald, 2010).

Interestingly, the unlicensed tuna purse seining and the illegal use of FADs appear to have been reported indirectly to the IATTC in the form of fisheries data collected by scientific observers but, until recently, went undetected as possible noncompliance. Hence, mechanisms seem to be lacking to detect and report IUU fishing within national and regional fisheries databases. Costa Rican authorities are aware of the report by the Costa Rican Fishing Federation. However, numerous gaps still exist: 1) the results of the report are not widely known, 2) the report did not

recommend broader implications for fighting IUU fishing, and 3) the results are still pending action on behalf of the authorities.

The possible cases of illegal fishing described above remain unverified by the Costa Rican government, and have not been reported to the IATTC by the government. If the information in the NGO report is correct, there are serious implications, including overexploitation, reduction of revenue to the state and legitimate fishers, and potential damage to the credibility of the Agreement on the International Dolphin Conservation Program ('dolphin safe' tuna certification) in the eyes of consumers. The suspects remain unidentified; however, the fishing and licensing data required to corroborate these alleged cases of illegal fishing, and identify suspect vessels, exist and could be analysed easily.

3 Potential solutions for combatting IUU fishing

Contrasting with previous chapters in this thesis, this chapter presents an interesting case of how fisheries noncompliance can be detected after the fact. As I discuss here, the detection can be made by either enforcement authorities or people from the general public. Nevertheless, mechanisms should be in place to facilitate this *post facto* detection.

If accurate, these suspected cases of illegal fishing imply a lack of mechanisms to detect, communicate, and act upon incursions. The detection and enforcement of illegal fishing within an economic exclusive zone is the coastal state's responsibility, in this case Costa Rica's. However, RFMOs can also monitor IUU activities and report to member countries. Costa Rica does not yet have a national observer program for purse seiners, so the information was most likely reported by IATTC scientific observers, and it is not clear whether observers and captains were aware that the alleged actions were illegal. Regardless of where the data originated, it is clear that a simple system could detect this type of reported noncompliance. By combining state and RFMO data in a single

database, it would be possible to alert authorities about noncompliance. For example, if countries provided licensing information to an RFMO database, a system alert could result from an unlicensed boat fishing in a particular country. Alternatively, if the RFMO database includes FAD regulations for each member country, the system alert would be triggered by illegal use of FADs when the data were entered. Having an effective database system in place to detect and communicate irregularities is essential for managing compliance. In this case the data were available but apparently went undetected in national and RFMO databases. Now, with potential evidence of large-scale illegal fishing, Costa Rica has yet to react: first, by verifying these cases, and second, by acting on noncompliance if the NGO report is accurate.

Had the data not been analysed by the Costa Rican Fishing Federation, the cases presented above, although unconfirmed, would probably have gone undetected. This underlines the importance that NGOs can have in environmental governance. There are multiple examples of how NGOs have played important roles in generating knowledge, raising awareness, lobbying, and ensuring compliance (Gemmill & Bamidele-Izu, 2002; Lemos & Agrawal, 2006). NGOs can engage and harness involvement by members of the public. In this case, the Costa Rican Fishing Federation sparked some public dissatisfaction with the way that tuna fisheries were being managed in Costa Rica (París-Chaverri, 2014) which ultimately led to a passage of a decree (38681-MAG-MINAE) that reduced the area where foreign tuna purse seiners can fish. Nevertheless, no investigations stemmed from the report and there have been no changes in the compliance management processes that were shown to be weak.

The case that I present here shows how information is crucial to confront IUU fishing; however, mechanisms need to be in place to collect, monitor, analyze and share these data. Simple systems can be used in

RFMO and country databases to allow the detection and communication of noncompliance. Importantly, public access to national and regional fisheries data, combined with formal and automated communication channels between RFMOs, national institutions, and the public (e.g., NGOs, academia, and civil society), would offer more transparency and ease the detection of noncompliance (Figure 12 b).

4 Timely action

Action upon these cases, on behalf of Costa Rican government, would be timely; Costa Rica recently became party to the FAO Agreement on Port State Measures to Prevent, Deter and Eliminate IUU Fishing (Asamblea Legislativa, 2015), and other countries in the region are expected to do likewise (OSPESCA, 2015). This international agreement seeks to block IUU vessels and their catch from entering ports and markets through minimum inspection standards and information-sharing between countries. Implementation and compliance with this and other international agreements, such as the Straddling Fish Stocks Agreement (of which Costa Rica is party), requires cooperation and information-sharing between countries, RFMOs and the public (Figure 12 b). Finally, I encourage others to analyse existing databases, national and regional, to look for signs of IUU fishing such as the ones described here.

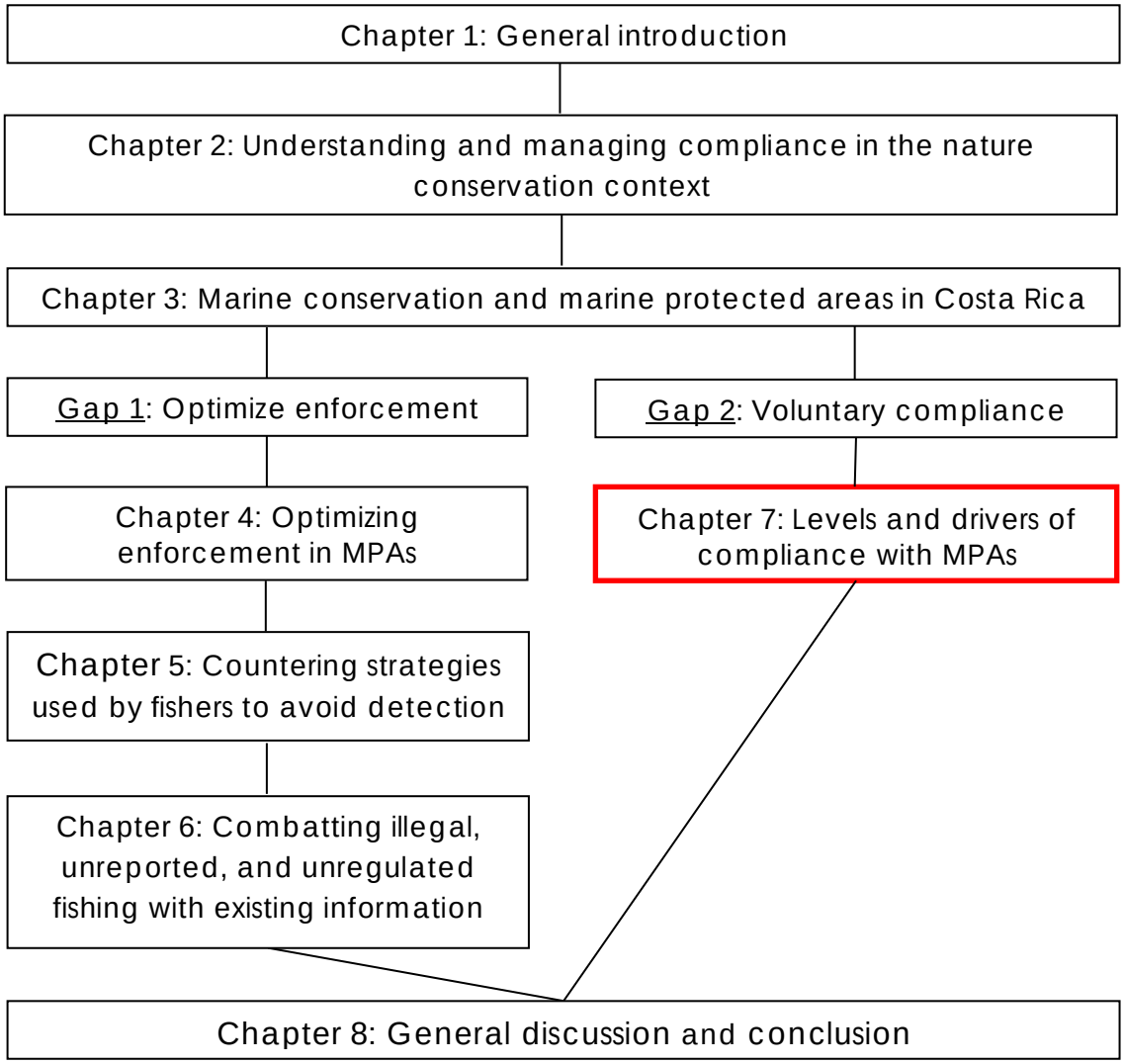
Chapter 7: Levels and drivers of compliance with MPAs[10]

Abstract

I investigate compliance through the lens of fishers' compliance with marine protected areas (MPAs). MPAs are widely-used tools for marine conservation and fisheries management. Studies show that compliance alone is a strong predictor of fish biomass within MPAs. Hence, fishers' compliance is critical for MPA effectiveness. However, there are few empirical studies showing what factors influence fishers' compliance with MPAs. Without such information, conservation planners and managers have limited opportunities to provide effective interventions. By studying 12 MPAs in a developing country (Costa Rica), I demonstrate the role that different variables have on fisher's compliance with MPAs. Particularly, I found that compliance levels perceived by resource users were higher in MPAs: 1) with multiple livelihoods, 2) where government efforts against illegal fishing were effective, 3) where fishing was allowed but regulated, 4) where people were more involved in decisions, and 5) that were smaller. I also provide a novel and practical measure of compliance: a compound variable formed by the number illegal fishers and the frequency of illegal fishing. My study underlines the centrality of people's behaviour in nature conservation, and the importance of grounding decision-making on the social and institutional realities of each location.

[10] This Chapter is published as: Arias, A., Cinner, J., Jones, R. E., & Pressey, R. L. (2015). Levels and drivers of compliance with coastal MPAs Socioeconomic conditions influence compliance with marine protected areas. *Ecology and Society*.

For this Chapter I developed the research questions, collected and analysed the data, and wrote the paper. Cinner and Pressey provided editorial support. Jones provided assistance with statistical analysis and interpretation of results. I specially acknowledge all the people who participated in this study.


Chapter 1: General introduction
Chapter 2: Understanding and managing compliance in the nature conservation context
Chapter 3: Marine conservation and marine protected areas in Costa Rica
Gap 1: Optimize enforcement
Gap 2: Voluntary compliance
Chapter 4: Optimizing enforcement in MPAs
Chapter 7: Levels and drivers of compliance with MPAs
Chapter 5: Countering strategies used by fishers to avoid detection
Chapter 6: Combatting illegal, unreported, and unregulated fishing with existing information
Chapter 8: General discussion and conclusion

Studies in other contexts have examined compliance, for example in hunting (Lindsey et al., 2013; Muth & Bowe, 1998) and fisheries (King & Sutinen, 2010; Raakjær Nielsen & Mathiesen, 2003; Sundström, 2012). While these studies provide useful information that could be applied to MPAs, their transferability is limited because of the different contexts. Further, although some studies have focused on measuring or understanding fishers' compliance in MPAs (Arias et al., 2016; Arias & Sutton, 2013; Peterson & Stead, 2011; Read et al., 2011; Wood, 2004), the current literature and evidence base on compliance levels and, importantly, the factors that influence fishers' compliance with MPAs, remain limited (Bergseth et al., 2015; Peterson & Stead, 2011). The theoretical concepts underpinning compliance have been recently reviewed in the broader context of nature conservation (Chapter 2), but compliance with MPAs is linked to complex social and institutional interactions (e.g., rules, socio-demographics, and enforcement) that are context-dependent.

Illegal fishing, either inside or outside MPAs, is a very broad topic, encompassing, for example, gear types, target species, regulations, and socioeconomic characteristics of regions where illegal fishing takes place (Chapter 2). This heterogeneity implies that we should not expect to find simple, generalizable, solutions to noncompliance. Successful management interventions are typically characterized by responses that are adequate for the local socioeconomic and institutional realities (Waylen et al., 2010). It can be expected, therefore, that global progress in minimizing illegal fishing can be achieved through the multiplication of well-designed, and locally-relevant interventions that consider contextual factors (Petrossian, 2014). Compliance management should be informed by a thorough understanding of factors that influence compliance in specific settings. Managers can then foster positive factors (e.g., high perceived legitimacy toward institutions) and mitigate negative ones (e.g., weak social barriers against undesired behaviours).

Here, I use MPAs in Costa Rica as a case study to analyse factors influencing fishers' compliance. MPAs in Costa Rica are affected by illegal fishing (Salas et al., 2012) which I define here as fishing done in MPAs where fishing is not permitted, or, where fishing is permitted, breaking fishing regulations (e.g., using gillnets where they are not allowed) (Table 5). Apart from Cocos Island National Park (Arias et al., 2016), there are no scientific studies focusing on illegal fishing in Costa Rican MPAs. I investigate illegal fishing within 12 MPAs in Costa Rica (Table 5) to answer two research questions. First, what are the levels of fishers' compliance in each MPA? And second, what is influencing fishers' compliance levels? These two questions are key for understanding and managing compliance (Arias, 2015). My broad goal is to help direct, and tailor management efforts that increase conservation effectiveness. The methods used here could also be applied to other areas, where my results could help contextualize compliance.

2 Methods

2.1 Study sites

I studied 12 coastal MPAs in Costa Rica (at the time of sampling these represented 46% of Costa Rica's coastal MPAs) each with different characteristics (Table 5 and link to Google Earth file with MPAs). MPAs were chosen purposively to provide a varied sample in terms of size, year created, location, and whether fishing was allowed or not. These characteristics have been described in the literature as factors likely influencing compliance with MPAs (Andrade & Rhodes, 2012).

Although Table 5 lists 12 MPAs, the Caletas-Arío and Camaronal MPAs were merged in the analyses because of: 1) geographic proximity (link to Google Earth file); 2) lack of clear boundaries (Table 5); 3) same regulations and similar size and age (Table 5), and 4) two artisanal fishing communities being located between them, with interviews revealing that

fishers from the two communities fished both areas. For analysis purposes I averaged the age and size of these two MPAs.

Table 5. MPAs included in the study and key characteristics. Caletas-Arío and Camaronal were considered as one MPA, as explained in the Methods.

Managing institution	Coast	Name	Fishing permitted	Year created	Area (km^2)	Clear geographic boundaries ‡
SINAC	Caribbean	Cahuita	Yes †	1970	233.0	No
SINAC	Pacific	Santa Rosa	No	1971	464.0	No
SINAC	Pacific	Manuel Antonio	No	1972	420.2	No
SINAC	Pacific	Cabo Blanco	No	1982	16.3	No
SINAC	Pacific	Ostional	Yes	1983	80.6	No
SINAC	Caribbean	Gandoca-Manzanillo	Yes	1985	49.8	No
SINAC	Pacific	Marino Ballena	No	1990	52.3	No
SINAC	Pacific	Caletas-Arío	Yes	2006	198.5	No
SINAC	Pacific	Camaronal	Yes	2009	160.3	No
INCOPESCA	Pacific	Palito-Montero	Yes	2009	6.3	Yes
INCOPESCA	Pacific	Golfo Dulce	Yes	2010	750.0	No
INCOPESCA	Pacific	Isla Caballo	Yes	2012	1.3	No

† Legally, fishing is not allowed in Cahuita (Asamblea Legislativa, 2005); however, SINAC allows local fishermen to fish in certain areas within the Park, although gillnets are not allowed.
‡ Boundaries that are easy to locate accurately, and are undisputed by the community.

2.2 Questionnaires and key informant interviews

Data collection was through questionnaires and key informant interviews, from February to April 2014. The survey was designed to collect information to address each research question; Table 6 summarizes the data and their purpose. Questionnaires were mostly quantitative, and respondents were artisanal fishermen and tourism operators, including those involved in sport fishing. These two stakeholder groups were selected because they spend considerable time on the water, giving them a good idea of the reality of each location. The questionnaires were conducted in communities adjacent to MPAs. I selected questionnaire respondents using snowball sampling, and convenience sampling at beaches, fish landing sites, marinas, and tourism companies. Key informant interviews were semi-structured, and were used to validate the information received from the questionnaires. Key informants included government staff (Coastguard, INCOPESCA, and SINAC), managers of tour companies, community leaders, leaders of fishing associations, and researchers. Most key informants were contacted by telephone or email to arrange meetings. All interviews were conducted in person and in Spanish by myself, a Costa Rican.

Noncompliance is a sensitive behaviour; therefore, compliance studies are prone to response and nonresponse bias. Response bias arises when people give inaccurate answers; nonresponse bias occurs when people refuse to participate in surveys. I employed several techniques to reduce these biases (see Arias, 2015 for a review). First, when approaching potential interviewees, the interviewer identified himself as a student. Students can be considered neutral parties when compared to, for instance, government employees, and respondents can feel more comfortable when talking about sensitive behaviours with a neutral or impartial party (Roggenbuck, 1992). Second, potential interviewees were told clearly that the questionnaire was anonymous. Anonymity reduces

the 'threat' of being accused of noncompliance. Third, the questionnaire started with non-sensitive questions and gradually increased their sensitivity. This allowed respondents to become accustomed to the interviewer and the interviewing process, rather than facing potentially confronting questions at the outset. Fourth, I used indirect questioning. Indirect questioning refers to the compliance behaviour of others and not about the respondent; I therefore refer to it as 'perceived compliance'. This technique has been used for several decades and has been shown to reduce bias (e.g., the bias arising from answering in a way that that will be viewed favourably by the interviewer), allowing respondents to mask their own attitudes and behaviours through impersonality (Fisher, 1993). Recent compliance studies in conservation contexts indicate the utility of perceived compliance (Arias & Sutton, 2013; Cross et al., 2013), coinciding with findings from fields such as marketing (Jo et al., 1997). Additionally, studies have found correlations between perceived compliance and ecological health (Pollnac et al., 2010). Perceived compliance therefore appears to be an adequate proxy for actual compliance. Actual compliance can only be established by direct observation, making it infeasible in most cases. In this study I measured perceived compliance with fishery regulations in MPAs. By using these four techniques, it is likely that I reduced response and nonresponse biases.

2.3 Compliance levels.

My first objective was to identify perceived compliance levels in each MPA. I used a composite measure of perceived compliance based on the number of illegal fishers and the frequency of illegal fishing. Including frequency is key because it provides a measure of illegal fishing effort (Arias, 2015; Arias & Sutton, 2013). For instance, the impact that five fishers would have on an MPA would be very different if they fished every day or only once a month. Preliminary analysis indicated that the number of illegal fishers and the frequency of illegal fishing were positively correlated

($r_s(93) = .47$, $p = 0$); hence, in areas where the number of illegal fishers was low, the frequency of illegal fishing also tended to be low, and vice versa. Because both variables measure compliance, and they were moderately correlated, the values for each variable were converted to z-scores and summed to create the composite score for perceived compliance across interviewees for each MPA. A z-score is a score's relationship to the mean in a group of scores, given in standard deviations. Hence, a z-score for an individual MPA can be positive, negative, or zero, indicating whether it is above, below, or equal to, respectively, the MPA population mean. I elicited two additional metrics of perceived compliance by asking participants two proxy questions: 1) if they personally knew somebody who had knowingly fished illegally in the MPA, and 2) if they had seen someone fishing illegally in the MPA within the last year. In Australia, Arias and Sutton (2013) found that fishermen who personally knew someone who intentionally fished illegally were more likely to have fished illegally themselves. I performed Mann-Whitney tests to assess if the compliance levels perceived by those who replied "Yes" were different from those who replied "No" to each of these two questions.

2.4 Factors influencing compliance

I then analysed the factors influencing levels of perceived compliance. I used a linear mixed-effect model to quantify the influence on perceived compliance of three MPA- and eight individual-level predictor variables (Table 6). MPAs were either long-established (24-35 years) or recent (less than 10 years). All recent MPAs allowed fishing (Table 6), so the effect of age group on compliance levels could only be tested in MPAs that allowed fishing, and preliminary analysis revealed no effect. Hence MPA age (Table 6) was excluded from the linear mixed-effect model. I used MPA as a grouping variable (random effect) to account for potential non-independence of respondents within an MPA. Because there is evidence suggesting that respondents project their own

beliefs and evaluations through indirect questioning (Fisher, 1993), I hypothesized that individual-level variables (e.g., support toward MPA, Table 6) can be related to the compliance levels perceived by respondents. I did not hypothesize or find a theoretical basis for examining interactions between predictor variables. Predictor variables were standardized using z-scores; this allowed direct evaluation, on the same scale, of their relative effects on perceived compliance levels. The variables included in the model were grouped into three categories: management, planning, and livelihoods (Figure 14).

Tourism data were provided by the Costa Rican Tourism Institute in 2015. Data analyses were performed using *SPSS v. 20* (IBM, North Castle, USA) and *S-PLUS v. 8* (TIBCO Software, Palo Alto, USA). Normality of modelled residuals was analyzed using Q-Q plots.

Table 6. Individual- and MPA-level variables used to explain compliance, with corresponding research question(s) for each variable.

Variables	Metric	Research question
Individual-level		
Number of people who fish illegally	Six point scale	1-2
Frequency of illegal fishing	Six point scale	1-2
Seen someone fish illegally in the MPA	Yes or no	1
Personally know someone who knowingly fished illegally in the MPA	Yes or no	1
Involvement in decision making	Not involved, passively involved, very involved	2
Support for MPA	Rated from 0 to 100	2
Effectiveness of government efforts against illegal fishing	Rated from 0 to 100	2
Fisherman or not	Yes or no	2
MPA-level		
Size	Km^2	2
Type	Take or no-take	2
Tourism levels	Number of hotel rooms in districts adjacent to MPA†	2

†Caballo was not considered as part of a district because it is located approximately 8 kilometres from the mainland, and it is a small fishing community with no tourism industry.

3 Results

I collected a total of 99 questionnaires and 41 key informant interviews (Appendix 1). The response rate was 95% for the questionnaires and 100% for key informant interviews. All questionnaire respondents were male, mostly between 30 and 49 years old. Sixty three respondents relied exclusively on fishing (hereafter: fishermen), all of whom were associated with Pacific MPAs. Thirteen respondents relied exclusively on tourism, and 23 had multiple livelihoods including fishing or tourism.

3.1 What were the levels of compliance in each MPA?

There was a high variability in perceived compliance levels between MPAs (Figure 13). Levels of perceived compliance in Palito-Montero, Cahuita, and Gandoca-Manzanillo were above average (Figure 13). The absolute number of illegal fishers was low to very low in Palito-Montero, Cahuita, and Gandoca-Manzanillo, and medium in all MPAs except for Caballo where it was high. Illegal fishing occurred nearly every day in all MPAs except Palito-Montero, Cahuita, and Gandoca-Manzanillo. Qualitative key informant interviews did not diverge from the information received from the quantitative questionnaires and helped as validation.

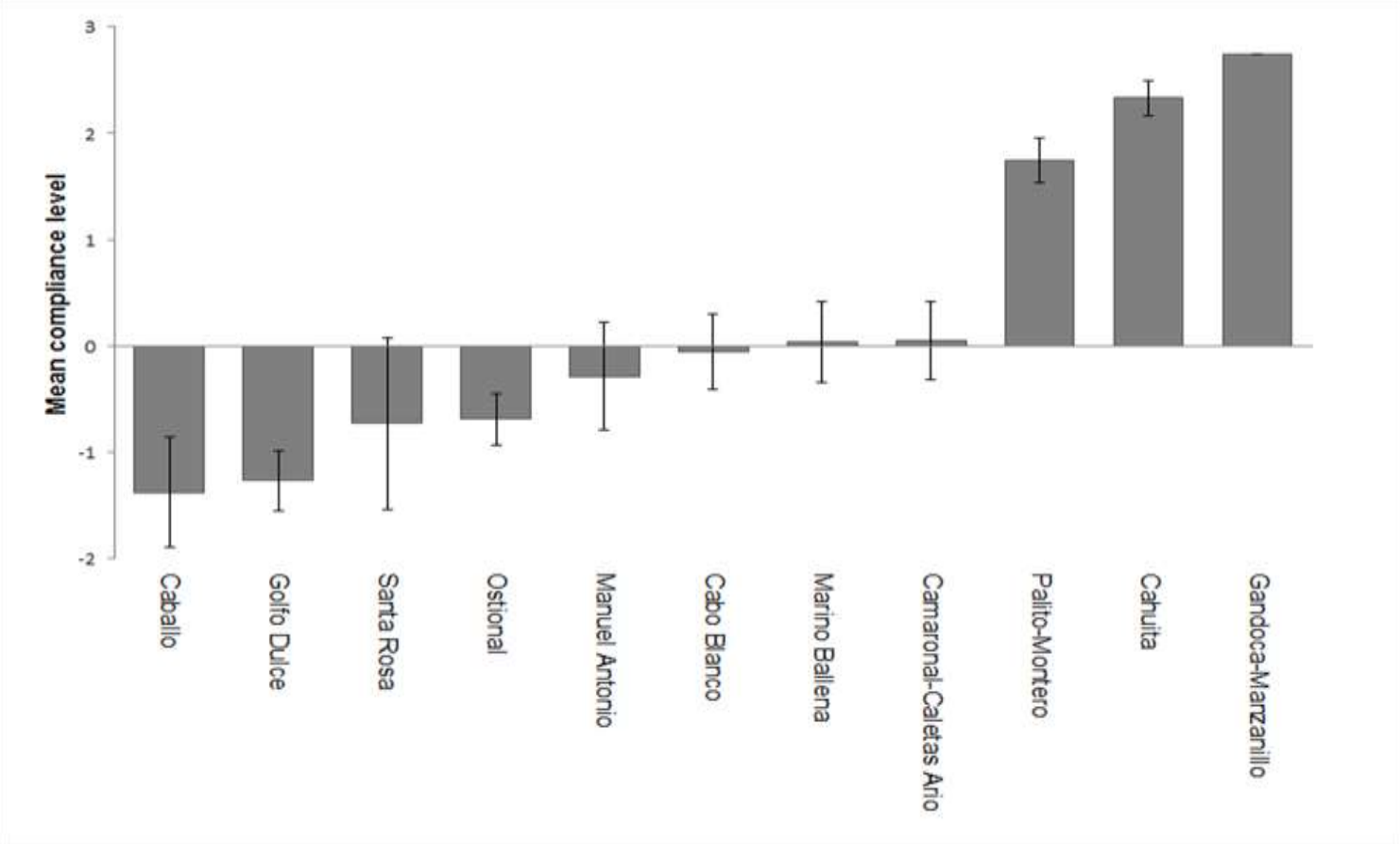


Figure 13. Mean perceived compliance level per MPA. Numbers on the y-axis indicate mean z-scores per MPA. Z-scores are standard deviations above or below the MPA population mean indicated by zero on the y-axis and representing the mean z-score across MPAs. Error bars indicate standard errors of the mean for each MPA, or variation between responses of interviewees for each MPA.

Sixteen percent of respondents said that they had not seen anyone fishing illegally within their corresponding MPA during the last year; 47% of these respondents were from Palito-Montero, Cahuita and Gandoca-Manzanillo. Eighty-four percent of respondents mentioned that they had seen someone fishing illegally within the MPA during the last year, and 85% personally knew someone who intentionally fished illegally within the MPA. The compliance levels perceived by those who reported seeing someone fish illegally within the MPA during the last year were significantly lower than those who did not (Mean=-0.2 and 1.3 respectively; U=299.5, p=0.002). The compliance levels perceived by those who reported personally knowing someone who fished illegally within the MPA were not significantly different from the compliance levels perceived by those who did not (Mean=-0.08 and 0.17 respectively; U=499.5, p=0.44).

3.2 What was influencing compliance levels?

3.2.1 Key informants

The key informant interviews provided important insights into perceived compliance with MPAs. Key informants mentioned that poverty and the lack of livelihood alternatives were serious problems causing some of the illegal fishing. They also reported a paucity of resources to patrol and adequately manage the MPAs. For instance, only Santa Rosa had a functioning patrol system operated by the Park; the other areas either had no boats or the boats were inoperable (e.g., damaged, lack of funds, no qualified staff to operate them). Key informants mentioned that the Coast Guard had multiple duties, and that illegal fishing was not a high priority compared to search and rescue and drug trafficking. Lastly, there was a general belief that artisanal fishermen and government institutions interacted sparsely, and that this lack of communication should be corrected.

3.2.2 Linear mixed effects model

The linear mixed effects model (Figure 14) revealed two predictor variables that had clear negative relationships with perceived compliance: 1) size of the MPA, and 2) being a fisher. Additionally, four other variables indicated a likely positive relationship with perceived compliance: 1) tourism levels, 2) effectiveness of government efforts to fight illegal fishing, 3) MPAs that allowed some fishing, and 4) strong involvement in decision-making. Support toward MPAs and passive involvement in decision-making (e.g., attending meetings but not participating in them) had no discernible relationship with perceived compliance.

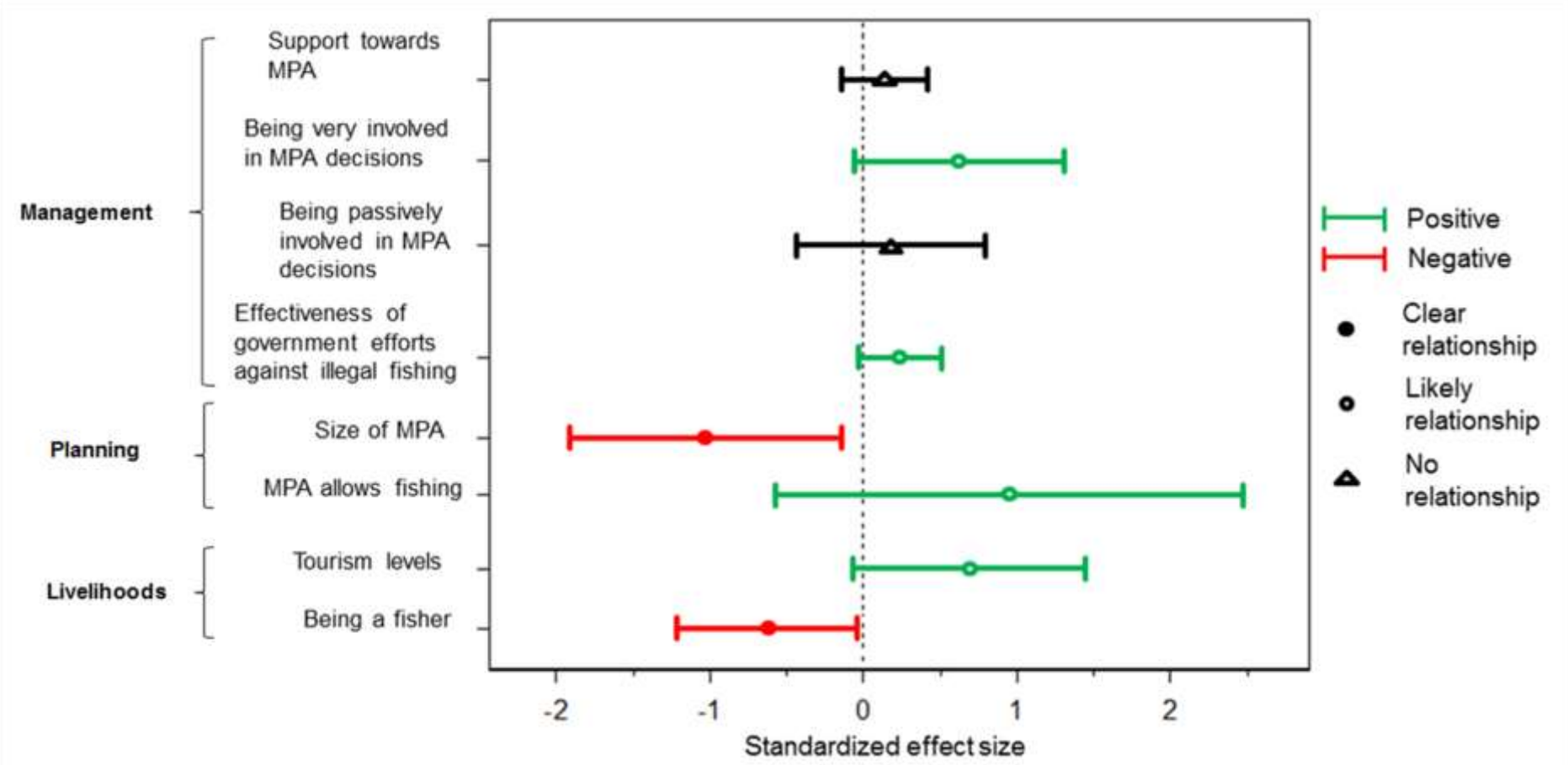


Figure 14. Relationship between MPA- and individual-level variables and perceived levels of compliance. Circles and triangles represent the estimated effect of each variable. Bars represent 95% confidence intervals. Positive estimates are shown in green, negative are in red, and no effect is black. Filled red circles indicate a clear negative relationship to compliance; open green circles represent likely positive relationships to compliance (≥80% of the confidence intervals in a positive direction).

4 Discussion

Illegal fishing is a problem for many marine protected areas globally (Mora et al., 2006; Pollnac et al., 2010), and I found it present, at varying levels, in all of the MPAs that I assessed. Nearly all respondents had seen illegal fishing occurring inside MPAs and personally knew someone who intentionally fished illegally within an MPA. These responses provide a measure of descriptive social norms—or what others do (Cialdini et al., 1991)—suggesting that illegal fishing is common. Only three MPAs (i.e., Palito-Montero, Cahuita, and Gandoca-Manzanillo) had markedly high levels of perceived compliance (Figure 13). Illegal fishing is of concern, not only because of its likely negative environmental effects, but also because noncompliance can have a domino effect. If fishers believe that others are fishing illegally, and perhaps are catching more fish (Appendix 2), they are less likely to comply themselves, so compliance levels would continually decline (Arias, 2015; Cialdini et al., 1991). For example, a participant from Cabo Blanco stated that most people used to respect the MPA, but government enforcement stopped and some free-riders started fishing illegally. Illegal fishing then became so widespread that there was no noticeable difference between fishing inside versus outside of this small MPA.

It is often assumed that MPA compliance is associated solely with enforcement efforts. Enforcement is typically necessary, but not sufficient to ensure compliance (Arias, 2015). I found that government efforts against illegal fishing, normally considered as enforcement, can have a positive effect on perceived compliance; however, other variables were also related to perceived compliance (Figure 14). Levels of perceived compliance were related to a range of socioeconomic and institutional conditions, some that are reasonably easy to influence and others that are more difficult to influence.

The compliance drivers that can be easiest to influence include those associated with management (i.e., participation, support, and enforcement). Conservation is mostly about managing people, and approaches that are inclusive of stakeholders tend to be more successful than those that exclude stakeholders (Jentoft, 2000; Schultz et al., 2011). A meta-analysis of 55 studies identified participation as a critical factor influencing compliance with protected areas (Andrade & Rhodes, 2012). However, my results suggest that it was only the higher levels of involvement with MPA decisions that were positively related to compliance. Simply supporting an MPA, or being weakly involved in decisions, seems insufficient to positively influence compliance (Figure 14). In fact, some studies mention that participation can have negative outcomes (e.g., dilution of scientific input, and 'elite capture' where only some participate and displace others) (Schultz et al., 2011). I did not collect information to further describe the participation processes, and therefore cannot determine if some aspects of participation were eroding compliance in my study sites. It has been suggested that elite capture of participation applies in Golfo Dulce (Solis et al., 2012), and this might negatively affect compliance. Management interventions should be adaptive, aiming for high levels of participation that foster positive outcomes such as empowerment, legitimacy, and, ultimately, increased compliance. Some of these positive outcomes can also be stimulated earlier through an MPA's planning process.

The compliance drivers associated with planning, such as size of the MPA and whether fishing is allowed or not, can be easy to plan for in advance, but can be difficult to change in existing MPAs, particularly when these changes require adjustments to laws that can take years to come into effect. Planning considerations such as MPA size, spacing and location can also influence the achievement of ecological objectives (Green et al., 2014). Yet there are critical trade-offs in planning between achieving compliance and achieving ecological objectives. My results

suggest that larger MPAs, and those that were no-take, had lower levels of perceived compliance (Figure 14). Ecological considerations for planning MPAs commonly suggest that large no-take MPAs are preferable to smaller ones because they can, for instance, encompass more habitats and highly mobile species, and offer higher levels of protection (Edgar et al., 2014; Green et al., 2014). However, larger MPAs can be harder to manage, and excluding fishing from coastal MPAs in developing countries is likely to create friction with fishing communities (Ban, Adams, Almany, et al., 2011); hence compliance and resultant ecological health are likely to weaken. Embedded in social-ecological systems in developing countries, smaller MPAs that allow regulated fishing tend to be more tractable. I think that Costa Rica's moves to include permissive MPA management categories (e.g., "responsible fishing areas") and increase stakeholder participation were steps in the right direction. However, further steps are required to significantly strengthen conservation planning, marine governance, and socioeconomic conditions in coastal areas.

I found two compliance drivers related to livelihoods, which are notoriously difficult to change in fishing communities (Cinner, 2014; Hill et al., 2012). I found that relying solely on fishing had a clear negative relationship with perceived compliance, and increased levels of tourism had a likely positive relationship with perceived fishers' compliance (Figure 14). Tourism levels can serve as a proxy for livelihood options, at least in this study's context. Costa Rica has a strong nature-based tourism market; most tourists engage in ecotourism and nautical tourism (e.g. beach-going, snorkelling, diving, sport fishing) (ICT, 2015a). High levels of tourism can generate more direct and indirect jobs. Protected areas are associated with reduced poverty in Costa Rica (Andam et al., 2010), mainly through tourism (Ferraro & Hanauer, 2014). Increased tourism can offer a wide diversity of livelihood alternatives, presenting fishermen with options for relying less on catch and hence, for some people, potentially reducing the motivations to fish illegally. Nevertheless, the economic

activity around sites with high levels of tourism could also act as an incentive for some fishermen to stay in the fishery or fish more (Daw et al., 2012), for example to meet increased local demand for seafood. Therefore, the causal mechanisms through which tourism and associated livelihoods influence fishers' compliance are unclear. While fishers' compliance with MPAs could potentially improve through more livelihood alternatives, I consider that this can be a challenging strategy that should be approached cautiously, and with objectives other than compliance with MPAs (e.g., poverty alleviation).

I identified steps toward informing and directing interventions to enhance conservation through increased compliance. At the time of sampling, I assessed perceived compliance with fisheries regulations in ~50% of Costa Rica's coastal MPAs. In this study I provided a novel and improved way of measuring compliance: a compound variable formed by the number of people fishing illegally and a measure of the frequency of illegal fishing.

5 Conclusion

I found considerable levels of illegal fishing in multiple Costa Rican MPAs. Yet there were sites with comparatively high levels of perceived compliance. My study builds on previous research (Andrade & Rhodes, 2012; Karper & Lopes, 2014; Peterson & Stead, 2011), adding information on the links between compliance, livelihoods, and participation in management of MPAs. However, the mechanisms through which participation and livelihoods affect compliance remain unclear, indicating an important area for future research. My results suggest that MPA design can play an important role in fishers' compliance (Arias et al., 2016; Ban, Adams, Almany, et al., 2011), and that enforcement is not a requirement for high compliance. Nevertheless, enforcement can help uphold compliance levels, especially in areas where there is a high dependence on fishing (e.g., Palito-Montero). Governments and

conservation practitioners have a suite of tools to increase compliance; here I identified several of these tools, along with some of the implications of using them. I emphasize, however, that adequate compliance interventions must be tailored to their particular contexts—there are no blanket solutions.

Chapter 8: General discussion and conclusion

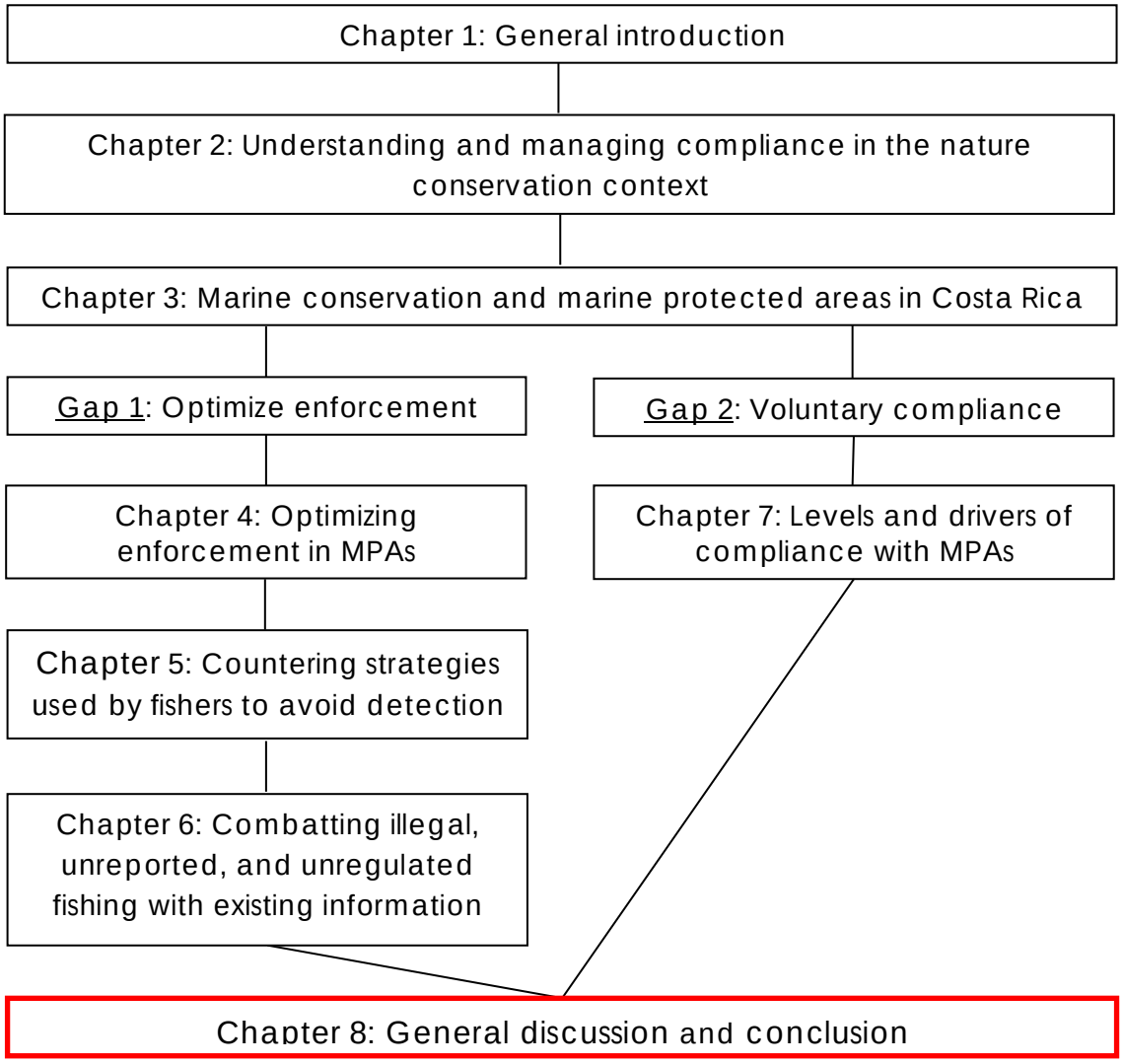
Abstract

It is clear that fishers' noncompliance can erode or nullify the ecological benefits expected from MPAs. Thankfully, the importance of fishers' compliance has been increasingly recognized, and my thesis adds to this growing body of theory and practice in the planning and management of MPAs.

As mentioned Chapter 1 and Chapter 2, illegal fishing can be managed only by influencing fishers' behaviour. While the traditional approach to managing fishers' compliance has been enforcement, there are nuances involved with enforcing MPAs, and voluntary compliance, a key supplement to enforcement, can be achieved through multiple tools such as persuasive communication and incentives (Chapter 2). Managing illegal fishing requires an understanding of the problem at hand, and knowing what tools are available. But because noncompliance is typically clandestine, understanding illegal fishing is not simple.

The central goal of my thesis was to better understand and manage fishers' compliance with MPAs. I addressed this by:

1) amalgamating knowledge on compliance from other fields and applying it to nature conservation;
2) developing methods to better estimate the levels of illegal fishing, including: i) deriving a composite score reflecting the number of illegal fishers and the frequency of illegal fishing, and ii) combining patrol records with freely available information to help predict illegal fishing in space and time;
3) studying the effect that multiple variables had on fishers' compliance; and
4) analysing and proposing ways of strengthening enforcement.


Chapter 1: General introduction
Chapter 2: Understanding and managing compliance in the nature conservation context
Chapter 3: Marine conservation and marine protected areas in Costa Rica
Gap 1: Optimize enforcement
Gap 2: Voluntary compliance
Chapter 4: Optimizing enforcement in MPAs
Chapter 7: Levels and drivers of compliance with MPAs
Chapter 5: Countering strategies used by fishers to avoid detection
Chapter 6: Combatting illegal, unreported, and unregulated fishing with existing information
Chapter 8: General discussion and conclusion

Thesis outcomes

Overarching research question 1: How can fishers' compliance with MPAs be better understood?

To address this question I first did a literature review (Chapter 2) that identified existing information on compliance, and research gaps. The review showed that compliance is relevant to many academic fields and domains of life. Hence, there is a wealth of methods and information that can be applied in the nature conservation context. A result of this review was the development of a framework that proposes the 5Ws for understanding compliance (i.e., WHO is DOING, WHAT, WHERE, WHEN and WHY), and adopting from the tax compliance literature, the "compliance pyramid" for balancing the use of different tools for coercion and voluntary compliance (Figure 2). The 5Ws and the compliance pyramid are used in other disciplines (e.g., policing and taxation, respectively). However, to my knowledge, this is the first time they have been both combined into a framework, and proposed for use in nature conservation. This framework is underpinned by: 1) having a good understanding of compliance (the 5Ws), 2) the preference for voluntary compliance, and 3) the concept of compliance as a gradation of behaviour—instead of a dualism ("illegal/wrong" or "legal/right"), which accords with the use of graduated sanctions. I then built on Chapter 2 by providing empirical studies that directly address the understanding of compliance.

To better understand fishers' compliance with MPAs, in Chapter 4 I used patrol records, and freely available information on bathymetry and lunar cycles to show how illegal fishing can be predictable in space and time. Patrol records can be a rich source of information which, when combined with additional information, can help reveal patterns of legal or illegal resource use. In Cocos Island National Park most of the illegal longlining (WHAT), from Costa Rican boats (WHO), occurred on a seamount (WHERE), and particularly around new moons within the third

quarter of the year (WHEN). This increased understanding of resource-use patterns can help managers improve their interventions, for example by better allocating limited management resources in space and time, such as patrols.

As mentioned in Chapter 2, a good understanding of WHAT the compliance problem is involves having an idea of its magnitude. Most studies, however, provide limited information on the magnitude of compliance, such as estimated numbers of people who engage in illegal fishing (Arias & Sutton, 2013). This metric is limited because it does fully account for the effort of illegal fishing (Arias & Sutton, 2013). In Chapter 7 I overcome this limitation by using a composite score to report the level of illegal fishing. To my knowledge, this is the first study that uses a composite score to report compliance levels in the conservation context. By combining the amount of people fishing illegally and the frequency of illegal fishing, practitioners can have a better idea of WHAT the problem is, helping them establish priorities. For instance, managers can decide to focus on areas with the highest levels of illegal fishing, understanding that the 'level' is robust because it is based on two key factors.

Finally, understanding WHY people follow or break rules is critical because it explains their behaviour, allowing for relevant management interventions. For instance, in several coastal MPAs that I studied, it was clear that illegal fishing was widespread—in some cases a daily activity (Chapter 7). So I also identified variables that were influencing fishers' compliance with MPAs, finding that perceived compliance was lower in bigger MPAs, and in areas with a higher dependency on fishing. Results like these offer better chances of successful interventions because they respond to a specific reality or context.

*Overarching r**esearch question 2: How can we better manage fishers'** compliance with MPAs?*

As reviewed in Chapter 2, voluntary compliance is desirable because it means that people approve the rules and institutions. Voluntary compliance can be encouraged mainly through legitimacy, incentives, alternatives, and persuasive communication (Chapter 2). In Chapter 7, I provided results that can help increase voluntary compliance (Figure 14). For instance, persuasive communication or incentives can foster involvement in MPA decisions, likely increasing compliance through a sense of legitimacy toward rules and institutions. Even though voluntary compliance is desired, it is unlikely that everyone will comply voluntarily; there are people who will occasionally break some rules, and people who will repeatedly and purposefully break rules (Chapter 2). Consequently, enforcement is typically necessary.

My thesis contributes to the practice of compliance management, particularly through improved enforcement. I dedicated Chapters 4-6 to studying ways of optimizing enforcement. To my knowledge, Chapter 4 was the first paper in the MPA and fisheries literature to empirically show how patrols can be optimized in space and time. Importantly, I did so using patrol records, generally available to managers, and freely available information. Also, Chapter 4 underlined the importance of a strong enforcement chain for effective coercion. The enforcement chain is a simple, yet powerful, concept that requires more attention from the conservation literature, and also appears to be inadequately addressed by many institutions which focus mostly on detection and arrest, the first two links of the chain.

Chapter 5 contributed to an important but very limited body of literature: detection-avoidance strategies. In this Chapter I provided some theoretical insight into the variables that can influence the adoption of detection-avoidance strategies, I described some detection-avoidance

strategies that I encountered in the field, and offered potential countermeasures that managers can use. Some managers are aware of detection-avoidance strategies, but these strategies are largely undocumented, and they are dealt with unsystematically. I proposed the Intelligence Cycle as a useful way for managing information and actions on detection-avoidance strategies. The risk of not addressing detection-avoidance strategies can be large because the probability of detection, which is already low, decreases further. Also, as people start adopting these strategies, the sense of legitimacy toward managing institutions can weaken as the environmental impact intensifies. Chapter 5 contributes to the theory and management of detection-avoidance strategies, and aims to trigger more work and discussion around this topic.

Another way to better manage fishers' compliance is by using existing fisheries databases. Chapter 4 demonstrates the value of patrol records and freely available data, such as bathymetry and lunar cycles, to increase the probability of detection. Chapter 6 expands on Chapter 4 by presenting an interesting and poorly known case in which national and regional fisheries databases were used to detect possible cases of illegal fishing. A major factor limiting the use of existing fisheries databases is access. Many fisheries databases are not publicly accessible, or access is difficult. Chapter 6 shows that fisheries databases are valuable for detecting noncompliance in large MPAs, and illegal, unreported and unregulated fishing in general. However, there is a clear need for open access to these data, and formal collaboration channels between relevant institutions and the public.

Limitations of this thesis

- General limitations

As discussed in Chapter 2, and shown in Table 1, there are multiple methods for studying compliance. Even though I used multiple methods throughout my thesis, I did not use multiple methods to answer any one

particular research question. This applies particularly to Chapter 4 and Chapter 7. For instance, in Chapter 7 I only used social surveys. By using other techniques, such as underwater visual census, I could have complemented my social data with environmental evidence of compliance levels. Compliance studies can combine multiple methods to provide a stronger case. However, all methods have advantages and disadvantages, and time and budget can restrict the type and number of methods used. For example, underwater observations of discarded fishing gear can help understand illegal fishing (Williamson et al., 2014), but such method is limited to areas with conditions that are favourable for diving (e.g., coral reefs). Given the variety of environmental characteristics in my sites (Table 5), my research questions, and budget and time restrictions during fieldwork, I believe that social surveys provided the best option; and I used two types of surveys, questionnaires and key informant interviews, to cross-check my results. Similarly, in Chapter 4 I focused mainly on patrol records, and another option would have been interviewing fishers and checking if their accounts matched the data extracted from patrol records.

- Specific limitations

In Chapter 4 I discuss the enforcement chain and show how patrol effort can be optimized in space and time. The main limitation of this study is that patrol routes were not included in the analyses. This is a limitation because the spatial analysis of patrol records can be biased when patrol routes are not considered. This bias might occur because wardens might have preferred or avoided routes, for instance because of distance and weather conditions. My spatial analysis would have been stronger had patrol routes been considered. However, the data were not available.

In Chapter 7 I measured levels and drivers of fishers' compliance with MPAs. I think that this Chapter has three main limitations. First, time and budget constrained my sample size. Although the sample was

enough to run statistical analyses and obtain interesting results, a larger sample would have been preferable. For example, more variables could have shown a stronger influence on compliance, tourism levels for instance (Figure 14). Second, my selection of MPAs was non-random; hence, the ability to draw inferences outside my sample is limited. However, and as mentioned previously, compliance can be very context-dependent, so readers should always be cautious when drawing inferences from compliance studies. And third, I did not measure perceptions of legitimacy. As I discussed in Chapter 2, other studies (Hønneland, 2000; McClanahan et al., 2006) have found that legitimacy can influence fishers' compliance. I regret not including legitimacy in Chapter 7, but thankfully during my PhD candidature I had the opportunity to collaborate on a project that is much related to legitimacy and marine resource users, particularly commercial fishers and tourism operators in the Great Barrier Reef Marine Park, Australia (Turner et al., 2016).

Additionally, some could consider that my measures of the number of illegal fishers and the frequency of illegal fishing in Chapter 7 were inadequate because they were measured categorically. Categorical variables are not as robust as numerical ones, they are not as accurate, and they can be subjective. However, when people are asked to provide an estimate, it becomes very difficult for them to give a definitive numerical value. Hence, it can be better to use categories when asking people to provide estimates. The field of risk analysis has developed valuable methods for eliciting people's opinions more accurately (Martin et al., 2012). Nevertheless, these methods are better suited for respondents with advanced education who can understand concepts like confidence intervals (Dr. Terry Walshe 2014, pers. comm., 16 September), so they were not appropriate in the context of my study: coastal communities in a developing country.

Management implications

My main goal during my PhD candidature has been to generate research that advances conservation theory and practice. I want my work to be useful for scientists, but also for managers. Here are some of the key management implications from my thesis:

1) A more structured approach to compliance management

When it comes to managing illegal fishing and environmental crime in general, many compliance managers would benefit from approaching their work in a more structured or systematic way. As I showed in Figure 2, Figure 5, and Figure 11, there are frameworks for structuring compliance management. However, from my experience, many MPA managers do not even collect compliance data, and if they do, the data are not always stored adequately (e.g., patrol records kept in paper filing cabinets), and hence not used to inform decisions. For instance, it took me several weeks to collate the patrol data for Chapter 4 because the data were in many Microsoft Word files—thankfully the data were not in papers in remote Cocos Island. I hope that managers find value in some of these frameworks that I proposed.

2) Strengthening enforcement

Most managers are habituated to using enforcement as a tool. My thesis had a strong emphasis on strengthening enforcement. I discuss the enforcement chain as a significant concept in MPA management, and I presented ways of bolstering specific links on this chain, particularly the probability of detection. Managers can become proficient at detecting noncompliance, but it is critical that they are backed by a strong enforcement chain. Understanding the enforcement chain is important for managers because they can more easily establish their accountability and the accountability of others (e.g., individuals and institutions). Establishing accountability is relevant because it can help managers leverage improvements across the enforcement chain.

3) Seeking voluntary compliance

As previously, managers are typically familiar with enforcement as a tool for influencing compliance. However, some managers seem to focus too much on coercion and overlook voluntary compliance. I underlined the importance of voluntary compliance and that there are multiple tools for influencing voluntary compliance: legitimacy, incentives, alternatives, and persuasive communication. I shared multiple examples and references for each of these tools. Of course, becoming proficient at using these tools can take time and support, but the first step is helping managers become aware of all the tools that they can have in their toolboxes—this alone can give some of them new prospects. To illustrate this, in 2015, I shared information about persuasive communication with an MPA manager from the Philippines and I suggested a book (Ham, 2013); a few weeks later I received a kind email from her, telling me that she bought and read the book, and that persuasive communication was now going to influence management in her MPA—this was pleasant news indeed.

Professional involvement with managers

Before embarking on my PhD endeavour, I worked closely with managers in Latin America, primarily through involvement with NGOs. During PhD my candidature, I have endeavoured to maintain and expand these professional networks, and, thankfully, I sense that these efforts have been successful. Some of my work has been possible because of these networks. For example, Chapter 4 would have been impossible without the contact and trust with the organizations that shared the law enforcement records—which is sensitive information in its original format—from Cocos Island National Park. In return, I provided a study that I translated to Spanish (available here: http://dx.doi.org/10.13140/RG.2.1.1956.2400), and that has been

influencing MPA management. My previous contacts also facilitated access to valuable interviewees and key informants for Chapters 4-7.

My professional networks expanded during my PhD candidature, allowing me to gain and share new knowledge. Good examples of this are two 'compliance management workshops' that I helped facilitate in 2014 and 2015; the attendees were managers from most of the marine World Heritage Sites around the world. In addition, I have been pleased to know that my work from Chapter 2 has been welcomed by protected area managers in Belize, and is being used to guide some of their work; and the paper from Chapter 4 (Arias et al., 2016) was featured in the cover of *Oryx*, and, as evidenced by its high Altmetric score (available here: http://www.altmetric.com/details/2570225/news), has had considerable impact in the media. Likewise, I hope that my other chapters are useful to others. As my PhD comes to an end, I am eager to share and apply my knowledge and skills.

Future work

Future research could look into the mechanisms (intervening causes) through which different management, planning, and livelihood variables influence fishers' compliance. Tourism, for example, seemed to be influencing fishers' compliance in some of my study sites (Figure 14), but the mechanisms through which tourism might influence compliance are unclear, and clarifying this will require empirical studies (Ferraro & Hanauer, 2015). Such studies would benefit from small geographical scales and large sample sizes. Also, conducting in-depth research in sites with high levels of compliance would provide insights into key drivers of compliance. Areas with markedly high compliance (or 'bright spots') can provide useful information on the factors that strengthen fishers' compliance. In the case of Costa Rican coastal MPAs, Cahuita, Gandoca-Manzanillo, and Palito-Montero seem to be bright spots (Figure 13).

Detection avoidance in environmental crime deserves more attention from scholars. The topic is relevant for conservation, and there is very little information about it in the peer-reviewed literature. The theoretical relationships shown in Figure 10 should be explored empirically, and they present an interesting direction for future work. Game theory, which has been used to address questions around interactions between people and rules (Rustagi et al., 2010), could provide useful methods for exploring these relationships.

A topic that I started scoping during my PhD candidature is evaluating the environmental impact of illegal fishing. Unfortunately, I did not manage to explore the topic in enough depth for its inclusion in this thesis. The environmental impact of fishing (legal or illegal) is variable. I assume that this variability depends on four key factors: 1) the type of fishing (e.g., fishing gear and target species), 2) the number of people fishing, 3) the frequency of fishing, and 4) the location where fishing takes place—in other words, and drawing on Chapter 2: 'WHAT', 'WHO', 'WHEN', and 'WHERE'. For example, the environmental impact that handlines have on marine habitats can be very different to that of bottom trawlers (Morgan & Chuenpagdee, 2003; Puig et al., 2012). However, the magnitude of this difference can vary according to the fishing effort with each fishing gear, and the type of habitat being fished (e.g., mobile muddy sediment vs seagrass). I think that combining these key factors can provide a good estimate of the environmental impact that illegal fishing has, or can have. This approach could also yield valuable information on the effectiveness of different types of MPA zoning that regulate fishing gear, seasons, and target species. Further, planners and managers should always account for illegal fishing (e.g., when assigning quotas, giving licences, and setting conservation targets), a tool like this could be useful in informing such process. This evaluation could be done through expert elicitation (Ban et al., 2014), and can be simulated using computer models.

There is an urgent need to manage compliance on the ground. The current knowledge and information on compliance management can always improve, but it is already enough to provide good outcomes. Managers need support for improving their compliance management. Several initiatives (e.g., Global Fisheries Enforcement Training Workshops [GFETW], the International Monitoring, Control and Surveillance network [IMCS], and INTERPOL working groups on fisheries and wildlife crime) are highly encouraging because they provide capacity building and information for managers, yet they require additional efforts to engage and collaborate more effectively (Österblom, 2014).

Lastly, a main limiting factor is political will. There must be a widespread realization that environmental noncompliance is not ‘‘only’’ an environmental problem, it is also a social problem (Bahadur, 2011; Brashares et al., 2014), with economic implications (Pramod et al., 2014; Sumaila et al., 2006), and a challenge for governance (Österblom & Bodin, 2012; Österblom et al., 2010). Tackling environmental noncompliance requires political will, otherwise many necessary steps such as interagency and international collaborations, robust legal frameworks, and changes in markets will be impossible or slow to achieve.

Concluding remarks

I underline that effective nature conservation, and hence effective MPAs, depends on peoples' compliance with rules. By borrowing and adapting from several disciplines, and through several empirical works, I showed how compliance can be better understood, and how this understanding can lead to better management interventions.

Specifically, I conclude that:

1) many academic fields and domains of life provide key knowledge for understanding and managing fishers compliance, with the social

sciences being are paramount because compliance is a human behaviour;

2) the framework combining the 5Ws and the compliance pyramid can be a useful tool for conservation practitioners because it provides an effective guide for understanding and managing compliance;

3) it is critical that enforcement, a means to achieve compliance, is optimized throughout its four links;

4) illegal fishers can adopt detection-avoidance strategies, as a response, practitioners can use the intelligence cycle to inform countermeasures;

5) fisheries databases, national and regional, can provide valuable information for detecting IUU fishing, but there is a clear need for open access to these databases, and structured collaboration across relevant institutions and the public;

6) practitioners need to be more critical about what 'compliance levels' means; a good metric comprises both the number of illegal fishers and a measure of the frequency of illegal fishing; and

7) fishers' compliance is context dependent and is typically driven by multiple variables, understanding what drives compliance is key for designing and implementing relevant management interventions.

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Appendix 1. Number of questionnaires and key informant interviews per MPA (Chapter 7).

Table A1.1 Number of questionnaires and key informant interviews per MPA.

Marine Protected Area	Questionnaires	Key informant interviews	Total
Santa Rosa	5	9	14
Ostional	11	4	15
Camaronal-Caletas Arío	9	3	12
Cabo Blanco	11	2	13
Palito-Montero	11	2	13
Caballo	8	1	9
Manuel Antonio	9	5	14
Marino Ballena	9	5	14
Golfo Dulce	16	5	21
Cahuita	7	3	10
Gandoca-Manzanillo	3	2	5
Total	99	41	140

Appendix 2. Additional methods, results and discussion (Chapter 7)

METHODS

To obtain additional information on factors influencing compliance we asked participants what they thought was driving compliance and noncompliance, ranking these responses according to the number of mentions.

RESULTS

Table A2.1 summarizes the salient factors that respondents thought influenced compliance (i.e., why fishermen follow MPA rules) and noncompliance (i.e., why fishermen break MPA rules).

Table A2.1 Three highest-ranked factors considered by respondents to influence compliance and noncompliance. n= number of mentions by respondents.

Rank	Compliance	Noncompliance
1	Afraid of sanctions (n=57)	Better/easier fishing in protected area (n=49)
2	Complying brings benefits (individual, communal, or environmental) (n=52)	Financial hardship (n=23)
3	Complying is the right thing to do (n=16)	Unlikely to get sanctioned (n=21)

DISCUSSION

The factors influencing compliance that were identified by respondents revealed that there is some degree of purposeful, voluntary compliance (Table A2.1). Voluntary compliance is preferable to coerced compliance because it can: 1) indicate that natural resource users are assertive about the benefits of regulating use of natural resources, 2) provide a buffer when costly enforcement is suspended, and 3) confirm effective governance and management (Arias, 2015). Some respondents believed that compliance involves environmental, personal, or communal benefits (Table A2.1). The fact that most respondents believed that fishing

illegally in MPAs could be better or easier than fishing outside of them (Table A2.1), suggests that MPAs, despite varying amounts of illegal fishing, could contain higher fish biomass than the non-protected areas. Even though voluntary compliance is preferred, a degree of enforcement is typically necessary (Arias, 2015; Braithwaite & Braithwaite, 2001; Tyler, 2003) to maintain deterrence and compliance (Table A2.1). We therefore consider that if the deficit of enforcement efforts detected in most of these sites were to continue, or deteriorate further, fishers who might be complying voluntarily could defect in the face of flagrant noncompliance. This is supported by our results, which suggest that effective government efforts to manage illegal fishing can relate positively to perceived compliance (Figure 14). Furthermore, patrol efforts (either formal or informal) tend to be more effective in smaller areas (Ban, Adams, Almany, et al., 2011), and this might explain why perceived compliance was lower in larger MPAs (Figure 14).

We were also interested in knowing what respondents thought was influencing noncompliance. Respondents cited poverty and better fishing in MPAs as the main reasons for noncompliance (Table A2.1). Coastal communities in Costa Rica are predominantly poor (Morales-Aguilar, 2013). Scarcity of food or income could induce some people to fish illegally in MPAs, mostly if they believe that there are more fish in them than outside (Table A2.1). It is worth noting that, in Cahuita and Gandoca-Manzanillo, both in the Caribbean, people do not rely entirely on fishing, and fishing in Costa Rica's Caribbean is much less productive than the Pacific (FAO, 2011). This low dependence on fishing can help explain the higher compliance in these two Caribbean sites. In contrast, the communities adjacent to MPAs with low perceived compliance (e.g., Caballo, Golfo Dulce, and Santa Rosa) rely substantially on fishing (Marín-Cabrera, 2012; Solis et al., 2012). This is particularly true at the small island of Caballo, where fishing is the only livelihood. These facts support the results of our model, which shows that fishers perceive lower levels of

compliance than non-fishers (Figure 14). It is likely that compliance levels were negatively affected by a high dependence on declining fisheries, and a lack of livelihood options. Similar conclusions have been drawn by previous studies. Peterson and Stead (2011) suggested that the main causes for noncompliance with MPAs in Rodriguez, an island in the Western Indian Ocean, were lack of food and limited livelihood opportunities. Similarly, Karper and Lopes (2014) found that artisanal fishermen that depended more on fisheries had stronger intentions to break rules in a Brazilian MPA. Thus, declining or collapsed fisheries can give rise to illegal fishing and other types of noncompliance, and a high dependence on fisheries exacerbates the problem (Brashares et al., 2014; Gettleman, 2015).