Addressing sources of data deficiency for sea turtles and fisheries in the Indian Ocean and Southeast Asia

Thesis submitted by

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Abstract

Marine turtle populations worldwide are threatened by a number of anthropogenic activities, of which fishing is unquestionably one of the most harmful. Though the effects of fisheries mortality have been documented across species, gear types and regions, management intervention remains constrained by data limitations even in well-monitored fisheries in developed nations. The issue of illegal, unreported and unregulated (IUU) fishing introduces further uncertainty into fisheries management regimes, with a lack of understanding of how IUU fishing activities affect marine turtle populations. For both legal and IUU fisheries, such data deficiencies hinder the development of targeted mitigation strategies for reducing fisheries-related injury and mortality of marine turtles. I chose to examine specific issues of data deficiency for marine turtles and fisheries in the Indian Ocean and Southeast Asia region (IOSEA), an area identified as having critical data needs for multiple fleet types and turtle populations.

I began by demonstrating the need for cross-jurisdictional assessment of turtle bycatch in legal, regulated fisheries. I evaluated the cumulative patterns of turtle bycatch in Australia using longitudinal datasets from commercial fisheries in three separate management jurisdictions (Chapter 2). The results of this chapter point to potential cumulative impacts to vulnerable turtle populations (i.e. leatherback and olive ridley) arising from interactions with multiple fisheries. Spatial analysis revealed a bycatch ‘hotspot’ in the Gulf of Carpentaria, where commercial fisheries impact multiple turtle species and genetic stocks. These results illustrate the need to set cumulative, cross-jurisdictional bycatch quotas for marine turtles, and to evaluate turtle bycatch at the population level instead of separately within individual fisheries. I also stress the need for timely collaboration between management agencies in order to implement effective, biologically relevant management strategies for marine turtles and other vulnerable taxa.

Next, I evaluated IUU fishing as a threat to marine turtles in the IOSEA (Chapter 3). The unlawful nature of IUU fishing makes it difficult to study directly and thus required gathering data from outside traditional bureaucratic reporting frameworks. Using the expert elicitation technique, I determined that IUU fishing is likely to have potentially significant impacts on marine turtle populations in the IOSEA through targeted exploitation, use of prohibited gears and international wildlife trafficking. IUU fishing activities were found to vary in nature and magnitude on sub-regional scales, with Southeast Asia emerging as an area of concern due to the targeted exploitation and trafficking of marine turtles by IUU vessels. This chapter constitutes the first expert consensus characterising IUU fishing as a serious threat to marine turtles. These results indicate a demonstrable need to strengthen monitoring, control and surveillance (MCS) efforts and to employ regional coordination to help build capacity in less-developed nations.

To complement the broad-scale assessment of IUU fishing performed in Chapter 3, I then examined IUU fishing dynamics relating to marine turtles within the Southeast Asia sub-region (Chapter 4). During interviews with commercial fishers in two Malaysian states (i.e. Terengganu and Sabah), I found that the root causes of IUU fishing differ considerably between states, as do the dynamics of marine turtle capture and trade. This chapter also provides evidence linking IUU fishing vessels to the direct capture, trade and transshipment of marine turtles in Malaysia; such activities are likely to occur in other nations throughout the IOSEA, particularly where underlying situational factors are similar. Given these state-specific differences in IUU fishing practices and motivations, I conclude that the enforcement response must be similarly nuanced in order to address the varying drivers of IUU fishing in each state context. Further, an international, collaborative and pluralistic regulatory approach is needed to reduce IUU fishing and wildlife trafficking, as these are interconnected facets of a broader issue of unlawful marine resource extraction.

As IUU fishing persists despite the large number of political instruments and initiatives aimed at eliminating it, an examination of the barriers to effective policy implementation and enforcement is needed. To address this need, I designed a structured survey for officials working in marine conservation, fisheries management and enforcement throughout the IOSEA (Chapter 5). Survey results indicate that while IUU fishing is considered a management priority throughout the IOSEA, on-ground action is hindered by scale mismatches and capacity shortfalls. Among management agencies in the IOSEA, there is a mismatch between the acknowledgement that inter-agency collaboration is important and the reported degree of its implementation. These results also identified a number of knowledge gaps that managers believed would be useful in reducing the incidence of IUU fishing and marine turtle exploitation. I emphasise that decentralised fisheries management strategies have the potential to develop targeted, locally-based solutions, and also present an opportunity for much-needed data-gathering. Finally, drawing partly on the results of Chapter 4, I conclude that improvements in MCS measures must develop alongside advances in understanding of the drivers and barriers present in each local context.

Based on the combined results of my interdisciplinary thesis, legal and IUU fisheries interact with marine turtles in a number of ways that have consequences for the survival of turtle populations. Existing national and international instruments are not sufficiently equipped to tackle the variety of fishing-related threats to marine turtles, and instead will require adoption of cross-jurisdictional, pluralistic and potentially decentralised management approaches in order to enact change at the level of individual fishers. In Chapter 6, I emphasise the value of my approach for evaluating widespread, complex and data-limited threats, and that my contribution informs management efforts for both fisheries and marine turtles. I then conclude the thesis by identifying avenues for useful future research.

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Glossary of Terms

Abbreviation	Full name
AFMA	Australian Fisheries Management Authority
APEC	Asia Pacific Economic Cooperation Forum
ARREST	Asia's Regional Response to Endangered Species Trafficking
ASEAN	Association of Southeast Asian Nations
ASEAN-WEN	Association of Southeast Asian Nations – Wildlife Enforcement Network
BRD	Bycatch Reduction Device
BOBLME	Bay of Bengal Large Marine Ecosystem Project
BPUE	Bycatch Per Unit Effort
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna
CMS	Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)
DAFF	Department of Agriculture, Fisheries and Forestry
DPIF	Department of Primary Industry and Fisheries
EBM	Ecosystem Based Management
EEZ	Exclusive Economic Zone
EPBC	Environment Protection and Biodiversity Conservation Act 1999
ETB	Eastern Tuna and Billfish fishery
FAO	Food and Agriculture Organisation of the United Nations
FOC	Flag of Convenience
IMO	International Maritime Organization
IOSEA	Indian Ocean and Southeast Asia
IOSEA-MoU	Indian Ocean and Southeast Asia Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats
IPOA-IUU	International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing
IUCN	International Union for the Conservation of Nature
IUCN-MTSG	International Union for the Conservation of Nature Marine Turtle Specialist Group
IUU	Illegal, Unreported and Unregulated fishing
MARPOL	International Convention for the Prevention of Pollution from Ships (1973)
MCS	Monitoring, Control and Surveillance
MMPA	Marine Mammal Protection Act 1972
MRAG	Marine Resources Assessment Group Ltd
MRF	Marine Research Foundation
MSC	Marine Stewardship Council
MTSG	Marine Turtle Specialist Group
NED	Northeast Distant statistical area
NGO	Non-Governmental Organisation
NIO	Northern Indian Ocean
NIOMTTF	Northern Indian Ocean Marine Turtle Task Force
NPF	Northern Prawn Fishery
NPOA-IUU	National Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing
NWIO	Northwestern Indian Ocean
PBR	Potential Biological Removal
PSMA	Port State Measures Agreement
RFMO	Regional Fisheries Management Organisation

Glossary of Terms (continued)

Abbreviation	Full name
RPOA-IUU	Regional Plan of Action to Promote Responsible Fishing Practices including Combating Illegal, Unreported and Unregulated (IUU) Fishing in the [Southeast Asia] Region
S-AIS	Satellite Automatic Identification System
SCP	Situational Crime Prevention
SEA	Southeast Asia
SWIO	Southwestern Indian Ocean
TED	Turtle Excluder Device
TSP	Torres Strait Prawn fishery
UMT	University Malaysia Terengganu
UN	United Nations
UNCLOS	Convention on the Law of the Sea (1982)
UNEP	United Nations Environment Programme
UNODC	United Nations Office on Drugs and Crime
UNTOC	United Nations Convention against Transnational Organised Crime
WIOMTTF	Western Indian Ocean Marine Turtle Task Force
WTB	Western Tuna and Billfish fishery

Chapter 1

General Introduction

1.1. Fisheries as a global resource

Marine fisheries play an important role in feeding humanity. Globally, an estimated one billion people rely on fish as their main source of animal protein (FAO 2009; WHO 2017), and consumption is increasing by 2.5% each year (Watson et al. 2016). With more than 65 million tonnes landed worldwide in 2015 (FAO 2017), fishery products are some of the world's most traded food commodities and represent about 10% of total agricultural exports (Sumaila et al. 2016). Fisheries also provide livelihoods to an estimated 260 million people, 78% of which are in developing countries and 86% in Asia alone (Teh and Sumaila 2013). Global fisheries capture production increased steadily from 1950, reaching a plateau of ~80 million tonnes per year in the 1980s (Worm et al. 2009).

However, these levels of exploitation are having negative impacts on marine species and ecosystems. Fish catches are declining worldwide by approximately 500,000 tonnes per year (Pauly et al. 2003). Up to one third of global fisheries are either overexploited or have collapsed (FAO 2009; Hutchings et al. 2010; Srinivasan et al. 2012), with consequences for ecosystem functions (Halpern et al. 2008; Jackson et al. 2001; Worm et al. 2006) and species abundance at multiple trophic levels (Baum et al. 2003; Maureaud et al. 2017; Pinsky et al. 2011).

Despite the evident need to reconcile seafood production with fishery sustainability, a study by Rice and Garcia (2011) predicts that this balance will only get harder to achieve given future projections of population growth and climate change. As fish populations worldwide continue to decline under the weight of rising fishing pressure (Pauly and Zeller 2016; Sumaila et al. 2016), implementing sustainable fisheries management strategies becomes increasingly relevant to global issues of food security and human health (Srinivasan et al. 2010).

1.2. Bycatch and mortality of non-target species

Following increases in global fishing effort over the past few decades (Anticamara et al. 2011), concerns have intensified over the potential impacts on non-target marine species and ecosystems (Alverson 1994; Crowder and Murawski 1998; Hall et al. 2000). Incidental capture, or bycatch, of non-target organisms in commercial fisheries is widely acknowledged to pose a significant threat to marine biodiversity (Hall et al. 2000; Millennium Ecosystem Assessment 2005; Soykan et al. 2008).

The ecological consequences of bycatch are numerous and far-reaching. Removing non-target organisms—particularly apex species at high trophic levels—has been shown to disrupt food web structures and trigger trophic cascades (Estes et al. 2011; Heithaus et al. 2008; Pauly et al. 1998). When discarded at sea, the bodies of bycatch species may sink and putrefy, creating hypoxic 'dead zones' that alter fundamental processes of marine primary production (Doughty and Carmichael 2012; Rabotyagov et al. 2014; Vaquer-Sunyer and Duarte 2008). Additionally, population-level effects of bycatch have been documented for several commercial fish stocks (see Diamond et al. 2000), illustrating the importance of bycatch mitigation as a strategy to manage fisheries for long-term sustainability and human food security (King 2013).

For non-target species with life histories characterised by low fecundity and iteroparity (e.g. marine megafauna such as marine mammals, elasmobranchs, seabirds and marine turtles), fisheries-related mortality of breeding-age individuals can cause dramatic and even irreversible population declines (Crouse et al. 1987; D'agrosa et al. 2000; Lewison et al. 2004). These declines have been documented for several megafauna taxa: seabirds (Anderson et al. 2011; Bergin 1997; Ryan et al. 2002), elasmobranchs (Arauz 2000; Baum et al. 2003; Dapp et al. 2013; Worm et al. 2013), marine mammals (D'agrosa et al. 2000; Marsh 2002; Read et al. 2006) and marine turtles (Chan and Liew 1996; Limpus and Reimer 1994;

Peckham et al. 2007; Spotila et al. 2000). The loss of marine megafauna—referred to as 'trophic downgrading' (Soykan et al. 2008)—also has implications for changes in ecosystem-level functions and processes, such as nutrient cycling (Estes et al. 2011; Lewison et al. 2014).

1.3. Fisheries and marine turtles

Marine turtles are especially vulnerable to the effects of fisheries bycatch. They exhibit long life spans and a late onset of sexual maturity (Heppell et al. 2003; Lewison et al. 2004); as a result, their population structure is most influenced by the survival of large immature or adult-stage age classes (Crouse et al. 1987; Žydelis et al. 2009). Marine turtles are also migratory (Musick et al. 1997; Plotkin 2003), occupying a variety of habitats during their life cycle and thus increasing the likelihood of interacting with multiple fisheries and gear types (Lewison et al. 2014; Moore et al. 2009; Riskas et al. 2016; Wallace et al. 2013). As such, levels of marine turtle bycatch are highly variable across both spatial and temporal scales, requiring management intervention that is based on robust, fishery-specific data.

While many studies have noted high levels of turtle bycatch and mortality in artisanal, or small-scale fisheries (Abdulqader et al. 2017; Alfaro-Shigueto et al. 2010; Alfaro-Shigueto et al. 2011; Kuperan and Abdullah 1994; Pingo et al. 2017), robust data on the extent of these fisheries and their rates of turtle bycatch are underrepresented in the fisheries literature (Chuenpagdee et al. 2006; Lunn and Dearden 2006; Pauly 2006). While these fisheries are important sources of food and employment throughout the developing world (Teh and Sumaila 2013), and they also represent a critical knowledge gap for marine turtles (see Lewison et al. 2014; Wallace et al. 2010b, I will place these fisheries outside the scope of this thesis. Information in the following sections refers to regulated commercial fisheries.

1.4. Bycatch research and mitigation measures

Seeking to rectify the turtle bycatch problem, scientists and fisheries agencies have worked to develop and trial a number of technical innovations to improve the selectivity of fishing gear. Here I provide an overview of general trends in bycatch research, followed by brief summaries of the bycatch reduction measures implemented in commercial fisheries by major gear type (i.e. longline, trawl and net; see Lewison et al. 2014; Wallace et al. 2010b).

1.4.1. General trends across fisheries

Research on marine turtle bycatch in commercial fisheries has largely followed two themes: (1) characterisation of bycatch levels for specific fleets or locations; (2) and evaluation of the effectiveness of bycatch mitigation strategies, such as gear modifications, time-area closures, setting depth and other fishing strategies. More recently, a third theme of study has arisen from the empirical foundation provided by the first two: (3) application of bycatch dynamics to evaluate conceptual conservation issues, including cumulative impacts, levels of risk, spatial bycatch 'hotspots' and population-level implications as inferred through reproductive value analyses (Finkbeiner et al. 2011; Fossette et al. 2014; Komoroske and Lewison 2015; Lewison et al. 2014; Riskas et al. 2016; Roe et al. 2014; Wallace et al. 2008). The third theme also reflects increasing awareness of the importance of moving beyond single-species fisheries management strategies towards more holistic, ecosystem-based management approaches (EBM).

Geographically, research and mitigation efforts for marine turtle bycatch have been concentrated in the northern Atlantic Ocean and the Mediterranean Sea, and to a much lesser extent the Pacific Ocean. In a spatially explicit, cross-gear, multi-taxa bycatch assessment, Lewison et al. (2014) highlight a paucity of bycatch data for the Indian

Ocean, Southeast Asia, the eastern Atlantic Ocean, and the central and western Pacific Ocean. Low observer coverage and high levels of uncertainty in the data further complicate efforts to identify potential bycatch 'hotspots', much less specific region-species-gear combinations (Wallace et al. 2010b). Despite the successful uptake of bycatch mitigation measures in some fisheries, many researchers stress the importance of assessing the suitability of gear modifications on a per-fishery basis (Bourjea et al. 2008; Gilman et al. 2010; Lewison et al. 2014; Peckham et al. 2016) in order to account for the influence of varying oceanographic, biological, socioeconomic and cultural factors. There is also a need to consider bycatch reduction strategies within a broader ecosystem context, as gear modifications aimed at reducing turtle bycatch may unintentionally increase interaction rates for other vulnerable taxa (see Gilman et al. 2016).

1.4.2. Longline fisheries

Research on the efficacy of bycatch mitigation techniques for longline fisheries grew steadily from the early 2000s, primarily in response to concerns over leatherback bycatch in fleets targeting swordfish at the productive Grand Banks area off Newfoundland (Brazner and McMillan 2008; Carlson et al. 2016; Coelho et al. 2015; Johnson et al. 1999). Investigations have been conducted primarily during at-sea fishing operations, although a small number utilised captive turtles in laboratory settings (e.g. Southwood et al. 2008; Swimmer et al. 2005; Wang et al. 2007). The majority of studies examined the influence of various physical gear modifications on marine turtle bycatch rates, namely circle hooks (Bolten et al. 2004; Gilman et al. 2007; Read 2007; Sales et al. 2010; Swimmer et al. 2010), bait type (usually fish versus squid; Echwikhi et al. 2011), light sticks (Wang et al. 2010; Wang et al. 2013),

baiting technique (single hooking vs. multiple hook threading; Gilman 2011, Stokes et al. 2011) and bait colour (Swimmer et al. 2005; Yokota et al. 2009).

Recognising that marine turtle feeding behaviour may be influenced by multiple sensory inputs (Gilman et al. 2007; Southwood et al. 2008), additional studies evaluated gear modifications used in combination, such as bait and hook type together (Brazner and McMillan 2008; Coelho et al. 2015; Gilman et al. 2006a; Santos et al. 2012; Watson et al. 2004; Watson et al. 2005). Reviews by Gilman et al. (2006a) and later Gilman and Hsiang-Wen (2017) concluded that the combination of wider circle hooks and fish bait resulted in lower bycatch rates for both leatherback and five of the six hard-shelled marine turtle species. However, as noted by Clarke et al. (2014), it can be difficult to evaluate the effectiveness of a single technique in reducing turtle bycatch, especially given that trial results vary across fisheries and reflect inter- and intra-species variation in bycatch rates (Carruthers et al. 2009).

Other measures, termed ‘operational controls’, seek to reduce bycatch by modifying the time, depth and location of fishing. Temporal and spatial fishery closures have been successful in reducing turtle bycatch in longline fisheries in Hawaii (Gilman et al. 2007; Howell et al. 2008; Walsh et al. 2002) and the Northeast Distant statistical area (NED) east of Newfoundland (Gardner et al. 2008). Setting longlines below the depths frequented by marine turtles is a feasible approach for fleets targeting tuna but not swordfish, and thus may not be economically feasible for all longline fleets without additional concessions (Clarke et al. 2014). Habitat avoidance measures using fleet communication (Alfaro-Shigueto et al. 2012; Gilman et al. 2006b) and bycatch maps informed by oceanographic modelling (Howell et al. 2008; Polovina et al. 2004; Sims et al. 2008) show promise when used in concert with gear modifications (Clarke et al. 2014).

1.4.3. Trawl fisheries

The turtle excluder device (TED) is arguably the most well-known bycatch reduction device (BRD) developed for trawl fisheries. TED development began in the 1970s in response to concerns over turtle capture in US trawl fisheries (Jenkins 2012). The general design of a TED features a grid that is inserted into the net before the codend; turtles entering the mouth of the trawl will hit the grid and be directed out of the net through a hole cut in the mesh. Modifications on the basic TED design have since been trialled in fisheries around the world, with many countries tailoring their versions to reflect spatial and temporal variability of target and non-target catches (Brewer et al. 1998; Broadhurst 2000; Kadir and Sulong 2015; Lucchetti et al. 2016; Mounsey et al. 1995). Broadhurst (2000) notes that so-called 'hard TED' designs incorporating rigid grids (as opposed to netting panels of 'soft TEDs') have shown greater success in eliminating turtles while retaining target species (but see Jenkins 2012).

In 1989, the US Government passed a law banning the import of shrimp (prawns) from countries that did not have in place a marine turtle protection program of comparable effectiveness to that of the US. The embargo initially applied only to countries in the Caribbean and South America, but was extended in 1996 to include all exporting countries (Eayrs 2007).

1.4.4. Net fisheries

Turtle bycatch in net fisheries—particularly coastal, small-scale fisheries—is understood to be a significant anthropogenic source of mortality (Alfaro-Shigueto et al. 2011; Gilman et al. 2010; Liles et al. 2017; Mancini et al. 2012). Nedelec and Prado (1990) describe the wide range of net gear designs and configurations in use

(e.g. gillnets, pound nets, tunnel nets, beach seines, etc.). While there are comparatively fewer techniques to mitigate bycatch in net fisheries than for longlines and trawls, Gilman and colleagues summarise then-current mitigation measures in their 2010 study, to which I have added updated information as it has become available: reducing net profile (Peckham et al. 2016; Price and Van Salisbury 2007; Eckert et al. 2008); increasing tiedown length, or eliminating tiedowns (Price and Van Salisbury 2007); placing shark-shaped silhouettes adjacent to the nets (Wang et al. 2009); and illuminating portions of the net using light sticks (Wang et al. 2009; Wang et al. 2010) and light emitting diodes (LEDs) (Ortiz et al. 2016; Wang et al. 2010; Wang et al. 2013). Of these technologies, it is important to note that only net illumination was not found to cause a significant decrease in target species catch rates (Gilman et al. 2010).

Further, research in Mexico by Peckham et al. (2016) found that removing buoys from float lines reduced turtle bycatch by up to 68% without reducing landings of the target catch. The latter factor is especially important to consider when implementing bycatch reduction strategies more generally: potential negative socioeconomic effects of catch reduction must be minimised in order to increase the likelihood of long-term adoption and compliance (Gilman et al. 2010; Peckham et al. 2016).

1.4.5. Knowledge gaps and sources of data deficiency

Despite this plethora of studies, a number of important knowledge gaps remain for marine turtle bycatch in certain geographic regions and fleet types. Lewison et al. (2014) highlight the paucity of data available for the Indian Ocean, eastern Atlantic, Southeast Asia and the central and western Pacific. The Indian Ocean is comparatively underrepresented in the bycatch literature, despite having some of the highest turtle mortality rates recorded worldwide (e.g. longline fisheries; Clarke et al.

2014). Quality and reliability of existing data is also an issue: a 2013 review urged "great caution" in interpreting fleet-wide extrapolations from Indian Ocean tuna fleets, citing low data availability and high uncertainty in reported bycatch data (IOSEA 2013).

Additionally, few data on catches and bycatches are available for distant water fishing fleets operating outside their own Exclusive Economic Zones (EEZs), and the presence of such fleets have been noted in coastal areas throughout West Africa (Falaye 2008; Riskas and Tiwari 2013) and the Indian Ocean (Anganuzzi and Secretariat 2004; Bourjea et al. 2008; Clarke et al. 2014). On the high seas (also 'international waters'), a number of regional fisheries management organisations (RFMOs) are responsible for collecting catch and bycatch from fishing fleets operating within an individual RFMO's jurisdiction. Despite promising steps taken by some RFMOs to increase the presence of onboard observers and improve reporting (see Kaplan et al. 2014), several authors have pointed out that RFMOs do not posess the fiscal or legislative capacity to enforce such regulations (see Cullis-Suzuki and Pauly 2010; Flothmann et al. 2010; Sumalia et al. 2016).

Small-scale fisheries—which are generally data-poor—are ubiquitous throughout the eastern Atlantic (Belhabib et al. 2015; Riskas and Tiwari 2013), Southeast Asia (Stobutzki et al. 2006; Teh and Sumaila 2013) and the western Pacific (Carpenter 1998; Zeller et al. 2006). Wallace et al. (2010b) note that more research is needed to characterise the dynamics of turtle bycatch in these regions for both industrial and small-scale fisheries.

There is also a growing recognition of the need to assess the cumulative impacts of fisheries bycatch for marine turtles and other long-lived, migratory taxa (Carretta and

Moore 2014; Davidson et al. 2016; Komoroske and Lewison 2015; Lewison et al. 2014), particularly for areas where marine turtles interact with multiple fishing fleets (see Fossette et al. 2014; Roe et al. 2014) and gear types (Finkbeiner et al. 2011). Lack of data on cumulative impacts hinders management agencies from adopting integrated policies to address the bycatch problem (Komoroske and Lewison 2015), also preventing agencies from expanding past the single-fishery management paradigm (Finkbeiner et al. 2011).

Further, efforts to assess and quantify marine turtle bycatch are confounded by a number of logistical, financial and statistical factors (Komoroske and Lewison 2015; Lewison et al. 2004; Stewart et al. 2010). Bycatch observer programs are expensive to maintain, and presuppose the existence of appropriate conservation legislation; as a result, such programs are scarce for developing countries and generally unregulated small-scale fisheries (Byrd et al. 2016; Pauly 2006). Additionally, bycatch events are rare relative to landings of the target catch (Barlow and Berkson 2012; Minami et al. 2007; Sims et al. 2008), requiring caution when interpreting bycatch rates from low observed effort and zero inflated data (Maunder and Punt 2004; Wallace et al. 2010b).

1.5. An emerging threat: Illegal, unreported and unregulated (IUU) fishing

Within the last three decades, the issue of illegal, unreported and unregulated (IUU) fishing has emerged as a major problem for marine resource governance worldwide (Agnew et al. 2009; Pitcher et al. 2006). The term 'IUU fishing' was first coined in 1997 by the Commission for the Conservation of Antarctic Marine Living Resources ('CCAMLR Commission'). In its Report of the Standing Committee on Observation and Inspection, the CCAMLR Commission noted the occurrence of 'unreported and unregulated fishing' within the area under CCAMLR's jurisdiction (Baird 2004; CCAMLR Commission 1997). Following increased attention to the problem of IUU fishing in the CCAMLR area and

elsewhere (Agnew 2000; Bray 2000; Constable et al. 2000), in 2001 the Food and Agriculture Organisation of the United Nations (FAO) issued an official definition of IUU fishing, broken down by its component parts as follows (emphasis added):

> ***Illegal fishing*** refers to activities: conducted by national or foreign vessels in waters under the jurisdiction of a State, without the permission of that State, or in contravention of its laws and regulations; conducted by vessels flying the flag of States that are parties to a relevant regional fisheries management organization but operate in contravention of the conservation and management measures adopted by that organization and by which the States are bound, or relevant provisions of the applicable international law; or in violation of national laws or international obligations, including those undertaken by cooperating States to a relevant regional fisheries management organization.
>
> ***Unreported fishing*** refers to fishing activities: which have not been reported, or have been misreported, to the relevant national authority, in contravention of national laws and regulations; or undertaken in the area of competence of a relevant regional fisheries management organization which have not been reported or have been misreported, in contravention of the reporting procedures of that organization.
>
> ***Unregulated fishing*** refers to fishing activities: in the area of application of a relevant regional fisheries management organization that are conducted by vessels without nationality, or by those flying the flag of a State not party to that organization, or by a fishing entity, in a manner that is not consistent with or contravenes the conservation and management measures of that organization; or in areas or for fish stocks in relation to which there are no applicable conservation or management measures and where such fishing activities are conducted in a manner inconsistent with State responsibilities for the conservation of living marine resources under international law (FAO 2001, pp. 2-3).

The FAO definition encompasses many different fishing transgressions (see Petrossian 2012 for examples), and the consequences of unmitigated IUU fishing are similarly far-reaching. The proportion of global catch taken by IUU fishers is estimated conservatively at 20% (Stiles et al. 2013) and can reach 50% in certain individual fisheries (Tinch et al. 2008). Though the clandestine nature of IUU fishing frustrates attempts to quantify its extent (Agnew et al. 2008; Christensen 2016), an estimated 11 to 26 million tonnes worth 10 to 23.5 billion USD are landed annually by IUU fishers worldwide (Agnew et al. 2009; MRAG 2005b; Pauly et al. 2002). This represents an enormous loss of catch and revenue for legitimate fishers, who bear proportionally higher operating costs than IUU fishers (EJF

2005) and may be incentivised to shirk regulations in order to remain competitive (Balton 2004).

IUU fishing thrives in areas where fisheries governance is poor, particularly in developing countries (BOBLME 2015; MRAG 2005b) and on the high seas (Cullis-Suzuki and Pauly 2010; HSTF 2006; Rigg et al. 2004). Developing countries rely more heavily on marine resources for food and employment (Belhabib et al. 2015; Chuenpagdee et al. 2006; Pauly and Zeller 2016; Teh and Sumaila 2013) but often lack the fiscal resources to build and maintain the monitoring, control and surveillance measures (MCS) that are so critical for reducing the incidence of IUU fishing within their EEZs (GOC 2013; Petrossian 2015). RFMOs are responsible for regulating fishing activities on the high seas; however, previous studies have found that most RFMOs are performing inadequately (Cullis-Suzuki and Pauly 2010) and failing to prevent fish stock declines (Gjerde 2009). Further, nations that are not party to an RFMO are not bound to follow the accompanying regulations of that RFMO (Le Gallic 2008). IUU fishers exploit this loophole by registering their vessels in these non-party 'flag of convenience' (FOC) states, thus placing themselves beyond the reach of enforcement by RFMOs when fishing on the high seas (Agnew and Barnes 2004).

The consequences of unmitigated IUU fishing can also be devastating for human social systems. Weak enforcement capacity in developing nations enables IUU fishers to exploit fish stocks at unsustainable levels, creating tension between resource user groups that can lead to armed conflict in extreme cases (e.g. Somalia's piracy crisis (Beri 2011; Brashares et al. 2014; Hughes 2011; Kraska and Wilson 2009) and the ongoing South China Sea dispute (Holmes and Phillips 2016; Pomeroy et al. 2007)). IUU fishing is being increasingly recognised as a form of transnational organised crime (Phelps Bondaroff et al. 2015; UNODC 2010), involving transhipment of catch to avoid detection by port authorities (Telesetsky 2014) and smuggling of drugs, weapons and other illicit substances (Liddick 2014; UNODC

2011). As IUU vessels operate at the margins of regulatory control, crew members are often trafficked, enslaved and subjected to unsafe, at times violent working conditions (EJF 2005; Le Gallic 2008). Consequently, the destabilising social and economic effects of IUU fishing are felt most acutely in the nations least equipped to mitigate them.

Crucially, IUU fishing jeopardises the health of the marine environment by undermining efforts to manage fisheries in a sustainable manner (Polacheck 2012). IUU fishers are less likely to comply with conservation mandates—such as gear modifications or spatial/temporal closures—intended to reduce bycatch and impacts to vulnerable species and habitats (FAO 2001; MRAG 2005a). Additionally, they are prone to misreporting catch and bycatch, or not reporting it at all (Agnew et al. 2009; De Young 2006; Field et al. 2009). Catches by IUU fleets thus introduce substantial uncertainty into estimates of stock biomass, preventing accurate assessment of fishery resources and subsequent setting of appropriate catch limits (Sumaila et al. 2006). Such estimates are essential for regulating catch quotas, monitoring bycatch and assessing the fishery more broadly within the context of ecosystem-based management paradigms (Hilborn 2004; Latour et al. 2003).

1.6. IUU fishing and marine turtles

As fishery management priorities primarily concern target species stocks, there are relatively few studies investigating the effects of IUU fishing on non-target species groups, including marine turtles. A 2005 report by the Marine Resources Assessment Group (MRAG) attempted to estimate the amount of turtle bycatch occurring in high seas IUU longline vessels by extrapolating from data reported by legitimate longline fisheries (MRAG 2005a). While a logical starting point, this approach assumes several operational similarities between the two fleet types and does not account for the possibilities of 1) intentional turtle capture and retention, and 2) mortality due to gear switching, as observed on illegal longline vessels in Mozambique (Louro et al. 2006). More recently in 2015, a broad-scale assessment of IUU

fishing in the Bay of Bengal Large Marine Ecosystem (BOBLME) included information on turtles and IUU fishing in a more generalised manner within a risk-likelihood matrix for each nation in the region (BOBLME 2015).

Many other studies surmise that IUU fishing is a threat to marine turtles, characterising it as a knowledge gap that exacerbates the already-difficult task of assessing and conserving marine turtle populations (Funge-Smith et al. 2015; Hancock et al. 2017; Le Gallic 2008; Okey et al. 2007; Rees et al. 2016; Riskas and Tiwari 2013). For example, in describing the prevalence of IUU fishing in the western Indian Ocean, Bourjea et al. (2008) state that "resolving [IUU fishing] is intimately related to mitigating problems of marine turtle bycatch". Despite a widespread, conceptual acknowledgement that IUU fishing likely poses a threat to marine turtle populations, the nature and extent of specific impacts have not been explored in enough detail to be useful for comprehensive threat assessment.

1.7. Geographic focus: Indian Ocean and Southeast Asia (IOSEA)

The Indian Ocean and Southeast Asia region (hereafter IOSEA) provides a highly suitable context for examining the linkages between fisheries and marine turtles. Estimates of coastal fishing pressure in the Western Indian Ocean and Southeast Asia are among the highest in the world (Stewart et al. 2010), and there are significant lacunae in understanding surrounding turtle interactions with certain fishing fleets (see Wallace et al. 2010b) as well as abandoned, illegal ghost nets (Stelfox et al. 2016) throughout the IOSEA.

Six of the world's seven marine turtle species occur within the IOSEA, namely: the loggerhead (*Caretta caretta*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*), olive ridley (*Lepidochelys olivacea*) and flatback turtle (*Natator depressus*). All species nest within the IOSEA, and the region supports globally significant nesting populations of loggerheads (Baldwin et al. 2003), greens (Bourjea et al.

2007), leatherbacks (Hamann et al. 2006), hawksbills (Meylan and Donnelly 1999), olive ridleys (Gopi et al. 2006) and flatbacks (Limpus 2007).

Legislative efforts to advance marine turtle conservation in the IOSEA have slowly gained traction over the past two decades. In 2001, the Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and Southeast Asia (IOSEA-MoU) came into effect, and comprises 35 Signatory States of the region's 44 countries and territories[1]. The IOSEA-MoU is a legally non-binding agreement under the Convention on the Conservation of Migratory Species of Wild Animals (CMS, Bonn Convention) and seeks to promote turtle conservation through regional cooperation among the Signatory States. Under the MoU, member states partake in data reporting on a number of themes relating to turtle biology and threats; these activities have enabled identification of priority areas for conservation (i.e. IOSEA Site Network) and fostered regional collaboration through the creation of two specialised task forces (i.e. Northern Indian Ocean Marine Turtle Task Force (NIOMTTF), Western Indian Ocean Marine Turtle Task Force (WIOMTTF)).

Reports of IUU fishing throughout the IOSEA include illegal longlining and turtle mortality in Mozambique (Louro et al. 2006) and the western Indian Ocean more generally (Bourjea et al. 2008), as well as conflict over fishery access in Somalia (Beri 2011) and decades of unchecked tuna exploitation by unlicensed foreign fleets (Anganuzzi and Secretariat 2004). Illegal border incursions and unreported catches by both commercial and artisanal fishers have been documented in the Persian Gulf (Daliri et al. 2015), the northern Indian Ocean (BOBLME 2015; Pramod 2010), Indonesia (Nurhakim et al. 2008; Sodik 2004), Malaysia (APEC Secretariat 2008b) and Australia (AFMA 2007; Vince 2007).

[1] www.ioseaturtles.org

Furthermore, Southeast Asia has been characterised as "an environment conducive to IUU fishing for both nationals and foreign fishers" (Baird 2010) (also see APEC Secretariat 2008a). Recent hauls of illegally-caught, protected marine turtles have attracted media attention (AFP 2017; Nuwer 2016; Toyos 2017), and disputes over maritime boundaries and fishing rights in the South China Sea have been examined by the International Court of Justice at The Hague (Holmes and Phillips 2016). Additionally, the region's historical subsistence use of marine turtles (Frazier 1980) is compounded by an increasing modern demand for wildlife products in East Asian markets (Lam et al. 2011; Stiles 2008). Recent studies have noted that IUU vessels are linked to poaching and trafficking of fish and protected species, including sharks (Varkey et al. 2010) and marine turtles (IOSEA 2014; Palma and Tsamenyi 2008).

Given the lack of knowledge surrounding fisheries-related threats to marine turtles in the IOSEA (Wallace et al. 2010a), as well as the number of critical data needs concerning several endangered marine turtle populations in the IOSEA (Wallace et al. 2011), knowledge and evaluation of IUU fishing as a threat to marine turtles is urgently needed.

1.8. Thesis aim

The overarching aim of this thesis is to advance our understanding of fisheries interactions with marine turtles, specifically for topics and geographic areas that are data deficient. While all identified knowledge gaps would benefit from additional research, I chose to pursue inquiry into the issues of bycatch (cumulative impact) and IUU fishing for several reasons.

First, I considered that, while bycatch is acknowledged almost ubiquitously as a management issue, cumulative impact assessments of longitudinal datasets are curiously underrepresented in the scientific literature. As such, I saw an opportunity to undertake this analysis using data collected by Australian fisheries agencies and thus directly inform management efforts in a

nation that supports globally significant marine turtle populations (Limpus 2009). Further, robust data on population abundance and migration patterns are not available for several turtle species nesting along Australia's vast and remote coastline (Limpus 2008a; Limpus 2008b). It is therefore prudent to adopt a precautionary approach to threat mitigation (e.g. González-Laxe 2005), in which cumulative assessment of fisheries mortality undoubtedly plays a crucial role.

Second, despite the breadth of literature on IUU fishing, there are no direct assessments of IUU fishing as a threat to marine turtles. Generalised summaries of likely impacts provide limited value to management and conservation efforts that require data in order to proceed. I chose to examine this immense knowledge gap with the intent to bring the unknown more clearly into focus, and thus supplant extrapolations and assumptions with evidence.

Finally, as mentioned, several marine turtle populations in the IOSEA are threatened with extinction (Wallace et al. 2011), and conservation intervention is hindered directly and indirectly by a number of data deficiencies. By gathering information on the threat of IUU fishing, I endeavoured for my study to have a high conservation impact and potentially trigger further action against IUU fishing in a region that would greatly benefit from such a contribution.

1.9. Thesis outline

This thesis is comprised of six chapters, with the four data chapters (Chapters 2-5) written as separate articles intended for publication in various discipline-specific journals. I elected to follow this 'thesis by publication' approach in order to shorten the duration between data collection and production of results, in the hope that their release may remain timely and relevant to global events.

At the time of thesis submission, two chapters have been published (Chapters 2 and 3) and one chapter is under review (Chapter 4). Though the four data chapters were originally written as individual papers, I have standardised the language and style in order to present the thesis as a unified body of work. Given the thesis approach and the variety of topics covered, some repetition of background information is provided as a reminder of the theoretical context for each chapter. A linking paragraph is also included at the beginning of each chapter as a means of clarifying the relation of one chapter to the next.

Chapter 1 is a general introduction to the thesis, beginning with an overview of fisheries as a threat to marine turtles. I then describe the emerging threat of IUU fishing. After identifying the knowledge gaps pertaining to fisheries and marine turtles, I define my chosen study area and conclude with an outline of the thesis structure. This chapter provides the theoretical background and justification for my thesis and its individual chapters.

Chapter 2 uses bycatch data from three Australian government agencies to evaluate the cumulative impact of fisheries bycatch on Australian marine turtle populations. I explore the significance of these impacts for specific species and geographic regions, and discuss the challenges of implementing biologically-relevant management practices within single-species, single-fishery governance paradigms.

- **Riskas KA**, Fuentes MMPB, Hamann M (2016). Justifying the need for collaborative management of fisheries bycatch: A lesson from marine turtles in Australia. *Biological Conservation* 196:40-47.

Chapter 3 moves beyond legal, regulated fisheries to investigate the impacts of IUU fishing on marine turtles over a broad geographic scale (i.e. the Indian Ocean and Southeast Asia – IOSEA). Using the expert elicitation technique, I identify sub-regions and issues of

conservation concern, emphasising the utility of eliciting local knowledge about a highly variable, data-limited threat.

- **Riskas KA**, Tobin R, Fuentes MMPB, Hamann M (2018). Evaluating the threat of illegal, unreported and unregulated (IUU) fishing to sea turtles in the Indian Ocean and Southeast Asia using expert elicitation. *Biological Conservation* 217:232-239 [online 16 Nov 2017].

Chapter 4 is a case study within a sub-region of concern (Southeast Asia) identified by my analysis in Chapter 3. By conducting structured interviews with commercial fishers in two Malaysian states, I provide a detailed analysis of IUU fishing dynamics in relation to marine turtles that can be used to guide targeted management intervention at multiple political scales (i.e. municipal, state and national).

- **Riskas KA**, Tobin RC, Pilcher NJ, Afifah NF, Hamza A, Hamann M (in review). Fisher interviews identify ties between IUU fishing, wildlife trafficking and transnational organised crime in two Malaysian states. *Marine Policy* XX.

Chapter 5 uses semi-structured interviews to explore how IUU fishing is perceived and regulated from a governance perspective in the IOSEA. Framing IUU fishing and marine turtle exploitation as interdependent issues, I identify institutional scale-mismatches, barriers and opportunities for improving the way agencies address this complex, pervasive threat.

- **Riskas KA**, Tobin R, Fuentes MMPB, Hamann M (in prep). Towards governance solutions for illegal, unreported and unregulated (IUU) fishing and marine turtle exploitation in the Indian Ocean and Southeast Asia. Target journal: *Journal of Environmental Management.*

Chapter 6 summarises the key findings of the thesis and discusses the implications for marine turtle conservation and management in the IOSEA and globally. I also emphasise the

importance of collaborative action in tackling multidimensional fisheries issues, and close by suggesting avenues for useful future research.

Chapter 2

Justifying the need for collaborative management of fisheries bycatch: A lesson from marine turtles in Australia

Chapter 1 established that bycatch in commercial fisheries is a major source of marine turtle injury and mortality. In this chapter, I demonstrate the need for cross-jurisdictional assessment of turtle bycatch using Australian fisheries as a case study. I use longitudinal and spatial analyses to show that cumulative fisheries interactions may threaten vulnerable Australian turtle populations, and that emerging bycatch issues are going undetected under prevailing management frameworks. I then explore the feasibility of implementing collaborative management arrangements among state and federal agencies, and I conclude by emphasising the importance of considering cumulative impacts in the management of marine turtles and other long-lived, migratory taxa.

Publication associated with this chapter:

Riskas KA, Fuentes MPB, Hamann M (2016). Justifying the need for collaborative management of fisheries bycatch: A lesson from marine turtles in Australia. *Biological Conservation* 196:40-47.

2.1. Introduction

Incidental capture, or bycatch, of non-target species in commercial fisheries has been globally recognised as a serious conservation issue for marine megafauna, including marine turtles (Lewison et al. 2014; Read et al. 2006; Žydelis et al. 2009). Localised declines in marine turtle populations have been repeatedly linked to high levels of bycatch in regional commercial fisheries (Casale 2011; Dapp et al. 2013; Limpus and Reimer 1994). As marine turtles are long-lived and take decades to reach reproductive maturity (Heppell et al. 2003), high mortality rates of breeding-age individuals have the potential to alter population structure and cause a drastic, sometimes irreversible collapse of the stock (Crouse et al. 1987; Heppell et al. 2005).

The highly migratory nature of marine turtles means that they occupy a diverse range of oceanographic habitats throughout their life histories (Musick et al. 1997; Plotkin 2003), thus increasing the likelihood of interacting with various threats, including multiple fisheries over broad spatial and temporal scales, often across international jurisdictions (Moore et al. 2009; Wallace et al. 2013). Mitigating bycatch over such vast areas therefore requires a comprehensive understanding of the numerous fisheries that each turtle species encounters throughout each part of its range and life cycle.

However, fisheries management agencies generally assess and mitigate turtle bycatch on a single-fishery or single-species basis, not taking into account the additional impacts of bycatch by other fisheries operating outside of the agency's jurisdiction (Finkbeiner et al. 2011). The apparent lack of cross-agency collaboration and failure to set cumulative bycatch quotas for marine turtles across multiple fisheries restrict the ability to draw meaningful conclusions regarding the impact of bycatch on turtle populations (Griffin et al. 2006; Moore et al. 2009). Assessing the cumulative impacts of multiple commercial fisheries is therefore a

critical analysis for guiding the prioritisation of marine turtle management and conservation actions (Bolten et al. 2010; Finkbeiner et al. 2011).

Australian commercial fisheries are known to incidentally catch marine turtles during fishing operations (AFMA 2009; Eckert and Eckert 1997; Robins 2002). Bycatch data for turtles and other protected species is recorded in fishers' logbooks and monitored by management agencies as required under national legislation, the Environment Protection and Biodiversity Conservation Act (EPBC Act, 1999). While a small number of Australian fisheries have been lauded internationally for their efforts to adopt sustainable fishing practices, mitigating turtle bycatch remains a management priority in many Australian commercial fishery sectors.

To address the need for a multi-fishery assessment of turtle bycatch, I evaluate the cumulative bycatch patterns for Australia's state and national (Commonwealth) fisheries collectively across management agencies from 2000 to 2013. This approach is globally applicable, informing cross-jurisdictional management solutions for non-target species with life histories rendering them vulnerable to the effects of fisheries-related mortality.

2.2. Materials and Methods

2.2.1. Study area and species

The scope of this study includes all licensed commercial fisheries operating within the Australian Exclusive Economic Zone (EEZ). Economically, fisheries are an important sector, with Commonwealth fisheries alone generating between USD150 million-171.5 million during the 2012-2013 financial year (AFMA 2014). Management of Australia's commercial fisheries is essentially two-tiered: state government agencies regulate fisheries in their coastal waters up to three nautical miles (5.5km) offshore; and both the Commonwealth government and individual states jointly manage fisheries operating from three nautical miles to the boundary of the EEZ (200 nautical miles offshore, 370km).

Australia provides a useful context for investigating the impacts of commercial fisheries on turtle populations. Six marine turtle species occur in Australian waters, and all are legally protected under Australia's EPBC Act: the loggerhead (*Caretta caretta*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*), olive ridley (*Lepidochelys olivacea*), and the endemic flatback turtle (*Natator depressus*) (Limpus 2007). While fishing pressure in Australia is not nearly as high as in other areas of the world (Watson et al. 2013), domestic and international commercial fleets have nevertheless had an impact on foraging and nesting turtles. Indeed, past declines in the eastern Australian breeding population of loggerhead turtles have been attributed to increases in trawling activities off the Queensland coast from the late 1960s to the early 1980s (Limpus and Reimer 1994). The mandatory introduction of turtle excluder devices (TEDs) in the 2000s greatly reduced the levels of reported bycatch and enabled recovery of the stock (Limpus 2008a). Yet, this same population has also been genetically linked to the juvenile loggerheads that are caught in great numbers in longline fisheries off Peru (Alfaro-Shigueto et al. 2011). As such, Australia serves as a data-rich example of how best to explore and manage fisheries bycatch for turtle populations already subjected to pressure from multiple and diverse fishing fleets.

2.2.2. Data acquisition and BPUE calculation

Since marine turtles are widely distributed in Australian waters, I attempted to source logbook bycatch data from management agencies in all Australian states and territories with a coastal jurisdiction (i.e., New South Wales, Northern Territory, Queensland, South Australia, Tasmania, Victoria, Western Australia) as well as Commonwealth government-managed fisheries for the period 2000-2013. I did not include derived or extrapolated bycatch rates in our analysis, nor did I include bycatch rates obtained under controlled conditions (i.e. TED trials). Despite the known issues with using logbook data (Baum et al. 2003), choosing this

data source allowed me to identify the baseline level of bycatch impacting Australian marine turtles, while acknowledging that the true amount is likely to be much greater. I also acknowledge that fisheries management agencies have implemented various mitigation measures during the period of the study, precluding any comparison of bycatch data between individual years.

I calculated annual bycatch per unit effort (BPUE) values using fishing effort data sourced from published reports and online databases provided by each management agency. As data collection protocols varied widely between states, I preserved the original effort metrics for each dataset and did not attempt to standardise metrics across agencies or similar gear types. The calculated annual BPUE values varied within each fishery as well, reflecting changes in fleet sizes throughout the study period. The BPUE values presented are therefore an indication of the range of turtle bycatch levels within study period.

2.2.3. Spatial analysis

When GPS coordinates were provided, I plotted the location of each bycatch event using ArcGIS 10.1 (ESRI, Redlands, CA, USA). I then created a raster grid of the study area (1°x1° cells) using the fishnet tool within the ArcGIS toolbox. As some bycatch records were provided to the nearest degree, the fishnet was offset by 0.5° in order to centre the capture location within the grid cell. When multiple bycatch events occurred within a single grid cell, records from all gear types were summed into a single value to display a total number of records for that cell. Locations of bycatch in the Queensland dataset were grouped according to the designated Mapstone region—spatial divisions of Queensland's coastal waters defined for management purposes (Figure 2.1)—in which the bycatch occurred.

My use of the term 'hotspot' in this study is largely qualitative, and can be defined as "an area at least 1x1° in size in which cumulative turtle bycatch is higher than in the immediate surrounding area". As such, I identified hotspots at a regional level for two reasons. Firstly, discrepancies in resolution between datasets prohibited any consistent, fine-scale analysis; and secondly, the fleet size and spatial range of each fishery has expanded and contracted during the period of the study. Designated hotspots therefore represent generalised geographic regions where turtle bycatch and fishing effort have been persistent throughout the duration of the study.

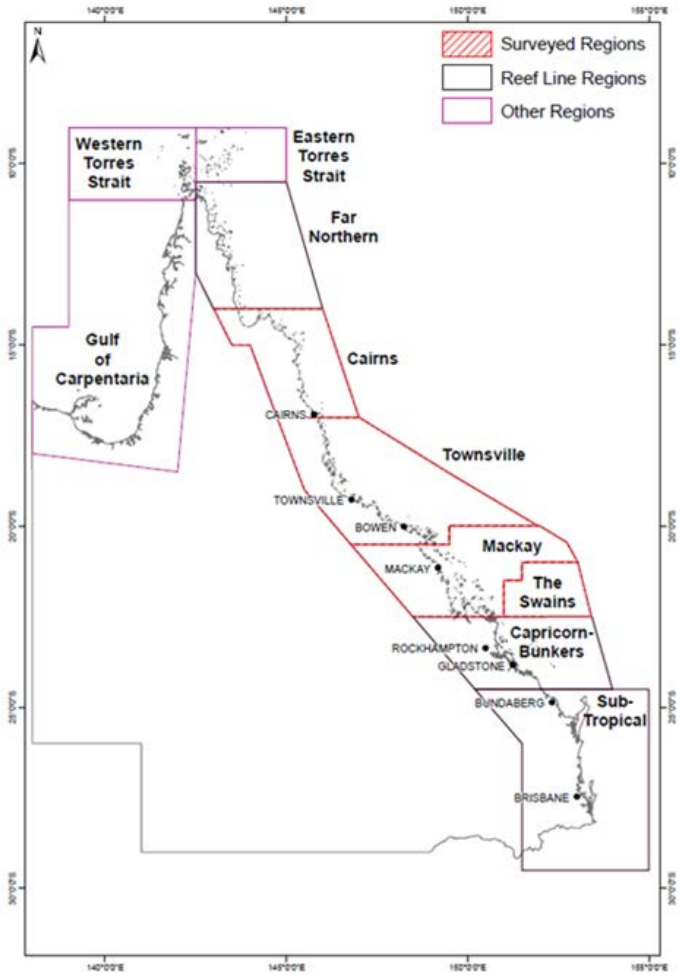

Figure 2.1. Distribution of Mapstone Region spatial fishery divisions as defined by DAFF, Queensland Government. Map provided courtesy of DAFF Qld.

2.3. Results

2.3.1. Data acquisition and analysis

Commercial logbook records of marine turtle bycatch were provided under data-sharing agreements with the following management agencies: the Australian Fisheries Management Authority, Australian Government (AFMA); the Department of Agriculture, Fisheries and Forestry, Queensland Government (DAFF); and the Department of Primary Industries and Fisheries, Northern Territory Government (DPIF). I chose to adopt the term 'interaction', defined by AFMA as "any physical contact a person, boat or fishing gear has with a protected species that causes the animal stress, injury or death" (AFMA 2015). For the purposes of this study, the term 'interaction' signifies a bycatch event.

Due to inconsistencies in bycatch reporting protocols, I was not successful in sourcing usable turtle bycatch records from relevant management agencies in the remaining states (i.e. New South Wales, South Australia, Tasmania, Victoria and Western Australia). Anecdotal and partial bycatch records were available from South Australia and Western Australia; however, these records were incomplete for the purpose of cumulative assessment and therefore were not included in my analysis.

2.3.2. BPUE by management agency and gear type

A total of 5,044 marine turtle interactions were reported collectively in fisheries managed by Commonwealth, Queensland and Northern Territory agencies from 2000 to 2013, an average of 362 turtles each year (SE ± 82.9). Numbers of turtles reported by each fishery ranged from a single turtle to several hundred over the thirteen-year period (Table 2.1). Summing turtle interactions across all agencies, green turtle interactions were the highest, followed by unidentified turtles and then falling an order of magnitude to leatherbacks, loggerheads, flatbacks, hawksbills and olive ridleys (Table 2.2).

Table 2.1. Calculated cumulative turtle interactions and BPUE values for Commonwealth, Northern Territory and Queensland-managed fisheries, 2000-2013. *Effort for gillnet fisheries in the Northern Territory is reported in hundred meter net days (hmnd). N/A denotes BPUE not calculated.

State (agency)	Fishery name	Gear type	Total interactions (2000-2013)	BPUE range (annual)
Commonwealth (AFMA)				
	Northern Prawn Fishery (NPF)	Bottom trawl	*537*	0.0005-0.014 turtles/boat day
	Eastern Tuna and Billfish (ETB)	Drifting pelagic longline	342	0.0006-0.0045 turtles/1,000 hooks
	Western Tuna and Billfish (WTB)	Drifting pelagic longline	146	0.0013-0.022 turtles/1,000 hooks
	Torres Strait Prawn (TSP)	Bottom trawl	32	0.0001-0.004 turtles/boat day
	Great Australian Bight (GAB)	Bottom otter trawl	1	N/A
	Gillnet, Hook and Trap (GHT)	Demersal longline	1	N/A
	Kimberley Prawn (KCP)	Bottom trawl	*1*	N/A
	Southern Shark and Scale fish (SSF)	Demersal gillnet	*1*	N/A
	Christmas Island (XMS)	Trolling	1	N/A
	Total turtle interactions		**1,062**	
Northern Territory (DPIF)				
		Pelagic gillnet	1,021	0.0157-0.476 turtles/boat day
		Line	102	0.0171-0.26 turtles/hook hours/500
		Fish trawl	17	0-0.0157 turtles/boat day
		Fish trap	8	0-0.026 turtles/boat day
		Gillnet	8	0.010989-0.018867 turtles/hmnd*
	Total turtle interactions		**1,156**	
Queensland (DAFF)				
		Net	2,451	0.00026-0.019 turtles/day
		Otter trawl	331	0.0036-0.343 turtles/day
		Pot	26	0.000017-0.00026 turtles/day
		Other gear types	15	N/A
		Line	2	0.000044-0.000046 turtles/day
		Beam trawl	1	N/A
	Total turtle interactions		**2,826**	
Cumulative total	**Total turtle interactions**		**5,044**	

Of the 18 Commonwealth-managed fisheries, nine reported marine turtle bycatch from 2000 to 2013 (Table 2.1). Collectively, these fisheries reported a total of 1,062 marine turtle interactions, an average of 77 turtles/yr (±9.4). Four fisheries accounted for 99% of turtle interactions: Northern Prawn Fishery (NPF), Eastern Tuna and Billfish (ETB), Western Tuna and Billfish (WTB) and the Torres Strait Prawn fishery (TSP). The two gear types used by these four fisheries are drifting pelagic longlines (ETB, WTB) and bottom trawls (NPF, TSP). The WTB had the highest calculated BPUE of the two longline fisheries, even though total turtle interactions were only half as high as the number reported in the ETB. For the trawl fisheries, the NPF reported more turtles caught per unit effort than the TSP (Table 2.1). I did not calculate BPUE values for the other five fisheries that each reported a single turtle interaction during the period of the study (Table 2.1).

A total of 1,156 marine turtles were reported to be caught incidentally in fisheries managed by the Northern Territory Government from 2000 to 2013, an annual average of 83 turtles/yr (±11.5). The overwhelming majority of interactions were recorded in fisheries using pelagic gillnets, followed to a much lesser extent by interactions with lines, fish trawls, then gillnets and fish traps (Table 2.1). BPUE values were likewise highest in gillnet and line fisheries, with the upper BPUE values reaching approximately 0.5 turtles per boat day for gillnet fisheries (Table 2.1).

From 2000 to 2013 a total of 2,826 marine turtles were reported to have interacted with fisheries operating in eight of the ten Mapstone regions managed by the Queensland Government, an annual average of 202 turtles/yr (±78.8). The highest number of turtle interactions was reported in net-based fisheries followed by trawls and, to a much lesser extent, crab pots and ‘other’ fisheries of unreported gear type (Table 2.1). The highest BPUE was reported in fisheries using otter trawls, despite net-based fisheries catching over seven

times the total number of turtles as the otter trawls (Table 2.1). Crab pots were also reported to interact with turtles (likely by entanglement) at very low BPUE rates.

2.3.3. Bycatch patterns by species

2.3.3.1.Loggerhead turtles

Loggerhead turtles represented a relatively minor proportion (4.60%) of turtles reported collectively across all agencies from 2000 to 2013 (Table 2.2). Commonwealth longline fisheries on the east and west coasts of Australia reported loggerhead interactions throughout the extent of their operational ranges. Bycatch of loggerhead turtles in Queensland fisheries was greatest in the Sub-tropical region and occurred in all east coast Mapstone regions up to the Eastern Torres Strait. No loggerhead bycatch was reported for Queensland fisheries in the Gulf of Carpentaria.

2.3.3.2.Green turtles

Green turtles were collectively the most commonly reported species, mainly due to high levels of interactions with net-based fisheries in the Sub-Tropical Mapstone region (Queensland fisheries; see Figure 2.1). The number of green turtles caught in this area was two orders of magnitude higher than the next highest number of interactions in any fishery or agency. Of the green turtles reported by Northern Territory fisheries, over 50% were attributed to pelagic gillnet fisheries.

2.3.3.3.Leatherback turtles

Leatherbacks were the most commonly reported species in Commonwealth fisheries, and the third most common overall (Table 2.2). Leatherback bycatch in Commonwealth fisheries was largely concentrated in two distinct oceanic areas: approximately 350km southwest of Perth on the Western Australian coast; and 100-300km northwest of Brisbane on the Queensland

coast, with an additional minor concentration 700km southeast of the Queensland-New South Wales border. Leatherbacks were only reported in 0.53% of all Queensland interactions, but were found in almost every Mapstone region, from the southernmost Sub-tropical north to the Gulf of Carpentaria. One third of total leatherback bycatch in Queensland fisheries was attributable to net fisheries in the Gulf of Carpentaria. No leatherback interactions were reported in Northern Territory fisheries during the period of the study.

2.3.3.4.Hawksbill turtles

Records of hawksbill bycatch were comparatively rare, comprising only 3.09% of all reported interactions. Two hawksbills were reported in the WTB fishery off Western Australia, in oceanic waters approximately 1,300km and 2,500km northwest of Perth. The highest number of hawksbills caught in Queensland fisheries were reported in the Sub-tropical Mapstone region. In fisheries managed by the Northern Territory, all hawksbill interactions were reported in pelagic gillnets.

2.3.3.5.Olive ridley turtles

Olive ridley turtles were reported least frequently of all turtle species (Table 2.2). Interaction rates for this species were the lowest of all species for both Northern Territory and Queensland fisheries. Allowing for misidentification by fishers and considering the prevalence of unidentified turtles in each dataset, bycatch of olive ridleys may be assumed to be higher than these records indicate.

2.3.3.6.Flatback turtles

In Commonwealth fisheries, flatback turtle interactions were reported exclusively in trawl fisheries operating in northern Australia: 91.67% of interactions were recorded in the NPF, 8.33% in the TSP. Flatback turtles in Northern Territory fisheries were caught exclusively in

pelagic gillnets, likely in greater numbers than indicated due to a lack of identification in these fisheries. Although flatbacks were a relatively minor proportion of the turtles caught by Queensland fisheries, most flatback interactions were reported in trawl fisheries operating in the Far Northern Mapstone region.

2.3.3.7. Unidentified turtles

Records of unidentified turtles were highest in pelagic gillnet fisheries managed by the Northern Territory, with unidentified turtles far outnumbering all other species combined (Table 2.2). In Commonwealth fisheries, the highest proportion of unidentified turtles occurred in the ECT and NPF, with unidentified turtles accounting for 26.02% and 23.65% of all turtle bycatch reported by each fishery, respectively. Unidentified turtles made up the second largest species group for Queensland fisheries and overall (Table 2.2).

Table 2.2. Calculated cumulative and mean annual turtle interactions by turtle species for Commonwealth, Northern Territory and Queensland-managed fisheries, 2000-2013. Percentages may be slightly above 100 due to rounding.

State (agency)	Turtle species	Total interactions (2000-2013)	Mean annual interactions (turtles/yr) (±SE)	Percentage of total interactions
Commonwealth (AFMA)				
	Loggerhead	95	7 (±0.5)	8.95%
	Green	218	16 (±2.7)	20.53%
	Leatherback	245	18 (±4.2)	23.07%
	Hawksbill	44	3 (±0.7)	4.14%
	Olive ridley	117	8 (±2.2)	11.02%
	Flatback	108	8 (±1. 8)	10.17%
	Unidentified turtles	235	17 (±3.1)	22.13%
	Total turtle interactions	**1,062**	**77 (±9.4)**	
Northern Territory (DPIF)				
	Loggerhead	4	0 (±0.3)	0.35%
	Green	78	6 (±3.2)	6.75%
	Leatherback	0	N/A	N/A
	Hawksbill	24	2 (±1.8)	2.08%
	Olive ridley	1	0 (±0.1)	0.09%
	Flatback	50	4 (±3.6)	4.33%
	Unidentified turtles	999	71 (±32.0)	86.42%
	Total turtle interactions	**1,156**	**83 (±31.9)**	
Queensland (DAFF)				
	Loggerhead	133	10 (±2.3)	4.71%
	Green	2,390	171 (±73.2)	84.57%
	Leatherback	15	1 (±0.4)	0.53%
	Hawksbill	88	6 (±3.2)	3.11%
	Olive ridley	3	0 (±0.1)	0.11%
	Flatback	52	4 (±1.0)	1.84%
	Unidentified turtles	145	10 (±4.4)	5.13%
	Total turtle interactions	**2,826**	**202 (±78.8)**	
Cumulative Total				
	Loggerhead	232	17 (±2.4)	4.60%
	Green	2,686	192 (±72.9)	53.25%
	Leatherback	260	19 (±4.2)	5.15%
	Hawksbill	156	11 (±3.1)	3.09%
	Olive ridley	121	9 (±2.3)	2.40%
	Flatback	210	15 (3.6)	4.16%
	Unidentified turtles	1,379	99 (±33.7)	27.34%
	Total turtle interactions	**5,044**	**362 (82.9)**	

2.3.4. Spatial distribution of turtle bycatch and conservation 'hotspots'

Each dataset identified at least one localised area (or 'hotspot') where bycatch records were grouped spatially. The highest density of marine turtle bycatch in Commonwealth fisheries occurred in the Gulf of Carpentaria region of northern Australia, specifically near Groote Eylandt and in coastal waters from the Sir Edward Pellew Islands southeast to the Wellesley Islands (Figure 2.2). Bycatch in these areas reached 29-46 turtles per 1°x1° grid cell, whereas the next highest density occurring outside of the Gulf was 17-29 turtles per grid cell. All

turtle interactions in these locations were reported in trawl fisheries. Outside of the Gulf, turtle interactions with Commonwealth longline fisheries (ETB, WTB) reached 3-16 turtles per grid cell on both the east and west coasts (Figure 2.2).

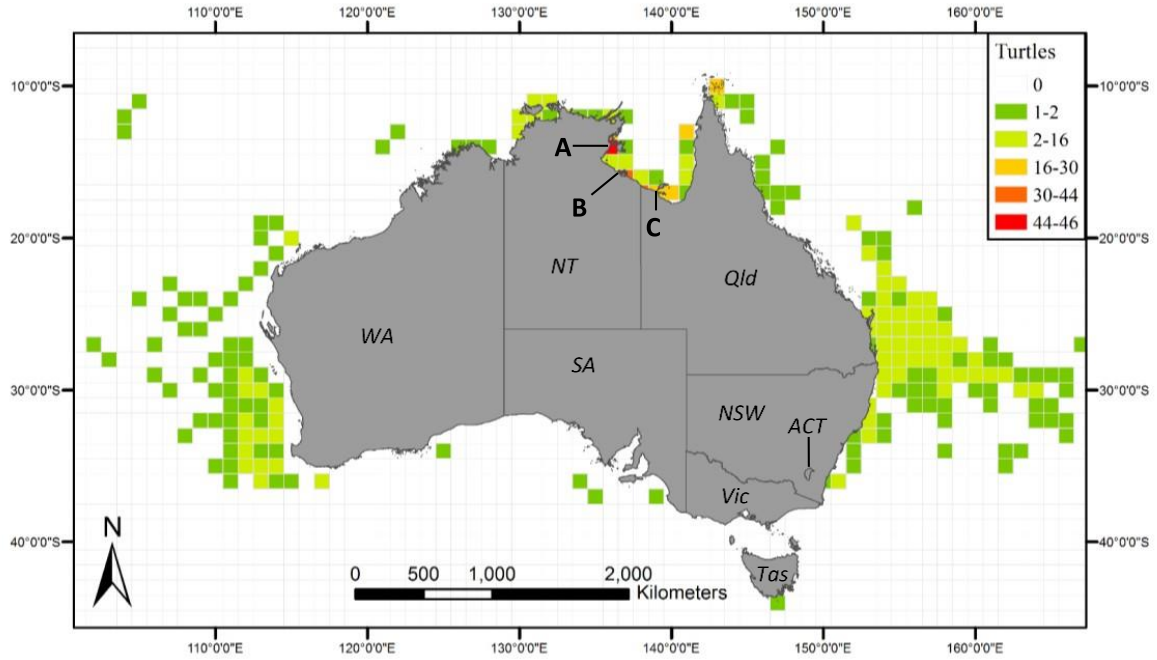

Figure 2.2. Spatial distribution of cumulative turtle interactions with Commonwealth-managed fisheries, 2000-2013. A: Groote Eyland; B: Sir Edward Pellew Islands; C: Wellesley Islands. States and territories are labelled: Australian Capital Territory (ACT); New South Wales (NSW); Northern Territory (NT); Queensland (Qld); South Australia (SA); Tasmania (Tas); Victoria (Vic); Western Australia (WA).

For fisheries managed by the Northern Territory, bycatch records were concentrated in a single 1°x1° coastal grid cell approximately 100km southwest of Darwin, with 462 turtle interactions recorded in this area (Figure 2.3). The next highest density of interactions reached 110 turtles in the neighbouring grid cell to the north, along the southern coast of the Tiwi Islands. Lower, more diffuse levels of bycatch extended eastward from the northern coast of the Tiwi Islands through coastal waters to East Arnhem Land. All interactions occurred in gillnet fisheries.

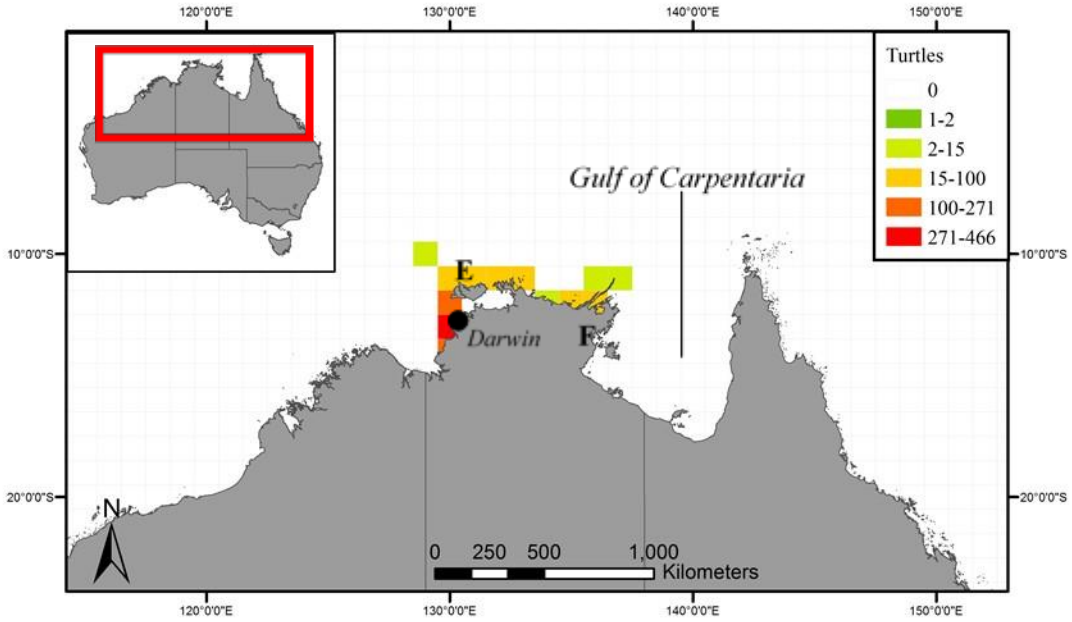

Figure 2.3. Spatial distribution patterns of cumulative turtle interactions with Northern Territory-managed fisheries, 2000-2013. E: Tiwi Islands; F: East Arnhem Land.

In Queensland fisheries, turtle bycatch in net fisheries in the Sub-tropical region was found to be two orders of magnitude higher than in any other gear type or Mapstone region. Due to the limitations of the data format, it was not possible to describe the distribution of turtle bycatch at a scale finer than that delineated by the boundaries of individual Mapstone regions.

2.4. Discussion

This study provides the first multi-agency synthesis of logbook records of turtle bycatch in Australia, and serves as an example of the type of analysis needed for implementing effective, biologically relevant bycatch programs for commercial fisheries. My results demonstrate the importance of evaluating turtle bycatch collectively across multiple years, gear types and management jurisdictions. I stress the need to conduct cumulative impact assessments at the population level for long-lived, migratory taxa, and for management agencies to act collaboratively in developing bycatch quotas for each species. The implications of my analysis are discussed below for the Australian context, with the resulting

management recommendations having broad, cross-taxa applicability for bycatch mitigation efforts within the region and worldwide.

2.4.1. Regional conservation issues

2.4.1.1.Spatial distribution and bycatch 'hotspots'

Of the bycatch records that were able to be mapped, the highest concentrations occurred in the Northern Territory near Darwin and throughout eastern Arnhem Land into coastal areas of the Gulf of Carpentaria. Turtle habitat use is not well studied throughout this remote region; nevertheless, it is highly likely that commercial fisheries bycatch may have management and conservation implications for several species. Five turtle species representing multiple genetic units are known to nest and forage within this high bycatch area: green, hawksbill, olive ridley, flatback and loggerhead turtles (foraging only). While the bycatch near Darwin can be attributed to the Northern Territory pelagic gillnet fishery, reports of turtle bycatch in the Gulf came almost exclusively from the Commonwealth's trawl fishery (NPF). When considered jointly, the bycatch reported in these two fisheries constitutes a significant source of potential mortality near key foraging and nesting sites. Furthermore, the high density of turtle bycatch in the Gulf of Carpentaria highlights a worrying possibility of low compliance with existing gear type regulations in trawl fisheries. The mandatory use of TEDs and their demonstrated efficacy in Australia notwithstanding (Burke et al. 2012; Robins et al. 2002), continued reports of turtle bycatch in the Gulf may indicate a need for more diligent enforcement of existing gear modification requirements.

In Queensland fisheries, turtle bycatch was unquestionably concentrated within the Sub-tropical Mapstone region, with net-based fisheries reporting the most interactions of any fishery in all three datasets. Fisheries personnel were able to confirm that tunnel nets, beach seine nets and gillnets are all used within this Mapstone region. Tunnel nets are not

associated with high levels of turtle mortality, as the net design allows turtles to surface and breathe before being released (C.J. Limpus, pers. comm). However, citing data confidentiality issues and inconsistencies between reporting sources, DAFF was unable to provide clarification on which net types were responsible for the interactions, or specific locations of the turtle captures. In the absence of such essential data, I was restricted in assessing the potential impacts of these interactions, as capture and mortality rates are likely to be heterogeneous across the different net types.

While the distribution of bycatch in Commonwealth-managed longline fisheries essentially mirrored the extent of mapped fishing effort, elevated levels of turtle bycatch were found for commercial longlines on both the eastern and western coasts of Australia. Calculated BPUE values for these fisheries are slightly lower than previous estimates made using Australian logbook data (Robins 2002), and substantially lower than those reported for longline fisheries in other parts of the world (Cambiè et al. 2013; Domingo et al. 2006; Donoso and Dutton 2010). However, these numbers reflect the known limitations of logbook data and are a minimum estimate of a figure that is likely to be much higher in reality. Indeed, in a compilation of global bycatch records, Wallace et al. (2013) classified longline fishing effort off Western Australia into the lowest 5% category, but BPUE values in the top 5% (Wallace et al. 2013).

2.4.1.2.Bycatch impacts on vulnerable Australian species

The number of leatherback interactions reported in Commonwealth fisheries warrants consideration, given the lack of any significant leatherback nesting aggregations in Australia (Hamann et al. 2006). In the absence of genetic studies confirming the origin of these incidentally-captured turtles, it must be assumed that Australian fisheries are impacting on leatherbacks migrating to non-nesting habitat areas from overseas rookeries. Indeed, previous

satellite telemetry studies have identified an area of leatherback foraging and overwintering habitat off Australia's east coast between 30-40°S (Benson et al., 2011; Roe et al., 2014). As bycatch records were not able to be obtained for state fisheries operating in this area, I recommend that bycatch be closely monitored for fisheries operating in waters identified as high-use habitat areas for leatherback turtles. Given the precipitous decline in the number of nesting females of this population (Hitipeuw et al. 2007), it is vital to monitor and address Australian bycatch issues in order to prevent further decline or extirpation (Wallace et al. 2011).

Determining conservation implications of bycatch is more difficult for leatherbacks caught by fisheries off Western Australia, as those turtles are not easily linked to a single nesting subpopulation or genetic stock (Limpus 2009). In addition to documented interactions with Commonwealth longline fisheries, anecdotal data from Western Australia suggests that leatherbacks are also caught in longline and crab pot fisheries managed by the state (Limpus 2009). Fatal entanglement of leatherbacks in the ropes and float lines of crab pots has been reported elsewhere, perhaps most notably in state waters adjacent to the previously described high latitude foraging area (Bone 1998). Bycatch in state-managed fisheries at foraging grounds off Western Australia may therefore constitute a more significant if understudied threat to Indian Ocean leatherback subpopulations than previously assumed.

Olive ridley turtles were reported in Commonwealth fisheries—mainly the NPF—at an average rate of eight turtles per year. In the absence of data describing long-term population dynamics for Australian olive ridleys, it is likely that even such 'low' annual bycatch rates could place proportionally higher pressure on these populations, which are already threatened by egg depredation and mortality in ghost nets (Jensen et al. 2013; Limpus 2008b; Wilcox et al. 2013). Available nesting data indicates that the number of olive ridleys nesting in Australia is a moderate one, on the order of a few thousand females annually (Limpus 2008b;

Whiting et al. 2007b). Satellite telemetry studies indicate that foraging and post-nesting migrations appear to be associated with the Australian continental shelf (McMahon et al. 2007; Whiting et al. 2007a), which may increase the risk of interaction with coastal fisheries at multiple life history stages. Indeed, the hotspot identified by our analysis overlapped with known key nesting sites within the Northern Territory and Gulf of Carpentaria (Limpus 2008b).

Although the quantities of olive ridleys reported in logbook records indicate a minimum baseline figure, qualitative examination of the dataset reveals that the actual bycatch is likely to be several times larger than the reported number. In Northern Territory fisheries, only a single olive ridley was reported in thirteen years of logbooks records, while 1,000 turtles caught in those fisheries were not identified to the species level during that same time period. Given that these fisheries operate in areas of known olive ridley habitat and along the some of the same coast as Australia's largest olive ridley nesting aggregations (Limpus 2008b), the potential for high levels of bycatch needs to be taken into account when evaluating cumulative impacts for this species.

2.4.1.3.Lack of species identification

Across all agencies from 2000 to 2013, a substantial proportion of turtles (27.34% of all interactions) were not identified to the species level, particularly in fisheries managed by the Northern Territory government (86.42%) and also the Commonwealth's ETB and NPF fisheries (26% and 23.65%, respectively). According to published bycatch and discarding work plans, Commonwealth fishers are provided with multiple resources to assist with on-board identification of bycatch species, including marine turtles. Furthermore, from 2003 to 2009, the NPF also benefited from government-funded training programs aimed at improving the accuracy of crew member observers' species identification of protected species (Fry et al.

2010). With an abundance of resources available to facilitate accurate species identification, the high number of unidentified turtles in these fisheries suggests either low information uptake by fishers, or possibly a lack of incentive or unwillingness to routinely identify turtles to the species level. Consequently, the lack of identification obscures actual bycatch trends and hampers the advancement of species-specific bycatch mitigation measures (e.g., spatial and temporal closures near known habitat areas) and frustrates efforts to provide accurate estimates of relative impacts for vulnerable populations.

2.4.2. Future directions: cumulative assessment and collaborative management of turtle bycatch

Managing the bycatch of long-lived, migratory species such as marine turtles requires a multi-fishery approach, timely and transparent collaboration among regulatory agencies, and concerted efforts aimed at improving and enforcing existing mitigation programs. The combined datasets presented in this chapter provide a compelling justification for the need to manage fisheries bycatch in a collaborative and species-relevant manner, in Australian fisheries and worldwide.

A population-scale analogy allows one to understand the potential gravity of the Australian bycatch problem: for the three datasets included in this study, the calculated average number of turtles caught as bycatch each year is comparable to the size of the breeding population of loggerhead turtles on the eastern Australian coast (Limpus 2008a). Such a figure is especially disquieting as a baseline because my results do not take into account additional records from the remaining five states that did not furnish bycatch data. As bycatch events tend to be rare relative to landings of the fishery's target species (Sims et al. 2008), it is likely that annual turtle interactions in a single fishery may not be perceived as an issue of concern requiring immediate intervention, especially if mortality is low and post-capture survival rates are

unknown. However, the total number of turtles caught collectively across multiple fleets has the potential for population-level impacts (Gilman et al. 2007), requiring expansion beyond traditional single-fishery assessments and management methods.

Adopting collaborative, cross-agency management of bycatch has shown positive results outside of Australia. The US Marine Mammal Protection Act of 1972 (MMPA) established a bycatch assessment process based on cumulative mortality levels for marine mammal populations using the potential biological removal (PBR) framework. Under this legislation, mandatory observer programs produce estimates of cumulative mortality on a per population basis, across all gear types and management jurisdictions (Finkbeiner et al. 2011). If cumulative mortality is found to be in excess of the designated PBR, responsive action is taken to reduce bycatch in the fisheries having the greatest impact on marine mammals. In addition to the conservation benefit of adopting a similar approach for marine turtles, shifting management attention away from the less problematic fisheries would allow for more efficient prioritisation of limited regulatory resources (Moore et al. 2009). As demonstrated by the MMPA, setting a bycatch quota for each turtle species at the population level would therefore provide a more cohesive, biologically relevant form of regulation than is currently possible when fisheries are managed separately.

However, there are a number of bureaucratic and procedural structures that hinder the progression of cumulative impact assessments for marine turtles caught in Australian fisheries and potentially elsewhere. The ability to access up-to-date bycatch records is crucial for detecting sudden changes in interaction rates as well as for assessing population impacts from multiple fisheries over broader scales. Yet, variation in administrative protocols across Australian states means that logbook records for individual fisheries are compiled and released on a quarterly or even yearly basis, making it difficult to address emergent bycatch issues in a timely manner. Expedited analyses of logbook records would allow for prompt,

targeted intervention once a fishery of concern is identified. Furthermore, my efforts to acquire detailed bycatch records for marine turtles were repeatedly met with confounding obstacles, including denials that such records existed, admissions that the data was inaccessible or of poor quality, and inability to provide essential metrics (e.g. fishing effort and GPS coordinates) because of 'confidentiality issues'. Such discrepancies in data availability restrict the ability to evaluate how bycatch affects the biology and population ecology of long-lived, migratory taxa. Addressing the population-level impacts of bycatch will require Australian fisheries management agencies to implement an overarching framework by which to facilitate cross-agency collaboration and standardise data reporting procedures.

Complementing a multi-fishery, cross-agency approach, improvements to existing mitigation and enforcement measures could be done within prevailing management structures with relative ease. Taking Australia's NPF as an example, it is an MSC certified fishery where the introduction of TEDs in the early 2000s dramatically reduced turtle bycatch and mortality rates (Brewer et al. 2006). Currently, observer coverage is about 2% of total fleet activity (Bycatch and Discarding Work Plan 2012-2014). Evidence from fisheries outside of Australia shows that it can be difficult to achieve the level of observer coverage needed to estimate bycatch rates with an appropriate degree of statistical certainty (Babcock et al. 2003). Particularly for fisheries with low numbers of licenses but high levels of bycatch, I recommend that efforts be taken to increase observer coverage to 20-50% of total trips (after Babcock et al., 2003) in order to bolster the statistical strength of fleet-wide bycatch figures and inform calculations of cumulative impact metrics. For further precision, Hall (1999) proposes using simulations to inform the creation of effective, fishery-specific observer programs: existing observer data can be used to calculate the level of sampling needed to produce reliable estimates of bycatch and mortality. Additionally, much-needed re-evaluation

of the effectiveness and suitability of gear modifications (i.e. TEDs) could be assessed periodically during fishing operations, with direct input from commercial fishers. Adopting such measures for single fisheries would function as part of a broader strategy to increase the quality of fisheries data available for cumulative impact assessments.

2.5. Conclusions

This chapter demonstrates the need to assess fisheries bycatch at the population level for vulnerable migratory taxa such as marine turtles. Going beyond the standard single-fishery management approach, the use of longitudinal datasets from three management agencies highlights concerning patterns of bycatch for specific gear types and spatial areas within the Australian EEZ. The diversity of these results illustrates the magnitude and complexity of addressing the bycatch problem in areas of variable fishing effort and disparate impacts from multiple fishing methods. Calculated statistics notwithstanding, efforts to produce precise figures of cumulative bycatch were partially hindered by a lack of species identification and inconsistent reporting protocols across agencies. I assert that there is a discernible need for regulatory bodies to work collaboratively in order to ensure that bycatch is monitored and evaluated in an effective, biologically relevant manner for marine turtles and other vulnerable taxa.

Chapter 3

Evaluating the threat of IUU fishing to marine turtles in the Indian Ocean and Southeast Asia using expert elicitation

Chapters 1 and 2 recognised and addressed specific sources of data deficiency surrounding marine turtle interactions with legal commercial fisheries. In this chapter, I venture beyond managed fisheries to evaluate illegal, unreported and unregulated (IUU) fishing as a threat to marine turtles. Using the expert elicitation technique, I identify priority issues and areas of concern within the Indian Ocean and Southeast Asia region. I conclude by suggesting several steps in order to allow managers and policymakers to take productive action against IUU fishing, with implications beyond marine turtles to the arenas of fishery management, food security and biodiversity conservation.

Publication associated with this chapter:

Riskas KA, Tobin R, Fuentes MPB, Hamann M (2018). Evaluating the threat of illegal, unreported and unregulated (IUU) fishing to marine turtles in the Indian Ocean and Southeast Asia using expert elicitation. Biological Conservation 217:232-239 [online 16 Nov 2017].

3.1. Introduction

Illegal, unreported and unregulated (IUU) fishing is a multifaceted regulatory issue that occurs in every ocean basin (Sumaila et al. 2006). The economic losses resulting from unlawful extraction of fisheries resources are believed to be substantial (Agnew et al. 2009; Nurhakim et al. 2008; WWF 2016), and the drivers and loopholes that perpetuate IUU fishing are numerous and highly diverse (Flothmann et al. 2010; OECD 2005; Schmidt 2005). The environmental impacts of IUU fishing have been discussed as being similar to overfishing, concerning the depletion of target stocks (Pomeroy et al. 2007), changes in trophic dynamics following unsustainable harvest (Field et al. 2009), and habitat damage caused by destructive fishing methods (McManus 1997). IUU fishing includes a broad array of unlawful activities (Agnew et al. 2009), making it difficult to quantify empirically while frustrating efforts to assess the impacts of IUU fishing over spatial and temporal scales, as well as for different species.

While it has been suggested that IUU fishing also has negative consequences for marine megafauna species, such as marine turtles (MRAG 2005; OECD 2005; UNODC 2016), the subject has not yet been rigorously investigated (see Chapter 1). To the best of my knowledge, there has not been any specific assessment of IUU-related threats to marine turtles, despite numerous media reports of illegal marine turtle capture and trafficking by IUU fishing vessels (see BOBLME 2015). Indeed, despite growing awareness that criminal organisations are involved in the illegal harvest and trade of valuable fish species (Telesetsky 2014; UNODC 2011), Lindley and Techera (2017) observe that “less attention has been paid to the link between IUU fishing and organized crime” relative to trafficking of weapons, drugs and people. As such, the connection between IUU fishing and trafficking of marine wildlife such as marine turtles is one of interest from both a criminological and a conservation perspective.

To improve our understanding of how threatened marine species are affected by IUU fishing fleets, I evaluated IUU fishing as a threat to a case study species group (marine turtles) in the IOSEA. This chapter elicits local/regional knowledge to outline the scope and gravity of the IUU-turtle problem, identifies key issues and knowledge gaps at regional and basin-wide scales, and uses these results to help guide future research and management action against IUU fishing in the IOSEA and worldwide.

3.2. Materials and Methods

3.2.1. Defining IUU fishing

The term 'illegal, unreported and unregulated fishing' encompasses a wide range of fishing contraventions (Bray 2000; Kao 2015) and is defined in the International Plan of Action to Prevent, Deter and Eliminate IUU Fishing (IPOA-IUU) (see Chapter 1; FAO 2001). Here I use 'IUU fishing' to refer to all activities within Exclusive Economic Zones (EEZs) that are illegal and often unreported, as well as all illegal and unreported activities on the high seas that are under the jurisdiction of regional fisheries management organisations (RFMOs), after Agnew et al. (2008). Discards and mortality from legal fisheries were not included in this analysis.

3.2.2. Study area and designation of sub-regions

The study area included every country with a marine coastline on the Indian Ocean, as well as Southeast Asia, the Philippines and China. Defining the study area to include Southeast Asia allowed me to complement existing organisational linkages between the two regions, such as the Indian Ocean and Southeast Asian Marine Turtle Memorandum of Understanding (IOSEA-MoU), an intergovernmental conservation agreement ratified by thirty-five countries in the region (IOSEA website, 2016).

I grouped countries into four sub-regions (Figure 3.1): Southwestern Indian Ocean (SWIO) includes territorial waters in countries from South Africa to Kenya, plus the island nations of Comoros, Madagascar, Mauritius, Mayotte, Reunion and the Seychelles; Northwestern Indian Ocean (NWIO), Somalia to Iran, including countries with coastline on the Red Sea and Persian Gulf; Northern Indian Ocean (NIO), Pakistan to Bangladesh, including the Maldives and British Indian Ocean Territory; and Southeast Asia (SEA), Myanmar to Australia, including the Philippines and China. To maintain continuity with ongoing conservation programs, these sub-regional boundaries match those used within the IOSEA-MoU framework.

3.2.3. Rationale for using expert elicitation

Expert elicitation is an established technique used for gathering knowledge about data-limited topics, increasingly so in conservation science (Aipanjiguly et al. 2003; Martin et al. 2012; Teck et al. 2010). Conservation decision-making often occurs on short time scales and with limited or incomplete information (Cook et al. 2009), whereby expert knowledge becomes a highly useful resource for guiding management actions (Burgman et al. 2011). Indeed, previous studies have used expert elicitation to identify threats and priority conservation actions for marine turtles (Donlan et al. 2010; Fuentes and Cinner 2010; Klein et al. 2016), typically a challenging task due to marine turtles' complex life histories and circumglobal distributions (Bolten 2003). As IUU fishing is unlawful and therefore difficult to study by conventional methods (Pramod et al. 2008), this approach enabled us to characterise the context of IUU-turtle dynamics on a large geographical scale, alleviate the research burden of gathering experimental evidence for each country, and allow for coordinated knowledge-gathering across broad geographic scales (White et al. 2005).

3.2.4. Scope of participants

Selected respondents included specialists in the fields of marine turtle conservation and fisheries and environmental management, from the sectors of government and/or academic research, policy making, consulting and non-governmental organisations (NGOs). Experts were identified in several ways: based on membership in the Marine Turtle Specialist Group of the International Union for the Conservation of Nature (IUCN-MTSG); referrals from colleagues working throughout the study area; attendance lists from relevant conferences and regional workshops; and by authorship of published literature and reports on IUU fishing- and turtle-related topics. When possible, at least one member of the IUCN-MTSG was contacted for each country in the study area.

3.2.5. Survey design

The expert elicitation survey consisted of 38 multiple choice and open-ended questions (Appendix A). All question formats were designed to be as simple as possible (after White et al. 2005). Multiple choice questions used five-point Likert scales as quantitative indicators (Boone & Boone, 2012). In an effort to harmonise with previous studies of IUU fishing in the Asia-Pacific region (e.g. APEC 2008), I sourced several questions from a 2008 survey employed by the Asia-Pacific Economic Cooperation forum (APEC). Questions were evaluated for compatibility with my research objectives prior to being included in the survey.

To encourage a high response rate, the survey was translated by bilingual native speakers into seven of the languages spoken in the region: Arabic, French, Bahasa Indonesia, Bahasa Malaysia, Portuguese, Swahili and Vietnamese. Languages were elected for translation based on prevalence (number of countries) and upon consideration that English was not likely to be widely spoken in those countries. Translated surveys were then back-translated by another native speaker to verify continuity of meaning.

3.2.6. Survey dissemination and data analysis

I used the SurveyMonkey online platform to distribute the survey and collect responses. Surveys were emailed to respondents between November 2015 and May 2016 as each language version became available. Completed survey data were exported from SurveyMonkey in an Excel spreadsheet for each language version. Data were pooled in the first instance before being grouped by sub-region for additional analysis. Descriptive statistics were generated for each question in order to determine the most common answer choice or choices.

3.3. Results

3.3.1. Survey completion metrics and respondent profiles

After sending 107 survey invitations, I received 49 completed surveys from 30 of the 44 countries in the IOSEA, representing 68% of IOSEA countries and a 46% response rate overall (Figure 3.1). The greatest number of responses came from the SWIO region (n = 16), followed by SEA (n = 14), NWIO (n = 10) and NIO (n = 9). The most-represented region was NIO (responses received from 83% of countries), followed by SWIO (82%), SEA (64%) and NWIO (56%). The number of responses received per country ranged from 0 to 6, with a mean of 1.6 responses. Response rates varied sub-regionally, with the highest response rate from the NIO (9 responses from 14 invitations; 64%), NWIO (10/16; 63%), SWIO (16/33; 48%) and SEA sub-region (14/44; 32%). Over 70% of respondents had experience working with marine turtle interactions and IUU fleets. A more detailed breakdown of the numbers of responses per country is provided in Appendix B.

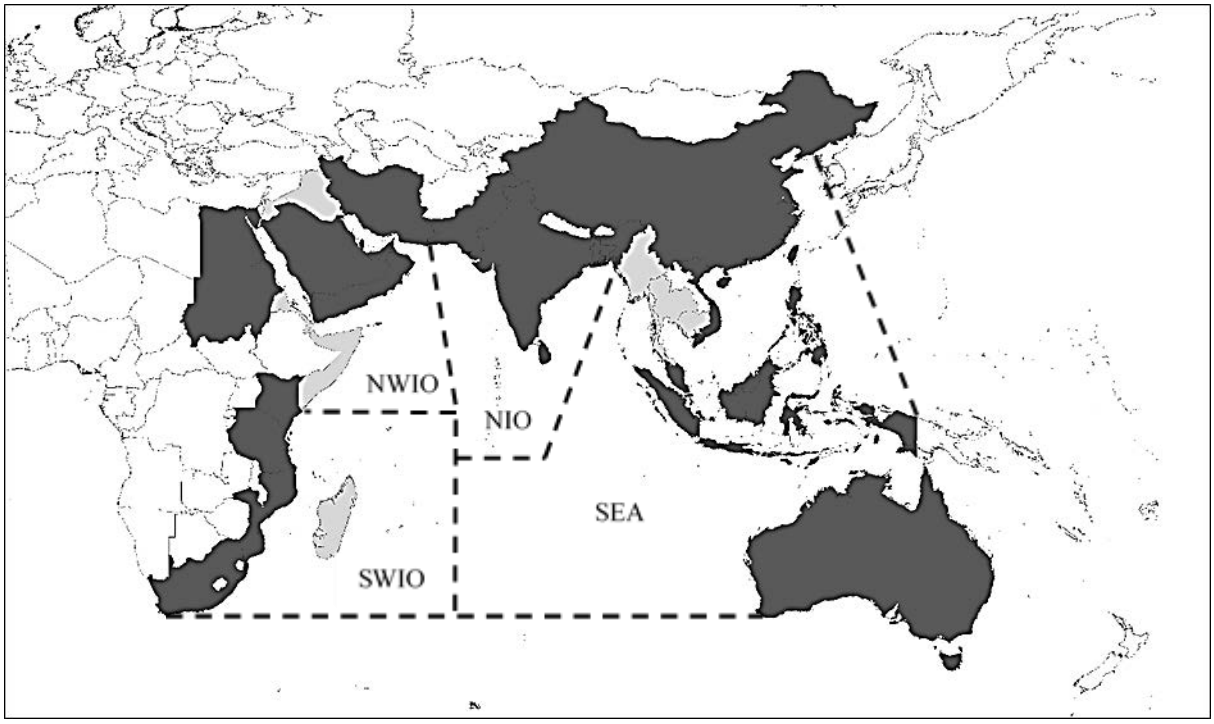

Figure 3.1. Summary of responses received and delineation of sub-regions within the IOSEA. Dark grey: response received; Light grey: no responses received. Sub-regions are defined as: SWIO (Southwestern Indian Ocean); NWIO (Northwestern Indian Ocean); NIO (Northern Indian Ocean); SEA (Southeast Asia).

Professional experience came from academic research (76% of respondents), non-governmental organisations (NGO) (65%), government research (45%), consulting (43%), policy making (35%) and fishery management (29%). Summed percentages exceed 100% due to respondents selecting multiple sectors. Respondents in many cases had professional experience in more than one sector: 80% of respondents said their experience came from two or more sectors, 61% from three or more sectors, and 33% from four or more sectors. The mean number of years of relevant experience reported was 8.9, with a maximum of 31 years.

3.3.2. Basin-wide consensus on IUU fishing as a threat to marine turtles

Across all sub-regions, the majority of respondents (83%) agreed that IUU fishing poses a threat to turtle populations in their country, with 27% of respondents labelling IUU fishing as a ‘somewhat serious threat’, 31% selecting ‘serious threat’ and 25% choosing ‘very serious

threat'. The remaining 17% was split among the 'no threat' (4%) 'minimal threat' (10%) and 'unknown threat' categories (3%), reported by respondents in multiple countries in the SWIO (n = 3 countries) and NWIO sub-regions (n= 2 countries).

Knowledge of turtle involvement in IUU fishing incidents was reported ubiquitously across the region, with turtles involved 'frequently' to 'very frequently' in IUU fishing incidents reported in SEA (64% of respondents) and the SWIO (63%), 'frequently' in the NIO (56%), and 'somewhat frequently' in the NWIO sub-region (60%).

Additionally, 88% of respondents surveyed deemed it 'important' to 'very important' to gain knowledge of the end destinations for illegally-caught turtles. A keyword analysis (after Babbie 1992) of recommendations for enhancing IUU fishing mitigation strategies showed strong convergence on the themes of 'increased and/or improved MCS' and 'awareness and education', with 'research' emerging as an additional theme in the SEA sub-region.

3.3.3. IUU fishing vessel characteristics and practices

3.3.3.1. Domestic versus foreign IUU fishing

In characterising the magnitude and severity of IUU fishing within a country's EEZ, the most common response (modal class) was 'widespread and a significant problem' for both foreign and domestic vessels engaged in IUU fishing (Table 3.1). More respondents overall selected this category for domestic IUU fishing (n = 23) than for foreign IUU fishing (n = 18). Responses showed more variability for foreign vessels at the sub-regional level (Table 3.1).

3.3.3.2. Vessel types

Domestic artisanal fleets were identified as the most common type of IUU vessel on a basin-wide scale. Sub-regionally, the involvement of foreign—namely artisanal—fleets was more pronounced as the next most-common fleet types were identified (Table 3.1). In SWIO,

foreign industrial fleets were second most-common; in NWIO, foreign artisanal fleets; in NIO, foreign artisanal fleets; and foreign artisanal fleets were tied with domestic industrial fleets in SEA (Table 3.1). Thus subsequent results presented here are likely linked to the most prominent fleet type(s) in each sub-region and may not be relevant to all vessel types.

3.3.3.3. IUU fishing practices and fisher motivations

Respondents ranked the types of IUU fishing happening in their country by frequency of known occurrences. From most common to least common (modal class): misreporting or under-reporting the catch (very frequently); fishing without authorisation (very frequently/frequently); using a prohibited fishing method (frequently); retaining protected species (somewhat frequently); and fishing in a closed or restricted-access area (somewhat frequently). The types of IUU fishing believed to have the biggest impacts on marine turtles were gillnets and other net (non-trawl) fisheries (n = 23), followed by longlines (n = 11) and trawls (n = 9). Open-ended responses identified additional forms of IUU fishing occurring prevalently throughout the study area, including use of destructive gears (e.g. cyanide, dynamite, small-mesh nets) and encroachment by commercial vessels into nearshore zones reserved for small-scale fisheries.

Respondents identified ‘lack of enforcement’ as the most likely explanation for why foreign (51% of respondents) and domestic fishers (55%) would engage in IUU fishing activities. The next most-commonly chosen answer for foreign IUU fishers was ‘access to valuable species’ (17%), whereas ‘overfishing of local waters’ was the next most-common answer for domestic IUU fishers (21%).

Table 3.1. Summary of key results by sub-region. Categories in each box represent the most frequently chosen answer for that question, while percentages indicate the proportion of respondents selecting that answer. Percentages may be slightly above 100 due to rounding.

Sub-region	Magnitude of IUU by foreign and domestic vessels	Primary vessel type	Location of IUU incidents	Turtle species (top 2)	Fate of turtles (top 2)
Southwestern Indian Ocean (SWIO)	Foreign IUU: widespread, significant problem (56%) Domestic IUU: widespread, significant problem (56%)	Domestic artisanal (66%)	Within EEZs (94%)	Green (50%) Hawksbill (50%)	Used for food (52%); Sold locally (24%)
Northwestern Indian Ocean (NWIO)	Foreign IUU: isolated incidents, not a significant problem (50%) Domestic IUU: widespread, significant problem (40%)	Domestic artisanal (50%)	Within EEZs (90%)	Green (50%) Hawksbill (40%)	Released alive (35%); Used for food (35%)
Northern Indian Ocean (NIO)	Foreign IUU: isolated incidents, not a significant problem (50%) Domestic IUU: widespread, significant problem (67%)	Domestic artisanal (89%)	Within EEZs (89%)	Olive ridley (78%) Green, loggerhead (11%)	Released alive (56%); Used for food (22%)
Southeast Asia (SEA)	Foreign: widespread, significant problem (36%) Domestic: isolated incidents, significant problem (36%)	Domestic artisanal (57%)	Within EEZs (64%)	Green (64%) Hawksbill (57%)	Sold locally (36%); Shipped overseas (36%)
All IOSEA	Foreign: widespread, significant problem (37%) Domestic: widespread, significant problem (47%)	Domestic artisanal (56%)	Within EEZs (92%)	Green (47%) Hawksbill (35%)	Used for food (36%); Sold locally (24%)

3.3.4. IUU fishing locations

Respondents indicated that IUU fishing happens most frequently in multiple habitat types (e.g. coral reefs, estuaries, open ocean) within their country's EEZ, with fewer incidents occurring in areas of multiple adjoining EEZs (i.e. border areas), or on the high seas (Table 3.1). IUU fishing was reported to happen at similar frequencies in inshore waters (including bays, coastlines, estuaries and shallow waters up to three nautical miles from shore), coral reefs, islands, and open ocean areas within the EEZ. The 'high seas' category was the least-chosen answer option.

3.3.5. Involvement of marine turtles

Marine turtles were reported to be involved in IUU fishing incidents 'frequently to very frequently' (61% of responses). Respondents ranked green (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) as the species most commonly encountered overall in known IUU fishing incidents involving marine turtles. Sub-regional differences in commonly-encountered turtle species reflected known variation in species distributions: loggerhead turtles (*Caretta caretta*) were more often reported in the SWIO and NWIO sub-regions, while olive ridley turtles (*Lepidochelys olivacea*) were mainly reported in the NIO and SEA sub-regions. Flatback turtles (*Natator depressus*), endemic to Australia, were ubiquitously categorised as 'Never encountered', even by Australian respondents.

Marine turtles were known to be targeted by foreign boats in several nations within two sub-regions: SEA (Australia, China, Malaysia, Philippines, Taiwan) and SWIO (Kenya, Mozambique, Seychelles). Transshipment at sea—transferring cargo from one vessel to another, including over international borders—of illegally-caught turtles was also confirmed to happen in several countries within these sub-regions: China, Indonesia, Malaysia, Philippines and Vietnam in SEA; and Kenya, Tanzania and Mozambique in SWIO.

Respondents also highlighted the issues of entanglement in discarded fishing gear (ghost fishing) and incidental capture of marine turtles in legal and illegal fisheries (nets, trawls) in multiple sub-regions.

3.3.6. Sub-regional use of marine turtles

3.3.6.1. SWIO

Responses described the widespread and multipurpose direct use of marine turtles by local people in the SWIO. Illegally-caught turtles are believed to be primarily consumed as food, as well as sold locally for use in traditional medicines and for production of curios and handicrafts (Table 3.1). The number of IUU fishing events occurring in each country were estimated at over 100 incidents annually.

3.3.6.2. NWIO

Turtles caught illegally in the NWIO were reported to be released alive or consumed for food, depending on the area in which they were caught (Table 3.1). Responses did not mention any usage of turtle products for traditional medicine or production of curios in this sub-region. There were indications that turtles were not commonly shipped overseas or found taxidermied in this sub-region. However, low participation precluded a more definitive assessment of turtle-related IUU fishing activities in this sub-region.

3.3.6.3. NIO

'Released alive' was the most commonly selected fate of illegally-caught turtles in the NIO. There was a strong indication that turtles are almost never found taxidermied for sale as curios or ornamental display, and are encountered intact more often than butchered. Turtles were also reported to be 'used for food' in Bangladesh, the Maldives and Sri Lanka.

3.3.6.4. SEA

Responses in the SEA sub-region described illegally-caught turtles that are mainly found dead and intact (i.e. not butchered), with 'sold locally' and 'shipped overseas' selected as the most common fates. The only country to report evidence of butchered turtles was the Philippines. Taxidermied turtles were reported in IUU fishing incidents in China, Malaysia and the Philippines. Taiwan and Vietnam reported the highest estimated number of IUU fishing incidents (>100 annually).

3.4. Discussion

This is the first study to synthesise expert assessment of how IUU fishing threatens marine turtle populations. Sub-regional analysis highlights the heterogeneity of IUU fishing practices occurring across geopolitical boundaries and demonstrates the need for implementation of tailored, country-specific solutions. IUU fishing is perceived by respondents to pose at least a 'serious threat' to marine turtle populations in nearly every country surveyed within the IOSEA. Given the vast diversity of fishing practices and turtle population sizes within the study area, achieving near-consensus on an issue as controversial as IUU fishing is a testament to the prevalence and gravity of the situation. The local/regional knowledge captured in this study is an essential tool for identifying and prioritising actions to address an otherwise vastly complex issue. This approach bears repeating across multiple geographic scales and has implications beyond marine turtles to the broader arenas of biodiversity conservation, food security and sustainable resource management.

Here I identify several themes emerging from this analysis and discuss the consequences for relevant sub-regions within the IOSEA. I then demonstrate how this contribution can be used to guide future research and drive the creation of effective IUU fishing mitigation strategies in the IOSEA and worldwide.

3.4.1. Variability of turtle-related IUU fishing incidents

The diversity of reported uses (e.g. used for food, sold locally, shipped overseas) for illegally-caught marine turtles exemplifies the difficulty of combatting IUU fishing effectively. Though not completely exhaustive, these results indicate that patterns of illegal use can be difficult to interpret and may differ significantly even between neighboring countries (see Table 3.1). As an example, consumption for food was a commonly-selected fate for turtles caught illegally in three of the four sub-regions, although not all countries reported consumption equally. There were also indications of traditional medicinal use of illegally-caught turtles in the SWIO sub-region. However, these activities are difficult to disentangle wholly from land-based capture methods (i.e. taking turtles from nesting beaches), and cannot be assumed to be driving IUU fishing activity in all sub-regions. I will therefore place these uses outside the scope of my study, and focus hereafter on the role of IUU fishing vessels in furthering at-sea exploitation of marine turtles for commercial uses.

Respondents identified ‘domestic artisanal fleets’ as the most common type of IUU fishing vessel operating in the IOSEA. When describing the severity of IUU fishing by domestic vessels, respondents chose ‘a widespread and significant problem’ twice as frequently as they chose ‘an isolated and significant’ one. It is unclear whether or not this points to a greater awareness of the fishing activities of local, coastal fleets, or rather indicates a truly higher proportion of domestic fishers engaged in IUU fishing activities. However, considering that small-scale fisheries are ubiquitous throughout the IOSEA (Johns 2013; Stobutzki et al. 2006; Van der Elst et al. 2005) and are generally restricted for a number of reasons to operating in nearshore waters (Chuenpagdee et al. 2006), these results likely reflect a general awareness of IUU fishing occurring prevalently within EEZs. Moreover, previous research validates this assumption, estimating that 90% of IUU fishing occurs within waters under the sovereign control of coastal nations, and on the high seas to a much lesser extent (MRAG 2008;

Petrossian et al. 2015a). While not all types of IUU activities are equally likely to have direct negative impacts on marine turtles, the frequency of reported IUU fishing by domestic artisanal fleets nevertheless merits a review and evaluation of local compliance and enforcement capacity in many IOSEA countries.

The issue of illegal incursions by foreign vessels into a country's territorial waters was also a prominent theme for every sub-region. Foreign IUU fishing is hardly unique to the IOSEA and is an ongoing issue for fisheries governance throughout the world (Bray 2000; HSTF 2006). In this study, marine turtles were reported to be targeted by foreign boats in multiple countries within the SEA (Australia, China, Malaysia, Philippines, Taiwan) and SWIO (Kenya, Mozambique, Seychelles) sub-regions. Although it is difficult in many cases to accurately assess the impact of distant-water fishing fleets, these results are corroborated by my own review of the literature. The co-occurrence of foreign vessel incursions and IUU-turtle activities suggests enforcement failure at multiple regulatory levels, including at-sea vessel monitoring, portside inspection and customs control. Additionally, the issue of foreign IUU fishing in the IOSEA reinforces concerns that many individual nations are unable to sustain effective monitoring, control and surveillance (MCS) programs (Agnew et al. 2009; GOC 2013), a capacity issue that is tied inextricably to the financial and logistical difficulties of monitoring distant maritime borders. As IUU fishing disproportionally impacts the environments and economies of developing nations (MRAG 2005), it is therefore essential that governments advocate for international cooperation to build these MCS resources for countries that are unable to do so themselves (after Petrossian 2015).

3.4.2. IUU fishing and the illegal wildlife trade

This study identified a convergence of themes indicative of the illegal wildlife trade in both the SEA and SWIO sub-regions. Marine turtles had been involved in IUU fishing incidents on a 'frequent' to 'very frequent' basis (67% and 63% of respondents in SEA and SWIO, respectively); confirmed to be targeted by foreign vessels in both sub-regions; and the indication of transshipment at sea occurring in both sub-regions raises concerns that IUU fishing vessels may play an important role in facilitating the exploitation of marine turtles for commercial purposes. Collectively, these factors suggest an intentional, coordinated and international component to IUU fishing in these sub-regions, with likely connections to known wildlife trafficking operations.

In particular, Southeast Asia is well-documented as the global capital of the illegal wildlife trade (Nijman 2010; Rosen and Smith 2010; Sodhi et al. 2004). Illegal trade is believed to be driven by the high demand for turtle-based traditional medicines and luxury products in China (Lam et al. 2011). In 2014, a paper produced by the IOSEA-MoU identified China, Japan and Taiwan as the intended end destinations for turtles harvested illegally in Southeast Asia (IOSEA 2014). Similarly in this survey, responses of turtles being illegally caught and 'shipped overseas' came mainly from the SEA sub-region, with China, Japan, Taiwan and Vietnam specified as putative end destinations. Vietnam has been identified as a transit country for illegally-traded wildlife (Ngoc and Wyatt 2013), and its appearance in this dataset gives credence to the possibility of links between IUU fishing vessels and the illegal trade in marine turtle products to East Asian markets (i.e. China, Japan, Taiwan; see Stiles 2008). I argue that IUU fishing vessels may be contributing to the targeted commercial exploitation of marine turtles, and therefore constitute a serious threat to marine turtle populations in the SEA sub-region.

Additionally, the identification of transshipment at sea happening in multiple jurisdictions signifies an organised rather than opportunistic smuggling of illegally-caught marine turtles. Survey results report transshipment in the waters of China, Malaysia, Philippines and Vietnam, suggesting linkages between IUU fishing vessels and regional wildlife smuggling operations. Pilcher et al. (2009) report transshipment of marine turtles by Chinese and Vietnamese poachers in the South China Sea, and my survey of fishermen in the Malaysian state of Terengganu indicates awareness of the practice happening in Peninsular Malaysia as well (see Chapter 4). Furthermore, respondents indicated that taxidermied turtles—unequivocally destined for East Asian markets—were found during apprehensions of IUU fishing vessels in China, Malaysia and the Philippines. As transshipment at sea has been identified as a transit pathway for other illegally-traded taxa in Southeast Asia (e.g. shark fins from Indonesia to Japan; see Varkey et al. 2010), the results of this survey demonstrate the importance of exploring and defining the associations between IUU fishing vessels and the trafficking of illegally-caught marine turtles.

Linkages between IUU fishing and a coordinated illegal trade of marine turtles were less extensive but still concerning for the SWIO sub-region. In Kenya and Mozambique, foreign vessels were reported to target marine turtles, with transshipment at sea confirmed to occur for illegally-caught turtles in Kenya, Mozambique and Tanzania. This presents the worrying possibility of a recent expansion of IUU-turtle activities, which were previously thought to be locally constrained for this sub-region (IOSEA 2014). The involvement of foreign boats may point to a lack of capacity to effectively monitor and patrol vast swaths of the east African coastline, despite recent increases in maritime security near the Horn of Africa (Agnew et al. 2009).

The evidence for a connection between IUU fishing and the illegal wildlife trade adds to the growing body of studies recognising IUU fishing as transnational organised crime (Liddick

2014; Telesetsky 2014). It is important to acknowledge the possibility that these processes may not be exclusive to the SEA and SWIO sub-regions, and may be developing elsewhere within the study area for other species and fleet types. While marine turtles are not always identified to the level of species or life history stage in grey literature reports, this chapter nevertheless supports the idea of sub-regional species heterogeneity in general fisheries-based interactions (Chapter 2). Caution is needed in interpreting results for sub-regions with low participation (i.e. NIO); however, recent apprehensions of turtle meat in Sri Lanka and Malaysia (Langenheim 2017; Toyos 2017) highlight the need to improve our understanding of the impacts of IUU fishing on marine turtles in all sub-regions. These efforts notwithstanding, it must be noted that fully stopping the illegal trade of marine turtles requires an understanding of the social, economic and cultural root causes of demand, and in the education of consumers and provision of economic alternatives to suppliers (see TRAFFIC 2008).

3.4.3. Use of surveys and data limitations

My choice to use the expert elicitation technique for this study is consistent with the growing trend of using of expert opinion to supplement knowledge of data-poor topics in conservation science (Aipanjiguly et al. 2003; Martin et al. 2012). Performing the elicitation via an online survey allowed for data collection on a large geographic scale, at a low cost and without the logistical constraints of in-person interviews. Additionally, the online format ensured that all questions were presented identically for each respondent, thereby avoiding potential biases introduced by way of extemporaneous interview techniques.

A number of studies have discussed the pervasiveness of psychological and motivational biases in both experts and lay people (Fischhoff et al. 1982; Kahneman and Tversky 1982), including within the marine turtle conservation community (Campbell 2002). Nevertheless,

Burgman et al. (2011) and others assert that expert estimates are nevertheless more reliable than those of lay people, subject to being restricted to their field of expertise (Burgman et al. 2011; Slovic 1999). In order to identify and minimise latent biases, future studies would benefit from employing an iterative Delphi-style process (after McBride et al. 2012) within participant groups on sub-regional scales. Participant feedback could also be sought to resolve any ambiguity surrounding the meaning of abstract concepts; for instance, perceptions of 'risk' and 'threats' can be subject to cultural and political factors (Slovic 1999).

The number of responses received was lower than desired given the number of countries in the study area. I acknowledge that the level of participation limits the scope of analysis and the insights that can be drawn from the results. When evaluating non-response rates by sub-region, a dichotomy emerges between response rate and sub-regional representivity. The SEA sub-region had the lowest rate of survey completion (14 responses from 44 invitations; 32%); but received the second-highest number of responses and represented 7 of the sub-region's 11 countries (64% representation). Contrastingly, the NWIO sub-region saw a higher completion rate (10 out of 16; 63%), but had the lowest proportional representation of any sub-region (9 of 16 countries; 56% representation). While the survey received more responses per unit effort for the NWIO, the lower number of known eligible respondents resulted in lower regional representivity. The response rate in the SEA sub-region may indicate a lack of awareness about the IUU-turtle issue, or perhaps an unwillingness to report on behalf of an agency and/or nation. It may also point to a broader lack of IUU fishing expertise, which is likely a substantial contributing factor to the issue of IUU fishing more generally.

3.4.4. Future research needs

Examination of the academic literature has highlighted a dearth of published studies investigating the impacts of IUU fishing on marine turtles, despite significant coverage of the issue in news media outlets (Chapter 1). I recommend that research effort be directed towards creating these evaluations for marine turtles and other threatened marine species at multiple scales. Furthermore, it would be constructive for regional and international bodies to mobilise their networks to increase the number of participants in survey work, particularly in areas where this study received comparatively fewer responses (i.e. NWIO and NIO). Such evaluations would be important data sources for quantifying relative threat levels of IUU fishing as part of species assessment frameworks, such as the IUCN Red List.

These results describe a variety of IUU fishing threats throughout the IOSEA, and also point to the possibility of further heterogeneity within individual nations. As the impacts on marine turtles are difficult to quantify directly, it is essential to utilise multidisciplinary approaches to address knowledge gaps through the capture and application of local/regional ecological and fisheries knowledge (see Gilchrist et al. 2005; Pomeroy 1995). Future efforts to ground truth the results of this study at smaller, more localised scales would allow for a greater comprehension of the situation in countries where turtle-related IUU fishing appears to be widespread. Interviews with local commercial and artisanal fishers would add another dimension of understanding, particularly in regards to varying local socioeconomic motivations (Rohe et al. 2017) and market drivers, both of which are especially crucial for guiding appropriate action. Efforts to understand the drivers, practices and impacts of IUU fishing, especially in relation to the illegal wildlife trade, are essential to inform mitigation measures and increase the likelihood of their success (TRAFFIC 2008).

There is also a need to describe and address any potential barriers to implementing effective IUU fishing mitigation strategies. Respondents largely agreed that IUU fishing poses a threat to marine turtle populations, and that information on market destinations is important for directing management actions. In cases where market destinations are known, future research could direct inquiry into management effectiveness against persistent (and oftentimes open) illegal activity. Conversely, further exploration is needed for responses in this survey characterising market drivers and end destinations as 'not important' for management. Furthermore, several studies have noted that the issue of IUU fishing persists despite the large number of national and international initiatives aimed at addressing it (Liddick 2014; Lindley and Techera 2017). It is not currently known to what extent the resulting 'treaty congestion' (Anton 2012) may complicate the regulatory arena and prevent management agencies from taking action against IUU fishing. I recommend that future work explore this idea and other issues of policy uptake within multiple agencies, countries and sub-regions.

3.4.5. Moving towards management solutions for IUU fishing and threatened marine species

Previous research has shown that MCS capacity and robust surveillance are strong predictor variables for the level of IUU fishing occurring in a nation's waters (Clarke et al. 2007; MRAG 2005; Petrossian 2015). Indeed, respondents in this study indicated that 'lack of enforcement' was believed to be the primary motivation for both domestic and foreign IUU fishing. Similarly, a keyword analysis of recommendations for enhancing IUU fishing mitigation strategies showed strong convergence on the themes of 'increased and/or improved MCS' and 'awareness and education', as well as 'research' in the SEA sub-region. Regarding the need for increasing awareness, my results report that 'lack of awareness of laws' is minimal for both domestic and foreign IUU fishers, suggesting that IUU fishing is deliberate and that management action might achieve a greater impact if prioritised

elsewhere. The recommendations for 'awareness and education' likely reflect the high degree of respondent experience with NGOs (65%). Organisations working to stop IUU fishing should thus consider diversifying their official activities by forming enforcement partnerships to fill the capacity vacuum (Bergenas and Knight 2016).

In addition to bolstering national MCS through internationally-assisted capacity building, Johns (2013) advocates for the use of 'coordinated regional action', recognising that single-nation action plans are insufficient to ameliorate IUU fishing. Where international and regional alliances already exist (such as the ASEAN-Wildlife Enforcement Network in Southeast Asia), a pluralistic regulatory paradigm would capitalise on the interconnectedness of IUU fishing and transnational criminal activity to achieve multiple positive outcomes (Lindley and Techera 2017). To maximise efficiency of resource allocation, an overarching, international framework for coordinating responses to IUU fishing (such as the International MCS Network) should be broadly adopted and strengthened, and new actors from the military and the private sector likewise incorporated (Bergenas and Knight 2016). Maritime security concerns could also be leveraged to justify ratification of the FAO Agreement on Port State Measures (PSMA), which entered into force in June 2016 and has already been adopted by roughly one quarter of IOSEA countries (as of November 2017; FAO 2016). In taking action to strengthen maritime borders and restrict access to markets for IUU vessels, transshipment and offloading of illegally-caught turtles would be similarly reduced.

Increasing the knowledge of IUU fishing will lead to a more holistic understanding of this complex issue, in turn enabling regulatory actors to act in a synergistic and pluralistic manner. Where there are overlaps between certain types of IUU fishing and other criminal activities (e.g. drug, weapons and human trafficking), legal responses may be similarly integrated (Lindley and Techera 2017). For instance, my findings of illegal capture and transshipment of marine turtles by IUU fishing vessels potentially reflect to varying degrees a

similar situation for other trafficked marine species, such as elasmobranchs, giant clams, sea cucumber and reef fish. It is necessary for managers to draw on local/regional knowledge to justify specific inclusion of marine turtles and other protected species in their policies and activities. Investing in programs to tackle the IUU-turtle issue will therefore have positive implications for other species that are being affected by similar exploitative processes and transit pathways. Efforts to eliminate the use of illegal gear types and destructive fishing practices are also likely to play a significant role in curbing habitat degradation, with ecological and socioeconomic benefits for the communities whose livelihoods are closely tied to the health of the marine environment. As such, taking action against IUU fishing in the name of threatened marine species serves to strengthen and complement existing initiatives to promote ecosystem health, sustainable tourism, biodiversity conservation and food security.

3.5. Conclusions

This chapter brings much-needed attention to the growing problem of IUU fishing and its role in furthering the exploitation of marine turtles and other threatened marine species. I stress the importance of considering IUU fishing as a potentially serious threat to marine turtles through intentional illegal take and international wildlife trafficking. Transshipment of marine turtles across maritime borders indicates a need for increasing MCS capacity, and raises the possibility of organisational linkages between IUU fishing and the larger illegal wildlife trade. The heterogeneity of IUU fishing practices occurring throughout the region illustrates the necessity for a diverse array of collaborative and country-specific mitigation measures. I emphasise the need for further research to investigate IUU fishing practices, market drivers, and barriers to effective management, and for regional and international stakeholders to adopt a pluralistic approach in addressing IUU fishing as a form of transnational organised crime. Including marine turtles and other marine megafauna species in the scope of IUU fishing mitigation programs will have positive implications for other

trafficked species, marine biodiversity, and the communities whose livelihoods depend on the health of the marine environment.

Chapter 4

Fisher interviews identify ties between IUU fishing, wildlife trafficking and transnational organised crime in two Malaysian states

In Chapter 3, I established that IUU fishing poses a threat to marine turtles in the Indian Ocean and Southeast Asia region (IOSEA). Though coarse geographically, my analysis highlighted the need to investigate potential heterogeneity in IUU fishing practices at local, management-relevant scales. In this chapter, I use Malaysia as a case study to demonstrate the need for context-specific mitigation measures against IUU fishing. Based on interviews with Malaysian fishers, I identify key differences between states concerning the root causes of IUU fishing, the involvement of marine turtles, and the degree of connectivity between IUU vessels and organised criminal syndicates. I conclude that a more nuanced approach to IUU fishing mitigation is needed, with an emphasis on knowledge gathering to identify and target specific causal factors.

Publication associated with this chapter:

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4.1 Introduction

Illegal, unreported and unregulated (IUU) fishing is widely recognised as an impediment to effective marine resource governance (Bray, 2000; Flothmann et al., 2010). In Southeast Asia, factors driving IUU fishing include population growth, poverty, fleet overcapacity and increasing local and global demand for seafood (Johns, 2013; Palma and Tsamenyi, 2008; Petrossian, 2012). Combined with abutting maritime boundaries (APEC Secretariat, 2008) and capacity shortfalls in fisheries licensing and enforcement (Funge-Smith et al., 2015; Morgan et al., 2007), Southeast Asia presents a challenging environment for exercising control over IUU fishing by foreign and domestic vessels (Baird, 2010). To maintain food security and economically viable fisheries, management strategies typically aim to reduce the impact of IUU fishing on target species. However, many studies have noted that IUU fishing may also negatively impact populations of non-target and protected species, such as marine turtles (BOBLME, 2015; MRAG, 2005; Okey et al., 2007).

Marine turtle populations in Southeast Asia face multiple anthropogenic threats (Shanker and Pilcher, 2003), the assessment of which is often hindered by data deficiencies (Chapter 1). In recent years, increases in at-sea poaching of marine turtles—particularly in the mega-diverse Coral Triangle (IOSEA, 2014; Pilcher et al., 2008)—have elicited concern from the conservation community (Lam et al., 2011; Pilcher et al., 2009; UNODC, 2016). In a recent survey of experts in the Indian Ocean and Southeast Asia, Riskas et al. (2018) (Chapter 3) found that IUU fishing vessels are participating in the intentional capture, transshipment and export of marine turtles to East Asian markets. This link between IUU fishing and marine turtle trafficking adds to a growing body of literature characterising IUU fishing as transnational organised crime (Liddick, 2014; Phelps Bondaroff et al., 2015; Telesetsky, 2014). As such, political responses to mitigate IUU fishing must be similarly nuanced to reflect this added level of complexity.

While a number of Southeast Asian nations have created national and regional plans to combat IUU fishing, these frameworks do not allow for fine-scale differentiation in the response to varying IUU fishing practices occurring within countries or states. In order to drive targeted, effective intervention programs against marine turtle exploitation by IUU vessels, an examination of IUU fishing practices in relation to marine turtles on a national basis is urgently needed. I chose Malaysia as a case study due to its location (i.e. encompassing the South China Sea and the Coral Triangle) and its multiple endangered marine turtle populations (Chan, 2006). Malaysia also has adopted a National Plan of Action to Prevent, Deter and Eliminate IUU Fishing (NPOA-IUU; Department of Fisheries (2013)), but it has not yet proved effective against illegal marine turtle capture (Kaur, 2017).

This study aimed to improve our understanding of the relationship between IUU fishing activities and marine turtles in two Malaysian states: Terengganu (Peninsular Malaysia) and Sabah (Malaysian Borneo). Terengganu has been labelled a 'hotspot' for incursions by foreign fishing boats (Majid, 2017; Marsh, 1992; The Malay Mail, 2014), while Sabah has recorded several apprehensions of foreign vessels targeting marine turtles in recent years (Borneo Post 2015; Toyos 2017; WWF 2007). By utilising structured surveys with commercial fishers, I sought to gather local knowledge about activities that are largely hidden and difficult to assess within traditional management frameworks.

4.2. Materials and Methods

4.2.1. Study area

Interviews with fishers were conducted at multiple coastal locations in the two Malaysian states: six sites in Terengganu, Peninsular Malaysia and six sites in Sabah, Malaysian Borneo (Figure 4.1).

Four marine turtle species nest in Malaysia (Chan, 2006): the green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*), and olive ridley (*Lepidochelys olivacea*). Populations of hawksbill, olive ridley and leatherback turtles have plummeted in the state of Terengganu following decades of egg harvest and incidental fisheries mortality; indeed, the leatherback is considered locally extinct in Peninsular Malaysia (Chan and Liew, 1996; Chan et al., 1988; Hamann et al., 2006). While green turtle populations in Sabah state are steadily increasing, hawksbills have declined since the late 1990s (Chan, 2006).

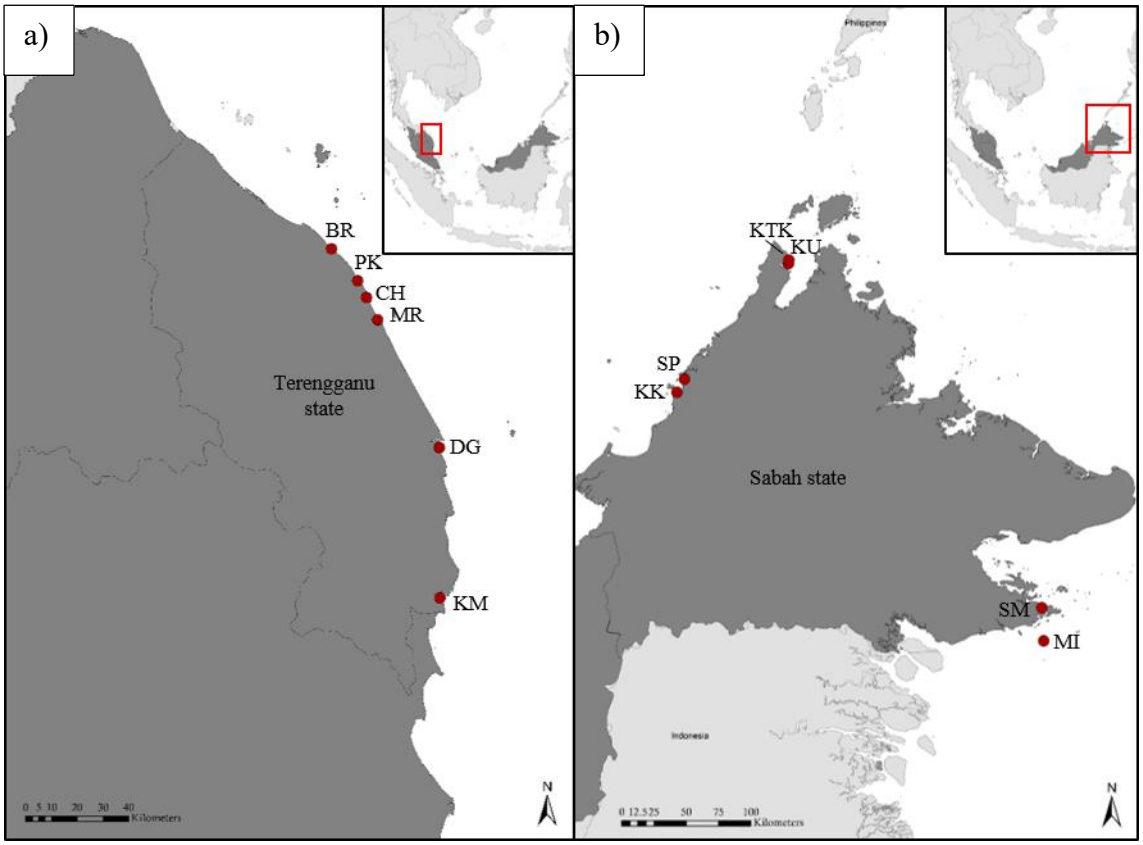

Figure 4.1. Distribution of study sites within (a) Terengganu and (b) Sabah states. Names of study sites are abbreviated: (a) Batu Rakit (BR), Pulau Kambing (PK), Chendering (CH), Marang (MR), Dungun (DG), Kemanan (KM); (b) Kota Kinabalu (KK), Sepangar (SP), Kampung Tanjung Kapor (KTK), Kudat (KU), Semporna (SM), Mabul Island (MI).

4.2.2. Collaboration with Malaysian researchers and authorities

In Terengganu, I partnered with the University of Malaysia, Terengganu (UMT) to conduct field work jointly, with UMT students providing translation and data collection as part of their degree research. Permission for the project was obtained from the Department of Fisheries, Terengganu. Departmental officers also assisted in providing access to interviewees on several occasions.

In Sabah, the research was facilitated by the Marine Research Foundation (MRF), a locally-based non-profit research foundation. Permission was obtained from the Department of Fisheries, Sabah, whose staff also provided on-ground support for the research and introduction to fishers.

4.2.3. Survey design

I designed a structured survey that consisted of multiple choice and open-ended questions. To integrate my research aims with those of the UMT team, the Terengganu survey included questions on several themes: fishing fleet characterisation; fishing effort; marine turtle presence and frequency of bycatch events; and fisher perceptions of IUU fishing. After receiving low response rates for all themes except those relating to IUU fishing, the survey was re-designed prior to commencing field work in Sabah. The Sabah survey was expanded significantly to focus primarily on the topic of IUU fishing (questions on this theme from the Terengganu survey were retained to ensure consistency). Both surveys were designed in English and translated into Bahasa Malaysia by a native speaker. The interviews were designed to be relatively short (<30 min) in order to ensure higher completion rates (White et al., 2005), an essential consideration for time-limited fishermen who are approached during post-harvest work (Close and Hall, 2006).

4.2.4. Interviews with fishers

Data collection took place from September 2015 to January 2016 in Terengganu and from September to October 2016 in Sabah. In both states, the survey was delivered in Bahasa Malaysia by Malaysian university students. Each student was familiarised with the interview questions and the appropriate survey protocol prior to conducting interviews. Responses were recorded on a Malay version of the survey and then transcribed onto an English version upon conclusion of the interview. Transcribed English versions were then checked for consistency and any uncertainties were resolved with the original translator on the same day.

Introductions to fishers were facilitated by key local contacts (e.g. departmental officials, representatives from local fishing associations) at each study site. Researchers began each interview by issuing a statement explaining the purpose of the study and assuring the fishers of the confidentiality of their responses (Fowler Jr and Cosenza, 2009; Moore et al., 2010). Initially, participation was limited to individuals who were known and trusted by the local contact in order to maximise the likelihood of obtaining high-quality, truthful responses. Upon completing interviews with these fishers, the interviewer asked if the fishers knew anyone else who they believed might consent to be interviewed, sensu the snowball sampling technique (Biernacki and Waldorf, 1981; Lunn and Dearden, 2006; Miles and Huberman, 1994; Waters, 2015). In addition to fishers, we interviewed captains and boat owners to access more knowledgeable participants (after Moore et al. (2010)) and to increase the sample size.

4.2.5. Data analysis

Responses were entered in separate electronic databases for each state. Multiple-choice questions were analysed using descriptive statistics and tested for significance where appropriate using a Chi-squared goodness of fit test. Open-ended responses were coded

thematically before undergoing a similar analysis. Questions that were asked in both states were analysed comparatively. For the Sabah dataset, study sites were assigned to one of three sub-regions due to the size and varying orientation of the coastline of Malaysian Borneo (Figure 4.1): Western Sabah comprised Kota Kinabalu (KK) and Sepangar jetty (SP); Northern Sabah comprised Kudat (KU) and Kampung Tanjung Kapur (KTK); and Eastern Sabah comprised Semporna (SM) and Mabul Island (MI). Terengganu study sites were similarly oriented on the same water body (i.e. South China Sea) and had similar administrative characteristics (i.e. fleet types, licensing protocols) and thus were not grouped into sub-regions.

The reliability of individual responses was assessed prior to including their answers in the analysis. Respondents were deemed unreliable if answers to multiple same-question rephrases were not consistent, if the respondent refused to answer more than one question in a section, or if the interviewer noted during the interview any reluctance, suspicion, aggression or physical behaviour consistent with concealing information (see ten Brinke et al. 2016).

4.3. Results

4.3.1. Participation metrics

A total of 170 surveys were completed across all study sites: 75 in Terengganu and 95 in Sabah. When screened for reliability, 14 surveys were deemed unreliable using the criteria listed previously and were excluded from further analysis for all questions. Thus the total number of reliable surveys analysed was 156: 73 from Terengganu (97% of Terengganu total) and 83 from Sabah (87% of Sabah total). The majority of respondents in Terengganu were captains and boat owners (33% and 32% of respondents, respectively); the majority in Sabah were fishers and captains (41% and 40%, respectively). The term ‘boat owner’ in this study refers to an owner that did not go out to sea with the vessel; when an owner did go out

to sea, he was classed as a 'captain and boat owner' (Table 4.1). A summary of the professions of reliable participants at each field site is presented in Table 4.1.

Table 4.1. Summary of participants surveyed in Terengganu and Sabah states. The field site of Marang (Terengganu) was omitted from the table due to low sample size (n=2), and one participant in Terengganu did not state his occupation. Field sites in Sabah were grouped by geographic sub-region. *Other: works at the port (n=2), aquaculturist and retired fisher (n=1).

Field site	No. of participants				Total
Terengganu	Fisher	Captain	Boat owner	Captain and boat owner	
Batu Rakit	4	0	0	1	5
Chendering	6	9	4	1	20
Dungun	0	5	2	4	11
Kemaman	1	5	10	0	16
Pulau Kambing	1	5	7	7	20
Subtotal	12	24	23	16	72
Sabah	Fisher	Captain	Boat owner	Other*	
Western Sabah	2	17	5	1	24
Northern Sabah	18	12	3	2	33
Eastern Sabah	14	4	5	0	23
Subtotal	34	33	13	3	83
Total	46	57	36	19	155

4.3.2. Intentional take of marine turtles by foreign vessels

The majority of respondents in both states agreed that marine turtles are targeted illegally by foreign boats in Malaysian waters (Table 4.2). Affirmative responses were recorded at higher rates in Sabah (73% of respondents) than in Terengganu (61%). Within Sabah, affirmative responses were highest in the Western Sabah and Northern Sabah sub-regions (88% and 83%, respectively). In contrast, responses in Eastern Sabah were much lower, with only 35% of respondents agreeing that marine turtles are targeted by foreign boats. For comparison, answering whether or not Malaysian boats targeted marine turtles (Sabah only), responses of 'No' predominated (92%, 67% and 78% in Western, Northern and Eastern Sabah, respectively).

Additionally, in Sabah, when asked if respondents believed that marine turtles were caught to supply overseas markets, affirmative responses were highest in Northern Sabah (71% of respondents), followed by Western Sabah (58%) and Eastern Sabah (27%) (Table 4.2). Across all the Sabah sub-regions, respondents attributed these activities to foreign boats (82% of respondents) rather than Malaysian ones (3%). The remaining proportion of respondents in Sabah believed that 'both foreign and Malaysian' boats were responsible (7%) or did not know (8%).

4.3.3. Variety of uses for illegally-caught turtles

Respondents in Terengganu indicated they believed that illegally-caught marine turtles were 'used for food' (64% of responses), 'exported overseas' (15%), 'sold locally' (10%) and 'released alive' (9%). In each Sabahan sub-region and in Sabah overall, the most commonly reported fate was 'exported' (56% in Sabah overall), with the highest proportion of such responses coming from the Northern Sabah sub-region (77% of respondents). The second highest reported use for illegally caught turtles in all sub-regions and in Sabah overall, was consumption for food (Table 4.2). In Terengganu, the majority of fishers noted high levels of incidental turtle mortality in bottom set ray nets (pukat pari), the use of which is illegal in Terengganu.

4.3.4. Transshipment of illegally-caught turtles and pre-export storage

Answers concerning transshipment at sea of illegally-caught turtles were polarised within states and sub-regions (Table 4.2). The majority of respondents gave an estimate of how often transshipment happened in Terengganu (60% of respondents providing estimates) and in the Northern Sabah sub-region (61%). Contrastingly, the majority of respondents did not give an estimate of transshipment in Sabah overall (58%), in Western Sabah (52%) or Eastern Sabah (91%). For the respondents that did give an indication of the frequency of at-sea

transshipment of illegally-caught marine turtles, responses were grouped on either end of the frequency scale: transshipment was deemed to happen most frequently in Western Sabah ('Frequently' to 'Very frequently': 75%); in Northern Sabah, responses were split between 'Frequently' to 'Very frequently' (40%) and 'Never' to 'Rarely' (50%); Eastern Sabah was divided evenly between 'Frequently' to 'Very Frequently' (50%) and 'Rarely' (50%); and in Terengganu, transshipment of marine turtles was characterized as happening either 'Never' to 'Rarely' (75%) or 'Frequently' to 'Very frequently' (16%).

Identification of known and putative end destinations—markets and trade hubs—for illegally-caught marine turtles varied geographically among study sites (Table 4.2). In Terengganu, 49% of respondents gave information on where marine turtles were taken post-capture; of these respondents, most named Vietnam (44%) as the likely end destination for marine turtles, followed by Thailand (30%). In comparison, 40% of respondents in Sabah provided information on end destinations, although half of these responses identified a transit pathway rather than an end destination: turtles were reported to be caught illegally, amassed in aggregations and transshipped to foreign boats at the Malaysian border. Reported end destinations included the Philippines (identified mainly in Northern Sabah; 50% of respondents) as well as China, Hong Kong and Vietnam (Western Sabah; 20%).

In Sabah, when asked about marine turtles being captured and stored prior to export, affirmative response rates were greatest in Northern Sabah (58% of respondents), followed closely by Western Sabah (56%). Surveys in Eastern Sabah produced a lower affirmative response rate (23%). Respondents identified several island locations where turtles were reported to be stored and amassed prior to export (Figure 4.2), several of which lie in Philippine territorial waters outside of the Malaysian Exclusive Economic Zone (EEZ). The Terengganu survey did not include questions asking about storage of illegally-caught turtles

because I was informed of the occurrence of this practice during data collection in Sabah, after the Terengganu data collection had finished.

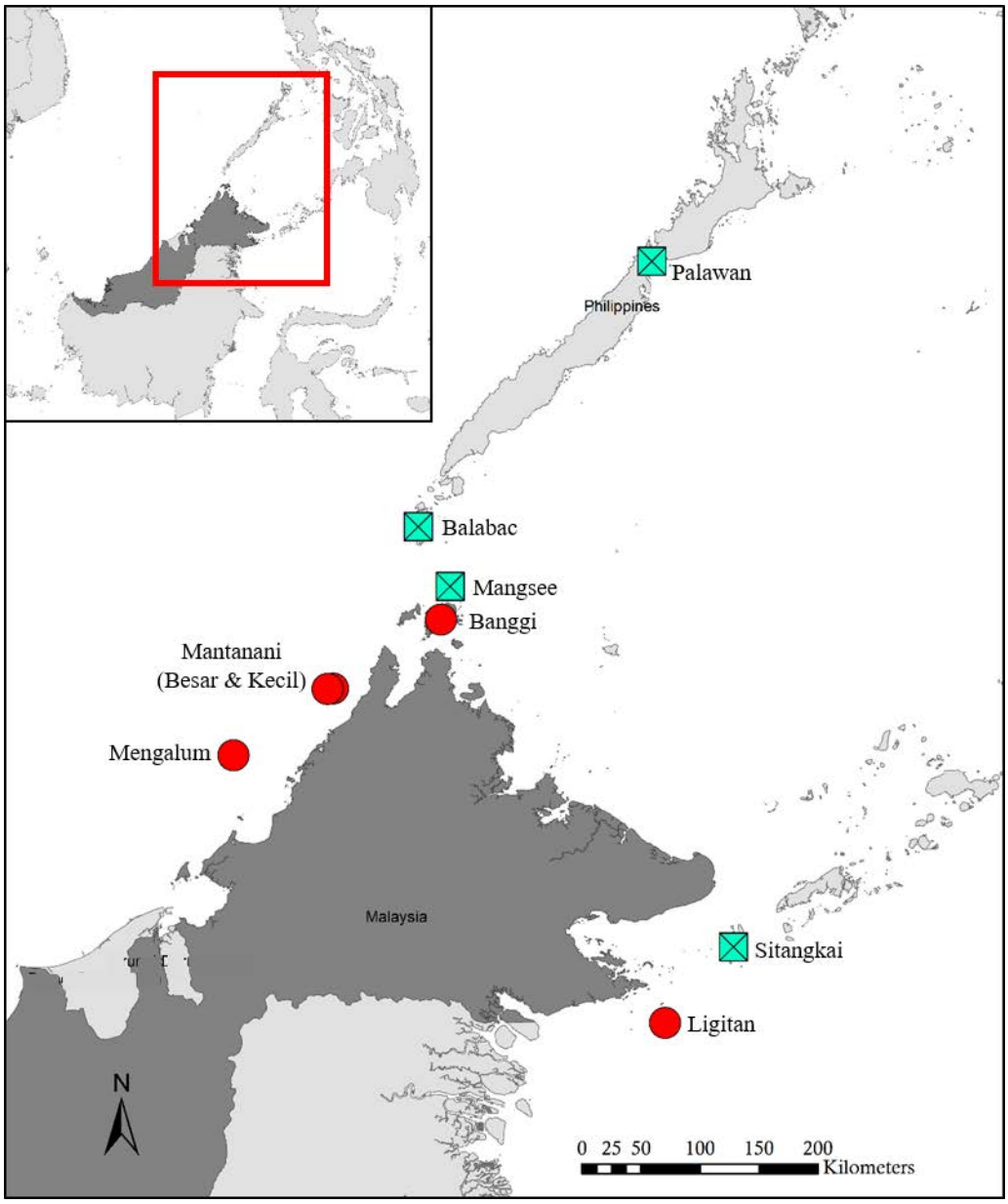

Figure 4.2. Map of island locations where turtles were reported to be stored and amassed prior to export. Locations coloured blue (Mengalum, Mantanani, Banggi, Ligitan) lie within the Malaysian Exclusive Economic Zone (EEZ), whereas green locations (Balabac, Mangsee, Palawan and Sitangkai) are within Philippine sovereign waters.

Table 4.2. Summary of key findings for each Malaysian state and sub-region. N/A denotes data not collected. *Summed percentages may exceed 100% due to respondents selecting more than one response.

Field site	Illegal take of turtles by foreign vessels	Supply to overseas markets	Fate of illegally-caught marine turtles	Transshipment at sea (% of respondents who provided estimates)	End destinations for illegally-caught turtles	Top 3 motivations for foreign IUU*	Top 3 motivations for Malaysian IUU*
Terengganu (all sites)	Yes (61%)	N/A	Used for food (64%) Exported (15%) Sold locally (10%) Released alive (9%)	'Never' to 'Rarely' (75%); 'Frequently' to 'Very Frequently' (15%)	Vietnam, Thailand, other Malaysian states	Depleted fishing grounds in home country (71%) Lack of enforcement (39%) Valuable species (31%)	Lack of enforcement (43%) Unaware of laws (25%) Valuable species (21%)
Sabah (all sites)	Yes (73%)	Yes (55%) Don't know (31%) No (14%)	Exported (56%) Used for food (19%)	'Frequently' to 'Very Frequently' (53%); 'Never' to 'Rarely' (41%)	Philippines, China, Vietnam	Ease and high returns of illegal methods (30%) Depleted fishing grounds in home country (22%) Valuable species (14%)	Ease and high returns of illegal methods (42%) Don't know (22%) Depleted fishing grounds (13%)
Western Sabah	Yes (88%)	Yes (58%) Don't know (33%) No (8%)	Exported (50%) Used for food (25%)	'Frequently' to 'Very Frequently' (75%)	Vietnam	Depleted fishing grounds in home country (47%) Valuable species (21%) Lack of enforcement (11%)	Lack of enforcement (27%) Depleted fishing grounds (27%) Valuable species (18%)
Northern Sabah	Yes (83%)	Yes (71%) Don't know (21%) No (9%)	Exported (77%) Used for food (13%)	'Frequently' to 'Very Frequently' (40%); 'Never' to 'Rarely' (50%)	Philippines, China	Ease and high returns of illegal methods (52%) Valuable species (15%) Lack of enforcement (11%)	Ease and high returns of illegal methods (62%) Unknown (14%) Valuable species (10%)
Eastern Sabah	No (65%)	Don't know (45%) Yes (27%) No (27%)	Exported (33%) Other (24%)	'Frequently' to 'Very Frequently' (50%); 'Rarely' (50%)	Philippines	Ease and high returns of illegal methods (28%) Depleted fishing grounds (22%) Unaware of laws (22%)	Don't know (40%) Ease and high returns of illegal methods (33%) Unaware of laws (13%)

4.3.5. Motivations for illegal fishing

Respondents were asked about the potential motivations for both foreign and local (Malaysian) fishers engaged in IUU fishing of all kinds (i.e. not just incidents involving marine turtles). Foreign fishers were believed to be motivated by 'depleted fishing grounds forcing fishers into other sovereign waters' in Terengganu (71% of responses) and in the Western Sabah sub-region (47%). In Northern Sabah, the 'ease and high returns of illegal methods' (e.g. cyanide, blast fishing) was believed to be the major motivation for foreign IUU fishing (52%). Responses in Eastern Sabah were split between 'ease of banned methods' (28%), 'depleted fishing grounds' (22%) and 'lack of awareness about fishing laws' (22%). 'Access to valuable species' was also reported to be a putative driver of foreign IUU fishing activity in Terengganu (31%), Western Sabah (21%) and Northern Sabah (15%) (Table 4.2).

In reference to IUU fishing by Malaysians, respondents in Terengganu named 'lack of enforcement' as the primary motivation (43% of respondents). Robust results were not achieved for Sabah due to low response rates for this question across all sub-regions; however, there were indications that the ease and high catch yield of banned methods (i.e. cyanide, blast fishing) is believed to be a significant factor for Malaysian fishers.

4.4. Discussion

4.4.1. Variable drivers require a state-by-state approach

The results of this chapter strongly indicate that although marine turtles are believed to be caught deliberately by foreign fishermen in both Malaysian states, the perceived degree and root causes of illegal exploitation are more variable on a state-by-state basis. Considering Malaysia's geography and proximity to other countries, the occurrence of foreign incursions is perhaps not surprising; indeed, instances of fisheries conflict and trans-boundary resource exploitation are well documented for the South China Sea (Holmes and Phillips, 2016; Johns,

2013; Stobutzki et al., 2006a). This context aligns with the results of this study characterizing the putative motivations of foreign IUU fishers (Table 4.2): in Terengganu (and Western Sabah to a much lesser extent), the most-reported motivation was 'depletion of fishing grounds in home country', which relates to the well-known collapse of several commercial fish stocks in the Gulf of Thailand (Christensen, 1998; Pomeroy et al., 2007; Stobutzki et al., 2006b). Given Terengganu's proximity to Thailand, it is plausible that some degree of foreign IUU fishing at these sites results from the secondary effects of the overfishing crisis in neighbouring waters. This illegal expansion-and-displacement fishing has been reported previously in other parts of Australasia (see Field et al. 2009), and this study adds further insight to its occurrence at more localised scales. Similarly, 'lack of enforcement'—selected second-most as a possible motivation for foreign IUU fishing in Terengganu—directly reflects the region's longstanding challenges with maintaining effective fisheries monitoring, control and surveillance (MCS) (Funge-Smith et al., 2015; Johns, 2013; Morgan et al., 2007). As MCS capacity has been shown to have a strong influence on the level of IUU fishing occurring in a nation's waters (Petrossian, 2015), these results suggest that foreign IUU fishing in Terengganu is primarily due to illegal expansion-and-displacement fishing and insufficient enforcement, and driven to a lesser extent by market-based incentives for the wildlife trade.

In contrast, Sabah state appears to sustain a higher degree of illegal activity related to the targeted exploitation of marine turtles and other sought-after species. In the Northern and Eastern Sabah sub-regions, reported motivations for foreign IUU fishing reflected a greater emphasis on obtaining valuable target species, as well as the pervasive use of destructive fishing methods such as explosives and cyanide (Table 4.2). The use of explosives (i.e. blast fishing) is prevalent in many parts of Sabah (RCM, 2016) and causes extensive physical damage to coral reefs (Fox et al., 2005), with associated negative impacts on biodiversity

(Pauly et al., 1989) and ecosystem resilience (Chan and Hodgson, 2017; McManus et al., 1997). Long-term economic losses from the resultant stock declines have also been documented elsewhere in Southeast Asia (Pet-Soede et al., 1999). Sodium cyanide fishing is widely used to supply the multi-million dollar live reef fish trade (Johnston and Yeeting, 2006; Sadovy et al., 2003; UP-MSI et al., 2002) and is an unsustainable practice that damages coral reef ecosystems (Barber and Pratt, 1998; Pet and Pet-Soede, 1999).

While neither of the above fishing methods is used to target marine turtles specifically, their presence in this dataset nevertheless illustrates a widespread issue with unlawful extraction of fisheries resources in the Northern and Eastern Sabah sub-regions. Combined with reported motivations of 'access to valuable species' in both Western and Northern Sabah, as well as responses of turtles being caught to supply overseas markets in these sub-regions (Table 4.2), there is an evident need for a state-wide review of existing MCS measures, as well as examinations of the root causes of fishers' use of illegal fishing methods (see Tungpalan 1989) and further investigation of market drivers perpetuating the illegal trade of marine turtles and other commercially-valuable species (TRAFFIC, 2008).

One of the more profound disparities between states was the reported scale of marine turtle export. While participants in Terengganu indicated that turtles were targeted by foreign IUU fishers, only 15% of respondents said that turtles were exported overseas; instead, the highest reported use for turtles caught illegally was consumption for food (Table 4.2). Similarly, frequency estimations of at-sea transshipment of illegally-caught marine turtles—an indicator of export—were the lowest overall in Terengganu (Table 4.2), suggesting a more locally-based, opportunistic consumptive use of turtles caught incidentally. In contrast, 'exported overseas' was the most-reported fate for illegally-caught marine turtles in all Sabah sub-regions, with 'used for food' reported at much lower frequencies (Table 4.2). In Sabah, the reported frequency of overseas export was highest in Northern Sabah (77% of respondents).

Combined with lower reported frequencies of transshipment in this sub-region, it appears that the export of marine turtles from Northern Sabah does not rely heavily on transshipment as a transit pathway, possibly due to the close geographic proximity of the Philippines and/or the direct trade routes northward to China and Vietnam.

While results indicated slightly lower reported rates of marine turtle export in Western Sabah (50% of respondents), this sub-region recorded the highest reports of transshipment of illegally-caught marine turtles (Table 4.2). Results concerning transshipment in Western Sabah are likely due to the growing practice of local fishers gathering turtles for sale to foreign boats (see below). In Eastern Sabah, where respondents reported the lowest frequency of export and mixed results of transshipment, it is possible that increases in maritime patrols and counter-terrorism security measures have had a dampening effect on boat-based illegal smuggling operations. However, such heightened security notwithstanding, it is notable that this survey still received affirmative responses of marine turtle capture, transshipment and export in Eastern Sabah. At the Semporna study site in early 2017, five Philippine fishers were arrested for possessing turtle meat and carapaces bound for China (Toyos, 2017). It is probable that the negative responses recorded in this study reveal a degree of disingenuousness from fishers in the Eastern Sabah sub-region, as well as an unwillingness to inform on illegal activity in a locality with such heavy enforcement presence. The degree of variability between states and sub-regions therefore reflects a highly-nuanced dynamic of economic, political and geographic factors, and as such requires an adaptable approach to mitigation.

4.4.2. Connecting IUU fishing and the illegal wildlife trade

These results point to the involvement of IUU fishing vessels in the organised, deliberate capture and export of marine turtles from Malaysian waters. Findings of marine turtle pre-

export storage at multiple island locations around Sabah (Figure 4.2) provide further evidence implicating fishing vessels in the broader illegal wildlife trade, of which Southeast Asia is unquestionably the world's nexus (Nijman, 2010; Rosen and Smith, 2010; Sodhi et al., 2004). Significantly, survey participants identified Balabac Island (in Philippine waters) as a location where illegally-caught turtles are stored prior to export. Earlier in 2017, a shipment of dead hawksbill turtles apprehended in Palawan province was reportedly bound for Balabac Island, a location characterised by Philippine police as "infamous as a trading place for wildlife poachers" (AFP, 2017). Additionally, respondents in Northern Sabah indicated that turtles are being caught and stored by locals at the behest of Philippine and Chinese buyers—a tactic that has been reported previously (Anda, 2014; IOSEA, 2012). While respondents largely attributed illegal activity to foreign rather than Malaysian fishers, incidents such as those listed above indicate that Malaysians also contribute to the illegal exploitation of marine turtles through foreign actors.

Reported end destinations for illegally-caught turtles varied by state but nevertheless describe an export-driven commercial trade rather than widespread subsistence use. Respondents in Terengganu identified Vietnam and Thailand as purported end destinations (Table 4.2), which are plausible given the relative geographic proximity. Furthermore, previous research has characterized Vietnam as a transit country for illegally-traded wildlife (Ngoc and Wyatt, 2013), and high-profile seizures of marine turtles have occurred there in recent years (Nuwer, 2016). In Sabah, putative end destinations included Vietnam as well as the Philippines, China and Hong Kong—a substantial market demand for turtle products exists in the latter two countries (IOSEA, 2014; Lam et al., 2011). These results demonstrate the existence of criminal links between fishing vessels and wildlife trafficking operations in Malaysia, and I stress that IUU fishers are likely to be aware of and involved in a combination of these illegal activities (e.g. capture, transshipment, export). In order to inform effective governance

regimes, it is therefore prudent to consider IUU fishing and wildlife trafficking as closely related facets of a broader problem.

The United Nations Office on Drugs and Crime (UNODC) reports that wildlife crime has grown to become one of the world's largest forms of transnational organised criminal activity (UNODC, 2011, 2014). Despite this, the United Nations Convention against Transnational Organised Crime (UNTOC) does not include suitable triggers that can lead to legal action against IUU fishing, in part because domestic penalties for IUU fishing are generally not severe enough to consider it a 'serious crime' under the UNTOC (Phelps Bondaroff et al., 2015; UNODC, 2016). In concert with legislative reform in Malaysia, the presence of protected, IUCN-listed species—including marine turtles—in fishing seizures could provide the impetus for action against IUU fishing within the purview of the UNTOC, and thus mobilise existing regulatory and enforcement mechanisms.

4.4.3. Strategic next steps: Context-specific mitigation measures, collaboration and regulatory pluralism

Reducing IUU fishing in each Malaysian state will require context-specific strategies in order to address the different ways that people react to the root causes of IUU fishing. To minimise the opportunistic illegal use of marine turtles by local fleets in Terengganu, fisheries-based mitigation strategies should aim to prevent incidental capture from occurring in the first place. Legislative efforts and industry trials to advance the adoption of turtle excluder devices (TEDs) are already underway in Terengganu's commercial trawl fleet (Pilcher, 2017), and the Department of Fisheries has recently begun to take action against the use of pukat pari (N. Pilcher, pers. comm.). To address the issue of foreign incursions, increases in regional MCS need to originate from an integrated, multi-stakeholder response from the Malaysian border security, military, customs and trade regulation agencies (after Bergenas and Knight 2016).

Such endeavours must be met by complementary efforts from Thai and Vietnamese authorities to address the root causes of illegal expansion-displacement fishing (i.e. by reducing fishing capacity (Kirkley et al. 2003; Morgan et al. 2007) and providing alternative livelihoods for fishers). There is also a strong need to engage local fishers in management regimes to strengthen the sense of stewardship among resource users and thereby incentivise more sustainable use of fisheries resources (Hilborn, 2004; Pomeroy et al., 2001). Such engagement may include participation in TED trials, uptake of satellite automatic identification systems (S-AIS; see de Souza et al. 2016) and other decentralised co-management strategies aimed at improving fisheries monitoring and knowledge gathering.

In Sabah, confronting the interrelated problems of IUU fishing, destructive fishing practices and international wildlife trafficking will require a complementary array of prevention and enforcement approaches. I stress the importance of creating and implementing collaborative, multi-agency frameworks through which to address different facets of the problem. For IUU fishing incidents involving marine turtles, training in genetic sampling should be incorporated into response protocols to assess the population-specific impacts of IUU fishing and wildlife trafficking. Additionally, there is a need for a centralised Malaysian database of IUU fishing incidents to facilitate knowledge sharing and coordinated cross-agency action (see Chapter 2; Schmidt 2005). Neighbouring countries should also consider creating these reporting frameworks in order to build a more detailed understanding of regional IUU fishing activity.

In order to be ultimately successful, efforts to stop wildlife crime must first gain the full participation of all nations involved in the supply, trafficking and demand of wildlife products. For instance, in 2014, a multi-stakeholder Global Programme for Combating Wildlife and Forest Crime was implemented (UNODC, 2014), but did not appear to gain the involvement of Malaysia, the Philippines, China or Japan. Similarly in early 2017, China, Japan, Malaysia, the Philippines and Vietnam did not participate in the Interpol-led Operation

Thunderbird, a global anti-wildlife trafficking task force (INTERPOL, 2017). As this study and others have identified these countries as major actors in the supply, trafficking and demand of illegal wildlife, it is critical that efforts to combat transnational wildlife crime are comprehensive in scope, inclusive in participation and collaborative in implementation.

The interconnectedness between IUU fishing and marine turtles presents opportunities for harmonising and consolidating legislative and enforcement efforts at the state, national and regional level. It has been acknowledged that numerous laws and agreements to tackle IUU fishing already exist at multiple socio-political scales (Lindley and Techera, 2017); however, the persistence of the problem suggests that such initiatives are not working in a complementary or cohesive manner, and that relevant legislation must be harmonized across Malaysian states to avoid creating an uneven regulatory environment (Chan, 2006; Flothmann et al., 2010; OECD, 2005). The need for harmonisation extends similarly to regional ratification and enforcement of the FAO Port State Measures Agreement to Prevent, Deter and Eliminate IUU Fishing (PSMA); in the absence of consistent PSMA implementation, IUU vessels can simply shift to areas where enforcement is lax (Flothmann et al., 2010; Schmidt, 2005). Where relevant organisations and agreements to tackle wildlife crime already exist (e.g. ASEAN-WEN, TRAFFIC), these should also be mobilised to act pluralistically in order to achieve shared goals (Lindley and Techera, 2017).

4.5. Conclusions

This study provides evidence that IUU fishing activities contribute to the targeted exploitation and trafficking of marine turtles in Malaysian waters. The value of this approach lies in capturing local knowledge about a problem that is otherwise hidden and difficult to assess empirically, and succeeds in advancing the idea of IUU fishing as a serious threat to marine turtles and potentially other valuable, commercially-traded taxa.

Fisher interviews reveal that marine turtles are caught intentionally—and principally by foreign boats allegedly targeting marine turtles—in both Terengganu and Sabah to supply overseas markets. Storage, transshipment and export of illegally-captured marine turtles indicate that IUU fishing vessels play a direct and potentially significant role in the capture and trafficking of wildlife from Malaysia. The variety of reported uses and end destinations for marine turtles illustrates that efforts to mitigate the IUU-marine turtle issue must be internationally cooperative, adaptable and tailored to the local context. A collaborative, pluralistic regulatory response is needed to reduce IUU fishing and wildlife trafficking, as these are interconnected facets of a broader problem. I sincerely hope these results can help drive the creation of informed, adaptable strategies to combat IUU fishing and wildlife trafficking in Malaysia and elsewhere.

Chapter 5

Towards effective governance solutions for IUU fishing in the Indian Ocean and Southeast Asia

The findings in Chapters 4 and 5 advanced our understanding of a data-deficient problem. This chapter examines the barriers to translating those findings into effective governance solutions. Based on structured surveys with management officials, I identify issues concerning inter-agency collaboration, scale mismatch and capacity, and relate these directly to existing knowledge gaps for IUU fishing and marine turtle exploitation. I then explore the potential application of decentralised management strategies to these complex, interrelated problems. This chapter challenges the perception that enforcement technology is a panacea, and rather asserts that data-gathering is a crucial precursor to targeted, effective management intervention.

Publication associated with this chapter:

Riskas KA, Tobin RC, Fuentes MPB, Hamann M (in prep). Towards governance solutions for illegal, unreported and unregulated (IUU) fishing and sea turtle exploitation in the Indian Ocean and Southeast Asia. Target journal: *Journal of Environmental Management*

5.1. Introduction

Many studies have recognised the economic, social and environmental consequences of the illegal exploitation of wildlife resources (Brashares et al. 2014; Nellemann et al. 2014; Solomon et al. 2015). Marine capture fisheries are particularly difficult to govern due to their large spatial extent, low barriers to access (Stobutzki et al. 2006), data deficiency of essential metrics (Chapter 1; Anticamara et al. 2011), transboundary nature of migratory fish species (Kaplan et al. 2014) and non-uniformity of the regulatory landscape (Flothmann et al. 2010). The growing issue of illegal, unreported and unregulated (IUU) fishing has generated concern within the scientific and diplomatic communities, leading to the creation of numerous national, multi-lateral and international anti-IUU initiatives (Liddick 2014). These measures aim to mitigate a number of situational factors contributing to the persistence of IUU fishing, such as the existence of ports of convenience (Swan 2006), weak enforcement capacity of developing nations (Department of Agriculture 2011) and use of flags of convenience (FOCs) (Gianni and Simpson 2005).

Several of these factors enable IUU fishing to occur in the Indian Ocean (Anganuzzi and Secretariat 2004; Pramod 2010) and Southeast Asia (Baird 2010; Palma and Tsamenyi 2008). Considered jointly, the Indian Ocean and Southeast Asia region (hereafter IOSEA) contains a number of ports of convenience (Petrossian et al. 2015a) and has seen low but increasing uptake of the Port State Measures Agreement to Prevent, Deter and Eliminate IUU Fishing (PSMA; FAO 2016). Many authors have noted the region's issues with fishery management capacity (Department of Agriculture 2011; Johns 2013) and the resultant proliferation of IUU fishing activities (Morgan et al. 2007). Despite challenging economic and social conditions, several nations have entered into bi- and multi-lateral agreements and memoranda of understanding (MoUs) to combat IUU fishing, or protect marine turtles within the IOSEA

(Hughes 2011; Palma and Tsamenyi 2008). Details of these agreements are presented in Table 5.1 below.

Table 5.1. Summary of relevant legislative agreements concerning the mitigation of IUU fishing and protection of marine turtle species in the IOSEA region.

Name of agreement (year enacted)	*Administering body*	*Legally binding (Y/N)*
IUU fishing		
International Convention for the Prevention of Pollution from Ships (MARPOL) (1973)	International Maritime Organization (IMO)	Y
Convention on the Law of the Sea (UNCLOS) (1982)	United Nations (UN)	N
Code of Conduct for Responsible Fisheries (1995)	Food and Agriculture Organisation of the United Nations (FAO)	N
International Plan of Action on IUU Fishing (IPOA-IUU) (2001)	FAO	N
Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries (2001)	FAO	N
Regional Plan of Action to Promote Responsible Fishing Practices including Combating IUU Fishing in the Region (RPOA-IUU) (2007)	11 national fisheries ministries: Australia, Brunei Darussalam, Cambodia, Indonesia, Malaysia, Papua New Guinea, Philippines, Singapore, Thailand, Timor-Leste and Vietnam	N
Agreement on Port State Measures to Prevent, Deter and Eliminate IUU Fishing (PSMA) (2009)	FAO	Y
Marine turtles		
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (1975)	International Union for Conservation of Nature (IUCN)	N
Convention on Migratory Species/Bonn Convention (CMS) (1983)	UN Environment Programme (UNEP)	N
Memorandum of Understanding on ASEAN Sea Turtle Conservation and Protection (1997)	Association of Southeast Asian Nations (ASEAN)	N
Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (IOSEA-MoU) (2001)	CMS	N

However, Lindley and Techera (2017) observe that global IUU fishing continues in spite of the many political instruments aimed at eradicating it. The limitations of these instruments are worth exploring (e.g. non-legally binding; de Bruyn et al. 2013), as they will be further exacerbated under future scenarios of climate change and environmental degradation (van der Marel et al. 2017). Additionally, the possibility of 'treaty congestion' (Anton 2012), noted to occur in other areas of environmental law, also merits consideration as a confounding factor. Further, a 2008 report by the Asia-Pacific Economic Cooperation Forum (APEC) noted a number of 'institutional weaknesses' relating to maintaining the legislation, enforcement and personnel resources necessary to combat IUU fishing within national jurisdictions for several Asia-Pacific countries (APEC Secretariat 2008). As such, those nations are also likely to struggle to exercise control over their flagged vessels operating in waters outside their national jurisdiction (i.e. on the high seas or within neighbouring EEZs).

Marine turtles are a group of species threatened by IUU fishing in the IOSEA region, and there are differences across the region in the types of turtles caught and their respective fates (Chapter 3). It is clear from the results of Chapter 3 that to develop and maintain effective governance solutions to IUU fishing, it is essential to examine the factors that may hinder management efforts on a national basis. The aim of this chapter is to examine the barriers to implementing management strategies to reduce IUU fishing and the related issue of marine turtle exploitation. I chose to conduct this study for the IOSEA region in order to identify priority areas of policy improvement relevant to the conservation of marine turtles.

5.2. Materials and Methods

5.2.1. Study area

As in Chapter 3, the IOSEA study area comprises 44 countries and territories with maritime coastlines on the Indian Ocean, as well as Southeast Asia, China and the Philippines (Figure

5.1). Six species of marine turtle are found within the broader IOSEA region, and each of them is comprised of more than one distinct genetic stock (FitzSimmons and Limpus 2014; Wallace et al. 2010): the loggerhead (*Caretta caretta*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*), flatback (*Natator depressus*) and olive ridley (*Lepidochelys olivacea*). As the ecological range of a turtle species—and the home range of individuals—therefore spans multiple national, regional and international management jurisdictions within the IOSEA, the scope of this study is similarly broad-scale.

Recognising the need for results at actionable management scales—and the existence of prevailing regional frameworks—I divided the study area into four sub-regions (Figure 5.1): Southwestern Indian Ocean (SWIO) includes territorial waters in countries from South Africa to Kenya, plus the island nations of Comoros, Madagascar, Mauritius, Mayotte, Reunion and the Seychelles; Northwestern Indian Ocean (NWIO), Somalia to Iran, including countries with coastline on the Red Sea and Persian Gulf; Northern Indian Ocean (NIO), Pakistan to Bangladesh, including the Maldives and British Indian Ocean Territory; and Southeast Asia (SEA), Myanmar to Australia, including the Philippines and China. As in Chapter 3, these sub-regional boundaries match those used within the IOSEA-MoU framework.

5.2.2. Survey design

I designed a survey consisting of 23 multiple choice and open-ended questions (Appendix D). Multiple choice questions utilised five-point Likert scales to allow for quantitative ranking of answer choices (Boone and Boone 2012). The survey addressed several research aims relating to the mitigation of IUU fishing, with an emphasis on incidents involving marine turtles. The survey was designed and implemented in English, as reasonable English comprehension was assumed for participants employed at senior management levels.

5.2.3. Scope of participants

Eligible participants were sought from every country with a marine border on the Indian Ocean, including Southeast Asia (see 'Study area', above). Individuals were invited to participate based on professional experience relating to the management and mitigation of IUU fishing. Examples of relevant experience included roles in fisheries management, maritime enforcement, marine conservation, protected area management, government research, academic research and consulting. Participants were also identified by attendance at relevant meetings and conferences, and by referrals from colleagues and other participants.

5.2.4. Modes of survey dissemination and data analysis

The survey was implemented online and in person. The survey was distributed to prospective respondents using the SurveyMonkey online platform between March and July 2017. In-person interviews were conducted during scheduled field work in the state of Sabah, Malaysia from September to October 2016. Introductions to qualified participants (see above) were made through local colleagues and their networks.

Responses to the online survey were downloaded from the SurveyMonkey website and entered in a custom-made Excel database. Data from in-person interviews were transcribed and entered manually into the database. Descriptive statistics and response rates were generated for each question. All open-ended responses were coded to identify emergent themes (Babbie 1992) to allow for thematic analysis and regional comparison (see Chapter 3). Responses to questions using Likert scales were coded numerically and tested for significance using the Chi-squared goodness of fit test where applicable.

5.3. Results

5.3.1. Participation metrics and respondent profiles

I received a total of 40 responses to the survey: 34 from the online version, 6 via the in-person, semi-structured interviews conducted in Malaysia. Four of the online responses were largely incomplete and were excluded from analysis, thus the following results are drawn from 36 completed surveys (Table 5.2).

Table 5.2. Summary of completed surveys received via both methods (online and in person) for all sub-regions.

Sub-region	Number of completed surveys	Number of countries represented
SWIO	4	3
NWIO	4	4
NIO	6	4
SEA	16 online 6 in person	4
Grand total	**36**	**15**

Respondents represented 15 of the 44 countries in the IOSEA (34% representivity) (Figure 5.1). The majority of responses came from the SEA sub-region (n = 22; 61% of responses), followed by the NIO (n = 6; 17%) and the SWIO and NWIO (n = 4 each; 11%). A more detailed breakdown of responses by country is provided in Appendix E.

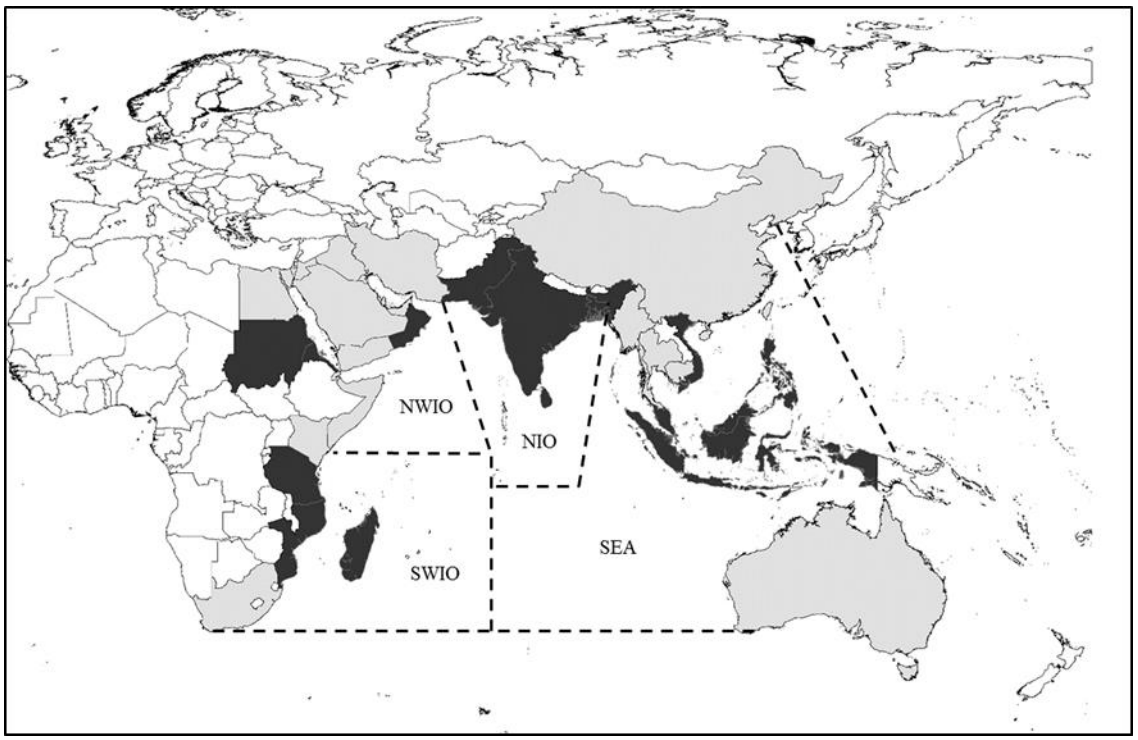

Figure 5.1. Summary of responses received and delineation of sub-regions within IOSEA (management survey). Dark grey: response received; Light grey: no responses received. Sub-regions are defined as: SWIO (Southwestern Indian Ocean); NWIO (Northwestern Indian Ocean); NIO (Northern Indian Ocean); SEA (Southeast Asia).

Respondents reported their professional experience from a number of sectors: academic research (47% of respondents), government research (47%), fisheries management (44%), non-governmental organisations (NGOs) (44%), policy making (28%), consulting (22%) and other sectors (6%). The number of years of experience ranged from 1 to 24 years (median 7 years). Variability in respondent experience was generally low across sub-regions, with the fisheries management sector selected most consistently (Table 5.3).

Table 5.3. Proportion of respondents selecting a certain sector of experience, by sub-region. Summed percentage exceed 100% due to respondents selecting more than one sector of experience.

	Sub-region				
Sector of experience	*SWIO*	*NWIO*	*NIO*	*SEA*	*All IOSEA*
Academic research	75%	50%	83%	32%	47%
Government research	25%	75%	50%	45%	47%
Fisheries management	50%	50%	50%	41%	44%
Policy making	0%	25%	33%	32%	28%
Consulting	75%	50%	33%	5%	22%
NGO	75%	0%	83%	36%	44%
Other	0%	0%	0%	9%	6%

5.3.2. Management responses to IUU fishing and marine turtle exploitation

The majority of respondents (75%) agreed that IUU fishing poses a 'high' to 'very high' degree of threat to marine turtles in the IOSEA. Zero respondents deemed IUU fishing to pose 'no threat' to marine turtles. However, when asked if turtle-related IUU fishing was a government priority in their country, responses were less definitive. 'Very high' to 'high priority' constituted 33% of responses, with 'low priority' following closely at 31%. Several countries overlapped in both categories, namely Indonesia, Malaysia and the Philippines, suggesting differing levels of government engagement, or polaried views of government priorities in those countries. Three respondents selected 'Not a priority', representing Sudan (NWIO sub-region), Tanzania (NWIO) and Vietnam (SEA).

Respondents indicated that collaborating with other in-country agencies and organisations is 'very important' to their agency (86% of respondents). Most respondents (62%) also deemed it 'very important' to collaborate with international organisations to address IUU fishing. When asked to list current domestic and international collaborations, respondents most often only named one agency or organisation with which they were actively collaborating (Figure 5.2a). Domestic collaborations largely involved government agencies or departments such as fisheries, marine parks, wildlife and forestry. Reported total collaborations were greatest for

countries in the SEA and SWIO sub-regions (Figure 5.2a). However, the number of these collaborations that involved international bodies was much lower, with only NIO and SEA respondents reporting more than one international collaboration (Figure 5.2b). Notable international collaborations included the United Nations Food and Agriculture Organisation (FAO), the United States National Oceanic and Atmospheric Administration (NOAA), TRAFFIC (the wildlife trade monitoring network) and the World Wide Fund for Nature (WWF).

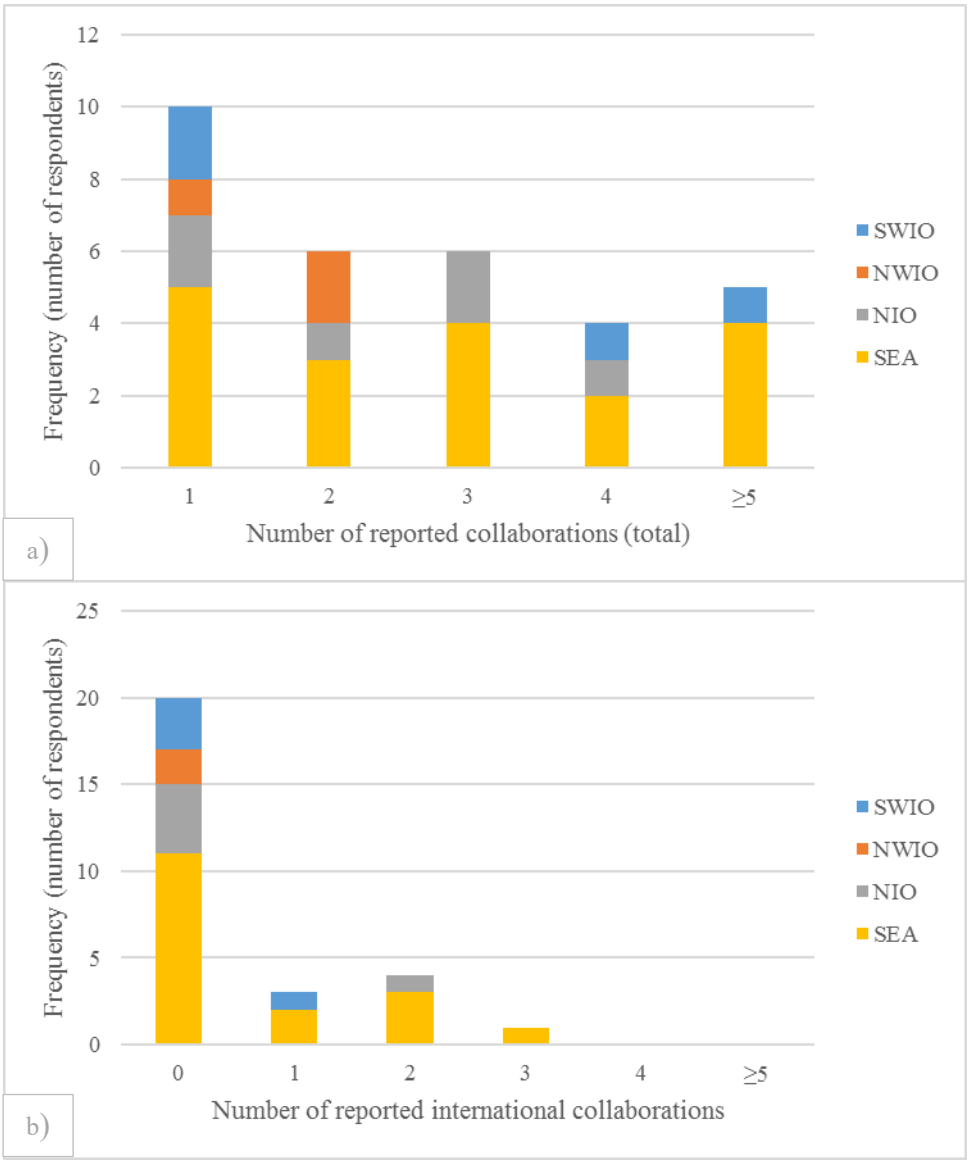

Figure 5.2. Frequency of reported collaborations among sub-regions: (a) total collaborations (domestic and international); (b) international collaborations only. Frequency estimations for zero collaborations in (a) were not tabulated to avoid interpreting non-answers as evidence of zero collaboration. Zero category in (b) refers to number of international collaborations present out of total collaborations identified.

When asked what kinds of information would be most helpful in curbing marine turtle-related IUU fishing, 69% of respondents offered suggestions. A content analysis of open-ended responses generated a list of 13 emerging and latent concepts, which were then grouped into four broader themes signifying types of information needed: trade and trafficking;

enforcement and regulation; turtle-human interactions; and turtle-only knowledge (Figure 5.3). Comparing the frequency of thematic answers among sub-regions, some dichotomies emerge (Figure 5.4). Respondents in all sub-regions indicated the importance of learning more about human-turtle interactions, including consumption and bycatch. However, SEA respondents reported a stronger emphasis on obtaining information related to trade and trafficking of marine turtles; indeed, no other sub-region identified this knowledge theme. There was an additional focus on increasing information on enforcement and regulation in the NIO, and on turtle biology and behaviour in the NWIO (Figure 5.4).

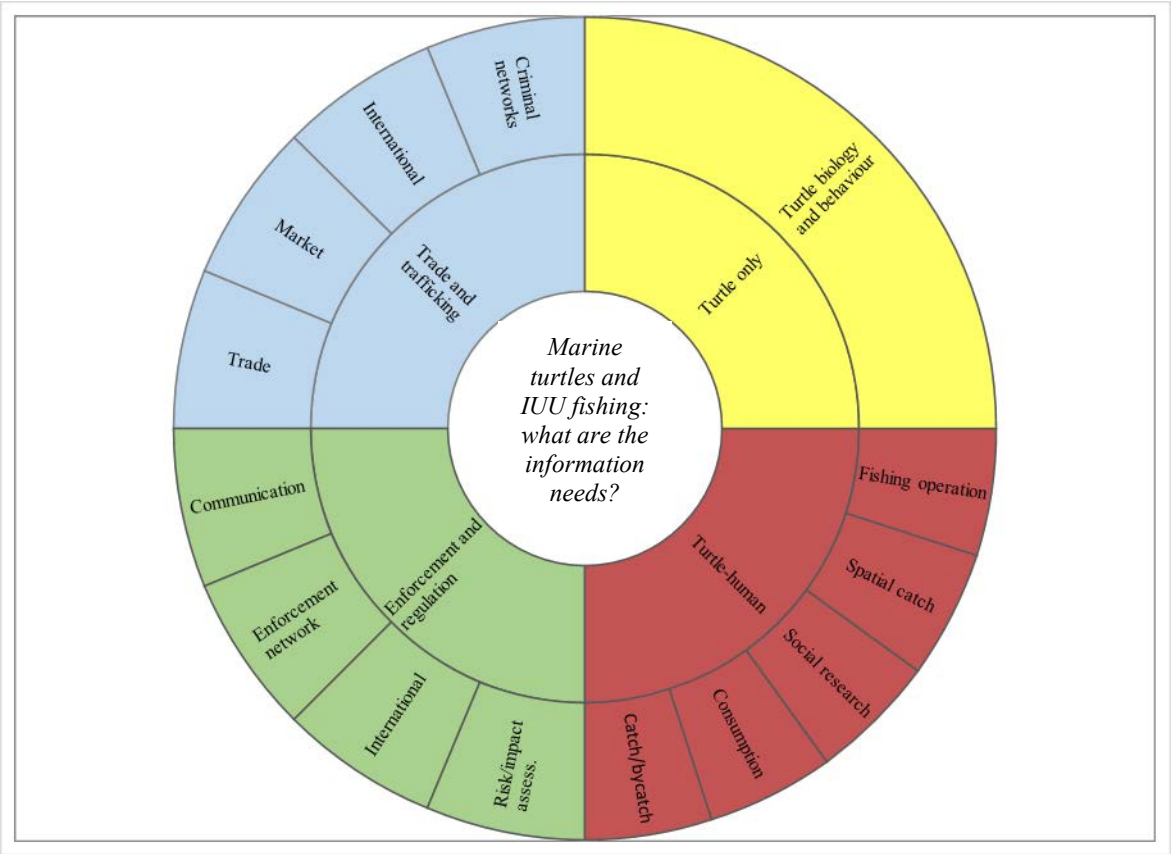

Figure 5.3. Schematic grouping of concepts (outer ring) into themes (inner ring) addressing the central question.

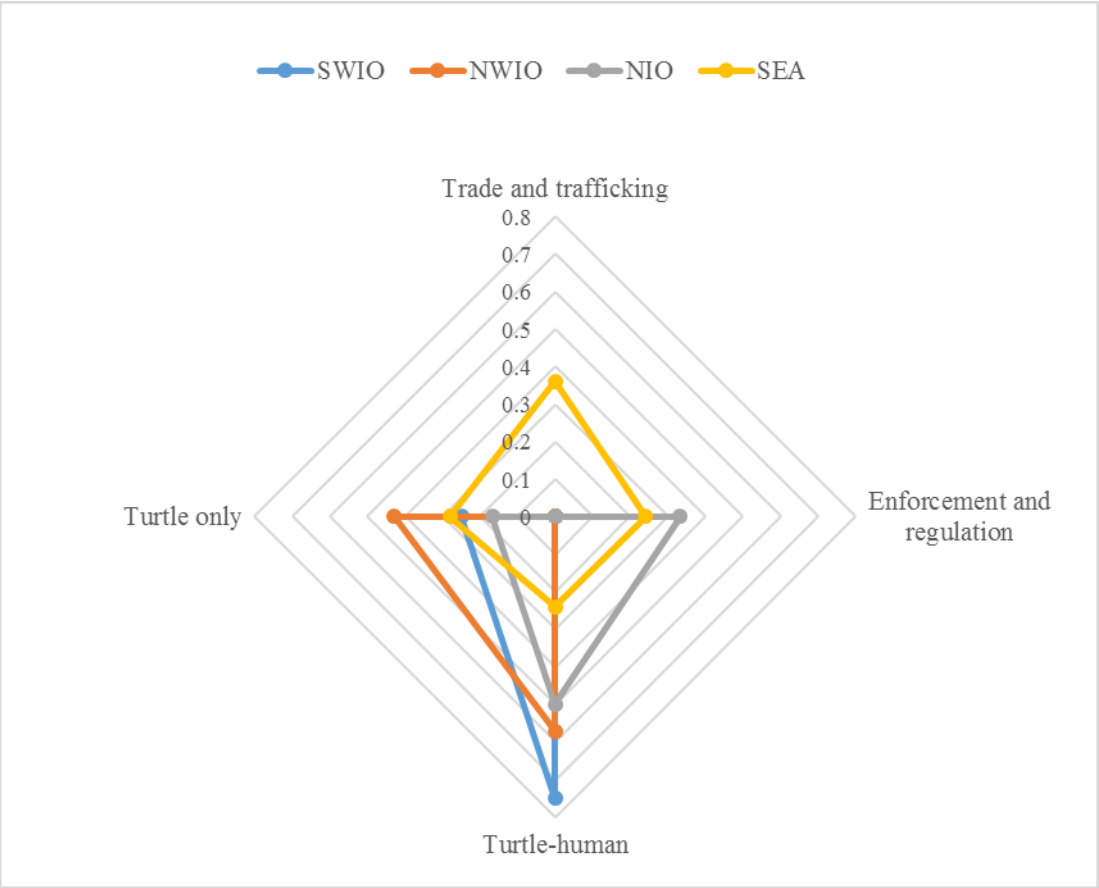

Figure 5.4. Concept map showing sub-regional variation in knowledge themes believed necessary to reduce IUU fishing and marine turtle exploitation. Intervals are proportions of responses received. Knowledge themes were derived from analysis of open-ended responses (see Figure 5.3).

Respondents were asked to identify what they believe is the most important action that needs to be taken to reduce IUU fishing in their country (note: an ideal scenario of unlimited, available funding was posited). Open-ended responses yielded eight categories of actions following latent content analysis. Responses were counted for each category and then grouped by sub-region (Table 5.4). Sub-regions differed in terms of the most common answer categories, with 'Monitoring, control and surveillance (MCS)' mentioned highly in SEA, 'Awareness and education' in NWIO, 'Gear modifications and fishing technology' in NIO,

and mixed responses in SWIO (Table 5.4). Low response rates and low statistical power precluded further analysis for this question.

Table 5.4. Categories of actions believed needed to reduce IUU fishing, by sub-region. Numbers indicate the number of responses suggesting each category.

Category of action	*SWIO*	*NWIO*	*NIO*	*SEA*
Monitoring, control and surveillance (MCS)	1	0	0	11
Research	1	1	1	0
Awareness and education	0	2	0	2
Cooperation	0	0	0	1
Alternative livelihoods for fishers	1	0	0	1
Harsher penalties for IUU fishing	0	0	1	0
Gear modifications and fishing technology	0	0	2	1
Policy/advocacy	0	0	1	1

Respondents were given a list of potential reasons (barriers) why an agency may have difficulty reducing IUU fishing, and then ranked the strength of each reason for their own agency or organisation. In order of decreasing strength, the barriers for all IOSEA countries were identified as follows (Figure 5.5): (1) Lack of money for monitoring, control and surveillance (MCS); (2) Magnitude of the IUU fishing issue; (3) Weak criminal sanctions for IUU fishing; (4) Lack of communication between agencies; (5) Weak or ineffective legal system; (6) Lack of knowledge regarding marine turtles and IUU fishing; (7) Low priority of marine turtle-related IUU fishing; and (8) Lack of clarity on which agency should act to address IUU fishing.

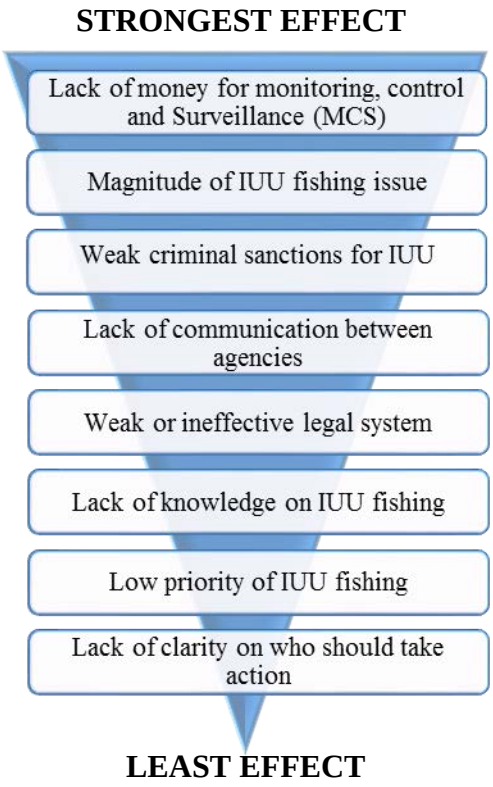

Figure 5.5. Respondent ranking of factors that may prevent an agency from reducing IUU fishing, from strongest effect (top) to least effect (bottom).

5.4. Discussion

This chapter provides a much-needed examination of IUU fishing mitigation from a management perspective. Based on the survey results, there is a need for increased inter-agency collaboration, particularly in building enforcement capacity and in addressing the root causes of IUU fishing. I also identify specific mismatches between management priorities and implementation, as well as an array of knowledge gaps relating to marine turtles and IUU fishing more generally. The small sample size is acknowledged as a limitation of this study; however, a majority of respondents (86%) hold current appointments in government research or fishery management, and should therefore be well-placed to comment on the topics presented in the survey. While most respondents were from the SEA sub-region, their insights are likely to apply to other areas of the IOSEA due to similar management realities

and challenges—fiscal, logistical and cultural—associated with regulating fisheries in developing countries.

In this section I discuss the key results emerging from the survey as they relate to existing paradigms of resource governance. I then apply these ideas to recommend strategies aimed at improving the effectiveness of IUU mitigation measures.

5.4.1. Collaboration and capacity

Results about collaboration reflect a widespread understanding of its importance, but a lesser reported degree of its implementation throughout the study area. Responses of existing collaborations between domestic agencies with related management priorities (e.g. fisheries, wildlife and conservation) are commendable if perhaps routine (Weiss et al. 2013). However, as IUU fishing is a criminal act, efforts to curb it will require a broadening of these domestic collaborations to include agencies with high enforcement capacity (e.g. Weiss et al 2013). I did receive responses indicating collaboration with such agencies (e.g. military, coast guard, border patrol), although these came almost exclusively from the SEA sub-region. It must be noted that the reported existence of these collaborations does not necessarily confirm that productive action is being taken against IUU fishing, or that participating agencies possess adequate capacity to advance their shared agenda in practice. As such, the extent to which these top-down collaborative agreements diffuse to the practical implementation stage depends on resource access and allocation within individual departments, agencies and nations.

Respondents in SEA strongly indicated their belief that increased MCS measures are the most important actions needed to reduce IUU fishing and marine turtle exploitation (low sample sizes precluded assessment of other sub-regions) (Table 5.2). Issues of enforcement capacity are well documented throughout the IOSEA (Department of Agriculture 2011; Stobutzki et

al. 2006), and a recent study found that the degree of MCS effort is one of the strongest predictors of IUU fishing worldwide (Petrossian 2015). Furthermore, the same study found that the presence of 'internationally attractive species' has a significant effect on the degree of IUU fishing occurring in Southeast Asia and Australia (Petrossian 2015).

The Australian context exemplifies these findings on both points: following a peak of illegal incursions by Southeast Asian vessels in 2005, Australia increased its border security and saw a marked reduction in illegal incursions by 2007 (AFMA 2007; Baird 2010; Vince 2007). Despite these increases in MCS effort, northern Australia is currently experiencing a resurgence of foreign IUU fishing, with East Timorese, Indonesian and Vietnamese boats implicated (Armbruster 2017; Collins 2017). It is likely that these IUU fishing activities are driven by a combination of factors, such as the high market value of 'internationally attractive species' in Australian waters (e.g. sea cucumber, marine turtles, trochus) and as a form of expansion-displacement fishing resulting from the ongoing overfishing crisis in neighbouring countries (Field et al. 2009; Stobutzki et al. 2006).

5.4.2. Mismatches and the 'top-down' governance problem

Where IUU fishing involves multiple nations and causal drivers (as in the Australia example above), the importance of regional cooperation and context-specific solutions cannot be overstated (Baird 2010). Johns (2013) points out that "MCS is reliant on regional cooperation", and that addressing the root causes of IUU fishing requires ongoing regional collaboration among countries and agencies (Johns 2013). And yet, in the framework prepared to define regional capacity development priorities for the Regional Plan of Action to Promote Responsible Fishing Practices including Combating Illegal, Unreported and Unregulated (IUU) Fishing in the [Southeast Asia] Region (RPOA-IUU), not a single action for strengthening regional and international cooperation was ranked in the 'high priority'

category (Department of Agriculture 2011). Actions assigned to the highest category were more nationally oriented: development of fishery management plans; vessel licensing and/or registration; strengthening analytical capacity for stock management; and strengthening MCS information systems. While action against IUU fishing must certainly build on a foundation of good fisheries governance, the low ranking of regional capacity development priorities reflects a mismatch between the acknowledged need for collaboration and its actual inclusion in the RPOA-IUU framework. As my results about collaboration also reflect this mismatch for multiple countries and sub-regions, further scrutiny of the factors influencing the uptake of IUU mitigation strategies is warranted.

In ranking the types of barriers that may prevent their agency from taking action against IUU fishing, respondents overwhelmingly identified 'Lack of money for MCS' as the barrier with the strongest effect on their agency or organisation (Figure 5.5). The next-strongest barrier recognised the 'Magnitude of the IUU fishing issue'. These barriers are closely linked in that managing a widespread, diverse and at times concealed activity can become fiscally untenable, especially for developing countries with large EEZs. The third barrier, 'Weak criminal sanctions for IUU', may stem from the lack of specificity in the United Nations definition of 'serious crime' (Phelps Bondaroff et al. 2015), weak harmonisation of legislation across states and nations (see OECD 2005) or from the issue of corruption in judicial systems, particularly in places where criminal groups hold significant social or political influence (Nellemann et al. 2014; UNODC 2016). However, caution is needed when advocating for legislative reform as a sole solution to pervasive, complex problems: Lindley & Techera (2017) note the global persistence of IUU fishing despite the many political instruments aimed at eradicating it. The survey results suggest that there is an additional mismatch between the adoption of legislation at the upper political echelon (national and/or

international) and the development of behaviour-changing incentives at the level of individual fishers.

Many studies have noted the advantages of decentralised fisheries management—where authority is shifted from central government to regional/local stakeholder groups—as a means to promote sustainable resource use through local participation in decision-making, implementation and enforcement (Coffey 2005; da Silva and Kitts 2006; Jentoft 1989; Jentoft et al. 1998; Velez et al. 2010). While co-management arrangements are not without resource and capacity requirements, they can emerge from a variety of institutional partnerships (Chuenpagdee and Jentoft 2007), especially with government, community groups and NGOs (also called 'bridging organisations; see Jamal et al. 2007). Successful co-management may also reduce the likelihood of scale mismatches common to centralised management regimes (see Cumming et al. 2006; Kalikoski et al. 2002; Weiss et al. 2012). While the theme of 'effective decentralisation' was not prioritised on a regional basis in the aforementioned RPOA framework, a recent example from Tanzania illustrates the potential benefit of applying community-based approaches to reduce IUU fishing throughout the IOSEA (Mesomapya 2017). As I discuss in the next section, the nature of marine turtle-IUU fishing activities varies substantially between sub-regions, with implications for the direction and degree of management intervention.

5.4.3. Knowledge gaps and opportunities for improvement

Survey results indicated sub-regional variation in the types of knowledge believed necessary to reduce IUU fishing and marine turtle exploitation (Figure 5.4); these knowledge gaps in many cases are linked thematically to patterns of marine turtle use common to each sub-region (see Chapters 3 and 4) (IOSEA 2014). In all sub-regions except SEA, respondents primarily emphasised the need for more information on marine turtle–human interactions,

such as fisheries bycatch and consumption. This was especially pronounced in the SWIO sub-region and is consistent with previous reports of regional marine turtle consumption and bycatch in subsistence fisheries (Humber et al. 2015; Williams 2017). The lack of marine turtle bycatch data has been recognised as a widespread conservation and management issue in the IOSEA (Wallace et al. 2011) and as a symptom of the single-species approach to fisheries management more broadly (Finkbeiner et al. 2011; Riskas et al. 2016)(Chapter 2). Moreover, nearshore subsistence fisheries are prevalent throughout the IOSEA (Stobutzki et al. 2006; Van der Elst et al. 2005) and have been shown to incur disproportionately high rates of marine turtle bycatch and mortality in other countries (Gearhart 2003; Ishihara 2007; Lum 2006; Peckham et al. 2007). Better knowledge of marine turtle–fishery interactions is necessary to establish baseline bycatch and mortality rates in legal, regulated fisheries for a variety of species–region and species–gear type combinations. Such investigations may serve as proxies for data on IUU fishing activities, and thus allow for relative risk assessment of different IUU fishing types (see Ermolin and Svolkinas 2018).

In the results of this chapter, there was an additional emphasis on the need for information about marine turtle biology and behaviour, particularly in NWIO and SEA, and to a lesser extent in SWIO and NIO. This finding on its own is not surprising; previous research has highlighted a plethora of knowledge gaps relating to marine turtle biogeography in the Indian Ocean (Wallace et al. 2010). Improving the body of knowledge on marine turtle population structure, migration routes and foraging locations throughout the IOSEA is thus a necessary first step towards informing mitigation strategies in areas where IUU fishing activities are a source of marine turtle mortality (see Chapter 3). Such strategies may include spatial or temporal fishery closures, as has been done to protect olive ridley turtles in India's Gahirmatha Marine Sanctuary (Behera et al. 2016) or the IOSEA-MoU initiative, Network of

Sites of Importance for marine turtles in the IOSEA region[1]. Further, species assessment frameworks such as the IUCN Red List rely on key types of biological data in order to determine a species' conservation status, as well as the nature and priority of intervention needed to prevent extinction (Rodrigues et al. 2006). Better information on marine turtle behaviour, habitat use and population dynamics will allow for more accurate evaluation of a population's vulnerability to multiple threats, including IUU fishing (Rees et al. 2016). Despite the many factors—biological and logistical—constraining the rapid development of such datasets, a recent study by Mazaris et al. (2017) found that short time-series abundance data may serve as useful complements to the IUCN assessments in certain cases. For the generally data-poor IOSEA, such an approach merits further consideration.

Significantly, SEA respondents identified a need for knowledge of marine turtle trade and trafficking. This theme was not raised in any other sub-region, likely a reflection of the region's ongoing issues with illegal capture and trade of marine turtles (Chapter 4) (IOSEA 2014; Stiles 2008), which is driven primarily by the market demand for marine turtle products in China and Japan (Lam et al. 2011). A recent study by Riskas and colleagues (2018) suggests that IUU fishers also engage in the capture, storage and transhipment of illegally-caught marine turtles in multiple countries within the SEA sub-region (Riskas et al. 2018). Wildlife crime is among the world's most profitable illicit activities (Haken 2011; Solomon et al 2015; White and Heckenberg 2014; Wyatt 2013), and the connections between IUU fishing and other forms of transnational organised crime are increasingly being recognised (Chapter 4) (Liddick 2014; Phelps Bondaroff et al. 2015; Telesetsky 2014; UNODC 2011). As such, better knowledge of criminal networks may help to identify and disrupt wildlife trafficking operations (Haas and Ferreira 2016), as well as to draw

[1] http://www.ioseaturtles.org/sitenetwork.php

management attention to specific communities where locals are abetting foreign syndicates (see IOSEA 2012). Further, such knowledge-gathering is also likely to have positive follow-on implications for efforts to combat other forms of transnational organised crime (e.g. drug trafficking), as these are often perpetrated simultaneously within existing criminal networks and transit pathways (Elliott 2009; South and Wyatt 2011).

5.4.4. Recommended actions

While developing countries often operate with limited regulatory resources (Sumaila et al. 2016) and are disproportionally affected by IUU fishing (MRAG 2005; Petrossian 2015), there is scope and precedence for sponsored aid to bolster management capacity. Pitcher and colleagues (2009) note that Malaysia—a regional stand-out in terms of fisheries compliance in their study—has previously received surveillance equipment through development aid schemes (Pitcher et al. 2009). I echo these authors in emphasising the importance of providing targeted aid that is informed by and adapted to the local context (Chapter 4). Indeed, previous research has noted that IUU fishing is highly variable over spatial and political scales (Agnew et al. 2009) and is driven by an interplay of economic and sociocultural factors (Arias et al. 2015; Petrossian 2012; Wallner-Hahn et al. 2016). Collaborative efforts to reduce domestic IUU fishing practices must therefore seek to understand these local dynamics, necessitating close engagement with fishing communities, research teams and local governance institutions. Efforts to build capacity through development aid must be similarly targeted to address the drivers of IUU fishing in each local context, with assistance tailored accordingly.

Furthermore, given the occurrence of foreign illegal fishing and other transnational criminal activities in the IOSEA (Baird 2010), the need for a coordinated, international approach to mitigating these threats must be strongly emphasised (Johns 2013; Riddle 2006). Particularly

in Southeast Asia—the global epicentre of the illegal wildlife trade (Nijman 2010)—regional partnerships are essential for facilitating information exchange and for building capacity to reduce IUU fishing (Baird 2010). Areas where IUU fishing activities have been linked to the capture and trafficking of marine turtles (see Chapter 3) should be prioritised under existing multi-lateral initiatives, such as the Association of Southeast Asian Nations Wildlife Enforcement Network (ASEAN-WEN), IOSEA MoU for turtle conservation, Convention on the Conservation of Migratory Species of Wild Animals (CMS) and others. In order to be successful, it is essential that collaborations be supported by the provision of adequate resource capacity in all relevant sectors. I also stress the importance of using international alliances to support research into the drivers and dynamics of IUU fishing at regional, management-relevant scales.

This study and others demonstrate that there is no blanket solution to the problem of IUU fishing. Rather, I assert that mitigation efforts need to be adaptive, collaborative and evidence-based in order to address the root causes of IUU fishing in a variety of contexts. MCS measures, while important for reducing IUU fishing, must be targeted to address the underlying drivers, with any sponsored aid similarly tailored to specific capacity shortfalls (after Pitcher et al. 2009). Decentralised fisheries management approaches may be bolstered through coordination with bridging organisations (e.g. community groups, universities and NGOs) and provide an opportunity for valuable data-gathering at regional and local scales. Better knowledge of regional IUU fishing practices is needed not only to inform fisheries management strategies, but also to enable more accurate threat assessment (such as the IUCN Red List) for multiple species potentially affected by IUU fishing (e.g. marine turtles, elasmobranchs, sea cucumbers, reef fish). Better information at national scales will also allow authorities to better track performance against relevant international agreements, such as the

United Nations Sustainable Development Goals (Blasiak and Wabnitz 2018; Nash et al. 2017).

5.5. Conclusions

The variable nature of IUU fishing poses ongoing challenges for state and non-state actors attempting to eradicate it. Therefore, mitigation efforts must first consider the drivers and dynamics of IUU fishing in each local context and tailor approaches accordingly. There is a mismatch between the acknowledgement that collaboration is important and the reported degree of its implementation throughout the study area. While capacity building is certainly needed for less-developed nations and should be collaborative in nature, I do not regard provision of MCS technology and equipment as a panacea. Instead, improvements in MCS measures must develop alongside advances in understanding of the drivers and barriers present in each local context. Decentralised fisheries management has the potential to develop targeted, locally-based solutions, and also presents an opportunity for much-needed data-gathering. Increasing our knowledge of IUU fishing and marine turtle exploitation at local scales is essential for curating sustainable management regimes, with direct consequences for communities that depend on healthy, productive marine ecosystems.

Chapter 6

General Discussion

6.1. Summary of key research findings

Marine turtle populations worldwide are threatened by a number of anthropogenic processes, of which fisheries are unquestionably one of the most harmful. Though the effects of fisheries have been documented across species, gear types and regions, management intervention for cumulative impacts remains constrained by data limitations even in well-monitored fisheries in developed nations. The issue of IUU fishing introduces further uncertainty into management efforts, and prior to this thesis was a topic on the fringe of discussion for marine turtles and many other marine megafauna taxa. In focusing on these two particular data deficiencies, I have produced findings that fill crucial knowledge gaps for both marine turtles and IUU fishing, complementing research and conservation efforts in the IOSEA and globally.

After establishing the relative rarity of cumulative impact assessments for marine turtle-fishery interactions (Chapter 1), I undertook this analysis using logbook data collected by Australian commercial fisheries in three different management jurisdictions (Chapter 2). By summing turtle bycatch longitudinally (>10 years) across gear types and agencies, the analysis identified population-level impacts that were being overlooked within the prevailing single-fishery, single-year approach to monitoring turtle bycatch. Despite the known limitations of logbook reporting, this chapter illustrated the importance of utilising available data to perform what should be a standard analysis in fisheries management, particularly for fleets interacting with protected populations of long-lived organisms.

This thesis then turned to the vast knowledge gap of IUU fishing, exploring its effects on marine turtles first at a broad, basin-wide scale (Chapter 3) and then more finely within an individual nation (Chapter 4). Previously, IUU fishing was assumed to be a threat to marine turtles in a general sense, but this assumption was not grounded explicitly in any scientific

study. Chapter 3 sought to establish an empirical basis for this threat within the data-deficient Indian Ocean and Southeast Asia region (IOSEA). Using the expert elicitation technique in an online survey, I gathered the first expert consensus that IUU fishing is a serious but heterogeneous threat to marine turtles in the IOSEA. Results also described the occurrence of intentional turtle take and transhipment across maritime borders within certain sub-regions, indicating the variety of potential drivers of IUU fishing and the need to conduct in-country assessments at finer scales.

In Chapter 4, I then sought to further understand these dynamics within Southeast Asia, a sub-region of concern identified in Chapter 3. Through interviews with commercial fishers in two Malaysian states, I discovered that IUU fishing poses an urgent threat to marine turtles due to rampant use of illegal fishing gear, foreign vessel incursions and criminal linkages between IUU fishers and organised wildlife trafficking operations. The chapter also found inter-state variability in the perceived drivers of IUU fishing, illustrating the need for tailored, context-specific solutions and legislation.

To determine the feasibility of adopting such a management response, Chapter 5 examined the barriers and knowledge gaps relating to mitigating IUU fishing in the IOSEA. Based on structured questionnaires and interviews with management officials, I found a number of mismatches between acknowledged priorities and implemented policies relating to IUU fishing, with minimal opportunity to incorporate context-specific mitigation measures within national, multi-lateral and international agreements. Further, these results identified sub-regional needs for more research on marine turtle biogeography and sources of mortality, including bycatch, illegal capture and trafficking. This chapter highlighted the barriers of cost and capacity in creating effective IUU mitigation programs, and proposed that decentralised management approaches may provide opportunities to circumvent these barriers, achieve targeted intervention and perform valuable knowledge-gathering.

6.2. Management significance

This thesis has spanned a range of topics relating to marine turtles and fisheries—legal and illegal—that may at first seem disparate to one another. In selecting these particular issues of data deficiency, I considered not only the potential to fill important knowledge gaps, but also their relevance to the needs of fisheries management and marine turtle conservation more broadly. Here I contextualise my findings by discussing their contribution to three themes central to achieving successful resource governance: context, connection and collaboration.

To address any type of problem requires an understanding of its dynamics as well as the factors that enable its existence; without these data, managers may implement misguided and ineffective policies (e.g. addressing 'Malthusian' overfishing; see Finkbeiner et al. 2017). Similarly, my findings describing the perceived sub-regional variability of IUU fishing (Chapter 3) demonstrate the importance of acknowledging and describing IUU fishing in its unique geographic, social and economic context: the 'best-fit' approach to mitigation in one sub-region would simply not be appropriate in another. Furthermore, in Chapter 4 I showed that the drivers of IUU fishing vary considerably even within a single country (Malaysia), with outcomes for marine turtles closely linked to those causal factors. This research shows that a detailed characterisation of IUU fishing is an essential precursor to implementing targeted conservation and mitigation measures; as such, Chapters 3 and 4 may provide the impetus for IOSEA-MoU member states to improve their collection and reporting of data on turtles and IUU fishing, thus satisfying their commitments under the MoU's conservation and management plan[1].

In their global analysis of turtle bycatch, Wallace et al. (2010) note that detailed, location-specific characterisations of fishing activities are needed to inform bycatch management for

[1] http://www.cms.int/sites/default/files/instrument/mou_cmp_2009_e.pdf

marine turtles and other non-target species. Accordingly, findings of cumulative impacts to marine turtles in certain Australian commercial fisheries and areas (Chapter 2) provide justification for introducing cross-jurisdictional management of bycatch. As these results were produced using Australian Government data, this approach could be adopted within regulatory agencies and for other vulnerable marine megafauna taxa with relative ease. Additionally, by identifying fisheries and areas of cumulative high bycatch (i.e. gillnets in the Northern Territory; the Gulf of Carpentaria), this analysis allows Australian agencies to prioritise these areas for management intervention, and thus allocate their resources more effectively (see Fuentes and Cinner 2010; Moore et al. 2009).

Where a problem still persists despite the existence of regulatory measures aimed at addressing it (as with bycatch and IUU fishing), it is prudent to examine the factors preventing the realisation of management objectives (Lindley and Techera 2017). Chapter 2 found that cumulative impact assessments of turtle bycatch were hindered not by political will, but by incompatibilities in data collection and non-uniform processing standards (e.g. publishing records yearly vs. quarterly, withholding fishing effort metrics, etc.). By demonstrating the value of the cumulative assessment approach, the findings of that chapter are a call to action for Australian fisheries management agencies to adopt standardised procedures for bycatch reporting in order to realise stated conservation and management objectives (e.g. Australian Government Species Recovery Plans).

Regarding IUU fishing, survey results in Chapter 5 identified disconnects between acknowledged management priorities for IUU and the inclusion of those priorities in multi-lateral development frameworks. Further, this chapter highlighted the need to transition from adopting legislation at the upper political echelon (i.e. national and/or international) and to focus more on developing behaviour-changing incentives at the level of individual fishers. Combined with the findings from Chapters 3 and 4, this chapter provides the justification for

trials of decentralised management strategies at various sub-regional scales throughout Malaysia and the IOSEA more generally. The results characterising IUU fishing practices and wildlife trafficking of marine turtles constitute important data sources that are now available for integration into conservation assessment frameworks, such as the IUCN Red List.

Finally, the importance of collaboration in addressing fisheries issues has been a recurrent theme throughout this thesis. Chapter 2 recommends that bycatch be managed collaboratively in Australia; Chapter 3 suggests leveraging existing collaborations in order to build regulatory capacity; Chapter 4 advocates for a collaborative, pluralistic approach to reducing IUU fishing and its associated links to wildlife trafficking; and Chapter 5 identifies the potential negative effects of *failing* to collaborate. Indeed, each of these chapters owe their very existence to a series of successful national and international collaborations between government agencies, universities, NGOs and members of the public (i.e. commercial fishers). There is great potential for collaboration among Australian national and state agencies to standardise their bycatch reporting protocols to enable cumulative impact assessment and thus more fully meet their obligations to national conservation legislation (e.g. *EPBC Act* 1999). In order to maintain a precautionary approach (see De Bruyn et al. 2013), these changes should apply to other megafauna taxa (i.e. marine mammals, elasmobranchs, seabirds) that are susceptible to the cumulative impacts of fisheries interactions.

6.3. Collaborating to address multidimensional issues in fisheries and conservation

Recognising the multidimensional nature of IUU fishing is a key first step towards forming successful collaborations to mitigate its effects. As IUU fishing jeopardises the sustainability of marine resources, it may be rightly viewed as an issue for fisheries monitoring and

enforcement agencies. My thesis joins a small but growing collection of recent work characterizing IUU fishing as a form of transnational organised crime, which is addressed traditionally by federal law enforcement, border patrol and customs agencies. Further, the operational linkages that are documented between IUU fishers and wildlife trafficking syndicates (Chapter 4) beg the involvement of wildlife protection agencies, as well as research tools like social network analysis and situational crime prevention (SCP) (see Clarke 1983; Rosenbaum et al. 1998). As a result, the causes and effects of IUU fishing span multiple social tiers, regulatory divisions and academic disciplines, underscoring the idea that a collaborative approach is vital.

The need for multidisciplinary research into complex environmental problems is increasingly being recognised (Blythe et al. 2017; Kinzig 2001), and recent initiatives tackling IUU fishing's many embodiments are the manifestation of this need. FISH-i Africa, a regional partnership established in 2012, coordinates enforcement agencies, legal experts and technical analysts via a data-sharing platform to respond to IUU fishing in near-real time. Similarly, Global Fishing Watch was launched in late 2016 as a partnership between NGOs, Google and governments to monitor global fishing activities using satellite data. The dataset is also publicly available, facilitating partnerships between universities (i.e. Oozeki et al. 2018) and other interested stakeholders.

As recently as this month, the European Union invested 30 million Euro (AUD 47 million) into a collaborative project aiming to curb cross-boundary wildlife crime in southern, eastern Africa and the Indian Ocean[2]. One of the key objectives is to strengthen governance and collaborative management at regional scales, and contracting parties represent political instruments of criminal law (United Nations Office on Drugs and Crime; UNODC), wildlife

[2] https://cites.org/eng/EU_invests_30_m_euro_to_counter_illegal_killing_trafficking_wildlife_05122017

trade (Convention on International Trade in Endangered Species of Wild Flora and Fauna; CITES) and biodiversity conservation (Convention on the Conservation of Migratory Species of Wild Animals; CMS).

The emergence of these collaborative initiatives signals progress, and the involvement of non-bureaucratic parties (e.g. Google, universities) is particularly noteworthy. As discussed below, future research activities would be greatly enhanced by combining expertise from disparate stakeholders and academic disciplines in order to understand the complex drivers and consequences of IUU fishing.

6.4. Future research priorities

This thesis provided important information on fisheries-based threats to marine turtles in the IOSEA. In order to further advance our knowledge in this field, and ultimately improve the efficacy of threat assessments and associated mitigation measures, I identify the following topics that would benefit from additional research:

- The cumulative assessment of turtle bycatch presented in Chapter 2 highlights a need for re-evaluation of the effectiveness of turtle excluder devices (TEDs) in Australian trawl fisheries. Despite legislation requiring the use of TEDs in trawl fisheries Australia-wide since the early 2000s (Brewer et al. 2006), this analysis suggests that current bycatch levels present the possibility of population-level impacts for vulnerable turtle species (i.e. leatherback and olive ridley). As such, there is scope for fishery-dependent research surveys to gather species-specific data on turtle interaction rates, overlaps between key turtle habitat areas and fishing activities, fisher compliance with TED use regulations and factors influencing compliance/non-compliance. This approach has the added advantage of providing opportunities for direct input from commercial fishers, thereby reinforcing their sense of stewardship

and improving uptake of management measures (Jentoft et al. 1998; Pita et al. 2010). Further research into the use of technology—such as onboard cameras and machine learning algorithms—to detect and monitor bycatch should also be prioritised.

- A broad-scale assessment of IUU fishing and marine turtles (Chapter 3) is useful for management prioritisation within the IOSEA and should be replicated for other ocean basins and at-risk taxa. However, the coarse spatial scale of this analysis means that the results should be regarded as a starting point only. In future, detailed on-ground surveys should be conducted at multiple sites within individual nations in order to capture nuanced dynamics of IUU fishing at finer scales (i.e. Chapter 4 and Moore et al. 2010). Where possible, these surveys should arise out of partnerships with local governments, universities and NGOs, and maintain continuity with existing conservation reporting frameworks (e.g. those associated with IOSEA-MoU, ASEAN-WEN, CMS, WIOMTTF etc; see Chapter 1). The recent introduction of publically available data-sharing platforms—such as Global Fishing Watch—may provide valuable, complementary sources of information on fishing vessel movements and likely hotspots of IUU activity. Integrating this information with known marine turtle habitat areas would enable quantification of turtle exposure to IUU fishing, and thus inform risk-likelihood analyses.

- Geographically, the Northern Indian Ocean (NIO) and Northwestern Indian Ocean (NWIO) sub-regions were least represented in my datasets, and therefore present opportunities for expanded knowledge-gathering. Recent research in the Persian Gulf has explored the motivations driving IUU fishing within small fishing communities (Daliri et al. 2016; Daliri et al. 2015), and some of these findings are similar to my

own results from Malaysia in Chapter 4 (i.e. lack of enforcement, potential for economic gain). These overlaps and their consequences for marine turtles are worth exploring in future surveys throughout the NIO and NWIO—especially in relation to loggerhead turtles, which are listed by the IUCN Red List as critically endangered in the northwest Indian Ocean (Casale 2015).

- Survey responses from management officials (Chapter 5) identified a number of perceived knowledge gaps that may have implications for efforts to mitigate the effects of IUU fishing on marine turtles. More knowledge of marine turtle-fishery interactions, including bycatch, was recommended for all sub-regions of the IOSEA, although somewhat less so in Southeast Asia (SEA). Given the potential for these data to inform technical mitigation measures for both legal and IUU fishing, I emphasise the importance of instituting research programs to collect data on fishing effort, catch characterisation and marine turtle bycatch in all operating fleets. Doing so would enable the likelihood and consequences of exposure to legal and IUU fishing to be quantified. Such data may be used as proxies for turtle bycatch and mortality in IUU fisheries for areas where these impacts have not yet been assessed directly (after Ermolin and Svolkinas 2018). This knowledge-gathering is crucial to improve data on turtle biogeography for the generally data-poor IOSEA and thus improve the accuracy of population-level threat assessments, such as those used by the IUCN Red List.

- While artisanal fisheries were not the focus of this thesis, many other studies have demonstrated the potential for these fleets to have significant, population-level effects for marine turtles and other marine megafauna taxa (Alfaro-Shigueto et al. 2011;

D'agrosa et al. 2000; Peckham et al. 2007; Riskas and Tiwari 2013). I echo these authors in highlighting the urgent need for research characterising turtle interactions with artisanal fleets, particularly for the IOSEA—where such fisheries are widespread and largely unregulated, and thus their catches and bycatches may constitute IUU fishing (Pauly 2006; Stobutzki et al. 2006).

- This thesis discovered a critical overlap between IUU fishing and the illegal wildlife trade, primarily in several Southeast Asian nations (Chapters 3 and 4). This discovery introduces further complexity—as discussed above—and necessitates the inclusion of techniques and expertise from multiple scholarly disciplines (see Blythe et al. 2017). Future research aimed at mitigating IUU fishing and wildlife trafficking would be strongly advised to consider the influence of market drivers, consumer preferences, trade pathways, criminal networks and legislative loopholes. Where policies and mitigation measures are in place to prevent and deter wildlife crime, evaluations of their effectiveness—which are lacking generally—would also be highly useful contributions (Kurland et al. 2017).

6.5. Concluding remarks

The rapid expansion of global fisheries has fundamentally altered the marine environment. As the harmful effects of overexploitation continue to become apparent, management solutions will be needed at a pace and scale that research cannot hope to match. This interdisciplinary thesis has proactively sought to fill some of these knowledge gaps for marine turtles, providing information to guide management and conservation efforts at multiple geographic and political scales. This approach is applicable beyond marine turtles to

other taxa affected by fisheries, and can easily be adapted to address other broad scale, data-limited threats.

The idea for this thesis was conceived at a time when IUU fishing and marine turtle exploitation were considered by the academic community to be largely separate issues. The ensuing years have witnessed an extraordinary proliferation of interest in IUU fishing, which has galvanized action from universities, political bodies, NGOs and the private sector. As such, this thesis is part of a larger snowballing movement that aims to understand and eliminate IUU fishing in its many forms. It is an exciting and promising time, where progress seems to march almost inexorably forward.

However, as conscientious scientists, politicians and citizens, we must resist the temptation to measure that progress by the number of signed treaties or the complexity of our technology. In exploring issues of data deficiency, this thesis is a reminder that progress is possible only when we acknowledge the unknown, and then work together to understand it.

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Appendices

PROJECT TITLE: **"Investigating the impacts of artisanal and industrial fisheries on marine turtle populations in the Indian Ocean"**

You are invited to take part in a research project pertaining to the interactions between marine turtles and fisheries in the Indian Ocean. The study is being conducted by Kimberly Riskas will contribute to her degree Doctor of Philosophy – Environmental Science at James Cook University.

The purpose of this research is to gain a clearer understanding of how industrial, artisanal and illegal fisheries are affecting marine turtle populations in the Indian Ocean. The fisheries in this region are diverse, dynamic and largely under-studied; as a result, there is a dearth of knowledge regarding the possible effects of fisheries on marine turtles, which are caught unintentionally as bycatch and targeted for consumption. To compound the problem, **illegal, unreported and unregulated fishing (IUU)** frustrates efforts to manage fisheries sustainably and poses a serious threat to the health and recovery of marine turtles in the region.

If you agree to be involved in the study, please complete the questionnaire using the link in this email. This questionnaire asks you about your views on the impact of illegal, unreported and unregulated (IUU) fishing on marine turtle populations in the Indian Ocean. The questionnaire is reasonably short and should take 10-15 minutes to complete.

Taking part in this study is completely voluntary and you can stop taking part in the study at any time without explanation or prejudice.

Your responses and contact details will be strictly confidential. The data from the study will be used in research publications and reports but you will not be able to be identified in any way in these publications.

If you have any questions about the study, please contact **Kimberly Riskas or Dr Mark Hamann.**

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If you have any concerns regarding the ethical conduct of the study, please contact:
Human Ethics, Research Office
James Cook University, Townsville, Qld, 4811
Phone: (07) 4781 5011 (ethics@jcu.edu.au)

Thank you for participating in our survey. The purpose of this survey is to collect information on the nature and extent of illegal, unreported and unregulated fishing (IUU) and to gain a clearer understanding of how IUU is affecting marine turtle populations in the Indian Ocean and Southeast Asia regions. IUU frustrates efforts to manage fisheries sustainably and poses a serious threat to the health and recovery of marine turtles in the region. As such, we are seeking information about IUU and turtles from people with experience in the fields of fisheries, environmental management, marine turtles, conservation and other related fields.

The following questions aim to describe the IUU activities taking place in your country's Exclusive
Economic Zone (EEZ), and to determine the motivations and practices of the IUU fishermen who catch marine turtles. Additionally, the survey asks about management structures and programs designed to monitor and mitigate IUU, and your opinion on the effectiveness of such measures.
The survey is reasonably short and should take 10-15 minutes to complete. The information provided will be used as part of my PhD thesis and other research publications. Your responses and contact details will be strictly confidential and you will not be identifiable in any way in these publications. Taking part in this study is completely voluntary and you can stop taking part in the study at any time without explanation or prejudice.

BACKGROUND INFORMATION

Questions 1-5 aim to collect basic information regarding your professional experience in your field.

1. What is the name of your current position and organisation? (E.g. Fisheries officer, Department of
Fisheries)

2. About how long have you been in your current position?
Years
Months

3. Please describe your additional relevant experience in the fields of environmental management, biology, fisheries and/or conservation, including past job or volunteer experience

4. Your expertise comes from which of the following sectors? Choose ALL that apply:
- Academic research
- Government research
- Fishery management
- Policy making
- NGO
- Consulting
- Other (please specify)

5. Country about which you will complete this survey

NATURE AND EXTENT OF IUU FISHING

6. To your knowledge, where is IUU fishing occurring? Choose ALL that apply:
- in your country's EEZ (waters under your jurisdiction)
- in waters that straddle your country's EEZ and adjacent high seas
- in waters that straddle your country's EEZ and the EEZ of another country or economy?

in high seas (waters outside any single country's jurisdiction)
Other (please specify)

7. Please estimate how many incidents of IUU occur yearly in your jurisdiction. Choose ONE only:

Fewer than 10 incidents yearly
Between 10 and 50 incidents yearly
Between 50 and 100 incidents yearly
More than 100 incidents yearly
Unknown
Other (please specify)

8. Please provide specific names of places where IUU frequently occurs, such as islands, reefs, coastal towns, provinces and high seas areas.

9. In which habitat type(s) does IUU fishing commonly occur within your jurisdiction? Choose ALL that apply:

Inshore waters (i.e. bays, coastlines and estuaries)
Coral reefs
Islands
Open ocean within your jurisdiction
Open ocean outside your jurisdiction (i.e. high seas)
Unknown
Other (please specify)

10. Please state, in your opinion, how often each type of IUU occurs within your jurisdiction.

-Fishing without authorisation
-Fishing in a closed or restricted area
-Using a prohibited method
-Misreporting or under-reporting of catch
-Retaining species that are protected by law (e.g. marine turtles, dugong, whales etc)

-Never occurs
-Rarely occurs
-Somewhat frequently occurs
-Frequently occurs
-Very frequently occurs
-N/A

11. Please rank how often IUU fishing occurs in your jurisdiction for each type of vessel listed below:

Foreign industrial fleets
Foreign artisanal fleets
Domestic industrial fleets
Domestic artisanal fleets

12. What percentage of IUU fishing would you say is done by foreign (industrial and artisanal) fleets? Choose ONE only:

0%
Up to 25%
Between 25-50%
Between 50-75%
Between 75-100%

100%

13. How would you characterise the amount and severity of IUU fishing by foreign vessels in your
jurisdiction? Choose ONE only:

widespread but not a significant problem
widespread and a significant problem
isolated incidents but not a significant problem
isolated incidents and a significant problem
other (please specify)

14. What do you believe is the main reason for IUU fishing by foreign vessels in your jurisdiction? Choose ONE only:

-overfishing of the areas and/or species for which they are authorised, meaning they need to fish in other waters
-access to high-value species
-lack of enforcement or adequate deterrents
-lack of knowledge about laws protecting certain areas and/or species
-unknown
-other (please specify)

15. What percentage of IUU fishing would you say is done by domestic (industrial and artisanal) fleets? Choose ONE only:
0%
Up to 25%
Between 25-50%
Between 50-75%
Between 75-100%
100%

16. How would you characterise the amount and severity of IUU fishing by domestic vessels in your jurisdiction? Choose ONE only:

widespread but not a significant problem
widespread and a significant problem
isolated incidents but not a significant problem
isolated incidents and a significant problem
other (please specify)

17. What do you believe is the main reason for IUU fishing by domestic vessels in your jurisdiction? Choose ONE only:

-overfishing of the areas and/or species for which they are authorised, meaning they need to fish in other waters
-access to high-value species
-lack of enforcement or adequate deterrents
-lack of knowledge about laws protecting certain areas and/or species
-unknown
-other (please specify)

IMPACTS OF IUU FISHING

For the incidents of IUU that you are aware of, please indicate how often the following animals are involved.

-Dugong (*dugong dugon)*
-Dolphins and whales
-sharks
-marine turtles

-Never
-Rarely
-Somewhat frequently
-Frequently
-Very frequently
-N/A

19. Are the marine turtles targeted in the waters of your country by foreign boats?

Yes
No
Unknown

20. Are the marine turtles involved in IUU incidents identified to species by enforcement or monitoring personnel? (Y/N)

21. Please rank the species below to reflect how frequently each one is encountered in the incidents of IUU that you are aware of:

Green turtle (Chelonia mydas)
Hawksbill turtle (Eretmochelys imbricata)
Leatherback turtle (Dermochelys coriacea)
Loggerhead turtle (Caretta caretta)
Olive ridley turtle (Lepidochelys olivacea)
Flatback turtle (Natator depressus)

22. Do any of the known incidents of IUU include the take of marine turtle eggs and/or live turtles from nesting beaches?

Eggs only
Live turtles from nesting beaches only
Eggs and live turtles from nesting beaches
Unknown
Other (please specify)

23. Please list the names of any known fishing methods that are designed specifically to catch turtles:

24. For the incidents of IUU that you are aware of, what is the body condition of the marine turtles when they are found? Please rank the following conditions to reflect how often they occur:

Alive
Dead
Intact
Butchered (i.e. cut into pieces)
Stuffed/taxidermied
Other (please specify)

What do you believe happens to the turtles that are caught illegally? Choose all that apply:

Released alive
Used for food
Sold locally
Shipped overseas
Other (please specify)

26. How often do you think illegally-caught marine turtles are transferred between vessels on the high seas so that the fishermen may avoid getting caught? Choose ONE only:
-Never
-Rarely
-Somewhat frequently
-Frequently
-Very frequently
-N/A

27. Do you have any knowledge of the end destinations of illegally-caught marine turtles? (Y/N)

28. Please list the villages, towns, markets, cities or countries where you believe illegally-caught marine turtles are transported to:

29. In your opinion, how important is it to gain knowledge of the end destinations of illegally-caught marine turtles for management purposes?
Not at all important
Minimally important
Somewhat important
Very important
Unable to say

30. To what extent do you believe that IUU fishing represents a threat to the health of marine turtle populations in your country? Choose ONE only:
No threat
Minimal threat
Somewhat serious threat
Serious threat
Very serious threat
Unknown

31. What type of IUU fishing do you believe most impacts marine turtles?

MANAGEMENT RESPONSE TO IUU FISHING

32. Does your agency have specific programs in place to deter, mitigate and/or manage IUU fishing activities taking place within its jurisdiction? (Y/N)

33. If you answered Yes to the previous question, please select the programs that are in place to deter, mitigate and/or manage IUU fishing in your jurisdiction. Choose ALL that apply:
Enforcement of license/permit system
Vessel monitoring system (VMS)
Catch monitoring programs for target and non-target species
Maintaining publicly available IUU vessel blacklists
Port inspections
Other (please specify)

34. How effective are these programs in deterring, mitigating and/or managing IUU in your jurisdiction? Choose ONE only:

- Completely ineffective
- Somewhat ineffective
- Unable to determine effectiveness
- Somewhat effective
- Very effective

35. If you answered No to question 32, please give your opinion as to why such programs are not already in place:

36. Please list **up to 3** appropriate and effective actions that you think your organisation could take to address major IUU issues within your jurisdiction:

37. Which other countries or agencies do you believe should be responsible for working to address IUU fishing in your jurisdiction?

38. Please use this space to comment further on IUU fishing in your jurisdiction or region. You may also use this space to provide PDFs, website links or any other additional information that you believe is relevant to the impacts of IUU fishing on marine turtles in the Indian Ocean.

Table B1. Summary of responses received for each country in the IOSEA study area.

Country	Response received (Y/N)	Number of responses	Primary language(s)	Subregion
Australia	Y	3	English	SEA
Bangladesh	Y	2	Bengali, English	NIO
China	Y	1	Mandarin	SEA
Comoros	Y	1	Arabic, French	SWIO
Egypt	Y	1	Arabic	NWIO
France (Îles Éparses)	Y	1	French	SWIO
France (La Réunion)	Y	2	French	SWIO
India	Y	2	Hindi, English	NIO
Indonesia	Y	3	Indonesian	SEA
Iran	Y	1	Persian	NWIO
Kenya	Y	3	English, Swahili	SWIO
Kuwait	Y	1	Arabic	NWIO
Malaysia	Y	2	Bahasa Malay	SEA
Maldives	Y	1	Maldivian	NIO
Mozambique	Y	6	Portuguese	SWIO
United Arab Emirates	Y	1	Arabic	NWIO
Oman	Y	2	Omani Arabic	NWIO
Pakistan	Y	2	English, Urdu	NIO
Philippines	Y	1	Tagalog, English	SEA
Qatar	Y	1	Arabic	NWIO
Saudi Arabia	Y	1	Arabic	NWIO
Seychelles	Y	1	French, English	SWIO
South Africa	Y	1	Afrikaans, English	SWIO
Sri Lanka	Y	2	Sinhala, Tamil	NIO
Sudan	Y	1	Arabic, English	NWIO
Taiwan	Y	1	Mandarin	SEA
Tanzania	Y	1	English, Swahili	SWIO
Vietnam	Y	3	Vietnamese	SEA
Yemen	Y	1	Arabic	NWIO
Bahrain	N	0	Arabic	NWIO
British Indian Ocean Territory	N	0	English	NIO
Cambodia	N	0	Khmer	SEA
Djibouti	N	0	Arabic, French	NWIO
Eritrea	N	0	Arabic, English	NWIO
France (Mayotte)	N	0	French	SWIO
Iraq	N	0	Arabic	NWIO
Israel	N	0	Arabic, Hebrew	NWIO
Jordan	N	0	Arabic	NWIO
Madagascar	N	0	Malagasy, French	SWIO
Mauritius	N	0	French, English	SWIO

Myanmar	N	0	Burmese	SEA
Somalia	N	0	Arabic, Somali	NWIO
Thailand	N	0	Thai	SEA
Timor-Leste	N	0	Portuguese	SEA

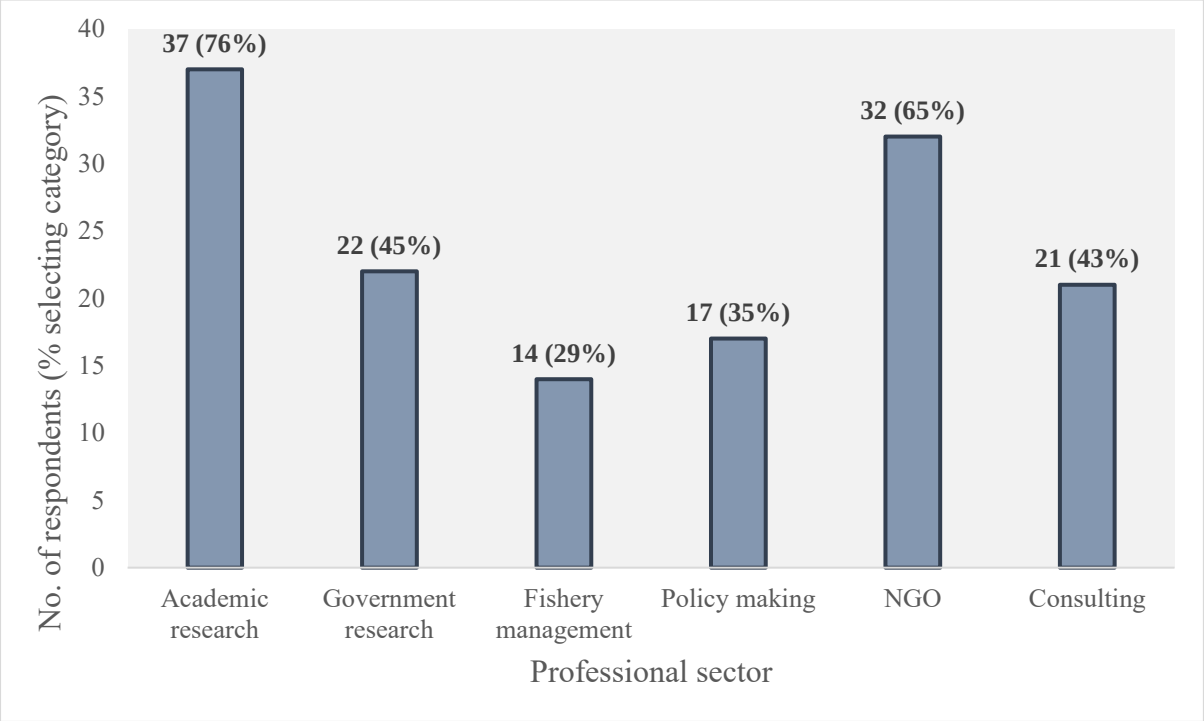

Figure B1. Breakdown of respondents by sector of professional experience. Summed percentages exceed 100% due to respondents being able to select more than one sector.

MARINE TURTLES AND ILLEGAL, UNREPORTED AND UNREGULATED FISHING (IUU) IN SABAH, MALAYSIA

Interviewer name: _____
Location: _____
Date: _____
Survey number: _____

A. BACKGROUND INFORMATION

i. Your age:
ii. Are you a: boat owner ☐ captain ☐ fisherman ☐
iii. Years of fishing experience:

B. NATURE AND EXTENT OF IUU FISHING

1. Have you ever seen people fishing illegally in the waters where you fish?
    a) Yes
    b) No
    c) Unknown

2. Please rank how often you believe each type of IUU fishing occurs in the waters where you fish:
    a) fishing without a permit (Never, Rarely, Somewhat frequently, Frequently, Very frequently, N/A)
    b) fishing in a closed area (Never, Rarely, Somewhat frequently, Frequently, Very frequently, N/A)
    c) using a prohibited fishing method (Never, Rarely, Somewhat frequently, Frequently, Very frequently, N/A)
    d) misreporting or under-reporting of the catch or bycatch (Never, Rarely, Somewhat frequently, Frequently, Very frequently, N/A)
    e) retaining species that are protected by law (e.g., marine turtles, dugong, whales, etc) (Never, Rarely, Somewhat frequently, Frequently, Very frequently, N/A)

3. In which habitat type(s) does IUU fishing occur? Please choose ALL that apply:
    a) inshore waters
    b) coral reefs
    c) islands
    d) open ocean in Malaysian waters
    e) open ocean in international waters (high seas)
    f) unknown
    g) other (please specify): _____

4. Please estimate how many incidents of IUU occur yearly in the waters where you fish:
    a) fewer than 10 incidents yearly
    b) between 10 and 50 incidents yearly
    c) between 50 and 100 incidents yearly

d) more than 100 incidents yearly
e) unknown
f) other (please specify): _____

5. Please rank how often IUU fishing occurs in the waters where you fish for each type of vessel:
   a) Foreign industrial fleets (Never, Rarely, Somewhat frequently, Frequently, Very frequently, N/A)
   b) Foreign artisanal fleets (Never, Rarely, Somewhat frequently, Frequently, Very frequently, N/A)
   c) Domestic industrial fleets (Never, Rarely, Somewhat frequently, Frequently, Very frequently, N/A)
   d) Domestic artisanal fleets (Never, Rarely, Somewhat frequently, Frequently, Very frequently, N/A)

6. In the waters where you fish, what percentage of IUU do you think is done by foreign boats?
   a) 0%
   b) up to 25%
   c) between 25-50%
   d) between 50-75%
   e) between 75-100%
   f) 100%

7. Why do you think foreign people would fish illegally? Choose ONE only:
   a) The areas where they fish are depleted, so they need to fish somewhere else
   b) To obtain valuable species
   c) Lack of enforcement means they can get away with illegal fishing
   d) They don't know about the laws protecting certain areas or species
   e) Don't know
   f) Other (please specify): _____

8. Please list the country or countries that you believe the foreign IUU fishermen come from:
   _____

9. In the waters where you fish, what percentage of IUU do you think is done by Malaysian boats?
   a) 0%
   b) up to 25%
   c) between 25-50%
   d) between 50-75%
   e) between 75-100%
   f) 100%

10. Why do you think Malaysian people would fish illegally?
    a) The areas where they fish are depleted, so they need to fish somewhere else
    b) To obtain valuable species
    c) Lack of enforcement means they can get away with illegal fishing
    d) They don't know about the laws protecting certain areas or species
    e) Don't know
    f) Other (please specify): _____

11. Are marine turtles intentionally targeted in Malaysian waters by foreign boats?
    a) Yes
    b) No *(go to question 13)*

12. If Yes, how often are these turtles shipped to overseas locations?
    a) Never
    b) Rarely
    c) Somewhat frequently
    d) Frequently
    e) Very frequently
    f) Don't know

13. What do you believe happens to the turtles caught illegally by foreign boats?
    a) released alive
    b) used for food
    c) sold locally
    d) shipped overseas
    e) other (please specify): _____

14. When illegally-caught turtles are sold locally, what do you believe they are sold for? Choose ALL that apply:
    a) food
    b) to be made into traditional medicines
    c) crafting of shell (carapace) into ornaments, curios etc
    d) stuffing the turtle for display
    e) stored on land before being sent overseas
    f) don't know
    g) other (please specify): _____

15. Are marine turtles intentionally targeted in Malaysian waters by Malaysian boats?
    a) Yes
    b) No *(go to question 17)*

16. If Yes, how often are these turtles shipped to overseas locations?
    a) Never
    b) Rarely
    c) Somewhat frequently
    d) Frequently
    e) Very frequently
    f) Don't know

17. What do you believe happens to the turtles caught illegally by Malaysian boats?
    a) released alive
    b) used for food
    c) sold locally
    d) shipped overseas
    e) other (please specify): _____

18. When illegally-caught turtles are sold locally, what do you believe they are sold for? Choose ALL that apply:
    a) food

b) to be made into traditional medicines
c) crafting of shell (carapace) into ornaments, curios etc
d) stuffing the turtle for display
e) stored on land before being sent overseas
f) don't know
g) other (please specify): _____

19. Do any of the incidents of IUU include the take of marine turtle eggs and/or live turtles from nesting beaches?
    a) eggs only
    b) live turtles from nesting beaches only
    c) eggs and live turtles from nesting beaches
    d) don't know
    e) other (please specify):

20. Please rank the turtle species to reflect how frequently each one is encountered in the incidents of IUU that you know of
    a) Green turtle (Never, Rarely, Somewhat frequently, Frequently, Very frequently, N/A)
    b) Hawksbill turtle (Never, Rarely, Somewhat frequently, Frequently, Very frequently, N/A)
    c) Leatherback turtle (Never, Rarely, Somewhat frequently, Frequently, Very frequently, N/A)
    d) Olive ridley turtle (Never, Rarely, Somewhat frequently, Frequently, Very frequently, N/A)
    e) Loggerhead turtle (Never, Rarely, Somewhat frequently, Frequently, Very frequently, N/A)

21. In Sabah, are turtles caught intentionally for overseas markets?
    a) Yes
    b) No *(go to question 18)*
    c) Don't know

22. If Yes, are they caught intentionally by:
    a) Malaysian boats
    b) foreign boats
    c) both
    d) don't know

23. Do you have any knowledge of where illegally-caught turtles are transported to?
    a) Yes
    b) No *(go to question 25)*

24. If Yes, please list the villages, towns, markets, cities or countries where you believe illegally-caught turtles are transported to: _____
    _____

25. Illegally-caught turtles may be transferred between boats while at sea to avoid being caught my maritime patrols. How often do you think this happens?
    a) Never
    b) Rarely

c) Somewhat frequently
d) Frequently
e) Very frequently
f) Don't know

26. Sometimes turtles are captured and brought back to land, then held until a large number accumulates, and then the turtles are smuggled to other towns or countries all at once. Have you heard of this happening in Sabah?
    a) Yes
    b) No

27. How does IUU fishing affect you personally? Please rank the following options:
    a) IUU causes fish populations to decline (Strongly agree, Somewhat agree, No opinion, Somewhat disagree, Strongly Disagree)
    b) IUU causes turtle populations to decline (Strongly agree, Somewhat agree, No opinion, Somewhat disagree, Strongly Disagree)
    c) I make less money because people are fishing illegally (Strongly agree, Somewhat agree, No opinion, Somewhat disagree, Strongly Disagree)
    d) IUU fishing physically damages the marine environment (Strongly agree, Somewhat agree, No opinion, Somewhat disagree, Strongly Disagree)
    e) The government needs to work harder to stop IUU fishing in Sabah (Strongly agree, Somewhat agree, No opinion, Somewhat disagree, Strongly Disagree)

28. What type of IUU fishing do you believe has the biggest impact on marine turtles? Please specify:

    _____
    _____
    _____

MANAGEMENT AND MITIGATION OF ILLEGAL, UNREPORTED AND UNREGULATED (IUU) FISHING INVOLVING MARINE TURTLES

Part A: Interviewee background information

i. Please list the country for which you will answer these questions:
ii. What is the name of your organisation?
iii. What is your current position here?

_____

iv. How long have you been in your current position?_____
v. Your expertise comes from which of the following sectors? Choose all that apply:
   a. Academic research
   b. Government research
   c. Fisheries management
   d. Policy making
   e. NGO (non-governmental organisation)
   f. Consulting
   g. Other (please specify): _____

Part B: Management of IUU fishing

1. Please estimate how many incidents of IUU fishing occur yearly in your jurisdiction:
   a. Never occurs
   b. One incident a year
   c. Fewer than 10 incidents a year
   d. Between 10 and 50 incidents a year
   e. More than 50 incidents a year
   f. Other: _____

2. Does your agency have specific programs in place to deter, mitigate and/or manage IUU fishing?
   a. Yes
   b. No *(go to question 5)*
   c. Don't know *(go to question 5)*

3. If you answered Yes to the previous question, please select the programs that your agency has in place to deter, mitigate and/or manage IUU fishing. Choose ALL that apply:
   a. Enforcement of license/permit system
   b. Vessel monitoring system (VMS)
   c. Catch monitoring programs for target and non-target species
   d. Maintaining publicly available IUU vessel blacklists
   e. Port inspections
   f. Awareness and education campaigns
   g. Other (please specify): _____

4. Considering your answer to Question 4, what do you think has made these programs **effective**? Please choose ONE of the following reasons:
    a. Enforcement resources (e.g. number of patrol boats, type of boats, etc)
    b. Personnel resources (e.g. number of staff members, competency of staff members)
    c. Amount of engagement with local fishermen
    d. Fishermen's level of cooperation (compliance) with the programs
    e. Level of local/political corruption
    f. Other (please specify): _____

5. Considering your answer to Question 4, what do you think made these programs **ineffective**? Please choose ONE of the following reasons:
    a. Enforcement resources (e.g. number of patrol boats, type of boats, etc)
    b. Personnel resources (e.g. number of staff members, competency of staff members)
    c. Amount of engagement with local fishermen
    d. Fishermen's level of cooperation (compliance) with the programs
    e. Level of corruption
    f. Other (please specify): _____

6. In your opinion, how effective have these programs been as a whole in reducing the number of incidents of IUU fishing in your jurisdiction? Choose **one** only:
    a. Completely ineffective
    b. Somewhat ineffective
    c. Somewhat effective
    d. Very effective
    e. Don't know

7. How often do management personnel from your agency work and/or meet directly with fishers?
    a. Never
    b. Once a year
    c. Twice a year
    d. Three times a year
    e. More than three times a year
    f. Other (please specify):_____

8. Do fishers in your country have an opportunity to provide feedback on your agency's management programs?
    a. Yes
    b. No
    c. Don't know

9. How important is it for your agency to collaborate with other agencies **in your country** and internationally to address IUU fishing?
    a. Not at all important
    b. Minimally important
    c. Somewhat important
    d. Very important
    e. Don't know

10. How important is it for your agency to collaborate with other agencies **internationally** to address IUU fishing?
    a. Not at all important
    b. Minimally important
    c. Somewhat important
    d. Very important
    e. Don't know

11. Please list the other agencies/departments that you coordinate with about IUU fishing:
    _____
    _____
    _____

Part C: Knowledge gaps relating to IUU fishing and turtles

12. Please indicate how often the following species are encountered in incidents of IUU in your jurisdiction:

	Never encountered	Rarely encountered	Somewhat frequently encountered	Frequently encountered	Very frequently encountered	N/A
Dugong	○	○	○	○	○	○
Dolphins and whales	○	○	○	○	○	○
Sharks and rays	○	○	○	○	○	○
Marine turtles	○	○	○	○	○	○
Commercial fish species	○	○	○	○	○	○

13. To what extent do you believe that illegal fishing represents a threat to the health of marine turtle populations in your country? Choose ONE only:
    a. No threat to turtles
    b. Minimal threat to turtles
    c. Moderate threat to turtles
    d. High threat to turtles
    e. Very high threat to turtles
    f. Don't know

14. How important is it to your agency to address the marine turtle-IUU fishing problem? Choose ONE only:
    a. Not a priority
    b. Low priority
    c. Moderate priority
    d. High priority
    e. Very high priority
    f. Don't know

15. What kinds of IUU practices do you believe have the biggest impact on marine turtles in your country? Please list:

    _____
    _____

16. What information do you believe your agency needs in order to protect marine turtles from IUU fishing?

    _____
    _____
    _____

Part D: Barriers to reducing IUU fishing

17. When fishermen are caught fishing illegally in your jurisdiction, how often do each of the following punishments occur?

	Never occurs	Rarely occurs	Somewhat frequently occurs	Frequently occurs	Very frequently occurs	N/A
Verbal or written warning	○	○	○	○	○	○
Monetary fine	○	○	○	○	○	○
Loss of fishing license	○	○	○	○	○	○
Criminal trial in court	○	○	○	○	○	○
Prison sentence	○	○	○	○	○	○
Destruction of boat	○	○	○	○	○	○

18. To what extent do you believe that reducing marine turtle IUU is a government priority in your jurisdiction?
    a. Not a priority
    b. Low priority
    c. Moderate priority
    d. High priority
    e. Very high priority
    f. Don't know

19. Listed below are 8 reasons why an agency may have difficulty stopping IUU fishing. Please rank each reason to show the degree to which each one is likely to prevent your agency from taking action to address marine turtle IUU:

    a. Lack of money for monitoring, control and surveillance (MCS)

Does not prevent my agency from taking action; **No effect**	Very slightly prevents my agency from taking action: **Minimal effect**	Moderately prevents my agency from taking action; **Moderate effect**	Somewhat strongly prevents my agency from taking action; **Somewhat strong effect**	Very strongly prevents my agency from taking action; **Very strong effect**
○	○	○	○	○

    b. Lack of knowledge about the turtle-IUU problem

No effect	Minimal effect	Moderate effect	Somewhat strong effect	Very strong effect
○	○	○	○	○

    c. Lack of clarity on which agency or department should take action

No effect	Minimal effect	Moderate effect	Somewhat strong effect	Very strong effect
○	○	○	○	○

    d. Lack of communication between government agencies

No effect	Minimal effect	Moderate effect	Somewhat strong effect	Very strong effect
○	○	○	○	○

    e. Lack of confidence in the legal system to prosecute IUU fishermen

No effect	Minimal effect	Moderate effect	Somewhat strong effect	Very strong effect
○	○	○	○	○

f. Punishments for IUU fishing are not strict enough

No effect	Minimal effect	Moderate effect	Somewhat strong effect	Very strong effect
◯	◯	◯	◯	◯

g. Problem is too big and/or too complex for one agency to tackle

No effect	Minimal effect	Moderate effect	Somewhat strong effect	Very strong effect
◯	◯	◯	◯	◯

h. The IUU-turtle problem isn't enough of a priority for my agency to take action

20. Please indicate how strongly you agree or disagree with the following statements:
    g. The definition of 'IUU fishing' should include the capture of protected marine turtles at sea
    h. The definition of 'IUU fishing' should include the use of fishing boats to transport illegally-caught wildlife, including marine turtles, between locations or across maritime borders
    i. The definition of 'IUU fishing' should include the unlawful retention of protected marine turtles that are caught accidentally (bycatch) during fishing
    j. It is unclear how protected marine turtles are included in the definition of 'IUU fishing'
    k. Protected marine turtles should not be included in the definition of 'IUU fishing'

21. If funding was available and unlimited, which three (3) actions would you recommend be taken by your agency to reduce IUU fishing? Please list 3 actions:

    _____
    _____
    _____

22. Of the 3 actions you listed in Q21, which one do you believe is the most important action that needs to be taken to reduce IUU fishing in your country?

    _____
    _____

23. Please use this space to comment further on your knowledge /opinion of IUU fishing and sea turtles.

    _____
    _____
    _____
    _____
    _____

Table E1. Summary of responses received for each country in the IOSEA study area.

Country	Response received (Y/N)	Number of responses	Primary language(s)	Subregion
Bahrain	Y	1	Arabic	NWIO
Bangladesh	Y	2	Bengali, English	NIO
Eritrea	Y	1	Arabic, English	NWIO
India	Y	1	Hindi, English	NIO
Indonesia	Y	3	Indonesian	SEA
Madagascar	Y	1	Malagasy, French	SWIO
Malaysia	Y	9	Bahasa Malay	SEA
Mozambique	Y	2	Portuguese	SWIO
Oman	Y	1	Omani Arabic	NWIO
Pakistan	Y	2	English, Urdu	NIO
Philippines	Y	6	Tagalog, English	SEA
Sri Lanka	Y	1	Sinhala, Tamil	NIO
Sudan	Y	1	Arabic, English	NWIO
Tanzania	Y	1	English, Swahili	SWIO
Vietnam	Y	4	Vietnamese	SEA
Australia	N	0	English	SEA
British Indian Ocean Territory	N	0	English	NIO
Cambodia	N	0	Khmer	SEA
China	N	0	Mandarin	SEA
Comoros	N	0	Arabic, French	SWIO
Djibouti	N	0	Arabic, French	NWIO
Egypt	N	0	Arabic	NWIO
France (Îles Éparses)	N	0	French	SWIO
France (La Réunion)	N	0	French	SWIO
France (Mayotte)	N	0	French	SWIO
Iran	N	0	Persian	NWIO
Iraq	N	0	Arabic	NWIO
Israel	N	0	Arabic, Hebrew	NWIO
Jordan	N	0	Arabic	NWIO
Kenya	N	0	English, Swahili	SWIO
Kuwait	N	0	Arabic	NWIO
Maldives	N	0	Maldivian	NIO
Mauritius	N	0	French, English	SWIO
Myanmar	N	0	Burmese	SEA
Qatar	N	0	Arabic	NWIO
Saudi Arabia	N	0	Arabic	NWIO
Seychelles	N	0	French, English	SWIO
Somalia	N	0	Arabic, Somali	NWIO
South Africa	N	0	Afrikaans, English	SWIO
Taiwan	N	0	Mandarin	SEA

Thailand	N	0	Thai	SEA
Timor-Leste	N	0	Portuguese	SEA
United Arab Emirates	N	0	Arabic	NWIO
Yemen	N	0	Arabic	NWIO

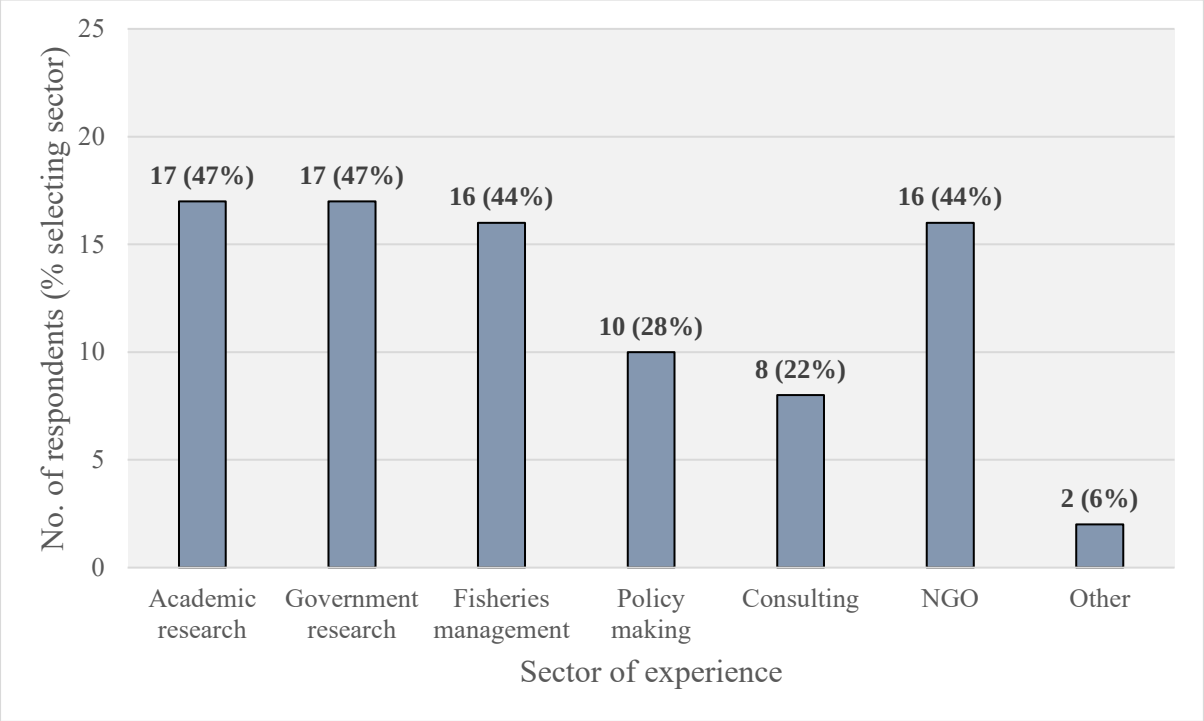

Figure E1. Breakdown of respondents by sector of professional experience. Summed percentages exceed 100% due to respondents being able to select more than one sector.