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

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ABSTRACT

Illegal, unreported and unregulated (IUU) fishing is a pervasive issue that affects economic, social, regulatory and environmental systems in all ocean basins. Research on the ecological impacts of IUU fishing has been relatively underrepresented, with minimal investigation into how IUU fishing may negatively affect populations of marine megafauna, such as sea turtles. To address this knowledge gap and identify priority areas for future research and management, we evaluated IUU fishing as a threat to a marine megafauna species group (sea turtles) in the Indian Ocean and Southeast Asia region (IOSEA). We designed and distributed an online survey to experts in the fields of sea turtle research, marine conservation, fisheries management, consulting and NGOs throughout IOSEA. Our results reveal that IUU fishing is likely to have potentially significant impacts on sea turtle populations in IOSEA through targeted exploitation and international wildlife trafficking. Addressing domestic IUU fishing needs to be actioned as a high priority within the study area, as does the issue of patrolling maritime borders to deter illegal cross-border transhipment. There is a demonstrable need to strengthen MCS and employ regional coordination to help build capacity in less-developed nations. Future research requirements include evaluating IUU fishing as a threat to sea turtles and other threatened marine species at multiple scales, further investigation into market forces throughout IOSEA, and examination of potential barriers to implementing management solutions. We advocate for introducing sea turtle-specific measures into IUU fishing mitigation strategies to help maximize the opportunity for positive outcomes in creating healthy ecosystems and stable communities.

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 and 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 sea turtles (MRAG, 2005; OECD, 2005; UNODC, 2016), the subject has not yet been rigorously investigated. To our knowledge, there has not been any specific assessment of IUU-related threats to sea turtles, despite numerous media reports of illegal sea turtle capture and trafficking by IUU fishing vessels (BOBLME, 2015). Indeed, alongside a growing awareness that criminal organizations 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 sea turtles is one of interest from both a criminological and a conservation perspective.

The Indian Ocean and Southeast Asia region (hereafter IOSEA) provides a highly suitable context for examining the linkages between IUU fishing and sea turtles. Reports of IUU fishing in the Indian Ocean include illegal longlining and turtle mortality in Mozambique (Louro et al., 2006), conflict over fishery access in Somalia (Beri, 2011) and

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decades of unchecked tuna exploitation by unlicensed foreign fleets (Anganuzzi and Secretariat, 2004). In Southeast Asia, hauls of illegally-caught, protected sea turtles have attracted worldwide media attention (Nuwer, 2016), 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. Furthermore, the region's historical subsistence use of sea turtles (Frazier, 1980) is compounded by an increasing modern demand for wildlife products in East Asian markets (Lam et al., 2011). Given the current precarious status of sea turtle populations within IOSEA and worldwide (Wallace et al., 2011), knowledge of IUU fishing as a threat to sea turtles is urgently needed.

To improve our understanding of how threatened marine species are affected by IUU fishing fleets, we evaluated IUU fishing as a threat to a case study species group (sea turtles) in IOSEA. Our study 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 IOSEA and worldwide.

2. Materials and methods

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) (FAO, 2001). Here we 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 organizations (RFMOs), after Agnew et al. (2008). Discards and mortality from legal fisheries were not included in this analysis.

2.2. Study area and designation of sub-regions

Our 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 us to complement existing organizational linkages between the two regions, such as the Indian Ocean and South-East Asian Marine Turtle Memorandum of Understanding (IOSEA-MoU), an intergovernmental conservation agreement ratified by thirty-five countries (IOSEA website, 2016).

We grouped countries into four sub-regions (Fig. 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.

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 sea turtles (Donlan et al., 2010; Fuentes and Cinner, 2010; Klein et al., 2016), typically a challenging task due to sea 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 characterize 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).

2.4. Scope of participants

Selected respondents included specialists in the fields of sea turtle conservation and fisheries and environmental management, from the sectors of government and/or academic research, policy making, consulting and non-governmental organizations (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.

2.5. Survey design

Our 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 and Boone, 2012). In an effort to harmonize with previous studies of IUU fishing in the Asia-Pacific region (APEC, 2008), we sourced several questions from a 2008 survey employed by the Asia-Pacific Economic Cooperation forum (APEC). Questions were evaluated for compatibility with our 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.

2.6. Survey dissemination and data analysis

We used the SurveyMonkey online platform to distribute our 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. Results

3.1. Survey completion metrics and respondent profiles

After sending 107 survey invitations, we received 49 completed surveys from 30 of the 44 countries in IOSEA, representing 68% of IOSEA countries and a 46% response rate overall (Fig. 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.

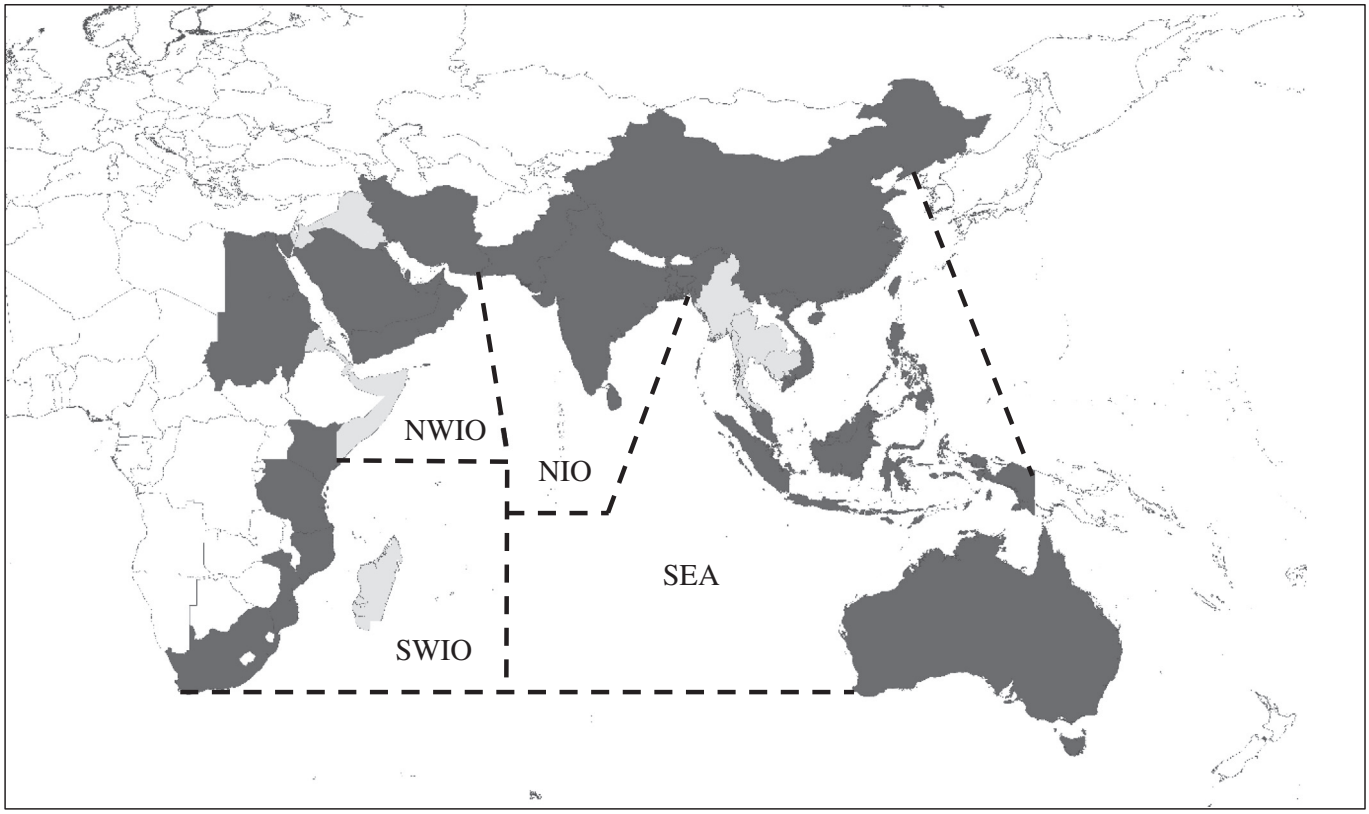

Fig. 1. Summary of responses received and delineation of sub-regions within IOSEA. Dark grey: response received; light grey: no responses received. Sub-regions are defined as: SWIO (Southwestern Indian Ocean); NWIO (Northwestern Indian Ocean); NIO (Northern Indian Ocean); SEA (Southeast Asia).

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 sea turtle interactions and IUU fleets. A more detailed breakdown of the numbers of responses per country is provided in Supplementary material.

Professional experience came from academic research (76% of respondents), non-governmental organizations (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.

3.2. Basin-wide consensus on IUU fishing as a threat to sea 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 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.

3.3. IUU fishing vessel characteristics and practices

3.3.1. Domestic vs foreign IUU fishing

In characterizing 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 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 1).

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 1). In SWIO, foreign industrial fleets were second most-common; NWIO, foreign artisanal fleets; NIO, foreign artisanal fleets; and foreign artisanal fleets were tied with domestic industrial fleets in SEA (Table 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. 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 authorization (very frequently/

Table 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%)

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 sea 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%).

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 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.

3.5. Involvement of sea turtles

Sea 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 sea 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 categorized as 'Never encountered', even by Australian respondents.

Sea turtles were known to be targeted by foreign boats in two sub-regions: SEA (Australia, China, Malaysia, Philippines, Taiwan) and SWIO (Kenya, Mozambique, Seychelles). Transhipment 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 sea turtles in legal and illegal fisheries (nets, trawls) in multiple sub-regions.

3.6. Sub-regional use of sea turtles

3.6.1. SWIO

Responses described the widespread and multipurpose direct use of sea 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 1). The number of IUU fishing events occurring in each country was estimated at over 100 incidents annually.

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 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.

3.6.3. 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.

3.6.4. 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).

4. Discussion

Ours is the first study to synthesize expert assessment of how IUU fishing threatens sea 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 sea turtle populations in nearly every country surveyed within 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 our study is an essential tool for identifying and prioritizing actions to address an otherwise vastly complex issue. We emphasize that our approach bears repeating across multiple geographic scales and has implications beyond sea turtles to the broader arenas of biodiversity conservation, food security and sustainable communities.

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

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 sea turtles illustrates the difficulty of combatting IUU fishing effectively. Though not completely exhaustive, our results indicate that patterns of illegal use can be difficult to interpret and may differ significantly even between neighboring countries (see Table 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. We will therefore place these uses outside the scope of our study, and focus hereafter on the role of IUU fishing vessels in furthering at-sea exploitation of sea turtles for commercial uses.

Respondents identified 'domestic artisanal fleets' as the most common type of IUU fishing vessel operating in IOSEA. When describing the severity of IUU fishing by domestic vessels, respondents were twice as likely to choose 'a widespread and significant problem' rather than '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 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), our 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 (MRAG, 2008; Petrossian et al., 2015). While not all types of IUU activities are equally likely to have direct negative impacts on sea 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 IOSEA and is an ongoing issue for fisheries governance throughout the world (Bray, 2000; HSTF, 2006). In our study, sea 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 our 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 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).

4.2. IUU fishing and the illegal wildlife trade

Our results identified a convergence of themes indicative of the illegal wildlife trade in both the SEA and SWIO sub-regions. Sea 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 transhipment at sea occurring in both sub-regions raises concerns that IUU fishing vessels may play an important role in facilitating the exploitation of sea 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). In our 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 our dataset gives credence to the possibility of links between IUU fishing vessels and the illegal trade in sea turtle products to East Asian markets (i.e. China, Japan, Taiwan; see Stiles, 2008). We argue that IUU fishing vessels may be contributing to the targeted commercial exploitation of sea turtles, and therefore constitute a serious threat to sea turtle populations in the SEA sub-region.

Additionally, the identification of transhipment at sea happening in multiple jurisdictions signifies an organized rather than opportunistic smuggling of illegally-caught sea turtles. Our results report transhipment occurring in the waters of China, Malaysia, the Philippines and Vietnam, suggesting linkages between IUU fishing vessels and regional wildlife smuggling operations. Pilcher et al. (2009) report transhipment of sea turtles by Chinese and Vietnamese poachers in the South China Sea, and a recent survey of fishermen in the Malaysian state of Terengganu indicates awareness of the practice happening in Peninsular Malaysia as well (Riskas et al., unpublished data). 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 transhipment 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), our results demonstrate the importance of exploring and defining the associations between IUU fishing vessels and the trafficking of illegally-caught sea turtles.

Linkages between IUU fishing and a coordinated illegal trade of sea turtles were less extensive but still concerning for the SWIO sub-region. In Kenya and Mozambique, foreign vessels were reported to target sea turtles, with transhipment 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).

Our evidence for a connection between IUU fishing and the illegal wildlife trade adds to the growing body of evidence recognizing IUU fishing as transnational organized crime (Liddick, 2014; Telesetsky, 2014). We 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. While sea turtles are not always identified to species in grey literature reports, our study nevertheless supports the idea of sub-regional species heterogeneity in general fisheries-based interactions (Riskas et al., 2016). Although we are cautious in interpreting our results for sub-regions with low participation (i.e. NIO), recent apprehensions of turtle meat (Langenheim, 2017; Toyos, 2017) highlight the need to improve our understanding of the impacts of IUU fishing on sea turtles in all sub-regions. These efforts notwithstanding, it must be noted that fully stopping the illegal trade of sea 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).

4.3. Use of surveys and data limitations

Our choice of the expert elicitation technique 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 sea 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 minimize latent biases, we suggest that future studies employ 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' are 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. We 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 we 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.

4.4. Future research needs

Examination of the academic literature has highlighted a dearth of published studies investigating the impacts of IUU fishing on sea turtles, despite significant coverage of the issue in news media outlets. We recommend that research effort be directed towards creating these evaluations for sea turtles and other threatened marine species at multiple scales. Furthermore, it would be constructive for regional and international bodies to mobilize their networks to increase the number of participants in survey work, particularly in areas where our 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.

Our results illustrate the varying nature of IUU fishing threats throughout IOSEA, and also point to the possibility of further heterogeneity within individual nations. As the impacts on sea turtles are difficult to quantify directly, it is essential to utilize multi-disciplinary approaches such as ours to address knowledge gaps through the capture and application of local/regional ecological and fisheries knowledge (see Pomeroy, 1995). Future efforts to ground truth our results at smaller, more localized 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 sea 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. Additionally, further exploration is needed for responses in our survey characterizing 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. We recommend that future work explore this idea and other issues of policy uptake within multiple agencies, countries and sub-regions.

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 our 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 subregion. Regarding the need for increasing awareness, our 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 prioritized elsewhere. The recommendations for 'awareness and education' likely reflect the high degree of respondent experience with NGOs (65%). Organizations 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', recognizing 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 and the Regional Plan of Action (RPOA-IUU) in Southeast Asia), a pluralistic regulatory paradigm would capitalize on the interconnectedness of IUU fishing and transnational criminal activity to achieve multiple positive outcomes (Lindley and Techera, 2017). To maximize 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 2016; FAO, 2016). In taking action to strengthen maritime borders and restrict access to markets for IUU vessels, transhipment and offloading of illegally-caught turtles would be similarly reduced.

Increasing our knowledge of IUU fishing will lead to a more holistic understanding of the 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, our findings of illegal capture and transhipment of sea 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 sea 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.

5. Conclusions

Our study brings much-needed attention to the growing problem of IUU fishing and its role in furthering the exploitation of sea turtles and other threatened marine species. We stress the importance of considering IUU fishing as a potentially serious threat to sea turtles through intentional illegal take and international wildlife trafficking. Transhipment of sea turtles across maritime borders indicates a need for increasing MCS capacity, and raises the possibility of organizational 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. We emphasize 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 organized crime. Including sea 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.

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Appendix A. Supplementary data

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