Assessing interactions between marine megavertebrates and small-scale fisheries on the Pacific coast of Guatemala

Rachel Brittain

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Abstract

Many marine megavertebrate species are globally in decline and face increasing pressure as a direct result of fishing through incidental take and/or bycatch. There is increasing evidence to suggest that small-scale fisheries (SSF) in particular have a high impact on vulnerable species of shark, ray and sea turtle. However, these fisheries are globally important, especially in developing countries where they principally operate, providing food and job security and many coastal communities are fisheries dependent. This is true of the SSF which operate on the Pacific coast of Guatemala, but poor governance and a paucity of baseline information threatens their long-term sustainability as well as the species of vulnerable marine megavertebrates that they interact with. The following thesis is intended to improve our understanding of SSF in Guatemala and their impacts on taxa of megavertebrates using a range of techniques, including: onboard observers; shore-based monitoring; fisher interviews; and in-water monitoring. We show that the SSF of Guatemala are multi species fisheries that are versatile and adaptable to changing environmental and economic conditions. Our results show that inshore SSF frequently interact with marine megavertebrates (both targeted and incidental take) many of which are, according to IUCN Red List criteria, threatened and of high conservation concern. Guatemala's SSF are data deficient and further work that employs fishers' knowledge and uses a participatory approach to improve fisheries governance is needed to ensure the long-term sustainability of these important fisheries.

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List of Abbreviations, Acronyms and Conversions

Abbreviations and Acronyms

CBD: Convention on Biological Diversity

CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora

CMS: Convention for Migratory Species

CONAP: *Consejo Nacional de Areas Protegidas*/ National Council of Protected Areas

DIPESCA: *Dirección de Normatividad de la Pesca y Acuicultura*/ Fisheries and Aquaculture Unit

EEZ: Exclusive Economic Zone

EP: Eastern Pacific

FAO: Food and Agricultural Organization

GRT: Gross registered tonnage

IAC: Inter-American Convention for the Protection and Conservation of Sea Turtles

IATTC: Inter-American Tropical Tuna Commission

IUCN: International Union for Conservation of Nature

MAGA: *Ministerio de Agricultura, Ganadería y Alimentación* / Ministry of Agriculture, Live Stock and Food

SIGAP: *El Sistema Guatemalteco de Áreas Protegidas/* Network of Guatemalan Protected Areas

SSF: Small-scale fisheries

UN: United Nations

Conversions

1 km: 0.539 nautical miles

1 nm: 1.852 km

1 tonne: 1000 kg

Author's declaration of contributions to co-authored chapters/research papers

Chapter I: Small-scale fisheries of Guatemala's Pacific coast

Rachel Brittain, Ever E. Rizo-Guardado, Brendan J. Godley and Annette C. Broderick.

In this chapter I describe the small-scale fishing fleet on Guatemala's Pacific coast. It gives an overview of small-scale fishing operations from size and distribution, to gear types used and potential interactions with marine megavertebrates. Data for this chapter were collected and analysed by R.Brittain and E.E. Rizo-Guardado assisted with field data collection at fishing ports. The chapter was written and prepared by R. Brittain under the supervision of A.C. Broderick and B.J. Godley.

Chapter 2: Incidental elasmobranch catches in Guatemala's Pacific coastal fisheries

Rachel Brittain, Ever E. Rizo-Guardado, Brendan J. Godley and Annette C. Broderick.

In Chapter two incidental catches of elasmobranchs in coastal fisheries by small-scale commercial vessels targeting demersal species of finfish and crustaceans is addressed. Data collection onboard commercial fishing vessels and shore based sampling of landings was carried out by R.Brittain with assistance from E.E. Rizo-Guardado. Data analysis and preparation of this chapter was written by RB under the supervision of A.C. Broderick and B.J. Godley. This chapter has been prepared for publication in *Fisheries Research*.

Chapter 3: In-water monitoring of olive ridley (*Lepidochelys olivacea*) sea turtles off the south-east coast of Guatemala

Rachel Brittain, Felicity W. Shapland, Ever E. Rizo Guardado, Brendan J. Godley and Annette C. Broderick.

Chapter three focusses on the vulnerable olive ridley sea turtle (*Lepidochelys olivacea*) and experimented with fisheries independent in-water surveys to determine density and abundance of these turtles at sea. R.Brittain undertook data collection at sea with the assistance of F.W. Shapland and E. Rizo-Guardado. All data was analysed and prepared by R.Brittain and written under the supervision of A.C. Broderick and B.J. Godley. The chapter was published in *Testudo*, the journal of the British Chelonia Group in 2015.

General Introduction

This thesis presents three chapters focussing on the interactions of small-scale fisheries (SSF) on Guatemala's Pacific coast with vulnerable and threatened marine megavertebrates. Guatemala's Pacific coastal waters are extremely productive and support a diverse and abundant array of marine megavertebrates (CBD, 2013). SSF are vital to coastal inhabitants, providing economic and food security to thousands of people, however, there is a paucity of information regarding their size, distribution and operational characteristics (Lindhop *et al.* 2015). This work hopes to better understand, characterise and quantify fishery interactions to ensure that SSF can continue to operate in the future sustainably whilst minimising their impact on vulnerable and threatened marine megavertebrates.

Chapter one describes the small-scale fishing fleet on Guatemala's Pacific coast. Here I review available official government statistics on distribution and capacity (type and number of fishing vessels and fishing gears) of SSF and compile them with survey data collected at 16 fishing sites across the Pacific coast. Information presented in this chapter provides the information needed to contextualise the bycatch of marine megavertebrates such as sea turtles, sharks and billfish caught by these fisheries.

Chapter two assesses incidental catches of elasmobranchs in coastal fisheries by small-scale commercial fishing vessels targeting demersal species of finfish and crustaceans. Using a mixed method approach of on board observations, shore based sampling of landings, harbour based surveys and fisher interviews we were able to determine the size and composition of the artisanal fishing fleet which enabled us to quantify direct and indirect take of elasmobranchs and estimate annual catch rates per fishing gear. High levels of incidental elasmobranch take were recorded in non-target fisheries with many species of high conservation concern. This work highlights the need to improve monitoring and management of small scale fisheries in order to concern some of the world's most critically endangered species of elasmobranch.

Chapter three focusses on the vulnerable olive ridley sea turtle (*Lepidochelys olivacea*), the most abundant sea turtle in Guatemala and for which exists a commercially important legal egg harvesting trade. In Guatemala, knowledge or

distribution and abundance of olive ridleys remains scant and overlap with artisanal fisheries is poorly studied. We used at sea sampling to fill this knowledge gap and further understand the temporal distribution of male and female olive ridley turtles that utilise Guatemala's Pacific coastal waters. This preliminary work shows high densities of turtles utilising Guatemala's coastal waters and suggests that the area may be significant within the eastern Pacific (EP) which may make them susceptible to coastal fishing activity.

Chapter I: Small-scale fisheries of Guatemala's Pacific coast

Rachel Brittain* [ab], Ever E. Rizo-Guardado [b], Brendan J. Godley [a] and Annette C. Broderick[a]

[a] *Centre for Ecology and Conservation, University of Exeter, Penryn Campus, Cornwall, TR10 9FE, UK.*

[b] *Akazul: Community, Conservation & Ecology, 34 Honiton Road, Exeter, Devon, EX1 3ED, UK.*

ABSTRACT

Small-scale fisheries (SSF) on Guatemala's Pacific coast are an important source of food and employment for coastal communities. According to official statistics the SSF sector comprises 3473 vessels across Guatemala's 254km Pacific coast and directly employs 9882 fishers, which is more than the medium to large-scale industrial fleet. SSFs have increased in parallel to the growth in the human population and are anticipated to continue to grow by 50% by the year 2040. Without suitable governance and monitoring, pressure on marine fisheries will increase and may lead to overexploitation. Baseline data on fleet size and structure is essential to adequately manage SSF activity. We surveyed 16 fishing ports located on Guatemala's Pacific coast carrying out vessel counts and fisher interviews in order to provide a detailed description of the SSF including; principal fishing gear used, target species and insight into the chain of commerce for fisheries products. Demersal finfish and shellfish were targeted at 14 (of 16) sites, with a distinct pelagic fleet targeting dolphinfish (*Coryphaena hippurus*) and shark operating out of just two of the sites visited. Results from fisher interviews highlighted catches of shark, turtle and billfish. We discuss the importance of these fisheries to Guatemala's coastal inhabitants as well as long-term sustainability concerns. We conclude that these fisheries would benefit from improved management, the importance of generating up to date information on SSF for the entire Pacific coast and the need to introduce mitigation measures to reduce incidental catches and utilisation of vulnerable or threatened marine megavertebrates.

INTRODUCTION

Small-scale fisheries (SSF) are sometimes described as artisanal and the terms are often used interchangeably. These fisheries may utilise various gear types ranging from traditional and simple to modern, some fish without a boat and others fish with motorised vessels (Salas *et al.* 2007). Catches from these fisheries can contribute to food for household consumption but are also sold by the fishers themselves, by family members at the market, or through a local commodity chain (Chuenpagdee *et al.* 2006).

SSF are of significant economic importance providing food and job security to the economies of some of the world's poorest countries (Andrew *et al.* 2007) and are responsible for between 25 and 33% of global fisheries production (Chuenpagdee *et al.* 2006). It is estimated that 200 million people are dependent on SSF globally, both directly as fishers and indirectly through associated livelihoods such as processing and sale of products (Delgado *et al.* 2003), which represents more than 90% of the world's fishers (World Bank/FAO/WorldFish, 2010). The FAO (2005a) estimated that 95% of SSF activity is focussed in developing countries. Subsequently, the importance of sustaining these fisheries is becoming increasingly recognised within fisheries management and development policy (Allison 2001; Allison and Horemans, 2006; Béné, 2006), particularly in rural coastal communities where poverty is high (Béné, 2003), there are limited economic opportunities and income generation is dependent on the harvesting of natural resources. In many of these areas population density is rising and with ongoing coastal migration and sprawl, sustainable use of marine resources becomes challenging (Salas *et al.* 2007). Fisheries collapse, through overcapacity and unsustainability, threatens many coastal fisheries around the world (Salas *et al.* 2007)*.* Most SSF located in the tropics and sub-tropics are showing signs of over-exploitation and excess fishing capacity (Erhardt and Deleveux, 2007).

Despite their potential to alleviate poverty (FAO, 2005a), knowledge of SSF is extremely limited (Salas *et al.* 2007), with a paucity of even the most basic information pertaining to fleet size and structure and overall contribution to annual fish production (Béné, 2006; Salas *et al.* 2007; Andrew *et al.* 2007).

Often there is no distinction between marine and inland fisheries (World Bank, 2008) and landings are unrecorded or combined with those of industrial fleets, with the latter dominating national statistics due to a higher volume of production (Chuenpagdee *et al.*; 2006; Salas et al. 2007; World Bank, 2008). Subsequently, landings and overall contribution of these fisheries are underestimated if not disregarded entirely (Chuenpagdee *et al.* 2006). Logistical challenges associated with sampling these fisheries relate to their inherent complexity such as the sheer number and high diversity of vessels within the sector (Chuenpagdee *et al.*, 2006) as well as limited infrastructure and poor access within the developing countries where they predominantly operate (Allison, 2001; World Bank, 2008).

Resource depletion, poor economic performance, food insecurity and social stress are all characteristics of SSF, particularly in developing countries where there are limited development alternatives (Graaf, *et al.* 2011). Lack of information, poor management and weak governance of SSF is leading to devastating ecological impacts from overexploitation of target species to indiscriminate fishing (Salas *et al.* 2007). One such negative impact is bycatch, defined as incidental capture and discard of unwanted species within a fishery (Davies *et al.* 2009), particularly in relation to vulnerable or threatened species of megafauna (e.g. sea turtles, sea birds and small cetaceans). Incidental catches of megafauna in SSF have been reported as significant (see: Peckham *et al.* 2007; Mangel *et al.* 2010; Alfaro Shigueto *et al.* 2011; Zydelis *et al.* 2013; Rojas-Bracho and Reeves, 2013) and have the potential to extirpate some populations of megafauna (Peckham, 2007; Rojas-Bracho and Reeves, 2013). It is assumed that these SSF have a low discard rate in comparison to industrial fisheries (Kelleher, 2005), however, when there are few fishing regulations the retention of incidentally caught and undersized species, such as shark (Alfaro *et al.* 2010; Dapp, *et al.* 2013; Doherty *et al.* 2014) can also be detrimental to sustainability of a fishery (Davies *et al.* 2009). Economic necessity often outweighs the need to protect the environment in fishery-dependent communities where SSF operate (Salas *et al.* 2007) and changes in fishing behaviour occur simultaneously with resource depletion (Kelleher, 2005). In some fisheries, immature individuals of commercially important pelagic species of elasmobranch can be important catch components of seasonal coastal fisheries (see Bizzarro *et al.* 2009). Such practices are damaging to vulnerable taxa such as shark

and batoid whose life history parameters include; slow growth, late maturity and low reproductive output and as a consequence one-quarter of chondrichthyans are threatened according to IUCN Red List criteria due to overfishing (targeted and incidental) (Dulvy *et al*. 2014). In order to effectively manage SSFs, ensuring long-term sustainability and minimising negative effects on the marine environment, these issues need to be addressed. Country specific baseline data is urgently required in order to develop effective mitigation strategies and reduce the potential and irreversible long-term negative impacts (Graaf *et al*. 2011).

Guatemala, with a current population of just over 16 million (World Bank, 2016), has the largest population of any other Central American country and is predicted to increase by 50% over the next 25 years (USAID, 2012). The country has an extensive Exclusive Economic Zone (EEZ) that covers over 117,000 km of marine habitat (www.seaaroundus.org). Most fishing takes place on the continental shelf of the Pacific coast which also hasa greater proportion of the coastal population (FAO, 2000). Coastal goods and services are estimated to generate between US$216 - 314 million in annual revenue for Guatemala (Yon Bosque, 2011).These resources sustain the livelihoods of the numerous impoverished communities that inhabit the six departments located on Guatemala's Pacific coast, most of which are considered to be fisheries dependent (Velasco, 2009). Fisheries management falls under the remit of the Fisheries and Aquaculture Unit (DIPESCA), a subdivision linked with the Ministry of Agriculture, Cattle Ranching, and Nutrition (MAGA), responsible for the administration and enforcement of fishing regulations and laws which are published in the Guatemalan Fisheries and Aquaculture General Law (MAGA, 2005). Within this law, fishing activity is divided into four categories 1) Commercial fishing, 2) Sports fishing, 3) Scientific fishing and 4) Subsistence fishing, each with its own set of regulations. Commercial fishing operations are then further divided into four main categories; artisanal, small-scale, medium-scale, large-scale and tuna fishing and is each group is classified according to their Gross Registered Tonnage (GRT) (Lindhop *et. al*. 2015). All commercial fishing enterprises must purchase a fishing licence and are subject to restrictions and in the case of artisanal and small-scale fishing activity the law states that it is an activity restricted to Guatemalan vessels only.

Artisanal fishing is classed as any fishing activity performed within inland waters and the sea without use of a boat or with vessels <0.99 GRT. Small-scale commercial (SSF) is described as any fishing activity which is performed for personal gain and performed with vessels between 1 and 1.99 GRT. Permitted gear types for SSF operations are as follows; nets, longlines, hooks and lines and traps/pots (MAGA, 2005). Here after, the term SSF will be applied to both artisanal and small-scale fishing operations.

SSFs contribute to 31.6% of Guatemala's total fisheries catches, and 28% of total catch on the Pacific coast (Lindop *et al.* 2015). Despite their economic importance, little attention has been paid to the SSF sector and governance and management of marine and coastal resources in general is poor (MARN, 2009). In a recent report by Lindop *et al.* (2015), reconstructed marine fish catches showed that Guatemalan fisheries are overfished with overall catches increasing during the late 1990s and then declining in the 2000s. This is consistent with continued population growth and is likely that effort from artisanal fisheries also increased whilst catches declined (Lindop *et al.* 2015).

Guatemala's Pacific waters provide habitat for many species of marine megafauna (CBD, 2013), a number of which are listed as vulnerable, endangered or critically endangered by the IUCN RedList (Version 2015-4) including five species of sea turtle, scalloped hammerhead (*Sphyrna lewini*), great hammerhead (*Sphyrna mokarran*), pelagic thresher (*Alopias pelagicus*) and oceanic whitetip (*Carcharhinus longimanus*) shark (www.iucnredlist.org) but there is little information on the interaction between these species and the fisheries. Turtles are protected under Guatemala's Fishing Law (Article 80 g) which states that it is prohibited to "*capture or target marine mammals, sea turtles or other species that are threatened or in danger of extinction*". However, it has been previously reported that some commercial fishers may illegally use incidentally caught olive ridley turtles (*Lepidochelys olivacea)* to bait longlines and some commercial fishermen also remove eggs from captured gravid females (Brittain *et al.* 2007; Higginson 1989).

Shark are often targeted by small, medium and large-scale (industrial) fisheries working beyond 20 nautical miles within Guatemala's Pacific EEZ (MAGA, 2005)

with catches mainly composed of silky shark (*Carcharhinus falciformis*) with smaller numbers of black tip (*Carcharhinus limbatus*)*,* whitenose (*Nasolamia velox*)*,* thresher (*Alopias pelagicus*) and scalloped hammerhead (*Sphyrna lewini*) shark (Ruiz *et al.* 2000). Chondrichthyans in general are considered to be one of the most globally threatened groups on the planet as a direct result of overfishing, especially large shark and batoid that inhabit shallow waters that are most accessible to fisheries (Dulvy *et al.* 2014). Despite international concern, Guatemalan law permits targeted fishing of six families of shark; Alopiidae, Carcharhinidae, Ginglymostomatidae, Lamnidae, Sphyrnidae, and Triakidae, which are grouped together as one resource because they occupy the same zones and are captured by the same gear (article 27, MAGA, 2005). Within this fishery there are no minimum landing sizes and restrictions pertain only to effort with a limit of 1000 hooks permitted on the mother line and hooks must be no less than 3.81 cm (article 29a, MAGA, 2005).

Guatemala is a member of several international fisheries organisations including the International Commission for the Conservation of Atlantic Tunas (ICCAT), the Western Central Atlantic Fishery Commission (WECAFC), the Central America Fisheries and Aquaculture Organization (OSPESCA), and the International Whaling Commission (IWC). It is also a signatory member to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Convention on Biological Diversity (CBD) and the Inter-American Convention (IAC) for the Protection and Conservation of Sea Turtles. Although Guatemala is classed as a "range state" with regard to sharks it is not a party to the Convention on Migratory Species (CMS) (CMS, 2016). Within the Guatemalan Law of Protected Areas (1989) biodiversity is identified as a key component of natural heritage which must be conserved through effectively managed protected areas. This network of protected areas, *El Sistema Guatemalteco de Áreas Protegidas* (SIGAP), is governed by the National Council of Protected Areas (CONAP, 2015). Of the current 322 SIGAP sites only six are marine or coastal which accounts for just 5.5% of the country's total protected areas. However, a further 11 coastal and marine sites have been proposed for inclusion into the network, ten of which are located on the Pacific coast (CONAP, 2016).

Few studies have been carried out to describe the characteristics of the SSF of Guatemala's Pacific coast (see Valle 1999; Ruiz and Lopez, 1999; Ruiz *et al.* 2000; ATP 2004; Morales *et al.* 2005) and many of these studies are over ten years old, with limited geographical coverage and inconsistencies in data reporting. Even fewer studies have addressed incidental catches of marine megavertebrates (Davila, 2009; Cuellar, 2009). In this study we review existing official government statistics to provide an estimate of the size and structure of Guatemala's SSF. We use harbour surveys and questionnaires to further augment this information and provide a detailed description of the SSF including; fishing activity, gear types, target species, effort, an insight into the commodity chain of fisheries products and marine megafauna bycatch.

METHODS

This study was approved by the University of Exeter Ethical Committee (2014/652) and adhered to the Code of Human Research Ethics set out by the British Psychological Society. Informed consent was obtained from all subjects and identities remained anonymous.

Information on SSF was obtained from the FAO country profile (2005b) to obtain an overview of the number, location and distribution of landing sites on the Pacific coast of Guatemala. According to official government statistics there are 46 small-scale commercial and subsistence artisanal fishing communities on Guatemala's 254 km Pacific coast, across six departments; San Marcos, Retalhuleu Suchitepéquez, Escuintla, Santa Rosa and Jutiapa (FAO, 2005b) (Fig. 1).

Between October 2013 and July 2014 we conducted harbour surveys and fisher interviews at 16 sites within five of the six coastal departments (Table 1). Site selection was based on past FAO (2005b) fisheries statistics and we focussed on areas with the most reported activity and site accessibility. Access to sites west of Sipacate was difficult due to poor infrastructure and sampling effort was restricted to three sites. At each fishing site we conducted basic vessel counts and collected information by interviewing crew members of vessels or leaders of community fishing associations. Interviews were designed for rapid data collection, each containing key questions; number of vessels operating, length of trips, principal gear type used by

the fleet, defined as gear type used >50% of the year, target species, and marine megavertebrates (e.g turtles, shark, batoid and billfish) catches (incidental and targeted). At three of these sites (el Hawaii, el Cebollito and la Curbina) we were unable to locate fishers to participate in interviews and it was only possible to carry out basic vessel counts.

RESULTS

The FAO (2005b) reports 46 fishing sites across the 254 km Pacific coast of Guatemala, however, two sites that we visited during harbour surveys were not reported (El Cebollito and La Curbina). A further four sites included in official statistics were known as inland mangrove fishing communities and omitted from our results, giving a revised figure of 44 SSF sites on the Pacific coast.

Description of the SSF fleet

Information collected during harbour surveys and fisher interviews enabled us to determine the composition of the fishing fleet in relation to gear type and target species at 16 fishing sites across five of the six coastal departments (Table 1). Within the classification of SSF there were two distinct sectors of the fleet, one which can be classed as inshore and the other as offshore.

The inshore fleet was generally located at the smaller coastal sites, with very basic landings facilities (vessels would launch from the beach) and were usually family run ventures. These vessels worked in near shore neritic waters less than 20 nautical miles from the coast with trips lasting for up to 24 hrs. Vessels favoured bottom set gear targeting demersal fish species including; snapper, catfish and grunt. Length of vessel was between 5 and 6 m with engines between 15 and 40 HP. The site of Sipacate differed slightly from other inshore sites with more advanced landing facilities, a purpose made dock hosting numerous small enterprises with an ice machine and fileting stations. Trip duration was also slightly longer, up to 3 days however fishing occurred in near shore neritic waters.

In contrast, the offshore fleet were located in sites with more sophisticated landings facilities (such as ice machines) at San Jose and Buena Vista. Vessels were mostly made of fibreglass from 3.6 to 10 meters in length using motors of 75 HP with an

auxiliary motor of 45 HP (FAO 2005b) and with a capacity of 1588 kg (Ruiz *et al*. 2000). These vessels typically undertook trips lasting three nights at sea, with three crewmen working up to 150 nm offshore. Fishers utilise pelagic long-lines known as a "*cimbra*" which consists of a polyethylene mainline measuring between 3 – 6 miles and an average of 400 baited hooks (Ruiz et al. 2000). Main species targeted were silky (*Carcharhinus falciformis)* and pelagic thresher *(Alopias pelagicus)* sharks and dolphinfish (*Coryphaena hippurus).*

Interviews and observations of fishing activity and landings revealed that there were two distinct fishing seasons corresponding to rainy (June – November) and dry (December to April) seasons, the latter being the least productive of the two, with variable catches. In San Jose, landings were very sparse and sporadic during February and March and we observed few shark or dolphinfish landed but saw an increase in sailfish landed. Although fishing was more productive during the rainy season, activity was limited in some sites by wave size as entrance into the sea was dangerous. At the sites of Las Mananitas, El Rosario and El Dormido locals commented on predictably large tides towards the end of March and beginning of April known as *Aguajones Marziales* making entry into the sea extremely difficult and dangerous. During this time, few vessels at these sites operated owing to low profitability from trips due to small catches of target species.

Commercialisation of catch

During interviews and observations made at landing sites, we learned that catches from the smaller inshore fishing fleet were largely sold to a domestic market. The majority of fish was sold fresh to merchants travelling in pick-up trucks along the coast buying fish from approximately five coastal sites between Puerto San Jose and El Dormido. A small amount of fish was sold to local merchants supplying the local domestic market and the remainder purchased by small scale merchants who buy a variety of seafood which is then transported this to the large fish market known as *El Terminal* in Zone 4 of Guatemala City. Specific high value, commodity items including; dried eel swim bladder, live puffer and grouper fish were reported to be sold to an international market, which included Korea and El Salvador.

From March to April, leading up to Easter the Catholic celebration known as Holy Week or "*Semana Santa*", there is great demand for fish and prices are at their highest. Traditionally dried and salted fish can fetch more than double the price of fresh fish and fishers would often process the fish themselves to increase profit. Catches of key target species such as grunt and croaker are sporadic during this time and a relatively new fishery targeting two species of piked conger eel known locally as *Anguila blanca* (unidentified species) and *Anguila amarilla* (*Cynoponticus coniceps*) has emerged. Meat of the eel is sundried and salted, sold to a local Guatemalan market which is highly prized during *Semana santa* and swim bladders or are removed, sundried and sold to an international market. One pound (0.45kg) of dried swim bladder can fetch between 600 and 1000 QTZ/ $79 - $131 USD.

The more sophisticated landing and processing facilities at San Jose have opened up international trade and one of the most important exports from the SSF is dolphinfish which goes to the USA. According to official statistics, fresh and dried meat, fins and skin are shark products exported from Guatemala, with 72% of products exported to Mexico followed by 22 % to the USA, 3% to Hong Kong and 3% to other countries (Ruiz and Lopez 1999). Domestic consumption of shark products is also common, with small shark often used in ceviche and oil is readily available to purchase in coastal villages and towns as a remedy for respiratory problems (Brittain pers. obs.).

Marine megavertebrates catches

Of the 13 sites where 44 interviews were carried out, all reported catches of marine megavertebrates (Table 1). Difficulties arose when applying the term "bycatch" (see Davies *et al.* 2009) to megavertebrates catches. Observations of landings and interviews revealed that although shark were not targeted at the smaller inshore fishing sites, they were occasionally caught and utilised with catches mainly comprising smaller individuals. At the larger site of San Jose, we observed landings of sailfish and small shark specimens from the dolphinfish fishery, which were not targeted but still retained and utilised. Incidental catches of; shark were reported at all 13 of the sites, six sites reported turtles and two reported billfish catches. From interviews we were also able to derive an unconfirmed species list, which comprised;

13 species of shark, four turtle species and two billfish, based on local names and descriptions (Table 2). The scalloped hammerhead was the most frequently reported species of shark and was reported at all but one of the sites visited. The olive ridley was the most common turtle species reported as incidental take. The offshore fleet targeting pelagic species reported catching all three marine megavertebrates taxa.

DISCUSSION

This study is the most recent assessment of Guatemala's SSF, compiling all available literature and existing official statistics on the fishery including number of fishing/landing sites, number of fishers, fleet size, and landings. This provides an important baseline for improving understanding of how and where these fisheries operate. We found that the broad definition of SSF in Guatemala in fact encompasses two distinct types of fishing activity; 1) offshore fleet targeting larger pelagic species such as shark and dolphinfish which largely supplies an international market, and 2) an inshore fleet predominantly targeting demersal species of fin fish and crustaceans supplying a domestic market. Harbour based surveys and interviews offered more detailed information on fishing operations at the smaller under represented sites and preliminary information on catches of marine megavertebrates.

SSF are of significant economic importance within coastal communities where there are limited employment opportunities (Salas *et al.* 2007; World Bank, 2008). The FAO (2000) reported a total of 3892 SSF vessels and 7652 fishers directly employed through SSF between1998–1999 and increased to 4320 vessels and 9882 fishers by 2005 (FAO, 2005b). In terms of number of vessels this was an increase of 11.0% over five years. Employment and growth within the SSF can be linked to Guatemala's rapidly growing population. In 2000 the population stood at approximately 10.5 million people (FAO, 2000) and grew to 12.3 million people by 2005 (FAO, 2005b). The current population stands at 16.0 million people (World Bank, 2016) and is predicted to increase by 50% by 2040 to 21 million people (USAID, 2012). Following previously observed trends, this could see a significant increase in the size of the SSF fleet and as a consequence, it is inevitable that the dependency on natural resources, in particular fisheries, will increase especially if

land-based employment opportunities were unable to support the growing population (Lindop *et al.* 2015). Globally, for many of those engaged in SSF, often the need to generate economic income is stronger than the need to protect the environment (Salas *et al.* 2007) and Guatemala will undoubtedly face similar sustainability challenges that have been reported in other Latin American fisheries (see Salas *et al.* 2007).

During harbour surveys at 16 sites we recorded a total of 1051 fishing vessels, which is unexpectedly lower than the 1796 reported at these same sites by the FAO in 2005. This may be due to variation in fisheries classification between the two studies. As discussed previously, several fishing communities reported by the FAO (2005b) were omitted from our study as they were known to be inland fishing communities not marine fishing communities. It is likely that the FAO (2005b) vessel counts may have also included inland fishing vessels thus giving higher totals. The alternative is that the number of fishing vessels has decreased since 2005 which is highly unlikely and contrary to previously observed trends.

Anecdotal information yielded from our interviews suggests changes in fishing behaviour over the last decade with a shift to previously non-target species becoming commercially important (e.g. batoid, eel). Change can be attributed to several factors including; declining target species, and emerging international markets (see Defeo *et al.* 2013). Such shifts in fishing behaviour have been observed in many of the world's fisheries (see Kelleher, 2005) and can be summarised as ''yesterday's bycatch may be tomorrow's target catch'' (Murawski, 1992). This is likely to be more pertinent for Guatemala, whose fisheries are affected by unpredictable oceanic conditions such as el Niño and may affect target fisheries, leading to a change in fishing behaviour. Throughout Latin America climate variability, globalisation of markets and governance, combined with climate variability (e.g. wind intensity, sea surface temperature anomalies), have been documented as intensifying stock depletion in SSFs (Defeo *et al.* 2013). This further highlights the importance to effectively manage Guatemala's SSF to ensure the long-term sustainability of these fisheries for a growing human population.

Impact of SSFs on marine megavertebrates

Guatemala's SSFs are data-deficient and there is limited accessible information on catches (both targeted and incidental) of marine megavertebrates. Interviews allowed a rapid and low cost approach to gathering preliminary data on species encountered, across multiple sites, and enabled us to identify taxa of marine megavertebrates most vulnerable to SSF activity. Although we had intended to specifically identify species taken as bycatch, this classification was not appropriate for what we observed. In the case of shark and sailfish, although they were not specifically targeted, often incidentally caught individuals were landed and utilised and contained undersized individuals of target species. This type of non-targeted catch utilisation is frequently observed in SSF, particularly when fisheries are multi-species and fishermen opportunistically utilise any catch that has a commercial value (see Kelleher, 2005; Defeo *et al*. 2013; Doherty *et al*. 2014). Shark, batoids and billfish were the three megavertebrates taxa reported during interviews and unconfirmed species included five listed by the IUCN (2015) as endangered or critically endangered (IUCN, 2015).

Of the 13 species of shark reported, five are listed as near threatened; silky (*Carcharhinus falciformis*) (Bonfil *et al*. 2009), bull (*Carcharhinus leucas*) (Simpfendorfer & Burgess, 2009), blacktip (*Carcharhinus limbatus*) (Burgess & Branstetter, 2009), tiger (*Galeocerdo cuvier*) (Simpfendorfer, 2009), blue (*Prionace glauca*) (Stevens, 2009); two vulnerable; pelagic thresher (*Alopius pelagicus*) (Reardon *et al*. 2009) and oceanic whitetip (*Carcharhinus longimanus*) (Baum *et al*. 2015), and two endangered; scalloped hammerhead (*Sphyrna lewini*) (Baum *et al*. 2007) and great hammerhead (*Sphyrna mokarran*) (Denham. *et al*. 2007). Of turtle species reported, olive ridley (Abreu-Grobois & Plotkin, 2008) and loggerhead (*Caretta caretta*) (Casale & Tucker, 2015) are listed as vulnerable, eastern Pacific green (*Chelonia mydas*) (Pilcher *et al*. 2012) are endangered, and hawksbills (*Eretmochelys imbricata*) (Mortimer & Donnelly, 2008) are critically endangered. Further work is needed to quantify levels of mortality, annual catch and temporal variation of catches for each of the three main taxa identified and these results should be considered preliminary.

Shark were the most susceptible to capture in SSF with incidences reported in both inshore demersal and offshore pelagic fisheries at all the survey sites. This is cause for concern especially as shark specific landings reported by Ruiz *et al.* (2000) show large declines in targeted catch. Landings figures also highlight the importance of shark to the SSF fleet operating from the two large fishing ports of San Jose and Buena Vista. Landings data reported between 1992 and 1998 show that SSF landings were significantly higher than those reported by the industrial fleet (Ruiz *et al.* 2000). Peak SSF landings were reported in 1995 at 142 tonnes but were followed by severe declines with just 17 tonnes reported in 2000 (see Ruiz *et al.* 2000).

Throughout the eastern Pacific (EP), many elasmobranch populations are declining (Baum *et al.* 2007; White *et al.* 2015) however there is a lack of time-series data (White *et al.* 2015) and many species are listed by the IUCN as data deficient (IUCN 2015). It is well documented that elasmobranch species display size and sex segregation with neonates, juveniles and gravid females predominantly using nearshore coastal habitats and adults, particularly of the larger pelagic species, using offshore waters (Heupal *et al.* 2007). Given that Guatemala's SSFs operate both within coastal and pelagic waters, for some species, such as scalloped hammerheads *S. lewini*, fishing activity overlaps with habitat utilised by all life stages.

Sailfish occur in large numbers in an area of the EP which includes Guatemala (Collette *et al.* 2011) and support multi-million dollar catch-and-release sport fisheries (Ehrhardt and Fitchett, 2006). It is also thought that sailfish are taken as by-catch in expanding coastal artisanal long-line fisheries across their EP range (Ehrhardt and Fitchett, 2006). In Guatemala, commercial catch and sale of sailfish is prohibited under Guatemalan law (article 80j, MAGA, 2005), however during this study landings were frequently observed at the larger fishing ports. During the study a high level of conflict was observed as enforcement efforts were increased at major fishing ports which led to a number of arrests and prosecutions. Fishermen interviewed during the study reported that sailfish are not targeted by long-liners but captured incidentally and are often found in convergence zones along with target species (dolphinfish and shark) dead after hauling. However, it is likely that in times of poor fishing, targeted fishing and utilisation may occur (Brittain pers. com.).

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International demand for dolphinfish, particularly from the U.S.A, has increased significantly since the 1990's and subsequently local artisanal fisheries have developed longline fisheries targeting this species (Ehrhardt and Fitchett, 2006). Dolphinfish landings are already showing signs of overexploitation with declines reported since 2000, most likely as result of overcapacity of the fishing fleets (Ehrhardt and Fitchett, 2006). Sailfish are an important species of bycatch in these fisheries and it is assumed that fishing mortality levels are high throughout the Pacific (Kitchell *et al.* 2006), especially as fishers now claim the need to make better use of the incidental catch (Ehrhardt and Fitchett, 2006).

In Guatemala, sailfish meat is not valuable, but widely available, most notably in times of poor fishing particularly in the lead up to Easter "*Semana santa"* when demand for fish is high but desired species are unavailable. Although sailfish present the opportunity for economic and social development through sports fishing tourism, due to the number of SSF fishers that are likely to be dependent on sailfish catches further work is needed to address overall fisheries sustainability and management whilst addressing incidental take at sea and identify areas of negative interaction. Sailfish are a fast growing species and are thought to reach sexual maturity at 2.5 years of age (Collette *et al.* 2011). The species is listed as least concern by the IUCN (2015) and given its life history parameters, has the potential to withstand controlled and managed fishing pressure.

Survey effort and consistency of data reporting

Distribution of sampling was constrained by logistical considerations such as transportation infrastructure, travel distance and safety (i.e. avoiding areas of civil unrest). Interviews focussed on those harbours identified as the most relevant to the study (i.e largest number of vessels). However due to time and logistical constraints we were unable to visit Guatemala's second largest fishing port of Champerico located in the department of Retalhuleu, where a small fleet also target shark. Future work should incorporate a greater number of sites on the west of the coast to ensure better representation. Interviews were successful for rapid gathering of information however consistency of data reporting varied across survey sites due to the sensitive nature of questions, especially on bycatch. It was perceived that many fishermen

were reluctant to report accurate information to the interviewer particularly with regard to sea turtles, which are protected species.

Future work

Information on the status and trends of fisheries, as well as socio-economic aspects, are vital for the development of responsible fishery management (Graaf, 2011). Reliable and current landings statistics for Guatemala's SSF are largely unavailable and data is somewhat piecemeal coming from a number of sources all with inconsistencies in reporting (Lindop *et al.* 2015). Time series, species specific, annual trends for the fleet are absent and this presents management problems considering, the size, scale, distribution and economic importance of Guatemala's SSF to the numerous people who are directly or indirectly dependent on them. Considering the reconstructed landings data from Lindop *et al.* (2015) and shark landings data reported by Ruiz *et al.* (2000) all evidence suggest that Guatemala's Pacific coast fisheries are overexploited. Further attention from managers and decision makers is needed to ensure that these fisheries are sustainable in the long term and without adequate baseline landings information this cannot be achieved. Utilising fishers' knowledge is proven to be of great benefit fisheries management (Mathew, 2011) and can be effective in developing countries where there is little institutional capacity for generating information on status of fish stocks (Mathew, 2011).

Location of fishing sites reported in official FAO fisheries statistics can be used as a basis for future work to help determine where to focus efforts. We observed very little variation in the species targeted between the sites, with demersal species of finfish and crustacea being of greatest importance to the inshore fleet and annual landings for larger fishing sites could be obtained by working closely with the 40 fishing cooperatives that exist on Guatemala's Pacific coast (FAO, 2005b).

Although there have been recent attempts to improve the laws and regulations governing fisheries there is still the need for much improved governance, regulation and effective enforcement recommended, in particular improved recording of catch data in SSFs (Lindop *et al.* 2015). Given the vulnerable conservation status of the marine megavertebrates taxa reported in SSF we would also recommend additional

action to reduce the impact of fisheries on these taxa. A shark specific management plan for Guatemala that enhances current international conservation efforts within the EP is highly recommended. More detailed information on species composition, sex, maturity and size of catches as well as annual landings totals is required as a basis to develop national management decisions. At present there are no restrictions in place for shark fisheries in Guatemala and several species of conservation concern, such as scalloped hammerheads, are taken as both target catch and bycatch, many of which are undersized or gravid females (pers. obs. Brittain). Future approaches to promote sustainable fishing practices, including reduction of bycatch through gear selectivity, should be practical, cost effective and take a collaborative approach, specifically considering the behaviours, motivations and attitudes of fishers (Campbell and Cornwell, 2008) to ensure a positive change.

ACKNOWLEDGEMENTS

Table 1. **Location of harbour surveys** conducted at 16 sites across 5 coastal departments on the Pacific coast of Guatemala. Table includes a comparison between number of vessels recorded by the FAO (2005b) and number recorded during the survey, as well as number of interviews, principal gear type utilised, fishing area per location, target species and reported megavertebrates catch by three main taxa (turtle, shark and billfish).

Port	Department	No. of vessels FAO	No of vessels	No. of interviews	Gillnet (%)	Longline (%)	Fishing area	Target species	Turtle	Shark	Billfish
La Barrona	Jutiapa	53	2	2		100	Neritic	Snapper		X	
El Jiote	Jutiapa	44	ND	1		100	Neritic	Snapper, marine catfish, batoid		X	
Las Lisas	Santa Rosa	277	50	5	100		Neritic	Shrimp, snapper, Pacific sierra		X	
El Dormido	Santa Rosa	30	9	2		100	Neritic	Grunt, croaker, corvina, berrugato, catfish, eel	X	X	
El Rosario	Santa Rosa	23	13	4		100	Neritic	Grunt, croaker, corvina, berrugato, catfish, eel		X	
Las Mananitas	Santa Rosa	43	75	35*		100	Neritic	Grunt, croaker, corvina, berrugato, catfish, eel, batoid	X	X	
Hawaii	Santa Rosa	93	1	0		100	Neritic	No data			
Cebollito	Santa Rosa	ND	9	0			Neritic	No data			
La Curbina	Santa Rosa	ND	4	0			Neritic	No data			
Monterrico	Santa Rosa	152	25	2	99	1	Neritic	Pacific sierra, quinoa, shrimp, snapper	X	X	
Buena Vista	Escuintla	309	~200	4		100	Oceanic & Neritic	Shark, dolphinfish, snapper		X	X
Puerto San Jose	Escuintla	385	~400	10		100	Oceanic & Neritic	Shark, dolphinfish	X	X	X
El Paredon	Escuintla	115	25	8	100		Neritic	Pacific sierra, threadfin, colita amarillo, marine catfish		X	
Sipacate	Escuintla	226	~200	2	100		Neritic	Shrimp, Corvina, snapper, Pacific sierra, berrugato	X	X	
Chiquistepeque	Suchitepéquez	ND	13	2	100	100	Neritic	Shrimp, snapper, roosterfish, snook		X	
El Chico	Retalhuleu	46	25	2	100	100	Neritic	Shrimp, snapper		X	
		1796	1051	44							

Table 2. Unconfirmed species list. Marine megavertebrates reportedly captured (both incidental and targeted) by small-scale commercial fishermen. IUCN global conservation status (ver. 3.1, IUCN, 2015) and locations reported per species. DD = data deficient, LC = least concern, NT = near threatened, EN = endangered, CR = critically endangered. LB = La Barrona, EJ = El Jiote, LL = Las Lisas, ED = El Dormido, ER= El Rosario, LM = Las Mañanitas, MO = Monterrico, BV= Buena Vista, SJ = Puerto San José, EP = El Paredon, SP = Sipacate, CH = Chiquistepeque, EC = El Chico.

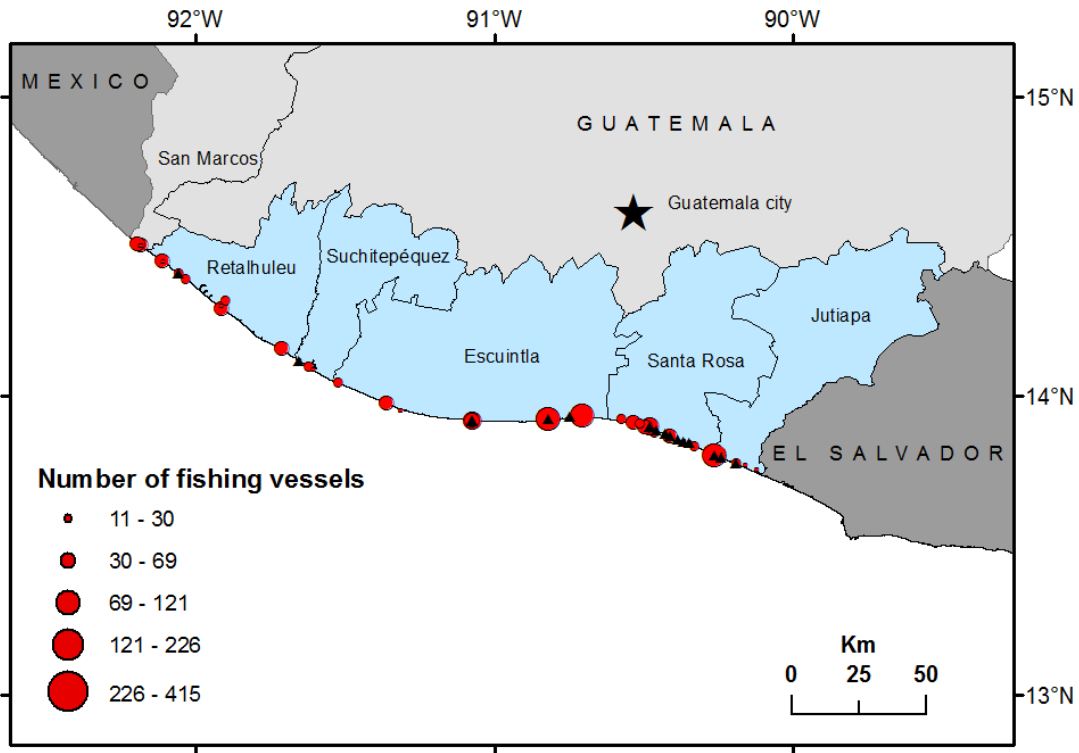| Species	Common name	IUCN status	Locations reported
Turtle			
Lepidochelys olivacea	Olive ridley	VU	ED, ER, LM, MO, SP
Chelonia mydas	East Pacific green	EN	SJ, SP
Caretta caretta	Loggerhead	VU	SJ
Eretmochelyls imbricata	Hawksbill	CR	LM, EC
Shark			
Alopius pelagicus	Pelagic thresher	VU	SJ
Carcharhinus falciformis	Silky	NT	SJ
Carcharhinus limbatus	Black tip shark	NT	ED, ER, LM, MO, EP, SP, EC
Carcharhinus leucas	Bull	NT	BV, SJ, EP
Carcharhinus longimanus	Oceanic whitetip		BV
Galeocerdo cuvier	Tiger	NT	EP, SP, CH, EC
Prionace glauca	Blue	NT	BV, SJ, PG
Ginglymostoma cirratum	Nurse	DD	BV, SP
Mustelus spp.	Smoothound	LC	SJ
Nasolamia velox	Whitenose	DD	SJ
Rhizoprionodon longurio	Pacific sharpnose shark	DD	LL, ED, ER, LM, SJ
Sphyrna lewini	Scalloped hammerhead	EN	LB, EJ, LL, ED, ER, LM, BV, SJ, EP, SP, CH, EC
Sphyrna mokarran	Great hammerhead	EN	SJ, EP
Billfish			
Istiophorus platypterus	Sailfish	LC	BV, SJ
Istiompax indica	Black marlin	DD	SJ

Fig. 1. **Distribution of 46 small-scale fishing sites** by department across the
Pacific coast of Guatemala. Circles detail the number of fishing vessels as reported
by the FAO (2005b). Harbour surveys were conducted at sixteen fishing sites,
denoted by black triangles, across five of the six coastal departments, shaded blue.

Chapter 2: Incidental elasmobranch catches in Guatemala's Pacific coastal fisheries

Rachel Brittain [ab], Ever E. Rizo-Guardado [b], Brendan J. Godley [a] and Annette C. Broderick [a]

[a] *Centre for Ecology and Conservation, University of Exeter, Penryn Campus, Cornwall, TR10 9FE, UK.*

[b] *Akazul: Community, Conservation & Ecology, 34 Honiton Road, Exeter, Devon, EX1 3ED, UK.*

ABSTRACT

Globally, many elasmobranch populations are in decline, yet the impact of artisanal fisheries on this vulnerable group of fish is largely undocumented. Throughout the eastern Pacific region they are reported to be an important component of landings but there is a paucity of baseline information to assess the impact of this catch. Artisanal fisheries account for 97% of all fishing activity in Guatemala and are vital to the livelihoods of coastal inhabitants. Between 2012 and 2013 we used fishery-dependent sampling to study targeted and incidental captures of elasmobranchs in Guatemala's Pacific inshore small-scale fisheries (SSF), as defined by Guatemalan fishing law (MAGA, 2015). We used a combination of onboard observers, shore based sampling of landings, harbour based surveys and fisher interviews to determine the size and composition of the artisanal fishing fleet and estimate elasmobranch catch in ten artisanal fishing communities (of 46). We estimate that 99% of elasmobranch catch was not targeted, with just 12.5% of observed trips directly targeting large batoids and catfish, the majority of which were longtail stingray (*Dasyatis longa).* Approximately 98% of incidental elasmobranch catch recorded was in demersal gill and trammel nets targeting crustaceans and teleost fish in relatively shallow waters (< 20m depth). Of the three species of shark and 11 species of batoid, small batoids were the most numerous elasmobranch observed during onboard observer trips (84.4%), but had no commercial value and 68% were discarded with the remainder used to bait longlines. The whitenose guitarfish (*Rhinobatos leucorhynchus)* was the most abundant batoid observed onboard (42.6%) followed by the vermiculate electric ray (*Narcine vermiculatus*) (25.7%)*,* both endemic to the eastern Pacific with little known of their life history and listed as near threatened by the IUCN. The endangered scalloped hammerhead shark (*Sphyrna lewini*) accounted for 93.6% of total shark catch observed onboard and on shore, all were classed as juveniles and retained. Post capture survival of shark was low with 87.5% of individuals hauled dead. Our calculated batoid CPUE rate in trammel nets was exceptionally high (42.7/trip), and considering the wide use of nets across the fleet annual batoid catches could be significant with further work on post capture survivability needed to determine levels of mortality. With an estimated 95,904 fishing trips taken annually by the fleet across our study sites, and given that our survey area encompassed just 22.0% (n=10) of the reported number (n=46) of SSF

sites on the Pacific Guatemala, the impact of these fisheries through incidental take is significant, especially with regard to the conservation status of many of the species recorded.

INTRODUCTION

The impact of direct and indirect take of elasmobranchs by small-scale fisheries (SSF) is largely undocumented, yet these fisheries can greatly affect abundance and size composition of populations (Dapp *et al.* 2013; Bizarro *et al.* 2009; Clarke *et al.* 2006). In developing countries, where 95% of SSF activity takes place (McGoodwin, 2001), these fisheries are of significant economic importance (Andrew *et al.* 2007; Salas *et al.* 2007) and fishing usually occurs in nearshore coastal waters with relatively small vessels (Chuenpagdee, 2006; Jacquet and Pauly, 2008). Many elasmobranchs spend their early life stages in shallow coastal waters (Knipp *et al.* 2010) and their habitat is likely to overlap with SSF activity (Duncan and Holland 2006; Lucifora *et al.*, 2011). The relatively long life spans, late ages of sexual maturity, low fecundity and long gestation periods make most elasmobranchs vulnerable to overfishing (Dulvy *et al.* 2014). It is widely recognised that baseline information on fishing effort and catch composition is vital to determine the status and trends of vulnerable elasmobranch populations in order to conserve them (Bizarro *et al.* 2009). Integral to developing appropriate conservation and management strategies is understanding socio-economic drivers that may lead to shifts in fishing behaviour (see Aguilera *et al.* 2015; Herndon *et al.* 2010) such as; non-size specific targeting of species (Doherty *et al.* 2014), targeting of species for high value commodity products (e.g. shark fin or ray gill raker trade) (Clarke *et al.* 2006; White *et al.* 2006), or utilisation of bycaught species due to overexploitation of commercial species. This ability to adapt to changing economic and environmental conditions is what enables artisanal fishers to survive (Aguilera *et al.* 2015) and needs to be considered in fisheries resource use assessments.

Throughout the eastern Pacific region (EP) elasmobranchs are important catch components of SSF and small bodied coastal species can make up large portions of the catch (Doherty *et al.* 2014; Bizarro *et al.* 2009). The rising demand for meat and fins has raised sustainability concerns (Costa Rica: Dapp *et al.* 2013; Mexico: Ramierez-Amaro *et al.* 2013; Bizarro *et al.* 2009; Bizarro *et al.* 2007; and Peru: Doherty *et al.* 2014) and in areas where some historical data are available, stocks are showing signs of overfishing (Whoriskey *et al.* 2011). For example, in Costa Rica large numbers of silky shark (*Carcharhinus falciformis*) are captured in the longline

fishery targeting dolphinfish (*Coryphaena sp.*) and over a seven year period there has been a decrease in body size, suggesting a reduction in relative numbers of adults within the population (Dapp *et al.* 2013). These patterns are being observed globally (Stevens *et al.* 2000) and with high rates of estimated elasmobranch mortality, some species may be pushed towards extinction unless there is timely and improved domestic and international management (Herndon *et al.* 2010). However, one of the biggest challenges facing fisheries managers and regulators is how to enforce effective restrictions when there is a scarcity of information for assessment purposes (Salas *et al.* 2007). There is a need to develop multidisciplinary and collaborative fisheries research that utilises socio-economic and biological data as well as the knowledge and experience of fishermen to carry out rapid assessment.

In Guatemala, 97% of fishing vessels recorded are classed as artisanal or small-scale (FAO, 2005). Artisanal and small-scale fishing are classed as any commercial fishing activity performed by vessels <1.99 gross registered tonnage (GRT) (MAGA, 2005). Herein, the term SSF will be applied to both artisanal and small-scale fishing operations.

Guatemala's Pacific SSF fleet comprises some 3473 vessels located across 46 fishing settlements spanning the 254 km coast (FAO, 2005). Vessels utilise a variety of manual gear including traps/pots, gillnets, trammel nets and longlines to target both pelagic and demersal species of fish, molluscs and crustaceans (FAO, 2005). At the two largest Guatemalan Pacific ports of San Jose, Escuintla and Champerico, Retalhuleu, a fleet of small-scale fishing vessels known locally as "*tiburóneros*" use surface longlines to target large species of pelagic shark including; silky and pelagic thresher (*Alopias pelagicus*) (Ruiz *et al.* 2000). Although vessel size limits fishing capacity, it was previously reported that annual landings from this fleet have surpassed those of the industrial fleet (Morales *et al.* 2005; Ruiz and Lopez, 1999). Across the numerous smaller coastal fishing sites accurate elasmobranch landings information from the inshore artisanal fleet remains scant.

To further the understanding, conservation, and management of elasmobranchs in Guatemala's Pacific coastal waters, we used a mixed methods rapid approach to assess the extent and composition of Guatemala's inshore small-scale fishing fleet

on the SE coast and its impact on elasmobranchs through targeted and non-targeted fishing activity.

METHODOLOGY

This study was approved by the University of Exeter Ethical Committee (2014/649) and adhered to the Code of Human Research Ethics set out by the British Psychological Society. Informed consent was obtained from all subjects and identities remained anonymous. The onboard handling and sampling of live animals followed procedures described in the Guidelines for Shark and Ray Recreational Fishing in the Mediterranean (Fowler & Partridge, 2012) from United Nations Environment Program, also approved by the University of Exeter Ethics Committee.

We reviewed available Food and Agricultural Organisation (FAO) fisheries statistics for Guatemala's Pacific coast and selected the SE region where 77.5% of the SSF landing sites were located, with accessible sites connected to transport links, for our study, which extended over three coastal departments (Escuintla, Santa Rosa and Jutiapa (Fig. 1).

Harbour surveys

Between October 2013 and July 2014 we conducted surveys at ten small-scale fishing sites located on Guatemala's Pacific coast (Fig. 1). At each site, basic counts of sea-going fishing vessels, known locally as "*lanchas*", typically open hulled fibre glass boats with outboard engines, were carried out as well as in person-interviews with fishermen. Interviews were informal but a core set of questions were asked each time: (a) principal gear type used (nets or lines) (b) target species, (c) fishing location (distance from shore), (d) trip duration, and (e) trip frequency. If fishermen had more time to spare, additional questions were asked on; fishing effort (e.g. number of days per month and months of the year principal fishing gear was used) and fishing gear specifications (number of hooks, length of mainline, mesh size of net, length of net), boat specifications, seasonality and location of fishing effort. Respondents were owners, captains or crew of artisanal fishing vessels, or leaders of community fishing associations. This information was later used to determine fishing effort for the sites and ascertain the prevailing principal gear type utilised by the fleet.

Onboard observer programme

Observers undertook a total of 27 fishing trips on inshore small-scale fishing vessels from four locations Sipacate (n=8), Las Mañanitas (n=8), El Rosario (n=8) and La Barrona (n=3) (Fig. 1) in the departments of Escuintla, Santa Rosa and Jutiapa during the period 5th December 2013 to 8th December 2014. A total of 66 gear sets were observed comprising; trammel nets, gill nets, and longlines. Vessels and crews initially participated in the programme voluntarily, however over time participation decreased and it proved more successful to offer a financial incentive. Captains of participating vessels were paid 100 Guatemala Quetzales (GTQ) (~$13 USD) per trip and consented to observers carrying out catch sampling onboard their vessels. Observers did not take part in fishing activity.

Observers

The Project Co-ordinator (RB) trained one of Akazul's Research Assistants (ERG) from the fishing community of La Barrona, in data collection activities and both carried out onboard and shore based sampling. For each trip the observers recorded: length of trip, target species, number of sets, location of set (longitude/latitude), depth of set, and start/end time of set (taken at the start of the set and at the commencement of hauling the gear). Information on gear type used included relevant metrics of gear, such as type of hook (J or circle, number of hooks, mainline length, mesh size and height of nets). For all elasmobranchs, local names of the species and sex were recorded, details on whether the animal was retained or discarded (including reason for discarding e.g. too small or no commercial value) and whether the animal was alive or dead). Observers took a series of standardised photographs (numbered with a time and date stamp) of each specimen; a full length lateral view detailing the head, trunk, pre-caudal tail and caudal fin regions, close up dorsal and ventral views of the head, a close up view of dorsal and caudal fins and a close up of pelvic and dorsal fins. With the exception of 40 small roundrays (*Urotrygon* sp.) captured in the trammel net fishery that could only be identified to genus, all individuals were identified to species level according to Fischer *et al.* (1995ab) and Allen and Robertson (1994) by RB.

For species of shark, total length (TL) (Musick & Bonfil, 2005) was measured using a flexible measuring tape. For species of batoid, disc width (DW) (Musick & Bonfil, 2005) was measured instead of TL as often fishers removed the tails of larger specimens prior to landing to avoid injury from tail barbs.

Shore based sampling of landings

From March – July and December 2013, shore based observations of elasmobranch landings were carried out infrequently and opportunistically at the four study sites to further augment information on species composition and size distribution collected during the onboard sampling. Vessels were approached whilst landing their catch and observers recorded species, sex, TL or DW for landed elasmobranchs. Information on the fishing trip (i.e. gear type and fishing effort) was obtained from either the captain or crew of the vessel.

Data analysis

Catch per unit effort

We used catch per unit effort (CPUE), defined as number of individuals per unit of effort, to detect relative abundance of batoid and shark and to determine catch rates by each of the sampled gear strata. We visualised the data in the form of several effort metrics including; trip, vessel, set, number of hooks and km of net. Sampling effort by gear strata was not evenly distributed throughout the year of study as fishing patterns were highly variable, so we broadly analysed batoid and shark catches by principal gear type (nets or lines) to detect possible quarterly variation in catches by gear.

Fishing effort

Using data collected during harbour surveys and interviews we estimated total number of vessels and fishing effort by principal gear type (nets or lines) which was defined as gear used for more than six months of the year, at all of the sites. This enabled us to estimate annual number of fishing trips for the small-scale fishing fleet at the ten sample sites and indicate the scale of fishing activity.

Estimates of elasmobranch catches

We aimed to estimate annual catches of shark and batoid, expressed as number of individuals caught by trip per vessel. To derive these values we applied the CPUE rates calculated during onboard observations to estimate the number of elasmobranchs captured per trip according to principal gear type recorded at each of the sites visited during harbour surveys. Data were then multiplied to estimate annual elasmobranch catch of the fleet.

Biological data

Data from shore based sampling and onboard observer trips were pooled to determine size composition and sex ratio of elasmobranchs. For species with ≥ 20 individuals measured, potential size differences between males and females were first evaluated for normality (Shapiro Wilks test), then data were evaluated using a two tailed *t*-test or Mann Whitney *U*, as appropriate, to test the null hypothesis that mean size was not significantly different between sexes (α = 0.05). Additionally, the assumption of equal sex ratios (1:1) within the landings was tested using chi-square analysis. All statistical analysis was performed using IBM SPSS Statistics 22.0.

RESULTS

Fishing sites and general fishery characteristics

We recorded 444 small-scale fishing vessels at our ten fishing sites on the SE coast (Table 1). In general, small-scale fishing operations that we identified were diverse and opportunistic, highly adaptable to inter-seasonal variability and were multi-species fisheries. Targeted elasmobranch fishing effort was observed at only one of the sites (Sipacate) and was not a year round fishery. The majority of fishing sites contained basic infrastructure, were located in the smaller coastal communities, and fishing operations usually operated within a family unit. Vessels worked in near shore neritic waters less than 20 nautical miles from the coast with trips lasting between 6 and 48 hours. Bottom set; gill nets, trammel nets and longlines were used to target a variety of demersal fish and shellfish including; eel, snapper, snook, catfish, grunt and shrimp. Target species and, subsequently, fishing method differed considerably among the sites and across the year and a prevailing principal gear type (used for

more than six Fig. 1). Bottom set nets (gill and trammel) was the predominant gear used by 67.3% (n=299) of vessels. Entry into the sea was either by launching from the beach or travelling via the mangrove canal system through to the river mouth. Wave size and state of the tide significantly affected a vessels ability to launch and during high seas vessels would not operate.

Catch composition and CPUE

During onboard sampling we monitored a total of 13 longline sets (table 2) and 54 net sets (table 3) over the months of December 2013, March - July 2014, September - October 2014 and December 2014. With the exception of four longline trips which specifically targeted large batoids (i.e stingray) (table 2), all captured and landed elasmobranchs observed were classed as bycatch (non-target species). A total of 353 elasmobranchs were recorded onboard comprising; 3 species of shark and 11 species of batoid (table 4). Sharks accounted for 11.3% (n=40) and batoids for 88.7% (n=313) of total number of elasmobranchs captured. Three predominant species; scalloped hammerhead (*Sphyrna lewini*) (n=37), whitenose guitarfish (*Rhinobatos leucorhynchus*) (n=146) and vermiculate electric ray (*Narcine vermiculatus*); n=88) were observed, comprising 76.3% (n=271) of total elasmobranchs.

Of 40 sharks that were observed, post capture survival was low with just 12.5% (n=5) hauled alive and the remaining 87.5% (n=35) hauled dead. In contrast 99.0% (n=311) of 313 batoids observed were hauled alive (n=236) and only 1.0% (n=2) were hauled dead. Of these 74.44% (n=233) were discarded alive and 0.32% (n=1) were discarded dead. All shark captured were retained; 77.5% (n=31) for human consumption and 22.5% (n=9) for baiting longlines. Only 1.3% (n=4) of batoids were retained for human consumption comprising two species; longtail stingray (*D. longus*) and round rays *Urotrygon* spp. and were larger individuals. The more abundant small bodied batoids (including whitenose guitar fish and vermiculate electric ray) had no commercial value, but 23.6% (n=74) were retained to bait longlines.

Elasmobranch catch per unit effort (no. of individuals/trip) was highest in the trammel net fisheries operating out of Sipacate targeting shrimp and elasmobranch catch components comprised mainly of small bodied batoids, with a maximum CPUE of

42.7 and catches at their highest during the third quarter of the year (Jul – Sep) (Fig. 3b). Maximum shark CPUE (2.3) was observed in both gill and trammel net fisheries during the second quarter (Apr – Jun) of the year (Fig. 3a). Elasmobranch catches were low in the demersal longline fisheries that we observed and accounted for only 2.7% (n=8) of the total elasmobranch catch.

During shore based sampling of landings we recorded a further 85 individuals comprising; black tip shark (*Carcharhinus limbatus*) (n=4), longtail stingray (*Dasyatis longus*) (n=16) and scalloped hammerhead shark (n=65) during 11 sampling events which were included in the analysis of size and sex compositions (Table 4).

Estimating annual totals

Harbour based surveys enabled us to quantify the number of sea going small-scale fishing vessels at each of the ten sites. Fishing activity was variable and difficult to predict on an annual basis due to a range of economic and environmental factors, therefore fishers were asked during interviews to relate responses to the previous year of fishing. Closed question responses to number of fishing days per month revealed that full time fishers fished between 15 and 21 days per month, for twelve months of the year. Using the median number of monthly trips (n=18) enabled us to obtain broad annual estimates of effort for the two main gear types (Table 5). We then used mean elasmobranch CPUE rates (individuals/vessel/trip) obtained during onboard observations to estimate; monthly elasmobranch catches per vessel per trip for each of the gear types recorded (Table 6). Survey data was coarse and we were unable to accurately determine the number of trips taken monthly by metier. As elasmobranch CPUE was highest in trammel net fisheries targeting shrimp, it was considered appropriate to apply these CPUE rates to the three sites where this gear type was recorded to minimise the risk of bias when extrapolating annual catch estimates.

We estimate that the small-scale fishing fleet across our ten study sites make 95,904 fishing trips annually; comprising up to 31,320 longline trips, 59,184 trammel net trips and 5,400 gill net trips. Based on our elasmobranch CPUE rates generated for the three main gear types fishing for the median number of days per month, we estimate

annual elasmobranch catch could be as high as 2,726,892 individuals per year for the fleet across our ten study sites (50,112 in lines; 13,500 in gillnets; 2,663,280 in trammel nets).

Size and sex composition

Species-specific size and sex composition were available for a subset (n=334) of the total elasmobranchs recorded (n=437). Onboard catches and landings were dominated by small individuals of small bodied coastal species of shark and batoid (Table 4).

For 88 vermiculate electric ray (Fig. 2a) males were the most abundant (n=49; 55.7%) but did not differ significantly from 1:1 (χ^2 = 1.136; P = 0.157) and there was no size difference between the sexes (U = 0.890; P = < 0.05). Reported minimum size at maturity is 19cm TL for males and 20 cm TL for females but disc width measurements are not reported in the available literature and we were therefor unable to determine age class composition based on size data.

The most abundant sex of 145 whitenose guitarfish recorded (Fig. 2b) was female (n=83; 57.2%) however the observed difference was not found to be statistically significant (χ^2 = 2.74; P = 0.98). Size distribution did not differ significantly between males an females (U = 0.148; P = <0.05). Minimum size at maturity is unknown for this species but maximum total length is reported as 62.5 cm and considering disc width distribution our data was skewed towards smaller individuals.

Of 53 scalloped hammerhead measured, neonates (< 55 cm TL) represented 90.6% (n=48) of individuals (Fig. 2c) with greatest prevalence from April to June, (68.8%, n=33), indicative of a time of parturition. The largest individual recorded was a female of 62 cm and could be classed as immature (see Compagno *et al.* 2005). Size composition did not differ significantly between the sexes for 53 individuals sampled (t = 0.659; P = 0.513). Females were the most abundant sex recorded (n=31; 58.5%) (Fig. 2c) but did not depart significantly from the ratio of 1:1 (χ^2 = 1.185, P = 0.276).

DISCUSSION

Utilising a mixed method rapid approach, this study has provided new insights into the SSF of Guatemala's SE coast. As a result of this work we are able to generate important baseline information to improve understanding of the scale and magnitude of these fisheries, characterise how they operate and quantify levels of bycatch, as well as document species diversity, utilisation patterns and sustainability.

Mixed method approach

Basic statistics and descriptions of Guatemala's small-scale fishing fleet are largely unavailable or outdated (see Valle, 1999; FAO, 2000; FAO, 2005b: Morales, 2005) and in existing literature there is no distinction between the number of vessels actively engaged in inland or marine fishing activity. Harbour surveys and fisher interviews were very effective at gathering large amounts of coarse data on fishing effort across multiple sites in a relatively short time frame, using few personnel and resources making them very cost and time effective. We were able to obtain an overview of the main composition of the fishing activity by site and determine the principal gear type used to facilitate bycatch estimates.

Onboard observer programmes are utilised around the world as a method of collecting detailed, unbiased information on commercial fishing activity (Faunce *et al.* 2015; Braccini *et al.* 2012). It is widely recognised that these types of programmes can address bycatch and discards that may go otherwise unreported, particularly when protected species are concerned (Braccini *et al.* 2012). Observer trips proved invaluable in this study as batoid discards were numerous, contributing significantly to overall calculated CPUE rates and would have been otherwise overlooked in shore based sampling alone. Observers were also able to record more detailed gear parameters on a trip by trip basis which was effective at capturing inter-seasonal changes in fishing activity and target species which were not detected in interviews. With a larger data set, over a longer study period this information will be incredibly useful for deriving more specific effort metrics and catch records.

Opportunistic sampling

Distribution of sampling effort for observer trips was not consistent with fishing effort based on number of vessels recorded during harbour surveys but rather logistical

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considerations including; distance between sites and transport infrastructure, and safety such as; avoiding areas of civil unrest and avoiding vessels with safety concerns. There were several occasions when observers aborted trips for reasons including; difficulty in launching, lost gear, and engine failure. Trips were carried out opportunistically and with a small pool of reliable vessels that observers deemed were safe to travel with, at sites with easy access. Therefore sampling may not have been wholly representative of overall fishing activity and in future studies, more intensive shore based sampling could be used to augment onboard catch sampling.

Elasmobranch catch and utilisation

The SSF observed at the ten study sites were predominantly inshore coastal demersal fisheries targeting teleost fishes and crustaceans. Shark and batoids were the only taxa of megavertebrates observed. Approximately 99.7% (n=352) of captured elasmobranch were not directly targeted and comprised of juveniles and small-bodied coastal species. This is similar to that reported in other EP artisanal fisheries (see Ramierez-Amaro, 2013; Cartamil, 2011; Bizzarro *et al.* 2009).

Sexual and size segregation is documented in elasmobranchs (Sims, 2005; Escobar-Sánchez *et al.* 2006), however sex ratios presented in this study for two ray and one shark species did not differ significantly. We also found no significant differences between size and sex composition for three species tested (vermiculate electric ray, whitenose guitarfish and scalloped hammerhead shark).

Of captured elasmobranchs, all sharks were retained but small batoids, the most prevalent being vermiculate electric ray and whitenose guitarfish had no commercial value and over 50% were discarded alive. Virtually nothing is known of the post capture survivability of these species therefore as a precaution we have included discards in with total catch estimates. Previous studies have determined that demersal chondrichthyans have high post capture survivability in comparison to pelagic species (Bracchini *et al.* 2012) and species specific information for Guatemala's batoids would be extremely useful for future assessments.

Incidental shark catches were dominated by scalloped hammerhead and all captured individuals were utilised for either meat or bait. In general, inshore fishermen gained

very little for shark meat, on average $1.3USD/lb (metric; Brittain, per obs) and although individuals were small it was still considered financially beneficial to land them. Meat of the shark was usually sold for consumption and was typically used as an ingredient in *ceviche*. Shark fins are harvested across the Pacific coast of Central America for the Asian fin trade (Cartamil *et al.* 2011) but we observed no specific targeting of shark for their fins by the artisanal fleet at any of the study sites. At the larger fishing sites of Sipacate and El Paredon, where fishers also reported catches of larger sharks such as tiger (*Galeocerdo cuvier*) , bull (*Carcharhinus leucas*) and hammerhead *Sphyrnidae* spp., fins were harvested as byproducts along with the skin and livers for extracting oil (Brittain pers. obs).

Sustainability concerns

We surveyed 22.0% of small-scale fishing sites (n=46) reported by the FAO (2005b) on Guatemala's Pacific coast and although we acknowledge caveats associated with scaling up from small sample sizes, it is likely that elasmobranch catches in the inshore artisanal fleet are in the many tens of thousands, if not hundreds of thousands per annum across Guatemala. Temporal variation in batoid catches in trammel net fisheries was observed therefore annual catch estimates based on mean CPUE per vessel/trip may skewed. However, even the more conservative elasmobranch catch estimate generated for line and gillnet fisheries is substantial at over 60,000 individual elasmobranchs per year. Furthermore, cause for concern is the elasmobranch species composition recorded in catches, with one listed by the IUCN (2015) as endangered, four as near threatened and six as data deficient with ten of these endemic to the EP region.

Globally, batoids have become an increasingly large component of fisheries catch and are emerging as target species in fisheries where they were once considered bycatch (White *et al.* 2013). During the study, coastal residents informed us that previously, batoids had no commercial value and only in recent years due to a decline in other target species has a market for the meat emerged. Dried, salted ray meat was frequently observed in urban markets during weeks preceding the religious festival of *Semana Santa* a time when fish is in highly demand (Brittain pers. obs). Long tail stingray, endemic to the EP region, was the most frequently observed batoid in shore based landings (100%; n=16) and listed as data deficient by the

IUCN (Smith, 2006). Limited landings information for this species is available outside of Mexico, however life history traits such as low fecundity and long gestation periods make it likely to be susceptible to overfishing and it is considered a research priority to better understand its conservation status (Smith, 2006). As domestic demand for batoid products increases it is of high importance that regular monitoring of landings are introduced in Guatemala to ensure catches do not exceed sustainable levels.

The whitenose guitarfish was the most frequently captured species of elasmobranch observed in our study and had no commercial value with 97.9% (n=142) of individuals discarded. Guitarfish (Rhinobatidae) are one of several families of shark-like batoids that are heavily fished in south-east Asia and targeted for their fins (called 'white fin'). 'White fin' is one of the profitable elasmobranch products in the region (White and McAuley 2003a, Clarke *et al.* 2006a,b, Compagno *et al.* 2006) and it is thought that populations are declining from targeted fishing (White *et al.* 2013). Guatemala currently has no management or conservation plan for elasmobranchs. High susceptibility of guitarfish to bycatch in trammel nets, limited knowledge on the life history of this species and the high demand their fins in Asia, could present significant threats to this species.

The EP population of scalloped hammerhead has been classified as endangered by the IUCN and drastic declines in its population have been observed (Baum *et al.* 2007). In this study, size distribution of captured scalloped hammerheads was skewed toward smaller size classes that represent neonates and juveniles. This is a trend also observed in the majority of artisanal fisheries throughout the EP region (see Pérez-Jiménez, 2005; Ramierez-Amaro, 2013) which has been attributed as a key factor in their decline (CMS, 2015). High CPUE in Guatemala's gill and trammel net fisheries coupled with observations of landed pregnant females (Brittain & Rizo, unpublished data) indicate that artisanal fisheries operate within breeding and nursery areas. The paucity of baseline data on catch quantities and lack of a management plan for scalloped hammerheads in Guatemala requires urgent attention and is vital for assisting regional conservation efforts.

Possible mitigation

Given the importance of SSF to Guatemala's coastal inhabitants overall improved management of fisheries is vital to ensure long-term sustainable exploitation of the resource. In our study we found that elasmobranchs are infrequently targeted by artisanal fishers and are predominantly taken as bycatch. Elasmobranchs are utilised opportunistically, mostly for their meat, but do not provide fishers with significant economic benefit. Within these smaller fishing communities there is great potential to obtain local support for conservation of elasmobranchs and introduce measures to minimise fishing impact.

Many fishers commented on the lack of general fisheries management and the prevailing perception was that fisheries resources were depleting. This is a known characteristic of SSF that has been linked to poverty in fishery-dependent communities (Graaf *et al*. 2011). Signs of overexploitation are also reflected in fishing effort. Unpublished data collected by the Project Coordinator in 2006 shows that one vessel targeting grunt and croaker had increased the number of hooks used on longlines from 500 to 1200 (Brittain, R. unpublished data). There is significant overlap between artisanal fisheries and commercial shrimp trawling grounds, the latter being blamed for a reduction in some key commercial species (CBD, 2013). Shrimp trawlers are known to have high levels of elasmobranch bycatch (Shepherd and Myers, 2005) and given the large number of small size classes of elasmobranchs reported in this study, additional fishing pressure from trawlers is of concern and needs further investigation.

It is recognised by resource managers and scientists that involvement of stakeholders is essential to effectively manage marine resources, largely due to the interdependency between the marine environment, its resources and users (Pomeroy and Douvere, 2008). In Guatemala, where government resources are limited, development of collaborative fisheries research and a participatory approach (see Soma, 2003) that utilises fishers' knowledge for an ecosystem approach (see Matthew, 2011) is a recommended approach to improving fisheries management.

Further work

SSF have great potential for obtaining important life history information on understudied species of elasmobranch present in Guatemala's Pacific waters. The value of fishers' knowledge in regard to oceanographic, biological and economic aspects has been identified as and effective method for generating timely and reliable data to aid fisheries management (Mathew, 2011). With modified survey design and implementation, using an improved mixed method approach, it would be possible to further understanding of types of fishing activity employed by the small-scale fleet, temporal patterns and interactions with elasmobranchs.

Limitations to the observer programme were largely due to the limited resources available to carry out the work. It is well known that sampling effort in such programmes determines how representative information is of overall fleet activity (Lopez *et al*. 2003; Lewison *et al*. 2004). Considering annual estimates of fishing activity, our trips may have represented just 0.04% of estimated trips undertaken by the study fleet. A revised programme with greater effort, improved temporal coverage across a wider geographic area used in conjunction with interviews and harbour surveys would provide further insight into elasmobranch catches.

For species that have been identified as vulnerable to inshore fishing activity (e.g. scalloped hammerheads, longtail stingray and whitenose guitarfish) it would be beneficial to learn more about their populations such as, habitat use and distribution, identify key areas that could be protected from commercial fishing, as well as determine life history parameters such as size at birth, age and size at maturity and fecundity. Artisanal fishing operations could be used as a platform to study these species whilst presenting an opportunity for artisanal fishers to be involved in collaborative fisheries research and develop participatory fisheries management.

Table 1. Location of harbour surveys conducted at ten sites across three coastal departments (JU = Jutiapa, SR = Santa Rosa, ES = Escuintla) on the SE coast of Guatemala. Table indicates number of small-scale fishing vessels recorded during harbour based surveys, principal gear type utilised by the site and target species. Also included are number of onboard observer trips and shore based observations of landings carried out at the study sites. ND = No data.

	Site	Dep.	No. vessels	No. interviews	No. obs.	No. obs. landings	Principal gear type Nets % (n)	Lines % (n)	Target species
1	Sipacate	ES	>200	8	8	2	100(>200)		Shrimp, croaker, grunt, snapper, Pacific sierra.
2	El Paredón	ES	25	4	0	0	100(25)		Pacific sierra, threadfins, catfish
3	Monterrico	SR	25	2	0	0	96(24)	4(1)	Pacific sierra, shrimp, snapper
4	Hawaii	SR	1	0	0	0		100(1)	Grunt
5	Las Mañanitas	SR	75	35	8	1		100(75)	Grunt, croaker, catfish, eel, stingray
6	El Rosario	SR	13	4	8	7		100(13)	Grunt, croaker, catfish, eel
7	El Dormido	SR	9	2	0	0		100(9)	Grunt, croaker, catfish, eel
8	Las Lisas	SR	50	5	0	0	100(50)		Shrimp, snapper, Pacific sierra
9	El Jiote	JU	44	1	0	0		100(44)	Snapper, catfish, stingray
10	La Barrona	JU	2	2	3	1		100(2)	Snapper
			444	63	32	11	n = >299	n = 145	

Table 2. Description of longline fisheries observed during onboard observations across four sites; SP = Sipacate, LM = Las Mañanitas, ER = El Rosario, LB = La Barrona. Catch per unit effort defined as number of individuals caught/trip and number of individuals per hook, was calculated shark and batoid fishes (retained and discarded).

	Bottom set longline For eel	Bottom set longline For grunt & croaker	Bottom set longline For catfish & stingray
Port(s)	LM	LM, ER, LB	SP
Mainline length (m)	ND	2000 – 3000	2400 – 3000
Target species	Eel	Grunt and croaker	Catfish & stingray
Set deployment (depth in m)	< 20m	< 20m	10 to 20
No. trips total	5	4	4
No. sets total	5	4	4
# set per trip	1	1	1
Total hooks observed	2640	4900	1700
No. of hooks per set	500 – 570	1200 – 1300	300 – 400
Hook type	C6	C8	C4
Set soak time (hours)	13 – 14	2 – 4	5 – 15
Months sampled	Mar	May, Oct, Dec	Jul, Sep, Dec
CPUE shark (n)	0.2 (1)	0	0
CPUE batoid (n)	0.2 (1)	1.25 (5)	0.25 (1)
CPUE shark/hook	0.0004	-	-
CPUE batoid/hook	0.0004	0.0010	0.0006

Table 3. Description of net fisheries observed during onboard observations across four sites; SP = Sipacate, LM = Las Mañanitas, ER = El Rosario, LB = La Barrona. Catch per unit effort defined as number of individuals caught/trip and number of individuals per km of net was calculated shark and batoid fishes (retained and discarded).

	Trammel nets	Bottom set gillnet	Bottom set gillnet
	For shrimp	For Pacific sierra	For demersal fish
Port(s)	SP*	SP	SP, ER, LB *
Net length (m)	900 – 2100	1500	200 – 300
Target species	Shrimp	Pacific sierra	Snapper, snook, grunt and croaker
Set deployment (depth in m)	7 - 20	8 - 12	6 - 20
No. trips total	7	2	10
No. sets total	40	2	12
# set per trip	2 – 9	1	1 – 3
Mesh size (cm)	3.5 & 4.5	4.5	4 & 10
Total length of net sampled (km)	40.8	3.0	3.2
Panel height (m)	2	5	4 – 7
Set soak time (h)	1 to 4	3 to 7	2 to 14
Months sampled	May, Jul, Sep, Dec	Dec	Mar, Apr, Jun
CPUE shark/trip (n)	2.3 (16)	0	2.3 (23)
CPUE batoid/trip (n)	42.7 (299)	2.5 (5)	0.2 (2)
CPUE shark/km net	0.39	-	7.19
CPUE batoid/km net	7.33	1.67	0.63

* No gear data recorded for 1 trip

Table 4. IUCN global conservation status (ver. 3.1, IUCN, 2015) and global distribution (WW = worldwide, EP = eastern Pacific) for species of elasmobranch recorded in Guatemala's SE coast SSF during onboard observations and shore based sampling of landings. Percentage contribution by number (%*N*) and length ranges per sex of species recorded from December 2013 – December 2014. DD = data deficient, LC = least concern, NT = near threatened, EN = endangered. DW = disc width and TL = total length. Note that 40 *Urotrygon* sp. are not included in the table.

Species	Common name	Local name	IUCN status	Global dist.	% N	No. Obs	No. Samp.	Measure	Male Mean ± SD (range)	Female Mean ± SD (range)
Shark										
Carcharhinus limbatus	Black tip shark	Punta negra	NT	EP	1.1	5	3	TL	(54 – 54)	64.5 ± 17.7 (52 – 77)
Rhizoprionodon longurio	Pacific sharpnose shark	Punta de zapato	DD	WW	0.5	2	1	TL	-	(41 – 41)
Sphyrna lewini	Scalloped hammerhead	Martillo	EN	WW	23.3	102	53	TL	49.5 ± 3.9 (38 – 58)	50.5 ± 5.1 (40 – 62)
Batoid										
Aetobatus narinari	Spotted eagle ray	Gavilán	NT	WW	0.5	2	2	DW	(35 – 35)	(17 – 17)
Dasyatis longa	Longtail stingray	Manta raya	DD	EP	4.3	19	8	DW	91 ± 5.6 (85 – 96)	99.4 ± 33.5 (67 – 138)
Gymnura marmorata	California butterfly ray	Raya mariposa	LC	EP	0.2	1	1	DW	(26 – 26)	-
Narcine entemedor	Giant electric ray	Raya eléctrica	DD	EP	0.2	1	1	DW	-	(36 – 36)
Narcine vermiculatus	Vermiculate electric ray	Raya eléctrica	NT	EP	20.1	88	88	DW	9.0 ± 12.5 (6 – 12)	9.0 ± 12.7 (6 – 12)
Rhinobatos leucorhynchus	Whitenose guitar fish	Pez guitara	NT	EP	33.4	146	145	DW	9.78 ± 1.8 (7 – 17)	9.45 ± 1.8 (5 – 20)
Rhinoptera steindachneri	Pacific cownose ray	Murciélago	NT	EP	1.8	8	8	DW	58.7 ± 17.2 (34 – 85)	72.1 ± 21.9 (40 – 74)
Urotrygon aspidura	Spiny tail round ray	Raya redonda	DD	EP	1.1	5	5	DW	15 ± 3.5 (9 – 21)	13.3 ± 2.5 (8 – 20)
Urotrygon chilensis	Thorny round ray	Raya redonda	DD	EP	2.7	12	12	DW	16.2 ± 10.7 (11 - 18)	14.3 ± 14.9 (9 – 21)
Urotrygon nana	Dwarf round stingray	Raya redonda	DD	EP	0.7	3	3	DW	(14 – 14)	10 ± 8.0 (9 – 11)
Urotrygon rogersi	Roger's round ray	Raya redonda	DD	EP	0.7	3	3	DW	-	34 ± 8.6 (30 – 37)
Total					100	397	334			

Table 5. The composition of Guatemala's SE small-scale fishing fleet from ten sites (Fig. 1), showing number of vessels, approximate number of fishing trips undertaken each month (derived from interview data on previous year's fishing activity). Median number of fishing trips per vessel have been used to estimate total monthly and annual trips for the fleet.

Gear	No. vessels	Estimated monthly trips/vessel			Estimated fishing trips for fleet	
		Min. trips	Max trips	Median trips	Monthly total	Annual total
Nets	299	15	21	18	5382	64584
Lines	145	15	21	18	2610	31320
All gears	444				7992	95904

Table 6. Estimated elasmobranch catches by small-scale fishing fleet at ten sites on the Pacific coast of Guatemala. Median number of fishing trips (n=18) was derived from interview data on previous year's fishing activity and number of shark and batoid individuals caught per vessel/trip (calculated from onboard observer data over an eight month period at four sites) were used to estimate elasmobranch catches for each of the gear types sampled.

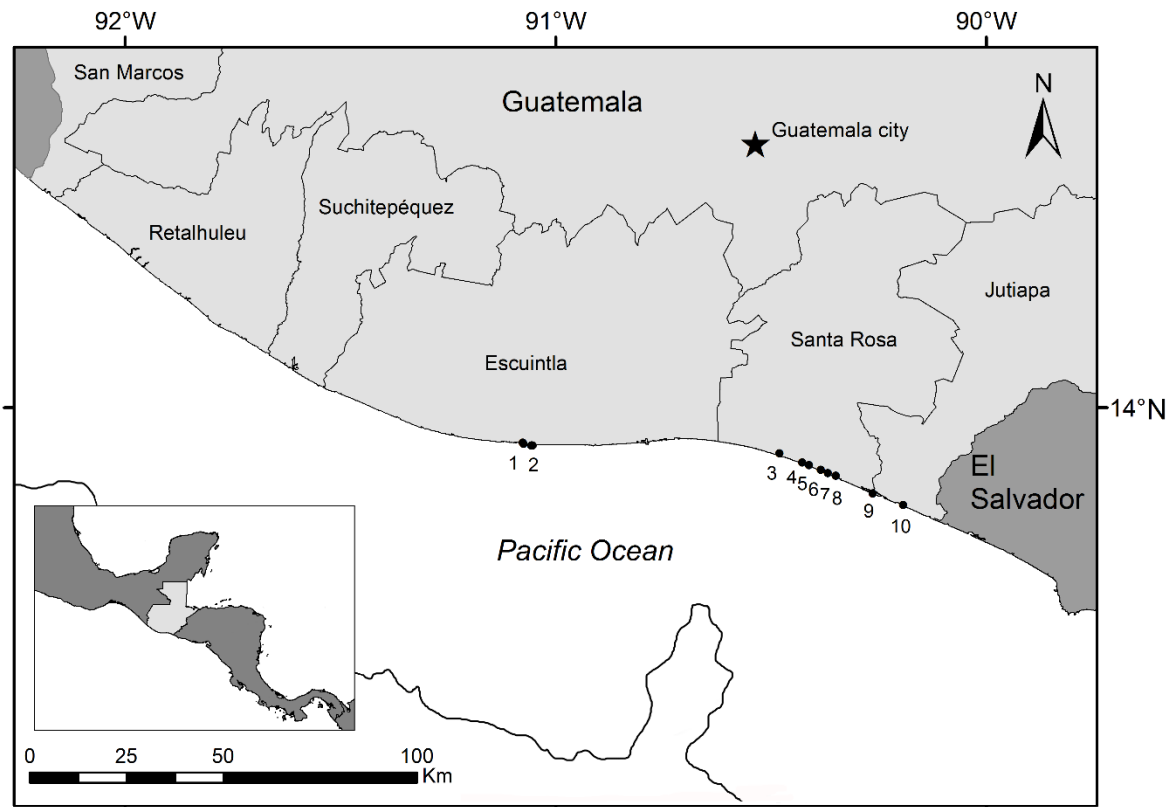| Gear	Estimated shark catches		Estimated batoid catches	
	Vessel/trip	Vessel/month	Vessel/trip	Vessel/month
Trammel	2.3	41.4	42.7	768.6
Gillnet (sierra)	0	0	2.5	45
Gillnet (snapper/snook)	2.3	41.4	0.2	3.6
Longline (eel)	0.2	3.6	0.2	3.6
Longline (catfish/stingray)	0	0	0.25	4.5
Longline (grunt/croaker)	0	0	1.25	22.5

Fig. 1. Location of ten small-scale fishing sites (table 1) studied on Guatemala's Pacific coast between October 2013 and July 2014. Black line indicates edge of the continental shelf at 200m.
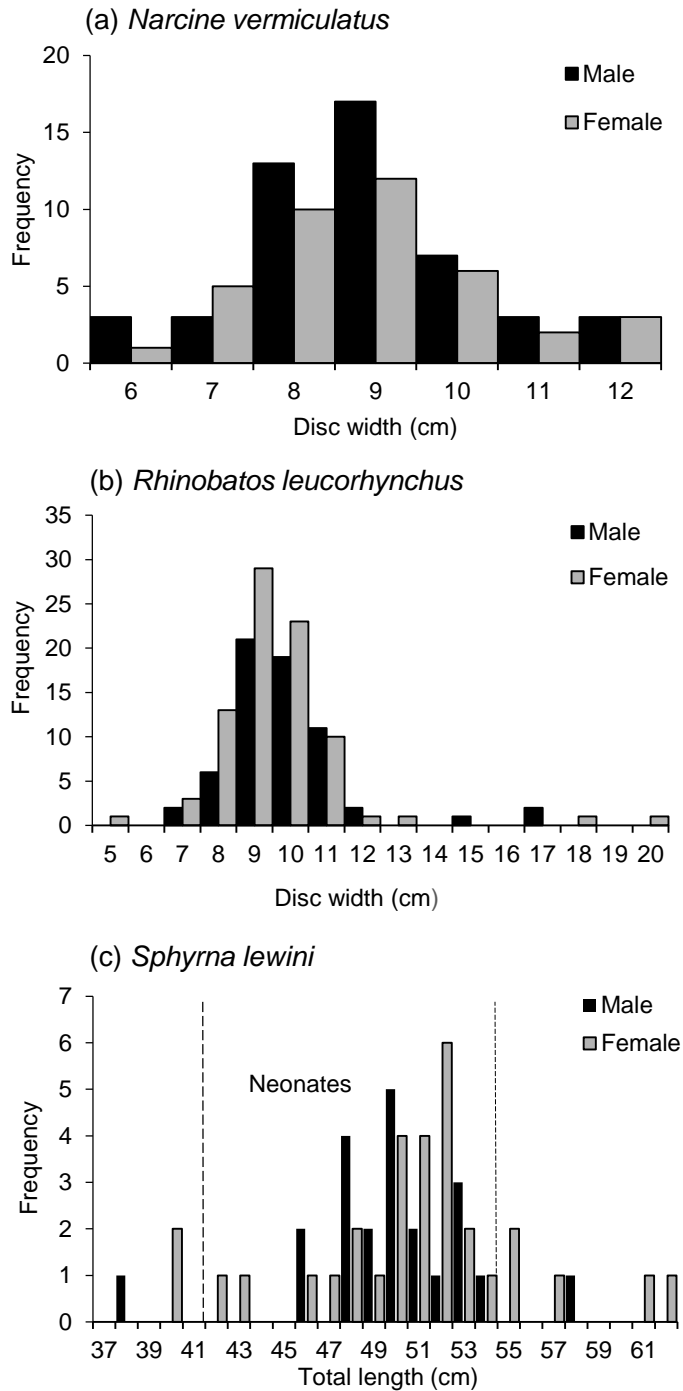
Fig. 2. Size composition per sex of elasmobranchs recorded in Guatemala's SSF located on the SE coast from December 2013 to December 2014. Only species with >20 individuals measured were included: (a) vermiculate electric ray (*Narcine vermiculatus*) (n= 88) comprising 49 males and 39 females, (b) whitenose guitar fish (*Rhinobatos leucorhynchus*) (n=145) of which 62 were male and 83 were female, and (c) scalloped hammerheads (*Sphyrna lewini*) (n=53) comprising 22 males and 31 females (size range at birth reported by Compagno *et al.* 2005 is indicated by

dashed lines). Sampling occurred at four sites on Guatemala's Pacific coast through onboard catch sampling and shore based observations of landings.

(a) Shark

(b) Batoid

Fig. 3. Quarterly CPUE, expressed as number of individuals per trip, of elasmobranch by taxa: (a) shark (b) batoid and gear type (nets & lines). Quarters are as follow; 1 = January to March, 2 = April to June, 3 = July to September and 4 = October to December.

Chapter 3: In-water monitoring of olive ridley (*Lepidochelys olivacea*) sea turtles off the south-east coast of Guatemala

Rachel Brittain [1] [2], Felicity W. Shapland [1], Ever E. Rizo Guardado [1], Brendan J. Godley [2].and Annette C. Broderick [2]

[1] *Akazul: Community, Conservation & Ecology, 34 Honiton Road, Exeter, Devon, EX1 3ED, UK.*

[2] *Centre for Ecology and Conservation, University of Exeter, Penryn Campus, Cornwall, TR10 9FE, UK.*

ABSTRACT

Several of the world's species of sea turtles frequent Guatemala's Pacific coastal waters, of these the most abundant is the olive ridley *Lepidochelys olivacea* which nests across the entire 254km of coast. Most national research has focussed on the nesting female population but little is known of Guatemala's sea turtles during their lives at sea. Over a period of four months, from February 2014 to June 2014, we conducted six in-water monitoring trips off the Pacific coast of Guatemala observing and capturing sea turtles to determine; species and sex composition, as well as distribution and abundance. During the study, a total of 202 olive ridley and two eastern Pacific green turtles (*Chelonia mydas*) over 311 km of transects were observed. A total of 34 olive ridleys were successfully captured using the sea turtle rodeo technique and all were at reproductive adult size. This preliminary work shows large numbers of olive ridley turtles utilising Guatemala's coastal waters outside of the peak nesting season, suggesting that these waters may be a significant location for olive ridleys in the eastern Pacific (EP). This pilot work shows great potential to further study the behaviour and ecology of olive ridley turtles within the EP.

INTRODUCTION

The south-east Pacific coast of Guatemala is classified as highly productive with great diversity in continental and coastal marine habitats (CBD 2013). At the edge of the continental shelf, 30 km from the coast, the marine area is characterised by a submarine canyon known as the canyon of San José. The canyon is 20 to 30 km wide (Ladd & Schroder 1985) reaching depths of up to 2,000 meters (Boix 2011) and extends out into the Middle America Trench (von Huene *et al.* 1985). This area provides important habitat for several species of sea turtles; olive ridley (*Lepidochelys olivacea*), leatherback (*Dermochelys coriacea*), eastern Pacific green (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) turtles (Higginson 1989). The most abundant turtle in the region is the olive ridley which nests along the entire 254km Pacific coast between June and December. It is estimated that almost 100% of eggs laid on the 254 km are legally harvested then sold for human consumption (Brittain *et al.* 2007). Despite their economic importance and international status as a vulnerable species (IUCN 2014), there have been no population assessments to determine the status of Guatemala's olive ridley turtles. In order to successfully manage the population, information about mortality, recruitment, and temporal changes in abundance or density is vital (Eguchi *et al.* 2007).

Beach counts of nesting females is commonly used as an index of abundance for marine turtles (Meylan 1995), however inter-annual variability in nesting abundance can make it difficult to make reliable estimates and the low nest site fidelity of olive ridley females adds further complications (Brittain *et al.* 2013). Eguchi *et al.* (2007) suggested utilising transect sampling at sea as an alternative and complimentary method to nesting beach surveys. In Guatemala, the majority of research focuses on nesting females and knowledge of distribution and abundance of male olive ridleys remains scant. At sea sampling presents an excellent opportunity to fill this knowledge gap and further understand the temporal distribution of male and female olive ridley turtles that utilise Guatemala's Pacific coastal waters.

Akazul: Community, Conservation & Ecology is a UK registered not for profit Community Interest Company and has been operating its sea turtle conservation project in La Barrona, Guatemala since 2011. Key to Akazul's long-term goal is conducting monitoring and research activities to further our understanding of

Guatemala's sea turtle populations. Between February and June 2014, in collaboration with University of Exeter we carried out preliminary surveys to obtain information on the abundance and distribution of olive ridley turtles in Guatemala's Pacific coastal waters.

METHODOLOGY

We observed and captured sea turtles in coastal waters on the Pacific coast of Guatemala, adjacent to the coastal settlement of Las Mañanitas in the department of Santa Rosa (Fig. 1).

From February 2014 to June 2014 six in-water monitoring trips were carried out making vessel-based, visual observations of sea turtles within the study area. In respect to observation effort, haphazard, unmarked, non-linear transects (HUNTs) as described by Bresette *et al.* (2010) were utilised**.** With this method, olive ridley turtle locations were recorded and opportunistic captures of turtles were made. During survey trips the captain used a Garmin Global Positioning System (GPS) following a straight line course up to 30 kilometres from the coast. Transects were near haphazard as the captain would deviate away from the predetermined course once a turtle was sighted to improve capture opportunities. We utilised a GPS tracker unit (I GOT U) to record effort tracks, to show the start and end location of surveys. Vessel speed during transects was kept as close to 10 km per hour as possible. Using two observers and a data recorder, all of whom were trained and experienced Akazul Research Assistants, the following information was recorded for each sampling trip: start time, end time, wind force and direction and sea state. For each turtle sighted, species (as described by Pritchard and Mortimer 1999), GPS location and time of encounter were recorded. For simple temporal comparisons, monthly mean sea turtle sightings per km of transect effort (km^{-1}) were calculated by dividing the number of turtles sighted by vessel track length.

Turtles were captured using the sea turtle rodeo technique (Ehrhart and Ogren 1999) and were then lifted on board for data collection (Fig. 3). Curved carapace length (notch to tip) (Bolten 1999; CCL) and curved carapace width (Bolten 1999; CCW) were measured to the nearest 0.5 cm with a flexible measuring tape. A series of photographs were taken of each turtle; dorsal and ventral views, close up view of the head and flippers, and photographs of any distinguishing features such as old

injuries. Once data had been collected, turtles were externally tagged on the two fore flippers (Balazs 1999) using uniquely numbered Monel metal tags (National Band and Tag Company, Kentucky, USA) and released (Fig. 3. Using a sterilised scalpel blade a small piece of skin (<0.5 mm in diameter) was collected from the neck region of captured turtles and preserved in 70% ethanol. Iodine solution was then applied to the collection site to prevent infection. Samples will contribute to future regional genetic assay work. . All turtles were released promptly within ten minutes of capture.

To maximize data collection opportunities, observers also recorded observations of other mega-vertebrates noting; GPS location, the number of individuals and species (as described by Jefferson & Leatherwood 1995) where possible.

Although the nesting season is between June and December, sea conditions at this time make surveying extremely difficult. Surveys were only carried out in optimal sea conditions with good visibility in less than Beaufort wind force scale level 3. This restricted sampling to four months (February, March, May, June).

RESULTS

Between February 2014 and June 2014, we observed 202 olive ridley and two eastern Pacific green turtles over 311 km of transects (Fig. 4). Cumulative sighting frequency of olive ridleys for all six surveys was 0.66 turtles km⁻¹ of transect (Table 1.). Maximum sighting frequency of sea turtles was 2.69 turtles km⁻¹ of transect and occurred on 13 March 2014. Minimum sighting frequency was 0.02 turtles km⁻¹ and occurred on 9 June 2014. Total number of turtle observations per survey followed a normal distribution pattern.

Of the 34 olive ridleys captured and measured (19 female and 15 male) mean (±SD) CCL was 64.0 ± 2.9 cm (range: 58 to 70 cm) (Fig. 5). Mean CCW was 68.1 ± 2.6 cm (range: 63 to 73 cm, n=33).

A further eight observations of marine mega fauna were observed during surveys comprising five species; Pacific cownose ray *Rhinoptera steindachneri*; Pacific sailfish *Istiophorus platypterus*; bottlenose dolphin *Tursiops truncatus*; spinner

dolphin *Stenella longirostris*, pantropical spotted dolphin *Stenella attenuata*, and positive species identification for one dolphin was not possible.

DISCUSSION

Our results show olive ridleys utilising coastal waters at distances between approximately 8 and 30 km from the shore and at depths between 24m and 136m adjacent to the Canyon of San José. We also observed a variety of other species of marine mega-vertebrates which is a strong indication that this is a significant marine site for Guatemala's marine mega-fauna with considerable study potential. The greatest number of turtles recorded during any one survey (13 March) was 104 which accounted for 51.5% of all recorded observations and also included the only sightings of *C. mydas* (n=2). During this survey a large localised convergence zone was observed beginning at 15 km from the shore which corresponded to the largest number of turtle sightings recorded in any one survey.

Of the 34 olive ridleys captured and measured mean CCL was 64.0 cm. Minimum carapace length of females nesting at La Barrona, Guatemala is 57cm (Brittain *et al*. 2013) suggesting that 100% of animals captured were at reproductive adult size.

In the months approaching the beginning of olive ridley nesting season (July) an increase in turtle observations was anticipated, however number of turtles observed peaked in March (n=102) and then decreased in the three subsequent surveys (May and June) down to just one turtle observation in June. Further to this we observed only one pair of mating olive ridley turtles (May 6) in the entire study period. The pair were observed approximately 26 km from the coast.

The behaviour of eastern (EP) olive ridleys is described as nomadic (Plotkin 2010) and their distribution appears to be related to the unpredictable seasonal and inter-annual variability that occurs within the EP (Swimmer *et al*. 2006, Eguchi *et al*. 2007; Plotkin 2010). Subsequently it is difficult to determine the origin of the turtles observed in the present study without analysis of genetic samples. It is probable that turtles observed in our study originate from other rookeries within the EP and are opportunistically feeding/following currents that led them into Guatemala's coastal waters, as described by Plotkin (2010).

This preliminary work shows olive ridley turtles utilising Guatemala's coastal waters and may be a significant location for olive ridleys in the EP. Information yielded from captured turtles can vastly improve knowledge of the migratory behaviour of olive ridley turtles and we recommend improving on or modifying the in-water capture work in the future to; increase the capture rate of turtles; include the investigation of the influence of oceanography on turtle distribution; extend the study area out into the Canyon and; improve regional collaboration to further our knowledge on olive ridleys in the EP.

ACKNOWLEDGEMENTS

Table 1. Sighting frequency of olive ridley and eastern Pacific green turtles km⁻¹ of transect.

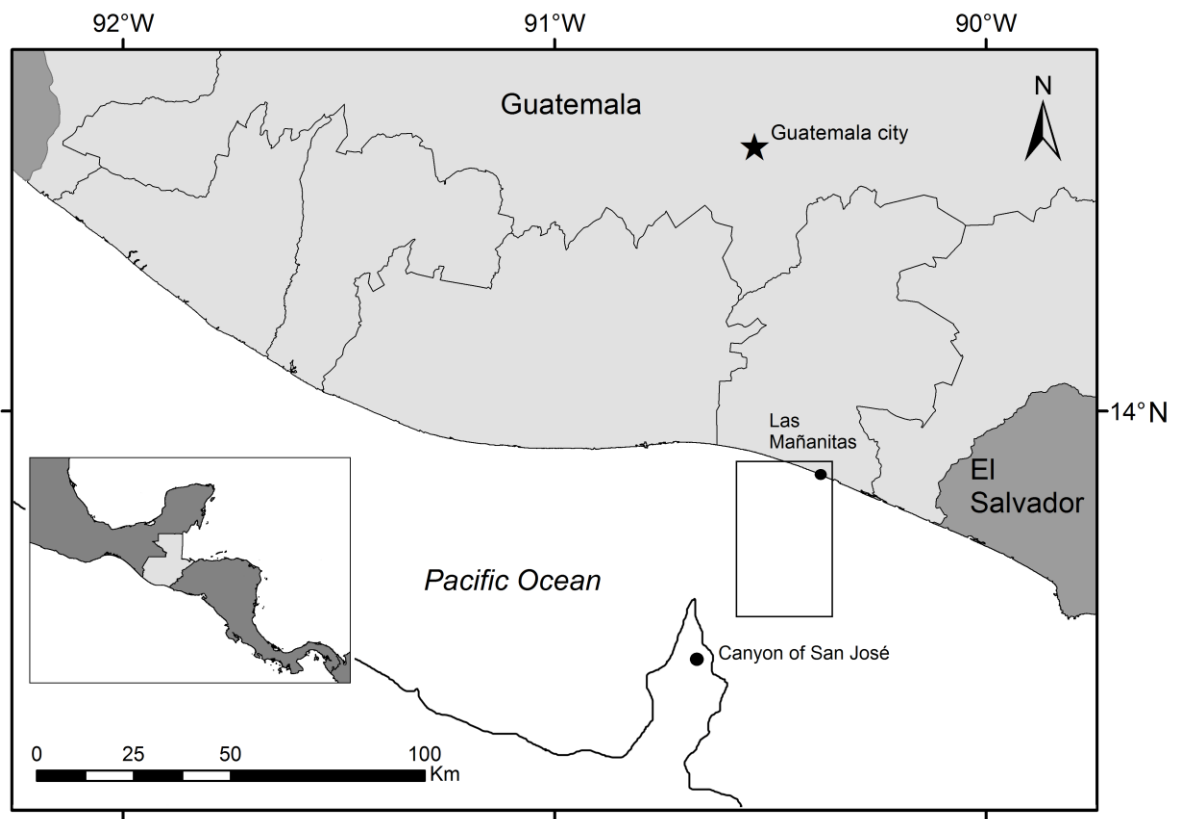| Survey date	*L.olivacea* sightings	*C. mydas* sightings	Length of transect (km)	Sightings km⁻¹ of transect
10-Feb-14	17		63.92	0.27
25-Feb-14	36		36.62	0.98
13-Mar-14	102	2	38.90	2.69
06-May-14	29		56.02	0.52
21-May-14	17		74.98	0.23
09-Jun-14	1		41.00	0.02
Total	202	2	311.44	0.66

Fig. 1. Map of study area on Guatemala's south-east Pacific coast, indicated by black box. Black line indicates edge of the continental shelf at 200m.
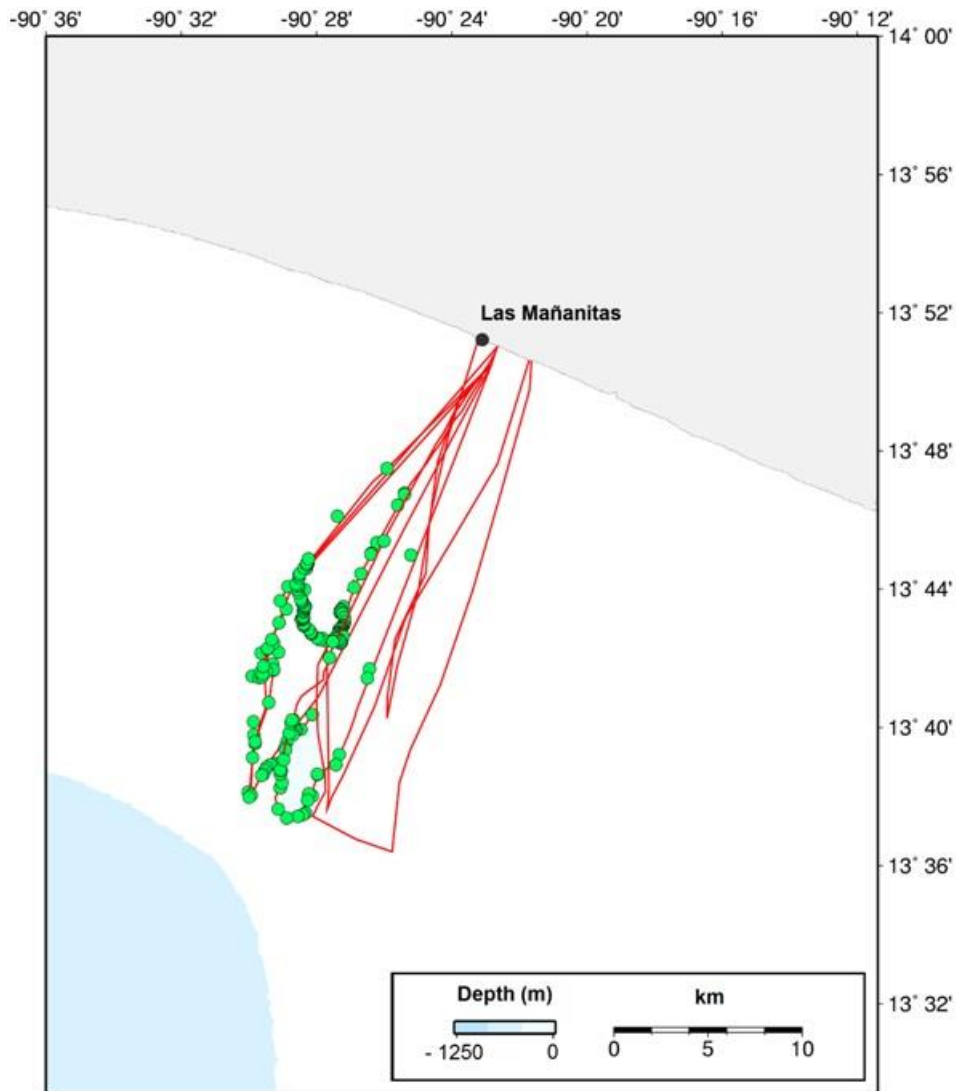
Fig. 2. Survey trips totalling 311 km (n=6) and olive ridley observations (n=202) recorded on the Pacific coast of Guatemala from February – March 2014 and June 2014. This map was made using Maptool program (www.seaturtle.org/maptool), with GEBCO bathymetry data.
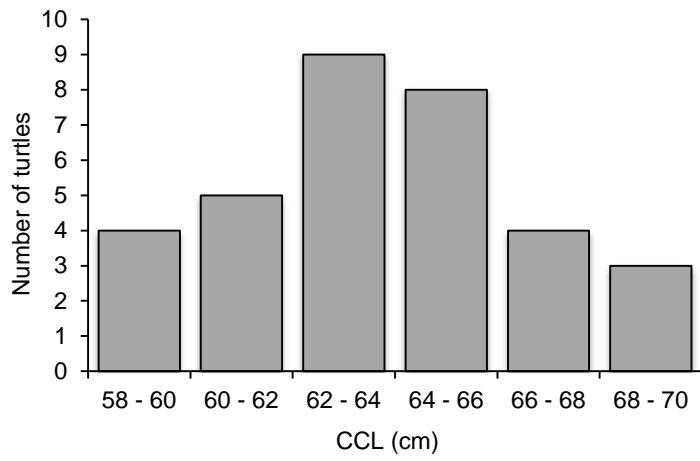
Fig. 3. Curved carapace length (CCL) distribution of olive ridley sea turtles (n=34) captured off the coast of SE Guatemala.

General Discussion

This thesis is a series of works assessing interactions between marine megavertebrates and small-scale fisheries (SSF) on the Pacific coast of Guatemala. Within, I highlight the economic importance of SSF to Guatemala's coastal communities and present findings on their potential negative impact on threatened taxa of megavertebrates. The mixed method approach utilised to gather baseline information reflects the complex and diverse ecological and sociological challenges facing these fisheries. In order to successfully secure a sustainable future for Guatemala's marine resources, and the coastal communities that rely on them, it is vital that a holistic approach is taken towards improved management and governance.

In chapter one "Small-scale fisheries of Guatemala's Pacific coast" I provide an overview of Guatemala's SSF and show that shark, turtle and billfish are the three megavertebrates taxa captured in these fisheries. In chapter two "Incidental elasmobranch catches in Guatemala's Pacific coastal fisheries" I report on high levels of incidental (non-targeted) elasmobranch catches in coastal demersal fisheries and highlight areas of concern, particularly in relation to the international conservation status of a number of species observed. The final chapter "In-water monitoring of olive ridley (*Lepidochelys olivacea*) sea turtles off the south-east coast of Guatemala" uses fisheries independent surveys to determine species composition, abundance and distribution of sea turtles in coastal waters to determine possible areas of interaction with SSF operations.

The overarching theme that emerged during research was that marine resources in Guatemala are understudied and subsequently poorly managed. Future work that builds on improving knowledge of SSF is strongly encouraged. Guatemala's coastal population has seen a faster growth rate in poorer rural areas (Lindhop *et al*. 2015) and as the 16 million national population continues to grow (World Bank, 2016), overcapacity and overexploitation of fisheries will likely happen. Overfishing has been observed as early as the 1980's within Guatemala's Pacific shrimp fishery (Velasco, 2009) and shark landings reported in the small-scale commercial fleet at San Jose and Champerico declined from 142 tonnes in 1995 to less than 17 tonnes in 2000 (Ruiz *et al*. 2000). With key fisheries resource already showing signs of

overexploitation it is likely that fishers will begin targeting other stocks and simply fish down the food chain.

The susceptibility of marine megavertebrates to incidental capture in SSF is well documented (see Peckham *et al.* 2007; Mangel *et al.* 2010; Alfaro *et al.* 2011; Doherty *et al.* 2014) and information presented in this study shows several taxa of international conservation concern being under potential threat from fishing activity. Current fisheries law permits targeted fishing of sharks (see MAGA, 2015) and there are no restrictions in terms of minimum landing size of individuals or total allowable catch. Nor is there any system in place to report species composition of landings or quantities. Given the global conservation status of shark, there is an urgent need to improve the current management of this resource, a revision of fishing law that considers the international recommendations would be a good starting point. However, in order to successfully improve governance and implement management measures, stakeholder engagement is crucial. Understanding drivers behind fisher behaviour would greatly improve management. A sustainable livelihoods approach (see Allison and Horemans, 2011) that aims to reduce poverty and vulnerability in communities engaged in small-scale fishing, fish processing and trading, through community development programs is recommended. Further to this, positive investment to improve infrastructure and opportunities within SSF would be beneficial. For example access to international market would enhance local profitability whilst serving as an incentive to mitigate impact on megavertebrates. Fisheries eco-labelling schemes such as the Marine Stewardship Council (MSC), could provide a useful platform for addressing negative ecological impacts that these fisheries currently have on the marine environment.

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