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Fish market surveys indicate unsustainable elasmobranch fisheries in the Saudi Arabian Red Sea

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ABSTRACT

Elasmobranch populations worldwide are severely threatened due to overexploited and unregulated fisheries. Despite the fact that sharks and rays are captured in fisheries operating along the Red Sea coast of the Kingdom of Saudi Arabia (KSA), information on any aspects of these fisheries are very limited. Here we document the structure, composition and biological characteristics of eastern Red Sea elasmobranch fisheries based on genetic identification and market survey data over an intensive two-year sampling period at the biggest Red Sea fish market in the KSA (Jeddah). Market surveys conducted two times per month between 2011 and 2013 revealed that 24 previously confirmed elasmobranch species for the Red Sea were landed by fishers and offered for sale. Genetic identification revealed two potentially undescribed guitarfish species as well as four batoid species not formerly reported from the Red Sea. Five coastal carcharhinid species dominated the landings—*Carcharhinus sorrah*, *C. amblyrhynchos*, *C. falciformis*, *C. limbatus*, *Rhizoprionodon acutus*, together comprising 73% numerically of the total catch. Targeted shark fisheries reportedly exist in shark nursery areas. Most elasmobranchs outside of these areas were reportedly landed as bycatch. Most strikingly, the large majority of landed elasmobranchs were immature males or females below their reported size of sexual maturity, which suggests potential for both growth and recruitment overfishing and emphasizes the urgent need to implement region-specific management and conservation strategies to avoid the loss of these critical predators.

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1. Introduction

Elasmobranch fisheries are highly susceptible to overexploitation, largely due to their K-selected life-history strategies (low fecundity, late-maturity and/or longevity, Stevens et al., 2000). Demand for seafood has been increasing due to a rapidly growing human population and this demand has outstripped wild-caught supply since at least the 1980s (Pauly et al., 2002). For many centuries elasmobranchs have traditionally been targeted for their meat but more recently the use of elasmobranch products in pharmaceutics and cultural practices, such as the consumption of shark fin soup has lead to an increase in demands (Vannuccini, 1999). Impacts of fisheries on elasmobranchs can range from alterations of population size structures, demography (age of maturity, fecundity) and abundance at the species level (Olsen, 1959; Holden, 1973; Walker, 1998) to large-scale changes impacting the entire ecosystem (Stevens et al., 2000; Jackson et al., 2001; Ruppert et al., 2013). Avoiding such negative effects requires baseline species-specific information of exploited elasmobranch populations to implement effective conservation and management plans.

Sharks and batoids in the Western Indian Ocean are thought to be heavily exploited by a wide variety of fisheries, yet there is a distinct paucity of specific fisheries data (Anderson and Simpfendorfer, 2005). Monitoring and management of Red Sea elasmobranch fisheries is undertaken by various agencies (e.g., the UNDP-FAO Red Sea Project, the FAO IV Fisheries Project) and these agencies have provided some training in shark and ray stock identification for local fisheries observers, species identification guides and detailed strategic action plans to promote sustainable elasmobranch fishing (Bonfil, 2003). However, several issues still face Red Sea elasmobranch fisheries, key among these being a general lack of data on elasmobranch ecology, species diversity, catch size and composition, and fishing effort (Bonfil, 2003; Spaet et al., 2012).

A preliminary recent analysis of the KSA artisanal fishery suggests that targeted teleost species have been overexploited since 1990 (Jin et al., 2012). While official fisheries statistics report limited landings of KSA Red Sea elasmobranch species (Ministry

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of Agriculture and Water, *Fisheries Statistics of Saudi Arabia*), historical data suggests that elasmobranch landings are much higher than reported by national and FAO statistics (Sanders and Morgan, 1989). Indeed, overfishing has been suggested as the cause for recent shark population declines along the eastern Red Sea coast (Clarke et al., 2013). Sharks are typically taken as bycatch in artisanal mixed-species reef fisheries, which operate gillnets, hand-lines and traps from small open speedboats but are also heavily targeted in nursery areas. Industrial fisheries operating bottom-trawls and purse seines are of minor importance (Jin et al., 2012) but are the primary fishery responsible for batoid catches (Bonfil, 2003).

As part of his consultancy work in the Arabian region, Bonfil (2003) provided the first baseline data on KSA elasmobranch fisheries. There has been no update on this data in over a decade. In 2008, a royal decree prohibiting all shark-fishing activities was enacted by the Ministry of Agriculture in an effort to protect KSA fisheries resources. Details on penalties for violations to the law, however, are not specified and enforcement strategies appear to be virtually non-existent. In addition, KSA is not participating in the International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks), as suggested for all countries involved in targeted or incidental shark fisheries by the United Nations Food and Agriculture Organization (FAO) in 1999 (FAO, 1999).

Over a two-year study period from 2011 to 2013 we conducted a survey of the biggest Red Sea fish market in the KSA (Jeddah). This study aimed to bridge the gap in knowledge of elasmobranch landings in the eastern Red Sea by determining the species, size and sex composition, and seasonal variation, of landings, and whether this was sustainable.

Collectively, this data provides the first detailed evaluation of KSA Red Sea elasmobranch landing data.

2. Methods

2.1. Sampling site

The Red Sea coastline of the KSA extends over a length of approximately 1760 km from the border with Jordan in the north to the border with Yemen in the south (Fig. 1). Out of all countries with a Red Sea coast, the KSA has the largest shelf area (*c.* 70 000 km^2). In the northern and central part, the coastal shelf is characterized by shallow fringing reefs that often have steep, wall-like drop-offs (Edwards, 1987). The southern region, in contrast, is characterized by nutrient-rich water and soft-bottomed communities, including shallow bays and lagoons, which are often fringed by mangroves (Khalil, 2004). Compared with the Indian Ocean, environmental conditions in the Red Sea are relatively extreme, with salinities up to 40 and annual sea surface temperatures ranging from 24 °C in spring to 35 °C in summer (Ngugi et al., 2012). The present study focused on elasmobranchs offered for sale in Jeddah, at the largest KSA Red Sea fish market (Fig. 1), where shark and ray landings from all along the KSA Red Sea coast are sold daily during auctions held in the early morning hours.

2.2. Data collection

2.2.1. Market surveys

Market surveys were conducted two times per month between May 2011 and May 2013 at the Jeddah fish market. Visits started between 0400 h and 0600 h in the morning and lasted until the end of the morning auction (between 3 and 8 h, depending on the season). All elasmobranchs offered during each survey day were identified to species and measured to the nearest cm using total length (L_T = the distance between the tip of the snout and the tip of the upper caudal fin (in a relaxed position), with the measuring tape stretched alongside the body axis) for sharks and guitarfishes, or disc width (W_D) for rays and sexed through the presence/absence of claspers. Whenever possible a small tissue sample was collected from the left pelvic fin of each encountered specimen. Tissue samples were preserved in 99% ethanol for subsequent genetic analysis. On rare occasions very large numbers of juvenile sharks were landed, which rendered the collection of data on each individual unfeasible. In such cases the number of individuals for each species auctioned was recorded and the average size of individuals was determined by measuring a representative number of specimens. Reproductive data were obtained opportunistically. Male maturity was determined based on the calcification stage of the claspers (non-calcified claspers: juveniles, partially calcified claspers: sub-adults, fully calcified claspers: fully mature adults). Elasmobranchs were purchased and taken to the laboratory for dissection in cases where there were doubts regarding species identification or when pregnant females were encountered.

2.2.2. Genetic analysis

All tissue samples collected during the survey were barcoded using the cytochrome oxidase barcode marker 1 (COI) to confirm initial species identification based on morphology. DNA was extracted using the Machery-Nagel Genomic DNA from tissue (Bethlehem, PA, USA) extraction kit following the manufacturers' instructions. Total amplification volumes for PCR reactions were 12.5 μL, and contained 1 μL of the template DNA, 1 μL of the primer mix (10 pmol/μL), 6.25 μL of the Qiagen Master Mix (Qiagen Inc.) and 4.25 μL of RNAse-free water. The primer combination FishF1 and FishR1 (Ward et al., 2005) was used for initial amplification and amplified the barcode region for the majority of samples. When these primers failed to produce a PCR product, primers FishF2 and FishR2 (Ward et al., 2005) were used. If this PCR was still unsuccessful, primer combination FishF1 and HCO2198 (Folmer et al., 1994) was used. The PCR thermal cycling employed was: 95 °C initial heating for 15 min to activate the hot start DNA polymerase, followed by 35 cycles of 94 °C for 30 s, 58 °C for 1 min, 72 °C for 1 min, and a 10 min final extension step at 72 °C. Amplifications were performed using Veriti 96-well thermal cyclers (Applied Biosystems). PCR products were visualized on 0.8% TBE agarose gels containing ethidium bromide for DNA quality and concentration, viewed on Gel Doc IT Imaging System (Mitsubishi) and purified using the Exonuclease I method (ExoSap, USB, Cleveland, USA). All sequences were sequenced in the forward and reverse direction and have been submitted to the GenBank database, under accession numbers: KM396932 - KM396952.

In addition to COI, the faster evolving NADH2 fragment was amplified for two shark species and all batoid species in order to distinguish between recently evolved elasmobranch sister species, which cannot be resolved based on COI alone (Wong et al., 2009; Naylor et al., 2012). The universal primer combination ASNM, ILEM (Naylor et al., 2005) was successful in amplifying the targeted fragment in 161 out of 163 cases. The PCR thermal cycling employed was: 95 °C initial heating for 15 min to activate the hot start DNA polymerase, followed by 35 cycles of 94 °C for 30 s, 48 °C for 1 min, 72 °C for 1 min, and a 10 min final extension step at 72 °C. All sequences were sequenced in the forward and reverse direction. The program Codon Code Aligner (CodonCode Corporation, Dedham, USA) was used to assemble and edit forward and reverse sequences. Species identifications were made using GenBank through BLAST (http://blast.ncbi.nlm.nih.gov/Blast.cgi) based on a 95% match criteria. All NADH2 sequences have been submitted to the GenBank database under accession numbers: KM396918 - KM396931. If sequence data did not match the original identification based on morphological characters, respective species identifications were reassessed morphologically when available.

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