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Identification of critical habitat in a data-poor area for an Endangered aquatic apex predator

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ABSTRACT

Conservation often focuses on "critical habitat" including areas important for the reproduction of threatened taxa. As for many aquatic species a priority of shark conservation is the protection of nurseries, yet few countries can support the costly fieldwork required to identify these according to strict criteria. Alternative approaches are therefore required where resource, capacity and security constraints exist. This study collates low-resolution data from alternative, remotely collected and inexpensive existing sources (fish market surveys, literature, museums, anecdotal accounts), to evaluate a possible nursery for the regionally Endangered bull shark (*Carcharhinus leucas*) in the Tigris-Euphrates system and adjacent northwestern Persian/Arabian Gulf (Iraq, Iran, Kuwait), a data-poor area long characterised by conflict and inaccessibility. Evidence is presented that aligns with two of the three nursery definition criteria (abundance and repeated use), along with other data supporting known *C. leucas* reproductive behaviour. While the necessarily low resolution data cannot answer the full suite of strict nursery criteria nor identify precise nursery locations, they nevertheless collectively provide compelling evidence for a broad area of importance to young and juvenile *C. leucas*. This area is both highly threatened (e.g. by damming, climate change, fisheries) and of potential major significance, given the apparent absence of similar estuary habitat for thousands of kilometres of arid northwestern Indian Ocean coast. The inexpensive desk-based approach to identifying critical habitat provides another toolkit option for conservationists and could best be applied to distinctive threatened aquatic taxa, especially in the developing world where conservation is often resource-limited.

1. Introduction

Biodiversity conservation often prioritises areas of 'critical habitat', a term whose use ranges from the informal for areas of elevated importance (e.g. Kelaher et al., 2015) to that defined by strict criteria, such as used by the US Endangered Species Act (ESA) and the International Finance Corporation (IFC). Often, critical habitat recognises the value of both highly threatened species and areas essential for their reproduction. For example, IFC critical habitat criterion 1 includes consideration of habitat 'required to sustain' IUCN *Red List* Critically Endangered or Endangered species, as does the US ESA for sites essential for breeding, reproduction and rearing of offspring (IFC, 2012; US Fish and Wildlife Service, 2017). In practice, funding and logistical concerns often constrain the identification of such areas, especially in data-poor developing or least developed countries. In these situations obtaining even the most basic information often necessitates low-resolution approaches to identify conservation priorities, such as for cetaceans in Tanzania (Braulik et al., 2017).

Sharks and their relatives have undergone well-documented declines and face a higher risk of extinction than most other vertebrates, with species that are both large-bodied and reliant on river systems identified as being particularly at risk (Dulvy et al., 2014). The aim of the 1998 International Plan of Action for Conservation and Management of Sharks is to ensure the global conservation and management of sharks and their relatives, and one of its goals is the identification of critical habitats such as nursery and pupping areas (FAO, 2017a). However, an explicit definition of a shark nursery was lacking until that proposed by Heupel et al. (2007). These authors highlighted that the occurrence of young sharks alone is not sufficient evidence, as it would likely result in most coastal areas being identified as nurseries. Heupel et al. (2007) proposed a definition of a shark nursery based on three criteria being met for "young" (neonate and < 1 year old) sharks. These were that young sharks 1) were more commonly encountered in the area than in other areas, 2) have a tendency to remain or return in the area for extended periods, and 3) use the area or habitat repeatedly across years (Heupel et al., 2007). While these criteria are currently the best available, authors testing them against a large dataset have noted that areas not qualifying as nurseries may still be of significant

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importance to juvenile sharks (Froeschke et al., 2010).

The shark nursery concept has been tested in countries with well-developed shark research programs using costly, extensive, and/or long-term field surveys to identify nursery areas: the USA (Froeschke et al., 2010; Curtis et al., 2011), Australia (Thorburn and Rowland, 2008) and South Africa (Hussey et al., 2009). Multi-faceted studies that involve less exhaustive field surveys have also advanced our knowledge of euryhaline coastal shark reproductive behaviour (Werry et al., 2011), but still rely on significant fieldwork and resources. These surveys, in a handful of countries, are not reflective of reality along coastlines of developing or least developed countries where elasmobranch research is absent or limited due to resource, capacity and other constraints. Alternative and complementary approaches are clearly needed to inform conservation and management in these locations.

A range of relatively inexpensive and land- or desk-based data collection techniques are available to shark researchers to directly inform conservation, including fish market surveys (e.g. White, 2007) and collating catch data from recreational anglers (Ajemian et al., 2016), the latter of which has been used to identify potential nursery grounds (Dicken et al., 2006). The growing field of marine historical ecology (MHE) draws on a range of alternative data sources such as archaeology, anecdotes, museum specimens and old photographs to inform conservation (Lotze and McClenachan, 2014), and MHE studies on marine megafauna in the Arabian region have documented rare species, identified potential areas of importance, and reconstructed historical baselines of sawfishes and dugongs (Moore, 2010, 2011, 2015; Al-Abdulrazzak and Pauly, 2017).

The bull shark (*Carcharhinus leucas*) is found in shallow warm coastal waters worldwide, although molecular data suggest it represents a cryptic species complex (Naylor et al., 2012; Ebert et al., 2013). *Carcharhinus leucas* is euryhaline and apparently reliant on freshwater and estuary systems for nurseries which are thought to provide a low-mortality environment for young (Heupel and Simpfendorfer, 2011). The occurrence of this large (maximum recorded total length (TL) 400 cm, McCord and Lamberth, 2009) shark in river systems has attracted research for decades across the globe, from the Amazon to Fiji (Thorson, 1972; Cardeñosa et al., 2016). In the Middle East, it has been known since antiquity that sharks occur in the Tigris-Euphrates system (Zorzi, 1995; Moore and McDavitt, 2009), from where there have been numerous recorded incidents of them biting humans (Wilson, 1941; Hunt, 1951; Thesiger, 1964; Coad and Papahn, 1988; Coad and Al-Hassan, 1989). There has however apparently been little or no research interest in the ecology of *C. leucas* there. A notable exception was in the late nineteenth century, when Dr. Albert Günther of the British Museum examined a young specimen from the Tigris at Baghdad and noted “It would be a point of great interest to ascertain whether this fish spawns in the river…or whether it descends to the sea for that purpose” (Günther, 1874, p. 36). *Carcharhinus leucas* has been assessed as Endangered in the Arabian region (Simpfendorfer et al., 2017).

The aim of the present study is to investigate the possible presence of a *C. leucas* nursery in the Tigris-Euphrates system and adjacent waters of the Persian (Arabian) Gulf (‘the Gulf’ hereafter) using available data, including testing it against the criteria of Heupel et al. (2007).

2. Methods and materials

2.1. Study area

The study area is centred around Kuwait and Iraq in the northwestern Gulf, but also considers the wider central and southern parts of the Gulf around Bahrain and Qatar (Fig. 1). Both the Tigris and the Euphrates rivers rise in Turkey and flow through Syria and then Iraq, where they support the Mesopotamian Marshes in southern Iraq (FAO, 2017b). They then combine to form the Shatt Al-Arab River, which is then joined by the Karun River, a significant tributary rising in Iran. The Shatt Al-Arab forms a boundary between Iraq and Iran, and discharges to the northwestern Gulf < 20 km from Kuwait's maritime border (Fig. 2). Although there are other drainages along the Iranian coast (Mand, Helleh, Hendijan) the Shatt Al-Arab is by far the main source of freshwater to the northern Gulf, where it is of major significance to marine ecological conditions and the only extensive estuarine system (Al-Yamani, 2008). The delta system in the northwestern Gulf also includes the Shadegan wetland in Iran with freshwater, tidal and marine habitats. The entire Tigris-Euphrates system has been heavily modified through extensive drainage, canal construction, damming, and irrigation projects (FAO, 2017b), such as the Shatt Al-Basrah Canal connecting the Khor Al-Zubair, an estuarine northwestern extension of the Gulf, with the marshes area. The area has been the focus of persistent armed conflict in recent decades, most notably the Iran-Iraq War (1980–1988), The Gulf War (1990–1991) and the Iraq War (2003 – 2011). This has restricted access to the area for ecological research and continues to do so for reasons such as military sensitivities, border disputes, and unexploded ordnance. Fisheries pressures are widely acknowledged to be intensive throughout the Gulf, and with an average depth of only 35 m makes most elasmobranchs highly available to fisheries; widespread declines in the abundance of elasmobranchs including carcharhinid sharks have been reported (Valinassab et al., 2006; Jabado et al., 2017).

2.2. Identification

Size of *C. leucas* is expressed as stretched total length (STL, caudal fin depressed), or total length (TL, caudal fin in natural position). In cases where the distinction between these was not made in the original data source, STL has been assumed, acknowledging that there is a relatively small difference between the two. All individuals were identified by the author where possible either directly or from good quality lateral photographs. While several species of *Carcharhinus* occur in the Gulf (Almojil et al., 2015), only one species, the pigeye shark *C. amboinensis*, shares with *C. leucas* key characteristics of a short blunt snout, a lack of distinct fin markings, and broadly triangular serrated upper teeth. As per Garrick (1982), the ratio of the measured height of the first to the second dorsal fins was calculated to separate *C. leucas* (< 3.1) from *C. amboinensis* (> 3.1). Records of unidentified sharks in freshwater or lower salinity environments were assumed to be *C. leucas*; *C. amboinensis* is reportedly restricted to inshore marine habitats (Ebert et al., 2013) and juveniles appear to display a low tolerance of low salinity environments (Knip et al., 2011). The enigmatic river shark genus *Glyphis* that has sometimes been confused with *C. leucas* is not known west of Pakistan (Ebert et al., 2013).

2.3. Data collection

Comparative surveys of elasmobranchs at artisanal fisher landing sites and fish markets are detailed elsewhere (Moore et al., 2012; Moore and Peirce, 2013). These identified and measured all elasmobranch individuals in the month of April and took place in Kuwait in 2008 and 2011 representing landings from fisheries operating in the northwestern Gulf, while surveys in Qatar in 2009 and Bahrain in 2012 sampled the central and southern Gulf (Moore et al., 2012; Moore and Peirce, 2013). Sharks at more easterly markets in the United Arab Emirates (UAE) (Moore et al., 2012; Jabado et al., 2015, 2016) were not considered in this study as they may include individuals caught outside of the Gulf (Jabado et al., 2015, 2016). Vessels landing small sharks in Kuwait, Qatar and Bahrain are primarily small (*c.* 7–10 m) open speedboats operating gillnets in local coastal waters catching sharks as bycatch. Fisheries in all locations were considered as equally likely to catch and land young *C. leucas* if present, given that all elasmobranch landings regionally are dominated by smaller carcharhinids (Moore et al., 2012; Moore and Peirce, 2013; Jabado et al., 2015). Species discovery curves of the Kuwait, Bahrain and Qatar surveys also