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First description of deep-water elasmobranch assemblages in the Exuma Sound, The Bahamas

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ABSTRACT

Deep-sea chondrichthyans, like many deep-water fishes, are very poorly understood at the most fundamental biological, ecological and taxonomic levels. Our study represents the first ecological investigation of deep-water elasmobranch assemblages in The Bahamas, and the first assessment of species-specific resilience to capture for all of the species captured. Standardised deep-water longline surveys ($n=69$) were conducted September to December 2010 and 2011 between 472 m and 1024 m deep, resulting in the capture of 144 sharks from 8 different species. These included the Cuban dogfish, *Squalus cubensis*, the bigeye sixgill shark, *Hexanchus nakamurai*, the bluntnose sixgill shark, *Hexanchus griseus*, the smooth dogfish, *Mustelus canis insularis*, the roughskin dogfish, *Centroscymnus owstoni*, Springer's sawtail catshark, *Galeus springeri* and the false catshark, *Pseudotriakis microdon*. Preliminary genetic analysis indicated two or more species of gulper sharks, *Centrophorus* spp.; however, for the present study they were treated as a single species complex. Water depth and distance from the rocky structure of the Exuma Sound wall were inversely correlated with species richness, whereas seabed temperature was directly correlated with species richness. These variables also had a significant influence on the abundance and distribution of many species. Expanded depth ranges were established for *S. cubensis* and *H. nakamurai*, which, in the case of *S. cubensis*, is thought to be driven by thermal preferences. At-vessel mortality rates increased significantly with depth, and post-release mortality was thought to be high for some species, in part due to high post-release predation. This study highlights the importance of utilising strategic geographic locations that provide easy access to deep water, in combination with traditional expedition-based deep-ocean science, to accelerate the acquisition of fundamental ecological and biological insights into deep-sea elasmobranchs.

1. Introduction

There is a fundamental lack of basic biological and ecological information pertaining to the majority of deep-water species (Devine et al., 2006; Haedrich et al., 2001; Norse et al., 2012), largely due to the logistical challenges and expense of sustained ecological investigation in this remote and challenging ecosystem (Ramirez-Llodra et al., 2011). Despite being home to ~50% of all known chondrichthyan species (Kyne and Simpfendorfer, 2007), the study of deep-water elasmobranchs is very much in its infancy; indeed, many genera need further investigation on the most fundamental genetic and taxonomic level (Last, 2007; Naylor et al., 2012; White et al., 2013). Estimates of species productivity and intrinsic rebound potential only exist for 2.2% of deep-ocean chondrichthyans (Kyne and Simpfendorfer, 2010), and those that have been assessed have among the lowest values documented for any species of fish to date (Simpfendorfer and Kyne, 2009). In areas where deep-water sharks have been actively targeted by fisheries, dramatic population declines have been triggered (Anderson and Ahmed, 1993; Barbier et al., 2014; Daley et al., 2002, 2015; Graham et al., 2001; Graham and Daley, 2011; Jones et al., 2005; Koslow et al., 2000; Morato et al., 2006; White and Kyne, 2010), and it is likely that bycatch of elasmobranchs in deep-water trawl and longline fisheries is having similar negative effects (Graham et al., 2001). Given the slow rate of scientific advancement in the deep-ocean, it has been suggested that many fisheries may become commercially extinct before scientific study can begin (Haedrich et al., 2001).

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The effective management and conservation of deep-sea shark stocks is dependent on access to pertinent life history, community structure and species resilience data; information which at present is largely absent. Virtually no fisheries-dependent or independent research has been conducted in the Western Central Atlantic Fishing (WECAF) region, which incorporates the tropical and sub-tropical western Atlantic, the Caribbean Sea and the Gulf of Mexico. The Food and Agriculture Organisation of the United Nations estimate that a total of 101 chondrichthyan species inhabit the WECAF region based on limited fisheries data (Kyne and Simpfendorfer, 2007). A recent WECAFC workshop on deep-sea fisheries (October 2014) concluded that there were no commercial deep-sea fisheries in the region operated by member states, however, there are many foreign vessels operating in the region and a request for fisheries data has been made to the relevant flag states (R. VanAnrooy, personal communication). The only two published fisheries independent studies in the region are the work of McLaughlin and Morrissey (2004) who undertook a series of deep-water longline surveys of various types off the coast of Jamaica, and the work of Russell et al. (1988) who undertook some bottom longline surveys off the coast of Puerto Rico. Other than these relatively limited studies, there has been no further structured investigation into deep-water elasmobranch assemblages within the WECAF region.

In addition to understanding the basic structure of deep-water elasmobranch assemblages, one of the most important areas of research from a management point of view is species-specific resilience to capture. The capture of an animal in commercial fishing gear imposes both physiological and physical insults, which can lead to either immediate (at-vessel), or post-release mortality (Brooks et al., 2012; Skomal and Mandelman, 2012). In deep-water sharks the stress of capture is potentially compounded by the additional thermal, barometric and photic stress associated with an ascent from the deep-ocean. Consequently, it is likely that deep-water sharks have higher rates of both at-vessel and post-release mortality than shallow water species; however, this has yet to be investigated. The quantification of post-release mortality is more challenging given the extreme conditions of the deep-water environment. In recent years pop-up archival satellite transmitters (PSAT) have been used to quantify the post-release mortality and behaviour of a number of shallow water species of shark (e.g. Campana et al., 2009; Hoolihan et al., 2011), however, the use of PSATs to monitor post-release survivorship and behaviour in deep-water species has seen limited application.

Given this acute lack of fundamental data pertaining to deep-water elasmobranchs, there were two objectives to this study. First, we investigate the diversity, distribution and demographic structure of deep-water elasmobranch assemblages in the north-east Exuma Sound, The Bahamas; and second, we provide preliminary estimations of the resilience of the species encountered to longline capture.

2. Methods

Research was carried out under the Cape Eleuthera Institute research permit numbers MAF/FIS/17 and MAF/FIS/34 issued by the Bahamian Department of Marine Resources and in accordance with CEI animal care protocols developed within the guidelines of the Association for the Study of Animal Behaviour and the Animal Behaviour Society (Rollin and Kessel, 1998).

2.1. Study area

This study was conducted September to December 2010 and 2011 in the waters adjacent to Cape Eleuthera, Eleuthera, The Bahamas (24.54°N, 76.12°W). The Exuma Sound is a deep-water inlet of the Atlantic Ocean 200 km in length and 50–75 km in width, orientated approximately NW/SE on its long axis. The Exuma Sound is surrounded by the shallow waters of the Great Bahama Bank and is characterised by steep walls dropping from ~30 m to over 500 m along its margin, slowly increasing to a maximum depth of 1600–2000 m approximately 25 km from the wall (Buchan, 2000). The steep walls at the edge of the Exuma Sound are characterised by rugose limestone outcroppings providing a complex benthic structure (Ball et al., 1969). As gradients become shallower on the floor of the sound, the benthos transitions to muddy silt dominated by clastic turbidites (Crevello and Schlager, 1980) which provide very little benthic structure. The northeast corner of the Exuma Sound is ~2.5 km from Powell Point, on the southeastern tip of the island of Eleuthera, with water depths in excess of 1000 m accessible in less than 4 km from shore.

All research was conducted in collaboration with the Cape Eleuthera Institute's sister organisation The Island School (www.islandschool.org). One of the tenants of The Island School programme is the immersion of students in ongoing primary research conducted at the Cape Eleuthera Institute. Students are guided through the research process from posing a question, gathering and analysing data, and finally communicating their results via scientific posters and presentations. Both the 2010 and 2011 field seasons were run as Island School research projects, thus this study performed a dual research and educational purpose.

2.2. Demersal longline sampling

Standardised demersal longline surveys consisted of a mainline anchored to the seabed by a single grapnel anchor. Thirty gangions terminating in one of four different sizes of circle hook (5 × 16/0, 5 × 14/0, 10 × 12/0, 10 × 10/0) were spaced approximately 10 m apart originating 5 m from the anchor. This wide range of hook sizes was designed to capture a wide range of jaw morphologies to ensure that the gear would sample the entire species assemblage and all demographics within a species. The ~300 m section of mainline to which the hooks were attached fished at prescribed depths throughout the survey. Hooks were baited with a mixture Atlantic bonito (*Sarda sarda*) and opportunistically sourced fish carcasses. To ensure all hooks were on the seabed, mainline length was a minimum of 1.5 times the water depth resulting in lengths between 1000 and 2000 m. An archival temperature and depth recorder (TDR) (Lotek LAT-1400, Newfoundland, Canada), programmed to record temperature and depth every second, was affixed to the mainline 10 m from the last hook. Depth and seabed temperature for each set were taken as the deepest and coldest record from the entire dataset. Soak time was ~4 h based on deployment and retrieval times, however, more accurate soak times were calculated post-hoc from TDR data, based on time at maximum depth. A maximum of two lines were deployed each field day, and never more than one at a time. Sets were conducted during both the day and night. For each survey, the straight line distance between the survey location and the vertical wall, marking the edge of the Exuma Sound, was measured using Arc GIS (Version 9.1, ESRI, Redlands, California, USA). Based on these measurements, surveys were assigned to six, 500-m wide geographic zones (Fig. 1). Since no surveys were conducted within 500 m of the wall to minimise entanglement and gear loss in the rocky structure, Zone 1 was defined as 500–1000 m from the wall of the Exuma Sound, Zone 2 1000–1500 m, and so on through to Zone 6 which was 3000–3500 m from the wall (Fig. 1).

All sharks captured were identified to species and pre-caudal (L_{PC}), fork (L_F) and total (L_T) lengths recorded. Sex was determined based on presence/absence of claspers. Maturity estimates for males were based