Additional information

Objectives and purposes

The aim of this study is to assess the influence of biotic (size, sex, feeding history) and abiotic (oceanographic and environmental conditions) on shark migrations and movement along the east coast of Australia, within the East Australian Current, and across the Tasman Sea. Research will be completed and data collected on an opportunistic basis, and may include shortfin makos and white sharks.

(1) Assess the movements of white sharks and shortfin makos to identify and protect habitat critical to the survival of the species

Habitat use and the ability to determine movement patterns seasonally and interannually are fundamental to species conservation, as well as an understanding of their life history and ecology. Acoustic tags and satellite tow tags will be externally placed to provide information on shark large-scale movements, residency and habitat use. Acoustic tag will enable to monitor sharks whenever they swim within the proximity of acoustic receivers (~500 m). Such receivers have been deployed throughout Australia by scientists and by the Integrated Marine Observing System (IMOS) Animal Tracking Facility. Detections from all these receivers are uploaded on a publicly accessible online database curated by IMOS (https://animaltracking.aodn.org.au/), enabling access to detections from >1,000 receivers deployed throughout Australia and on Lord Howe Island. Satellite tow-tags provide accurate location estimates whenever sharks are sufficiently close to the surface for the tag's antennae to be in air. Combined, these tags will enable to assess the movement of tagged white sharks and shortfin makos.

(2) Determine the feeding history (diet) of white sharks and shortfin makos

The need to meet energetic requirements is one of the key drivers of animal movements and migrations. Biochemical tracers, stable isotope and fatty acid analyses (Meyer et al 2019; Shipley and Matich 2020), will be used to determine feeding history and assess its influence on animal movements.

The diet of a species has traditionally been estimated based on stomach content analysis, whereby individuals' stomach contents are removed and prey items are identified (Cortes 1997, Cortés 1999, Espinoza et al. 2015). Stomach content analysis provides valuable information on the recent prey preferences of a species but are affected by variable rates of digestion affecting identifiability, and only reflect relatively recent meals (Hussey et al. 2011). Biochemical methods are less invasive and solve these issues by reflecting a species' diet over larger spatial and temporal scales than is possible with stomach content analyses due to the assimilation and retention of biochemicals in species' tissues. Stable isotope analysis is currently the most widely used biochemical method for exploring trophic ecology due to its ability in detailing the resource use and habitat preferences of organisms in a largely non-invasive manner (Hussey et al. 2012b, Newsome et al. 2012, Pethybridge et al. 2018). Stable isotopes are a valuable tool for exploring the trophic ecology of highly mobile and elusive elasmobranch species (Hussey et al. 2012b). The isotopes are incorporated into an animal's tissues over a scale of months to years, so they reflect an organism's resource use over large time scales but cannot discern fine-scale details in habitat and prey preferences (Hussey et al. 2012b).

Fatty acid analysis is a biochemical method increasingly used to explore resource use and feeding ecology (Parrish 2013) and can provide information on a species' feeding ecology at finer resolutions than is possible with stable isotopes (Beckmann et al. 2013, Meyer et al. 2019). Fatty acids are biochemical compounds that are synthesised by primary and secondary producers and vary according to the type of producer and environmental conditions of the ecosystem (Dalsgaard et al. 2003). These fatty acids are transferred throughout the food web as higher order species prey upon primary, secondary producers, and consumers, assimilating their fatty acids. Reliable fatty acid tracers have been linked to specific prey items, habitats, water temperatures, and trophic guilds, allowing ecologists to use the fatty acid profiles of high-order consumers to identify feeding habits, resource use, and trophic levels (Meyer et al. 2019). Fatty acids also have shorter turnover rates (weeks to months) than stable isotopes, making them suitable for exploring feeding ecology at finer time-scales (Beckmann et al. 2013, Every et al. 2017, Meyer et al. 2019). Fatty acid analysis has been used to complement other methods, such as stomach content analysis (e.g. Pethybridge et al. 2011), stable isotope analysis (e.g. Brewster et al. 2016, Sardenne et al. 2016, Every et al. 2017), or all three methods (e.g. North et al. 2019), demonstrating the efficacy of fatty acid analysis in describing feeding ecology and providing complementary results to other methods.

(3) Quantify activity and energy expenditure of sharks to assess energetic costs associated with wildlife tourism

A recent study has shown that wildlife tourism can change the activity levels of white sharks (Huveneers et al 2018). However, this study was based on activity recorded at the Neptune Islands only during periods when cage-diving operators were present, with limited period when operators were absent. The ability to access sharks at locations where wildlife tourism has not been undertaken provides the opportunity to record white shark activity levels away from the cage-diving site and use this data as a control treatment to compare it against activity at the cage-diving site. This will allow to better entangle the factors that might influence activity and energy expenditure of white sharks, interpret the data obtained, and ultimately assess the effects of the cage-diving industry on white shark energy expenditure.

This study directly relates to the following objectives of the White Shark Recovery Plan:

Objective 5: Investigate and manage (and where necessary reduce) the impact of tourism on the white shark;
Objective 7: Continue to identify and protect habitat critical to the survival of the white shark and minimise the impact of threatening processes within these areas; and
Objective 8: Continue to develop and implement relevant research programs to support the conservation of the white shark.

Equipment and methods

Aim 1 will be achieved using acoustic tags and satellite tags; Aim 2 will be achieved by collecting muscle biopsies; and Aim 3 will be achieved by deploying bio-logging tags which incorporates a 3D accelerometer, gyroscope, magnometer, speed sensor, and camera.

Tagging - Acoustic tag

Acoutic tags will be attached externally below the first dorsal fin (Fig. 3) using a modified low-power spear gun while sharks are free-swimming next to the vessel. This method has and continue to be used in South Australia to monitor the residency of white sharks at the Neptune Islands Group Marine Parks (Huveneers and Udyawer 2018).

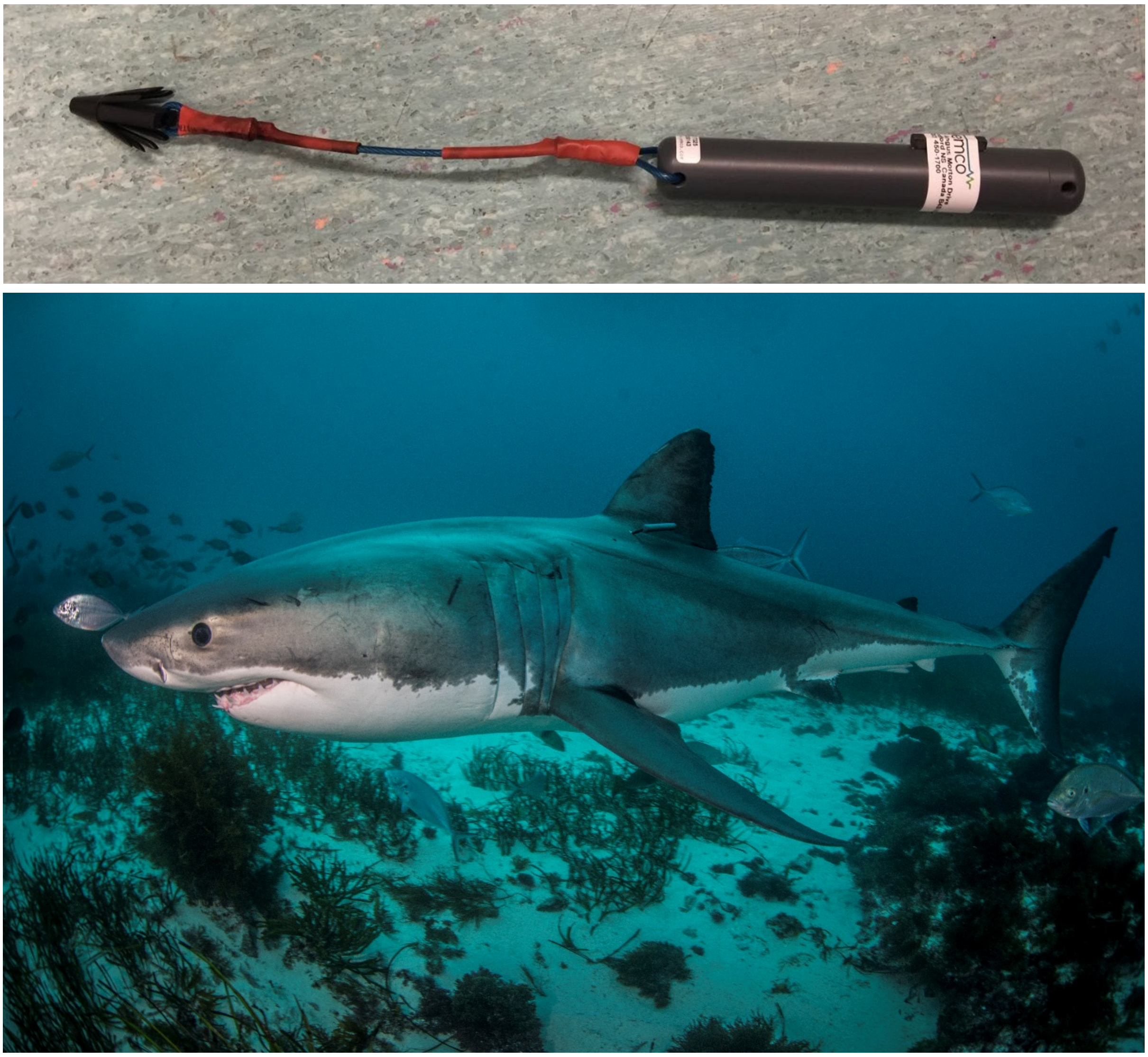

Figure 3. Top: Acoustic tag use to monitor residency of sharks; Bottom: example of a white shark externally tag with an acoustic tag (below the first dorsal fin). This white shark was tagged as part of the South Australian cage-diving industry monitoring.

__Tagging - Satellite tow-tag__

Satellite tow tags will be deployed in the same way and will have a tether of ~1 m to maximise time when the tag will be at the surface and provide location estimates (Fig. 4).

Figure 4. Example of a satellite tow-tag deployed on a whale shark. Note that the clamp and yellow float shown on the photographs are not part of the tow-tag.

Biopsies

Tissue samples of < 2 g will be collected using a modified speargun, using the technique describe in Meyer et al (2018). A specialised biopsy tip (Fig. 5) attached to the end of a spear will be used from a low-power speargun to collect a small skin and muscle sample. The injury sustained by the shark is far smaller than those typically observed from interactions between mating individuals or during prey capture. This method has previously been used to collect biopsies from 75 white sharks (Meyer et al 2019).

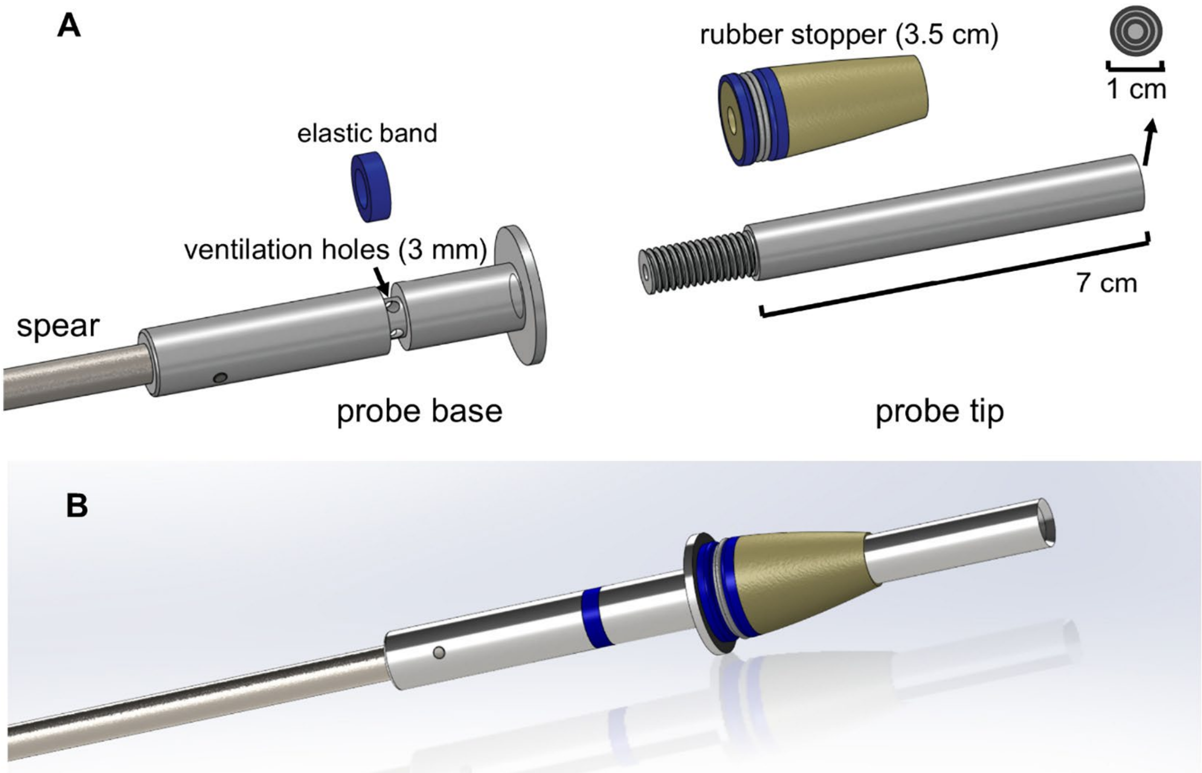

Figure 5. Biopsy tip used to collect muscle sample (for more information see Meyer et al 2019).

Bio-logging tag

The bio-logging tag (camera and accelerometer) will be attached to the leading edge of the dorsal fin of each shark as they are free-swimming beside the vessel using a custom-built attachment pole (Fig. 6). The tag is attached via a clamp sleeve with pads, making it less invasive than conventional tags (Chapple et al. 2015; Huveneers et al 2018; Watanabe et al 2019). The bio-logging tag will detach from the shark after 2-4 days, with the clamp sleeve detaching a few days afterwards using a corrodible magnesium link.

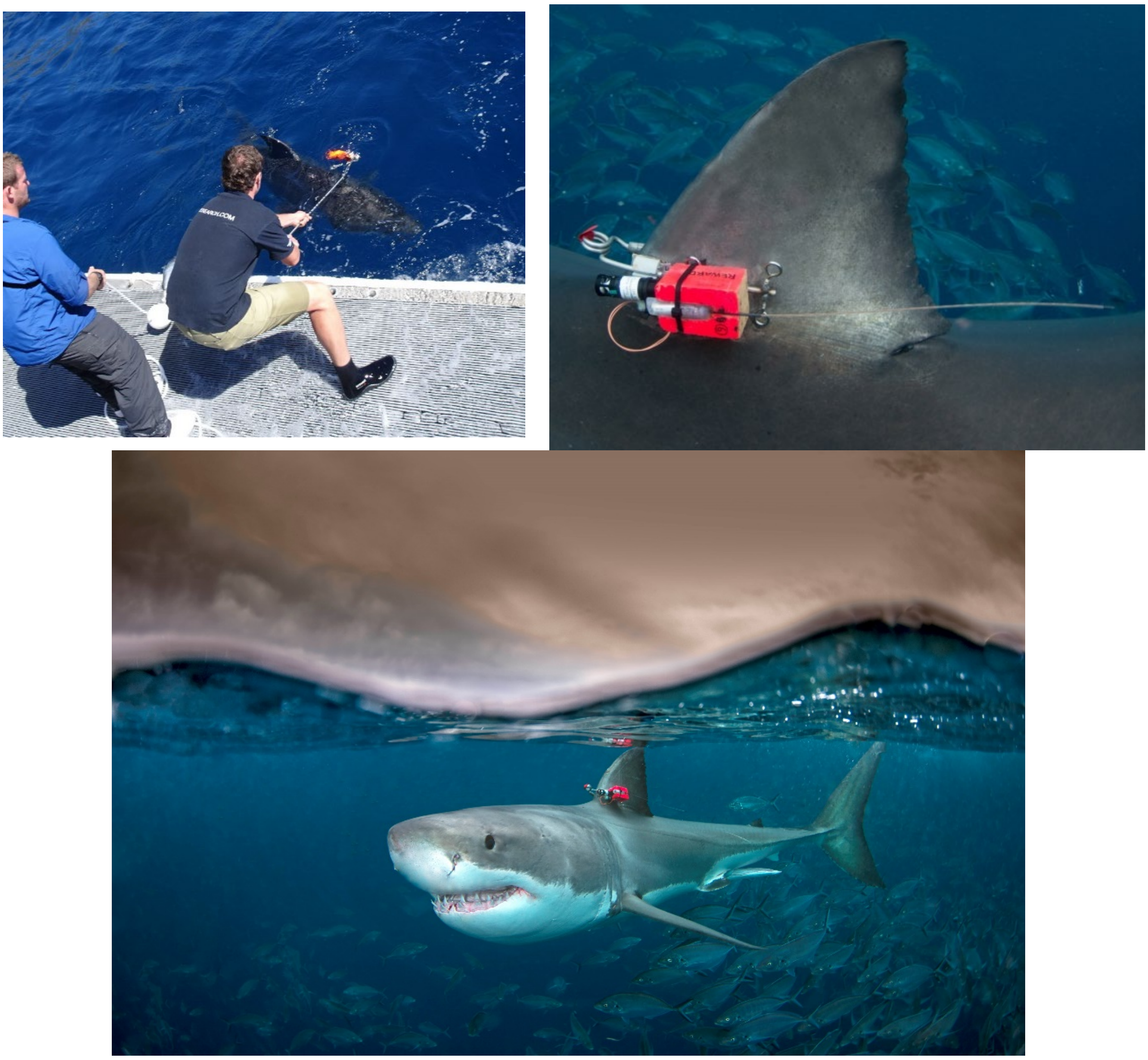

Figure 6. Top left: Example of a bio-logging tag deployment on a white shark; Top right & bottom: Examples of a deployed bio-logging tag on a white shark.

The tagging, handling and sampling procedures employed during the expedition will follow Flinders animal ethics approval.

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