

Chasing tail: putative pre-copulatory behaviour in free-living zebra sharks (*Stegostoma fasciatum*)

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Abstract

Endemic to the Indo West-Pacific region, zebra sharks (*Stegostoma fasciatum*) are on the International Union for Conservation of Nature endangered species list. Despite this, little is known about the reproduction behaviour or where individuals copulate. In October 2015, two zebra sharks - one male and one female - were observed on a baited remote underwater stereo-video system (stereo-BRUVs) with the male shark biting the end of the female's caudal fin as they swam together in 53 m water depth off the coast of the Dampier Archipelago, Western Australia. This is the first recorded observation of free-living zebra sharks displaying pre-copulatory behaviour at this depth and is documented to be the early stages of courting, whereby the male is trying to slow and tire the female to then obtain a better position for clasper insertion. Observations of pre-copulatory behaviour in sharks are extremely rare and even more so in the depths sampled here. Documenting similar behaviours and building on singular observations to work towards a better understanding of the zebra sharks reproductive behaviour is needed to identify critical habitats and allow for better informed management decisions.

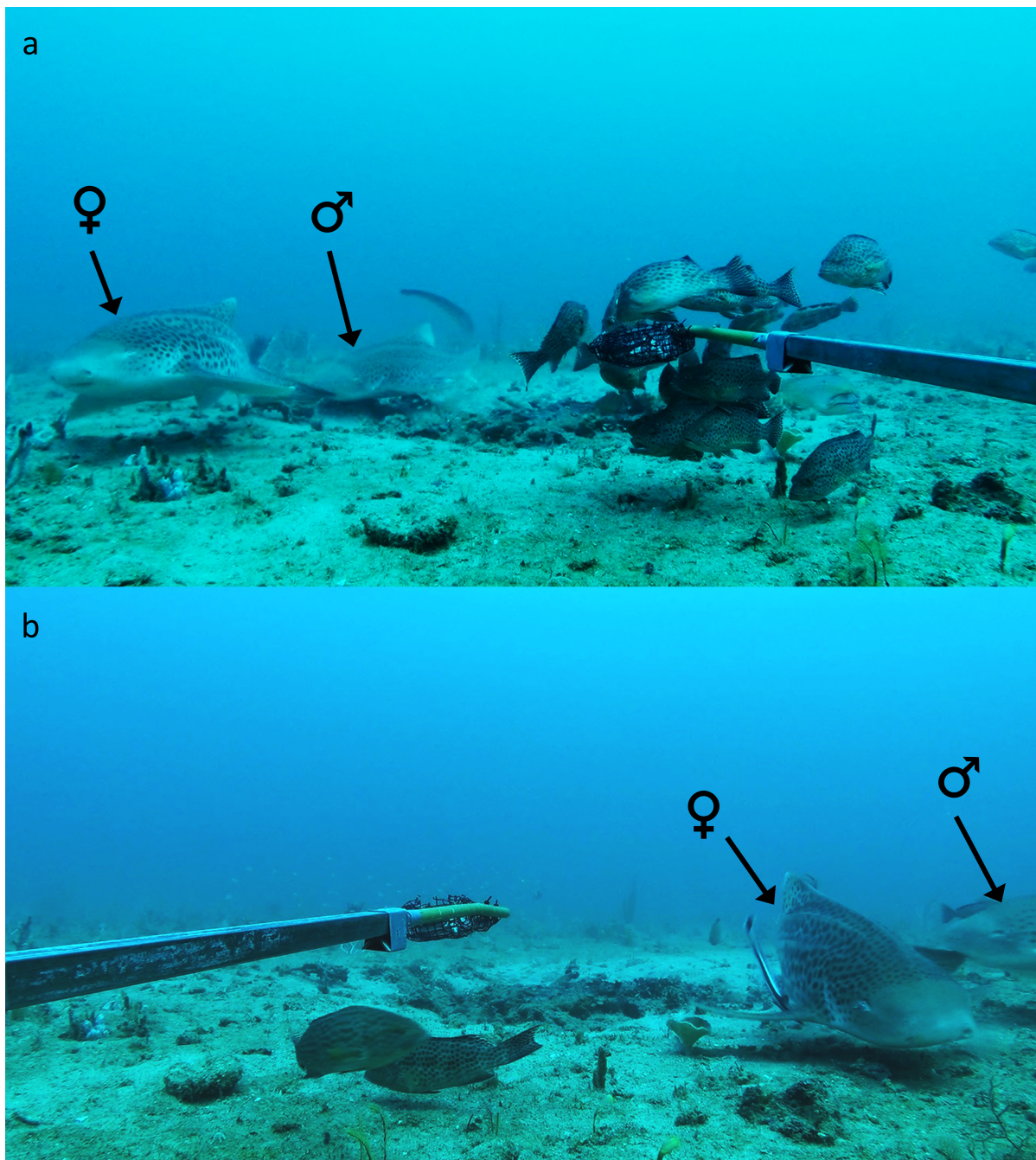
Introduction

Zebra sharks (*Stegostoma fasciatum*) are endemic to the Indo West-Pacific region. As the demand for shark products remains high throughout Southeast Asia, the zebra shark remains on the International Union for Conservation of Nature (IUCN) as a globally endangered species [1]. Although this species is considered by the IUCN to be of least concern in Australian waters, recruitment from the unexploited Australian waters to Southeast Asia is minimal which increases the risk of regional depletion [2]. Data on the reproductive behaviour of this species is important for making well-informed management decisions and better understanding its full life history.

Observations of pre-copulatory behaviour in free-living sharks are extremely rare and, to our knowledge, has never been documented for free-living zebra sharks. Copulatory behaviour of the zebra shark has been observed in captivity where the mating pair successfully reproduced [3]. Prior to copulation, the pair was observed swimming together for several hours with the male biting the tail of the female. In the wild, Dudgeon *et al.* (2008) [4] observed potential pre-copulatory behaviour on two occasions when studying an aggregation of zebra sharks in the coastal waters of southeast Queensland. They observed male individuals slowly following the female sharks, but were not observed biting their tail. Here, we have filmed what we believe to be the same pre-copulatory behaviour observed by Kunze and Simmons (2004) [3] in the shark exhibit at the Henry Doorly Zoo.

Objective

Here, we describe what we believe to be the first documented observation of pre-copulatory behavior in free-living zebra sharks. Very little is known about where zebra sharks copulate and this rare encounter provides some insight into the depth, habitat and location at which copulation might be happening.



a

Figure Legend

Figure 1. Images of two zebra sharks demonstrating pre-copulatory behaviour where the male is biting, and holding onto, the female's caudal fin.

Image (A) shows the first observation and image (B) shows the sharks entering the field of view for a second time.

Supplementary video evidences are included.

Results & Discussion

The observations of *Stegostoma fasciatum* pictured here (Fig. 1; Supplementary video

1), occurred in 53 m depth, approximately 38.8 m from Dampier (20.0901S, 116.3673E), Western Australia. The sharks first entered the field of view 53 min after the stereo-BRUV had reached the sea floor and were visible for 17 sec before swimming out of view (Fig. 1A). The sharks returned 16 sec later and remained in view for a further 25 sec (Fig. 1B). Unique markings behind the pectoral fins identified that these were the same individuals as first encountered. Sex was determined by the presence or absence of claspers which was clearly visible in the footage. The male individual was biting the female's tail for the entirety of all observations and the bite location remained unchanged between observations. The male was measured in a single length as 154.26 cm; the female could only be measured in sections and was estimated to be 151.98 cm in length. Including the two *S. fasciatum* reported, 218 individual fish from 25 species were recorded in this deployment. Habitat in the region is dominated by soft sediment, with complex invertebrate communities recorded intermittently. The habitat present at this stereo-BRUV deployment was diverse and included turfing algae, hydroids, sponges, and octocorals growing on a mixed substrate of sand and rocky outcrops.

We believe this is the first documented observation of pre-copulatory behaviour in free living zebra sharks. Pre-copulatory biting behaviour observed here is not unique to zebra sharks (see [5] [6] [7]). Males are described biting and holding onto the fins (most commonly the pectoral and dorsal fins) and flanks of female sharks in several species. Pratt and Carrier (2001) [7] discussed that these behaviours invoked female acquiescence and were used to facilitate insertion of the clasper and maintain proper position and proximity until copulation was complete. In contrast, we observed a male zebra shark biting the tip of the female's caudal fin whilst not in a position to insert its clasper. Biting the caudal fin is a behaviour rarely described, but the male was likely in the early stages of courting, trying to slow and tire the female to then obtain a better position for clasper insertion. Kunze and Simmons (2004) [3] described the same behaviour in captive zebra sharks, where biting occurred over several days. The female shark we observed did not have visible bite marks on her fins or flanks, which could suggest the pair had not been interacting for long and that courtship had just begun.

Little is known about where and when zebra sharks copulate. Seasonal aggregations have been observed in southeast Queensland, although it is difficult to know if these aggregations facilitate reproduction as no copulation events have been documented [4] [8]. If zebra sharks copulate in depths like that recorded here (53 m), then it is understandable that little is known about their reproductive behaviour as observations at these depths are difficult to obtain. Furthermore, if the depth and location of this observation is a typical courting area for zebra sharks then the implications for management need to be considered, particularly with trawl fisheries operating beyond the 50 m contour in the region [9]. Stereo-BRUVs were able to capture this rarely observed behaviour which provides an integral step towards a better understanding of this endangered species' reproductive behaviour. Furthermore, information on the size of the sharks and the depth, habitat and location of this interaction provides a scientific record useful for biologists and managers and may contribute to prompting species-specific research in this unique region.

Conclusions

To our knowledge, this observation is the first documented video of pre-copulatory behaviour in free living zebra sharks. Little is known about where copulation occurs in free living zebra sharks and observations such as this provide a clue into what types of habitats and locations these sharks might be using for copulation. As BRUVs and other video techniques become an increasingly popular sampling tool, we encourage analysts to document similar behaviours and build on singular observations to work towards a better understanding of the zebra sharks reproductive behaviour.

Limitations

This is a single observation and we have no evidence that the zebra sharks proceeded

to copulate. Our assumption that this observation is pre-copulatory behavior is based on documented observations made in an aquarium whereby zebra sharks proceeded to copulate after demonstrating the same behaviour.

Alternative Explanations

Male zebra sharks are documented to reach sexual maturity between 147 and 183 cm and females maturing between 169 and 171 cm [10]. The male observed here is likely to be sexually mature although the female may not yet be sexually mature according to the length of sexual maturity identified by Compagno (2002) [10]. Although we believe the behaviours observed here are pre-copulatory, we have no evidence that the pair proceeded to copulate. An alternative explanation could be the pair were showing agonistic behaviour which is similar in appearance and has been documented to occur in a pair of male zebra sharks [11].

Conjectures

This rare observation was made by chance during a field campaign where we were investigating ontogenetic shifts in fish offshore from the Dampier archipelago. As stereo-BRUVs are becoming increasingly popular as a sampling tool for fish research, we hope observations such as this become more common and don't go unnoticed. With numerous institutions analyzing hundreds of hours of video imagery in Western Australia alone each year, we can continue to build on a singular observation and gather traction into prompting further research.

Additional Information

Methods

Footage was recorded on the October 11, 2015 using a baited remote underwater stereo-video system (stereo-BRUV) during a survey of the fish assemblage off the coast of the Dampier Archipelago, Western Australia. This stereo-BRUV consisted of a pair of video cameras (Canon Legeria HFG25) mounted 0.7 m apart on a steel frame in underwater housings. A plastic-coated wire mesh bait bag was filled with approximately 1 kg of crushed pilchards (*Sardinops* spp.). The stereo-BRUV was deployed on the seafloor for 65 min before retrieval. Stereo-BRUVs were calibrated using the CAL software [12] and EventMeasure [13] was used to view and annotate video footage, while the stereo function of the program allowed for accurate length measurements [14]. Measurements were made for the total length of each animal.

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Ethics Statement

Sampling was conducted in waters off north-western Australia and was covered by The University of Western Australia Animal Ethics Approval # RA/3/100/1317.

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