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Deep-water observation of scalloped hammerhead *Sphyrna lewini* in the western Indian Ocean off Tanzania

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A scalloped hammerhead Sphyrna lewini *was observed opportunistically from a remotely operated vehicle 1 m off the seabed at 1042 m depth, during hydrocarbon exploration activities in the Ruvuma Basin off Tanzania. The observation, which occurred during night hours, is the deepest accurately recorded for this species and the first deep-water record for the Indian Ocean. The record adds support for the occurrence in deep water during night hours being a widespread and possibly common behaviour in this species, and further expands a small but growing literature that meso- and bathypelagic environments may be of greater importance to elasmobranchs previously considered to be primarily epipelagic.*

Keywords: shark, elasmobranch, bathypelagic, Ruvuma Basin, vertical migration

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INTRODUCTION

Knowledge of the spatial distribution of any marine organism is essential to understanding its ecology. While the geographic range of many shark species is often (and increasingly) well documented, their vertical distribution can be much less well understood owing to the numerous challenges in collecting accurate data. The geographic distribution of the scalloped hammerhead *Sphyrna lewini* (Griffith & Smith, 1834) (n.b. notwithstanding unresolved taxonomy, e.g. Zemlak *et al.*, 2009) is well known, and encompasses a range of habitats from estuaries to the open ocean in tropical and warm temperate waters worldwide (Ebert *et al.*, 2013). However, the vertical distribution of *S. lewini* is not as well understood. Compagno *et al.* (2005) cite 'surface to >275 m', and while studies using tagging technology have reported the species to greater depths, accurate depth recording has often been constrained by the limitations of the tagging technology. Using ultrasonic transmitters on four individuals in the Gulf of California, Klimley (1993) recorded repeated excursions to a maximum depth of approximately 475 m. Also in the Gulf of California, Jorgensen *et al.* (2009) recorded a single *S. lewini* over 74 days diving to depths of at least 980 m with a pop-up satellite archival tag (PSAT). Bessudo *et al.* (2011) recorded occasional night-time dives to approximately 1000 m by a tagged *S. lewini*, in the tropical eastern Pacific. Most recently, an individual female *S. lewini* fitted with a PSAT was recorded as making repeated night-time dives >700 m (with 16 of these >900 m, reaching a maximum depth of 964 m) over a period of 27 days in the Gulf of Mexico (Hoffmayer *et al.*, 2013). These authors suggested that such diving may be a common behaviour in *S. lewini*, but noted that more data would be required to verify this. The current paper reports an incidental observation of a *S. lewini* individual made from a remotely operated vehicle (ROV) that extends the accurately recorded depth range of this species.

METHODS

Footage was collected opportunistically using an Ocean ProHD video camera (1080i) mounted on an Oceaneering International Millennium work class ROV (Mill 113), which was deployed from the *Deepsea Metro I* drill-ship during routine drill-support operations at BG Group's Jordari hydrocarbon exploration site, approximately 40 km off the coast of southern Tanzania in the Ruvuma Basin. The video was made available because of BG's involvement in the collaborative SERPENT Project (Jones, 2009) (www.serpentproject.com), in which ROV footage from the oil and gas industry is made available to marine scientists. Water column parameters (temperature, salinity and depth) were collected during the dive with a datalogger on the ROV. In addition, temperature, salinity and dissolved oxygen at a site 30 km away from the *Sphyrna lewini* observation were recorded from a datalogger (RBR Model XR-420CTDmTi + pH + DO) fitted to the ROV during a SERPENT offshore visit. The shark was identified as scalloped hammerhead *S. lewini* based on a cephalic foil with a median and two smaller lateral indentations, and the relative size and shape of the fins (Ebert *et al.*, 2013).

RESULTS

The video clip (59 s in length) commenced at 00:30 h local time on 27 September 2012, after the ROV had been working in

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view of the seabed for over 3.5 h. Figure 1 presents still images extracted from video footage (online Supplementary Material 1), and shows an individual *Sphyrna lewini* swimming just above the seabed at 1043 m depth, making three sharp turns at 5, 20 and 30 s into the clip. On each of these occasions it turned back and re-entered the area of seabed illuminated by the lights of the ROV. After 43 s the individual left the frame, still swimming close to the seabed, and it was not observed after this. Although no claspers were clearly visible, the sex could not be confidently determined, and from the scale of the nearby seabed markers the total length of the shark was estimated at approximately 1.5 m. The water column temperature was 5.9°C and salinity was 35. Based on similar temperature and salinity profiles at both the observation site and the site 30 km distant, it is estimated that dissolved oxygen would also be similar and approximately 1–1.5 ml l^{-1} (Figure 2). Similar video surveys at other sites near this observation recorded the following biota in low abundance: xenophyophores, sponges, molluscs (cirrate octopods and squid), suprabenthic crustaceans, echinoderms and fishes including grenadiers (Macrouridae), cusk eels and relatives (Ophidiiformes) and cutthroat eels (Synaphobranchiidae).

DISCUSSION

Although it cannot be assumed that the single individual we observed at depth originated from surface waters (and, therefore, represents deep diving behaviour), our report from 1042 m exceeds the previous accurately recorded depth maximum of 964 m for this species (Hoffmayer *et al.*, 2013). It also exceeds the depth of 'at least 980 m' (and probably not exceeding 1500 m) recorded by Jorgensen *et al.* (2009), who were not able to report more accurate depths due to limitations of the pressure sensors on the tags used. The current observation is also the first deep-water record for this species in the Indian Ocean. A further SERPENT observation of *Sphyrna lewini* at a near-bottom depth of around 580 m in the Indian Ocean off Western Australia is also of interest (Jones *et al.*, 2009). These records of *Sphyrna lewini*, together with those of whale sharks (e.g. Brunnschweiler *et al.*, 2008) and devil rays (Thorrold *et al.*, 2014) add weight to the idea that meso- and bathypelagic environments may be of greater importance than previously thought to taxa traditionally considered as epipelagic.

The current observation was made during the hours of darkness. Although the significance of our single incident should not be overstated, it may add further evidence to previous studies of *Sphyrna lewini* that have recorded deep dives almost exclusively during night-time and/or evening twilight (Bessudo *et al.*, 2011; Hoffmayer *et al.*, 2013; Hoyos-Pallida *et al.*, 2014).

Water column profiles show that this *Sphyrna lewini* individual was recorded in cold (6°C) waters consistent with the classification of 'hypoxic' ($<5.5\ \text{mg l}^{-1}$, equivalent to approximately 3.85 ml l^{-1}; it should be noted that the entire water column deeper than approximately 75 m would also be hypoxic according to these criteria, a result consistent with other studies reporting low oxygen concentrations in the tropical Indian Ocean e.g. Schlitzer, 2000) in experimental work on three shark species, including *Sphyrna tiburo* (L. 1758), a congener of *Sphyrna lewini* (Carlson & Parsons, 2001). Both factors are likely to present *Sphyrna lewini* with significant physiological challenges, although experimental work has suggested that *Sphyrna tiburo* is physiologically able to tolerate moderate levels of hypoxia (Carlson & Parsons, 2003). While endothermy, as an adaptation to cold, has been reported in other elasmobranch taxa (notably lamnid sharks and mobulid rays), it has not been for hammerhead sharks (Bernal *et al.*, 2012), and, therefore, time at this depth is likely limited. Nevertheless, tolerance of this environment, even for short times, presumably provides benefits; although, the purpose remains unclear. It has been suggested that diving of *Sphyrna lewini* into cold and potentially anoxic water could be to exploit deep-water prey less accessible to other pelagic competitors (Jorgensen *et al.*, 2009; Hoffmayer *et al.*, 2013), and video footage from nearby areas to our observation showed the presence of likely *Sphyrna lewini* prey items (cephalopods and fishes). Most recently, Hoyos-Pallida *et al.* (2014) suggested that a single *Sphyrna lewini* juvenile female tagged in the Gulf of California visited deeper waters (up to 250 m) to increase foraging success and as part of an ontogenetic migration from coastal to offshore waters.

Fig. 1. Stills from the video of *Sphyrna lewini*. (A) Cropped image of the shark as it passed close to the ROV, (B) full screen view as the shark swims out of shot close to one of the marker buoys at the seabed.

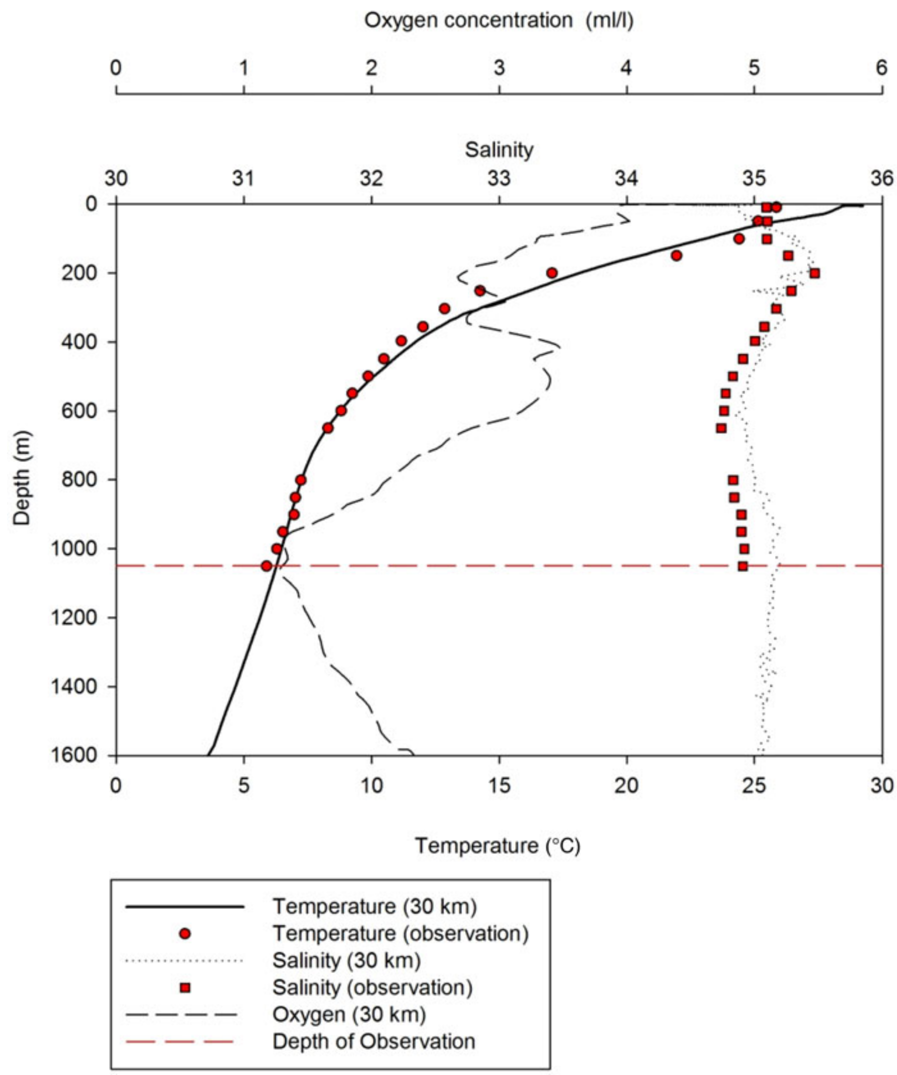

Fig. 2. Water column temperature and salinity at the observation site (red) and temperature, salinity and oxygen profiles at a nearby site.

Supplementary materials and methods

A supplementary video is available for download at: http://www.serpentproject.com/sphyrnalewini.php

The supplementary material for this article can be found at http://www.journals.cambridge.org/MBD

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