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Novel techniques and insights into the deployment of pop-up satellite archival tags on a small-bodied deep-water chondrichthyan

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ABSTRACT

Acquiring movement data for small-bodied, deep-water chondrichthyans is challenged by extreme effects of capture and handling stress, and post-release predation, however, it is urgently required to examine important fisheries interactions and assess the ecological role of these species within deep-water food webs. Here we suggest a novel release-cage mechanism to deploy pop-up satellite archival tags, as well as present vertical habitat data for a data-deficient, small-bodied, deep-water bycatch species, the Cuban dogfish (*Squalus cubensis*). Data were gathered from seven of eight High Rate X-Tags deployed on mature Cuban dogfish in the Exuma Sound, The Bahamas. Recovery periods appeared variable between individuals and are likely driven by capture-and-handling stress and tag burden. Application of the cross-correlation function to time-series depth and temperature data indicated three of the seven individuals suffered mortality through predation, which occurred during daytime, and suggests Cuban dogfish may constitute a proportion of deep-water apex predator diet in the Exuma Sound. Two animals were successfully released via a novel release-cage mechanism and displayed either no, or rapid (< 15 mins) vertically stationary recovery periods and were not consumed by predators; data for these individuals were recorded for the entire deployment duration (14 days). Vertical habitat data suggests Cuban dogfish are diel-vertical migrators, similar to other deep-water taxa, and exhibit a relatively broad temperature and depth range, which may be driven by preference for specific bathymetric structures. These techniques provide an important first step into acquiring and presenting vertical habitat data for small-bodied, deep-water chondrichthyans, which can be directly applied to fisheries and ecosystem-based management approaches.

1. Introduction

Examining movement in fishes can provide insights into population connectivity (Duffy et al., 2012; Sequeira et al., 2013), stock size (Goethel et al., 2011), fisheries interactions (Coelho et al., 2015), and the spatial extent of species' ecological functioning (Comfort and Weng, 2015). Acquiring useful movement data via methods such as acoustic and satellite telemetry relies on high rates of post-release survival following exposure to a multiple physiological and physical stressors. The effects of the initial capture event (e.g. physiological perturbations in blood chemistry) (Cooke and Sneddon, 2007; Brooks et al., 2012; Skomal and Mandelman, 2012), barotrauma (Hannah et al., 2012), and handling-and-tagging stress (Hoffmayer and Parsons, 2001; Brooks et al., 2011), must be mitigated to promote post-release survival. Post-release survival is further impeded by predator interactions, whereby capture-based effects may alter normal behaviour (e.g. loss of equilibrium), and increase predation risk (Danylchuk et al., 2007).

Decreasing the mortality of tagged animals in more neritic systems has been demonstrated through methods such as in-situ tagging (Sigurdsson et al., 2006) and returning animals to depth via SCUBA (Nemeth et al., 2007); however, these approaches are limited in their use because they cannot be applied to more inaccessible habitats (e.g. deep-water). More recently, cage-release mechanisms, designed to quickly transport, protect, and release fish at depth, have received increasing attention, as these methods can reduce predator interactions during their initial return to depth (Williams et al., 2015). Validations of various cage-release mechanisms have been illustrated in species such as the red snapper (*Lutjanus campechanus,* Piraino and Szedlmeyer, 2014; Williams et al., 2015), grey triggerfish (*Balistes*

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capricus; Williams et al., 2015), Pacific rockfish (*Sabestes* spp.; Hannah et al., 2012), and Greenland halibut (*Reinhardtius hippoglossoides*; Simonsen and Treble, 2003), providing a foundation on which to develop such methods for application to a broader range of habitats.

Deep-water chondrichthyans (sharks, rays, skates and chimaeras) exhibit some of the slowest intrinsic population rebound potentials amongst all marine species (Simpfendorfer and Kyne, 2009), and dramatic increases in deep-water fisheries have resulted in rapid population declines at numerous locales (Anderson and Ahmed, 1993; White and Kyne, 2010; Graham and Daley, 2011; Barbier et al., 2014). Vertical habitat-use distributions of vulnerable deep-water chondrichthyans can be used by managers to establish and mitigate potential fishery interactions by overlaying tracks with areas of high fishing (Coehlo et al., 2015). However, tracking data are limited to a disproportionate number of large-bodied species, such as bluntnosed sixgill (Comfort and Weng, 2015; Nakamura et al., 2015), leafscale gulper (Rodríguez-Cabello and Sánchez, 2014; Rodríguez-Cabello et al. 2016), and Greenland sharks (Campana et al., 2015) that comprise only a restricted proportion of global deep-water chondrichthyan biomass. Despite their prevalence in commercial fisheries catches (Akhilesh et al., 2011; Rigby et al., 2016), there has been no attempt to track the vertical behaviour of smaller-bodied, deep-water chondrichthyans that remain largely understudied.

Deep-water species have higher rates of post-release mortality because the effects of capture, handling, and release are exacerbated by extreme thermal, photic, and barometric gradients (Brooks et al., 2015). Furthermore, these animals must travel long vertical distances upon release, and therefore, stand a greater chance of post-release predation. These effects subsequently preclude the use of costly contemporary tagging technologies, and often provide comparably low data return, compared to deployments on epipelagic species (Wahlberg et al., 2014). In order to bridge the knowledge gap between these smaller-bodied, deep-water species and their coastal and pelagic counterparts, innovative techniques must be developed that 1) return animals safely to depths; 2) enhance survivorship; and 3) have limited effects on individuals post-release. In deep-water ecosystems, release-cage mechanisms have yet to be robustly tested, however, may provide an important first step to increase the survival of physiologically and physically vulnerable small-bodied, deep-water chondrichthyans.

The Cuban dogfish (*Squalus cubensis*) is a small-bodied (< 120 cm) squaliform, and a common bycatch species in deep-water fisheries off the Gulf of Mexico (Jones et al., 2013), where up to 95% are discarded alive (Gulak et al., 2012). The ubiquity of Cuban dogfish in fisheries catch is further illustrated by scientific surveys; for example, they constituted approximately 40% of the total catch of experimental longline surveys in the Exuma Sound, The Bahamas (Brooks et al., 2015) and were among the five most common chondricthyans surveyed by Menni et al. (2010) in waters off Argentina and Brazil. A semi-controlled survivorship study from the Exuma Sound suggests Cuban dogfish may be relatively resilient to fisheries capture, with a post-release mortality rate of approximately 50% (Talwar, 2016), which remains high compared to other common deep-water species (*Centrophorus* spp. =83 ± 16% S.E., *Mustelus canis insularus* =75 ± 25% S.E., Talwar, 2016). Data pertaining to both fisheries landings and wider life-history and ecology of Cuban dogfish are mostly absent in the literature, and this species remains listed as 'data-deficient' by the International Union for the Conservation of Nature (IUCN) (Monzini, 2006). Further, there remains a lack of vertical movement data required to quantify fisheries interactions and understand the ecological roles this species plays in the deep-water ecosystems.

Here we present a first attempt to deploy pop-up satellite archival tags to track the vertical movements in Cuban dogfish. We propose a novel release-cage mechanism designed to decrease animal post-release mortality. Finally we analyse recovery behaviour, investigate tag consumption, and present vertical habitat data for tagged animals, up to 14 days post-release.

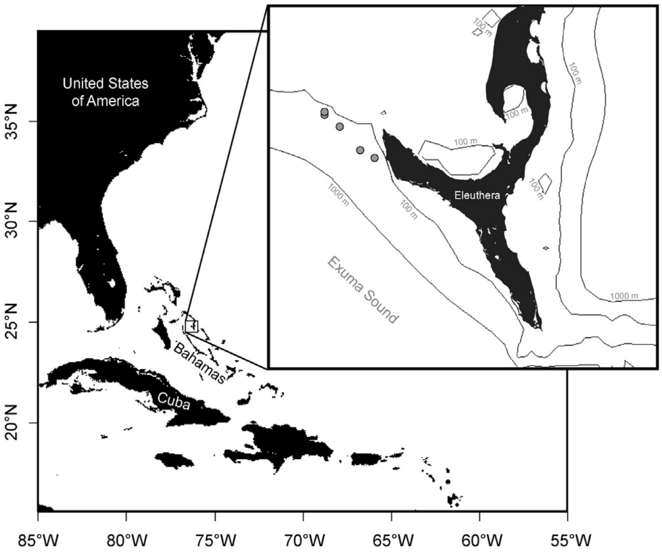

Fig. 1. Map of study area with (inset) southern Eleuthera and the Exuma Sound, The Bahamas indicating the tagging sites (grey circles).

2. Methods

Research was conducted between September 2015 and March 2016, in the north-east Exuma Sound, The Bahamas (Fig. 1, see Brooks et al., 2015 for detailed description of study site) under permits MAF/FIS/17 and MAF/FIS/34 from the Bahamian Department of Marine Resources, and animal sampling followed guidelines of the Association for the Study of Animal Behaviour and Animal Behaviour Society (Rollin and Kessel, 1998).

2.1. *Animal capture and tagging*

Animals were collected via 1000 m long demersal deep-water longlines (see Brooks et al., 2015 for detailed methodology), at depths ranging from 500 to 750 m. Lines were soaked for approximately 2.5–3 h and were retrieved using a stainless steel electronic pot-hauler (Waterman Industries Inc., Florida, USA). Animals were removed from the mainline, submerged in a cooler and worked–up (< 15 min) on board the research vessel. Only animals in a healthy condition were selected for tagging; this was based on a 'excellent' vitality score (no external injuries and vigorous mobility, Talwar, 2016) once on board the research vessel. High Rate (14-day, ~133-second resolution) X-Tags (120 mm length ×32 mm float ×185 mm antenna) (Microwave Telemetry, Inc., Columbia, MD) measuring depth (± 1.3 m), temperature (± 0.16–0.23 °C) and light levels ($< 4\times10^{-5}$ lx at 555 nm) (http://www.microwavetelemetry.com/fish/HRXtag.cfm), were secured via a monofilament bridle passed through the lower quarter of the anterior edge of the dorsal fin, and secured under the proximal margin with a metal crimp. Tags were left to trail roughly 10–20 cm posterior to the trailing edge of the dorsal fin so animal movement was not obstructed. X-Tags are designed to release from the bridle and animal through either the 'memory full' release mechanism after the programmed two week deployment period or the 'constant pressure' release mechanism after remaining in a narrow depth band (3 m) for 3 consecutive days. Additionally, the tag may release prematurely if exposed to pressures at which the functional integrity of the tag may be compromised (> 3500 psi/1250 m) (http://www.microwavetelemetry.com/fish/HRXtag.cfm). Once the tag had detached and floated to the surface, data were transmitted to and retrieved from the Argos satellite system (www.argos-system.org).