Journal of Experimental Marine Biology and Ecology 497 (2017) 120–126

Contents lists available at ScienceDirect

Journal of Experimental Marine Biology and Ecology

journal homepage: www.elsevier.com/locate/jembe

Evaluating time-depth recorders as a tool to measure the behaviour of sharks captured on longlines

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ARTICLE INFO

Keywords:
Elasmobranch
Chondrichthyan
Fisheries
Stress
Movement
Bycatch

ABSTRACT

Quantifying the behavioural response of chondrichthyans to capture in longline fisheries can assist in understanding the physiological changes resulting from capture stress and ultimately aid in developing fishing practices that increase the survival of released bycatch species. Here, we evaluated the use of time-depth recorders (TDR) as a tool to quantify the amount of movement during capture across 42 animals from seven species of shark and one species of ray caught on hooks with TDRs attached in either a demersal or surface longline. Depth changes over time were analysed using three methods to estimate the percentage of time sharks and rays struggled on the line. Methods used were; 1) a Visual Assessment Method (VAM) of the TDR trace conducted by two investigators quantifying movement by summing the duration of movement bouts visually identified by erratic changes of depth; 2) the Gangion Extension Method (GEM) which quantifies movement by summing periods when captured animals altered their depth by > 50% of the gangion length; and 3) the Vertical Excursion Method (VEM) which quantifies movement by summing periods when the absolute depth change between successive data points exceeded a threshold determined from the maximum depth change in the TDR data prior to capture of the animal. We found that the VAM was consistent across investigators and produced significantly higher estimates of movement than GEM and VEM. Estimates of movement from GEM and VEM were not significantly different to each other, but unlike GEM, VEM could be applied to TDRs used in both surface and demersal longlines. The amount of movement observed was different between species and such differences were consistent across all methods, indicating that species-specific behavioural responses to capture can be identified. The ability to assess capture behaviour using VEM allows inter-species comparisons, which may be used as a metric for rapid, generalised assessment of species' responses to longline capture where physiological data may be limited or lacking. Such assessments are important in the design of species-specific management for bycaught animals.

1. Introduction

Utilising behavioural indicators of stress can provide increasingly practical, non-intrusive methods to assess animal condition in response to environmental stressors (Berger-Tal et al., 2011). Compared to terrestrial animals however, measuring the behaviours of marine animals is logistically difficult and expensive because of the challenges in accessing and recapturing the same individuals in the marine environment (Cooke et al., 2013). Furthermore, the technology utilised to track marine animals remotely (so that animal recapture or retrieval of tracking devices are not necessary) is relatively expensive and limits their application (Campana et al., 2009).

Chondrichthyans (sharks, rays and chimaeras) are generally elusive marine vertebrates making them difficult to capture, and studies measuring their behaviour in response to capture are largely limited to post-release monitoring of their movement (Campana et al., 2009; Hoolihan et al., 2011; Kneebone et al., 2013; Musyl et al., 2011; Rogers et al., 2017; Sepulveda et al., 2015). Even fewer studies have measured their behaviour during capture in an effort to better understand how physiological processes and fishing gear may influence their post-capture mortality (Bouyoucos et al., 2017; Gallagher et al., 2017; Guida et al., 2016b). Developing fishing practises conducive to chondrichthyans' survival is largely based on the ability to assess their physiological tolerance to capture, which is closely related to their level of exertion and ability to respire during capture (Dapp et al., 2016a; French et al., 2015; Frick et al., 2010; Guida et al., 2016a; Kneebone et al., 2013).

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http://dx.doi.org/10.1016/j.jembe.2017.09.011
Received 18 February 2017; Received in revised form 16 July 2017; Accepted 15 September 2017
Available online 02 October 2017

The ability to assess movement during capture is important because it can provide information about the level of physical exertion and physiological stress experienced by an animal (Brownscombe et al., 2014; Guida et al., 2016b). Erratic movement during capture may be exhibited by obligate-ram ventilating species in an effort to ventilate their gills to meet oxygen demands and to escape capture. In contrast, movement may rapidly cease in species capable of stationary respiration (e.g.. buccal-pumping) because they are not as physiologically restricted by the reduced ability to move as obligate-ram ventilators (Guida et al., 2016b). The ability to freely respire during capture is a key determinant of the risk of mortality from fisheries capture (Dapp et al., 2016b) and therefore quantifying the amount of movement relative to a species respiratory mode during capture is important to understand the likely consequences of capture. Cameras placed above individual hooks can be used to monitor swimming behaviour and intensity (O'Shea et al., 2015) but low water visibility and limited battery life may limit their application. Accelerometers can also be used as they can quantify the intensity of movement of captured animals (Brownscombe et al., 2014), but their cost (typically several hundred US dollars each) may prohibit their use on tens to hundreds of individual hooks. Time-depth recorders (TDRs) attached to hooks present a useful compromise compared to the use of accelerometers because they are considerably less expensive and can record changes in depth throughout capture, although they cannot directly measure movement intensity (Guida et al., 2016b).

To our knowledge, TDRs have only been employed twice to quantify movement during capture, and only once on a chondrichthyan species (Grace et al., 2010; Guida et al., 2016b). We previously provided a framework for interpreting TDR traces of animals captured on demersal longlines, whereby movement representative of struggling was inferred from changes in depth profile (Guida et al., 2016b). However, that study used only one species, the gummy shark, *Mustelus antarcticus*, and one fishing method. Because fishing mortality depends on both the gear used and species caught (Dapp et al., 2016b), it is necessary to test the suitability of TDRs to quantitatively measure capture behaviour in other gear configurations and across different species.

The primary aim of this study was to evaluate the suitability of TDRs in two longline configurations (surface and demersal) by comparing three methods of quantifying data collected by TDRs, including that proposed by Guida et al. (2016b). Using these three methods, our secondary aim was to evaluate their ability to compare capture behaviour across eight chondrichthyan species. We hypothesise that the development of additional analytical methods explored in this study will improve upon that of Guida et al. (2016b), demonstrating TDRs as an effective tool to measure the relative differences in capture behaviour across both longline configurations and species. Quantifying and comparing behaviour across different longline configurations may not only improve our understanding of how different fishing gear configurations contribute to a given species' physiological response to capture, but also provide a rapid, generalised assessment of a species' tolerance to capture where direct physiological data may be limited or lacking.

2. Methods

2.1. Animal collection

A total of 42 animals comprising of *M. antarcticus* (n = 12), bronze whaler, *Carcharinus brachyurus* (n = 11), draughtboard shark, *Cephaloscyllium laticeps* (n = 7), smooth hammerhead, *Sphyrna zygaena* (n = 5), school shark, *Galeorhinus galeus* (n = 2), dusky shark, *Carcharhinus obscurus* (n = 2), southern fiddler ray, *Trygonorrhina dumerilii* (n = 2), and Port Jackson shark, *Heterodontus portusjacksoni* (n = 1), were caught on hooks with TDRs (LAT1100, Lotek Wireless, Newfoundland, Canada) attached in either demersal or surface longlines set in Western Port, Victoria (38.433° S, 145.376° E) and Gulf of St. Vincent, South Australia (34.770°S, 138.228°E), respectively. Hooks were spaced apart by a relatively large distance – ~6 m apart in the demersal longline and ~10 m in the surface longline reducing the likelihood that TDR recorded movement on one hook influenced that of adjacent hooks. Species caught on demersal sets were *M. antarcticus*, *C. laticeps*, *G. galeus*, *H. portusjacksoni* and *T. dumerilii.* Species caught on surface sets were *C. brachyurus*, *S. zygaena* and *C. obscurus*. Details of fishing methods are described in Guida et al. (2016b) and Dapp et al. (2016a). TDRs were attached to gangions at a distance of either 10 cm (demersal longline) or 80 cm (surface longline) from the eye of the hook. The difference in TDR spacing from the hook was a conservative estimate to avoid the TDR being bitten off (given the expense of TDRs and the limited numbers available) by larger pelagic species, such as white sharks (*Carcharodon carcharias*), often found in the areas in which surface longlines were deployed. Although closer spacing from the hook increases sensitivity to capture movement, the primary focus of this study was to explore methods for analysis of data using relative comparisons from each analytical method, rather than calculate absolute values of movement during capture.

Upon landing on the vessel, the condition of each animal was recorded as per Guida et al. (2016a) and Dapp et al. (2016a) whereby each animal was scored from 1 to 4 indicating (1) excellent condition, (2) fair/moderate condition, (3) poor condition, and (4) moribund/dead. All fieldwork was approved by and performed in accordance to Animal Ethics Committees of Flinders University (E360) and Monash University (BSCI/2009/16, BSCI/2014/22), and Fisheries Victoria permits RP1000 and RP1115.

2.2. Programming TDRs and preparing data for analysis

Programming of TDRs and data retrieval was done using TagTalk software (Lotek Wireless, Newfoundland, Canada). TDRs recorded data every 4 s, providing maximum resolution of depth change while ensuring sufficient data storage capacity for the duration of the longline deployment. Depth resolution and accuracy of TDR data were 0.05% and ± 1%, respectively. The time of initial capture (T_0) was visually identified in each TDR dataset as described below, after which the percentage of the total time spent moving during capture could then be estimated using the criteria of the Visual Assessment Method (VAM), Gangion Extension Method (GEM), and Vertical Excursion Method (VEM). Movement was functionally defined in our study as being deviations in the TDR depth trace from which we could infer the animal was struggling in an attempt to escape, dislodge the hook or meet respiratory demands. Movement was assessed for the first 20 min after capture because this was the length of the shortest period between capture on the hook and landing on the boat and thus allowed comparison of analytical methods and species-specific responses across all captured animals. For each method, the duration of all movement bouts were summed to the nearest second and determined as a percentage of the 20-min period.

2.3. Determining the time of initial capture (T_0)

Each TDR dataset was plotted in 1-h intervals to provide adequate resolution for determining T_0. T_0 was estimated by visually identifying an abrupt and marked depth change from an otherwise consistent depth in the TDR trace (Fig. 1). This depth change was caused by biting of the hook by the captured animal, the hook becoming lodged in the jaw, and the animal's initial flight reaction. The reliability of visually identifying T_0 was assessed by two investigators (referred to as Investigator A and Investigator B) who independently estimated T_0 as the time elapsed (seconds) from setting of the hook and repeated the assessment three days later. Due to violations of normality, the consistency within and between investigators' assessments of T_0 were determined by a Wilcoxon signed-rank test. Visual identification of T_0 was consistent within (Investigator A: $t_{39} = -1.138$, $p = 0.262$; Investigator B: $t_{39} = -1.138$, p = 0.262) and between (T_0: $t_{39} = 1.182$, $p = 0.244$)