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A float-release package for recovering data-loggers from wild sharks

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ABSTRACT

The rapidly expanding use of high-resolution data-loggers to study marine vertebrates presents a wealth of new opportunities for understanding the behavior, physiology, and ecology of these animals in situ. It also presents a number of new logistical challenges, one of the biggest of which is the need to physically recover the tag in order to acquire data, thus, a novel data-logger release and recovery package was designed and tested. This package consisted of a microsphere-resin float, very high frequency (VHF) transmitter, and galvanic timed release (GTR) device which allowed acceleration data logger (ADL) tags to remain on free-living sharks for several days before detaching from the fin. Upon release, tags floated to the surface and were located using a VHF receiver and yagi antenna. This method has been used successfully on blacktip, bull, nurse, and white sharks to produce an overall recovery rate of 95.7% on 47 deployments over periods of 1–111 h and shark displacement distances up to 35 km. This represents a cost-effective method for recovering data-loggers from sharks and large teleosts.

1. Introduction

The International Union for the Conservation of Nature has identified 74 species of sharks as either critically endangered, endangered, or vulnerable, with an additional 209 species labeled data deficient (Dulvy et al., 2014). Vulnerability of these species is attributed to both anthropogenic effects (overfishing, bycatch, and finning) and life history characteristics of sharks, such as low fecundity and late maturity (Barker and Schluessel, 2005; Godin and Worm, 2010; Molina and Cooke, 2012; Schindler et al., 2002). In order to better understand and manage pelagic and coastal shark fisheries, it is necessary to acquire data on not only their horizontal movements and home ranges, but also on the behavior, and energy requirements of individuals (e.g., Whitney et al., 2012; Wilson et al., 2015).

In recent decades, field-based studies of sharks have commonly relied on tracking shark movement and behavior through the use of satellite or acoustic tracking tags (Eckert and Stewart, 2001; Goldman and Anderson, 1999; Heithaus et al., 2007; Heupel et al., 2004; Hueter et al., 2013; Jewell et al., 2014; Jorgensen et al., 2010; Speed et al., 2010). These tagging methods typically provide data pertaining to the geographic movements of the animal, but do little to address their in situ behavior. Camera systems (Heithaus et al., 2002, reviewed by Moll et al., 2007) can provide excellent behavioral information but are limited by ambient light, water clarity, and memory storage.

Recently, acceleration data-logger (ADL) tags have been developed and used successfully to measure and record animal movements, behaviors, and energetics that otherwise could not be directly observed (e.g., Davis et al., 2004; Ropert-Coudert and Wilson, 2005; Shepard et al., 2008; Tanaka et al., 2001; Wilson et al., 2008; Yoda et al., 1999, 2001). In sharks, these devices have been used to study differences in swimming speed and tailbeat frequency (Nakamura et al., 2011; Watanabe et al., 2012; Whitney et al., 2007), identify swimming behaviors such as active swimming or resting (Gleiss et al., 2009a; Whitney et al., 2007), distinguish mating behavior (Whitney et al., 2010), and analyze diving behavior (Gleiss et al., 2009b, 2011; Nakamura et al., 2011).

In order to identify fine-scale body movements and behavior, acceleration data are typically collected at a high sampling rate (>5 Hz). This makes it impossible to transmit the raw data using the traditional methods of acoustic or satellite transmissions, due to the limited bandwidth of these systems (Whitney et al., 2012). Therefore, data are written to the internal memory of the logger, and success of the experiment thus requires its physical recovery. In early shark accelerometer studies, loggers were recovered through the recapture of each tagged individual (Gleiss et al., 2009a; Whitney et al., 2007), or through the use of galvanic timed releases (GTR) that allowed the tag to fall off of the animal, sink to the sea floor, and be recovered using a hydrophone (Whitney et al., 2010). These methods can lead to low logger recovery rates (e.g., 67% reported by Whitney et al., 2010) and are only appropriate for animals with small ranges or that are easily recaptured, preventing them from being applied to most shark species.

Abbreviations: ADL, Acceleration data-logger; VHF, Very high frequency; GTR, Galvanic timed release.

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More recently, shark accelerometer studies have used proprietary float and release mechanisms that are either not specifically designed for sharks or have not been described in detail (Nakamura et al., 2011; Watanabe et al., 2012). Gleiss et al. (2009b) outlined a floating recovery package that used a clamp for attachment, specifically for use on very large and free swimming animals that could not be restrained, e.g., whale sharks (*Rhincodon typus*), though in practice this package was usually removed from the shark manually. Speed et al. (2013) used a floating recovery package for use with acoustic transmitters on blacktip reef sharks (*Carcharhinus melanopterus*), cowtail rays (*Pastinachus atrus*), and porcupine rays (*Urogymnus asperrimus*), but it relied on the acoustic tag and a float with reflective tape for retrieval. Chapple et al. (2015) has recently described a floating tag recovery package for white sharks (*Carcharodon carcharias*) that uses a clamp device for rigid attachment of the tag to the animal, a GTR for release, and a very high frequency (VHF) transmitter for recovery, however, the size of this system may preclude it from being applied to smaller shark species with less rigid dorsal fins.

Here, is described a similar floating tag package recovery system, specifically designed for sharks, that uses a GTR for release from the animals and a VHF transmitter for relocation and recovery. The results of successful field tests on several species of shark are also presented, along with a discussion of the limitations of this system.

2. Materials and methods

2.1. Recovery package development

The package was designed to accommodate an ADL, a VHF radio transmitter, and a variety of GTRs, while also minimizing drag. The chosen ADL was a Cefas G6A (Cefas Technology Limited, UK) ADL, with dimensions of 40 × 28 × 16.3 mm (length × width × height) and a mass of 18.0 g. The selected VHF transmitter was a MM130B series (Advanced Telemetry Systems, Isanti, Minnesota) 15 × 52 mm (diameter × length) and 19.0 g. Various sizes of GTR were used ranging from 1-day to 7-day tropical releases (International Fishing Devices, Northland, New Zealand), with the release specifically chosen for each individual shark based on water temperature and time of day. Time of day was considered so that releases would come off in early morning hours, allowing search and recovery to commence as soon as the package reached the surface. The largest GTR that was used for this tag package (model G9, 7-day tropical) was 63.5 × 16.5 mm (length × diameter of anodes) weighed 18.1 g in air.

Initial recovery package designs were drawn using a computer aided drafting program (ProEngineer, Needham, Massachusetts). A prototype recovery package was then created by aligning the logger and VHF transmitter into their respective positions and applying spray foam to generate a cast around the devices. This cast was shaped and hardened with layers of bondo (3 M, St. Paul, Minnesota) until the cast resembled the pre-drawn prototype recovery package. A silastic rubber mold was poured around the prototype and used to produce recovery packages consisting of a resin and microsphere mixture (Gleiss et al., 2009b). Additionally, to better camouflage the recovery package on the shark and maintain a high optical contrast at sea, the recovery package was painted primarily brown or gray, with a small patch of fluorescent orange above the buoyancy line of the float package. The fluorescent orange was deemed to be minimally disruptive as this wavelength is absorbed within the upper 50 m of the water column (Talley et al., 2011). To increase the likelihood of any lost tags being found by others and returned, researcher contact information was printed on small (2 × 2 cm) squares of waterproof paper and epoxied into the back of the floats to permanently label the recovery package. Labels said, "REWARD," and included the name and contact information of N.M.W.

Various tests were conducted on the initial packages to determine the total buoyancy, stability, and angle of the VHF antenna while floating. Buoyancy was measured as the force required to submerge the device below the surface. Stability was qualitatively assessed based on the ability of the device to remain upright despite wave action. Finally, the angle of floatation was measured as the offset of the VHF antenna from a plane relative to the water surface.

2.2. Galvanic timed release mechanism testing

Accurate GTR release times were imperative for a timely recovery of the tag package, and thus laboratory and field tests were conducted to test experimental release times. A GTR consists of a cylinder of varying thickness with eye loops of a dissimilar metal screwed in to each end. Release times vary depending on salinity, temperature, and other physical factors such as the velocity of water movement over the device (A. Labonte, pers. Com.).

In the field, ADL tag package deployments on live animals served as a method to test the precision of the GTR release time. The initial deployment time was noted when the GTR entered the water, and precise release times along with average water temperature values were gathered from data collected by the ADL. The precision of the GTR release was calculated as a percent variance from the theoretical release time given by the manufacturer for the specific water temperatures. An ANCOVA was used to test for an effect of temperature on variance in GTR release time. Tags were excluded from the GTR timing analysis if they released >90% earlier than expected, as this was most likely attributable to strap failure rather than GTR corrosion.

2.3. Recovery package deployment and recovery

Animals were captured using hand nets (nurse sharks, *Ginglymostoma cirratum*), rod and reel (blacktip sharks, *Carcharhinus limbatus*, bull sharks, *Carcharhinus leucas*) or hand lines (bull and white sharks) and restrained in the water or on deck to allow for tag attachment. Upon capture, a leather punch (nurse) or a cordless drill (blacktip, bull, white) was used to place two holes into the animal's first dorsal fin. A GTR type was selected based on time of day, location of capture, size, species, and expected range of the animal. The GTR was attached to a strap of either eighty-pound test monofilament (nurse sharks) or plastic cable ties (blacktip, bull, and white sharks) that was threaded through the GTR eye bolts and then guided over the grooves on the tag recovery package. The total package was mounted to the first dorsal fin by threading the strap through the punched holes and securing it using a combination of roto-tag backs and additional crimp sleeves or cable tie backs (Fig. 2). A VHF receiver and handheld yagi antenna were used to listen regularly for detached tags floating at the surface, and search grids were conducted by vessel once tags were expected to have released from the sharks. Once detected, the logger was recovered and the time and GPS coordinates of the recovery location were recorded.

2.4. Animal tagging locations and durations

Nurse sharks averaging 252 ± 8 cm (mean ± SD) in total length (TL) were tagged in Dry Tortugas National Park, Florida, USA for periods ranging from 1 to 111 h. Bull sharks (227 ± 30 cm TL) and blacktip sharks (142 ± 17 cm TL) were tagged in or near Charlotte Harbor, Florida, USA for periods ranging from 3 to 72 h (bull: 27.53 ± 13.13 h, blacktip: 26.76 ± 22.07 h, mean ± SD). White sharks (468 ± 29 cm TL) were tagged off Cape Cod, Massachusetts, USA, for periods of 10 or 12 h.

3. Results

3.1. Final float package design

The final float package had overall maximum dimensions of 122 × 70 × 45 mm (length × width × height), displaced a volume of