Improving Large Cetacean Implantable Satellite Tag Designs to Maximize Tag Robustness and Minimize Health Effects to Individual Animals

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LONG-TERM GOALS

This project aims to develop robust implantable satellite tags for large cetaceans by addressing tag design flaws observed during studies focused on Gulf of Maine (GOM) humpback whales (*Megaptera novaeangliae*) (Robbins et al. 2013; Zerbini et al. 2013). In addition, potential trauma caused by muscle penetrating devices (Moore et al., 2013) will be evaluated through experiments on cetacean carcasses. These experiments along with existing information on tag vulnerabilities will inform development of new tag designs that are expected to minimize potential health effects to individual whales while maintaining or improving tag duration.

OBJECTIVES

The specific objectives of this project are as follows:

1) Design, build, and test robust blubber and/or muscle penetrating tags, which will (a) resolve structural limitations of existing designs (e.g. those found during the Gulf of Maine humpback follow-up study) and (b) minimize tissue trauma while extending retention time;

2) Evaluate structural integrity of designs created in Objective (1) during laboratory experiments and in cetacean carcasses;
3) Examine structural tissue damage in the blubber, sub-dermal sheath and muscle caused by penetrating dummy implantable tags in cetacean carcasses, including manipulation to simulate live motion;
4) Assess performance of the new tags in populations of large cetaceans where extensive follow-up studies can be performed (e.g. Gulf of Maine humpback whales and eastern Pacific gray whales).

APPROACH

In cetaceans the outer blubber and skin (dermal) layer can slide over the inner (sub-dermal) muscles layers. If a foreign body such as a tag transect both the blubber and muscles layers then local tissue damage may occur when the layers move. This project will evaluate the magnitude of tissue trauma caused by this 'shearing' when implantable tag devices penetrate the sub-dermal sheath at different parts of a cetacean body. This assessment will be conducted in carcasses and its results will, along with existing information on tag vulnerability, inform the development of new tag designs. Impact tests on new designs will be performed in the laboratory as well as in fresh carcasses to ensure new tags and retention devices are robust to the forces to which they are subject during and after deployment. Improved tags will be deployed in free ranging GOM humpback whales and in eastern Pacific gray whales (*Eschrichtius robustus*) in the spring/summer 2015 and 2016. Tag performance will be assessed during follow-up studies. These populations were chosen because they have been subject to intensive, fine temporal scale follow-up studies, and because implantable satellite tags have been previously deployed on individuals within these populations. Therefore, existing information on tag performance and potential health effects will be compared with results of new tag deployments. Final tag designs will be made publicly available to the marine mammal community after the conclusion of the project.

This study has been carried out by scientists and engineers from eight organizations: Cascadia Research Collective (CRC), Woods Hole Oceanographic Institution (WHOI), the Alaska Sea Life Center (ASLC), the Australian Marine Mammal Centre (AMMC), the National Marine Mammal Laboratory (NMML), the Provincetown Center for Coastal Studies (PCCS), Texas A&M University (TAMUCC) and Wildlife Computers (WC).

WORK COMPLETED

1. Workshop

A workshop with project participants was held in Seattle on 9 and 10 November 2013 to discuss the technical approaches proposed in this project. The workshop focused on the following topics: (1) current status of implantable satellite tags and design flaws, (2) a review of information and potential causes of physiological effects of tagging to individual animals, and (3) a discussion of the work to be undertaken in the present proposal. Key outcomes of the workshop included a proposed method to conduct experiments to assess shearing at the blubber-muscle interface in cetaceans (item 3 below), the identification of multiple laboratory and carcass tests to evalute ballistics and tag robustness, and the identification of possible design changes that could minimize tissue trauma and improve current implantable tag designs. Participants of the workshop were the following: R. Andrews (ASLC), M. Baumgartner (WHOI), J. Calambokidis (CRC), P. Clapham (NMML), N. Crandall (WC), M. Double

(AMMC), A. Fahlman (TAMUCC), T. Hammar (WHOI), M. Holland (WC), A. Kennedy (NNML), M. Moore (WHOI), J. Robbins (PCCS), G. Schorr (CRC), S. Wilton (WC), A. Zerbini (CRC/NMML).

2. Tag Design Modifications

An existing implantable tag design was modified to address design weaknesses identifed during post-deployment follow-up studies on GOM humpback whales (Robbins et al. 2013; Zerbini et al. 2013), notably (1) the failure of the anchor-transmitter interface, and (2) the possible damage of the epoxy bulb at the posterior end of the transmitter housing. Welding of the anchoring system and the transmitter housing would have been appropriate to eliminate the anchor-transmitter interface in existing tags. However, the temperatures at which the metal is subject to during welding could potentially damage the electronic components of the transmitter. Therefore, for existing tags, design fault (1) was partially resolved by designing a reinforcement sleeve at the interface between the anchoring system and the transmitter housing (Fig. 1). A permanent solution for (2) was developed by completely integrating these two tag components into a single stainless steel assembly (Fig. 1). In addition, a new flush posterior end of the transmitter was designed. The epoxy bulb was removed and the wet/dry sensor (or salt water switch) which was originally designed using a Monel ring and attached to the raised epoxy bulb was replaced by an 0.16 cm diameter Nitinol cable. The elimination of the bulb improved hydrodynamic flow and improved the function of the wet dry sensor by reducing the risk of bio-fouling. The Nitinol conductivity switch protruded from the flush surface approximately 0.8 cm and was parallel to the Argos antenna (Fig. 2).

3. Assessment of Tissue Trauma and Shearing at the Muscle/Blubber Interface

Experiments to evaluate shearing at the muscle-blubber interface and consequential trauma caused by intramuscular implantable tags were conducted in the laboratory at WHOI. Scaled, intramuscular tags were modeled after full size baleen whale satellite transmitters. Miniature tags (n=9, Fig. 3) were inserted into the blubber and muscle on the dorsal midline and right dorsolateral side of a common dolphin (*Delphinus delphis*) carcass at stations that are exposed to the air during normal cetacean swimming. A reciprocating oscillator was fabricated to mimic swimming movements (Fig. 4). The cadaver was floated in a water tank and the peduncle was moved by the oscillator for 18 hours (~3240 oscillations)[1]. After completion of this experiment, 1.5 mm diameter needles (n=4 per station) were inserted on the midline and left side at stations equivalent to the tag implant sites with the purpose of measuring shearing (Fig. 5). The needles were inserted penetrating depths of 1cm (only in the blubber), and 1.5 cm, 3 cm, and 4 cm (through the blubber into the sub-dermal sheet/muscle). The angle of penetration was measured for each needle using a protractor (Fig. 5), with the animal in the relaxed, dorsal flexed and ventral flexed positions. The change in angle for each needle was calculated between dorsal and ventral flexion. Subsequently, each tag site was excised and dissected. The extent to which the retention features had deployed and the orientation of the tip were recorded. The height and width of any cavity present around the tag was measured.

RESULTS

1. Tag Design Modifications

Tag design modifications have not yet been fully assessed in whale populations for which detailed follow-up studies can be carried out (e.g. GOM humpback whales, Eastern Pacific gray whales), and where a more rigorous comparison with previous designs can be made. However, the most recent tag design (with an integrated anchor/transmitter interface and modified posterior end) has been used in

[1] A video of the oscillator can be seen here: https://www.youtube.com/watch?v=Xy-85UrkfSM&list=UUCpPEkFQTIIwpvgvrq1ol3Q.

other regions (e.g. humpback whales in Oman and the Cook Islands, Southern right whales in Argentina) and while sample sizes are relatively small for quantitative comparisons and some of the deployed tags are still transmitting, their overall performance appears to have improved.

2. Assessment of Tissue Damage and Shearing at the Muscle/Blubber Interface

The shearing experiment indicated that angles of penetration of needles vary according to (1) the depth of implantation and (2) the region of the body where needles were placed. Measured angles were smaller for penetration at 1 and 1.5cm, but substantially greater at 3 and 4cm, indicating shearing forces to be greater at higher depths of penetration. Larger angles were observed in stations located in the posterior (closer to the peduncle) and in the dorsolateral regions of the body. Differences in angles between relaxed and flexed were smaller in areas of the body where tags are typically deployed (e.g. near the anterior insertion of the dorsal fin), but results indicate that shearing occurs to some extent in such areas.

Dissection of the tag sites after 18 hours of oscillation indicated variable results. Muscle cavities were found in six out of nine deployment stations, with the largest ones associated with deployments in the posterior portion of the body. Detachment of one of the retention flaps from the model tag body was associated with a relatively larger cavity with torn and shredded edges. Retention flaps did not fully deploy in six of the stations and changes of orientation in the tag position (rotation) were observed in fixed stations.

Initial results indicated that experiments on carcasses were informative to evaluate tissue trauma caused by intramuscular tag designs and that there is potential to improve animal welfare with the use tags that are robust, can compensate for shearing, and minimize the use of cutting edges.

IMPACT/APPLICATIONS

We expect that our results will have broad-reaching impact within the scientific community by increasing the applications of satellite tagging while reducing possible impacts to tagged whales. Satellite tagging is increasingly being used worldwide to study large cetacean movements, habitat use patterns, vulnerability and responses to anthropogenic activities with direct applications to conservation and management. One of the great advantages of this method is tracking individuals in near real time and sampling their environment for a lower cost than most observational studies. Evaluating possible welfare issues is important to better understand the potential impacts this technology can cause to individual animals and can inform development of improved tags. Making implantable satellite tags as effective and benign as possible will increase the number of individuals, populations, and species to which it can be applied. Therefore, this project has the potential to benefit the marine mammal community on a global scale as we expect to improve whale satellite tagging technology and provide more reliable tags. Perhaps as important, tag designs will be made publicly available to the marine mammal community shortly after the conclusion of the project.

RELATED PROJECTS

This study will be integrated with ongoing assessments of physical/physiological tag effects and tag robustness in Gulf of Maine humpback whales (Project Evaluating Potential Effects Of Satellite Tagging In Large Whales: A Case Study With Gulf Of Maine Humpback Whales) funded by NOAA and Exxon through the National Fish and Wildlife Foundation/National Oceanographic Partnership Program). In this study, led by PCCS, implantable satellite tags have been deployed to known individuals to assess their short-term behavioral responses to tagging and potential physiological effects of tags to individual animals. New satellite tags produced with the present ONR project will be deployed in GOM humpback whales to assess the performance of new designs in comparison with the existing technology from the point of view of animal welfare as well as tag duration.

The present ONR project will also build into long-term photo-identification studies on Eastern Pacific gray whales conducted by CRC in the west coast of the United States. This will provide a basis to assess tag performance in a different large whale species and will allow for comparison with humpback whales. In addition, because these whales have also been subject to tagging with existing technology, there will be an opportunity to evaluate performance of different types of tags.

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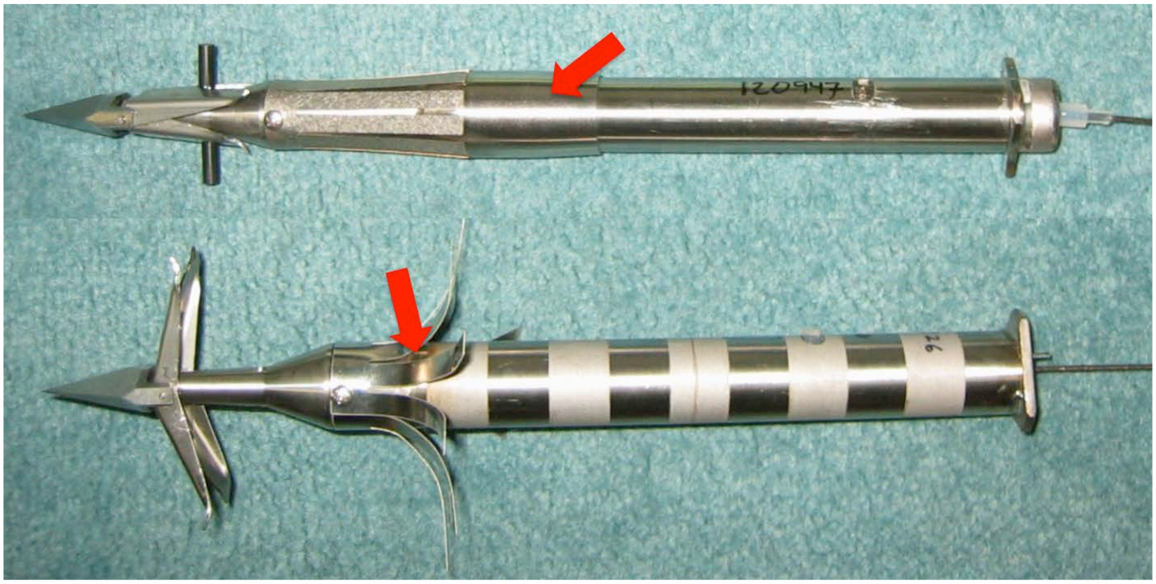

Fig. 1 – Implantable satellite transmitters showing design modifications to minimize or resolve failure of the anchor-transmitter interface. The red arrows show the reinforcement sleeve (top) created for existing tags in which welding of the transmitter body and anchor was not possible and the integrated (bottom) anchor-transmitter interface.

Fig. 2 – Design modifications in the posterior end of implantable satellite tags. The previous design with an exposed epoxy bulb is shown on the left while the new model with a flush posterior end and with the wet/dry sensor (salt-water switch) represented by a Nitinol cable is shown on the right.

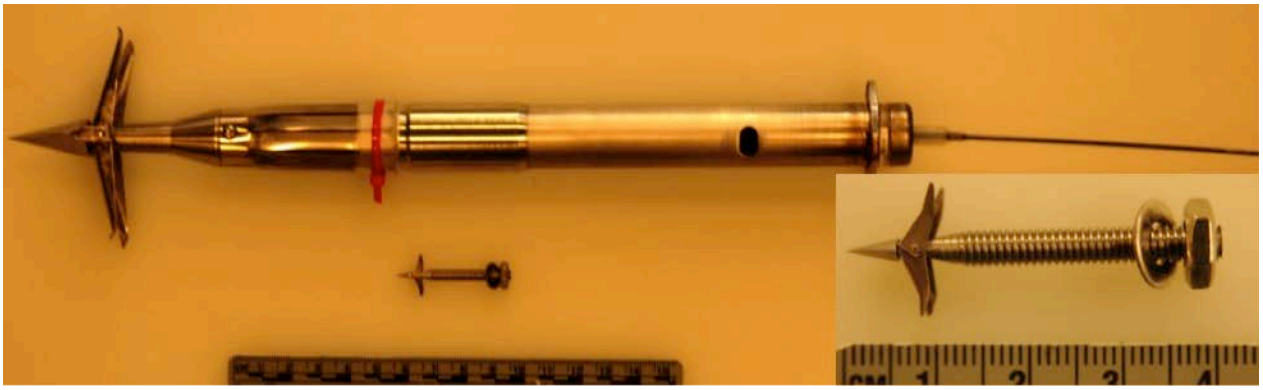

Fig. 3 – Large whale transdermal satellite tag and 1/7th scaled dolphin dummy tag. Inset shows dummy at a larger scale. Scales in cm.

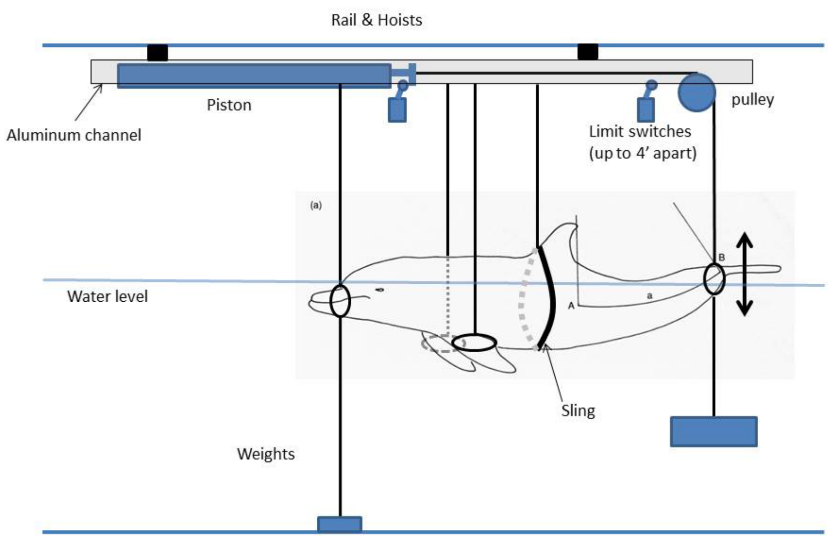

Fig. 4 – Experimental system for repeated oscillation of dolphin cadaver.

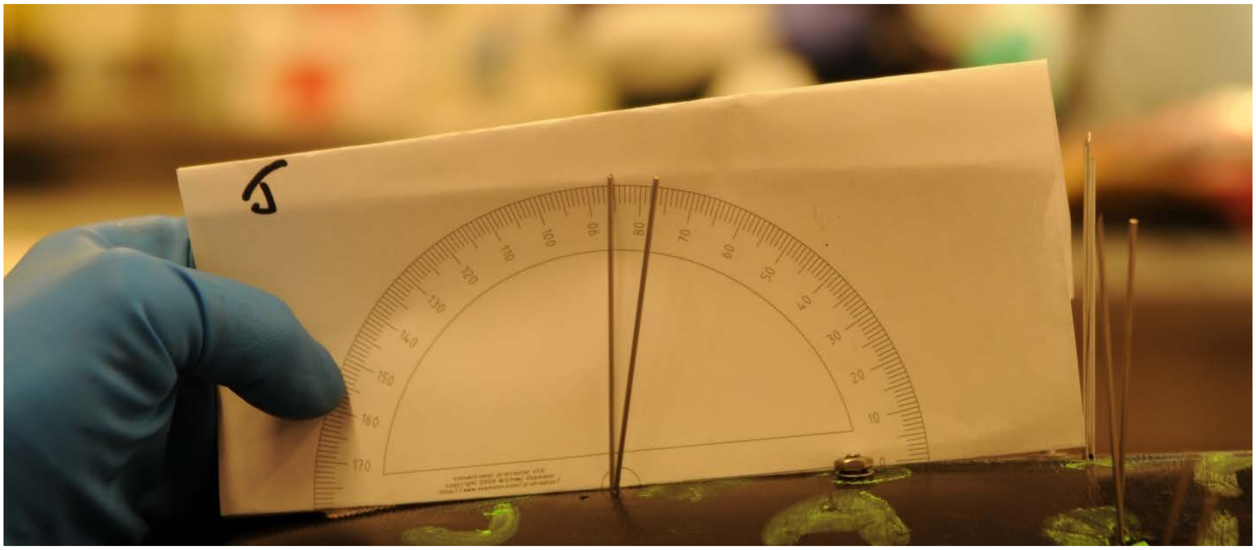

Fig. 5 – Measurement of angle between needle inserted into blubber only versus, though blubber into muscle of a common dolphin.