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FORUM

Considering the fate of electronic tags: interactions with stakeholders and user responsibility when encountering tagged aquatic animals

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Summary

1 The use of electronic tagging (e.g. acoustic, archival and satellite telemetry) to study the behavior and ecology of aquatic animals has increased dramatically over the past decade. As scientists continue to use these tools, it is inevitable that other researchers and the public at-large will encounter animals carrying such tags with increasing frequency. If the animals appear burdened or injured by the tag (e.g. showing signs of trauma), or if the tag is functionally impaired (e.g. cracked or severely biofouled), these encounters have the potential to generate conflict with various wildlife stakeholders (e.g. tourists/operators, divers, fishers, hunters) that can negatively affect research efforts and undermine conservation work. Yet, these encounters also present an unparalleled opportunity to advance the field of biotelemetry by improving animal welfare, tagging technology and practices, while also gaining the trust and support of wildlife stakeholders. Therefore, as scientists, it is important to consider the fate of our electronic tags.

2 Here we consider tagged animals as encountered by different user groups and discuss the potential steps and recommendations that scientists can take to improve tagging techniques and animal welfare as a result. We also discuss interactions with stakeholders and the manifold benefits if such interactions are taken into account and embraced.

3 We examine the situation where a researcher encounters, and is able and trained to handle a previously tagged animal equipped with a functionally impaired tag and/or the animal is exhibiting signs of burden due to the tag. We generate a decision tree for scientists faced with such a scenario and discuss the best course of action, whereas such a situation was relatively unlikely in the past, but is now a reality in all aquatic animal tagging studies.

4 The framework in which these issues are discussed is novel and failure to address them can significantly impede advances in the development and use of biotelemetry and even one's ability to conduct research. It is our hope that our essay stimulates further discourse, debate, technological improvements and consideration of the fate of electronic tagging.

Key-words: animal welfare, cetaceans, fish, satellite tags, seals, sharks, tagging, telemetry, tracking, turtles

Introduction

Many aquatic vertebrates are of conservation concern due to population declines arising primarily from overfishing and habitat alteration (Myers & Worm 2005; Crain *et al.* 2009; Harnik *et al.* 2012). As such, understanding their biology to underpin management and conservation efforts has become a significant focus of aquatic research in the 21st century (Hixon *et al.* 2001). Recent advances and increased use of electronic tagging have provided new insight into the energetics, resource use and movements of aquatic animals, significantly enhancing our understanding of their biology and ecology (Cooke 2008; Block *et al.* 2011; Costa, Breed & Robinson 2012). In turn, these data have also been used to support conservation of threatened species (Costa, Breed & Robinson 2012).

Despite the importance and conservation benefits of biotelemetry, there has been ongoing controversy as to the potential negative consequences of tagging on the behaviour, physiology, welfare and even fitness (i.e. long-term sublethal impacts) of aquatic animals (Wilson & McMahon 2006). For example, in one study area, satellite tags mounted to dorsal fins of white sharks (*Carcharodon carcharias*) were found to cause fin damage, although the actual sublethal fitness impacts (if any) on these animals remain unknown (Jewell *et al.* 2011).

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Conversely, sublethal impacts on fitness have been detected in other species; tags on king penguins (*Apteno dytes patagonicus*) have been found to negatively affect breeding success in resource-poor years (Saraux *et al.* 2011). A study examining the impacts of electronic tags and handling on Antarctic fur seals (*Arctocephalus gazelle*) found that pup growth was lower when mothers carried bulkier tags, leading researchers to recommend instrument streamlining and suggest that caution should be taking when deploying tags on lactating females (Blanchet *et al.* 2014). However, there still remains a general paucity of empirical studies yielding information on the long-term impacts of electronic tags on aquatic animals, partly because once tags are attached to animals, there are rarely encountered again by scientists. What is considered acceptable in terms of tagging practice and harm needs to be an area of further discussion and research on quantifying such effects could clarify such issues and potentially facilitate decisions made by ethics committees (Wilson & McMahon 2006).

Another potential issue with tagging technology is that after deployment, electronic tags will eventually fail or cease to transmit (Hays *et al.* 2007). For example, in their review of shark satellite tagging studies, Hammerschlag, Gallagher & Lazarre (2011) found that of the 48 studies reviewed, 81% had tags that failed to transmit in excess of 30 days, 44% of which contained tags that failed to provide a single geographic position. Considering the expense associated with purchasing and tagging animals, especially in the case of rare species, tag failure is also counterproductive and costly. However, unless the tag itself is recovered after deployment, it is extremely difficult (usually impossible) to determine the true cause of electronic tag failure and thus how to adapt the technology and practice.

The premise behind and wide-scale use of conventional identification tags has relied on recapturing tagged animals to obtain movement information. As a growing number of scientists engage in tagging studies, which affix electronic tags to free-swimming aquatic vertebrates, it is inevitable that the public at large will encounter these tagged animals with increasing frequency. This phenomenon is amplified when it comes to animal aggregation sites (e.g. reproduction or feeding grounds) that are targeted by scientists and sought after by various other wildlife stakeholders (e.g. tourists/operators, fishers and hunters). Such situations can cause animosity towards scientists if the tags appear to be non-functional (e.g. cracked or severely biofouled) and/or if the animals appear to be burdened or injured by the tagging (e.g. body damage, infection and poor health). These incidents have the potential to negatively affect research efforts, curtail technological developments and undermine conservation work.

Here, we consider the fate of electronic tags as encountered by different user groups and discuss potential steps that researchers can take to improve tagging technologies, animal welfare, project success and garner public support. We structure our discourse as follows: (1) identifying potential sources of conflict with stakeholder groups and the consequences that may arise; (2) discussing the benefits gained if researchers or other stakeholders encounter a previously tagged animal; and (3) providing a series of solutions and recommendations. This essay is not intended to serve as a guideline; in contrast, our aim is to spark a wider discussion and debate to help advance the field of biotelemetry.

Potential sources of conflict with stakeholders arising from encountering tagged animals

Wild animals, including aquatic vertebrates, can hold significant socio-economic, scientific and nutritional value to a wide range of stakeholders and cultures. Due to the potential for conflict arising from different stakeholders encountering previously tagged aquatic animals, it is worth considering how these concerns might be generated and/or evolve and how the varied perspectives of different types of users can be a foundation to create solutions to potential conflict. Below we discuss two of the most common interactions likely to occur.

WILDLIFE TOURISM

Ecotourism is one of the fastest growing sectors of the tourism industry (Wearing & Neil 2009) and it is now well understood that people are willing to pay large quantities of money to experience wildlife in natural settings (Liu 2003; O'Malley, Lee-Brooks & Medd 2013). Aquatic tourism often involves snorkeling, diving, wildlife watching, boating, fishing and hunting (although we exclude fishing and hunting here, to be discussed separately) to enable close interactions with the animals and habitats of interest (Miller 1993).

Due to the inherent difficulties in locating highly mobile aquatic vertebrates, wildlife tourism proprietors commonly centre their operations around aggregation sites where animals congregate either seasonally or year-round (e.g. feeding or reproductive grounds). Facing similar logistical and financial constraints, researchers often target the same sites. For example, off Western Australia, seasonal aggregations of whale sharks (*Rhincodon typus*) support 20 or more dive tourism businesses (which can hold between 10–20 people per boat per day; Gallagher & Hammerschlag 2011). Concomitantly, whale sharks are among the most highly satellite-tagged large elasmobranchs on the planet (Hammerschlag, Gallagher & Lazarre 2011) and researchers target these types of aggregations, thus illustrating the high potential for overlap between dive tourists and tagged sharks.

Scenarios where wildlife tourists and operators have encountered previously electronically tagged animals have raised concerns and general conflicts with scientist tagging activities for a number of reasons. These include (1) the animal is being harassed and/or harmed, consequently affecting their behaviour, physiology and/or welfare; (2) too many animals are being tagged; (3) tags ruin photos or videos; (4) tags reduce the 'natural' experience; and (5) the tag or tagging process alters the animal's behaviour around tourists (such as avoidance), artificially influencing the experience (e.g. Petko-Seus *et al.* 1985; Ballantyne, Packer & Hughes 2009; Newman 2011a, J. Romeiro, pers. comm.). Craighead (1979), for example, reported that officials in Yellowstone

National Park believed acoustic tags on bears offended visitors, especially photographers. Similarly, recent efforts to conduct telemetry studies on muskellunge fish in eastern Ontario saw angler requests to use tags that did not have 'unsightly' radio tag antennas exiting the body cavity leading researchers to place antennas internally (S. J. Cooke pers. obs.). Researchers must be sensitive and tactful when seeking solutions to these concerns, especially as the wildlife tourism industry as a whole has grown into one of the strongest contemporary arguments for the conservation and preservation of many threatened aquatic species (Krüger 2005).

FISHERS AND HUNTERS

The fisher/hunter user group may arguably spend the largest proportion of time on or near the water and these stakeholders therefore have great potential for encountering previously tagged aquatic species, such as fish, turtles and mammals. In some scenarios, there is a predisposed conflict between fishers and scientists, an inherent reality borne from the fact that conservation science often (but not always) results in limiting access to fishing/hunting opportunities – an issue in both the recreational (Danylchuk & Cooke 2011; Cooke *et al.* 2014) and commercial (Cooke & Cowx 2006) sectors. Given the capability of tags to reveal highly accurate spatial information about animal movements, observing or even capturing an electronically tagged animal may cause fishers and hunters to fear that their fishing/hunting locations may be exposed and the data used against them, which in turn may be perceived as a threat to and/or may limit their future activities. Moreover, fishers and hunters interested in removing and consuming species may feel that electronic tagging change the behaviour of animals causing animals to leave or avoid certain areas (see Cooke *et al.* 2013). For example, Nguyen *et al.* (2012) examined the perspectives of aboriginal fishers in British Columbia on the use of telemetry to study adult Pacific salmon (*Oncorhynchus* spp). The researchers revealed that the aboriginals were concerned for the welfare impacts of the tagging on the behaviour and survival of the fishes. Fishers and hunters may also fear that the tag itself can change/reduce the quality of the animal for consumption. Despite this seemingly inherent source of potential conflict, scientists often rely upon the expertise and assistance from fishers and hunters in tagging studies (McCay *et al.* 2006). For example, the success of fish mark-recapture studies using conventional identification tags is often dependent on fishers catching and reporting previously tagged animals (Pine *et al.* 2003; Queiroz *et al.* 2005; Taylor *et al.* 2006) as well as use of fishers to capture animals for tagging (Nguyen *et al.* 2012).

WHAT'S AT STAKE?

The conflict between stakeholders over tagging studies has the potential to negatively affect research efforts and undermine conservation work. This is especially the case if animals are observed swimming with fouled or damaged tags, and/or if the animals are exhibiting physical trauma, tumours, impaired locomotion, infection or body deformity as a result of the tag or tagging procedure (e.g. Newman 2011b, Jewell *et al.* 2011) (Fig. 1). Such concerns have previously resulted in ecotourism operators removing tags (Fig. 2), intentionally discarding electronic and conventional tags, or ecotourists asking if they could remove the tags themselves (N. Hammerschlag and A. J. Gallagher, pers. obs.). Such concerns can generate sufficient public animosity and opposition towards research projects that may have the potential to result in public petitions or use of social media platforms to prevent tagging, legal battles and ultimately even permit revocation (not to mention issues raised within research institutions and between granting agencies; Nguyen *et al.* 2012). In the Arctic, for example, there have been persistent issues with concerns among aboriginal fishers regarding animal tagging as well as the deployment of telemetry infrastructure to track animals, ultimately resulting in

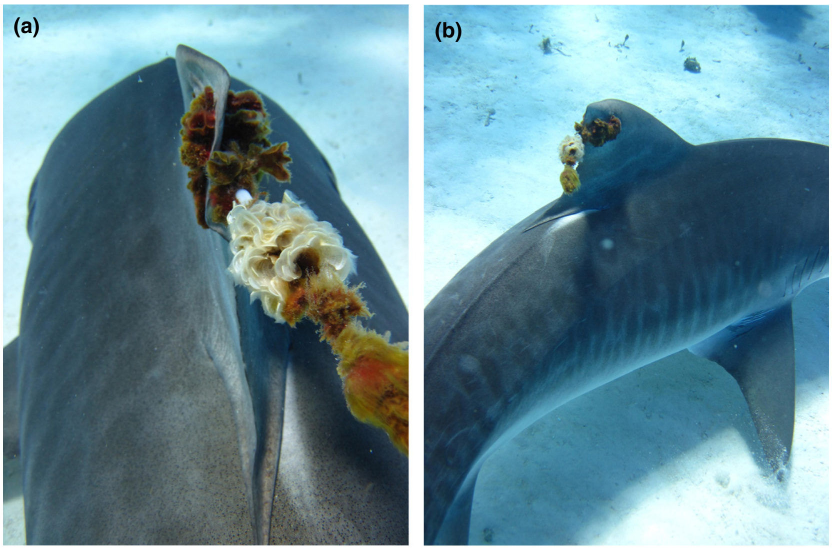

Fig. 1. Tiger shark (*Galeocerdo cuvier*) with a satellite tag photographed by an ecoutourist at a popular shark dive tourism site in the Bahamas. (a) The antenna is highly biofouled beyond *in situ* cleaning and (b) the tag has rotated in the fin such that the antenna will not sufficiently be able to break the water's surface and transmit to an orbiting satellite. Images courtesy Sean Williams.

Fig. 2. Biofouled acoustic tag physically removed from a white shark (*Carcharodon carcharias*) by a dive ecotour operator. The shark had a fresh minor abrasion at the contact point of the tag on the shark's skin. The recovered tag weighed 800 grams due to the growth. Matchbox included for scale. Image and information courtesy Chris Fallows.

restricted scientific access to territorial waters and the scaling-back and limitation of research efforts (Cooke *et al.* 2013).

Acquiring stakeholder support through engagement

The above that stakeholders can have with tagging practices often arise from lack of knowledge, misunderstandings, miscommunication and/or the difficulty or inability of scientists to involve or educate the public of the goals and benefits of the tagging research (Wilson & McMahon 2006). Often, stakeholder concerns can be ameliorated, or support garnered, through engagement. It has been well documented that wildlife tourists (much like other wildlife stakeholders) are willing to tolerate 'inconvenience' in their wildlife interactions (such as being less able to approach animals closely or take close-up photographs) if they understand the reason behind it, such as to support the animal's well-being or conservation (Petko-Seus *et al.* 1985; Ballantyne, Packer & Hughes 2009). In a study evaluating the attitudes and emotions of volunteers working with sea turtle research tagging programs, Campbell & Smith (2006) found that volunteers were concerned about the stress endured by the turtles during the tagging process, but dismissed their feeling when educated on the importance of gathering scientific data to further turtle conservation. In cases where tagged cetaceans have approached whale watching boats, scientists have provided on-water presentations about the tags, including advantages and disadvantages of using electronic tags, as well as the significance of the research (J. Calambokidis, pers. comm.). Subsequent feedback from whale watching tourists has been positive and the presentations received have been reported by operators as a highlight of the tourist's trip. Some recommendations to help engage local stakeholders in the significance of tagging research include (1) use of informative posters or flyers; (2) meetings with stake holders ahead of time; (3) involving members of the public in the research (i.e. citizen science) or inviting them to observe the tagging activities; (4) providing public talks (e.g. schools, clubs and museums); (5) working closely with stakeholders (such as hiring guides or tourism operators to help with research); (6) use of traditional mass media (print, radio and television); (7) publishing tagging results in peer-reviewed journals in a timely fashion; (8) use of online materials such as websites, short videos, teaching via social media and even online platforms that allow the public to follow the movements of the tagged animals; and (9) keeping the public updated on results.

What benefits can be gained if scientists and other stakeholders encounter a previously tagged animal?

As has been the case and premise behind use of conventional identification tags, the potential for scientists to encounter previously electronically tagged individuals by other research groups continues to increase as more tags are deployed. Here, we present a decision tree that outlines the possible options and consequences for scientists faced with such a scenario (Fig. 3). First, if it is safe, ethical and legal to do so, the researcher should record and photo-document the tagged animal, focusing on the instrument and attachment site, with the goal of sharing this information with the original tagger and manufacturer. The following pathways on the decision tree and discussion that follows are restricted to researchers that are trained and permitted in the handling and tagging of the species encountered as well as experienced in tag function. If the animal is showing signs of burden (e.g. animal listing as a result of tag drag) or injury due to the tag (i.e. trauma, infection), and/or if it the tag is functionally impaired (Fig. 1), the ideal option is for the researcher to try and remedy the issue in the field and re-release the animal (for example, cleaning or repositioning a tag). There are several ways that trained researchers are able to determine tag functionality or degree of animal injury as a result in the field, but these technical aspects are beyond the scope of this article. However, if these issues to animal welfare or impaired tag function cannot be ameliorated in the field, the decision tree suggests that by default, the next optimal decision is for the researcher to remove the tag and return it to the original tagging group (if known) or manufacturer. Such a situation would most often be the case if the initial tag was falling off or causing tissue damage such that it

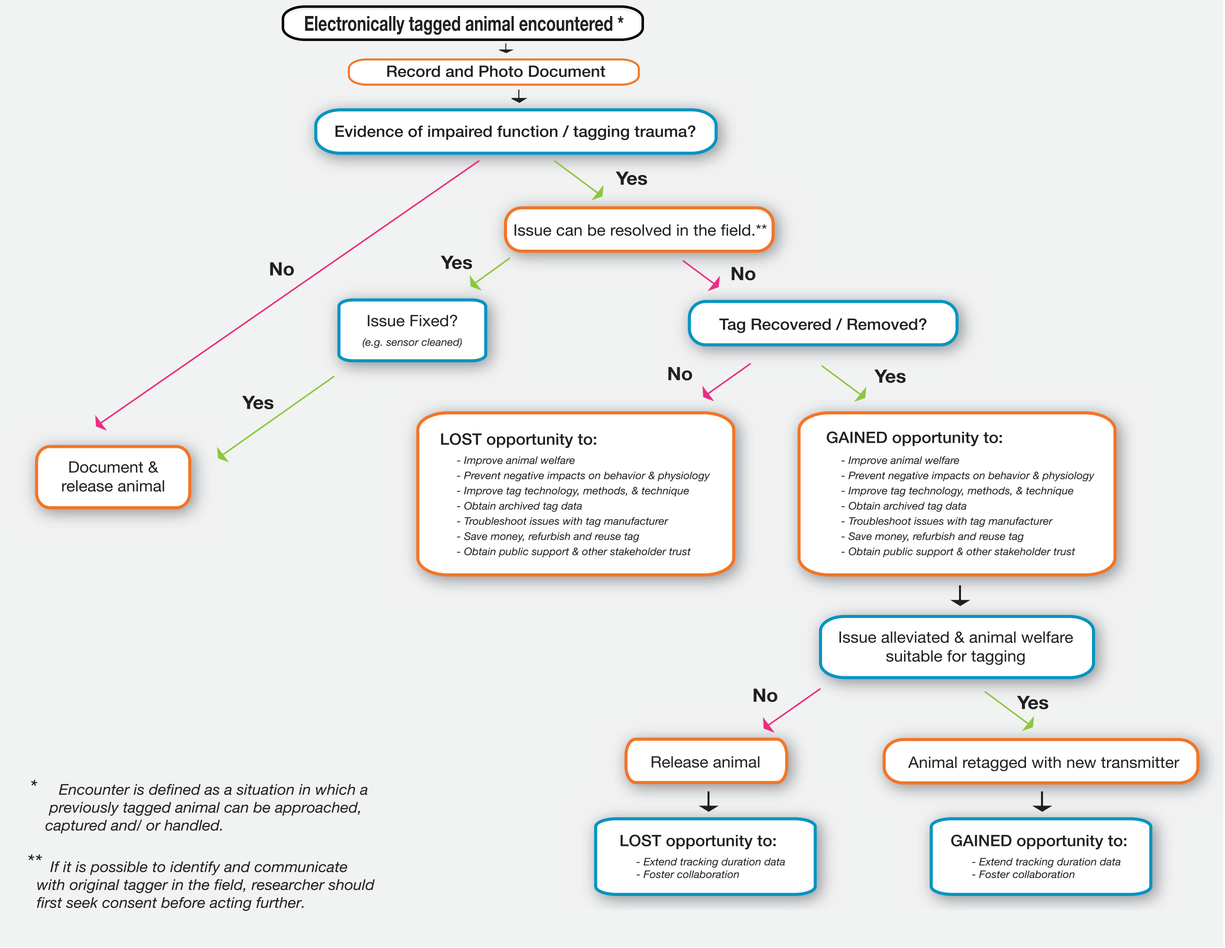

Fig. 3. Decision tree for researchers that outlines the options and consequences following encountering an electronically tagged animal.

could not be re-attached, if the battery died, or if the tag became biofouled beyond the possibility to be cleaned in the field (Figs 1, 2 and 4). Benefits for such a decision include the possibility of (1) preventing potential, unnecessary, or ongoing negative physiological or behavioural impacts on the animal from tags; (2) determining the reasons for tag failure providing the opportunity to troubleshoot and improve future deployments; (3) obtaining replacement tags if the failure was due to manufacturer error; (4) reusing the tag and thus recovering research costs; (5) recovering archived data that would otherwise be lost; and (6) gaining the trust and support of other stakeholders, ameliorating some of the conflicts outlined in the previous sections. Further, if removing the tag subsequently alleviates the problem and the animal's welfare thereafter is then suitable for retagging, the subsequent optimal decision is to tag the animal with a new device, which also results in a gained opportunity to extend tracking data and foster collaboration among research groups if so desired (Fig. 3). In both scenarios, we would suggest researchers document these situations and immediately provide this information to the other research groups. If possible to identify and communicate with the original 'tagger' in the field (without jeopardizing human or animal safety), the researcher should first seek consent before acting.

The details and benefits outlined in our decision tree are based on numerous reported situations. For example, the

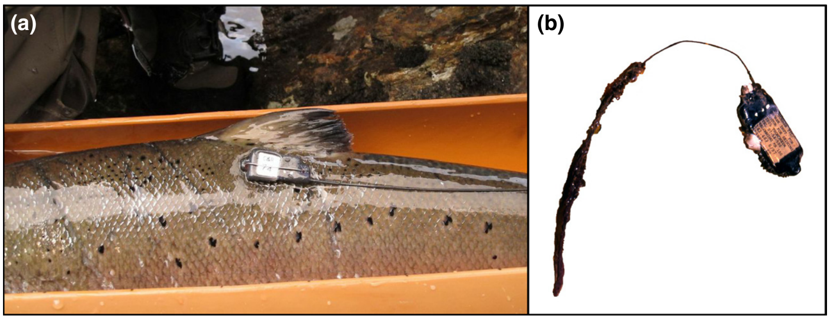

Fig. 4. (a) Atlantic salmon (*Salmo salar*) being released with an external radiotransmitter. (b) A radiotransmitter with highly fouled antenna and body casing removed from a recaptured Atlantic salmon that spent time as an adult in the ocean. Evaluating the state of the recovered tag allowed Thorstad, Okland & Heggberget (2001) to refine tagging methods. Image courtesy Eva Thorstad, Norwegian Institute of Nature Research.

nesting behaviour of leatherback turtles (*Dermochelys coriacea*) and incidental capture in fisheries have allowed researchers to inspect harness-based satellite tags after extended periods at sea (e.g. Troëng *et al*. 2006; Salinas, Ramoso & Rodriguez 2009). These incidents lead to the realization that fouling and chafing were the primary issues of concern, thereby leading to researchers considering alternate tracking methods that had apparently less impact on the behaviour of tagged turtles (Fossette *et al*. 2008; Witt *et al*. 2011). Additional model testing subsequently validated the significance of these changes (Jones *et al*. 2011). Recapture of Atlantic salmon (*Salmo salar*) affixed with external radiotransmitters after being at sea revealed fouling that could impair swimming ability (Thorstad, Okland & Heggberget 2001), thus leading researchers to consider alternative tagging methods (e.g. intracoelomic tag placement and elimination of antennas through the use of acoustic tags; Fig. 4). Repeated encounters of bottlenose dolphins (*Tursiops truncatus*) with electronic tags by researchers have allowed them to determine the factors impacting transmission failure and dorsal fin damage, which ultimately lead to the development of a new satellite transmitter design (Balmer *et al*. 2014). While the decision tree presented provides the optimal decision pathways following a researcher encountering a previously tagged animal, it is not intended to serve as a set of universal guidelines.

As discussed earlier, other stakeholder groups (tourists/operators, fishers/hunters) that spend significant time on the water are most likely to encounter previously tagged animals (Figs 1, 2 and 4). Such situations can be taken advantage of by researchers if considered and embraced. For example, in December 2011, members of our authorship team (N. Hammerschlag and A. J. Gallagher) deployed satellite tags on five adult tiger sharks (*Galeocerdo cuvier*) in the Bahamas. The tags were programmed to record, archive and then transmit stored data at specified times. After the deployment, the tags failed to report any data as programmed, thought to be due to a hardware malfunction. In February 2012, a dive ecotour operator specializing on close encounters with tiger sharks notified our team that he had seen two of the tagged sharks swim through one of his dive sites. We provided detailed instructions on how to safely and non-invasively remove the tags from the animal if such a chance arose. One month later, the operator encountered the sharks again and removed the two tags as instructed. After obtaining and analysing the tag data, we ascertained that they failed to report due to a programming error and not a hardware malfunction. Moreover, the tag still archived all sensor data that we were able to recover manually, providing a rich data set of over 200,000 points. As such, we recommend researchers contact the relevant local stakeholder groups which may come in contact with the animals and consider providing instructions on what they can do if they encounter a previously tagged animal as long as ethics, legalities and safety are not compromised.

While this discourse has mostly focused on stakeholder attitudes as well as user consideration and responsibilities, manufacturers have an important role to play in improving tag function and animal welfare. While there is certainly considerable manufacturer effort to improve tag performance (battery life, transmission rate and size), there needs to be a greater focus on engineering instruments that eventually detach from animals, especially if a large proportion of tags inevitably become functionally impaired. The software does exist for some tags (mostly satellite tags) to determine their functionality (e.g. battery life/power level or light level that could determine biofouling) which could trigger release mechanisms of external tags. Tools could be further developed or studies designed in a way that tagged animals are recaptured at the end of a study (Jepsen, Mikkelsen & Koed 2008). For example, Jepsen & Aarestrup (1999) designed a study to track northern pike (*Esox Lucius*), in which they were able to recapture and remove the tags from all of their tagged fish after 12 months. This would not be practical or possible in all investigations, but studies would benefit from new tools or design consideration that permit tag recovery at the end of the project or if the tags become impaired.

Given the importance of electronic tagging and tracking of aquatic wildlife, it is imperative that this type of research continues with the support of those that will inevitably encounter tagged animals. It is our hope that the discourse presented here helps encourage a greater dialogue and consideration on the fate of electronic tags among researchers, tag manufactures and the public, which will ultimately foster trust, improve animal welfare and advance the field of animal biotelemetry.

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Data accessibility

This paper does not use quantitative data.

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