Tagging Wild Cetaceans: Investigating the Balance Between More and Less Invasive Techniques

by

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Abstract

On-animal tags provide an incredible window into the world of cetaceans, allowing researchers to track movements across ocean basins and investigate fine-scale behavior deep below the surface. The earliest cetacean tags were *Discovery marks* developed by the British Colonial Office at the turn of the 20th century, and their influence continues to inform some of the implanted cetacean tags being deployed. Today, there are a wide variety of tags in use that can be broadly divided into two principal categories driven by the length of attachment required—disposable transmitting systems that are implanted in the animals and archival tags that must be recovered in order to collect the data. Archival tags typically use a non-invasive attachment with a release to get the data back. These tags provide essential information for conservation and management of these vulnerable species. In the United States, a broad suite of regulations protects cetaceans and other marine mammals. Welfare protection stems from the Animal Welfare Act and Conservation protection stems from the Marine Mammal Protection and Endangered Species Acts. To navigate this policy landscape, both regulators and Institutional Animal Care and Use Committees need to weigh the benefits of a tagging study against the potential for serious harm and evaluate whether a proposed method is the least harmful way to answer a scientific question. However, the effects of tagging wild cetaceans are not well-understood and difficult to compare, leading to challenges for objectively assessing proposals. In this environment of uncertainty, specific guidelines from professional societies would be helpful, but varying institutional and individual approaches to the balance between conservation and welfare will make consensus difficult. Given this context, we ought to employ the precautionary principle when evaluating impacts, interpreting guidelines and implementing them.

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Chapter 1

Introduction

All of a sudden the whales were gone. We had been following a group of six long-finned pilot whales (*Globicephala melas*) in the Strait of Gibraltar, and they had just disappeared. Fourteen minutes later they surfaced 500m away. Where had they gone, and what had they been doing? From our research vessel on the surface it was impossible to tell what was happening underwater. Fortunately, these animals were wearing acoustic and kinematic tags that revealed a foraging dive 600m down to the bottom with echolocation buzzes and fast sprints to catch prey.

This is why we tag wild cetaceans. Whales and dolphins are very challenging to study in the field. They are difficult to distinguish from each other, and they spend much of their lives in places where we cannot follow them, either below the surface or traveling quickly over large distances. Field studies that rely solely on surface observations are going to miss out on the behavior that is occurring deep underwater.

A wide variety of on-animal tags are currently in use on cetaceans today. They give us a critical window into the world of these animals: they can show us data such as where the animals go, how they move, what sounds they produce and what they hear. Instead of being limited to observing that our six pilot whales kept disappearing for fifteen-minute intervals throughout the day, we are able to track their underwater movements and get a better sense of what they are actually doing and how they experience their environment. This thesis will consider the balance between more and less invasive methods for tagging wild cetaceans, the challenges for comparing across methods, and approaches relying on guidelines from professional societies for moving forward in a context of uncertainty.

While tags provide essential conservation information for managing and studying cetaceans (B. Mate, Mesecar, & Lagerquist, 2007; P. Tyack, 2009; DeRuiter, Boyd, et al., 2013; F. H. Jensen, Beedholm, Wahlberg, Bejder, & Madsen, 2012), in recent years there has been an growing concern about the potential for them to impact animals (Walker, Trites, Haulena, & Weary, 2012). This focus is significant because cetaceans and other marine mammals are extremely well protected in the US by a suite of legal regulations prohibiting injury or harassment (Baur, Bean, & Gosliner, 1999). These protections have accompanied a broader transition—driven by the baby boomer generation—from seeing wild animals as commodities to be exploited to appreciating them as ends in and of themselves, to be observed in the wild rather than killed (Lavigne, Scheffer, & Kellert, 1999).

The Animal Welfare Act (AWA) requires institutional ethics review boards to assess research that proposes to tag cetaceans in order to ensure that the least invasive possible methods are used. However, as I will discuss, for a variety of reasons, it is challenging to objectively evaluate the impacts of different tags. How do review boards assess what the least invasive method is when it is not possible to compare them?

This thesis will begin by defining a key difference between conservation and welfare. Then it will look back to the earliest cetacean tags developed at the dawn of the twentieth century in order to provide context for some of the implanted telemetry tags being used today. From there, it will consider present-day tags in more detail and provide a sense of the range of types being deployed and the sorts of data they are able to collect. Then, I will step back to the regulatory context protecting cetaceans before using that lens to delve into the potential effects and impacts of deploying tags. Finally I will discuss challenges for ethics and welfare committees charged with assessing tagging research methods, and strategies for moving forward in a context of uncertainty.

Chapter 2

Conservation vs Welfare

Before going any further, it is necessary to draw a distinction between the two related concepts of conservation and welfare with respect to tagging cetaceans. In casual conversation, these terms are often used flexibly and somewhat interchangeably; however, they represent two very different concepts with their own associated cultural mores and perspectives. In the US, legal protection for the welfare of marine mammals comes primarily from the Animal Welfare Act of 1966, while protection for conservation comes from the Marine Mammal Protection Act of 1972 and for endangered species, the Endangered Species Act of 1969. Animal welfare focuses on the wellbeing and suffering of a single individual animal as opposed to conservation, which is concerned with the overall status of an ecosystem, population or species with respect to its ability to grow and reproduce (McLaren, Bonacic, & Rowan, 2007). In terms of cetacean tagging, whether a particular piece of regulation or tag design is informed primarily by conservation or welfare thinking will influence the way that it is employed and evaluated from a degree of invasiveness point of view. This tension becomes particularly apparent as society's values towards cetacean animal welfare shift throughout the 20th Century (Lavigne et al., 1999).

Chapter 3

Early Cetacean Tag Development

In order to better understand the use of some of the implanted cetacean tags being deployed today, it is helpful to appreciate the influence of early tag development in a context of commercial whaling. Under those circumstances, the first tags were not perceived as particularly invasive; however, current conceptions of animal welfare would likely evaluate them differently. The earliest cetacean tags were *Discovery marks* developed by the British Colonial Office at the turn of the 20th century for use in Antarctica. Southern Ocean whaling began with the Norwegians, and by 1904, Antarctic whaling based in the Falkland Islands had become the largest modern whaling industry in the world (Kemp, Hardy, & Mackintosh, 1929). Concerned that the stock of whales might diminish, the British Colonial Office launched the *Discovery Expeditions* in 1918 with a mandate to investigate the biology of Southern Ocean whales. In particular, they wanted to know answers to questions such as stock size, migration patterns and the maximum annual sustainable harvest (Kemp et al., 1929). Returning to the distinction between conservation and welfare, these are all conservation questions concerned with the status of the stock, not welfare questions considering any pain or distress of individual animals.

To answer these questions, biologists needed to be able to study live animals rather than dead ones. The requirement to be able to identify individual whales led to the development of the *Discovery mark*, the precursor to modern cetacean tags. The mark was essentially an identification tag: fired from a shotgun with a serial number, it became embedded in the blubber and was retrieved upon whaling (Kemp et al., 1929; Raynor, 1940). The goals for the tag design were to keep it simple and low cost in order to allow mass production, to be carried permanently by the whale once embedded, not to inflict serious injury and to be distinctive enough in appearance that it would be visible amongst all the blood during harvest. An early design only penetrated 2.5 inches, and the whales' bodies' rejected the marks. The final design consisted of a barbed 10" stainless steel tube with a serial number and the words: "Reward for return to the Colonial Office, London." It was designed to deploy from a reinforced 12-bore shotgun at ranges of up to 70 to 80 yards. At tagging, scientists would record position, time and best estimate of species. Then, if the tag was uncovered inside an animal during harvest, whalers would return it to the Colonial Office along with the position of capture, species, sex, status of wound healing around the tag, whale length and condition. They were compensated 1£ as a reward (approximately 60£ adjusted for inflation to 2014[1]) along with the option to have the mark returned as a memento (Raynor, 1940). 5219 whales were reported marked between 1934 and 1939. Unfortunately, later tests with high speed cameras demonstrated that many of the tags reported as successful may have ricocheted away instead of implanting (Schevill & Watkins, 1977).

The underlying motivation of the expeditions and subsequent tag development was to preserve the whaling industry. These are conservation motivations concerned with sustaining an exploited resource. The connection to whaling was implicit in the *Discovery Expeditions*, even the tags were often deployed by Norwegian whale gunners from hired whale-catcher boats (Raynor, 1940). Without the death of the animal, there was no re-sighting. In the context of whaling, some pain to individual animals for the good of the stock was not considered a problem. While present-day conceptions of animal welfare might evaluate this differently, echoes of the *Discovery* focus on overall stock can be seen in conservation-informed thinking primarily concerned with maintaining an overall population and ecosystem. Now that conservation is one of

[1]http://www.thisismoney.co.uk/money/bills/article-1633409/Historic-inflation-calculator-value-money-changed-1900.html

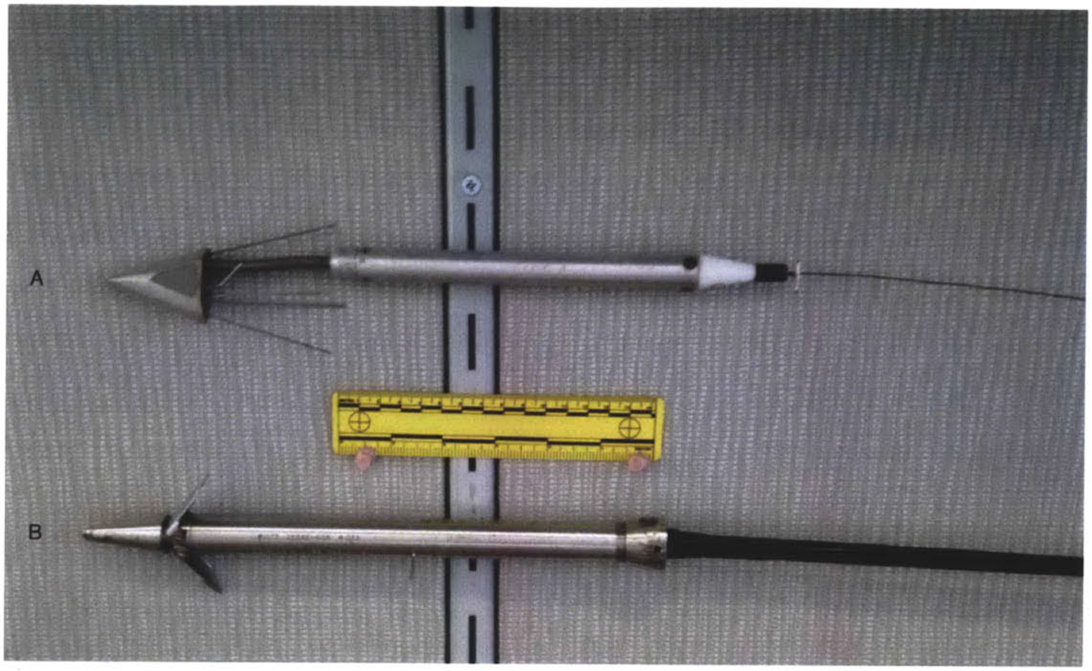


Figure 3-1: Early tags developed by Schevill and Watkins at Woods Hole Oceanographic Institution. Photo credit: Peter Tyack.

the primary concerns of tagging (Read, 2002; B. Mate et al., 2007) it is useful to understand some satellite tag development as informed by the early *Discovery marks*.

Forty years later, in the mid 1970s, the state of the art of tag development remained influenced by the *Discovery marks*. Working at Woods Hole Oceanographic Institution (WHOI), Schevill & Watkins, 1977 developed a radio tag that would transmit a signal to help track large whales (*Watkins tag*). Apart from the transmission ability, the tag was very similar to the *Discovery marks* and shared many of the same design and implantation goals. The requirements were a tag that could be deployed from tens of meters using a 12-gauge shotgun and penetrate the blubber with a target attachment duration of 13-14 months. Unlike the *Discovery mark*, an antenna would remain outside the blubber, and Schevill and Watkins made an explicit point of wanting to disturb the whale as little as possible (1977).

An early version of the Watkins tag, developed in the early 1960s was dropped from a helicopter on a weighted pole (Figure 3-1A). It consisted of a 15.5cm metal cylinder with a barbed point and an antenna. A later version for shotgun deployment measured

1.9cm in diameter and 29cm from barbed tip to flange (Figure 3-1B). The body of the tag was designed to be contained in the animal, penetrating the blubber and muscle with the antenna protruding from the body. Even with these later tags, the connection to whaling remained strong: they were developed and tested by working with Icelandic whalers and firing at freshly harvested whale carcasses (Schevill & Watkins, 1977). To place this timing in the regulatory context that will be discussed in chapter five, this tag development occurred prior to the Animal Welfare Act of 1966 (AWA), the Marine Mammal Protection Act of 1972 (MMPA) and the International Whaling Commission's ban on commercial whaling in 1986 [2]. This kind of research collaboration with whalers would have been more common prior to the MMPA.

More recent satellite implantable tags, such as the ones developed by B. Mate et al., 2007, can also be viewed as informed by *Discovery mark* and subsequent Watkins tag development. Like the earlier tags, the overall design was based on a tube with a barbed tip: the first implantable satellite tag was a metal cylinder 19cm long by 1.9cm in diameter with a barbed tip (B. Mate et al., 2007). Deployment mechanisms were similar, with the tags being launched by a compound crossbow or an air-powered gun (B. Mate et al., 2007). Moreover, like the earlier tags, these tags were designed to penetrate the blubber and implant into the muscle, sometimes using two rows of sub-dermal stainless steel barbs (B. Mate et al., 2007). Finally, like the *Discovery mark* these tags were designed to remain in the animal for long periods of time to collect migration and movement data, one of the early tags' primary motivations.

Over the years, there have been many refinements to cetacean satellite tags as electronics and batteries become smaller, but the *Discovery marks* were developed not that long ago, and it can be useful to understand the design and deployment of present-day tags as informed by that development, either drawing on similar design goals or reacting to them.

[2]Iwc.int/commercial

Chapter 4

Modern Cetacean Tags

Early tags such as the *Discovery marks* served primarily to identify individual animals. Today, there are a wide variety of cetacean tags in use that can be broadly divided into two principal categories—disposable transmitting systems like the radio and satellite tags already described and archival tags that must be recovered in order to collect the data. These two categories of tags are driven by different attachment requirements with satellite tags that investigate geodetic movements requiring much longer attachment durations than archival tags studying more fine-scale behavior. These attachment requirements not only dictate tag design, but also to some extent reflect the difference between a more conservation-focused (satellite tags) and a more welfare-focused (archival tags) approach to cetacean tagging: as I will describe, longer-attachments needing a more invasive tag are primarily required for telemetry tags used for conservation ends such as stock assessment management of overall populations. In contrast, higher resolution archival tags only require shorter attachments that can rely on suction cups and need to be more concerned about biasing results by affecting fine-scale animal behavior during the attachment period.

There are many different kinds of cetacean tags that transmit data. In general they are implanted in the animals and provide a small amount of information over a period of time up to 18 months [1] . The earliest tags were radio transmitters like the one developed by Schevill & Watkins, 1977 for tracking large whales. These tags were

[1] www.wildlifecomputers.com

quite large and required that a follow vessel stay in range of the transmitter in order to receive a signal. In contrast, modern transmission tags are smaller and use satellite links to send data remotely (Read, 2002): the tag emits a signal to satellites, and as the satellites move over the horizon, Doppler shift of the transmitter's characteristic frequency allows the tag positions to be estimated. These telemetry tags primarily provide two-dimensional geodetic coordinates for an animal. However, more recent ones can also transmit some behavioral information too: they are often combined with loggers such as depth and temperature sensors that can relay data or summary statistics back to land. Examples of behavioral information collected are the duration of time spent at depth, the maximum dive depths, or full dive profiles.

Telemetry tags are generally implanted into the animals, either through the dorsal fin or across the blubber into the muscle. Although there are some companies such as Wildlife Computers (Bellevue, WA) that have begun to develop and mass-produce tags, they often evolve in individual labs leading to a huge variety in shapes, size, and use. Deployment mechanisms also vary from tag to tag ranging from compound crossbows to air-powered guns (e.g., Andrews, Pitman, & Ballance, 2008).

These tags provide critical information for cetacean conservation: in order to protect an animal, you must know where you need to protect it. While it may be challenging to tag a representative sample of a population, data from satellite tags can direct further research such as ship-based or aerial surveys by helping them hone in on likely locations for finding animals (B. Mate et al., 2007). One example is the case of the western population of North Pacific gray whales (*Eschrichtius robustus*). Distinct from the healthier eastern population, the critically endangered western whales are estimated to number only 130 individuals. They summer near Sakhalin Island in Russia, but their winter feeding grounds and migrations are not well understood (Weller et al., 2012). A satellite tag deployed on a male western gray whale showed a previously unknown migration to the Eastern Pacific off the coast of North America. This unexpected development spurred a photo-identification comparison of catalogs of the western and eastern populations that led to confirmed matches in both populations, implying a much greater deal of mixing between the two populations than previously thought (Weller et al., 2012). Satellite tags have also played an important role in understanding the ranging and migration patterns of many different cetacean species such as Antarctic killer whales (*Orcinus orca*) (Andrews et al., 2008), bottlenose dolphins (*Tursiops truncatus*) (B. R. Mate et al., 1995), Southern Right whales (*Eubalaena australis*) (B. Mate, Best, Lagerquist, & Winsor, 2011) and North Atlantic Right whales (*Eubalaena glacialis*) (B. R. Mate, Nieukirk, & Kraus, 1997). More recently, two satellite-tagged female North Atlantic Right whales demonstrated that the migratory range extends further offshore than previously thought, and it might be beneficial to extend a 20-mile conservation buffer around major ports to 30 miles (Schick et al., 2009).

As illustrated by the case of the western gray whales, satellite tags have been primarily used for conservation issues such as stock assessment. Understanding animal movements provides key information for managing cetacean populations and ensuring that they are sustainable. In turn, obtaining the movement information requires long-term attachments. That requirement dictates tag design and leads to the influence of the Discovery mark and Watkins tags—both long-term attachments with similar design features and attachment strategies—on the barbed cylindrical satellite tags described here.

In contrast with satellite tags, archival tags capture behavior with a higher sample rate than it is possible to transmit. Thus, they must then be retrieved in order to access the data (Johnson, Aguilar de Soto, & Madsen, 2009). Often they are fitted with a short-range radio transmitter to ease retrieval. They can store very high-resolution data, but they can be expensive and logistically complicated to recover. The earliest archival tags for marine mammals were time-depth recorders that were based on kitchen timers (Kooyman, 1972). Technological advances in the miniaturization of memory and electronics for cetacean tags led to their ability to incorporate a suite of different sensors and measure ever subtler behaviors at these higher sample rates (Johnson & Tyack, 2003; Johnson et al., 2009).

These capabilities are implicitly connected with attachment durations and the corresponding welfare and invasiveness considerations. At these high sample rates,

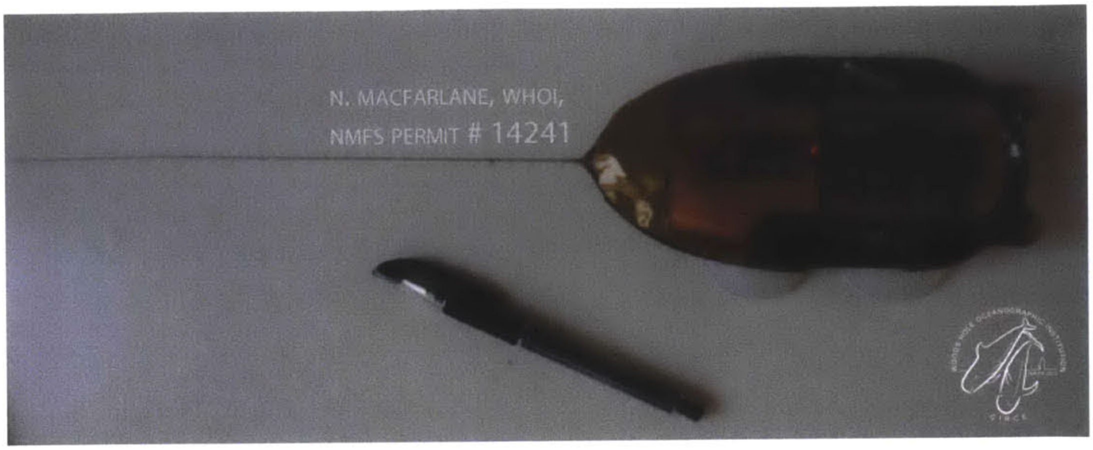


Figure 4-1: A digital acoustic recording tag (DTAGV3) developed by Johnson and Tyack at WHOI. Photo credit: Nicholas Macfarlane

even a short-term tag can provide an enormous amount of data. Longer tag deployments would be overwhelming to analyze. Moreover, the battery and memory capabilities of most archival tags are limited to deployments on the order of several days. This means that the long attachment requirements of satellite tags do not apply to archival tags, and there is no need for the implanting tag design to obtain them. Rather, archival tags are measuring such fine-scale behavior that the tag needs to be as non-invasive as possible in order to avoid confounding the scientific results. This concern for affecting individual research subjects in turn is often paralleled by greater focus on individual animal welfare than we saw with the satellite tags.

Because sound is such an essential modality for cetaceans, many archival tags focus on acoustics (Johnson et al., 2009). One example of an acoustic tag, the A-Tag, was designed to measure the sonar of porpoises. It measured 12cm x 2.1cm, weighed 70g and sampled at up to 2000 Hz with a depth rating of 200m (Akamatsu, Wang, Wang, & Naito, 2005). Today, one of the most commonly deployed cetacean archival tags is the Digital Acoustic Recording Tag (DTAG, see Figure 4-1), developed at WHOI by Johnson & Tyack, 2003.

The most recent version of the DTAG records audio from two hydrophones at a rate of up to 500KHz. It also contains kinematic sensors made up of 3-axis accelerometers and magnetometers to measure pitch, roll and heading sampled at up to

Figure 4-2: Deploying a DTAG on a long-finned pilot whale (Globicephala melas) using a carbon-fiber pole. Photo credit: Frants Jensen. NMFS permit # 14241

500Hz. Depth is calculated from pressure and temperature sensors. It weighs 190g in air and measures 15.2cm x 3.5cm x 6.6cm. It has 30-64Gb of flash memory allowing a recording life of 2-6 days constrained by battery and memory. Like other archival tags the recording duration is much shorter than that of telemetry tags (Johnson et al., 2009). The DTAG is deployed by hand with a carbon fiber pole (Figure 4-2).

Rather than implanting into the skin, it attaches with suction cups and uses nichrome wires to release upon an electronic command and float to the surface at a pre-determined time. A vhf radio transmitter allows the tag to be tracked and retrieved (Figure 4-3).

Archival cetacean tags provide an incredible window into the underwater behavior of these animals that is essential for conservation ends. In addition to knowing where in the world to protect a species, we must understand its behavior in order to know how to protect it. To do this, it makes sense to sample information in a way that is relevant to an animal, something for which on-animal archival tags are particularly suited (Johnson et al., 2009). Archival tags have allowed researchers to study many different conservation-oriented aspects of behavior ranging from understanding the interplay between foraging and communication at depth with man-made noise

Figure 4-3: Radio-tracking a DTAG deployed on a pilot whale using a hand-held VHF antenna. Photo credit: Frants Jensen

(F. H. Jensen, Marrero Perez, Johnson, Aguilar Soto, & Madsen, 2011) to investigating the behavioral responses to anthropogenic disturbances such as naval sonar (DeRuiter, Southall, et al., 2013; Goldbogen et al., 2013). Thus although archival tags are still used for conservation, they are deployed through a behavioral perspective that generally focuses on individual animals rather than stocks.

Modern cetacean tags are much more sophisticated than their earlier counterparts. Widespread use and technological development in electronics miniaturization have led to many different kinds of tags and tagging practices that are driven by the required attachment times. Broadly speaking, telemetry tags that investigate animal movements and migrations must remain on the animals on the order of months to be most useful. The research goal of conserving populations is not that far removed from the *Discovery expeditions*' motivations and has led to some modern telemetry tags being informed by the design and attachment strategies of the *Discovery mark* and *Watkins tags*. This influence is connected by a broader conservation culture that may focus more on managing populations rather than the welfare of individual animals. In contrast, archival tags collect high-resolution data that require short-term attachments; therefore, they primarily use suction cups and are not implanted. Rather than investigating broad movements over long periods of time, they are concerned with subtle measures of animal behavior, leading to a corresponding emphasis on non-invasive tagging in order to avoid biasing fine-scale data.

Chapter 5

Present-day Regulatory Context

Unlike during the height of commercial whaling, today cetaceans and other marine mammals are extremely well protected in the US. While the motivations of the established protective legislation are clear, the regulatory landscape itself is complex, particularly with regard to scientific research. At the same time as laws prohibit any injury or harassment to cetaceans, further conservation research (whose protocols might require harassment or injury) was an important part of regulations such as the MMPA. Scientific research exceptions to these prohibitions are granted by the National Marine Fisheries Service (NMFS), and internal Institutional Animal Care and Use Committees (IACUCs) evaluate research proposals for compliance with the AWA. However, a lack of expertise, information and guidance can make it difficult for IACUCs to carry out their duties.

Today's policy context is quite different than it was in the early 20^{th} Century when the Discovery Expeditions were launched. There has been a significant change in American attitudes towards cetaceans that has translated into legal protections. As late as 1978, 75% of Americans endorsed hunting of non-endangered whales if it led to useful products (Kellert, Berry, Yale, Fish, & Wildlife, 1982). Twenty years later a poll by the International fund for Animal Welfare showed that this number had dropped to 14% (Lavigne et al., 1999)[1]. This change is a symptom of a broader transition–

[1] In contrast the majority of Japanese and Norwegians, two countries still engaged in whaling, were unopposed to whaling as recently as 1992 (Freeman & Kellert, 1994, as cited in Lavigne, Scheffer, & Kellert, 1999)

driven by the baby boomer generation–from seeing wild animals as commodities to be exploited to appreciating them as ends in and of themselves, to be observed in the wild rather than killed (Lavigne et al., 1999). This change also reflects a cultural shift between a focus on cetaceans solely as stocks to be managed, to one that takes individual animal welfare into more prominent consideration. These evolutions have manifested themselves in a broad collection of laws and policies protecting cetaceans and other marine mammals. Marine mammals are protected by regulations ranging from the Endangered Species Act (ESA), to the AWA, to the National Environmental Policy Act (NEPA), but the centerpiece protection of cetaceans is the Marine Mammal Protection Act of 1972 (MMPA) and its 1994 amendment.

The MMPA was the first comprehensive legislation protecting marine mammals (Baur et al., 1999). Enacted at the dawn of the US environmental movement, at a time when commercial whaling still occurred in the US, it took a precautionary approach. In the words of the Honorable John Dingell during the opening congressional debate: "...once destroyed, biological capital cannot be recreated" (Baur et al., 1999). In fact, the MMPA was the first piece of government regulation anywhere in the world that explicitly valued a healthy ecosystem as integral to single species' conservation (NMFS, 2014). Moreover, in striking contrast with previous fisheries management that was concerned solely with maintaining adequate stock,

> "...the primary objective of [the MMPA] must be to maintain the health and stability of the marine ecosystem; this in theory indicates that animals must be managed for their benefit and not for the benefit of commercial exploitation. The effect of this set of requirements is to insist that the management of animal populations be carried out with the interest of the animals as the prime consideration." (House of Representatives, No. 707, 92nd Congress, 1st session, 18, 22 [December 4, 1971], as cited in NMFS, 2014).

These directions marked a significant departure from existing protections and required that cetacean management must be conducted with the best interests of the animals as paramount. The principal result of the MMPA was a moratorium on taking. The MMPA defines 'take' as "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture or kill any marine mammal." The 1994 amendment further clarifies harassment as "...any act of pursuit, torment, or annoyance which (i) has the potential to injure a marine mammal or marine mammal stock in the wild; or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding or sheltering." (Baur et al., 1999). The central distillation is that it is forbidden to injure or harass cetaceans or other marine mammals in any way.

This language introduces a tension between some of the tagging strategies already described and the prohibition on harassment. The following chapter on the effects of tagging will delve deeper into this apparent conflict. Section 101 (a) of the MMPA outlines exceptions to the moratorium on taking for the purposes of scientific research according to permits issued under section 104 of the act. Permit decisions are made by the National Marine Fisheries Service (NMFS) and must be based on the best scientific evidence possible. They have a mandate to comply with the MMPA and cannot hurt the stock of cetaceans (Baur et al., 1999). Throughout its history, cetacean science was primarily centered on the study of dead animals in commercial whaling (Watson, 1981), but the MMPA and other policies evolved along with the science to change that focus to live animal research. For example, section 2 of the act requires the "...protection of essential habitats." Without knowing where these are–for example by satellite tagging as we saw in the case of the western gray whale–this is not possible (Baur et al., 1999). Likewise, the NEPA requires environmental impact statements on federal actions that can affect the environment such as naval exercises that may impact cetaceans in the area (eg., P. L. Tyack et al., 2011). Producing these statements necessitates being able to predict the impacts, but to do this well requires good science to understand them. Thus, the regulatory context of cetacean policy and conservation benefits from interaction and integration with marine mammal scientific research.

Two principle ways that the interplay between regulation and cetacean research manifests itself are through the application to NMFS for permission to break the moratorium on taking and proposal review by internal IACUCs, charged with implementing the AWA. Placing any tag on a wild cetacean has the potential to disrupt behavioral patterns, thus qualifying as a take under the MMPA. Therefore, should a researcher wish to tag cetaceans, a permit application must be submitted to NMFS for an exception to the moratorium on taking under section 104 of the MMPA. The researchers must show that the proposed taking will not adversely affect the animals or the ecosystem, and NMFS assesses whether or not the research aligns with the MMPA's requirement that the resource must be managed with the animal's interests at heart (NMFS, 2014). All permitted research must be 'humane' and use the method with the least possible pain and suffering practicable (MMPA Section 104(b)(2)(B)). Here we see both conservation and animal welfare concerns in play. The permitting decision must also be based on the best available scientific evidence (Baur et al., 1999). Once submitted, permits are published in the Federal Register for notice and comment. In addition to receiving a NFMS permit, prior to tagging cetaceans, researchers must comply with the AWA by securing the approval of their IACUC. This requirement can present an obstacle for independent researchers who are not affiliated with a large institution.

While the ecosystem focus plays into the broader conservation philosophy, the IACUC assessment is about animal welfare. The AWA regulates the treatment of animals used for research. It was enacted primarily for animals in captivity and grants an exception for field studies, defined as "... any study conducted on free-living wild animals in their natural habitat which does not involve an invasive procedure, and which does not harm or materially alter the behavior of the animals in the study." (7 U.S.C.2131-2159). However, since tagging might qualify as materially altering the behavior of the animals under study, any tagging study should consider whether the AWA must be applied for cetacean tagging field research as well, and most IACUCs do not employ this exception. This can introduce complications because the regulations have been primarily designed with laboratory research in mind. Compliance with the AWA falls to each institution's IACUC, a committee required by the AWA to vet proposals with live animals. Every research institution must have an IACUC composed of specific roles–a chairman, a veterinarian from the institution who has experience with laboratory animal science and someone unaffiliated with the institution. Often it will also include a scientist familiar with using animals in research and a non-scientist (USDA, 2013). Proposals to the IACUC must identify and justify the species and number of animals used as well as involvement of animals in the research. They must also include a detailed protocol description as well as procedures to limit any discomfort and pain (USDA, 2013). The primary goal is to assess whether the benefits of the proposed research outweigh the potential costs to the animals.

In summary, cetaceans and marine mammals are extremely well protected by a variety of regulations and laws. Injury and harassment are prohibited, and the primary consideration for managing cetaceans must be the benefit of the animals. However, while the regulatory language is clear, the policy landscape is complicated, particularly when it comes to scientific research. Exceptions to the moratorium on taking can be granted by NMFS for scientific research such as tagging, but the information required to best evaluate the proposed research is not necessarily available. In particular, the rapid development of disparate cetacean tagging technologies and methods that are only used by small communities of researchers makes it difficult to create standards that reliably assess impacts in order to guide IACUCs in their implementation of the animal welfare act. By definition IACUCs are a local body, unique to each institution, and their composition will be made up of members grounded in different philosophies on the balance between conservation and welfare. These inter-committee differences mean that there may be large variability between the evaluations of proposals from one committee to the next. Moreover, the members often have little experience with cetacean tagging leading to difficulties judging the least harmful method for achieving a scientific objective as required by the AWA, particularly when a researcher is only required to propose a single approach. These challenges will be further discussed in chapter seven. Effectively assessing the potential harm to animals from a welfare point of view requires understanding the impacts of cetacean tags, something that I will now consider in chapter six.

Chapter 6

Effects of Tagging Wild Cetaceans

As already described, the many kinds of conservation information provided by tagging cetaceans are necessary for regulators to effectively manage and protect cetacean populations. However, barring certain exceptions for fisheries, the legal context outlined in chapter three prohibits injuring or harassing these animals in any way. This introduces an apparent tension, for in some cases deploying tags may injure or harass the same animals that we are trying to conserve. These conflicts are navigated through exceptions to the moratorium on taking granted for scientific research. Nevertheless, in order to comply with the MMPA's requirement that management of cetaceans and other marine mammals be conducted with the best interests of the animals at heart and the AWA's instruction to use the least harmful method possible, it is necessary to assess whether the likely benefits of a particular tagging study outweigh the potential costs. Understanding these costs requires being able to predict the consequences of tagging a wild cetacean.

Studies in birds and mammals show that tagging can cause pain and distress, interfere with behavior, and even reduce survival and fitness (Wilson & McMahon, 2006). Over the last couple of decades there has been an increasing focus on the effects of tagging cetaceans. Unfortunately, the majority of reports are opportunistic and anecdotal rather than controlled and comparative, making it very challenging to compare across species and contexts (Walker et al., 2012). Using these case studies, here I will describe the kinds of effects that are possible. Looking first at implanted telemetry and then archival suction-cup tags I will consider the physiological and behavioral effects of tagging. I will also chronicle a rare physiological effect of deploying a suction-cup tag on long-finned pilot whales *Globicephala melas*). Finally I will begin to discuss the challenges of evaluating the potential effects and using this information.

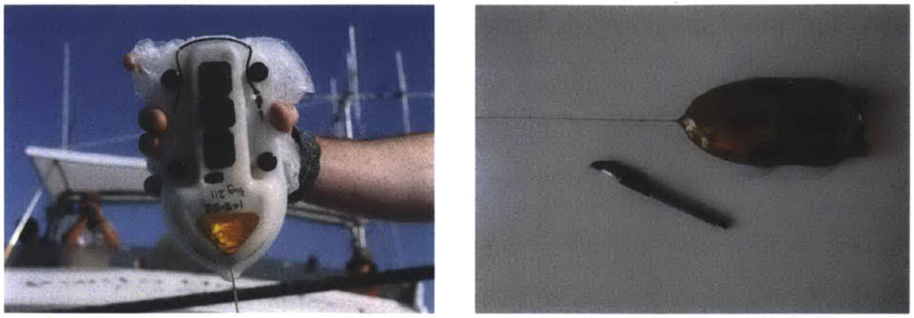
In terms of implanted satellite tags, there are a variety of potential physiological effects. These can range from trauma resulting from implantation, to inflammation from the wound healing process, cutting and tearing trauma and shearing from tag movement, to saltwater ingress and infection, and chronic pain or stress. These effects often result from the healing process to the injury of tagging that is disrupted by the implanted tag (Weller, 2008). At present, the evidence for the breadth of the physiological effects of implanted tags is limited and not necessarily decisive. It can be challenging to draw conclusions from anecdotal reports and small sample sizes; however, at the moment, that is the information that is currently available. The following sample of case studies illustrates the potential effects. B. R. Mate, Harvey, Hobbs, & Maiefski, 1983 describe a radio-tag designed for gray whales (*Eschrichtius robustus*) that led to inflammation at the site of implantation, two weeks after tagging. On belugas (*Delphinapterus leucas*), St. Aubin, Deguise, Richard, Smith, & Geraci, 2001, captured and instrumented fifty-five animals in the Canadian Arctic. They discovered that two of the recaptured whales showed changes in leucocyte counts, hematocrit and other blood factors indicating inflammation and physiological response to handling and tagging, nineteen and twenty-four days after first capture. In this case it is difficult to distinguish between the effects of tagging and capture. On Southern Right Whales (*Eubalaena australis*), Best & Mate, 2007 report many scars and divots on the animals after tagging them with at 24cm cylinder telemetry tag deployed from a crossbow. Seven of the cows with calves that were tagged were also re-sighted with new calves three years later suggesting that the tagging did not prevent their ability to reproduce. However, the ability to reproduce does not address the harassment or injury that is the regulatory standard. Moreover, these observations were opportunistic, and the sample size is too small to be able to draw definite conclusions.

Over the years, forty of the whales tagged with similar cylindrical telemetry tags were re-sighted and anecdotally described not to be emaciated or have increased parasite loads (B. Mate et al., 2007). However, without a sensitive, consistently deployed method for evaluating health, such as the photographic approach used by (Pettis et al., 2004), it is difficult to draw strong conclusions from those reports. Moreover, any physiological effects may be difficult to observe on live animals. A recent account by (Moore et al., 2012) of a necropsy on a previously-entangled North Atlantic Right Whale (*Eubalaena glacialis*), suggests that rigid, implanted tags penetrating through the blubber into the muscle may move more than previously though, creating a craniocaudal slot in the muscle.

Reported behavioral effects of implanted telemetry tags are mostly short term. Watkins & Tyack, 1991 reported minimal reactions to tagging sperm whales (*Physeter macrocephalus*) with a 26cm tag fired from a shoulder launcher at distance of about 25m. In fact, the reactions were stronger when the tags missed and hit the water. In a review of their lab's decades of satellite tagging studies, Bruce Mate et al. (2007) generally describes responses in a variety of species as short-lived and similar to a close approach by a boat with animals returning to pre-tagging behavior shortly afterwards. Observed responses ranged from head lifts, diving and increased swimming speed to defecation, evasive swimming and the cessation of singing. Different whales responded to implanted tagging differently: only 15% of blue whales (*Balaenoptera musculus*) exhibited a response, but 85% of sperm whales (*Physeter macrocephalus*) did.

In contrast with implanted tags, very little has been reported on the physiological effects of suction cup archival tags. The non-penetrative nature of the tags and their relatively short attachment period has led to the assumption that any effects would be relatively minor. Here I describe a case study of a rare physiological effect of tagging observed on two long-finned pilot whales.

Over the last two years, I have spent three field seasons deploying archival DTAGs on long-finned pilot whales (*Globicephala melas*) in the Strait of Gibraltar. During the first two expeditions, we deployed fifty-one DTAGV2s (Figure 6-1A) and in the third season we deployed thirteen smaller DTAGV3s (Figure 6-1B) for a total of

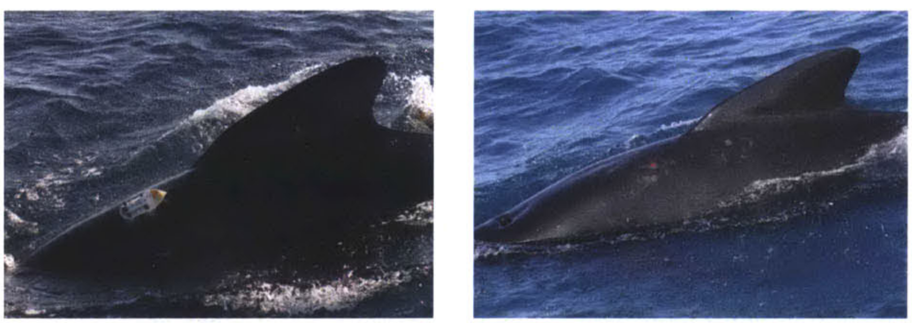


(A) (B)

Figure 6-1: DTAGV2 (A) and DTAGV3 (B). The V2 weighs 330g in air and has overall dimensions of 20.5cm x 10.0cm x 2.5cm, with a frontal area of 38cm2. Four 63mm suction cups attach it to the animal. The smaller V3 weighs 190g in air and measures 15.2cm x 6.6cm x 3.5cm with a frontal area of 24cm2. It uses four softer 45mm suction cups. Photo credits: Frants Jensen (A) and Nicholas Macfarlane (B).

sixty-four deployments.

In one instance, at the end of our second field season, we relocated a large pilot whale twenty hours after it had been tagged with a DTAGV2, twelve hours after release. We noticed a red discoloration and broken epidermis where the suction-cups from the tag had been attached (Figure 6-2).



(A) (B)

Figure 6-2: Photographs of the long-finned pilot whale with a suction cup DTAGV2 (A) and 12 hours after detachment (B). Photo credits: CIRCE.

We had never seen anything like this before. It was,

> "...likely a consequence of increased tissue strain deriving from the lift forces acting on the suction cup tag during periods of fast swimming activity. While the underlying blubber is intact, the lack of epidermis

> may allow for subsequent bacterial infection and is therefore a cause of concern." (F. Jensen & Tyack, 2014)

Our collaborators observed the animal again a week later, and it is possible to see evidence of apparent healing (Figure 6-3).

Figure 6-3: Photograph of the same long-finned pilot whale, a week later. Photo credit: CIRCE..

Following this finding we consulted our post-tagging photos from the previous field season and found one other likely incident of an adult pilot whale tagged with a DTAGV2. The photo is from three days after tag release, and shows similar healing marks suggesting that the epidermis was broken while the tag was attached. Thus it seems that two instances out of 64 deployments occurred. After examining the photos, WHOI IACUC veterinarian, Dr. Michael Moore concluded the following:

> "The sprinting pilot whale is generating substantial tag lift, and where the suction cups adhere well, the weakest link in the system appears to be the epidermal/dermal junction, which separates, resulting in the inner

> dome of the cup tearing out a disc of epithelium, leaving a defect with early evidence of healing apparent in [Figure 6-3]. This lesion could be described as a primary abrasion as it appears to involve the epidermis. The lesion is likely confined to species that sprint such as pilot whales, and that therefore generate substantial tag lift. Current tag biomechanical studies should include the consideration of minimizing tag lift forces, testing the force required to abrade the epidermis on a fresh cadaver, and designing the suction cup to release at forces below that force, to minimize the risk of this lesion in future projects." (F. Jensen & Tyack, 2014)

While the healing is reassuring, as a researcher and someone tagging cetaceans, the initial disruption, however minor, was upsetting. I believed that the suction-cup tags we were deploying were completely non-invasive, but that is evidently not the case one hundred per cent of the time. While the observed defect seems rare and minor, especially when compared to implanted satellite tags, it was still unexpected and makes me think very carefully about how I am assessing the potential scientific and welfare disruptions of deploying this version of tag on these animals. In particular, it makes me take the act of tagging very seriously and continue to limit deployments to instances where the tags have the highest change of collecting extremely useful information.

This particular small resident population of pilot whales is unique because it has been well studied over the last decade (de Stephanis, Cornulier, et al., 2008; de Stephanis, Verborgh, et al., 2008; Verborgh et al., 2009), and the animals are all known and identified. At other study sites animals are often never seen again after tagging, or if they are it is not possible to tell for certain because they cannot be identified. The continuous surveys and monitoring of the small Strait of Gibraltar population means that effects of the kind reported here are much more likely to be able to be observed at that study site than anywhere else, and even under those ideal conditions for follow-up observations, it is reassuring to see that the effect appears to be quite rare.

Moreover, it seems to be limited to the larger DTAGV2 (Figure 6-1A). The smaller DTAGV3 (Figure 6-1B) that was deployed in our final field season has softer suction cups and has been designed to reduce drag and lift. With the DTAGV3, we did not observe any incidents of the kind reported here. In certain respects, such as reduced radio range, the current version of DTAGV3 is more difficult to use than the DTAGV2; however, these two incidents make me want to continue using the smaller V3 rather than return to the previous version.

In terms of behavioral responses to suction-cup tags, again the reported effects are mostly anecdotal, unpublished and collected opportunistically. Like the behavioral responses to telemetry tags, the observed responses are generally short-lived. In one of the few published studies, Schneider, Baird, Dawson, Visser, & Childerhouse, 1998 deployed a suction-cup tag on bow-riding bottlenose dolphins (*Tursiops truncatus*) in Doubtful Sound, NZ, using a pole and crossbow. The dolphins reacted by increasing swimming speed, leaping and diving and eventually avoiding the boat altogether. I observed a similar reaction when we deployed tags on four short-beaked common dolphins (*Delphinus delphis*) in the Bay of Algeciras, Spain. The dolphins were slowly bow-riding, and the tags were very gently deployed using a pole from a distance of approximately 6". Tagged dolphins immediately twisted and turned, quickly accelerating and sometimes leaping out of the water until the tags were shed. In another study on northern bottlenose whales (*Hyperodon ampullatus*) Hooker, Baird, Al-Omari, Gowans, & Whitehead, 2001 reported responses to 84 tag attempts (29 making contact with animals), using a time-depth-recorder tag with a single 8cm suction cup deployed from a modified crossbow. They reported mostly low-level reactions to tagging, with whales slightly modifying their behavior by diving rapidly or flinching. Importantly, the reaction depended on the pre-tagging behavioral state of the animals.

In another example, over the last five field seasons (two in the Alboran Sea and three in the Strait of Gibraltar), we have deployed ninety-six suction-cup Dtags (Johnson & Tyack, 2003) on long-finned pilot whales (*Globicephala melas*) in the Mediterranean Sea using a 5m carbon-fiber pole. Short-term responses to tag attachments were recorded using a categorical scale based on Weinrich, Lambertsen, Baker, Schilling, & Belt, 1991. The reactions were categorized from 0-3 as follows: 0—no detectable change in pre-tagging behavior, 1—a low-level reaction where the animal modified behavior in a mild way such as a short dive, 2—a moderate reaction that was more forceful such as a tail slap but with no prolonged disturbance, 3—strong forceful reactions such as surges, quick spins or multiple tail slaps. Tags were deployed on a variety of demographic types ranging from juveniles to adults, and multiple group-members were often tagged in quick succession. In general, animals would become more evasive as more group members were tagged and the vessel made more close approaches.

The responses are shown in Table 6.1, including seventeen deployment attempts that contacted the animal, but did not result in a successful attachment. The first four expeditions deployed the larger DTAGV2 and the final expedition deployed the smaller DTAGV3. However, we saw no observable difference in responses to the two tag types, and since the short-term response appears to be to the act of tagging rather than the DTAG, the tag types have been pooled together. A low level reaction was the most common response, occurring in seventy-six tagging attempts. Twenty-seven saw no reaction, eight a more moderate reaction, and we observed a single strong reaction where the whale dived and breached half-way out of the water three times until the tag was dislodged.

Table 6.1: Long-finned Pilot Whale Response to Tagging

Response Score	Deployed	Attempted	Total
0: No reaction. No detectable change in behavior	24	3	27
1: Low-level reaction. Mild modification of behavior	64	12	76
2: Moderate reaction. More forceful modification of behavior but no prolonged disturbance	7	1	8
3: Strong reaction. Behavior modified to succession of forceful responses	1	0	1

In summary there do seem to be behavioral effects of suction cup tagging, but any observed reactions appear to be mostly low-level and short-lived. However, the responses vary widely depending on the deployment method, behavioral context and type of species. Moreover, since researchers are only observing obvious surface responses, the ability to detect more long-term subtle changes is limited.

Thus, although there are many anecdotal and published reports on the physiological and behavioral effects of instrumenting cetaceans with archival and telemetry tags, there are several challenges with interpreting these results and applying them to policy and management. These challenges stem from differences in technology, differences in the context of tagging, differences between species and animals and the opportunistic nature of the studies.

First of all, differences between the tags themselves make it difficult to pool data across different reports. As already discussed in chapter two, there are many different kinds of cetacean tags. They vary in size, penetration, material and overall design. Even within smaller categories of archival or implanted tags, there is a huge amount of variability. Moreover, these tags are deployed from a variety of different mechanisms ranging from crossbows to air-guns, to poles. In turn, as described, these deployment mechanisms and tags lead to a wide variety of deployment ranges from less than a meter to some tens of meters. Furthermore, the development of tags within individual labs means that there are no real standards for tagging, and even given identical equipment, different groups and taggers will deploy tags differently. This is significant, for anecdotally, I have personally found that the forcefulness with which the tag strikes the whale during attachment appears to affect the reaction, as well and an individual tagger's decision to pause or continue after an unsuccessful attempt. Even different tagging vessels can influence the observed effects. All of these considerations can influence the individual reactions and effects of tagging observed and complicate the process of drawing conclusions from the reports. It is also important to remember that neither the technology nor its use are static. New tags and deployment strategies are constantly evolving, meaning that it is difficult to compare reports of effects across several years.

The environmental and behavioral context of deployment can also influence the observed results. Environmental factors such as sea state and time of day appear to influence the behavior of the animals: in long-finned pilot whales, we have observed that rougher weather often causes them to surf the swells rather than log at the surface where they are more easily approached. More generally, an animal's behavioral state clearly influences the observed reactions; for example, whether whales are foraging or socializing and the number of group-members around appear to affect the reaction to tagging. In particular, when other group-members have already been tagged it becomes harder to gently tag subsequent animals and repeated approaches can provoke a stronger reaction. These factors make it difficult to compare across studies.

Differences between species may also influence reactions to tagging. The reports and anecdotal evidence on the effects of tagging involve many different species of cetacean. While there are obvious differences in tag size relative to body size, there are also differences in temperament and responses, both between species (B. Mate et al., 2007) and between different groups of the same species. Moreover, from our experience tagging pilot whales, we see that individual animals have apparent differences in their behavior around the vessels and in their responses to tagging. Perhaps an animal's familiarity with boat approaches or ectoparasites such as remoras could influence reactions. Demographic differences between animals of the same species and even the same populations may also affect observed responses.

Two further complications for assessing the effects of tagging are close vessel approaches and the opportunistic nature of most studies. The effects of tagging may be difficult to distinguish from the responses to a close vessel approach for non-tagging purposes; therefore, the response to the close approach must be included in the response to tagging (Watkins, 1981). This difficulty is connected with a confounding effect of close focal follows that are often performed after tagging which may mask effects of tagging. In terms of the reported data on tagging effects, the studies are generally opportunistic and often do not record pre-tagging behavior, and the recorded observations are often subjective (Walker et al., 2012). Moreover, it is generally only possible to observe what is visible at surface. Tags with kinematic and acoustic sensors may be able to record some information, but will not have a pre-tagging condition, and telemetry tags will be even more limited. We also rarely have a sense of what is occurring physiologically except for instances when the animals are recaptured or necropsied (Moore et al., 2012; St. Aubin et al., 2001)

Although the effects of tagging cetaceans are beginning to come under recent scrutiny, the available information is limited, and all of these challenges for comparing across studies make it difficult to apply to policy. A more general problem is the tendency to report effects only when they occur (i.e. not to report cases when no response was observed), potentially biasing the available data and making them appear more frequent than they are (Walker et al., 2012). These challenges have led to calls for more comprehensive follow-up studies (Weller, 2008) to accompany tagging studies. However, it may not be possible to obtain funding for follow-up research, particularly among populations that are large, highly mobile, unmarked or not already the subject of long-term studies. These challenges become a policy problem. Without being able to measure and generalize the effects of tagging in a concrete way, it is difficult for IACUCs to implement the AWA requirement that the research be conducted in the least harmful method possible. Without thorough evaluation of the impact of different tagging methods, it is complicated to assess them objectively.

Chapter 7

Moving Forward in a Context of Uncertainty

As outlined in chapter four, the regulatory and policy context requires that the management of cetaceans must be conducted with the benefit of animal populations as the primary consideration. With respect to cetacean tagging, the increasing focus in recent years on the animal welfare effects of tagging can lead to tension between science and conservation aims and welfare aims. To navigate this policy landscape, both regulators and IACUCs need to weigh the benefits of a tagging study against the potential for serious harm and evaluate whether a proposed method is the least invasive way to answer a scientific question. Here we discuss some of the consequences of uncertainty for assessing that balance and the challenges for the regulatory bodies and the greater scientific community as they wrestle with these issues, attempting to craft best practices that will provide standards and guidelines.

That balance between costs and benefits in cetacean tagging is particularly complex because of the extent of the uncertainty surrounding the impacts. As described in chapter six, despite increasing interest, the majority of studies on the effects of tagging have been opportunistic rather than designed, leading to a lack of control. Moreover, other factors such as variation in species, populations, deployment context and tag design create challenges for observing results and comparing across those studies that exist.

This uncertainty leaves IACUCs in a quandary. In their role as ethical arbiters from an animal welfare point of view, they must assess whether a proposed study uses the methods with the least possible discomfort, pain or distress (USDA, 2013). However, IACUCs often have little expertise with research techniques used on marine mammals, particularly when it comes to tagging (N. Gales, Brennan, & Baker, 2003). Given the level of uncertainty surrounding the effects of cetacean tags, this lack is understandable, but it means that a project approved by an IACUC at one institution might be rejected by a different one somewhere else (N. Gales et al., 2003). The delegated responsibility and lack of consistency can create large variability in the assessment of proposals between institutions. Although IACUCs were implemented on a local basis in order to reflect differences between standards in particular communities, some greater standards and guidance than currently exists might be helpful. The variation in standards can open the door for polarizing debates that are played out in the media rather than serious discussion amongst practitioners (for example in the case of hot iron branding of pinnipeds, see Green & Bradshaw, 2004). While the unaffiliated member of an IACUC brings a perspective on local community concerns, the expert assessment is necessary not only to ensure that proposals that might have serious impacts are not permitted prior to taking adequate consideration for the animal welfare issues involved but also to allow important work, that might be misunderstand and prohibited, to proceed (N. Gales et al., 2003). Often the people with the best information to address the issue of expertise are the very scientists whose proposals are being evaluated, leading to potential conflicts of interest.

A particular issue is the development of new tags and other novel methods. This development is critical to advancing cetacean science, and if the tags described here had not been developed, we would be missing much essential conservation information. However, techniques that already exist often continue to be favored because of familiarity and already developed methods (N. Gales et al., 2003). Thus regulators must balance the choice between familiar methodology that is available and in widespread use against new tags that might be better for cetaceans but less well tested.

Another key difficulty stems from an IACUC mandate to evaluate whether the proposed method is the least harmful one possible to address the scientific question. Without an objective way of comparing amongst different tagging methodologies, how are IACUCs able to effectively judge the 'least harmful' one? This issue is exacerbated by the fact that researchers generally only propose one potential methodology to an IACUC for review, so unless the committee already comprises experts in that specific area of cetacean tagging, the questions becomes not how to choose the least harmful method, but rather the more difficult one of whether the study should proceed at all. If researchers were to present alternative methodologies, as mandated by NEPA for federal work or major developments, this might go a small way towards ameliorating this situation. A better option would be to have scientists work with IACUCs during proposal development rather than simply presenting an already in motion proposal for a final stamp of approval en route to implementation. Given the present regulatory context, and in the face of uncertain effects of tagging that have the potential to cause harm to cetaceans, I think the appropriate strategy for assessing proposals is to implement the precautionary principle and err on the side of minimizing any potential effects. In a similar vein, N. J. Gales, Johnston, Littnan, & Boyd, 2010 argue that proposals ought to be designed in order to minimize false negative type II error where we are unable to observe potential effects, rather than false positive Type I error where effects are observed that do not actually exist. This would be a departure for scientists accustomed to attempting to ensure they have enough statistical power to observe effects.

There have been a couple of approaches to formalizing a way forward when it comes to animal welfare concerns such as these. At the center of modern-day animal welfare thinking are the 3Rs of refinement, reduction, and replacement developed by Russell, Burch, & Hume, 1959. They define refinement as changing experiments to minimize any potential negative impacts to the animals such as pain or distress. Reduction implies reducing the number of animals used to the minimum possible number while still achieving enough statistical power to answer the research questions. In cetacean tagging studies, the opposite issue is often true, where it is not possible to tag sufficient animals to have appropriate power. This lack of power remains a significant welfare problem, for it can lead to animals being instrumented without the ability to address a research question. Lastly, replacement means not using animals unless it is absolutely necessary. In an effort to aid comparison across studies, Wilson & McMahon, 2006 operationalize a version of the 3Rs for application to animal instrumentation. They combine the features into an overall numeric detriment index of the effects of tagging. The detriment index takes into account how bad the detriment is, how many animals are involved and how long the detriment lasts in order to provide a single number that can be used to compare experiments. However, the extent of the detriment and its length are plagued by all the uncertainty already discussed. Assessing them would require the kind of controlled follow up studies and comparisons that are not currently available, so implementing this kind of index is challenging.

Another approach seeks to take advantage of the expertise of scientists practicing cetacean tagging by calling for professional societies such as the Society of Marine Mammalogy (SMM) to produce ethics guidelines to help regulators and IACUCs. The argument is that it is preferable to have scientist practitioners wrestling with the ethics and self-regulating rather than having codes enforced from the outside by bodies with less information. Since scientists are likely the best informed about any potential effects, this makes sense. In calling for these guidelines, N. Gales et al., 2003 ask for professional societies to discuss ethics, talk with other societies and produce consensus guidelines discussing tagging as well as directing training requirements, degree of invasiveness and appropriate levels of disturbance. These guidelines should also include best practices for commonly used protocols. In 2007, SMM did just that, assembling an ethics committee of 10 members from 8 countries. This committee produced a list of guidelines that were ratified by the membership in 2007.

These guidelines were published in the society's journal, Marine Mammal Science. Broadly, they outlined the deciding question for researchers to be: "do we really need to know this about this particular species." They also urged adequate sample size, minimizing potential impacts and disturbance, and applying good training for researchers (N. Gales et al., 2009). In the case of cetacean tagging, the training is particularly relevant since the skill of the tagger often impacts the extent of disturbance by shortening the duration of a close approach or placing a tag more gently, so that the deployment lasts longer. If an animal is being disturbed for an experiment, I think it is important to ensure that the data as as well and efficiently collected as possible. Specifically, with respect to tagging, the guidelines (reproduced from N. Gales et al., 2009) argue that tags should:

1. Sample the parameters they are designed to record with minimal effects on the behavior of tagged individuals

2. Be attached in the least invasive practical manner

3. Be of a size, construction and design so as to cause negligible energetic costs to the animal

4. Not render the animal more exposed to predators or by-catch

5. Be able to be retrieved, or released from the animal in a predictable manner and in a timeframe appropriate for the research and to ensure the impacts to the animal are minor

6. In the case of penetrative attachments, wound healing should be predictable and relatively brief and have no more than a trivial impact to the animal

This list provides an important beginning, and SMM is the most appropriate body to produce them, but the actual guidelines are too vague to be that helpful to IACUCs and regulators. We will consider each guideline in turn. Like refinement and the detriment index, complying with the first one requires assessing the extent of the effects on behavior, something that we have already discussed is extremely difficult to do. The second one arguing for minimizing attachment invasiveness is complicated because the 'least invasive practical matter' will vary by lab and requires controlled comparisons of techniques that are uncommon. Although recent work is beginning to make progress on the energetics front (Andrews et al., 2011), at present, the energetic costs referenced by guideline three are not well understood and may vary widely between species, population and demographic group. This makes a requirement to have 'negligible energetic costs; too broad to be easily implemented. With respect to guideline four, if the animals are not re-sighted after tagging, it is difficult to assess whether they are more exposed to predators or by-catch, particularly if the effects linger after tag release. Likewise, with the retrieval timeline referenced in number five, it remains unclear how to assess the level of impacts to ensure that they are minor. This uncertainty carries over to the final guideline because outside of unique well-studied populations like the pilot whales in the Strait of Gibraltar, the difficulty re-sighting animals after tagging makes it quite challenging to assess healing in a meaningful way. The guidelines could also benefit from some definitions of phrases such as 'negligible' and 'invasive' and 'trivial impact' rather than delegating their interpretation to IACUCs and scientists.

While these guidelines are an excellent start, at the moment they are more of a wish list than a document that can aid IACUCs when it comes to assessing the realities of specific tagging proposals. For them to be truly useful, they would need to be much clearer and specific. This will be difficult to accomplish for several reasons. First of all, the real experts are often only the small group of individuals actually developing and deploying the particular tags and following tagged animals. As evidenced by the attempted follow-up studies, even researchers conducting the studies find it challenging to conclusively extrapolate effects from opportunistic observations. Secondly, the ethics committee of SMM will not necessarily be familiar with every tagging technique in the depth required to provide adequate guidance. In turn, consensus among committee appointees and the broader SMM membership will be challenging, for scientists often have careers, logistics and infrastructure investments riding on a particular tagging technology, that they may have sometimes developed themselves. In addition, the tension between evaluating invasiveness from a conservation or welfare perspective will be informed by particular researchers' individual perspectives, experience and institutional culture. Nevertheless, these deliberations would provide a critical piece of leadership for IACUCs and help ensure that cetacean tagging best reflects the moral and regulatory landscape. In the interim, given the uncertainty that exists with respect to the potential effects, it behooves us to apply a very precautionary approach, both in the SMM guidelines and in their implementation by IACUCs and regulators.

Chapter 8

Conclusion

In summary, on-animal tags have completely changed the way that researchers study cetaceans in the wild. Instead of trying to extrapolate from intermittent surface observations, with tags, we are given an incredible window into the world of these animals. Whether tracking migrations across ocean basins or investigating acoustic and kinematic behavior a thousand meters below the surface, tags allow us to collect information that it is otherwise impossible to study. As I have discussed in this thesis, the kinds of data tags provide is essential for the conservation and management of these vulnerable species. Today there are many different kinds of tags in use. These tags fit into two broad philosophical and design streams driven by attachment requirements—implanted telemetry and suction-cup archival tags.

On the one hand are telemetry tags that transmit tagged animal location in order to study movements. These tags require long-term attachments on the order of months to be able to track animal migrations that occur over those timescales. To achieve those attachment times, these tags are informed by the earlier designs of the *Discovery mark* and *Watkins tag*, using barbed metal cylinders that penetrate the blubber into the muscle. Thus, the attachment requirement dictates the invasive nature of the design, drawing on earlier technology that was developed in a context of whaling. These satellite telemetry tags are primarily used from a conservation and stock-assessment mindset that focuses on managing and sustaining the overall population numbers rather the welfare of individual animals. From this perspective, the invasive deployment of a tag on a small number of animals may be justified if it provides essential information for the sustainability of the whole population.

In contrast, archival tags that collect high-resolution behavioral information have a different approach. As I have discussed, these tags were developed more recently as a result of breakthroughs in electronic miniaturization that allow them to record much more sensitive information, such as acoustics and kinematics. The memory capacity and the sheer volume of information mean that they only need shorter attachments on the order of days. These attachments are best provided by suction-cups that do not penetrate the body of the animal, so again the attachment requirement is dictating the level of invasiveness in the design. These tags ask fine-scale behavioral questions, and the non-invasive nature of these tags is significant, for the subtlety of the information recorded implies that it is essential to avoid confounding the data by impacting the animals.

These two design streams flow through a regulatory context in the US where marine mammals are very well protected with legal regulation of cetacean welfare stemming from the AWA and conservation protection from the MMPA and ESA. Today's policy context is quite different than it was in the early 20th Century when the Discovery mark was developed. In particular, there has been a significant change in American attitudes towards cetaceans that has driven these legal protections (Lavigne et al., 1999). This change reflects a cultural shift between a focus on cetaceans solely as stocks to be managed, to one that takes individual animal welfare into more prominent consideration. Although regulation treats all tagging the same way, this evolution towards a focus on cetacean welfare may result in tension between the general public and telemetry tags drawing their development from a different social context. As I have discussed, the central distillations of cetacean protection are that it is prohibited to harass or injure a marine mammal and that IACUCs must evaluate proposed permitted research to ensure that it uses the least invasive methods possible to address a particular research question.

This IACUC mandate is complicated because great uncertainty exists surrounding the effects of tagging wild cetaceans. Some effects have been reported, although they are mostly opportunistically observed. For implanted telemetry tags, physiological effects range from inflammation around the tag site to infection and trauma from implantation (Weller, 2008). Reported behavioral effects are mostly short-term such as head lifts and dives (Bruce Mate et al., 2007), but they may be difficult to observe if they occur underwater because telemetry tags are not suited to measuring them. For suction-cup archival tags, reported physiological effects are rare, but we saw that they have some potential for epidermal damage resulting from drag and lift. Behavioral effects are better studied, and reported ones appear to be mostly short-term such as dives and tail splashes. Despite these reported effects, as I have discussed, there are many challenges for objectively evaluating and comparing them. These difficulties stem from differences in tagging technology, the context of tagging, the species of animal and the opportunistic rather than designed nature of the reports.

These factors leave IACUCs in a difficult position. There are tasked with assessing whether the least invasive method possible is used to answer a particular research question, but without an objective way to compare particular tagging methods this is very complicated. IACUCs are forced to make a subjective judgment, and they often lack the expertise in marine mammal tagging to do so. This difficulty is exacerbated by the fact that researchers often only propose a single method. Given the level of uncertainty surrounding the effects of tags, this lack is understandable, but it means that one IACUC may approve a project that another one would reject (N. Gales et al., 2003). Returning to our two attachment design streams, this difference is affected by the particular orientation on the conservation-welfare spectrum of the individual IACUC members: what seems invasive from an animal welfare point of view might not from a conservation or stock-assessment mindset.

In this context of uncertainty, guidelines from professional societies are helpful. Some were drafted by the SMM ethics committee and ratified by the membership in 2007 (N. Gales et al., 2009). However they are too general to be useful. For them to be helpful they would need to be much more specific, but this will be very difficult to accomplish because of the difficulties comparing and assessing the effects of tagging. Moreover, consensus among the membership, or even the ethics committee will be complicated to attain because every person is informed by a particular perspective and tradition when it comes to conservation and welfare. In this situation of uncertainty, I think we ought to take a very precautionary approach to interpreting the guidelines and implementing them with IACUCs and regulators.

A final thought is that, in this thesis we have only considered American approaches to tagging cetaceans. However, these animals do not stay nicely in national jurisdictions; rather they cross borders and boundaries at will. The particular attitudes and best practices will differ across cultures and countries, leading to complications for implementing a balance between invasive and non-invasive research methods that affects animals as a whole rather than when they are in a single geographic area. There is also the risk of a race-to-the bottom where more invasive research could simply migrate to countries and jurisdictions that regulate the least. To help combat these concerns, the ethical standards of journals and professional societies will be important for influencing researcher conduct.

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