July 2008

Report of the Large Whale Tagging Workshop

Convened by the

U.S. Marine Mammal Commission
U.S. National Marine Fisheries Service

10 December 2005
San Diego, California USA

Contract Report to

U.S. Marine Mammal Commission

David W. Weller
NOAA Fisheries
Southwest Fisheries Science Center
La Jolla, California USA
dave.weller@noaa.gov

Table of Contents

Introduction

Waterproof, animal-borne archival and transmitting technology has greatly advanced our knowledge of the movements, distribution, physiology, and behavior of marine mammals and the characteristics of their marine environment (see reviews by Costa 1993, Stone and Kraus 1998, Read 2002). Information derived from such studies also has improved our understanding of human/marine mammal interactions that pose risks to some populations, especially those that are small and at elevated threat of extinction.

The devices used to track and monitor marine mammals have been attached by a variety of methods, including harnesses, tethering, glue, suction, bolting through body parts, and implantation into the body. Such methods vary in their ease of application, duration of attachment, and effect on the subject animals. The aim of all methods is to secure the devices in a way that ensures instrument performance while preventing, or at least minimizing, influence on the animal either though alteration of its behavior or risk to its health. As is the case for many new research methods, scientists have spent years attempting to perfect instrument design and attachment methods both to improve the efficacy of their studies and to ensure that the applications are humane.

Tagging studies of whales have been particularly challenging because of the difficulty of approaching large, powerful animals to attach an instrument. The challenges have been overcome in many instances, yielding valuable data on a number of species and populations, including some that are listed under the U.S. Endangered Species Act as endangered or threatened (e.g., Mate *et al*. 1997, 1998, 1999, 2000, Baumgartner and Mate 2005, Wade *et al*. 2006).

Despite the clear benefits of tagging, the scientific and conservation communities have debated the advisability of tagging large whales under certain circumstances. A general cost-benefit analysis for tagging is not practical because both the costs and the benefits vary depending on a range of variables, such as the species involved, tagging methods, the condition of animals to be tagged, their natural history, their conservation needs, and the utility of tagging information with regard to those needs. For that reason, cost-benefit analyses are best carried out on a case-by-case basis.

Few would question the benefits derived from tagging studies. Those benefits are relatively easy to describe and are related to information about the distribution and movement patterns of the animals, their behavior, features of their environment, and the risks they face as they move about the world's oceans. Such information is vital to promote conservation in the context of the ever-expanding human use of and presence in the marine environment.

Much of the debate over tagging has not been about the potential benefits, but rather the potential costs. Like the benefits, the costs are relatively easy to describe hypothetically, but they are more difficult to describe based on data and observations. At the individual level, costs are defined in terms of the potential risks associated with approaching and tagging individual whales. Those costs may take the form of disturbance of behavior and habitat-use patterns, physical injury, infection, and (again, at least hypothetically) death. At the population level, costs are defined in terms of possible effects on survival and reproductive rates and are of particular concern for small populations. Evaluating effects has proven difficult due to the large-scale movements of these animals and the difficulty and cost of locating and observing them at sea after they have been tagged. Similar debates have surrounded other scientific tools or methods of study (e.g., branding), and the net effect of such has been to provide the impetus for continual improvements in research technology and procedures.

To provide an opportunity for discussion of the risks (i.e., costs) of tagging and of ideas for evaluating and reducing them, the Marine Mammal Commission and the National Marine Fisheries Service sponsored a workshop on 10 December 2005, in conjunction with the Society for Marine Mammalogy's 16th Biennial Conference on the Biology of Marine Mammals in San Diego, California (the workshop agenda and list of participants are attached as Appendix I and II, respectively). The purpose of the workshop was stated as follows:

> *Acknowledging the many important benefits of tagging large whales, the purpose of this workshop is to identify potential adverse effects of tagging, consider the evidence regarding the significance of such effects, consider research to better describe them, and consider potential mechanisms to avoid or mitigate them if necessary. Ultimately, our purpose is to promote the conservation of marine mammals through better decision-making and science.*

The following questions were used to guide the workshop presentation and discussions:

> *(1) What are the potential effects of tagging? Is the information currently available sufficient to determine whether these effects occur?*
>
> *(2) What factors should be considered when assessing the potential risks and benefits of tagging (e.g., to what extent are sample size needs factored into tagging studies; to what extent should they be)?*
>
> *(3) What are the key remaining questions and information/research needs to be addressed relative to potential effects of tagging? What are the impediments to short- and long-term monitoring and how might monitoring capabilities be improved? Are there specific studies that can and should be completed to bring clarity to this issue?*

This report, co-funded by the Marine Mammal Commission (MMC) and the International Union for Conservation of Nature (IUCN), provides a record of the workshop based on: (1) notes from the workshop rapporteur (M. Simpkins), (2) slide presentations of invited speakers at the workshop, and (3) recently published papers, unpublished reports, and personal communications. The addendum to the report provides background for the Western Gray Whale Advisory Panel established by IUCN and for the Scientific Committee of the International Whaling Commission (IWC). Both of these bodies are considering the advisability of tagging studies on western North Pacific gray whales (*Eschrichtius robustus*), a population classified in the IUCN Red List as “critically endangered.”

Potential Physical/Physiological Effects

Tagging may have both acute and chronic effects. Immediate physical effects may include those related to blunt trauma from tag implantation (i.e., impact upon penetration of the tag), such as hemorrhage and cell damage with possible radiating damage in both the dermis and muscle. Immediate physiological responses to tagging include blood clotting and the onset of inflammation to remove debris from the wound. The inflammatory response includes swelling from an influx of blood and serous fluid.

Potentially chronic effects of tagging also are attributed to the cutting/tearing trauma from piercing of the skin, blubber, fascia, and muscle (or variable combinations thereof). In addition, contemporary tags are generally percutaneous in application, keeping the wound partially open to the surrounding environment to allow the function of external components such as saltwater conductivity switches or antennae. The wound serves as a pathway or portal for saltwater ingress and the introduction of epithelial cells and associated fauna, including bacteria. Bacteria and fauna on the epidermis are sources of infection that may be carried deep into the wound and, depending on the depth of the wound, may enter the blood stream or muscle. Saltwater ingress may lead to osmotic cell death, particularly at the blubber-muscle interface, and also may promote bacterial growth resulting in localized or regional infection and inflammation. Whether and how often such infections might become systemic (i.e., affecting the whole organism) is uncertain. Chronic physiological responses may include the persistence of inflammation or infection, swelling from the influx of blood and pus, epithelial proliferation, and development of granulation tissue working to sequester or reject the tag. Chronic consequences are thought to include: (1) fossa (ruptured swelling), (2) development of excessive scar tissue, and (3) the loss of surface (epidermal) tissue.

Chronic health effects also might result from complications (e.g., lipid leakage) related to protracted tag movement in the form of continued vertical tearing of the wound within the blubber layer, and/or horizontal shearing/movement-induced trauma, such as at the blubber-muscle interface. The implantation of tags must result in a protracted healing process, which imposes elevated energetic costs and, conceivably, predisposes the tagged animal to other risk factors such as disease.

Finally, tagging may result in both acute and chronic pain and stress. St. Aubin *et al*. (2001) described two belugas (*Delphinapterus leucas*) that were recaptured 19 and 24 days after tagging and that had leucocytic responses consistent with inflammation and stress assumed to be related to handling and tagging. In general, however, the nature, persistence, and significance of pain and stress, and their effects on behavior, reproduction, and survival, are largely unknown.

Despite studies such as those by St. Aubin *et al*. (2001), the actual evidence for long-term effects of tagging is limited and inconclusive. Wild animals are known to suffer and recover from large and more serious injuries (e.g., from predation, ship strikes, entanglement). Records of whales surviving the subcutaneous implantation of Discovery tags (small stainless-steel bolts implanted in the muscle via shotgun or rifle), harpoon points (made of stone, slate and metal) as well as metal harpoon bomb-lances (Rayner 1940, Philo *et al*. 1993, New Bedford Whaling Museum 2007) provide evidence that at least some whales have tolerated those kinds of wounds.

Healing Responses

Healing responses to penetrating wounds and tag implantation in whales are poorly understood because of limited information on the types of tissue damage that occur from tagging, the healing properties of those tissues, particularly blubber, and the probability and nature of secondary wound effects. For mammals, the typical wound healing response involves: (1) stopping blood loss, (2) restoring function, and (3) preventing infection. The inflammatory phase begins at the time of injury and serves to curtail bleeding, cleanse/sterilize the wound area, and initiate removal of debris from the wound. The proliferative-repair phase is characterized by the filling and closure of the wound area. The remodeling-maturation phase may or may not include formation of scar tissue, and constitutes final resolution of the wound (Dee *et al*. 2002).

In general, wound healing can be divided into two broad categories: (1) *primary wound healing* or healing by first intention and (2) *secondary wound healing* or healing by second intention. Primary wound healing usually occurs when a wound is the result of a "clean cut" (e.g., surgical incision) where the margins of the wound can be neatly brought back together (sutures are used to facilitate this process in surgical situations). Primary healing generally results in a minimum of scarring. Secondary healing, the process which best approximates healing of tag-related wounds in whales, occurs when a full-thickness wound is allowed to close or "fill in" and heal. Secondary healing results in an inflammatory response that is more intense than with primary wound healing and is, overall, a slower process. Here, cells move in from the border of the wound, one layer at a time, and ultimately fill in the wound cavity. As a result, a larger quantity of granulomatous tissue is fabricated because of the need for wound closure. Secondary healing results in pronounced contraction of wounds as well as scarring.

The integument of cetaceans, including large whales, is well described (for example see Ling 1974, Haldiman *et al*. 1993, Reeb *et al*. 2007), but most information on wound healing is based on studies and observations of smaller odontocetes, particularly bottlenose dolphins (*Tursiops truncatus*) and belugas. The inflammatory response and rate of healing in the skin of those species have been characterized (Bruce-Allen and Geraci 1985, Geraci and Bruce-Allen 1987) and responses to implants, tags, and marks also have been studied (Geraci and Smith 1990). The results from those studies have been used in the development of tags for large whales (Mate *et al*. 2007). The hematology and plasma chemistry of belugas that were captured, tagged, and released also have been studied (St. Aubin *et al*. 2001), and related findings have been used, to some degree, as a proxy for what might be expected in large whales.

As noted above, however, the normal progression of wound healing is disrupted when an implanted tag remains in place. Presumably, the persistent presence of the tag elicits a foreign body response as observed in other mammals, including humans. This response begins as normal wound healing, but full healing cannot occur until the tag has been fully rejected (i.e., shed) from the body. Unlike Discovery tags that are fully implanted and over time become permanently encapsulated within the body, percutaneous tags keep the wound at least partially open until the tag has been rejected.

Observations of Wound Healing

Seeking to investigate the potential effects of their tagging efforts, some investigators have been able to describe the physical appearance of tag sites subsequent to attachment (Watkins *et al*. 1981, Quinn *et al*. 1999; Kraus *et al*. 2000; Best and Mate 2007; Mate *et al*. 2007). In a tagging study of humpback (*Megaptera novaeangliae*) and fin whales (*Balaenoptera physalus*) off Alaska, Watkins *et al*. (1981) observed no signs of infection or tissue reaction at four tag-related wound sites 16-18 days post-attachment. Mate *et al*. (2007) indicated that over 40 of the more than 430 whales they tagged between 1990 and 2005 had been resighted either opportunistically or during follow-up studies. Although some of these whales exhibited varying levels of swelling or scarring at the tag site, none were in poor health or showed signs of tissue sloughing at the tag site. Mate *et al*. (2007) summarized some of their observations of physiological responses to tagging as follows:

> *Nine of 16 North Atlantic right whales tagged in the Bay of Fundy in 2000 have been resighted, with four of them exhibiting swelling (two regional and two localized) around their tag sites. After a single year, only one of these animals maintained swelling. Four of 15 resighted sperm whales (of a total of 57 tagged whales) showed slight localized swelling around their tag sites, after periods of 213-351 days after tagging. Because we have seen swelling over time and no degradation in body condition, we believe such swellings are not debilitating*.

During a tagging study on eastern gray whales, one whale was found dead on the beach without its tag 18 days post-attachment (Mate and Urbán 2005). A necropsy performed on this whale approximately two weeks post-mortem found no evidence of tag site infection or other signs suggesting that the death was tag-related (WGWAP 2006). However, the pronounced state of decomposition and the fact that the tag was no longer implanted precluded a detailed evaluation of the tag-induced wound, including histological assessment.

Quinn *et al*. (1999) reported a study of North Atlantic right whales (*Eubalaena glacialis*), which was summarized in the report of a 1999 workshop on tagging effects (Kraus *et al*. 2000) and in a presentation at the 2005 workshop. In that study, 55 tags of varying design were deployed on 49 individual whales between 1988 and 1997. It should be noted that the tagging operations evaluated in this study were based on tag designs that are now one to two decades old and considerable design changes have occurred in the intervening period (Mate *et al*. 2007). Pre- and post-tagging photographs from the photo-identification catalogue maintained by the New England Aquarium were used to look for evidence of effects attributable to tagging. Forty-eight (87 percent) of the tag sites were classified as either: (1) scar, (2) divot, (3) divot with cyamids ("whale lice"), (4) localized swelling, or (5) regional swelling. A divot was defined as an indentation varying in size depending on tag type. Localized swelling (< 30 cm in diameter) and regional swelling (30-90 cm in diameter) described swollen areas near the tag site that were not present before tagging. The types of injuries observed did not appear to be related to tag type (i.e., any of the tag types could have caused any of the five types of injury). In some cases, divots persisted for over five years and twenty percent of the divot sites hosted cyamid communities. Sixty percent of the whales tagged were observed to have some level of swelling at the tag site. For a few of these whales, swelling persisted for up to seven years.

Participants at the 1999 right whale workshop expressed no major concern about divots or scars, although a question was posed regarding cyamids and whether their presence in divots might indicate compromised health status. Local and regional swelling, however, raised concern. Possible explanations for such swelling include: (1) hematoma, (2) abscess, (3) active inflammatory response to a foreign body or agent (such as bacteria), (4) rupture through the subdermal sheath, (5) foreign body granuloma, (6) infection, (7) scar tissue, or (8) benign tumor.

In summary, participants at the 1999 workshop considered the available data insufficient to determine conclusively if tagging posed significant risks to individual whales. They were divided as to how future tagging efforts should proceed, some being more cautious than others. Despite the differences in opinion, all participants agreed that workshops should be held regularly to: (1) facilitate improvements in tag technology and discuss issues related to tag success and failure as well as alternative technologies (e.g., suction cup tags), (2) evaluate, modify, and standardize protocols for follow-up assessment, and (3) review the implications of observed physical, physiological, and behavioral effects.

Recommended actions from the 1999 workshop included: (1) search for funding to support follow-up studies on tagged whales, (2) mine existing data to evaluate long-term effects of tags, (3) conduct dedicated follow-up studies in future tagging efforts, and (4) make visual assessments of body condition of tagged whales for comparison to nontagged whales. Participants also agreed that, if available, alternatives to invasive tags should be used if they provide the necessary data. Finally, the workshop emphasized the need to minimize the size of tags to help reduce the likelihood of effects, particularly physical or physiological effects, in future tagging studies.

Behavioral Effects of Tagging

The behavioral effects of tagging large whales are not well understood. While several studies have provided descriptions of the reactions of individual whales to tagging, these accounts are mostly qualitative and non-systematic. Despite the limitations of the existing observations, they generally indicate that the reactions of large whales to tagging are frequently unnoticeable or mild and quickly followed by a return to "normal behavior" within a "short time" (Watkins 1981, Watkins *et al*. 1981, Watkins and Tyack 1991, Mate *et al*. 2007). More pronounced reactions, albeit less frequently observed, include vigorous swimming, underwater exhalations, breaching, and group disaffiliation (Watkins 1981, Mate *et al*. 2007). Mate *et al*. (2007) described their observations of short-term responses as follows:

> *The behavioural responses whales exhibit when tagged are usually identical to those exhibited during a close approach by the tagging vessel when tags are not deployed. Responses most often include head lifts, fluke lifts, exaggerated fluke beats on diving, quick dives, or increased swimming speeds. Less frequently, responses include fluke slaps, head lunges, fluke swishes, defecation, decreased surfacing rates, disaffiliation with a group of whales, evasive swimming behaviour, or cessation of singing (in the case of humpback whales). In all cases where we have followed tagged whales, the responses to tagging have been short-term. For example, a humpback whale that stopped singing upon tagging, resumed singing 13 min later. A North Atlantic right whale that was tagged while sleeping, went back to sleep within five min after tagging. Feeding blue whales have resumed lunge feeding immediately after tagging, as have bubble-net feeding humpback whales. Curious gray whales continued to be inquisitive after tagging. Seven of a group of 10 sperm whales were tagged within 90 min, without dispersing the group. We have never had any serious whale–boat contact problems, nor seen a whale act aggressively after tagging. All of the preceding experiences give us some measure of confidence that the immediate effects of tagging are minimal. Responses to tagging appear to vary by species, with sperm whales reacting more often than other species.*

Those authors also present a table indicating the propensity for response of different whale species, ranging from 22 responses to 146 tagging attempts (15 percent) for blue whales (*Balaenoptera musculus*) to 51 responses to 60 attempts (85 percent) for sperm whales (*Physeter macrocephalus*). Such data are informative, although as Mate *et al*. (2007) themselves and other authors (Hooker *et al*. 2001) point out; more in-depth analyses would be useful. Responsiveness and types of response probably depend on circumstances and a variety of factors such as the whale's species, age, sex, body condition, environmental context, behavior, reproductive state, and experience. Short-term responses should be relatively simple to document, at least as indicated by surface behavior. Long-term effects would be more difficult, although certain populations that return to the same feeding and reproductive sites each year may be particularly amenable to such studies. Effects may range from negligible to severe, and from acute to chronic. In the few cases where data on behavior have been collected, the results are largely subjective, have not been standardized, and are difficult to compare to control animals or evaluate in a statistical manner.

The need for close approach to tag whales adds a level of disturbance that is difficult to distinguish from the effects specific to tag attachment (Watkins 1981, Watkins *et al*. 1981). Although approach requirements vary for different species and deployment systems (e.g., air rifle, pole, crossbow), researchers often must approach whales repeatedly to within several meters to achieve the position needed for successful tag deployment. In contrast to the summary statistics provided by Mate *et al*. (2007), the literature contains little information on such matters (e.g., number of approaches made per whale, reactions of whales to vessel approach, etc.). Close vessel approaches may cause increases in: (1) blood adrenaline and cortisol, (2) metabolic rate, (3) heart rate, (4) body temperature, and (5) respiratory rate. Potentially significant behavioral responses include leaving preferred habitat or, in the case of an adult female, disassociation with her calf.

Arguably, behavioral responses are not biologically significant unless they affect the probability of survival and reproduction of an animal or its offspring. Because information to evaluate such potential effects is generally lacking, participants at the 2005 workshop emphasized the importance of collecting the data needed to fully evaluate potential long-term behavioral effects. This obviously will require commitments by investigators to carry out the necessary observations, and certain whale populations may be more amenable than others to such studies, as described below. Participants also emphasized that certain activities (boat driving, tag attachment, and photo-identification) should be conducted by, or at least under the guidance of, experienced personnel. This practice should help reduce the amount of disturbance from approach, the number of approaches necessary for tag attachment, and mistakes or uncertainty about which animals are tagged.

Follow-up Studies

With few exceptions, published studies involving the tagging of large whales (and other wildlife, for that matter) provide little detailed information regarding the long-term responses of animals to tag attachment. This shortage of information is understandable given the difficulty of relocating animals that may move about entire ocean basins, and it pertains not just to studies of marine mammals, but to other animal groups as well. Godfrey and Bryant (2003) found that only 10 percent of 836 radio-tagging studies (on a variety of species) attempted to address tag-related effects, with studies on mammals less likely than those on birds or fish to test for effects. Clearly, more studies are needed to evaluate the effects of tagging so that the potential risks and benefits in any particular case can be weighed in a more informed manner (Wilson and McMahon 2006, Cooke 2008).

Three important attempts have been made to evaluate the long-term effects of tagging large whales. In the first case, an unpublished assessment by M. Fujiwara (cited in Kraus *et al*. 2000, Mate *et al*. 2007) found resighting rates of tagged versus untagged North Atlantic right whales to be the same, suggesting no tagging effect on the survival of tagged whales. In the second study, the sighting patterns and reproductive intervals for southern right whales (*Eubalaena australis*) tagged off South Africa were examined (Best and Mate 2007). In this study, six of seven reproductive females that were resighted post-tagging had given birth to a new calf and exhibited calving intervals that were similar to untagged whales, supporting the null hypothesis of no major effect on the reproductive success of adult females or (by inference) the survival of their calves. In a third study, conducted by S. Mizroch and colleagues, photographs of seven humpback whales tagged with implantable radio-tags between 1976 and 1978 off Alaska were compared to a longitudinal humpback whale photo-identification archive. Of the seven whales tagged in the 1970s, all had subsequent resightings extending over at least a 17-year period in the same general vicinity of where they were tagged. Five of the seven individuals had resightings extending over a 30-year period, including one reproductive female that produced a number of calves at regular intervals subsequent to being tagged (S. Mizroch, pers. comm.). These observations represent the longest follow-up records from any large whale telemetry study and provide insight regarding the survival and, in at least one case, reproduction of tagged individuals.

Such studies are of great value to assessing potential effects, and more studies of this type would be useful to further test the null hypothesis that tagging poses little or no long-term effect on behavior, reproduction, or survival, irrespective of the particular species involved, age of tagged animals, behavior, environmental conditions, and so on. For this purpose, direct monitoring of tagged animals is more useful than remote tracking, as the status of remotely tracked animals can only be inferred based on downloaded data on distribution and behavior (Scott *et al*. 1990). To address the remaining need for information on tagging effects, the 2005 workshop participants suggested that follow-up monitoring of tagged individuals should be an integral component of any research plan and warranted significant attention whenever possible. Research proposals should include budgets for the costs of follow-up studies, and agencies should give priority to such funding. Scientists engaged in tagging studies should be expected to conduct follow-up monitoring of tagged animals as they are able to do so and to publish the results in peer-reviewed literature. Without wider adherence to such practices, participants were concerned that tagging would continue to be considered experimental and somewhat controversial, as has been pointed out by Wells (2005) for tagging studies on dolphins.

Some populations of large whales are especially suitable for studies of the long-term effects of tagging. Those populations are sufficiently large that there is only a negligible risk that tagging will have significant effects on reproductive and survival rates. Also, individuals in such populations can be identified and tracked, they are sufficiently accessible so that costs of research are not prohibitive, and their movements are suitably predictable in time and space (e.g., seasonal habitat use) that they can be relocated over time to allow long-term assessment of their condition. Workshop participants identified several regional populations meeting those criteria, including (1) humpback whales off southeast Alaska, (2) blue whales off California, (3) the Pacific feeding aggregation of gray whales off the west coast of North America or those summering off Chukotka, Russia and (4) southern right whales off South Africa.

Eastern gray whales off Chukotka were highlighted as providing a unique opportunity for follow-up work. Individuals from this population come near shore in summer (i.e., they are accessible for study), they are seasonally residential (or semi-residential), and local hunters kill a number of individuals each year. Thus, there is the possibility that in this special circumstance tagged individuals can be monitored closely over the course of a feeding season (by using real-time positional data being transmitted from the tag for relocation), and, ultimately, evaluated post-mortem for tag-related wounds and other parameters.

North Atlantic right whales also are a useful study population because, as noted earlier, 49 individuals were tagged in the period from 1988 to 1997, and many of those animals are likely still alive. The photo-identification catalogue maintained by the New England Aquarium provides sufficient records to evaluate the fates of those animals and compare their reproduction, survival, distribution, and habitat use patterns to those of untagged individuals. Such a study would provide a useful test of the potential long-term effects of earlier tag designs.

Where tags are necessary to identify and track individual animals, studies will be compromised by the fact that comparisons can only be made among tagged whales rather than comparing tagged whales to untagged control animals. To address this issue, workshop participants concluded that longitudinal studies would be ideal if they allowed comparisons of animals pre-tagging (which may require other types of technology such as suction cups), animals with tags attached, and animals after tag rejection. Whether such study designs are feasible will depend on a number of factors, such as listed above (e.g., accessibility, abundance, natural history, ease of identification). Companion studies also might provide important supplemental data, including: (1) fecal analysis, (2) stress hormone analysis, and (3) isotope analysis.

Finally, a relatively simple and direct approach to follow-up evaluation is to use real-time positional data to relocate tagged whales. Such relocation provides the opportunity for direct observation of the animal and the tagging site. Although this kind of follow-up is often difficult and costly due to the distribution and movement patterns of the whales, it is being used with some success in a study of blue whales off California (J. Calambokidis, pers. comm.).

Investigators also might establish an online database to compile an up-to-date listing of the following information: (1) animals tagged - including approximate size, sex (if known) and descriptions or photographs of any distinctive marks useful for individual identification, (2) geographic location and date where the tag was deployed, (3) position on the body where the tag was attached, and (4) description of the type of tag used. Stranding networks could, in turn, use such information as a guide to search for tag sites on stranded whales suspected to have been tagged and, when possible, conduct examinations of tag-related wounds (F. Gulland, pers. comm.).

Measures to Reduce Tag Effects

Since the inception of tagging studies on large whales, a variety of tag designs, deployment systems, and attachment techniques have been used (Watkins 1979, Mate *et al*. 2007). At present, scientists are generally using pointed, cylindrical tags that are implanted through the skin and into the blubber. In many cases, these tags also are likely to penetrate the fascia and muscle. The cylinders are held in place by barbs of various designs (Heide-Jørgensen *et al*. 2003, Mate *et al*. 2007). Development of this design has attempted to ensure prolonged tag attachment, reduced drag, minimal tissue damage and risk of infection, and prevention of tag migration.

The depth to which a tag should penetrate into the body of a whale has long been a topic of discussion. For many years scientists, in an effort to minimize the health risks to tagged whales, used tags that penetrated only into the blubber. However, the poor structural stability of blubber allowed significant tag movement to occur, resulting in premature detachment. Investigators then developed tags that penetrated deeper to attach to the muscle and fascia. The aim was to reduce tag movement and the propensity for upward/outward lift, thereby increasing attachment duration and, ultimately, the volume and value of data obtained. The increased stability of deeper tags also was expected to promote healing by reducing tag movement. New epithelial cells and scar tissue were expected to form around the tag to encapsulate and wall it off to minimize adverse internal effects. In addition, investigators anticipated that the greater circulation of blood in muscle (as opposed to blubber) might allow white blood cells to mobilize more quickly to fight infections at the tag site.

Although implantation into the fascia and muscle appears to increase the longevity of tag attachment, it also may increase the chance of systemic infection. In addition, deeply seated tags may remain attached beyond their functional lifetimes, prolonging the healing process and the period of exposure to sources of infection. Matching the period of tag attachment with the functional lifespan of the tag will be a difficult undertaking, but workshop participants considered it a task worth pursuing to reduce the risk to tagged animals.

Other practices currently being used to mitigate physical damage and infection caused by tagging include: (1) use of surgical quality tag materials, (2) sterilization of tag components prior to deployment, (3) use of topical and long-dispersant antibiotics, and (4) use of tapered, bladed cutting tips at the entry point of the tag to reduce blunt trauma, minimize the unwanted introduction of epidermal cells and bacteria into the wound, and better control inward trajectory. Mate *et al*. (2007) described the development of these practices over the past several decades.

With one exception, workshop participants agreed on the four practices listed above and on the need to minimize tag size and related hydrodynamic drag to reduce the potential for adverse effects. The single disagreement pertained to antibiotics. Some participants argued that application of antibiotics could not hurt, regardless of how effective they are, and may help prevent transfer of pathogens from the tag itself. Other participants cited the potential drawbacks of using antibiotics, including the creation of antibiotic-resistant bacteria and the ineffectiveness of single-dose treatments. Although workshop participants did not arrive at consensus on this particular issue, various approaches are being used that should, over time, provide a better understanding of the usefulness of antibiotic treatment during tag application.

Alternative Tags

Suction cup tags have proven to be very useful in short-term deployments on whales (Nowacek *et al*. 2001, Calambokidis 2003, Baumgartner and Mate 2003, Watwood *et al*. 2006) but are not yet suitable for collecting data over periods longer than a few days. Further, their potential effects over longer periods have not been evaluated. Other highly miniaturized satellite-linked tags, capable of transmitting for up to several months, in which the transmitter package remains external to the body and only the attachment system penetrates the skin, are being used successfully to track odontocetes (Andrews *et al*. 2005, Baird *et al*. 2007, Pitman *et al*. 2007, Schorr *et al*. 2007). Observations of killer whales (*Orcinus orca*) and short-finned pilot whales (*Globicephala macrorhynchus*) after tag detachment suggest that this type of tag causes minimal physical damage and, in the few documented cases, complete healing has occurred (Andrews *et al*. 2005, www.cascadiaresearch.org/robin/satellite.htm).

A miniaturized tag designed for use on killer whales (Andrews *et al*. 2005) was attached to a gray whale off Alaska in May 2008. As of July 2008, nearly 60 days post-deployment, this tag remained attached to the whale and continued to function (J. Durban, pers. comm.). Similarly, external tags (i.e., surface-mounted transmitter with implanted attachment device) were used to track Antarctic humpback whales for up to 80 days – outperforming the implantable tags used in the same study (Dalla-Rosa *et al*. 2008). The use of highly miniaturized external tags may become increasing prevalent in studies of large whales. Such use would alleviate at least some of aforementioned physical/physiological concerns surrounding the use of implantable tags.

Other alternative tag technologies, including a non-invasive towed telemetry buoy being developed for use on North Atlantic right whales, were discussed briefly during the 2005 workshop. Another device called a “float tag”, in which a floating tag package is tethered to a whale via an implanted anchoring system, has been used to track bowhead whales (Heide-Jørgensen *et al*. 2006). Although these tags had the benefit of low initial failure rates, deployment durations were relatively short (2–33 d).

In general, workshop participants favored increased efforts to find alternative, non-invasive techniques for studying large whales over long timescales. All other things being equal, non-invasive tags would be preferable if they can provide similar information with less risk. However, all other things probably are not equal as, in some cases at least, non-invasive tags may pose more risk of energy-consuming drag and in most cases the period of attachment is shorter.

Ethics and Guidelines

Scientific ethics and professional guidelines also were discussed at the workshop. Participants agreed that tagging research should be conducted within an ethical framework following standards of acceptable practice (see Wilson and McMahon 2006) and, on balance, should not further endanger already threatened populations. Participants also discussed the establishment of an expert panel to create a set of guidelines and recommendations for studies using telemetry on whales. These guidelines could be adopted by relevant scientific societies, permitting agencies, and regulatory bodies to help ensure that tagging practices conform to standards designed to prevent unnecessary risks to the health and welfare of tagged individuals.

Conclusions

It stands to reason that information on the effects of tagging large whales would be difficult to collect—after all, scientists use telemetry devices to provide information that cannot be obtained easily by other existing methods. Given the difficulty of operating in the marine environment and the vast range of many large cetaceans, follow-up studies to monitor potential effects of tagging are inherently difficult, will require considerable resources to undertake, and will call for determination on the part of investigators to ascertain whether such effects occur. Nonetheless, such studies are important for both humane and scientific reasons. The intent of tagging large whales is not to harm them, but to learn about them, usually for the purposes of informing conservation efforts. In addition, verifying that such effects do not occur is necessary for accurate interpretation of collected data, particularly data that are intended to provide insights into the behavior of whales under natural conditions.

For the past several decades, scientists carrying out tagging studies of whales have made significant progress in developing more effective tags and attachment methods. Such enhancement improves the quality of the resulting data and reduces the likelihood of adverse effects on the whales. Still, more work is necessary to reduce risks further and provide assurance that the residual risks are at an acceptably low level for all species of interest. Similar processes have occurred in the development of other invasive scientific methods or methods that involve or pose a risk of injury. Scientists themselves will need to lead this effort and should make every effort to collect information on tag effects as part of their study designs. Such efforts should be published and thereby incorporated into the body of scientific information on large whales, where it is available to all.

At the same time, funding agencies and organizations also must assume responsibility by providing the support needed to carry out such studies. The progress made to date is good evidence that we, collectively, can improve on study methods such as tagging, and the responsibility to do so lies with all of us.

Acknowledgments

The workshop on which this report is based would not have been possible without the efforts of L. Lowry (panel moderator), M. Simpkins (rapporteur), and the presenters and/or panelists including: N. Gales, M. Johnson, S. Kraus, B. Mate, M. Moore, B. Woodward and S. Young. The author, Marine Mammal Commission, and National Marine Fisheries Service gratefully acknowledge their contribution. T. Ragen and R. Reeves offered support, encouragement, editorial reviews and sage advice. F. Gulland, S. Kraus, F. Larsen and M. Simpkins provided insightful reviews of an earlier version of this report. Useful communications and materials were provided by: R. Andrews, P. Best, J. Calambokidis, J. Durban, N. Gales, M.P. Heide-Jørgensen, S. Kraus, F. Larsen, B. Mate, S. Mizroch, M. Moore, D. Nowacek, R. Pitman, R. Rolland, T. Rowles and M. Simpkins. The U.S. Marine Mammal Commission and IUCN co-funded the development and completion of this report.

Literature Cited

Andrews, R.A., Matkin, C.O. and Mazzuca, L. 2005. Satellite tags and attachment techniques for killer whales. In Abstracts of the 16th Biennial Conference on the Biology of Marine Mammals, 12-16 December 2005, San Diego, CA. p. 15.

Baird, R.W., McSweeney, D.J., Schorr, G.S., Mahaffy, S.D., Wester, D.L., Barlow, J., Hanson, M.B. and Andrews, R.D. 2007. Site fidelity and movements of Cuvier's and Blainville's beaked whales at three spatial/temporal scales: combining VHF radio tracking, satellite tagging and long-term photo-identification. Presentation at the 21st Annual conference of the European Cetacean Society, San Sebastian, Spain, April 24, 2007.

Baumgartner, M.F. and Mate, B.R. 2003. Summertime foraging ecology of North Atlantic right whales. Marine Ecology Progress Series 264, 123-135.

Baumgartner, M.F. and Mate, B.R. 2005. Summer and fall habitat of North Atlantic right whales (*Eubalaena glacialis*) inferred from satellite telemetry. Canadian Journal of Fisheries and Aquatic Sciences 62, 527-543.

Best, P.B. and Mate, B. 2007. Sighting history and observations of southern right whales following satellite tagging off South Africa. Journal of Cetacean Research and Management 9(2): 111-114

Brownell, R.L., Kasuya, T. and Weller, D.W. 2007. Entrapment of western gray whales in Japanese fishing gear: population threats. Paper SC/59/BRG36 presented to the IWC Scientific Committee. 9pp.

Bruce-Allen, L.J. and Geraci, J.R. 1985. Wound healing in the bottlenose dolphin (*Tursiops truncatus*). Canadian Journal of Fisheries and Aquatic Science 42: 216-228.

Calambokidis, J. 2003. Underwater behavior of blue whales examined with suction-cup attached tags. Annual report to the Office of Naval Research. 6 pp.

Cooke, S.J. 2008. Biotelemetry and biologging in endangered species research and animal conservation: Relevance to regional, national, and IUCN Red List threat assessments. Endangered Species Research 4: 165-168

Cooke, J.G., Weller, D.W., Bradford, A.L., Burdin, A.M. and Brownell, R.L., Jr. 2008. Population assessment of western gray whales in 2008. Paper SC/60/BRG11 presented to the IWC Scientific Committee. 10pp.

Costa, D.P. 1993. The secret lives of marine mammals: Novel tools for studying their behavior and biology at sea. Oceanography 6: 120-128.

Dalla Rosa, L., Secchi, E.R., Maia, Y.G., Zerbini, A.N. and Heide-Jørgensen, M.P. 2008. Movements of satellite-monitored humpback whales on their feeding ground along the Antarctic Peninsula. Polar Biology 31: 771-781

Dee, K.C., Puleo, D.A. and Bizios, R. 2002. Wound Healing. *In*: An introduction to tissue-biomaterial interactions. Wiley and Sons Inc. pp. 165-214.

Geraci, J.R. and Bruce-Allen, L.J. 1987. Slow process of wound repair in beluga whales, *Delphinapterus leucas*. Canadian Journal of Fisheries and Aquatic Sciences 44: 1661-1665.

Geraci, J.R. and Smith, G.J.D. 1990. Cutaneous response to implants, tags, and marks in beluga whales, *Delphinapterous leucas*, and bottlenose dolphins, *Tursiops truncatus*. *In*: Smith, T,G., St. Aubin, D.J. and Geraci, J.R. (editors). Advances in Research on the Beluga Whale, *Delphinapterus leucas*. Canadian Bulletin of Fisheries and Aquatic Sciences 224:81-95.

Godfrey, J.D. and Bryant, D.M. 2003. Effects of radio transmitters: Review of recent radio-tracking studies. Science for Conservation 214: 83-95.

Haldiman J.T. and Tarpley, R.J. 1993. Anatomy and physiology. *In*: Burns, J.J., Montague, J.J. and Cowles, C.J. (editors). The bowhead whale. Special publication number 2. The Society for Marine Mammalogy. New York: Allen Press Inc. pp. 71–156.

Heide-Jørgensen, M.P., Laidre, K.L., Wiig, Ø., Jensen, M.V., Dueck, L., Maiers, L.D., Schmidt, H.C. and Hobbs, R.C. 2003. From Greenland to Canada in ten days: Tracks of bowhead whales, *Balaena mysticetus*, across Baffin Bay. Arctic 56(1): 21-31.

Heide-Jørgensen, M.P., Laidre, K.L., Jensen, M.V., Dueck, L. and Postma, L.D. 2006. Dissolving stock discreteness with satellite tracking: Bowhead whales in Baffin Bay. Marine Mammal Science 22(1): 34-45.

Heide-Jørgensen, M.P., Laidre, K.L., Litovka, D. and M. Villum Jensen, M. In Prep. Important foraging grounds for gray whales (*Eschrichtius robustus*) along the Chukotka peninsula, Russia.

Hooker, S.K., Baird, R.W., Al-Omari, S., Gowan, S. and Whitehead, H. 2001. Behavioral reactions of northern bottlenose whales (*Hyperoodon ampullatus*) to biopsy darting and tag attachment procedures. Fishery Bulletin 99: 303-308.

International Whaling Commission. 2004. Report of the Scientific Committee. Annex F. Report of the Sub-Committee on Bowhead, Right and Gray Whales. Journal of Cetacean Research and Management (Supplement) 6: 211-242. .

International Whaling Commission. 2007. Report of the Scientific Committee. Annex F. Report of the Sub-Committee on Bowhead, Right and Gray Whales. Journal of Cetacean Research and Management (Supplement) 9: 142-155.

International Whaling Commission. 2008. Report of the Scientific Committee. Annex F. Report of the Sub-Committee on Bowhead, Right and Gray Whales. Journal of Cetacean Research and Management (Supplement) 10: 150-166.

International Whaling Commission. In Press. Report of the Scientific Committee. Annex F. Report of the Sub-Committee on Bowhead, Right and Gray Whales. Journal of Cetacean Research and Management (Supplement) 11.

Kraus, S., Quinn, C. and Slay, C. 2000. A workshop on the effects of tagging on North Atlantic right whales. Unpublished report, New England Aquarium, Boston, MA. 14 pp.

Ling, J.K. 1974. The integument of marine mammals. *In*: Harrison, R.J. (editor). Functional anatomy of marine mammals, Vol. 2. New York Academic Press pp. 1-44.

Mate, B.R., Nieukirk, S.L. and Kraus, S.D. 1997. Satellite-monitored movements of the northern right whale. Journal of Wildlife Management 61, 1393-1405.

Mate, B.R., Gisiner, R. and Mobley, J. 1998. Local and migratory movements of Hawaiian humpback whales tracked by satellite telemetry. Canadian Journal of Zoology 76, 863-868.

Mate, B.R., Lagerquist, B.A. and Calambokidis, J. 1999. Movements of North Pacific blue whales during the feeding season off southern California and their southern fall migration. Marine Mammal Science 15, 1246-1257.

Mate, B.R., Krutzikowsky, G.K. and Winsor, M.H. 2000. Satellite-monitored movements of radio-tagged bowhead whales in the Beaufort and Chukchi seas during the late-summer feeding season and fall migration. Canadian Journal of Zoology 78, 1168-1181.

Mate, B. and Urbán, J. 2005. The spring northward migration and summer feeding of eastern North Pacific gray whales. Poster from the 16th Biennial Conference on the Biology of Marine Mammals. San Diego, CA

Mate, B., Mesecar, R. and Lagerquist, B. 2007. The evolution of satellite-monitored radio tags for large whales: One laboratory's experience. Deep-Sea Research Part II 54, 224-247.

New Bedford Whaling Museum. 2007. 125-year-old New Bedford bomb fragment found embedded in Alaskan bowhead whale. Unpublished report, New Bedford Whaling Museum, MA. 3. pp.

Nowacek, D.P., Johnson, M.P., Tyack, P.L., Shorter, K.A., McLellan, W.A. and Pabst, D.A. 2001. Buoyant balaenids: the ups and downs of buoyancy in right whales. Proceedings of the Royal Society 268: 1811-1816.

Philo, L.M., Shotts, E.B., Jr. and George, J.C. 1993. Morbidity and Mortality. *In*: Burns, J.J., Montague, J.J. and Cowles, C.J. (editors). The bowhead whale. Special publication number 2. The Society for Marine Mammalogy. New York: Allen Press Inc. pp. 275-312.

Pitman, R.L., Andrews, R. and Ballance, L.T. 2007. Tracking cold killers: Satellite telemetry reveals movement pattern variation between two different ecotypes of Antarctic killer whales. In Abstracts of the 17th Biennial Conference on the Biology of Marine Mammals, 29 November to 3 December 2007, Cape Town , South Africa.

Quinn, C.A., Hamilton, P.K., Kraus, S.D. and Slay, C.K. 1999. An assessment of wounds caused by the attachment of remote sensing tags to North Atlantic right whales (*Eubalaena glacialis*): 1988-1997. Unpublished report, New England Aquarium, Boston, MA USA. 35 pp.

Rayner, G.W. 1940. Whale marking, progress and results to December, 1939. Discovery Reports 19: 245-284.

Read, A.J. 2002. Telemetry. *In*: Perrin, W.F., Würsig, B and Thewissen, H. (editors). Encyclopedia of Marine Mammals. Academic Press, San Diego, CA pp. 1232-1235.

Reeb, D., Best, P.B. and Kidson, S.H. 2007. Structure of the integument of southern right whales, *Eubalaena australis*. The Anatomical Record 290: 596-613.

Reeves, R.R., Smith, T.D. and Josephson, E.A. 2008. Observations of western gray whales by ship-based whalers in the 19th century. Paper SC/60/BRG7 presented to the IWC Scientific Committee. 19pp.

Schorr, G.S., Baird, R.W., Webster, D.L., McSweeney, D.J., Hanson, M.B., Andrews, R.D. and Barlow, J. 2007. Spatial distribution of Blainville's beaked whales, Cuvier's beaked whales, and short-finned pilot whales in Hawai‘i using dorsal fin-attached satellite and VHF tags: Implications for management and conservation. In Abstracts of the 17th Biennial Conference on the Biology of Marine Mammals, 29 November to 3 December 2007, Cape Town , South Africa.

Scott, M.D., Wells, R.S., Irvine, A.B. and Mate, B.R. 1990. Tagging and marking studies on small cetaceans. *In*: Leatherwood, S. and Reeves, R.R. (editors). The bottlenose dolphin. Academic Press, Inc., San Diego, CA. pp. 489-514.

St. Aubin, D.J., Deguise, S., Richard, P.R., Smith, T.G. and Geraci, J.R. 2001. Hematology and plasma chemistry as indicators of health and ecological status in beluga whales, *Delphinapterus leucas*. Arctic 54(3): 317-331.

Stone, G. and Kraus, S.D (editors) 1998. Marine animal telemetry tags: What we learn and how we learn it. Journal of the Marine Technology Society 32: 1-114.

Wade, P., Heide-Jørgensen, M.P., Shelden, K., Barlow, J., Carretta, J., Durban, J., LeDuc, R., Munger, L., Rankin, S., Sauter, A. and Stinchcomb, C. 2006. Acoustic detection and satellite-tracking leads to discovery of rare concentration of endangered North Pacific right whales. Biology Letters 2:417-419

Watkins, W.A. 1979. A projectile point for penetrating whale blubber. Deep-Sea Research 26A: 1301-1308.

Watkins, W.A. 1981. Reactions of three species of whales *Balaenoptera physalus*, *Megaptera novaeangliae* and *Balaenoptera edeni* to implanted radio tags. Deep Sea Research 28A: 589-599.

Watkins, W.A., Moore, K.E., Wartzok, D. and Johnson, J.H. 1981. Radio tracking of finback (*Balaenoptera physalus*) and humpback (*Megaptera novaeangliae*) whales in Prince William Sound, Alaska. Deep Sea Research 28A: 577-588.

Watkins. W.A. and Tyack, P. 1991. Reaction of sperm whales (*Physeter catodon*) to tagging with implanted sonar transponder and radio tags. Marine Mammal Science 7:409-413.

Watwood, S.L., Miller, P.J.O., Johnson, M., Madsen, P.T. and Tyack, P.L. 2006. Deep-diving foraging behaviour of sperm whales (*Physeter macrocephalus*). Ecology 75: 814-825.

Weller, D.W., Burdin, A.M., Würsig, B., Taylor, B.L. and Brownell, R.L., Jr. 2002. The western gray whale: a review of past exploitation, current status and potential threats. Journal of Cetacean Research and Management 4(1):7-12.

Weller, D.W., Bradford, A.L., Lang, A.R., Kim, H.W., Krukova, N., Tsidulko, G.A., Burdin, A.M. and Brownell, R.L., Jr. 2008. Status of western gray whales of Sakhalin Island, Russia in 2007. Paper SC/60/BRG3 presented to the IWC Scientific Committee.

Weller, D.W., Bradford, A.L., Kato, H., Bando, T., Ohtani, S., Burdin, A.M. and Brownell, R.L., Jr. in Press. Photographic match of a western gray whale between Sakhalin Island, Russia, and Honshu, Japan: First link between feeding ground and migratory corridor. Journal of Cetacean Research and Management.

Wells, R.S. 2005. Report of the small cetacean electronic tag attachment workshop. Unpublished report, Marine Mammal Commission, Bethesda, MD 14 pp.

WGWAP. 2006. Report of the Western Gray Whale Advisory Panel at its first meeting. Unpublished report, http://www.iucn.org/themes/marine/sakhalin/, Prangins, Switzerland 42 pp.

WGWAP. 2007. Report of the Western Gray Whale Advisory Panel at its second meeting. Unpublished report, http://www.iucn.org/themes/marine/sakhalin/, St. Petersburg, Russia 52 pp.

WGWAP. 2008. Report of the Western Gray Whale Advisory Panel at its fourth meeting. Unpublished report, http://www.iucn.org/themes/marine/sakhalin/, Lausanne, Switerland 58 pp.

Wilson, R.P. and McMahon, C.R. 2006. Measuring devices on wild animals: What constitutes acceptable practice? Frontiers in Ecology and the Environment 4(3): 147-154.

Addendum

A Case Study of the Western North Pacific Gray Whale Population

The above issues and concerns regarding tagging of large whales recently have been raised with regard to the critically endangered western North Pacific population of gray whales (WGWAP 2007, 2008, IWC 2004, 2007, 2008, in press). Since 1995 these whales have been monitored and studied on their summer feeding grounds off the northeastern coast of Sakhalin Island, Russia. Their wintering area(s) and migratory path(s) are largely unknown (Weller *et al*. 2002), but entanglements in fishing gear off the Pacific coast of Japan are reminders that the whales face a number of threats throughout their range (Weller *et al*. in press). Satellite telemetry has been proposed to investigate their migratory routes and winter grounds and provide information about both their natural history (e.g., reproduction) and obstacles to recovery.

Scientists have been cautious about tagging these whales largely because of the population's critically endangered status. The population consists of about 130 individuals age one or older (i.e., excluding calves) and only a small portion of those are reproductively active females (about 25) (Cooke *et al*. 2008, Weller *et al*. 2008). Tag-related harm to a single female could have population-level consequences. The Scientific Committee of the IWC has commented that the potential risks to individual whales from the tagging process must be carefully weighed against the potential benefits of the study and agreed that the process should first be tested on gray whales from the eastern North Pacific population (IWC 2004).

In keeping with the Scientific Committee's recommendation, Sakhalin Energy Investment Company and Exxon-Neftegas Limited, both oil and gas companies working on the Sakhalin Island shelf, funded telemetry studies on eastern gray whales. The aim of those studies was to determine (1) potential challenges and complications of tagging gray whales, (2) effectiveness of deployment techniques, performance of tags, and longevity of attachments, and (3) potential physical, physiological and behavioral effects related to tagging. Evaluation of tag performance on feeding whales was considered particularly valuable because gray whales are in regular physical contact with the bottom while feeding and tag effectiveness in such a situation had not been evaluated previously, and because any future tagging of western gray whales likely would occur when they are actively feeding in shallow waters off Sakhalin Island.

In 2006, the IWC Scientific Committee reviewed the results of a tagging study on eastern gray whales conducted by B. Mate and J. Urbán in San Ignacio Lagoon, Baja California, Mexico (IWC 2007). In March 2005, satellite-monitored radio tags were attached to 17 adult gray whales (16 females with calves and one unaccompanied adult). All tags transmitted data (albeit for varying durations) indicating migratory movements by some whales exceeding 17,000 km. Four whales were tracked for more than 200 days, six for more than 100 days and seven for fewer than 30 days. The tagged single adult (i.e., not accompanied by a calf) was found dead on the beach 18 days after tagging. As noted earlier in this report, a necropsy conducted approximately 11 days post-mortem found no evidence of tag site infection or that the death was in any way tag-related. Another whale lost its tag, which was subsequently recovered in a gill net outside the lagoon 23 days after tagging. Finally, local hunters killed one whale 202 days post-tagging off the Chukotka Peninsula in Russia.

The tagging study by Mate and Urbán was deemed highly successful with tag performance and data return exceeding previous efforts of a similar nature. Despite the fact that tags were attached on the wintering grounds where feeding behavior does not often occur, a number of tags continued to function throughout the northward migration, through the entire summer feeding season while the whales were in the Bering and Chukchi Seas, and during the onset of the following southward migration. Importantly, data return of 100+ days by some tags should be sufficient to determine the southern migratory destination for western gray whales if swim speeds are similar between eastern and western gray whales. In addition, the persistence of tag attachments throughout an entire feeding season bodes well for tag duration on the Sakhalin feeding ground if the feeding behavior of eastern gray whales in the deeper-water habitat of the Bering and Chukchi Seas is comparable to that of western gray whales in the shallow waters off Sakhalin.

Follow-up observations were available for three of the 17 whales tagged in this study. The whale killed off Chukotka was noted to have mild swelling within 2-4 cm of the tag site. A second individual resighted 41 days post-tagging off the coast of central Oregon showed no adverse effects at the tag site. The third whale (described above) showed no apparent tag-induced effects, although necropsy was approximately two weeks post-mortem and it is possible that because of decomposition any effects no longer would have been discernible.

The study by Mate and Urbán provided valuable information regarding the utility of tagging gray whales to determine migratory paths and destinations. At its 2006 meeting, the IWC Scientific Committee recommended that telemetry studies on western gray whales be initiated, but with certain caveats intended to minimize risk to the whales. Specifically, it recommended that the study be conducted by experienced investigators using only proven techniques, and that tags be attached only to known males (IWC 2007).

More recently, the Western Gray Whale Advisory Panel (WGWAP), convened by the IUCN, reviewed the study of Mate and Urbán and other related materials on the topic and concluded (WGWAP, 2006):

> *After considerable discussion, the WGWAP agreed that, in principle, telemetry work on western gray whales should be carried out provided that:*

(a) it be under the direction of B. Mate using his tags;

(b) it be restricted to 'non-skinny' males and take into account the occurrence of males with rare and common haplotypes when the final tagging protocol is adopted (A. Bradford of the Russia-USA programme is able to identify animals in real time in the field);

(c) Mate submits to the Panel, for review, a detailed experimental protocol including measures to be taken to minimise the possibility of accidental injury or stress to the animals, and a proposal on sample size in terms of attempts as well as successful attachments;

(d) a formal report is submitted to the Panel by the vet who determined the cause of death of the gray whale in Mate's Mexican study (see WGWAP 1/INF.12);

(e) the Panel receives and considers the report of the Society for Marine Mammalogy's workshop on whale tagging [this report]*;*

(f) experience from around the world on safeguards for the process (e.g. number of approaches allowed per day or other unit of time, total time spent with a particular animal) has been reviewed by the Panel – initial collation and drafts of associated recommendations to be carried out by Weller under contract to the Panel (IUCN);

(g) efforts have been made by the Panel to arrange contacts with appropriate range-state scientists for possible follow-up work;

(h) a final recommendation on protocols, time in the season to attempt tagging and sample size is not made until after consideration of the results of (c) – (g) and taking into account the view of the IWC Scientific Committee at its forthcoming meeting in Anchorage in May 2007; and

(i) weekly positional updates from transmitting tags are made available to the Panel (while maintaining the usual rights of data owners).

In a second satellite tagging study conducted on eastern gray whales in September 2006 off Chukotka, Russia (Heide-Jørgensen in prep.), 13 tags were deployed. Nine provided locations for an average of 39 days (range = 12-81 days), while the remaining four failed to provide information. No information was provided regarding the behavioral, physical, or physiological effects of tagging on individual whales in that study.

The investigators conducting the Chukotka study suggested that attachment problems and the limited data return from some tags were likely the result of whales making contact with the bottom during feeding. They recommended that smaller tags be designed and tested on eastern gray whales on their feeding grounds. They also recommended development of a new or modified tag delivery system to allow longer-range deployment because whales were difficult to approach closely (the average approach time for tag deployment in their study was 45 min). Finally, they concluded that investigators would need to attach tags to more than 20 western gray whales to obtain meaningful results

(Heide-Jørgensen in prep.).

After reviewing the Chukotka study, the WGWAP agreed with the authors that their system had not been adequate for use on western gray whales and emphasized the following points: (1) any new tag and delivery system should be evaluated first on eastern gray whales in a feeding area, (2) the question of how many animals should be tagged will be a function of the efficacy of tagging efforts and the specific questions to be addressed, and (3) it is premature to determine the most appropriate sample size for a western gray whale tagging experiment. The WGWAP summarized its review of the study by reiterating its conclusion from a previous meeting that, in principle, telemetry work on western gray whales is desirable but should be conducted only after the above conditions have been met (WGWAP 2007).

Most recently, during the April 2008 meeting of the WGWAP, satellite tagging of western gray whales and the related recommendations made by the IWC Scientific Committee at its 2007 meeting were discussed (WGWAP 2008). In summary, the IWC Scientific Committee had recommended that it act as a coordinator for a tagging/telemetry project to ensure, among other things, that such a project is carried out in a risk-averse manner (IWC 2008). Further, a coordination group was established to ensure consistency between the Scientific Committee's recommendations and those of the WGWAP. With this advice in mind, the WGWAP again agreed that, in principle, tagging/telemetry work on western gray whales should be carried out. Moreover, the WGWAP agreed that all of its previous recommendations concerning satellite tagging would be superseded by the following single recommendation:

> *The Panel recommend**s** that telemetry work on western gray whales should be carried out provided that it is guided by an IWC Scientific Committee coordination group. This guidance would include specific advice on experimental protocols, study design and measures to be taken to minimise the risk of negative impacts on the whales or the population as a whole.*

Finally, the IWC Scientific Committee also discussed the subject of telemetry studies on western gray whales at its annual meeting in June 2008. A summary of the discussion, as presented in Annex F of the Scientific Committee report (IWC in press), states the following:

> *The sub-committee reiterated the fact that the development of mitigation measures for the threats to the western gray whale population are greatly hindered by the lack of information on migratory routes, breeding destinations and extent of its feeding range. The Committee has recognised the great value of telemetry work to providing this information but also the need to exercise great care before undertaking such work on an endangered population (e.g. IWC, 2008). The Committee had expected to finalise its discussions of the use of telemetry and potential effects on western gray whales this year based on the report (edited by*

Weller) from a 2005 workshop on tagging of large whales (convened by the U.S. Marine Mammal Commission). Last year, the Committee recommended that the IWC act as a co-ordinator for a tagging/telemetry project inter alia to ensure that it is carried out in a risk-averse manner and to enable potential sponsors to contribute financially without necessarily assuming any responsibility for the programme's design, conduct or results. In that context a number of rigorous safety precautions had been recommended (IWC, 2007).

Last year, a co-ordination group had been established, consisting of Brownell, Donovan, Gales, Reeves and Weller, to provide scientific advice and ensure consistency between the IWC Scientific Committee's recommendations and those of the WGWAP. Noting that any telemetry work will occur in Russian waters, the sub-committee suggested that a Russian scientist be identified and added to this co-ordination group.

The sub-committee noted that the aforementioned Marine Mammal Commission report has not yet been finalised for public release and could therefore not be reviewed by the sub-committee at this meeting. However, the sub-committee noted that a near-final version had been presented in April 2008 to the WGWAP and carefully reviewed. The WGWAP concluded that, in principle, tagging/telemetry work on western gray whales should be carried out provided that such work is guided by the co-ordination group referred to above, recognising that this guidance would include specific advice on experimental protocols, study design and measures to be taken to minimize the risk of negative impacts on the whales or the population as a whole.

The sub-committee noted that the final MMC report should be available for discussion at the rangewide western gray whale meeting convened by IUCN that will take place in Tokyo in September 2008 (Appendix 2). The report of that meeting and the final MMC report will be presented to the Committee at the 2009 annual meeting. This will allow for a review of information on the use of telemetry and potential effects on whales with an emphasis on the use of such techniques on endangered populations prior to making recommendations regarding a 2010 or later tagging effort.

Given the critically endangered status of the western gray whale population, alternatives to tagging should be explored at the same time as additional research and development of tags and deployment systems proceeds. Surveys of local knowledge might be conducted and historical records examined (e.g. Reeves *et al*. 2008) in combination with vessel surveys in regions where whales were present historically. Photo-identification also might be used at locations known or thought to be along the migratory route. Some initial efforts along these lines have been undertaken and more are underway using photographs from Japan (e.g., Weller *et al*. in press).

Appendix I

Large Whale Tagging Workshop
Agenda

Convened by the
U.S. Marine Mammal Commission
U.S. National Marine Fisheries Service
10 December 2005
San Diego, California USA

9:00 – 9:15 INTRODUCTION

Tim Ragen

- Statement of Purpose
- Genesis of need for workshop
- Benefits of tagging and need
- General concerns regarding effects of tagging
- Summary of workshop structure and anticipated products
- Introduction of presenters and panelists

9:15 – 9:30 SUMMARY OF A 1999 WORKSHOP ON THE EFFECTS OF TAGGING ON NORTH ATLANTIC RIGHT WHALES

Michael Moore

9:30 – 10:15 OVERVIEW OF CURRENT METHODS AND TECHNOLOGY

Bruce Mate and Mark Johnson

- Size and types of tags
- Benefits of different types of tags
- Information obtained by using various tags on different species
- Tag size and placement for various species and size classes
- Attachment methods, including methods of tag deployment
- Multiple tagging of individual animals (e.g., double-tagging an individual animal or multiple tagging of an individual animal over time)
- Current practices for antibiotic usage during tag application

10:15 – 10:30 BREAK

10:30 – 11:00 OVERVIEW OF POTENTIAL PHYSIOLOGICAL/PHYSICAL EFFECTS

Nick Gales

- Describe potential effects of tagging activities, including attachment and close approach for deployment, etc.
- Summarize studies and evidence related to potential effects
- Summarize “critical uncertainties”
- Suggest studies or approaches to gathering evidence to address uncertainties
-

11:00 – 11:30 OVERVIEW OF POTENTIAL BEHAVIORAL EFFECTS

Scott Kraus

- Describe potential effects of tagging activities, including attachment and close approach for deployment, etc.
- Summarize studies and evidence related to potential effects
- Summarize “critical uncertainties”
- Suggest studies or approaches to gathering evidence to address uncertainties

11:30 – 12:00 DISCUSSION (QUESTION AND ANSWER PERIOD)

12:00 – 1:30 LUNCH

1:30 – 2:45 PANEL I: PHYSIOLOGICAL/PHYSICAL EFFECTS

Nick Gales, Bruce Mate, Michael Moore

2:45 – 3:00 BREAK

3:00 – 4:15 PANEL II: BEHAVIORAL EFFECTS

Nick Gales, Mark Johnson, Scott Kraus, Bruce Mate, Sharon Young

4:15 – 5:00 DISCUSSION AND RECOMMENDATIONS

5:00 ADJOURN

Appendix II

Large Whale Tagging Workshop
List of Participants

Name		Affiliation	Workshop Role
Tim	Ragen	Marine Mammal Commission	Workshop Chair
Lloyd	Lowry	Marine Mammal Commission	Panel Moderator
Mike	Simpkins	Marine Mammal Commission	Rapporteur
Nick	Gales	Australian Antarctic Division	Presenter and Panelist
Mark	Johnson	Woods Hole Oceanographic Institution	Presenter and Panelist
Scott	Kraus	New England Aquarium	Presenter and Panelist
Bruce	Mate	Oregon State University	Presenter and Panelist
Michael	Moore	Woods Hole Oceanographic Institution	Presenter and Panelist
Becky	Woodward	University of Maine	Presenter
Sharon	Young	Humane Society US	Panelist
Richard	Abrams, Jr.	Retired	
Tammy	Adams	National Marine Fisheries Service	
Olive	Andrews	SWWRC	
Mark	Baumgartner	Woods Hole Oceanographic Institution	
Matteo	Bernasconi	IMR (Norway)	
Peter	Best	Mammal Research Institute, Univ. of Pretoria	
Daniel	Burns	Southern Cross University	
Simone	Canese	ICRAM	
Danielle	Cholewiak	Cornell University	
Luiz	Cla'udio Alves	UFJF (Brazil)	
Bob	Cooper	New England Aquarium	
Luciano	Dalla Rosa	UBC	
Erin	Estrada	University of New England	
Bob	Gisiner	ONR	
Mike	Gosliner	MMC	
Karina	Groch	IWC/Brasil (Right Whale Project)	
Katia	Groch	IBJ/Brasil (Humpback Whale Inst.)	
Shane	Guan	NMFS	
James	Hall	Exxon Mobil	
Cyd	Hanns	North Slope Borough, Barrow, AK	
Brad	Hanson	NOAA/NMFS/NWFSC	
Rob	Harcourt	Macquarie University	

Name		Affiliation
Elsa	Haubold	Florida Fish & Wildlife Conservation Commission
John	Hildebrand	SIO-UCSD
Roger	Hill	Wildlife Computers
Kim	Holland	University of Hawaii
Carrie	Hubard	NMFS
Nathalie	Jaquet	Center for Coastal Studies
Amber	Kumek	Cascadia Research Collective
Bill	Lang	MMS - Gulf of Mexico
Jennifer	Latusek	SAIC
Kevin	Lay	Sirtrack Ltd.
Steve	Leathery	NMFS
Allan	Ligon	Humpback Whale Sanctuary, Maui
Peter	Madsen	University of Aarhus/WHOI
Christie	Mahaffey	University of Maine
Yoko	Mitani	Texas A&M University
Maria Emilia	Morete	University of Sao Paolo (Brazil)
Kyoichi	Mori	Ogasawara Whale Watching Association
Chris	Morris	ORES (Canada)
Michael	Noad	University of Queensland
Tom	Norris	SAIC
Erin	Oleson	University of California at San Diego
Joel	Ortega	Oregon State University
Christian	Ortega Ortica	CICIMAR-IPN
Richard	Pace	NMFS, NEFSC, Woods Hole
Simone	Panigada	Tethys Research Institute
David	Paton	Southern Cross University
Lori	Quakenbush	Alaska Dept. of Fish & Game, Fairbanks
Carol	Roden	MMS/New Orleans
Teri	Rowles	NOAA/NMFS
Ann	Rupley	Wildlife Computers
Ted	Rupley	Wildlife Computers
Greg	Schorr	Cascadia Research
Ruth	Searle	Univ. of Wales Swansea, UK
Brian	Sharp	Center for Coastal Studies
Steve	Shippee	University of Central Florida
Trevor	Spradlin	NOAA/NMFS
Alison	Stimpert	HIMB/University of Hawaii

Name		Affiliation
Kate	Swails	NMFS
Gisli	Vikingsson	MRI (Iceland)
Cecile	Vincent	University of La Rochelle, France
Leslie	Ward	Florida Fish & Wildlife Conservation Commission
Bridget	Watts	Moss Landing Marine Labs
Frederick	Wentzel	NOAA, NMFS, Woods Hole
Sarah	Wilkin	NOAA/NMFS
Nicky	Wiseman	Auckland University
Ulrike	Wolf	Cascadia Research/Ani Kassel/Germany
Andrew	Wright	NMFS PR
Alex	Zerbini	University of Washington (Seattle)