SC/68a/Rep03

Report of the Joint U.S. Office of Naval Research, International Whaling Commission and U.S. National Oceanic and Atmospheric Administration Workshop on Cetacean Tag Development, Tag Follow-up and Tagging Best Practices

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1. INTRODUCTORY ITEMS

The workshop was held at the National Marine Fisheries Service office in Silver Spring, Maryland, USA from 6 to 8 September 2017. During this workshop, limited time was devoted to the topic of understanding the impacts of invasive tagging and improving invasive tagging techniques. Therefore, a subgroup of the Silver Spring workshop participants met at the Alaska Fisheries Science Center in Seattle, WA, USA on 19 and 20 June 2018 to develop more detailed recommendations for future directions in the development of invasive tag attachments. This report integrates discussions held during the two meetings. The agendas of the meetings in Silver Spring and Seattle are provided in Annexes A and B, respectively.

Funding for the workshop was provided by the International Whaling Commission (IWC), the United States National Oceanic and Atmospheric Administration' National Marine Fisheries Service (NOAA/NMFS) and the United States Office of Naval Research (ONR). A total of 42 participants from 9 different countries attended the Silver Spring meeting, and 19 from 6 countries participated in the Seattle meeting. Participants included tag developers, tag users, veterinarians, engineers, representatives of governmental and inter-governmental agencies, and tag manufacturers. The list of participants is provided in Annex C.

1.1 Introduction of Chair and Rapporteurs

Donovan was appointed Chair and Simeone, Double and Rowles acted as rapporteurs for the workshop in Silver Spring. Weise and Schorr were nominated, respectively, Chair and rapporteur for the meeting in Seattle.

1.2 Terms of Reference

The terms of reference of the workshop are presented as Annex D.

1.3 Expected Outcomes

The expected outcomes of the workshop included a review of progress in tag design and attachment over the last decade since the Cetacean Tag workshop (ONR, 2009) and a review of studies that have examined the effects of tagging. In addition, the workshop was expected to review a draft of the 'Cetacean Tagging Best Practice Guidelines' (hereafter referred to as "the Guidelines"), which was prepared by a group of 22 experts in cetacean tagging and cetacean medicine and was shared with the participants prior to the workshop. The Guidelines would be finalized after the workshop to serve as a global resource to assist researchers, veterinarians, animal care committee members, and regulatory agency staff, in the interpretation and implementation of current standards of practice and promote the training of specialists in this area. It was expected that the Guidelines would be endorsed by the IWC Scientific Committee, and published in the peer-reviewed literature.

2. TAG TERMINOLOGY

New definitions of tag terminology were introduced and are presented in detail and illustrated in Annex E. Briefly, two categories of cetacean electronic tags were specified according to the method of attachment to the animal: invasive and non-invasive. "Invasive" is defined as a tag type with an attachment that intentionally breaks the skin, regardless of how large or deep the break may be, and non-invasive tags are those for which attachments do not penetrate through the skin (*e.g.*, suction-cup tags). Invasive tags can be further divided into three categories. Type A refers to tags that are *anchored* to the dorsal fin or the body. The anchoring systems terminate below the skin but the electronics are external to the body. Type B corresponds to *bolt-on* tags with external electronics and piercing anchor(s) fixed with external bolts, typically attached through the dorsal fin or dorsal ridge of small to medium-size cetaceans. Type C includes tags in which the anchoring systems and the electronic packages are *consolidated* and embedded in the body of the animals with an external antenna. These latter tags are typically used on large cetaceans and are designed to anchor below the blubber-muscle interface.

3. PRESENTATIONS

Since the 2009 Cetacean Tag Design Workshop (ONR, 2009), a National Oceanographic Partnership Program (NOPP) topic with funding from ONR, Bureau of Ocean Energy and Management (BOEM), National Science Foundation (NSF), NOAA, and American Petroleum Institute (API) supported a variety of studies to improve tagging technology and to better understand the effects of tags on cetaceans, both on individual and population levels. Presentations by workshop participants (Annex F) summarized information from these NOPP studies. Presentations also reviewed the benefits and limitations of the use of antibiotics on invasive tags, and on potential new technologies that could be considered in future development of tag housing and tag attachments.

3.1 Invasive tags

3.1.1 Type A tags

Andrews presented information on Type A (anchored) tags, focusing on the Low Impact Minimally-Percutaneous External-electronics Transmitter (LIMPET) satellite tag. This tag was initially developed for application to killer whales (*Orcinus orca*), but its modest success with that species led to a desire to apply it more broadly and to make it commercially available. Before that could be done, refinements were necessary, and the presentation focused on those refinements that have occurred since the 2009 ONR-sponsored cetacean tag workshop, and especially the results of the NOPP project, funded by ONR, entitled "Improving attachments of remotely-deployed dorsal fin-mounted tags: tissue structure, hydrodynamics, in situ performance, and tagged-animal follow-up". Collaborators on that project were R. Baird, G. Schorr, R. Mittal, L. Howle, and B. Hanson. The goal was to improve the LIMPET tag methodology to achieve longer, less variable attachment durations, and to work to ensure that the tag provided data without significantly affecting tagged animals adversely. The approach included four topics: 1) hydrodynamics of tag shape; 2) dorsal fin tissue structure; 3) performance of tag attachments – simulated and actual; and 4) effects of tags, based on follow-up studies of wound healing, behavior, and vital rates. Using computational fluid dynamics (CFD) and physical models in a water tunnel, effects of tag shape, orientation relative to flow, and location on the dorsal fin were examined. The hypothesis that lift was just as significant as drag in the total external force on the tag was supported through both CFD simulations and water tunnel experimentation. Although the hydrodynamics work was important in developing the new LIMPET tag package designs that are now offered by Wildlife Computers, the current hypothesis is that the majority of tags are displaced by contact with con-specifics or other objects, and therefore the ability to stay attached when exposed to those forces in addition to the forces of water flow must be considered in future tag package and attachment designs. The team examined dorsal fin tissue from five species to assess structural layer geometry and collagen composition along with fiber strength. However, variation within a fin was nearly as great as variation amongst species, and additional work on this topic will be required before understanding of how tissue composition may relate to tag attachment performance will be advanced. Performance of the titanium tag attachment darts used in LIMPET tags, using both tissue surrogates and blubber and dorsal fin tissue salvaged from carcasses, showed that during static pull tests, the backwards-facing petals usually bent around in an arc and did not break. However, field observations showed that in some cases the small petals were retained in the fin. As part of the process of transferring designs from the academic realm to the commercial vendor, the manufacturing procedure was significantly improved, leading to a 60% increase in the pull-out strength. However, this did not eliminate the susceptibility of petals to breakage. Current work is on development of appropriate testing protocols, including dynamic testing to simulate the range of forces truly acting on these tags.

These tags have been successfully applied to 22 cetacean species, including species previously difficult to track. When tag elements did not break upon attachment or detachment, wound healing followed an expected progression with remodeling, repigmentation, and limited scarring within 1 year. When visual evidence of tagging persisted past one year, it was limited to small (< 2 cm diam., < 1 cm height) depressions or swellings, with no photographic evidence of infection. In the small percentage of cases in which the tag body or the attachment darts were observed to break, resulting in retained darts or petals, chronic inflammation was observed, and in at least two cases, possible infection. In the worst case, tag implantation may have been the source of a lethal fungal infection in the southern resident killer whale L95 (presentation by Raverty below). Forward looking infra-red (FLIR) thermal imaging of tagged whales confirmed that LIMPET tagging did not compromise the ability of the fin vasculature to radiate heat.

Schorr presented data on the performance of LIMPET tags on tagged cetaceans. Recent research has led to significant improvements in the LIMPET tagging methodology, but attachment durations are still quite variable and not as long as desired, and some tags still break (Andrews *et al.*, 2015). Due to the highly variable nature of LIMPET satellite tag durations, the deployment information for 247 of similarly deployed, location-only tags were

assessed within a Generalized Linear Model framework. The effects of species, tag mold, dart version, and vertical and horizontal position of the tags on the dorsal fin on transmission duration were evaluated. A newer dart manufacturing process, which eliminated individually welded petals (Andrews *et al.*, 2015) resulted in significantly longer attachment durations with the median attachment duration increasing by 13 days ($p < 0.01$). Within species comparisons were made with the inclusion of the covariate Region where applicable, but should be viewed with caution due to small sample sizes. Three species had no significant factors influencing attachment duration, while pilot whale (*Globicephala* spp.) tags deployed in the Atlantic were attached for significantly longer than in Hawaii ($p = 0.03$), and sperm whale (*Physeter macrocephalus*) tags deployed in Alaska were attached significantly longer than those on whales in Hawaii ($p = 0.02$). A ballistic comparison between the three types of LIMPET tags currently in use indicate that both tag type and distance to target play an important role in flight trajectories, which should be considered during deployment. Results of this study suggest that additional research and development work is required to reach consistent attachment performance, while minimizing the impact on tagged whales.

Raverty discussed a case report of mucormycosis in a tagged southern resident killer whale. A 20-year-old male, L95, was satellite tagged February 23, 2016. At the time of deployment, the animal appeared in good body condition, but follow up re-sighting on February 25 revealed that the animal was in suboptimal body condition with a prominent depression along the nape and apparent shapes of the ribs and scapula. L95 was observed dead March 26 and towed ashore for a necropsy April 1, 2016. L95 presented in an advanced state of autolysis with two penetrating tag wounds along the right base of the dorsal fin, splenic enlargement, and acute peritonitis. Serial sections of the tag entrance wounds disclosed transmural vasculitis with invasive fungal hyphae morphologically consistent with mucormycosis. These organisms are most commonly associated with detritus and soil, and infection in terrestrial animals and humans is usually opportunistic, secondary to traumatic penetrating wounds or tissue damage or associated with generalized debilitation or immunosuppression. Similar hyphae are evident within blood vessels and infiltrating adjoining tissue and airways in multiple lung sections suggesting initial fungal invasion of the skin, with subsequent dissemination to the lung and possibly other tissues. The proximate cause of death may be attributed to the relatively deep tissue perforation with the tag deployment and the ultimate cause of mortality is disseminated mucormycosis. Despite multiple attempts the fungus could not be cultured or speciated by molecular means from fresh and formalin-fixed tissues. It could not be conclusively determined whether the fungus may have been introduced to the tag site by a contaminated tag or if the fungus may have colonized the skin prior to tag deployment, with introduction of hyphae into deeper tissues either via tracking the tag shaft or the retained petals acting as nidi of infection and inflammation. The possibility of a pre-existing condition that may have predisposed L95 to fungal invasion cannot be discounted.

Baird discussed using remotely deployed LIMPET tags to study movement and behavior as part of a long-term assessment of odontocete populations in Hawaiian waters. Since 2006 over 300 LIMPET satellite tags have been deployed on 12 different species, nine of which have populations that are resident to the main Hawaiian Islands. Individual photo-identification catalogs of six of the nine species have been used to assess reproduction of tagged individuals, and for two of these species estimates of survival of tagged and untagged individuals have been generated. For assessing reproduction of females, only adult females that were seen in one or more years post tag loss were considered. Since the likelihood of documenting calving will depend on sample size, the mean number of years females were seen post-tagging was presented for females seen with or without calves. For Blainville's beaked whales (*Mesoplodon densirostris*), three of six adult females have been sighted with calves in years subsequent to tag loss. Inter-birth interval is thought to be three to four years for this species. Those seen with calves were seen in an average of 5.3 years since tagging, while those seen without calves were seen in an average of only 1.3 years since tagging, suggesting that the probability of documenting calves for those individuals was small. Three of five adult female Cuvier's beaked whales (*Ziphius cavirostris*) have been documented with calves, with those seen with calves documented in an average of three years, while those not seen with calves were documented in an average of two years. The one known adult female bottlenose dolphin (*Tursiops truncatus*) that was tagged was documented with a calf post-tag loss (seen in one year post-tag loss), while three known adult female pygmy killer whales (*Feresa attenuata*) have been documented with calves. These three females were documented in an average of 5.3 years. Two species with long inter-birth intervals (short-finned pilot whales (*Globicephala macrorhyncus*) ~5 years; false killer whales (*Pseudorca crassidens* ~6-7 years) and some post-reproductive females in the populations have a lower proportion of known females that have been documented with calves post tag loss. For false killer whales from Cluster 1 of the endangered main Hawaiian Islands population, three of 10 females have been documented with calves. Females with calves have been documented an average of 6.3 years, while those without calves were seen an average of 3.2 years, suggesting that the relatively low proportion of females documented with calves is related in part to the small number of years they've been documented. Three of 16 female short-finned pilot whales

have been documented with calves, with those with or without calves seen in an average of 3.3 years post tag loss. Given known factors influencing the likelihood of detecting calves (*e.g.*, long intervals among sightings, long inter-birth intervals, duration of study), the evidence suggests that LIMPET tagging is not preventing reproduction among tagged adult females. For false killer whales and short-finned pilot whales, survival of tagged and untagged individuals was estimated using Cormack-Jolly-Seber models. These models tested the hypotheses that survival and capture probabilities were influenced by acute or chronic tag effects, varied by social cluster or time, or a combination of these factors. Overall, results indicated that survival estimates of tagged and untagged false killer whales and short-finned pilot whales were not significantly different, although it should be noted that the power to detect an effect is low, given the relatively low average capture probability and the relatively small proportion of individuals in these population that have been tagged.

Calambokidis discussed development and experience with dart-attached archival tags. Starting in 2014 Cascadia Research, working with collaborators, has been deploying dart-attached archival tags on blue (*Balaenoptera musculus*), fin (*B. physalus*), and humpback (*Megaptera novaeangliae*) whales in the eastern North Pacific. These tags have dramatically increased the amount of detailed multi-sensor (including acoustics) data being gathered with the longer tag durations, and have helped inform: 1) studies of ship strike risk and interactions between ships and whales, 2) behavioral response studies to Navy sonar, and 3) studies of vocalization rates of blue and fin whales. A few key insights from these efforts include: a) longer tag durations mean longer periods for animals to travel away or interact in ways that might compromise tag (this makes use of a satellite transmitter for recovery of the tag and knowing when the tag is off the whale essential), b) contact among whales occurs more frequently than realized previously. This information comes from observation of contact by suction-cup attached video tags as well as suggestion by the type of damage to the dart-attached tags, c) use of stainless steel darts and petals and modified heat treatment to improve malleability and reduce brittleness, which dramatically reduced/eliminated dart and petal breakage that had been seen in initial deployments using titanium darts, and d) additional recent evidence of new injuries and tissue retained on darts after loss from the animal which is being used to evaluate response to tags. Two important issues to consider in the continuation of this work include: i) evaluation of the tradeoff between dart material selection to reduce breakage versus selection for inertness in the event of retention, and ii) evaluation of the use of topical antiseptic coating to address control of microbes and fungus pushed into the tag site by deployment.

3.1.2 Type B tags

Balmer shared factors influencing transmission duration of fin-mounted tags. The factors that influence transmission duration of satellite tags can be highly variable and difficult to assess without systematic follow-up studies of animal and tag condition. Bottlenose dolphins tagged during health assessments in the estuarine and coastal waters of the southeastern U.S. have relatively localized movements that allow for a more detailed assessment of factors that influence transmission duration. The goals of this study were to identify and review these factors from previous studies that deployed single-pin, fin-mounted tags (radio and satellite); test these factors utilizing computational fluid dynamics (CFD) models to identify optimal tag placement on the dorsal fin and modifications to the single-pin satellite tag design; and evaluate a new single-pin satellite tag design through subsequent field studies. The results of this study suggest that optimal single-pin tag attachment is > 30 mm from the trailing edge and along the lower third of the dorsal fin. Of the 87 single-pin satellite tags deployed from 2011-2016, 46% (n=40) ceased transmitting as a result of battery failure, suggesting that options to extend battery life without increasing tag size and/or weight may be of value. Attachment was the second leading cause of tag failure in which potential modifications to the attachment flanges/pin/nut may increase tag transmission durations. A low number of tags ceased transmitting because of damage to the antenna, biogrowth, or migration of the tag out of the dorsal fin.

Wells shared results about health, behavior and vital rates of tagged bottlenose dolphins. Since the 1970s, telemetry has provided much information about small cetaceans that could not have been learned in any other way. As technology improves and more sensors are added to tags, the potential for data collection will increase tremendously. Tag designs are compromises between minimizing: 1) the risk of injury to the animal, 2) drag, 3) mass, and 4) thermoregulatory effects, while attempting to maximize: 1) signal strength, 2) range, 3) location accuracy, and 4) longevity of the transmissions and the attachment. Until recently, electronic tags were quite large and required multiple pins to secure them to dorsal fins, sometimes leading to fin injuries. Efforts since 1975 by the Sarasota Dolphin Research Program and collaborators to develop safe and effective electronic dolphin tags have led toward using only a single attachment pin, mounted low along the trailing edge of the dorsal fin, with a trailing tag. Computational fluid dynamics modeling was used to refine the design of Wildlife Computers SPLASH time-depth-recording tags to reduce drag and improve attachment performance. Modifications were made to the tag shape and

size, and lock nuts were replaced with thread-forming flat-head screws, altogether reducing drag by about 50%. ONR-sponsored field tests of the resulting design were conducted during May-August 2012, involving health assessment, tagging, monitoring and recapture of long-term resident bottlenose dolphins in Sarasota Bay, FL. Ten dolphins were tagged in May 2012. Five of these tags were treated experimentally with *Propspeed* antifouling coating. The dolphins were observed, photographed, and video-recorded over the 69-92 days they carried tags. Eight of the dolphins were recaptured in July 2012, the tags were removed, and health assessments were performed, 69-75 days after deployment. The remaining male pair was observed until the tags came off their fins, as designed, sometime between post-deployment day 92 and day 119. Analyses indicate that the new tag design worked very well. Fin damage was minimal compared to earlier tag designs, with little or no migration of the attachment pin through the fin. Observations of the tagged dolphins with the tags found no behavioral differences associated with the tags, in terms of respiration patterns or ranging patterns. No differences in social patterns were observed. In total, three females were tagged for the experiment. Both tagged adult females became pregnant while carrying tags, and all three have had subsequent calves. Follow-up assessments during tag removal in July found no indication of health problems associated with the tags. The anti-fouling coating worked very well. Minimal growth occurred on coated tags as compared to the heavy growth on uncoated tags (up to 38% increase in mass from barnacles and algae). Every indication is that the tag design, attachment, and coating combination developed and/or tested during this experiment are a significant improvement over previous designs, in terms of performance and reduction of risk of injury to the animal.

Moore presented preliminary results on the development of a new remote tag application device (the TADpole). The prototype developed by Wells and Moore is designed to attach an off-the-shelf SPLASH Finmount satellite-linked TDR tag to bow-riding dolphins, and collect a genetic sample from the tagged individual, with a view to adapting that tool to other cetacean species with dorsal fins, and to other tag configurations such as the SPOT location-only tag. The tag is loaded into a pole-mounted holster that delivers it to the dorsal fin when the animal surfaces. Tag attachment is triggered when correctly positioned on the fin. Attachment and biopsy retrieval occur pneumatically. This new device is undergoing field-testing and is expected to allow for remote deployment of satellite-linked tags in some cetacean species that currently require capture and restraint in order to deploy Type B tags. This tag concept could also be considered for large whales with dorsal fins, to replace more invasive systems.

3.1.3 Type C tags

Kleivane presented information about tag anchor designs. More than 20 years ago the first whale was anchor tagged with a tube satellite tag using the Air Rocket Transmitting System (ARTS) launching system. Since then, this deployment device has been widely in use and a large number of tags have been deployed on a variety of species. However, the tag anchoring design has not been modified in a significant way over the years. Tagging projects have developed their own anchoring system with some differences, but typically obtaining a tag-sensor component and integrating it with custom-made cutting anchor holding various fly systems. Similar tag designs are performing very differently, even on the same species, and good replicate data for duration of the tags on whale time is rare.

Double presented a summary of the tag development project conducted by the Australian Antarctic Division, which began in 2003. Initially the project aimed to develop a ‘blubber only’, invasive ‘Type C’ satellite tag for large baleen whales. Various tag designs of lengths less than 20cm were deployed on humpback and blue whales between 2003 and 2008. The performance of these tags (days transmitting) was generally poor with 50% (n = 54) providing no location data and only 17% providing location data ten or more days following deployment (mean = 1.5 days; median = 0.5 days). After 2007 the tag length was increased to around 30cm and the performance improved greatly to a median of approximately 27.5 days (mean = 44 days; n = 288). Although superficially this suggests tag length is key for improved tag performance the evidence from this study remains equivocal. Prior to 2007 the high proportion of tags that failed to provide any location data suggests immediate electronic, structural or deployment failures. The specific causes of failure could not be identified without follow-up, which is not feasible for migrating whales in large populations. Of the pre-2007 tags that provided some location data 85% ceased transmitting within 12 days after deployment. These data suggest poor retention, but structural failure of the tag is also possible (and has been observed in other studies). While it remains unclear whether tags less than 20 cm can be developed that deliver reasonable retention times our recent data suggest Type C tags of 22.5 cm perform similarly to the ~30cm tags now commonly used on large whales. At three locations (two off Australia and one off Antarctica) 22.5 (n = 24) and 30cm (n = 17) tags were deployed in approximately equal numbers on humpback whales. The mean and median deployment durations were similar for both the long and short tag types (mean = 42.5 & 34.6; median = 34 & 30 days respectively). In conclusion, in this dataset deployment method, tag design and tag robustness confound any analysis of tag performance by length and so these data should not be used to infer that short (~23 cm) or even

‘blubber only’ (< 14 cm) tags cannot be developed for large baleen whales. Indeed, recent data suggest short (but not ‘blubber only’) tags can perform as well as commonly used long (30cm) tags.

Zerbini, Gulland and Robbins presented the results of a follow-up study conducted in the Gulf of Maine from 2011-2015 to assess tag performance and impacts in North Atlantic humpback whales (*Megaptera novaeangliae*) and to develop robust large whale satellite tags. This study represented two projects, a NOAA/API-funded NOPP with supplementary funds from the US Marine Mammal Commission and another supported by ONR. During this study, sixty-five Type C satellite tags were deployed on well-studied individuals with strong prior residency characteristics and known demographic traits. Short-term responses to tagging were assessed during a one-hour focal follow of each tagged whale and a control sample was established from comparable whales that were also identified in the tagging study area. Tagged whales were regularly re-encountered to assess the state of the tag, tissue responses and the overall condition of the whale. A scoring system was developed to quantify tissue responses at the tag site and statistical modeling was employed to identify variables influencing tag duration and potentially responsible for a range of host responses. Mark-recapture statistical analysis was used to compare survival, detection probabilities and calving probabilities of tagged whales and controls. This was a designed study of tag performance and impacts intended to address: 1) physical and physiological responses to satellite tags; 2) deployment and design factors as they relate to tag performance and the potential for impact on tagged individuals; 3) behavioral responses to tagging, including the potential for post-tagging shifts in distribution; and 4) movements and habitat use of humpback whales in the Gulf of Maine. One of the most significant outcomes of this study was the detection and correction of multiple design flaws in tags that had been previously tested and used widely in the field. One involved a feature that was common to a range of tagging projects conducted over the past 10-15 years, and it is possible that similar failures have occurred previously but were not documented. Gulf of Maine humpback whales were relatively resilient to the tag designs and deployment practices applied in this study, at least through the observations made to date. All females tagged through 2013 survived through 2016. They were less likely to calve in the first year after tagging than control females, but this effect may have been related to breakage versus proper tag function. Mark-recapture statistical results were equivocal regarding reduced survival among adult males versus controls, but possible effects were limited to years of tag breakage. Tag site tissue responses tended to diminish over time. One of the most consistent predictors of host response was the location of the tag on the body, which appeared to influence both tag site tissue responses and animal behavior. Although these results must still be validated in other species, they suggest that deployments that target the upper flank near the dorsal fin are least likely to produce a negative effect. Contrary to other studies, tagged whales exhibited pronounced immediate and extended responses to tagging and the significance of these responses is still under investigation. The need to repair tag designs led to the development of new fully integrated satellite tags over the course of the study. Deployment of these tags resulted in significant increases in tag transmission duration, reduced tag-related tissue responses and possibly other changes. This study highlights importance of follow-up studies to evaluate and improve satellite tagging technology. Its findings confirm that even with prior testing and wide use, Type C tags do not necessarily perform as designed. Given the number and nature of the flaws that were detected, fully integrated tag designs may be the most appropriate way to minimize the risk of Type C tag breakage and associated injuries. Continued efforts to develop more robust and benign anchoring systems would enhance the scientific value of this technique and reduce risks to tagged individuals.

Mate discussed tag adaptations in a variety of deployments. Most Oregon State University (OSU) Argos tags have been like those described in Mate et al. (2007). From 2007 to 2013, pop-up archival advanced dive behavior (ADB) tags using Wildlife Computer PATF Mk 10 technology were developed (Mate *et al.*, 2017), which required release from the whale and recovery. Attachment durations up to 42 d were achieved using an attachment "sleeve" that was 26 mm in diameter with the same style of bladed nose cone and attachment petals as OSU conventional Argos tags. During this development, there were problems with the burn wire, which released the tag from its housing/sleeve either too early or not at all, as well as epoxy casting issues that allowed saltwater intrusion. The tags were too heavy to float if the tag was shed while still in the attachment "sleeve", but were programmed to release after sitting on the bottom for >24 h. ADB tags were attached to sperm, blue and fin whales. Except for ADB tags, the rest of the tags were like those in Mate et al. (2007) using ST15, ST16, ST21, RDW 660/665 from Telonics (19 mm diameter) or SPOT-5 and -6 tags from Wildlife Computer (20 mm diameter), varying in length from 22.8 to 27.8 cm. In 2009, the “shortest” two battery-cell version of the SPOT-5 tag (22.8 cm) was deployed on Pacific Coast Feeding Group (PCFG) gray whales (*Eschrichtius robustus*) off northern California along with “longer” 3-cell (27.8 cm) tags typically used. Although the sample size was small, average transmission duration was significantly longer (mean = 113 d) for long tags than for short tags (mean = 65 d). In 2016, the thickness of petal attachments was changed from 0.010” to 0.015” to improve their holding power. However, there was no discernable difference in attachment

duration for either blue or fin whales. In July 2017, the petals of the row closest to the nosecone (opposite of the previous design) were lengthened, but results are not yet available. In 2016 and 2017 RDW 665 tags were deployed in the same housing as past location-only tags, but with onboard pressure sensors and accelerometers which could detect feeding lunges and analyze these data on board to report summarized dive and feeding information through Argos without the need for tag release and recovery, as required for older ADB tags. Preliminary results spanning periods >3 months demonstrated changes in dive depths and numbers of feeding lunges as blue and fin whales moved over large distances, providing insights into individual and environmentally-related variability.

Heide-Jørgensen presented results from deployments of satellite tags in North Atlantic baleen whales. These species are often found in rough seas, and in some areas and seasons in dispersed pack ice. Tagging of whales is often done in offshore operations from big vessels and sometimes even from helicopters. Furthermore, several of the whale species are very skittish compared to whales in other areas, perhaps as a consequence of past and present history of exploitation and interactions with other human activities. These circumstances make tagging of whales particularly difficult and only remote instrumentation techniques that are refined for long distance deployments will provide reliable tagging results. The toolbox for tagging of whales in the North Atlantic includes both the Air Rocket Transmitter System (ARTS), the smaller Dan Inject rifle, compound crossbows and an 8 m fiberglass pole. The most widely used approach is the ARTS that is often used with the cylindrical location-only (SPOT) tags (20 mm diameter configuration with separate anchoring system) that penetrates the skin and has a spear that penetrates at varying depths. Depending on the species, the tag anchors in the blubber or below the muscle/blubber interface. The larger archival (MK10/SPLASH) tags (22 mm diameter) are also sometimes used for collecting dive data but these tags are considered sub optimal due to their relatively large size and mass. Both tag configurations can be shot into the whales at long distances and even from a helicopter, but the success of the deployment depends heavily on the ballistics of the instrument package and the plastic rocket/applicator that carries the tag and ensures a straight flight to the whale. The fiberglass pole is primarily used for attaching large instrument packages, some for short-term duration, which includes dive data collection, acoustic recorders (Acousonde tags), CTD tags and fluorometers. This deployment method is primarily used on bowhead whales (*Balaena mysticetus*) but has also been used on humpback whales. Some of these tags are mounted in a swing configuration that allows the tag to turn with the water flow on the back of the whales. This has proven to be very successful on bowhead whales where about 10% of archival tags have lasted >1 yr. It has proven to be a successful deployment method for the larger CTD tags where maintaining a water flow along the axis of the whale is important. Short-term effects of tagging on whales included increased stroking activity for up to several hours after the whales have been approached. Longer chasing of the whales also increases the risks of a detrimental physiological conflict between bradycardia (dive response) and increased stroking (flight response). The long-term effects include inflammation of the tagging area eventually with rejection of the tag. Evidence of strong healing ability in cetaceans has been observed. Tags deployed on harbor porpoises (*Phocoena phocoena*) and narwhals (*Monodon monoceros*) can be embedded (enclosed by) in the skin, but this is unlikely for large whales where the opening through the skin and the vibrations of the tag caused by water flow, associated with the physiological rejection of a foreign body, will eventually result in the loss of the tag.

Calambokidis and Norman reported on a collaborative study of blue whales and PCFG gray whales that had been tagged by Oregon State University. This BOEM-funded NOPP study focus was on identifying the individual whales that had been tagged and synthesizing follow-up information on these whales. Follow up information was used to examine resighting rates and survival estimates of tagged animals in comparison to a group of control animals (animals seen in the same areas and times as when animals were tagged but were not tagged). While there were some possible indications of lower resighting rates of PCFG gray whales in years following tagging, they were not significant, and survival models including a tag effect were not significantly different from other models without this effect. There were no indications of higher mortality in tagged blue whales though sighting histories were sparser. There were a few cases of significant swelling in one case appearing to impact reproduction in a blue whale that apparently retained a prong from an earlier tag design (Gendron *et al.* 2015). Follow up studies are essential but often have low power due to small sample size and low resighting rates.

Norman shared information about photographic assessment of tag-wound healing of North Pacific blue whales and PCFG gray whales (Norman *et al.*, 2018). Implantable satellite tags are used extensively in tracking whale movements but there is little detailed information on long-term wound healing. Methods to assess external consequences of tag deployments and wound healing in 34 gray and 63 blue whales were developed. Tag-site appearance and healing characteristics were evaluated by two reviewers and a time series evaluated by five veterinarians from photographs taken during 995 post-deployment encounters. Extensive follow-up observations of blue whales were more dispersed over a longer period than the more focused gray whale observations. Swellings

were common in blue whales where pieces of tag were retained from earlier tag designs, but rare with current tag types. Depressions occurred in most gray (82%) and blue (71%) whales. This study also demonstrated the value of follow-up studies of tagged animals and systematic scoring to compare tag response.

Minamikawa discussed deployment of pop-up archival transmitting tags on Pacific white-sided dolphins (*Lagenorhynchus obliquidens*), and differences in attachment duration by anchor type. The attachment durations of pop-up archival transmitting tags deployed on Pacific white-sided dolphins were compared between the anchor types. Although the maximum attachment durations of the Wilton dart were longer than those of the titanium dart, there was no significant difference in mean attachment durations between anchor types because of large variance. Falling off within a short period of time was thought to be due to the bad tagging position and penetrating angle.

Moore shared results of an ONR-funded study investigating dolphin blubber/axial muscle shear, and implications for rigid, trans-dermal, intramuscular tracking-tag-associated trauma in whales (Moore and Zerbini, 2017). Whale-tracking tags often penetrate semi-rigid blubber, with intramuscular sharp tips and toggling barbs under the subdermal sheath to reduce premature shedding. Tag sites can show persistent regional swellings or depressions. Fibroelastic blubber grips a tag, so if muscle shears relative to blubber during locomotion, the tag tip could cavitate the muscle within overall shearing distance. Shearing of blubber relative to muscle was modelled within the dorsal-ventral peduncular movement range of four common dolphin (*Delphinus delphis*) cadavers (mean length 186 cm). The net change in angle and hence tip distance moved was calculated with dorsal and ventral flexion, between 1.5 mm diameter needles inserted into blubber only, versus through blubber into muscle. Shearing ≤3.6 cm, was greatest ventral and caudal to the dorsal fin. Scaled dummy tags were also inserted and the animal cyclically flexed dorsally and ventrally for 18 hours. Tag sites were dissected and cavities around the tag tips documented. If this shearing is comparable in large whales, depressions and regional swellings observed with intramuscular tracking tags are likely the result of tissue loss and repair respectively. Placing tags para-sagittally anterior to the dorsal fin would cause the least trauma, but pain from such tags remains a concern. Regional swellings and divots observed with intramuscular tracking tags in large whales are likely the result of underlying muscle swelling and necrosis, respectively. Similar studies with entanglement/abrasion in cadavers matches quite closely with necropsy findings of entangled whales (Moore *et al.* 2013), so the paradigm appears to be followed with tagging. Findings of this study warrant further consideration of engineering tags that can remain attached for multiple months without penetrating into the muscle, or to consider developing tags that penetrate the sub-dermal sheath but minimize trauma by anchoring at the fascia, and compensate for shearing.

3.1.4 Use of antibiotics during invasive tag placement

Mulcahy discussed antibiotic use during tag placement and advised that antibiotics should not be used without a demonstrated need, or misused in any form (*e.g.*, antibiotic ointment on a tag). Demonstrated need should be documented, through observation, culturing of tag sites, and necropsy. It is important to establish a working relationship with a knowledgeable wildlife veterinarian, to share knowledge and ask for advice, as well as to follow national laws and conventions covering antibiotic use. If antibiotics are used, as much data as possible should be collected about the potential for post-tag infections. Mulcahy also described the difference between an antiseptic[1] and an antibiotic, which largely differ in mode of action. Antibiotics inhibit growth through a metabolic route, while an antiseptic is a chemical that directly denatures something that causes the death of the pathogen. Aseptic technique reduces the need for antimicrobials, thus the focus should be on using these techniques, rather than use of antibiotics.

3.2 Non-invasive Tags

Shorter discussed results of tag design testing from a NSF-funded NOPP study. The overall goal of this project was to increase the longevity of suction-cup attachments for short-term archival tags such as the DTAG. Specifically, work is underway to extend the routine attachment duration for this tag type to multiple days by improving the hydrodynamic design of the tag body, characterizing the response of skin and soft tissue to pressure loading, and developing quantitative metrics to assess the impact of a tag on the animal. This presentation focused on: 1) simulation and experimental results for a new hydrodynamic housing design; 2) experimental results of soft-tissue testing; and 3) algorithm development and experimental design that enhance fine-scale motion analysis of tagged

[1] Throughout this report, antiseptic is defined as an agent that inhibits or destroys microorganisms that is applied to living tissue including skin, oral cavities, and open wounds. Aseptic constitutes as a set of specific practices and procedures performed under carefully controlled conditions with the goal of minimizing contamination by pathogens. Sterile is defined as an environment in complete absence of microorganisms, including bacteria, fungi or their spores.

dolphins. During an on-animal attachment, drag forces acting on the tag can remove the package or adversely affect the behavior or energetics of the animal. As such, it is important to be able to predict the forces generated by the tag in fluid flow, and develop designs that reduce those forces as much as possible. Computational fluid dynamics simulations were used to aid in the design of a housing that greatly reduces the magnitude of the forces compared to the current DTAG housing. The forces created by the tag are transferred to the animal through the suction cups at the point of attachment, potentially creating elevated pressure loading. In an effort to understand how pressure loading affects soft tissue at the attachment site, a series of experiments using controlled pressure loading were conducted at multiple sites on nine bottlenose dolphins, and the results demonstrate that pressure response is dependent on the site-specific anatomy. The ability to test the performance of the tag on a swimming animal is essential for testing and assessment of potential effects of drag loading on the swimming mechanics of the animal. This work addresses this through the development of a controlled experimental environment with dolphins in a managed environment, and a method to estimate the location of the animal in the managed environment by combining measured animal dynamics from biologging tags with position and speed estimates derived from overhead video data. The results from this project will lead to the creation of improved suction cup based tags, and a controlled experimental environment for tag evaluation.

van der Hoop discussed the effects of drag on swimming animals. Biologging tags add drag to swimming animals. Understanding how increased drag affects individuals' behavior, metabolics, and kinematics is critical for improving tag attachment, refining tag design and dimensions, and assessing the impact of tagging on study animals. van der Hoop reported results from an experimental setup to measure drag forces on tags and the resulting effects on animals' metabolic rate, swimming biomechanics, and behavior (van der Hoop *et al.*, 2018). To investigate drag effects, bottlenose dolphins in human care have been instrumented with a modular tag built on the design of the DTAG3 (an external, suction-cup tag) to increase the hydrodynamic drag by up to 2.4×. van der Hoop *et al.* (2018) found no significant difference in oxygen consumption rates when four male dolphins performed a 10-min swimming task with different levels of drag loading, but measured swimming speeds that were up to 34% (>1 m s^{-1})_slower in the highest drag condition. When swimming speed was constrained using a remote-controlled boat driven at relatively constant speeds, the effect of exercise on oxygen consumption increased between the control (no tag) and tag drag conditions. To further investigate the relationship between speed, drag and biomechanics, drag was incrementally decreased and then increased in six loading conditions, as animals swam at their own pace. When drag was reduced, dolphins increased swimming speed (+1.4 m s^{-1}; +45%) and fluking frequency (+0.28 Hz; +16%). As drag was increased, swimming speed (0.96 m s^{-1}; -23%) and fluking frequency (-0.14 Hz; -7%) decreased again. Swimming efficiency and maneuverability declined at the highest levels of drag loading. Swimming speed was consistently adjusted to levels that maintained external drag forces, based on Computational Fluid Dynamics simulations. Combined results from the experimental environment via camera-tracking algorithms, biomechanics from multi-sensor tag data, and respirometry suggest there are quantifiable responses to the added drag loading. The modular approach has also allowed the investigation of the effects of various sizes and the formulation of recommendations of tag-size to body-size ratios for deployments across species. The experimental approach is valuable to investigate the effects of tags of smaller sizes and the importance of *e.g.*, tag placement.

3.3 New Approaches from the Biomedical Field

Rajachar discussed results from an ONR-funded project, including the potential use of hydrogels in cetacean tagging. Hydrogels are water swollen gels of polymers held together by inter-linking forces (cross-links). Cross-links can be chemical (covalent bonds between chains) or physical (van der Waals, ionic, hydrophobic, hydrogen bonding interactions) in nature. The inherent character of the polymer draws and retains water in the gel and the cross-links allow for the maintenance and tailoring of the properties. Hydrogels have great use for biological applications since most tissues owe a significant portion of their final architecture and function to the presence of water in their hydrated state. Adhesive hydrogels, more specifically, can be defined as hydrogels that are capable of physically or chemically binding (cross-linking) to biological tissue and/or implantable materials or devices thus also allowing for a more seamless transmission of physical and chemical cues. Composite adhesive hydrogels that can integrate and reliably gel under the relatively harsh environmental conditions associated with marine mammals have the potential application to help stabilize satellite telemetry tags for large whales. Existing hydrogels are limited by their inability to gel under non-physiologic pH, salt, and lipophilic content similar to what is seen at the skin-blubber interface in large marine mammals. Rajachar looked to use the tissue-cell adhesiveness and inducible gelation chemistry (i.e. tissue factor and thrombin activated) of fibrin-based hydrogels and the marine mussel adhesive amino acid, 3,4 di-hydroxyphenylalanine (DOPA), that enables mussels to attach to both organic and inorganic surfaces in hydrophilic and salt micro-environments to create a prototypical composite adhesive hydrogel

that is 1) able to integrate and gel reliably; 2) act as a strong tissue-device (tracking tag) interface promoting integration, and 3) act as a natural antimicrobial/antifungal even under relatively harsh pH, salt content, and hydrophobic-hydrophilic tissue microenvironments. Using the hypothesis that improving tag biocompatibility will improve tag service life, preliminary results from the current research program have shown that: 1) a composite tissue-adhesive hydrogel to aid in stable wound healing can be made that can reliably gel under the harsh environmental conditions seen in service including high salinity, the varying pH seen in the deployed tag tissue environment, and under solution conditions consisting of elevated lipid content seen in whale blubber compared to normal biological tissues; 2) surface modifications including protrusions and dimples of low pitch angle can potentially be used to reduce surface shear stresses and improve stability of deployed tags by improving the wound-healing microenvironment (reduced damage and exposure to elevated stresses with time); 3) regenerative polymer surface coatings can potentially minimize potential infective agents at the tag surface during deployment using antibiotic-free means such as transient local delivery of reactive oxygen species.

4. CETACEAN TAGGING BEST PRACTICES GUIDELINES

Andrews provided an overview of the development and content of the draft Cetacean Tagging Best Practices Guidelines. A draft document produced by a group of twenty-two co-authors was circulated to the workshop participants one month before the workshop for review. The goal was to have participants reflect upon the information presented in the Guidelines, and if necessary suggest revisions to the document in light of the discussions held throughout the workshop. Time was dedicated during the workshop to compile a list of agreed upon revisions to the Guidelines (Annex G) with the understanding that, pending those suggested changes, the workshop would recommend the IWC endorse the Guidelines. The list of required major revisions, as presented in Annex G, was agreed upon by the workshop participants and the Guidelines co-authors in attendance (10 co-authors, including the four lead editors). The workshop participants agreed to recommend to the IWC Scientific Committee (SC) that the SC should endorse the Guidelines at their next meeting, as long as those revision recommendations were addressed satisfactorily. Whether the Guidelines co-authors did adequately address the revision requests would be determined by the chair of the Silver Spring workshop (G. Donovan), where the Guidelines were discussed. Upon review of a revised version of the Guidelines (Andrews *et al.*, in review) the workshop **recommended** these guidelines to be endorsed by the IWC Scientific Committee.

5. DISCUSSION OF CURRENT RESEARCH AND FUTURE RESEARCH NEEDS

During the Silver Spring workshop, participants were divided into two breakout groups generally along the lines of: "tag users" and "veterinarians" to discuss research needs to further develop tag attachments, better assess tag impacts, and improve animal welfare in tagging studies. The terms of reference for these two groups are presented in Table 1.

Table 1 – Terms of reference for the break-out groups

Tag Users	Veterinarians
1. From the results of the studies presented in item 4 above, discuss potential modifications in tags or deployment methods that can be implemented in the short-term and lead to improvements in tag outcomes. 2. Identify research needs to further develop tag designs; 3. Identify research needs to better assess impacts (*e.g.*, best methods, level of effort required); 4. Discuss choice of best candidates for tagging or evaluation of tag effects on individual, population or species level.	1. Discuss a standardized review and scoring of photographs to improve assessment of tag effects. 2. Best assessment for how to obtain goal of maximum duration with minimum impact. 3. Research needs or future directions to better assess impacts 4. What questions do you have for the tagging community? 5. Discuss choice of best candidates for tagging or evaluation of tag effects on individual, population or species level.

A synopsis of each breakout group's discussion was presented by a rapporteur and was followed by discussions with all workshop participants. These plenary discussions culminated in the compilation of a list of recommendations for the future of cetacean tag development, use and assessment. A similar endeavor occurred during the Seattle meeting, and the explanatory text and accompanying recommendations listed in items 5.1 to 5.6 below are an integration of the discussions and recommendations made during both the Silver Spring and Seattle meetings.

During the Seattle meeting, before drafting key recommendations, an exercise was conducted to identify the most critical challenges of successfully conducting invasive tagging with cetaceans. Participants were asked to list their top five limitations and shortcomings of current attachment methods. Meeting participants then determined the five most commonly reported challenges or limitations:

- Deployment – It is difficult to remotely deploy tags with accuracy and precision.
- Follow-up – It is challenging to conduct effective follow-up studies in order to improve the tag design and understand tagging effects on animals.
- Tissue response – Ignorance of the tissue response to tagging, including normal wound healing, skin flora and potential pathologies, hinders progress.
- Uncertainty about causes of tag failure – It is critical to better understand the causes of tag failure to improve tag designs and to prove efficacy of telemetry studies.
- Anatomy – Poor understanding of variations in skin, blubber, fascia and muscle anatomy within and amongst individuals and species hinders tag design and deployment strategy.

After the exercise to identify these key challenges and limitations, breakout groups further clarified the challenges and identified potential solutions, which carried over to the subsequent discussions. The information presented below is a summary of the discussions from both meetings, resulting in specific recommendations for the future of cetacean tag development, use, and assessment, agreed upon by the workshop. Broad categories were used to organize the more detailed discussion within each topic and are made up of: 1) Data Sharing, 2) Anatomy and Physiology, 3) Tag Sterilization, 4) Tag Deployment, 5) Tag Attachment, and 6) Tag Follow-up. For clarity, points of discussion that were related to each other are grouped where possible, though some overlap exists between the broad categories. For a list of all recommendations see Section 6 below and Annex H. Overall, the workshop participants **agreed** that the over-arching goal within the tagging community is to extend tag duration, while minimizing impacts to the animal.

5.1 Data Sharing

5.1.1 Tag registry and deployment databases

The Workshop noted that many tag types are not recovered once they detach from the tagged individual (*e.g.*, medium and long-term satellite tags) but that retrieval could yield important data that are retained in the memory of the tags, but not transmitted. The workshop **agreed** that, going forward, an international tag registry, perhaps using existing broadly used databases (*e.g.*, the U.S. Animal Telemetry Network, ATN, Moustahfid *et al.*, 2011), and/or imprinting of serial number and contact information on tags would facilitate identification of the instrument's owner in case of tag recovery by a third party. More critically, the participants recognized that developing a centralized database with information on tag deployment, tag performance and tag effects (*e.g.*, from follow-up of tagged cetaceans) would be beneficial to improve data standards, facilitate data management, and promote sharing of information across the community and regulatory agencies. Such a database could be incorporated in existing initiatives (*e.g.*, the ATN) or be developed by governmental (*e.g.*, national regulatory agencies) or intergovernmental organizations (*e.g.*, the IWC).

Developing a form to standardize data collected upon tag deployment and sharing this form with the tagging community would be important to promote data collection in a consistent fashion and facilitate integrated analysis of large datasets for tag attachment performance. This is particularly useful as the use of electronic tags becomes more widespread in the future. One potential way to share this form would be for tag manufacturers to distribute the form when a tag is purchased and shipped. The form could be linked to a site for data submission. This site could also hold data on tag effects in case tagged animals can be followed after tag deployment. A tag deployment database could also facilitate the identification of previously tagged cetaceans by unaffiliated researchers or stranding responders (see Section 5.1.2 below). The workshop proposed that a data form template be developed, and that it potentially could be added to the Guidelines.

Additionally, the workshop recognized that sharing of information across tag users, veterinarians, and other scientists involved in tagging-related studies should be enhanced in order to further develop tagging technology and understand impacts of tags on cetaceans.

Recommendations:

The workshop **recommended** tags to be permanently marked with a unique serial number and contact information to facilitate identification in the case of third party recovery.

The workshop **recommended** that a central database be developed to:

(a) Collate information on tag deployment (*e.g.*, species, tagging platform, deployment system, tag type, tagging range and pressure, animal identity, geographical location, tagging date), tag performance metrics and follow-up of tagged animals (*e.g.*, tag wound photographs, documentation of injuries, stranding) in a standardized fashion,

(b) Facilitate analysis of factors influencing tag duration and tag impacts,

(c) Serve as a source of information for regulatory agencies,

The workshop **recommended** that a standardized approach and database to enhance communication among the tagging community be developed to share experiences, information on development of tag delivery and tag attachment methods, and information on tag performance and tag impacts.

The Workshop recognized that there is large variability in tag duration, for a variety of potential reasons (*e.g.*, species, location on the body, depth of penetration, tag type). Because of this large variability, statistical analysis and understanding the factors involved in tag duration require large sample sizes. Collecting and collating data in a standardized way can allow these questions to be assessed. The workshop recognized that existing information (*e.g.*, from community databases, laboratory or individuals) on duration of tags already deployed might offer an opportunity to investigate factors affecting tag duration, and to potentially understand variability in tag performance between and within species as well as differences in duration across tag designs.

Recommendation:

The workshop **recommended** that existing tag deployment information be combined in order to develop meta-analyses to:

(a) Identify factors affecting tag duration,

(b) Understand variability in tag duration between and within species,

(c) Understand differences in performance and variability across tag designs.

5.1.2 Coordination between taggers, sightings of opportunity and stranding networks

Participants noted that in certain regions, long-term tagging studies of small populations make it likely that a stranded animal may have been tagged, and stressed the importance of communication with stranding responders. The data gained from stranded, tagged cetaceans is valuable regardless of the population being tagged, so a protocol to have researchers provide information on tagged cetaceans to stranding networks would be beneficial for the understanding of tag design, function and animal impacts. This will take coordination amongst groups tagging, conducting photo-ID, and stranding networks.

Recommendation:

The workshop **recommended** the development of protocols for communication between tagging programs and stranding networks to understand effects of tagging by:

(a) Providing stranding networks with ID photographs of tagged cetaceans to better assist networks in identifying previously tagged stranded cetaceans and increase exchange of ideas and information,

(b) Specific communication tools could include workshops, notifying stranding coordinators, attending stranding network meetings, preparation of 'outreach' information for government stranding or research coordinators to disseminate,

(c) Development of standardized quantifiable aspects/techniques/parameters to aid in tracking status before, during, and post tag release,

(d) Development of standard operational protocols (SOPs) for necropsies of previously tagged animals and a database to document or archive necropsy findings, along with an effort to synthesize current knowledge. These SOPs may need to be specific to populations with a high proportion of tagged animals as well as the tools to rapidly identify specific individuals.

5.2 Anatomy and physiology

5.2.1 Limited understanding of relevant anatomy

Workshop participants recognized there is relatively poor understanding of variations in skin, blubber, fascia and muscle anatomy within and amongst individuals and species and that this hinders development of tag design and tag deployment strategies. It was **agreed** that areas of future research need to include more extensive descriptions of inter and intra individual variation in the anatomy of the body of cetaceans where tags are typically deployed (*e.g.*, skin, blubber, sub-dermal sheath, vascularization, innervation).

Recommendation:

The workshop **recommended** research to describe inter and intra-species/individual variation in anatomical features to inform future development of tag attachment mechanisms and to guide future tag deployment. In this context, a protocol for appropriate sampling of freshly stranded cetaceans should be developed.

5.2.2 Limited understanding of tissue response to tagging

The difficulty of forensic analyses of free-swimming cetaceans has limited our knowledge about tag attachment injury, including how wound healing occurs, and if the tag wound is a significant problem for the animal. The workshop **agreed** that a better understanding of the tissue response to invasive tagging could be gained in studies with captive or rehabilitated animals or animals under human care, with stranded or sick individuals and perhaps from current whaling operations. The workshop also **agreed** that consideration should be given to convene a group of experts to assess the formulation of an experimental design for a possible study, should it be done with harvested animals. Finally, it was noted that there is a growing body of literature on foreign-body response to implanted materials in humans and the workshop **agreed** that experts on this subject should be consulted in the future.

Workshop participants noted that while photographs of lesions associated with tag sites are available, it is difficult to determine the nature of the lesions without additional information (*e.g.*, whether swelling associated with a tag wound represents hematoma, inflammation or infection). It was **agreed** that biopsies have the potential to provide diagnostic information on the etiology of a lesion. However, it was noted that only in very few cases in thousands of captured animals did a biopsy yield adequate diagnostic data. It was noted that biopsy sampling of lesions associated with tag deployments may be required to penetrate into deeper tissue to obtain an appropriate sample, but that could result in additional harm to the animal. Workshop participants **agreed** that collecting biopsy samples from a tag-related lesion should be decided on a case-by-case basis and in consultation with a veterinarian.

Recommendation:

The workshop **recommended** development of research to:

(a) Understand what drives suites of tissue responses from tagging events (including foreign body, tag type, implant material) with the objective of minimizing short- and long-term effects on animals and improving current tag retention. Such studies should assess the feasibility of using animals under human care, stranded/rehabilitated or sick individuals, or animals from harvested populations,

(b) Assess growing body of literature on foreign-body response to different implant materials in human and other animals in the context of improved tag design.

5.2.3 Pain assessment and minimization

The workshop **agreed** that there is limited information on the pain associated with the deployment or retention of tags in the field, and that determining the extent to which animals interpret pain, the magnitude of the pain and whether it is temporary or persistent, is challenging. Observational studies have documented varied behavioral responses to tagging, including no response, temporary, and severe reactions (*e.g.*, Alves *et al.*, 2010; Robbins *et al.*, 2016). The general standard (*e.g.*, US Animal Welfare Act) is that one should assume that a procedure is painful if the same procedure caused pain when performed on a human, i.e., pain that is in excess of that caused by injections or other minor procedures. The workshop **agreed** that all tags have the potential to cause pain at different stages in the application and rejection process. Future work should investigate whether it is possible to predict how a cetacean might experience pain following tagging and how the animal may change its behavior in response to feeling pain. Sneddon et al. (2014) provide a useful review on the definition of pain and on the existing methods to assess pain in animals, including mammals. These methods include studies to assess changes in behavior (*e.g.*, respiratory rates, body postures), changes in body weight and steroid hormones. The workshop also **agreed** that pain during tag deployment, tag carriage and rejection/loss/post-loss should be minimized by improving tag design, deployment protocols/technique, and anatomic location of application. For instance, pain can be minimized at live capture-release tag bolt-on using local/topical anesthesia, analgesics, or other means, and deployment techniques during live capture-releases or remote deployments (i.e. lowest force, quickest attachment) can also minimize pain at attachment. It was noted that the lack of an overt reaction does not necessarily indicate absence of pain.

Recommendation:

The Workshop **recommended** that further studies and review papers should address:

(a) Basic understanding of potential pain during and following tagging, and how the animal may change its behavior, including swimming kinematics, in response to pain,

(b) Engineering of tag design, deployment systems, deployment protocols, and tag placement during deployment on the part of the body that strive to minimize potential pain as much as possible,

(c) Comparative anatomy and histology to describe nerves, sensory organs and vasculature in skin, blubber, and muscle.

5.3 Tag Sterilization

5.3.1 Tag preparation

The Workshop noted that sterilization (freedom from bacteria and other living microorganisms) of the portions of the tag designed to be implanted in a cetacean body should be required. In the past, disinfection (reduction, but not complete elimination, of pathogens) of implanted tags was commonly accepted, but full sterilization, meaning killing or removal of all microorganisms, including viruses, fungi, protozoa and bacterial spores is now the standard. Portions of the tag designed to remain outside of the skin need to be cleaned and disinfected, but do not need to be sterilized. The sterility of the implanted parts of a tag should be maintained until deployment. This may be difficult in some field situations, but with forethought sterility can be maximized. Shrouds, hoods, or a variety of covers could be used to minimize environmental contamination and avoid accidental handling of sterile portions of the tag. Additionally, tags or peripheral handles could be designed to facilitate easy handling of implantable components to maintain sterilization. It was noted, however, that sterility may not be maintained throughout the deployment because the tag is deployed into a non-sterile environment (e.g., the animal skin). Training, practice, and experience with aseptic technique will help ensure compliance.

Recommendations:

The workshop **strongly recommended** that implantable portions of invasive tags be sterilized prior to deployment.

The workshop also **recommended**:

(a) Training and practice with aseptic technique by tag users,

(b) Directing research to determine the degree of contamination of implantable portions of tags over time under field conditions.

5.3.2 Use of antimicrobials / antiseptics

In discussion of the use of antibiotic coating of tag attachments, it was noted that as bacteria are removed by antibiotics, this may enhance the ability of a fungus to establish locally. It was also noted that previous results of photographic evaluation of wound healing in baleen whales did not show specific evidence of infection in the majority of cases, although it is difficult to differentiate between inflammation and infection remotely. Additionally, antibiotic coatings will not address possible fungal infections, such as seen in killer whale "L95" (case study presented by Raverty in Section 3.1.1). The workshop also noted that in stranded cetaceans, fungal infections are only observed when there is immunosuppression, or when the skin surface is markedly altered.

Local versus systemic use of antibiotics was discussed, and further investigation into the local microflora of the skin was recommended (including sharing existing reports such as the study by Apprill *et al.* 2014). It was noted that this study focused on skin microbiome. It is important to further examine the skin microbial ecology of pathogenic organisms. In humpback whales surveyed in various geographic regions, sequencing survey approaches have demonstrated that a unique ecosystem of microflora exists on the skin containing microorganisms that are distinct from those found in the surrounding seawater (Apprill *et al.* 2011). The sequencing survey data also reveal differences in skin bacterial flora between healthy and health-compromised humpback whales (Apprill *et al.* 2011, 2014). While studies of the skin microbial communities to date do not directly indicate if and/or when an antibiotic coating should be applied to an internal tag, they do describe how the relative composition of the skin microbial communities can differ by geographic area as well as the whale's metabolic state (on breeding grounds - catabolic state *vs*. feeding grounds – anabolic state), and not by sex or age. Based on two core bacterial community members that are shared across populations of humpback whales, the research suggests that skin bacteria may serve to reflect humpback whale health and might serve as a health and skin disorder monitoring index (Apprill *et al.* 2014). Currently, it is unknown what effect the application of an antimicrobial agent to a tag, which by its very nature causes a break in the skin surface barrier, will have on minimizing infection at the tag site or altering the core microbial skin community. Based on studies of skin microbial communities thus far, one suggestion might be to consider the geographic region and metabolic state of the whale population under tagging consideration in deciding whether to use antimicrobial coating on the tag, and if so, what type (*e.g.*, bioadhesive or silver product). However, the bacteria described by Apprill *et al.* (2011) are unculturable, and as far as known not pathogenic. Recognizing their presence is important, the effect of antibiotics on whale microbiomes, the effect of the microbiome on pathogenic bacteria or the effect of stab wounds on the skin microbiome are not known. Thus, any prophylactic antibiotics should at this point be used with extreme caution on implantable tags, with sterile technique a far better option.

Workshop participants noted that a challenge with using an antiseptic on a tag or a dart is that an antiseptic requires extended contact with tissue to be effective, which is problematic as antiseptics are water-soluble and so will likely be flushed out quickly after tag deployment. Additionally, if an antiseptic is put inside a whale, it is going to have a local effect, and a material such as an ointment may act as a foreign body in the whale's tissue. Additionally, antiseptics may cause harm to the tissues one is trying to protect (*e.g.*, Brennan *et al.* 1986).

One potential aspect to further investigate is the manufacturing process of the dart, and whether crevices exist that could be eliminated to reduce bacterial seeding (see Section 5.5.2.1). Surface texture is important for host cellular and microbial viability, thus tag manufacturing should consider surface designs to minimize microbial contamination. Use of additional substances with known antimicrobial properties should be investigated as well, including bioadhesives, silver, and reactive oxygen species.

Recommendation:

The participants **recommended** that before the widespread adoption of antimicrobials in invasive tagging methods, the justification for their use and their potential efficacy and systemic effects should be further investigated.

5.4 Tag Deployment

5.4.1 Ballistic and tag application device accuracy and precision

A combination of tag weight, poor aerodynamics, and a desire to have flight velocity just high enough to obtain full tag penetration may lead to poor ballistic properties for remotely deployed tags, particularly over greater distances. Overlaid with those challenges are the difficulties of precisely hitting a moving target from a moving platform, any combination of which can result in poor tag placement. Poor placement can lead to limited tag functionality (*e.g.*, shorter attachment durations, poor transmission performance), potentially greater forces being applied to the tag than those normally required for placement, and increased risks to the tagged whale. The workshop **agreed** that improvements are needed in the ballistics properties of tags, tag carriers, and in devices used to deploy tags in order to increase accuracy and precision across a variety of tag types and deployment platforms. In addition, the workshop recognized that development of smaller and simpler tags might increase deployment success (*e.g.* placement of the tag in the proper location on the body, increase in duration) and reduce possible failures (see Section 5.5.1).

Recommendation:

The workshop **recommended** that research be conducted to develop improved deployment methods that can safely deliver a tag with increased accuracy and precision, preferably from greater distances than current methods.

5.4.2 Proper training of tagging teams

Tags require precise deployments (i.e. position on the body) in order to optimize performance. A lack of training of taggers and boat drivers can lead to poorer deployments and consequential decreased attachment durations and data return. The group **agreed** that the feasibility and practicality of training courses for taggers and boat drivers in tagging operations should be investigated.

Workshop participants also highlighted the importance of anatomical guidelines to guide tag users and provide information about tag placement and potential for adverse effects. It was **agreed** that invasive taggers need a basic understanding of the anatomy of the animals they are tagging to minimize the potential impact of the implanted portions of the tag to the tissue.

Recommendation:

The workshop **recommended** the development of tagger/boat driver training courses. Trainers should include those with extensive tag deployment experience (including driving), and trainees should be required to have previous experience in collecting biopsy samples. Training should include appropriate information about the species of interest, especially behavior and anatomical details, and descriptions of the areas of the body targeted for tagging.

5.4.3 Selection of a tagging candidate

A decision tree (Annex I) was suggested for assisting researchers in selecting the appropriate population and/or individual for tagging. Additionally, consideration needs to be taken in the field to ensure each individual whale is an appropriate candidate for tagging. The workshop noted that tagging of health-compromised individuals could contribute to worsening of that animal's health. There may be strong justification for tagging an individual in poor health, and this must be assessed on a case-by-case basis (*e.g.*, tracking an animal being treated with a series of injections or disentangled), but for studies seeking more general information on the behavior and movements of a population, a pre-tagging health assessment may be appropriate. Assessing body condition in the field, however, can be challenging and the workshop **agreed** that developing protocols for assessing body condition immediately before tagging is desirable.

Recommendation:

The Workshop **recommended** developing standard protocols for rapid assessment of body condition and health status immediately before tagging (for identifying healthy tagging candidates).

5.5 Tag Attachment

5.5.1 Limitations of current tag attachment designs

Workshop participants discussed the need to identify possible points of failures for invasive tags, which can result in tag breakage with important negative effects to individual animals as exemplified by the southern resident killer whale L95 case (see 3.1.1) and follow-up studies with Gulf of Maine humpback whales (Robbins *et al.*, 2016) and North Pacific blue and gray whales (Norman *et al.*, 2018) (Section 3.1.3). The workshop **agreed** that there is a need for the tagging community to develop protocols to (1) adequately determine the minimum level of robustness for invasive tags across different species and (2) to develop standardized empirical testing of the structural integrity of tag prototypes. The latter would likely include laboratory testing and field assessments of tag performance once minimum robustness standards have been achieved. The workshop also **agreed** that deployment of tags should be avoided in circumstances where high failure rates are suspected or have been documented.

Recommendation:

The workshop **recommended** the tagging community:

(a) Describe required minimum taxon-specific levels of tag robustness,

(b) Develop standard protocol to test the structural integrity of tag prototypes including a combination of laboratory experiments and field assessments of tag performance,

(c) Decide on an acceptable tag failure rate in advance, and if that failure rate is exceeded in field deployments, a comprehensive review of technology and procedures should be conducted.

It was noted that it is often difficult to characterize the causes of lack of transmissions (a summary of potential causes is provided in a table in the Guidelines). The workshop discussed potential reasons for tags to become dislodged. It was hypothesized that some sort of physical trauma likely removes some proportion of the tags that remain attached only for a short period of time. In addition, at least for some species, a small proportion of tags is suspected to be removed by conspecific interactions. If tags are placed in a sub-optimal anatomical location, their placement in different tissue types may lead to them not being retained as if they were placed in an ideal location (*e.g.*, dorsal fin).

The workshop discussed whether existing sensors or new technologies could help send diagnostic information to help distinguish between modes of tag failure. It was noted that temperature and light level sensors have been used to assess the outward migration rate in implantable tags (*e.g.*, Kennedy *et al.*, 2013, Robbins *et al.*, 2016, L. Irvine, pers. comm.).

Recommendation:

The workshop **recommended** exploring transmission of existing and/or additional sensor data to identify potential causes of tag failure.

5.5.2 Future Development Ideas for Tag Attachment

5.5.2.1 INVASIVE TAGS

Workshop participants noted that use of tags embedded only in the blubber resulted in relatively poor performance, at least in terms of tag duration, compared with tags that anchored below the sub-dermal sheath (*e.g.*, Mate *et al.*, 2007). However, many of the results of past comparisons of shorter length (including blubber-only) and longer length (sub-dermal sheath-penetrating) tags may have been confounded by other factors (*e.g.*, failure of the tag package, housing, or anchoring elements). The workshop noted that a rigorous comparison of tag duration of tags implanted in the blubber with tags implanted in both the blubber and underneath the fascia has never been performed. Such comparisons require the use of tags differing only in their lengths and deployments in individuals of the same population and with similar characteristics (*e.g.*, sex and age). Considering that tags that are embedded only in the blubber may reduce the health risk to individual cetaceans, assessing their performance relative to tags that anchor below the muscle/blubber interface is relevant to improving animal welfare.

Recommendation:

The workshop **recommended** the development of rigorous studies to quantify differences in duration and effects of tags on animals embedded only in the blubber and tags that anchor below the sub-dermal sheath.

The workshop **agreed** that continued development of cetacean tag attachment methods is needed and that innovation towards the development of anchoring methods that would minimize risks to individuals should be encouraged, particularly for the more invasive technologies. Development of new attachments should take into consideration materials that are biocompatible, bio-compliant, biodegradable and that could encourage healing and minimize foreign-body responses. For example, certain combinations of biocompatible alloys (*e.g.*, magnesium or zinc) and other materials could degrade the cutting edge and petals with time, which may reduce the traumatic impact of retained parts. Tags or attachment systems using these materials must still have sufficient structural integrity to withstand forces associated with tag deployment.

Additional consideration should be given to materials with anti-microbial, antiseptic and bioactive properties by their design (not, for example, by coating). The workshop also **agreed** that if degradable metals made of magnesium or zinc are used in the engineering of new attachment methods, it is important to determine whether metal ions could produce local tissue reaction as they degrade in cetacean tissue.

Recommendation:

The workshop **recommended** development of new cetacean tag attachments that take into consideration materials that:

(a) Include biodegradable, bio-compatible and/or bio-compliant features,

(b) Minimize tissue trauma (short and long-term), foreign-body response and encourage healing,

(c) Have anti-microbial, antiseptic and/or bioactive properties by design.

Participants **agreed** that there is a need to develop a smaller and lighter long-duration location-only tag for large whales to answer, *inter alia*, important questions regarding migratory destination and population structure. Current technology requires close approaches for optimal tag placement and is therefore difficult or impractical to be used in certain conditions. Modifying the length and the diameter of the tag to reduce size and weight would likely result in less tissue trauma during implantation because of the volume of tissue displaced by tag on deployment would be reduced (lower "footprint"). This could lead to longer duration and would likely minimize tag effects to individual animals. Development of this new tag design would require the use of smaller size cell batteries (*e.g.*, AAA versus the current AA used on many Type C tag designs) and additional testing to assess whether battery power is sufficient to maintain levels of performance consistent with existing tag designs.

This new tag could be deployed from multiple platforms (*e.g.*, bows of ships, helicopters) and would be more applicable for use in certain areas (*e.g.*, open ocean) or species/populations of cetaceans that are more difficult to approach (*e.g.*, common minke whales). The reduced size and weight of the tag should provide better ballistic performance where tags can be deployed with greater precision, at longer distances and at lower pressure. It was also **agreed** that a new tag should be rigorously examined for mechanical robustness before field trials (see item 5.1.1 above) and that initial deployments should be done in populations with high re-sighting rates for assessment of impacts and performance before it is used more widely. Workshop participants also **agreed** that deployments of this tag in 2 or 3 length and weight configurations and in a coordinated effort among researchers on selected whale species would ensure consistency in the evaluation of tag performance, including attachment duration.

Recommendation:

The workshop **recommended** a coordinated study to develop a small and light satellite tag for large cetaceans. This study should include:

(a) Rigorous testing for mechanical robustness,

(b) Evaluation of tag performance and potential effects on the animal through follow-up with populations with high re-sight rates,

(c) Assessment of attachment duration in multiple species.

5.5.2.1 NON-INVASIVE TAGS

Workshop participants acknowledged that tags and in particular, tag size, have an impact on behavior and energetic cost to the tagged individual, which may reflect on the quality and relevance of data collected. Currently no standards exist for guidelines on tag size for cetaceans, but recommendations should be made for tag size, particularly for cetaceans less than 5 m in length (van der Hoop, 2017). Discussion also occurred about tag placement and orientation, and the challenges of obtaining the best orientation in remote deployment situations (*e.g.*, pole or projector).

Workshop participants noted the discussion during the workshop focused mainly on invasive tagging, and that lack of time dedicated to non-invasive technology does not indicate a lack of importance of these tools, nor diminish other research and developments that may need to be considered.

Recommendation:

The workshop **recommended** that guidelines for tag size in relation to body size for cetaceans, particularly those less than 5 m in length, should be generated by an expert group.

5.6 Tag Follow-Up

5.6.1 Need to conduct follow-up to identify tag failure and sub-lethal effects

Workshop participants recognized that follow-up studies on live animals are essential to assess tag performance, tag structural integrity and tag impacts, both on individual and population levels. Follow-up studies are particularly critical for small, endangered populations and when new technology is developed. The workshop **agreed** that substantial new information on tag limitations and on behavioral, physical and physiological, and demographic impacts was gained by observational studies conducted with various cetacean species (item 3.1) and that these types of studies should continue.

There is a growing body of evidence suggesting that electronic tags have little impact on the survival of tagged cetaceans from a population perspective (*e.g.*, studies comparing survival of tagged and control animals in item 3.1, above). However, it was **agreed** that additional research on sub-lethal effects of tagging is needed. Examples include studies on the baseline ability of cetaceans to feel pain and possible effects on reproductive rates (*e.g.*, Robbins et al. 2016). Future work should investigate whether it is possible to predict how a cetacean might experience pain following tagging and how the animal may change its behavior or kinematics in response to feeling pain (see also item 5.2.3 above). It was noted that kinematic sensors may detect changes in behavior and that these changes could potentially manifest in the tag data themselves. It was noted that measuring reproductive rates could be difficult and require long-term studies, especially when the magnitude of a potential effect is small. Thus, it was **agreed** that time frame and sample sizes for such studies need to be carefully considered to ensure the research questions are properly addressed.

Recommendation:

The Workshop **recommended** the continuation of follow-up studies to assess behavioral, physical/physiological and demographic effects of tagging with particularly emphasis on:

(a) Potential sub-lethal demographic effects (*e.g.*, calving rates),

(b) Ability of cetaceans to feel pain at tag deployment, while carrying a tag and during the healing period once the tag is lost.

5.6.2 Improvements in the relocation of tagged individuals

The workshop noted that the development of effective follow-up studies is challenging for many species, particularly when resighting probabilities are low. Improving the ability to relocate tagged animals at sea would significantly strengthen the value of these studies. In that sense, participants of the workshop **agreed** that identifying

a process for exchanging information on tagged individuals with observational networks in an expedited fashion could lead to faster and more frequent re-sightings of tagged cetaceans. In addition, it was noted that detection of animals instrumented with electronic tags has been facilitated by recent technological advancements. One example includes the goniometer, an electronic instrument designed to find active ARGOS platforms in the field by providing an approximate range and direction to the location where transmission occurred (*e.g.*, an animal carrying a satellite tag). Workshop participants **agreed** that further development of this type of technology could increase the likelihood of finding animals at sea and enhance follow-up information on tagged cetaceans.

Recommendations:

The workshop **recommended** improvements in methods to relocated tagged animals at sea including:

(a) Identifying a process for exchanging information with observational networks in an expedited fashion to maximize chances of relocation of tagged individuals,

(b) Continue development of electronic devices designed to detect individuals carrying tags.

5.7. Other remarks

Some other topics of discussion weren't easily generalizable or didn't result in specific recommendations, and therefore aren't covered in this report. These included 'outside the box' ideas such as a fully implanted tag that could transmit through tissue, and therefore not require a constant percutaneous opening for the antenna. Discussions of future tag designs emphasized considering: minimizing entanglement risk, maximizing sensor capabilities with battery capabilities, and assessing issues of material selection and deployment techniques. Regardless of the approach, all tag development, deployments, and follow-up need to be considered in light of the potential for increased regulatory restrictions on tagging.

6. PRIORITIZATION OF RECOMMENDATIONS

Workshop participants were requested to prioritize the recommendations specified in item 5 above according to the following questions and prioritization criteria:

A. In their opinion, how important is the recommendation towards improving tag attachment (including understanding factors affecting duration or designing new methods that would effectively extend attachment duration), while understanding and minimizing impacts to individual animals? 1 = "High" Priority, 2 = "Medium" Priority, 3 = "Low" Priority. In ranking these recommendations, workshop participants are requested to select ~4-6 higher priority recommendations (*e.g.*, those receiving score = 1, above), 10-14 medium priority (those receiving score = 2) and 4-6 lower priority recommendations (those receiving score = 3).

B. Is the recommendation reasonably achievable given current technologies, methods, materials, and accessibility of animals? 1 = feasible within 3 years, 2 = feasible within 6 years, 3 = unlikely to be feasible within a reasonable time frame/unknown.

Recommendations that received a scored of "3" were still considered a priority. Topics that were not deemed a priority by workshop participants for advancing cetacean tag attachment technology and for understanding their potential effects on individuals and populations were not included in the recommendations. A list of the recommendations and their prioritization scores are provided in Annex H.

Participants also noted that some of the recommendations made at the 2009 Tag Development Workshop (ONR, 2009) have not yet been fully or have only been partially addressed and reiterated those recommendations (Annex J).

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Annex A

Agenda for the Cetacean Tag Development, Tag Follow Up and Tagging Best Practices Workshop (Silver Spring)

Day I

1. Registration (0800 – 0830)
2. Opening Remarks (0830-0915) (IWC, NOAA, ONR)
    a. Terms of Reference
    b. Expected outcomes
    c. Introduction of Chair and Rapporteurs
3. Tag Terminology (0915 – 0925) (Andrews)
4. Short presentations and brief plenary discussions (Day I, 0925-1730 and Day II, 0800- 1000)
    a. **Invasive Tags**
    b. **Plenary Discussion** (1555 – 1730)

Day II (0800-1600)

4. Continuation of presentations and plenary discussion (0800 – 1015)
    a. **Non-Invasive Tags**
    b. **Future Advances**
        1. New materials / New approaches from biomedical field
    c. **Plenary Discussion** (0855 – 1015)
5. **BREAK** (1015-1030)
6. 'Cetacean Tagging Best Practices Guidelines' (1030 – 1230)
    a. Outline of process for review, revision, publication of Guidelines
    b. Review of draft of Guidelines content c. Initial discussion of Guidelines
7. **LUNCH** (1230 – 1330)
8. Breakout groups (Group I: Tag users and Follow-up. Group II: Vets) (1330 – 1730).

Only those workshop participants that are actively deploying or designing tags, involved in follow-up, or are veterinarians are invited to the breakout group. Other attendees that are not tag users/developers or veterinarians may skip the afternoon session and return on Day III at 0900 when summaries of breakout group discussions will be presented.

a. Group Specific questions

i Tag users and follow-up

1. Given synopsis of Day I, are there simple things to implement now that can improve all tag outcomes (duration/minimize impact)?
    1. How can we overcome limitations we have now?
2. Future directions in tag developments
3. Use of antibiotics with invasive tags
4. Assessing impacts; best methods, level effort required, and others
5. Choosing the right candidate on individual, population or species level.
6. What questions do you have for the vets?

ii Vet group.

1. Choosing the right candidate on individual, population or species level.
2. Use of antibiotics with invasive tags
3. Standardizing review of photos for assessment.
4. Best assessment for how to obtain goal of maximum duration with minimum impact.
5. What questions do you have for the tagging community?

Day III (0800 – 1600)

10. Continuation of Breakout group (0800 - 0900)
11. Summaries by break-out group rapporteurs (0900 - 930)
12. Plenary discussion of breakout group topics, including feedback on Guidelines (0930 – 1230)
13. LUNCH (1230 – 1330)
14. Continuation of plenary discussion (1330 – 1430)
15. Research recommendations and future directions (1430 - 1500)
16. Agreement on Guidelines revision (1500 – 1545).
17. Concluding remarks and plan for workshop report composition (1545 - 1600)
18. ADJOURN (1600)

Annex B

Agenda of the Cetacean Tag Attachment Development Small Group Meeting (Seattle)

1. Opening remarks
    a. Nomination of chair and rapporteurs
    b. Terms of reference
    c. Expected outcomes

2. Introductions

3. Review of recent tag attachment development and assessment work (participant presentations)
    a. Design and performance of current attachments
    b. Assessment of impacts: methods and results

4. Identification of limitations and shortcomings of current attachment methods
    a. Impact
    b. Duration
    c. Sensors
    d. Deployment

5. Future directions
        i. Near-term solutions to improve in attachment outcomes (longer durations/reduced impacts)
        ii. Longer-term research on improvements in attachment outcomes
            1. New Materials
            2. Alternative approaches from biomedical field
        iii. Better impact assessment approaches

6. Recommendations for future R&D of improved attachment methods

7. Concluding remarks

Annex C

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(* Denotes the subset that participated in both the Silver Spring and Seattle meetings and # denotes participants that were present only in the Seattle meeting)

Annex D

Terms of Reference for the Cetacean Tag Attachment, Tag Follow-up, and Tagging Best Practices Guidelines Workshop

The purpose of the workshop is to review and evaluate progress in tag design and attachment since the 2009 ONR Cetacean Tag workshop, with an emphasis on recent tag attachment improvements and follow-up studies that examined the effects of tagging.

All tagging studies, using either invasive or non-penetrating attachments, require significant deliberation of all alternative research methods, including an examination of whether tagging is the best choice for meeting the research and/or conservation needs, while balancing the ethical concerns of individual animal welfare and the potential for population level effects. However, it is not the purpose of this workshop to debate the processes by which those considerations are made. The focus of this workshop is how best to apply tagging technology after a carefully considered decision has been made that tagging is a fully justified part of a cetacean study.

The purpose of the workshop was neither to highlight the demonstrated benefits of using tagging technology for an array of research and conservation questions, nor the valuable developments made in the area of tag electronics and sensor design and capabilities. The goal is to share information and debate the best available science on the design and effects of tagging to facilitate future advancements in the development of tag attachment and application, maximizing attachment durations to the extent required to answer the questions being posed, while minimizing the impacts to animals.

The workshop will provide a forum for an open and honest discussion about current tag designs and limitations, and strategies for future improvements in tagging and the study of its effects. A draft of the "Cetacean Tagging Best Practice Guidelines" has been distributed to all workshop participants. The Guidelines will be reviewed and debated during the workshop, and if necessary, revised, in order to produce a document that the workshop participants can recommend for endorsement by the IWC Scientific Committee (one of the three funders of the workshop). The final Guidelines will serve as global resource to assist researchers, veterinarians, animal care committee members, and regulatory agency staff, in the interpretation and implementation of current standards of practice and promote the training of specialists in this area.

Annex E

Tag Terminology

Tag Types will be referred to using the language from the 'Cetacean Tagging Guidelines' (Andrews et al., in review), which focuses on the method of attachment: invasive or non-invasive. Invasive is defined as a tag attachment that intentionally breaks the skin, regardless of how large or deep the break may be.

Invasive tags:
Type A = Anchored. Anchored tags are tags with external electronics and subcutaneous termination anchor(s). The electronics package is external to the skin, but is attached by anchors that puncture and terminate below the skin. The anchors, often solid shafts with backwards-facing barbs, usually terminate in the central core tissue of the dorsal fin or in dermal or hypodermal tissue along the dorsum. Anchored tags are usually deployed using remote-attachment methods that do not require restraint, such as projection from crossbows, pneumatic devices, or placement with a pole.

Type B = Bolt-on. Bolt-on tags are tags with external electronics and piercing anchor(s). An element of the tag is attached to both ends of one or more "bolts" that pierce tissue, with an entry and exit site (like an ear-ring or pinniped flipper tag). For example, single-point dolphin tags "bolted" to the dorsal fin, or "spider-legs" tags where the tag sits as a saddle above or near the dorsal ridge, connected via cables to piercing pins, rods or bolts. Creating the hole for the pin/rod/bolt currently requires capture and restraint of the animal, and manual contact with the skin.

Type C = Consolidated. The electronics and retention elements are consolidated into a single implanted anchor. The electronics are typically inside a metal case, usually a cylinder, designed to be partially implanted in the body, with only a small part of the top of the tag and antenna(ae) and/or sensors projecting above the skin. Retention elements, such as backwards facing barbs, are connected directly to the implanted package. Puncture typically occurs on the body (not the dorsal fin), and the distal end of the tag sometimes terminates below the muscle/blubber interface. These tags do not require restraint and are always deployed with remote-attachment methods.

Non-invasive Tags:
Non-invasive tag attachments include harnesses, peduncle belts, and suction cups.

References

Andrews, R.D., Baird, R.W., Calambokidis, J., Goertz, C.E.C., Gulland, F.M.D., Heide-Jørgensen, M.P., Hooker, S.K., Johnson, M., Mate, B., Mitani, Y., Nowacek, D.P., Owen, K., Quakenbush, L.T., Raverty, S., Robbins, J., Schorr, G.S., Sphak, O.V., Townsend, F.I., Uhart, M., Wells, R.S. and Zerbini, A.N. in review. Best Practice Guidelines for Cetacean Tagging. Submitted to the *Journal of Cetacean Research and Management*.

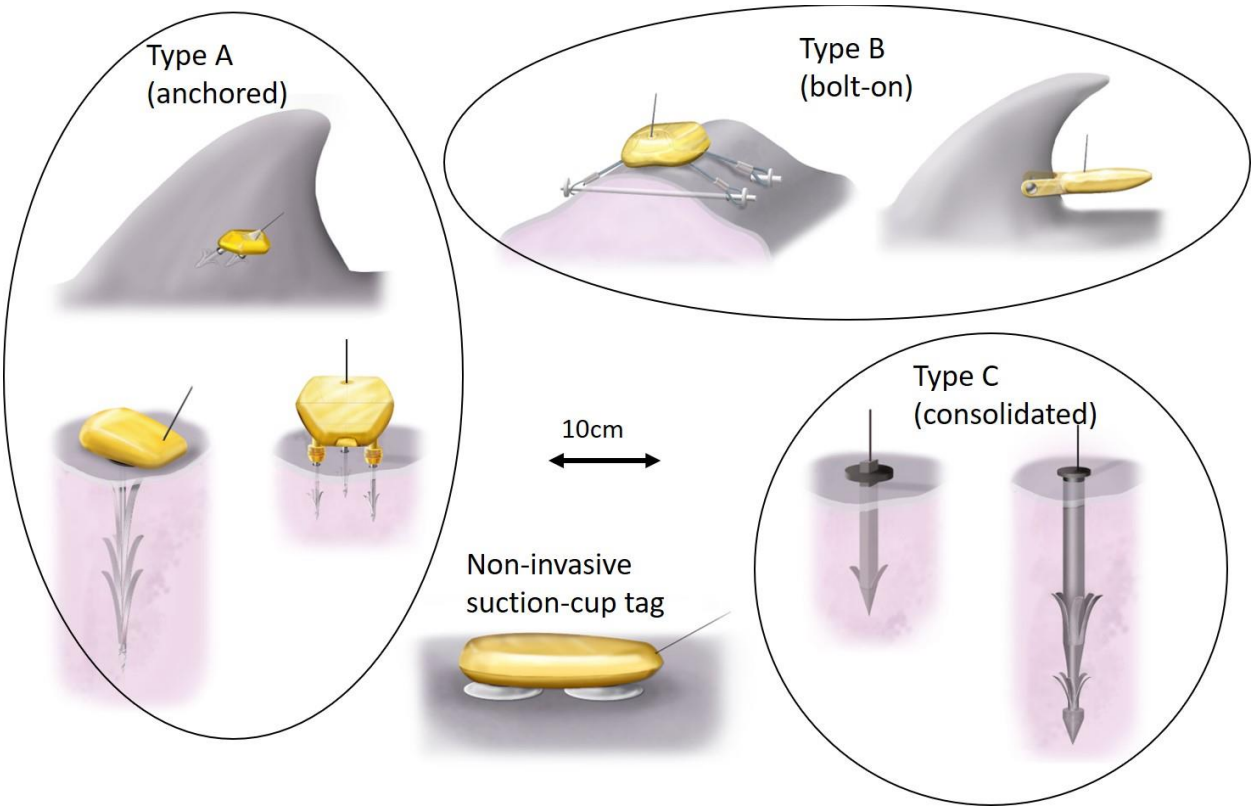

Fig. 1. Illustrations of a non-invasive suction cup tag (bottom center), and the three most common configurations of invasive tags, Type A: Anchored; Type B: Bolt-on; Type C: Consolidated (illustration from Andrews *et al.*, in review).

Annex F

Name of Workshop Presenters and Title of Presentations

Presenters	Title
Andrews	Improving attachments of remotely deployed dorsal fin-mounted tags: tissue structure, hydrodynamics, in situ performance, and tagged-animal follow-up.
Baird	Assessing reproduction and estimating survival of odontocetes tagged with LIMPET tags: case studies from Hawai'i.
Balmer	Factors influencing transmission duration on fin-mounted tags.
Calambokidis	Development and experience with medium duration archival tags.
Double	“Blubber-implanted” tags.
Gulland/Robbins/Zerbini	Large cetacean implantable satellite tags (type C): Assessing impacts and improving designs through follow-up studies on Gulf of Maine humpback whales.
Heide-Jørgensen	Tagging workshop.
Kleivane	Cetacean tag workshop.
Mate	Whale tag attachment development at Oregon State University.
Minamikaua	Deployment of pop-up archival transmitting tags to Pacific white-sided dolphins: Difference in attachment duration by anchor type.
Moore	Variation in cetacean blubber shear over axial muscle, in the context of rigid trans-dermal intra-muscular tracking tag trauma.
Mulcahy	Use of antibiotics during tag placement.
Norman/Calambokidis	Assessment of wound healing of tagged gray and blue whales in the Eastern North Pacific using long-term photographic data
Rajachar	Development of adhesive composite hydrogels for marine application
Raverty	L95
Schorr	Assessment of LIMPET tag performance
Shorter	Suction cup tags: design, testing and evaluation
van der Hoop	Towards size recommendation for cetacean tags
Wells	Health, behavior and vital rates of tagged bottlenose dolphins

Annex G

Revisions to the draft Guidelines necessary for the workshop participants to recommend that the Guidelines be endorse by the IWC

On the final afternoon of the Silver Spring meeting, a list of Guidelines revisions was prepared and agreed to by the workshop participants and the Guidelines co-authors in attendance (10 co-authors, including all 4 lead editors). Below we have listed those revision recommendations:

Major revisions

1. Add a flow chart or decision tree to guide the choice to utilize tagging. Greg Donovan offered an example of a flow chart used when the Western Grey Whale Advisory Panel considered a proposal to tag near Sakhalin Island, Russia. A second flow chart for the selection of candidates was recommended by the Vet breakout group, but additional text in the body of the Guidelines could suffice.
2. Revise the text to include new recommendations regarding sterilization of implanted parts of tags which were discussed in the Vet breakout group.
3. Revise the text to more specifically address and acknowledge the potential for pain during deployment and carriage of the tag, and possibly after tag loss, and that mitigation strategies during all stages of tagging should be considered.
4. Revise the text to include new recommendations regarding the use of antibiotics or other antimicrobials, which were discussed in the Vet breakout group.
5. Include better descriptions of the anatomy in the targeted tag implant sites, including an illustration and a new paragraph of text.
6. Guidelines authors should consider whether the text in the draft regarding use of biocompatible materials and the mention of International Standard ISO 10993-1:2009 needs to be revised.

There were three further suggestions for additions to the Guidelines, but the workshop participants did not reach a consensus on whether they should be recommended as mandatory revisions. Therefore, the decisions of whether to include these following items are left to the Guidelines authors:

A. Consider whether an Executive Summary should be drafted and included as part of the Guidelines or as a separate document.

B. Include a table of blubber thickness measurements.

C. Include a data form template to standardize data collected upon tag deployment and facilitate entry of those data into a tagging community database.

Annex H

Prioritized recommendations for future cetacean tag development and for minimizing effects of tagging on cetaceans

The recommendations identified under Section 5 are presented in the table below after being prioritized by workshop participants. These recommendations were ranked according to the median scores assigned to criterion A (1 = higher priority, 2 = medium priority and 3 = lower priority), followed by criterion B (1 = feasible within 3 years, 2 = feasible within 6 years and 3 = unlikely to be feasible within a reasonable time frame). Recommendations that received similar scores for criteria A and B were then listed by the sequential order that they appear in Section 5 (report item number).

	Priority Score			
Recommendation	Criterion (A) Improving attachment / minimizing tag effects	Criterion (B) Timing / feasibility	Report Item Number	Report Item Heading
Sterilization of implantable portions of invasive tags prior to deployment	1	1	5.3.1	Tag preparation
Develop research to (a) understand what drives suites of tissue responses from tagging events (including foreign body, tag type, implant material) with the objective of minimizing short- and long-term effects on animals and improving current tag retention. Such studies should assess the feasibility of using animals under human care, stranded/rehabilitated or sick individuals, or animals from harvested populations, (b) assess growing body of literature on foreign-body response to different implant materials in human and other animals in the context of improved tag design.	1	2	5.2.2	Limited understanding of tissue response to tagging
Development of new cetacean tag attachments that take into consideration materials that: (a) Include biodegradable, bio-compatible and/or bio-compliant features, (b) Minimize tissue trauma (short and long-term), foreign body response and encourage healing, (c) Have anti-microbial, anti-septic and/or bioactive properties by design.	1	2	5.5.2.1	Future development ideas for tag attachments - Invasive tags
Conduct a coordinated study to develop a small and light satellite tag for large cetaceans. This study should include: (a) rigorous testing for mechanical robustness, (b) evaluation of tag performance and potential effects on the animal through follow-up with populations with high re-sight rates, (c) assessment of attachment duration in multiple species.	1	2	5.5.2.1	Future development ideas for tag attachments - Invasive tags
Continuation of follow-up studies to assess behavioral, physical/physiological and demographic effects of tagging with particularly emphasis on (a) potential sub-lethal demographic effects (*e.g.*, calving rates), (b) ability of cetaceans to feel pain at tag deployment, while carrying a tag and during the healing period once the tag is lost.	1	2	5.6.1	Need to conduct follow-up to identify tag failure and sub-lethal effects
Develop a central database to: (a) Collate information on tag deployment (*e.g.*, species, tagging platform, deployment system, tag type, tagging range and pressure, animal identity, geographical location, tagging date), tag performance metrics and follow-up of tagged animals (*e.g.*, tag wound photographs, documentation of injuries, stranding) in a standardized fashion, (b) Facilitate analysis of factors influencing tag duration and tag impacts. (c) Serve as a source of information for regulatory agencies.	2	1	5.1.1	Tag registry and deployment databases
Develop a standardized approach and database to enhance communication among the tagging community to share experiences, information on development of tag delivery and tag attachment methods, and information on tag performance and tag impacts.	2	1	5.1.1	Tag registry and deployment databases
Combine existing tag deployment databases in order to develop meta-analyses to: (a) Identify factors affecting tag duration, (b) Understand variability in tag duration between and within species, (c) Understand differences in performance and variability across tag designs.	2	1	5.1.1	Tag registry and deployment databases

Further studies and review papers should address: (a) basic understanding of potential pain during and following tagging, and how the animal may change its behavior, including swimming kinematics, in response to pain, (b) engineering of tag design, deployment systems, deployment protocols, and tag placement during deployment on the part of the body that strive to minimize potential pain as much as possible, and (c) comparative anatomy and histology to describe nerves, sensory organs and vasculature in skin, blubber, and muscle.	2	1	5.2.3	Pain assessment and minimization
(a) Training and practice with aseptic technique by tag users, (b) develop research to determine the degree of contamination of implantable portions of tags over time under field conditions.	2	1	5.3.1	Tag preparation
Develop improved deployment methods that can safely deliver a tag with increased accuracy and precision, preferably from greater distances than current methods.	2	1	5.4.1	Ballistic and tag application device accuracy and precision
Development of tagger/boat driver training courses. Trainers should include those with extensive tag deployment experience (including driving), and trainees should be required to have previous experience in collecting biopsy samples. Training should include appropriate information about the species of interest, especially behavior and anatomical details, and descriptions of the areas of the body targeted for tagging.	2	1	5.4.2	Proper training of tagging teams
Develop a protocol for communication between tagging programs and stranding networks to understand effects of tagging by: (a) Providing stranding networks with ID photographs of tagged cetaceans to better assist networks in identifying previously tagged stranded cetaceans and increase exchange of ideas and information, (b) Specific communication tools could include workshops, notifying stranding coordinators, attending stranding network meetings, preparation of 'outreach' information for government stranding or research coordinators to disseminate, (c) Development of standardized quantifiable aspects/techniques/parameters to aid in tracking status before, during, and post tag release, (d) Development of standard operational protocols (SOPs) for necropsies of previously tagged animals and a database to document or archive necropsy findings, along with an effort to synthesize current knowledge. These SOPs may need to be specific to populations with a high proportion of tagged animals as well as the tools to rapidly identify specific individuals.	2	2	5.1.2	Coordination between taggers, stranding networks and sightings of opportunity
Describe inter and intra-species/individual variation in anatomical features to inform future development of tag attachment mechanisms and to guide future tag deployment. In this context, a protocol for appropriate sampling of freshly stranded cetaceans should be developed.	2	2	5.2.1	Limited understanding of relevant anatomy
Before the widespread adoption of antimicrobials in invasive tagging methods, the justification for their use and their potential efficacy and systemic effects should be further investigated.	2	2	5.3.2	Use of antibiotics/anti microbials
Development of standards for rapid assessment of body condition immediately before tagging (for identifying healthy tagging candidates).	2	2	5.4.3	Selection of a tagging candidate
The tagging community shall (a) describe required minimum taxon-specific levels of tag robustness, (b) develop standard protocol to test the structural integrity of tag prototypes including a combination of laboratory experiments and field assessments of tag performance, (c) decide on an acceptable tag failure rate in advance, and if that failure rate is exceeded in field deployments, a comprehensive review of technology and procedures should be conducted.	2	2	5.5.1	Limitation of current tag attachments
Explore transmission of existing and/or additional sensor data to identify potential causes of tag failure	2	2	5.5.1	Limitation of current tag attachments
Development of rigorous studies to quantify differences in duration and effects of tags on animals embedded only in the blubber and tags that anchor below the sub-dermal sheath.	2	2	5.5.2.1	Future development ideas for tag attachments - Invasive tags
Development of guidelines for tag size in relation to body size for cetaceans, particularly those less than 5m in length.	2	2	5.5.2.2	Future development ideas for tag attachments - Non invasive tags

Permanently mark tags with a unique serial number and contact information to facilitate identification in the case of third party recovery.	3	1	5.1.1	Tag registry and deployment databases
Improvements in methods to relocated tagged animals at sea including: (a) identifying a process for exchanging information with observational networks in an expedited fashion to maximize chances of relocation of tagged individual, and (b) continue development of electronic devices designed to detect individuals carrying tags.	3	2	5.6.2	Improvements in the relocation of tagged individuals

Annex I

An example decision tree for cetacean tagging studies (modified from Andrews et al., in review)

Tagging Study Decision Process

Initial Considerations:

1. Clearly specify the short- and long-term objectives
2. Are there existing tag data that can be used to meet objectives?
3. Compare overall benefits vs. costs (multiple factors including population status)
   - e.g., risk to individuals vs. benefits to population
4. Likelihood of success?
   - encounter rates in project area
   - tagging success and data recovery for target and similar species
5. Is tagging the most appropriate approach?

→

Practicalities:

1. Tag options
   - select a tag that will best provide the data needed
   - tag should be of reasonable size, shape and attachment design, with appropriate sensors
2. Deployment options
3. Location/study site
4. Timing (e.g., season)
5. Sample size
6. Candidates – age, sex, health, etc.; relate to objectives
7. Tagging protocols to minimize disturbance and maximize success
   - e.g., establish *a priori* criteria for tag/no-tag field assessment of individuals
8. Recruit team members with tagging experience
9. Design follow-up studies of 'effects' to inform future work

→

Phased and iterative approach:

1. Pilot project if warranted
2. Review results
3. New/revised priorities & approach
4. Conduct further tagging if needed, with refinement informed by initial results
5. *Stop* when sufficient data have been collected and objectives have been met

Annex J

Recommendations from the 2009 ONR Tag Development Workshop

The Cetacean Tag Development Workshop hosted by ONR in 2009 (ONR, 2009) provided a series of recommendations for research related to the use of electronic tags on cetaceans. These recommendations were either general or were specific to different tag types and are listed below following the new tag terminology specified in Item 2 of the present report. Workshop participants noted the need to reiterate the following 2009 recommendations that have not been addressed or have only been partially addressed by research conducted since that Workshop:

General Recommendations

- Assess hydrodynamics of tags and all tag attachment types: initially using computer models and then transition to wind tunnel/water flumes.
- Evaluate increased energetic requirements of animal due to increased drag for all tag designs using computer simulations and captive animal experiments.

Invasive Tag Types

- Examine performance of current tag attachment designs by assessing holding power and anchoring performance in carcasses using imaging (CT scans, X-Ray).
- Quantify delivery force of each delivery system as a function of attachment success and duration.
- Design physiology sensors (pH, temp) for the tip of tag attachment to collect information about wound healing/condition, and depth of tag penetration (myoglobin).
- Develop new antennae design to reduce vibration of the tag (antenna or exposed tag) - consider reducing coupling of antenna with tag body.
- Investigate variability of biofouling as a function of tag attachment materials.
- Investigate reactions (*e.g.*, abrasion and sensitivity) to different materials placed against the skin and other related issues (dead skin buildup) using captive animals.
- For invasive tags type B, determine bolt tightness for surgically placed dorsal fin tags to avoid pressure necrosis.
- For invasive tags type B, assess effect of bolt size or shape on tag retention.
- Develop release mechanism for proper release of dorsal fin attachments (active and passive releases).
- Test positioning of tag on the dorsal fin using captive animal experiments.

Non-invasive Tag Types

- Test effects of tissue necrosis under suction cups using captive animal experiments.
- Investigate effects of temperature and pressure on suction cups.
- Investigate engineering/methods (i.e. suction cup type, material, size, number, configuration) for longer suction cup attachments.