Proceedings of "Tying One On"— A Workshop On Tag Attachment Techniques For Large Marine Animals

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SUMMARY

The workshop was convened in Honolulu on December 4–5, 2002 to address the perception that unreliable methods of attaching telemetry transmitters to marine fishes and turtles were limiting the success of these experiments. The workshop was underwritten by the Pelagic Fisheries Research Program (PFRP), Joint Institute for Marine and Atmospheric Sciences, University of Hawaii. The following proceedings were prepared by rapporteurs Kim Holland and Melinda Braun and are based on presentations and discussions from the workshop and on subsequent input from attendees. In this report, emphasis is placed on the findings and recommendations of the workshop rather than an extensive recapitulation of the oral presentations.

The basic questions posed to the attendees were 1) is there in fact a problem with attachment/implantation reliability and, if so, 2) what are the sources of those problems and 3) are there solutions to those problems? It was hoped that specific suggestions for future empirical experimentation or other ways of advancing the field would emerge from the workshop.

To provide a point of departure for discussion, the workshop format consisted of a series of oral presentations from researchers conducting tagging experiments with various marine species. These presenters were asked to focus on the attachment/implantation aspects of their work. Following these presentations, there were papers presented by a specialist in biomedical materials research and a veterinarian with expertise in fish surgery techniques. These presentations were followed by opportunities for rebuttal from the attendees and finally by a roundtable discussion and an attempt to identify and prioritize common problems identified by the group.

The consensus of the group was that good long term success (over a year in some cases) is being achieved through intraperitoneal (abdominal cavity) implantation, although there are probably species-specific variations in this success and room for improvement in the materials used ("coatings") and the shape of the tags. On the contrary, long-term (> a few months) external attachment of electronic tags does seem to have significant reliability problems. However, it was recognized that there is no generally accepted definition of a premature release and no existing compilation of the performance of externally attached tags deployed under different conditions. At the moment, separating the source of this unreliability into tissue rejection or external hardware failure or predation events is not possible because of a paucity of data. As a whole, the attendees were somewhat surprised by the lack of empirical testing that has been conducted on these topics. Representatives of tag manufactures attending the workshop expressed frustration that a significant number of researchers attempting tracking experiments do so without apparent prior knowledge of the field or an appreciation of the limits of the technology or its appropriate application.

Based on the presentations and discussions, the attendees agreed on several specific recommendations that would advance the field of electronic tagging and tracking of fishes.

1. WORKSHOP DELIBERATIONS

For the purposes of organization, these proceedings will report on the main subject areas covered at the meeting rather than present a strict chronological presentation of the oral presentations and their associated discussions.

1.1 Internal Implantation of Tags

Several speakers addressed the issue of the status of the use of internally implanted sonic or archiving tags. Kurt Schaefer reported consistently reliable retention by bigeye and yellowfin tuna of internally implanted archival tags for periods of up to several months. Although he did not use any type of additional materials to coat the epoxy resin bodies of the tags that he used, his recovery rates equaled or exceeded those for conventional external spaghetti tags. He reported that there is evidence in some specimens of invagination of the tag into the intestine from where it could eventually be voided. He emphasized the use of good surgical procedures on the boat and felt that using wet, smooth surfaces on the tagging cradle decreased potential damage to the fish and should aid in recovery.

Similar internal retention results were reported by Kim Holland. In tropical reef fishes, several specimens had been recaptured showing evidence of encapsulation of sonic tags by a sheath of tissue. He felt that this appeared to represent a stable situation in which the encapsulated tag would probably be retained indefinitely. However, some other attendees felt that this could also be the first stage in eventual expulsion of the tag—either through the gut or directly through the body wall. Holland also reported the recovery of a large acoustic pinger from a tiger shark after three years at liberty. However, although implanted in the gut cavity, the NMFS observer who recovered the tag stated that the tag was actually in the stomach. This again points to invagination into the gut although in this case the tag was retained. Holland reported that his group uses a beeswax/paraffin wax mixture to coat the tags. However, in his subsequent presentation, Chris Harvey-Clarke indicated that there was no evidence that this type of coating imparted any particular tissue rejection advantage and may in fact be deleterious.

David Welch reported that his group had experienced very good tag retention and post-operative recovery from dummy tags placed in salmonid smolts—including very small specimens (11 cm). Under the circumstances of his experiments, it is possible to anesthetize the animals during implantation surgery. However, Welch pointed out problems with existing laws governing the use of various anesthetics. In the USA and Canada, Tricaine methanesulphonate (MS-222) is not sanctioned for use on animals that may be consumed by humans within 21 days of use. On the other hand, clove oil (which is also an effective fish anesthetic), while approved for human use, has not been officially approved as an anesthetic for fish in either country. Welch argued that resolving this dilemma should become a priority for the tagging community.

Along similar lines, Julian Metcalfe reviewed the pros and cons of internal versus external attachment of tags but also pointed out the pressing need for the tagging

community to be proactive in defining appropriate best practices for different tagging situations, including whether or not to use anesthesia and if so, what type and in what manner (general or local). Metcalf pointed out that the European scientific community had recently released an extensive tagging handbook that dealt with some of these issues. He felt that it was of the utmost importance that a similar document be produced for the North American scientific community and should include protocols for field work and the use of large animals. Metcalf emphasized the need for expanded testing of tag materials and attachment methods and emphasized that these tests should combine both lab and field components.

Heidi Dewar presented an extensive review of the scientific literature of relevance to tag implantation and attachment. Her review raised many issues about the appropriate types of materials that could be used as tag coatings or tag anchors (e.g., different grades of stainless steel) and the relative merits of using anchors with smooth surfaces or textured surfaces (to promote tissue invasion) and whether or not to use antibiotics during field operations. Dewar pointed out that although there were many possible strategies, empirical data were scarce about the best materials to use and which field techniques to employ. She also introduced the topic of the possibility of developing intra-muscular tags that might be designed to become irritating to the tissues at pre-set times and thereby cause the animals to expel the tag. Insertion into the dorsal musculature has met with some success during limited testing and has the advantage of not requiring extensive surgery and not inducing the type of drag (or tempting predation target) or a towed tag.

1.2 External Attachment of Tags

External attachment is necessitated under several circumstances. In smaller fishes, external attachment of sonic tags is necessary for species with small amounts of space in the gut cavity (e.g., Carangidae). In these cases, external attachment using through-body methods has proven effective for periods of up to several months. Usually, however, external attachment of tags is used with animals that are too large or unwieldy to bring on board and/or where the tagging platform is high above the water line. In the case of marine turtles, external attachment is the only viable option. Another major reason for external attachment is to allow fishery-independent recovery of data using devices such as pop-off tags that detach from the animal and float to the surface and uplink archived data to satellite. Most of the workshop discussion of external tagging centered on issues concerning the use of external pop-off tags. Although success has been achieved in reliably attaching pop-off tags for periods of a few weeks, there was consensus among the attendees that problems persist with the reliability of long-term external attachment of pop-tags. This unreliability precludes the documentation of annual movement patterns and confounds experiments where release of the tag is used to document the death of the animal carrying the tag.

Presentations by Eric Prince, Don Hawn, Michael Domeier, Josh Loefer, and Yonat Swimmer highlighted the difficulties involved with high-seas external attachment of tags to large fish and turtles. A common theme in all cases was the difficulty in stabilizing the animals in the water in order to allow reliable, standardized application of the tag. Eric

Prince said that while he has experienced incidents of premature release of external tags, his data show improved success correlated with improved boat-side handling of animals. He stressed the importance of using the "snooter" device to control marlins at boat side and to allow resuscitation of the animal following tag attachment. He emphasized that billfish research was largely dependent on using "vessels of opportunity" (e.g., sport fishing vessels) and that this circumstance required techniques that could be easily adapted for use on a variety of relatively small vessels (often with untrained crew.) To his end, he has refined the use of a snooter tool that is designed to grasp the marlin's bill and thereby immobilize the fish while keeping the head submerged during tagging and resuscitation. When using this system, he has achieved very good success with deployments programmed to release after forty days and he intends to try and increase this period in the near future.

Similarly, Josh Loefer presented results showing a dramatic improvement in multi-week pop-up tag retention by Atlantic swordfish following slight modification of the shape of the tag anchors that he used. The modifications included rounding of lateral and rear edges and corners of the arrowhead (anchor) and bending downward the rear tines of the arrowhead.[1] However, because none of these tags were physically recovered, it was not possible to attribute either this success (or the previous failures) to a specific cause or a specific component of the tag assembly. The paucity of empirical evidence from recovered tags was a recurring theme throughout the workshop.

The theme of the unreliability of pop-up tags was also raised by Michael Domeier who has applied these tags to a variety of large pelagic species—in some cases in order to investigate post-release mortality. While he felt that the manufacturers were making progress in improving both hardware and software components of their pop-up tags, he argued that more data are needed in order to identify the sources of failure and to thereby improve the product. He felt that the design of the tag nose and strength of the corrosible pin were particularly important to successful retention of pop-off tags. Other participants argued that tissue rejection issues or insufficient anchoring could be equally responsible for the release of the tags. Again, there are no published empirical data concerning the efficacy of different anchors although Prince mentioned that one of his students (Chris Jones) had recently completed his PhD dissertation investigating the "holding power" of various anchor designs and it was hoped that these data would soon be published.

In discussions triggered by Domeier's presentation, the question arose of how to actually define a "premature" release. As a hypothetical example, Roger Hill pointed out that there are significant differences between a tag that is programmed to release from a shark after a year but releases after 10 months versus a similarly programmed tag that releases from a marlin or swordfish after only three days. Thus, the question arises as to what is the definition of a premature release and is there really a problem? One way of answering this question would be to construct a compendium table from various researchers around the world who have used pop-up tags on various species using various methods of tag attachment. In this way, the expectations and methods of the researchers

[1] A similar modification was previously described by Holland et al., 1990. Horizontal and vertical movements of Pacific Blue marlin caught and released using sport fishing gear. Fish. Bull., 88:397-402.

could be objectively compared with the actual longevity of the deployments. This idea of compiling such a table was endorsed by John Sibert (Manager, PFRP) who felt such a compendium would be the fastest way to identify good and bad practices (whether they be those of the manufacturers or of the users).

The compromises associated with open-ocean fieldwork were also raised by Yonat Swimmer who said her research group used epoxy glue to attach electronic tags to turtles because it was felt that drilling attachment holes on the margin of the shell would be too difficult at sea. However, premature releases were occurring with the glue attachment method. Similarly, Prince reported that even though his group mechanically attached tags to turtles using holes drilled in the margin of the shell, even this method had resulted in some early releases.

Two very informative presentations were made by Jim Anderson, who specializes in the development of synthetic materials for biomedical uses, and Chris Harvey Clarke, who is a veterinarian interested in the healing processes of fishes—especially as related to surgical techniques involved in fish research.

Harvey Clarke provided a comprehensive overview of fish surgery issues from a veterinarian's perspective. This review covered topics from the ethical treatment of fish to some practical recommendations regarding surgical techniques involved with tag attachment and implantation. He pointed out that there are guidelines issued by the American Society of Ichthyologists and Herpetologists that give advice on the handling of fish. These guidelines could act as a point of departure for future papers that would deal specifically with the ethical and surgical issues involved with tagging experiments. The ethical issues are somewhat clouded by the fact that pain perception in fishes is not clearly understood because there are distinct neuroanatomical differences between fishes and mammals. Nevertheless, it is widely agreed that reasonable steps should be taken to minimize stress to fishes used in research. Especially in the case of tracking experiments, these steps are in fact in the best interests of researchers who need to observe normal behaviour in tagged fishes.

He pointed out that there is a body of literature that deals with quantitative evaluation of surgical techniques in fishes—albeit not with salt water pelagic species. These studies suggest that pre-surgical preparation should be minimal because of the deleterious influence of mucus interruption and because wound healing is not improved by prior use of topical antiseptics; there is no evidence that swabbing a wound with compounds such as betadine reduces the incidence of infection. Because of tension lines in the skin and lack of subcutaneous tissue, "gridiron" or tunneling incisions may be preferable to vertically oriented incisions for the insertion of internal tags.

Harvey Clarke presented a fascinating review of the concept of "degree days" (temperature x time) in terms of the progression of tissue repair following injury or surgery. For example, the inflammatory phase immediately following surgery can be expected to last approximately 80 degree days, wound contraction occurs between 200 and 400 degree days and complete healing around 1200 degree days following injury or

surgery. Fortunately for field researchers, skin healing is promoted when animals are returned to their optimal preferred temperatures.

Of importance to tagging experiments using internal tags, Clarke noted that controlled experiments with captive fish indicated that healing was promoted by ensuring that opposing faces of the wound were closely mated during closure. Also, since galvanic action and movement (vibration) are known to delay wound healing, it would be preferable to use tag anchors and tethers constructed from similar metals and designed in such a manner to reduce the amount of vibration experienced at the site of insertion. Although monofilament suture material might reduce wicking of water into a wound, Harvey Clarke recognized that in field situations, the more easily tied braided sutures might be preferable. In general, wound clips do not work well with teleosts because of their thin skin and poor apposition of wound surfaces when using this technique. There are some reports of improved healing through the use of surgical adhesives but, in Harvey Clarke's opinion, the jury is still out regarding the benefits of this technique in fishes.

In response to a question, he stated that he was unsure of the merits of using liquid antibiotics during ocean fieldwork but that there was no reason why that and other normal sterile procedures could not be used and, in fact, they should be used. Also, these procedures would promote the safety of the researchers in the case of accidents. Cold sterilization of instruments is possible in the field, but it should be remembered that these chemicals lose their efficacy when mixed with organic compounds resulting from surgery and they should therefore be frequently replenished. When attempting to determine causes of tagging success or failure, it would be informative to score the condition of each fish prior to release.

Harvey Clarke thought that emphasis should be placed on anchoring external tags to hard parts (e.g., pterygiophores) rather than intramuscular placement and that titanium anchors would be preferable to stainless steel components because of the stable nature of the titanium oxide layer that develops on this material. And, presaging subsequent remarks made by Jim Anderson, Harvey Clarke felt that there was considerable merit in pursuing medical grade silicon and UHMW polyethylene as materials for the manufacture of anchors and as the external coatings of implanted tags.[2]

Anderson addressed some of the practical issues that he had perceived in the preceding talks. It was apparent to Anderson that the field of tagging research needs an improved understanding of the inflammatory, wound healing, and biocompatibility issues involved with the various anchor shapes and materials. He was surprised that more accelerated testing of components had not been conducted in ways that are common in other biomedical disciplines. He was particularly concerned that the shapes and materials of the various anchor designs were too sharp to promote adequate encapsulation by the host animal and too small in surface and cross-sectional area to provide good anchorage for towed tags. He pointed out that the tissue capsule laid down around foreign objects was

[2] Subsequent to the workshop, Harvey Clarke prepared a comprehensive review of current techniques and methods concerning surgery in fishes for the PFRP Newsletter, vol. 8(2) April-June 2003.

thinnest at sharp corners. These thin areas reduce the strength of the tissue capsule and compromise its longevity and ability to resist rupture or being cut by sharp edges of the anchor. He advised against the use of porous anchor materials (those designed to allow invasion of tissue growth) because they were more likely to encourage infection. He pointed out that there is a variety of suitable smooth materials from which tag bodies and tag anchors could be constructed including stainless steel, silastic (biomedical grade silicon), Teflon, and various grades and formats of polyethylene and high grade plastic. The polyethylene and plastic compounds can be quite easily tooled and molded. In his opinion, the best anchor material must be tough but somewhat elastic.

2. TOPICS COVERED DURING GENERAL DISCUSSION

There was general agreement among the tag manufactures at the workshop that, although they were extremely interested in improving the reliability of internal and external tag attachment and retention, the ultimate responsibility for deployment success lies with the scientists who are actually deploying the tags. In particular, there was frustration expressed that whereas earlier participants in the field recognized the cutting edge nature of the work and the inherent risks and chances of failure, newer arrivals to the field sometimes had the impression that this was an off-the-shelf technology and held the manufacturers responsible for failure even when the technology was being used in inappropriate or high risk circumstances. There was agreement between manufacturers and scientists attending the workshop that compiling an exhaustive archive of previous telemetry experiments and their successes and failures would be of great utility to all parties. Sibert said that he would be inclined to look favorably on funding the section of such an archive that dealt with pelagic species. Similarly, there was support for compiling a compendium list of tag attachment performance—especially for pop-up tags. It was felt that this might be the most efficient way to determine if there were common themes underlying these successes or failures. Data to be included in a summary table should include a) species, b) tag type, c) anchor type, d) anchor depth and location, e) tag implant information—location on the animal, method of application, use of restraining device, f) condition of fish at release and whether resuscitation was attempted. These data could then be analyzed in terms of percentage of tags reporting, percentage of target deployments achieved, percentage of target deployment duration achieved, etc. Such a survey would most effectively be achieved through an e-mail survey.

Roger Hill suggested that pop-up tags could be designed to specifically monitor and report the sources of failure of the tag (that is, pin failure, tether failure, attachment failure, software, etc). It was noted by Michael Domeier, Eric Prince, and others that more recent generations of tags are using hardware (e.g., pressure release mechanisms) and software (e.g., tag release and data transmission in the event of 'flat line' depth data) that have helped reduce the loss of data due to tag attachment failure or animal death. In general, the success rate of pop-up tags is improving.

Kim Holland expressed the opinion that, although there were very valid reasons for using pop-up tags in experiments that required deployments of a few weeks (e.g., to obtain fisheries–independent data regarding dispersal from a specific site or to acquire depth

data from previously untracked species), the full potential of the technology would not be realized until reliable multi-year deployments were feasible. Only then could the existence of consistent or predictable migration routes be demonstrated (Jeff Polovina noted that some sense of these routes could be achieved from shorter tracks of multiple animals released more or less simultaneously at the same location). In Dr Holland's opinion, these long-term deployments would require surgical implantation of tag anchors of the type hypothesized by Anderson. This surgery would require restraining even large animals on deck (or in the water) and this led to discussion of lifting and restraining devices for large pelagic fish.

Bruno Leroy and David Itano showed a video of a portable lifting device designed by M. Leroy to lift large pelagic fish into a variety of vessels (e.g., large research or fishing vessels). Kim Holland showed a conceptual sketch of a raft equipped with inflatable cuffs that might be used to immobilize billfish after they had been maneuvered into the raft as it was towed behind the fishing boat. It was noted that Brian Luckhurst in Bermuda had designed a system for lifting and immobilizing ono (wahoo—*Acanthocybium solandrii*) for tagging experiments that involved an inflatable lining inside a fiberglass tube.

The participants agreed that research and development of restraining and lifting devices for large pelagic species would be a worthwhile pursuit. Holland suggested that experiments attempting to acquire long-term deployments should be selective in the size of the fish they used so that the fish would match the size of the restraining devices and therefore be amenable to surgical implantation of the anchor. However, Prince and Domeier both felt that in the circumstances under which they often work (i.e., from sport fishing vessels provided by members of the public), some form of in–water method requiring minimum additional apparatus or vessel modification was the only appropriate method for attaching tags to billfish. Holland noted that for both Prince and Domeier, long-term (> 1 year) deployments were not always the primary objectives of their research. In some of their experiments, post-release mortality or the documentation of medium-term dispersion patterns were the primary objectives.

There was some support for convening a followup dedicated marine animal tagging and telemetry workshop/symposium.

3. RECOMMENDATIONS

The attendees felt that certain concrete steps could be taken to advance the reliability of long-term external attachment and internal implantation of electronic tags. In addition to research into new designs and materials, these steps included better education of researchers about the limits of the technology and improved surgical and fish handling techniques. Without reference to the availability of funding, the recommendations included the following.

- Prepare an easily accessible archive of methods (and species) used in previous telemetry experiments. Such an archive should include not only methods and

approaches that were successful but also those that were not. Ideally, it should include both published and unpublished sources of information. Such an archive would be of direct benefit both to the scientific community and to tag manufactures who often have to deal with naïve customers.

- Publish a refereed paper outlining the preferred practices and protocols for various types of tag attachment and implantation surgery. The group felt that such a paper would directly benefit researchers in their preparation of research proposals and would assist new researchers in improving the success of their experiments. David Welch undertook to convene a workshop to begin preparation of such a paper.

- Conduct an e-mail survey to compile a summary table of the performance of pop-off tags used under various circumstances and with various species. Wildlife Computers offered to assist in this effort by sending an email to all of their PAT customers asking for their input into such a table.

- Encourage the expanded controlled testing of the "swimming" characteristics of external tags. The performance of various tether components (i.e., between the dart anchor and the tag) should be empirically tested for their impact on the swimming and drag characteristics of tags and the transmission of vibration to the host.

- Encourage accelerated and expanded testing of the tissue compatibility of various anchor (dart head) designs and their holding power. This testing should include various dart head designs and materials based on concepts and criteria described by Jim Anderson and Chris Harvey Clarke. For instance, dissimilar metals should not be used in the construction of tag anchors and tethers—particularly in sections that might be contained within the body of the animal. Wherever possible, anchors should be without sharp edges and with sufficient surface area to provide adequate resistance to the drag of the tag. Hard-part attachment sites are preferable to intra-muscular or subcutaneous anchor sites. Experiments should be conducted in the laboratory and in the field. Large numbers of dummy tags (and anchors) could be deployed in areas where high recapture rates might be expected.

- Encourage improved ship-side and shipboard handling of animals. This includes adopting standard sterile surgery techniques for tag implantation. Emphasis should be placed on designing and implementing improved lifting and restraining techniques for large animals. Reversible anesthesia techniques should be explored. Where on-board methods are not feasible, the use of appropriate restraining methods (e.g., the snooter) should be encouraged for animals tagged while they are still in the water.

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