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Book Review

TAGGING AND TRACKING OF MARINE ANIMALS WITH ELECTRONIC DEVICES. Editors: J. L. Nielsen, H. Arrizabalaga, N. Fragoso, A. Hobday, M. Lutcavage, & J. Sibert. Springer Dordrecht Heidelberg London New York, 2009. ISBN 978-1-4020-9639-6, 452 pp.

Separate conferences tend to be held for marine mammals versus other aquatic animals. Although this keeps the conferences to a manageable size, there is a risk that methods (and mistakes) get re-invented in each community, wasting time and effort. Given the interrelatedness of fisheries and marine mammal conservation issues, there may be a lot of benefit in an active dialogue between these fields. However, when it comes to tag technology, there are some good reasons why work on marine mammals and other aquatic animals has diverged, and this book is a great primer for those who haven't been keeping up with what's being done with the "less-charismatic" animals (to borrow a term from the Preface). The book is a collection of 25 papers submitted by attendees of the 2nd International Tagging and Tracking Symposium held in Spain in late 2007. The conference's focus was on the application of biotelemetry methods in fisheries science and followed an earlier conference in 2000 in Hawaii.

In tagging, we usually want to learn where an animal goes and what it does. Depending on the study question, more emphasis might be placed on the former or the latter information, but learning something about the track taken by an animal is a fundamental reason to tag. The methods available to track animals depend a lot on behavior. Tags for obligate (and unquestionably charismatic) air breathers can use radio signals to track or geolocate the animal and to transmit data, taking advantage of frequent surfacings. The long range of radio transmissions means that fairly accurate positions can be obtained anywhere in the world whether by tag transmissions to Argos satellites or cell phone networks, or by reception of GPS signals on the tag. Thus, there are existing global infrastructures that can be used to track tags on marine mammals, albeit with many restrictions that we would love to overcome.

In comparison, numerous species of aquatic animals surface infrequently, if at all, and this dictates a fundamentally different approach to animal tracking and tag design. Two methods are widely used to track submerged animals. The first involves acoustic beacon tags which produce a high-frequency sound burst (typically around 70 kHz and 140 to 150 dB SPL) every few seconds or minutes. One or more acoustic receivers in the vicinity are needed to detect this signal. Most acoustic tags (as they are called in fisheries' biotelemetry; not to be confused with sound recording tags used on marine mammals) encode a unique number in their signal to allow different individuals to be identified. Some tags also encode a reading from a pressure or temperature sensor into the signal. Acoustic tags are small (e.g., 8 mm diameter × 20 mm long), disposable, and can have a lifetime of multiple years at a low transmission rate. Compared to radio, the operational range of acoustic tags is very low, typically < 1 km. Thus, researchers must track tagged animals closely with a mobile receiver or install a network of receivers to create their own local tracking infrastructure.

The other popular method for tracking submerged animals is geolocation. This method, attributed to the 17th century navigator Captain Cook, involves taking light level measurements at precise times. From these, the time of sunrise and sunset, and the time lag between them, can be estimated giving the latitude and longitude. Although accuracy is not great, this method is easy to implement in a tag and works, apparently, even when light levels are measured at depths of tens or even hundreds of meters. Accuracy can be improved by recording water temperature and, at least for demersal animals, water depth on the tag but, nonetheless, positional errors of 100 km or more are typical as discussed by one of the papers in this volume. Geolocating tags are usually archival, meaning that the tag must be recovered to access the data. For harvested species, tags are returned by fishermen in exchange for a reward. An alternative strategy is to have tags detach after a predetermined time and float to the surface for the data to be transmitted via Argos.

Given these two options for tracking non-air-breathers, researchers have to decide whether they prefer to know where their animal is or what it is doing: you can't really have both with current technology. Acoustic beacon tags can facilitate precise positioning of tagged animals, at least over areas of tens of km^2, but provide relatively crude information about the behavior of animals (e.g., a dive depth measurement every few minutes). Archival tags, on the other hand, can record detailed behavioral information from depth sensors and a growing range of other sensors (e.g., the Daily Dairy [Wilson et al., 2008] and two papers in this volume) but have to resort to geolocation for positioning the animal. Pop-off tags, although the only option for some species, are in a sense the worst of both worlds: they use geolocation and thus have poor tracking accuracy but cannot collect much data either due to the low bandwidth of the Argos data relay system. Despite these limitations, an enormous amount has been learned from tags on aquatic animals. This book covers studies on commercial fish, sharks, and protected species such as southern bluefin tuna. The book is divided into three parts, dealing with behavioral studies using tags, new methods for geolocation, and applications of tag-derived data in fisheries management.

Twelve papers in the book report on behavioral studies using acoustic beacon and/or archival tags. In most cases, the variables measured were location (either by acoustic ranging or geolocation) and/or depth and temperature, with one study adding a jaw opening sensor. The low data rate of most of these tags meant that behavioral inferences were drawn from summary statistics like the depth distributions and time spent in different habitats. Two papers reported preliminary results from new fast-sampling, multisensor archival tags, enabling fine-scale behavioral sequencing, similar to the growing range of studies on sea birds, seals, and cetaceans. The potential for these tags to assess the energy expended in different behavioral states seems promising, although much remains to be done to validate such methods.

For studies involving acoustic tags, the short telemetry range of these devices is a major constraint. Two papers discuss the potential for acoustic tracking arrays that would pool resources to track animals over large areas. The Ocean Tracking Network is one such initiative which aims to unite regional networks into a global observatory system (GOOS). A major issue for all such schemes is the lack of interoperability of acoustic tags from different manufacturers, requiring the use of multiple or more complex receivers. Another issue is the diversity in attachment methods (e.g., implanted vs. external), each requiring different data processing methods to extract compatible data from raw sensor readings. Nonetheless, these networks represent a tremendous opportunity for researchers (including marine mammal researchers) to contribute to, and benefit from, a global-scale understanding of the marine habitat.

Even with large-scale receiving arrays, the limited range of acoustic beacon tags means that fish will pass in and out of coverage, resulting in frequent outages in the data. Numerous error sources also plague geolocation data, resulting in outages and poor data quality. Thus, the challenge in fish biotelemetry studies is often in interpreting partial, noisy, or irregularly sampled data. A number of methods have been developed to smooth or interpolate these data, and several papers in this volume describe sophisticated techniques such as Monte Carlo Markov Chains and particle filters. A paper by Thygesen and colleagues introduces a Hidden Markov Model method for determining the most probable track from noisy data, a method that has application to Argos positioning data collected from marine mammals. Another excellent paper by the same author develops a methodology for predicting the spatial and temporal resolution of geolocated tracks using quantities that may be available to the researcher before performing the study such as mean fish speed, sampling interval, and geolocation error. This *a priori* power analysis is a great example of how an experiment design can be tested and refined before going to the field, improving the quality and quantity of data.

The final section of the book is devoted to fisheries management issues. Several papers describe the application of biotelemetry data to stock management initiatives by improved understanding of habitats or spawning behaviors, or by improving abundance estimates. In one case, real-time localizations of blue fin tuna, obtained from pop-up satellite tags, were used to update exclusion zones for a longline fishery to minimize by-catch of this quota-controlled species. By-catch and overexploitation of the oceans are obviously critical issues for marine mammals as well, and a closer collaboration between the fish and marine mammal scientific communities could only help to focus effort and resources on these problems.

Almost all of the work reported in this book was achieved using commercially available tags. Only three of the 17 papers describing tag-based studies used a noncommercial tag or extensively modified a commercial device. The majority of commercial tags were produced by just two companies: Lotek and Vemco. This is not so surprising given the expense involved in developing electronic tags, but it raises a question. Does reliance on commercial products to define the parameters that can be measured lead to a lack of research diversity? Companies have to pick products that have a wide enough appeal to recover their development costs, and this tends to promote uniformity in the available methods. Some tags are now sold with propriety data analysis and visualization software, increasing the odds that everyone ends up plotting the same graph. Another result of the commercial development of tags is that the precise methods used to acquire, store, and process data are often unknown to the user. This is especially an issue in tags with low bandwidth data links (e.g., Argos) for which the data must be compressed aggressively. Given the expense of maintaining patents, secrecy may be the most expedient way to preserve intellectual property in a small business, but this does not benefit the customers. Researchers need to have faith in their tools and the results that come from them. This requires a detailed understanding of how data are obtained and what data might be lost by compression or duty-cycling algorithms. Several papers in the book reiterate this issue, and I share the plea for complete disclosure of how data are handled in tags. As customers, the power is ours to enforce this!

The level of invasion in many of the studies reported here is well beyond what is practiced with marine mammals, making for hard reading in places. In one study, archival tags with as little as six hours of recording time were implanted in cod using extensive "blunt dissection." Only one of the cod ever resumed eating after the operation, but even though the objective of the study was to detect foraging, the authors characterized all five attachments as successful. This, it seems to me, is an unusual usage of the word "successful." Only one study in this volume attempted to quantify the effect of tagging (Jolivet et al.), in this case on hake. Two types of tags were tested against a control group: a superficial implanted T-bar (non-electronic) marker and a 25 × 8 mm archival tag implanted in the peritoneal cavity. Other than tag insertion, the control group was treated in the same way as the other groups, including being given anesthesia. The results were strong: after 100 days, the mortality rate of tagged animals was more than 70% compared to < 30% for the control group. The authors conclude that, while some animals die due to handling stress within a few days of tagging, longer-term effects such as nutritional stress in animals that do not resume eating adequately may be an important eventual source of mortality necessitating long study durations to fully assess the impact of tags (a result in concordance with a recent long-term study on penguin flipper tags; Saraux et al., 2011).

As is often the case with this sort of paper compilation book, the review process seems to have been less rigorous than in a journal. This is not intended as a criticism of the editors who probably had trouble enough just persuading authors to complete their manuscripts in time. However, the "review-lite" results in several papers containing poor explanations, incorrect units, low-quality graphics, and erroneous ideas. The errors don't really reduce the value of the book, but they do make for difficult reading at times. Another minor gripe is that, even though this volume is in a Springer review series on fish biology, there are few actual review papers. Only two of the 25 papers review tag technology or its applications, while the remaining papers present new and focused results. Overall, this is a book for researchers and resource managers to find out what is being achieved with commercial tags. It is also a great way to catch up on what is new in a field which has seen a lot of activity in the last decade.

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Literature Cited

Saraux, C., Le Bohec, C., Durant, J. M., Viblanc, V. A., Gauthier-Clerc, M., Beaune, D., Park, Y-H., et al. (2011). Reliability of flipper-banded penguins as indicators of climate change. *Nature*, *469*, 203-206. doi:10.1038/nature09630

Wilson, R. P., Shepard, E. L. C., & Liebsch, N. (2008). Prying into intimate details of animal lives: Use of a daily diary on animals. *Endangered Species Research*, *4*, 123-137. doi:10.3354/esr00064