Rev Fish Biol Fisheries (2011) 21:1–9
DOI 10.1007/s11160-010-9183-5

RESEARCH PAPER

An introduction to the practical and ethical perspectives on the need to advance and standardize the intracoelomic surgical implantation of electronic tags in fish

Richard S. Brown · M. Brad Eppard · Karen J. Murchie · Jennifer L. Nielsen · Steven J. Cooke

Received: 15 September 2010 / Accepted: 3 November 2010 / Published online: 30 December 2010

Abstract The intracoelomic surgical implantation of electronic tags (including radio and acoustic telemetry transmitters, passive integrated transponders and archival biologgers) is frequently used for conducting studies on fish. Electronic tagging studies provide information on the spatial ecology, behavior and survival of fish in marine and freshwater systems. However, any surgical procedure, particularly one where a laparotomy is performed and the coelomic cavity is opened, has the potential to alter the survival, behavior or condition of the animal which can impair welfare and introduce bias. Given that management, regulatory and conservation decisions are based on the assumption that fish implanted with electronic tags have similar fates and behavior relative to untagged conspecifics, it is critical to ensure that best surgical practices are being used. Also, the current lack of standardized surgical procedures and reporting of specific methodological details precludes cross-study and cross-year analyses which would further progress the field of fisheries science. This compilation of papers seeks to identify the best practices for the entire intracoelomic tagging procedure including pre- and post-operative care, anesthesia, wound closure, and use of antibiotics. Although there is a particular focus on salmonid smolts given the large body of literature available on that group, other life-stages and species of fish are discussed where there is sufficient knowledge. Additional papers explore the role of the veterinarian in fish surgeries, the need for minimal standards in the training of fish surgeons, providing a call for more complete and transparent procedures, and identifying trends in procedures and research needs. Collectively, this body of knowledge should help to improve data quality (including comparability and repeatability), enhance management and conservation strategies, and maintain the welfare status of tagged fish.

Keywords Surgery · Tagging · Transmitter · Telemetry

R. S. Brown (✉)
Ecology Group, Pacific Northwest National Laboratory, 902 Battelle Blvd., P.O. Box 999, MSIN K6-85, Richland, WA 99352, USA
e-mail: rich.brown@pnl.gov

M. B. Eppard
United States Army Corps of Engineers, Portland District, P.O. Box 2946, Portland, OR 97208, USA

K. J. Murchie · S. J. Cooke
Fish Ecology and Conservation Physiology Laboratory, Department of Biology and Institute of Environmental Science, Carleton University, 1125 Colonel By Dr., Ottawa, ON K1S 5B6, Canada

J. L. Nielsen
United States Geological Survey, Alaska Science Center, 4210 University Drive, Anchorage, AK 99508, USA

Background

Electronic tags have been used for decades to gain a better understanding of the behavior and survival of free-swimming fish in marine (Arnold and Dewar 2001; Sibert and Nielsen 2001) and freshwater (Lucas and Baras 2000) systems. Today, there are a range of electronic tag technologies including transmitters (e.g., radio telemetry, acoustic telemetry, passive integrated transponders [PIT]; reviewed in Lucas and Baras 2000; Cooke et al. 2004; Cooke 2008), and archival biologgers (Sibert and Nielsen 2001; Block 2005), all of which can be affixed to fish in different ways. Early tagging approaches tended to focus on external tagging or gastric implantation, however, both of these techniques have a number of limitations (Bridger and Booth 2003). External tag retention can be poor and the tag can induce drag that impairs swimming ability, accelerates energy use, and may facilitate predation (Thorstad et al. 2001). Gastric tag retention can also be relatively poor (Mellas and Haynes 1985; Brown et al. 2009) although retention time can be increased on fish that are not eating (e.g., adult migratory Pacific salmon, *Oncorhynchus* spp.; Ramstad and Woody 2003) or if tag ingestion is voluntary (Winger and Walsh 2001), but otherwise it can impede digestion and will eventually be shed. While external and gastric techniques are relatively simple and non-invasive, their short-term retention (i.e., days to weeks) tends to make them undesirable for longer-term studies (i.e., weeks to years). As such, one of the most common approaches for tagging fish is the use of surgical procedures where a laparotomy is performed to enable the intracoelomic (note–some of the literature refers to tag placement as being "intraperitoneal" which is less correct that the term "intracoelomic" that we have decided to use throughout this special issue upon extensive consultation with veterinary professionals) implantation of the electronic tag. Given the relative invasiveness of this procedure, it is important that investigators have a thorough understanding of the techniques used to implant electronic tags and all of the activities associated with implantation.

One of the first detailed accounts of intracoelomic implantation of electronic tags was in a study by Hart and Summerfelt (1975) where they implanted radio transmitters into the coelom of flathead catfish (*Pylodictis olivaris*). Since that seminal report, numerous research studies have been conducted with the objective of improving techniques used to implant transmitters in fish (for reviews, see Summerfelt and Smith 1990: Harms and Lewbart 2000; Jepsen et al. 2002; Mulcahy 2003; Cooke and Wagner 2004; Wagner and Cooke 2005). Despite the extent of research that has been performed on surgical implantation of electronic tags into fish, there still are differences in the techniques used among researchers. In addition, it is evident from photographs shown during scientific presentations, in images and videos posted on the internet, and in technical reports and peer reviewed papers, that there are many professional fish biologists using antiquated implantation techniques or equipment that have the potential to lead to an undesirable outcome. To date, there is no synthesis published evaluating all aspects of the intracoelomic implantation of electronic tags in fish covering a range of species and tag types. Hence, the goal of this collection of papers is to provide such a document of the best available science for the intracoelomic implantation of electronic tags in fish to advance the practice and thus improve surgical outcomes, provide better data and ensure that the welfare status of tagged fish is maintained. The objective of this introductory paper is to emphasize the practical and ethical context for this compilation and to provide a brief overview of the content of the various papers and how they are interconnected.

Although the special issue attempts to be broadly useful for those wishing to tag a variety of species with a range of tag types in many jurisdictions, the genesis of the special issue was the tagging of Pacific salmon smolts in the Columbia Basin, USA. There are many groups that routinely conduct biotelemetry studies on juvenile salmonids within the Columbia Basin using a wide range of techniques for surgical implantation. A lack of consistency in implantation techniques among studies (which can be influenced by research group, project or year) can make the comparison of results between studies more difficult or impossible. The need for a single set of guidelines based on scientific research is important when you consider that the U.S. Army Corps of Engineers (USACE) currently funds studies that result in the release of over 120,000 electronic tags (acoustic, radio, inductive) per year in the Columbia Basin. Moreover, given the large amount of funding invested in tagging studies and the fact that management, conservation and legal decisions are often based on the outcome of tagging studies, it is critical that the techniques used are the best possible and are able to withstand the scrutiny of the courts. This special issue extends beyond the focus on Pacific salmon smolts in the Columbia basin, to also draw upon the broader literature. However, several of the "how to" papers within this issue including the ones on anesthesia (Carter et al. 2011), pre- and post-surgical care (Oldenburg et al. 2011), water quality and conditioners (Harnish et al. 2011), and the incision and wound closure (Wagner et al. 2011) rely heavily on data on salmon smolts given that they are so widely studied and thus provide a useful framework for how other taxa-specific guidelines could be developed. Other papers are intentionally broad, covering all existing studies on intracoelomic implantation of electronic tags in fish.

Each of the papers in this special issue includes a thorough review of the literature in an effort to provide a scientific background on intracoelomic implantation. We have endeavored to have each set of authors supply researchers with the reasons why certain procedures should be used instead of simply providing a list of procedures. However, research performed in several areas of fish surgical implantation has been insufficient to allow researchers to base their methodology on empirical science. Therefore, some techniques used for implantation of electronic tags often are based on recommendations from veterinarians or from years of experience by fisheries researchers. The papers in this special issue delineate the difference between methods based on these two different sources. When a scientific basis is not available for a certain surgical method, suggestions are provided for future research that could provide one (See Cooke et al. 2011b for research agenda). When researchers think of intracoelomic implantation, it is likely that their focus is on the surgical procedure itself. As evident in Table 1, the actual surgical procedure represents a small (but important) component of the entire implantation process. The special issue addresses nearly all aspects of the entire implantation process in order to emphasize the interconnectedness of the various stages and to remind potential fish surgeons that there are many ways in which the surgical outcome can vary for the fish independent of techniques used during the laparotomy.

Overview of special issue

The first paper in the special issue is focused on surgical training, an often overlooked aspect of any intracoelomic electronic tagging study. Cooke et al. (2011a) summarize literature from the veterinary science, human medicine and more recently, fisheries research that demonstrates relationships between factors such as training and surgical experience with the outcome of the surgical procedures. Such relationships emphasize the need for rigorous training and evaluation for fish surgeons. However, there are currently no guidelines or consistent training methods for those intending to implant electronic tags in fish. In an effort to emphasize the need for training, the authors present an overview of common surgical errors with an extensive series of photographic plates. The authors identified attributes related to knowledge, understanding, and skill that they argue should be demonstrated by potential surgeons prior to performing fish surgery. Further, the authors suggest that training include a "hands on" assessment using live fish to evaluate surgical outcomes. Cooke et al. (2011a) developed a suite of core competencies that should be required of surgeons and outline a 3-day curriculum for training surgeons to conduct intracoelomic implantation of electronic tags in fish. If adopted, this curriculum has the potential to elevate the practice of fish surgery.

Also included in this special issue is a paper by Harms and Lewbart (2011), two veterinarians with extensive experience in intracoelomic surgeries on fish. Given their background, they were able to offer a unique perspective on the potential role of vets in the surgical implantation of electronic tags in fish. The authors acknowledge that the current role of veterinarians participating in the intracoelomic surgical implantation of electronic tags in fisheries research projects is limited, but could be expanded. Of particular relevance to fisheries scientists is the fact that veterinary training is broadly applicable to conducting surgeries on any species, and there are increasing numbers of veterinarians with fish-specific experience. Harms and Lewbart (2011) identified a number of roles that veterinarians can play including advising on surgical instrument selection and acquisition, interfacing with Institutional Animal Care and Use Committees, devising strategies for anesthesia, complying with regulatory requirements, providing individualized surgery instruction, and occasionally performing field surgeries. The authors are clear that the role of the veterinarian is not to replace "non-veterinary" fish surgeons. In an attempt to break

Table 1 Components of the intracoelomic electronic tagging process that are addressed in this issue organized in approximate order of completion

Component	Relevant Papers From Special Issue (Bolded) and Elsewhere
Preparation	
Review literature to obtain information on best practices and lessons learned from studies on conspecifics or closely related taxa (where available)	Bridger and Booth 2003; Jepsen et al. 2002; Mulcahy 2003; **All papers in special issue;** See Cooke et al. 2011b for review; Loher and Rensmeyer 2011
Consult veterinarians and others with relevant experience/knowledge	Harms and Lewbart 2011; Thiem et al. 2011
Develop tagging SOP that uses standardized techniques to the extent possible	**All papers**
Apply for animal care clearance from relevant authority	Thiem et al. 2011
Apply for scientific collection permit from relevant authority	NA
Develop biosecurity protocol	NA
Order tagging supplies and develop surgery suite	NA
Train staff and provide opportunities to practice surgery on live fish similar to those that will be used for formal study	Cooke et al. 2011a
Capture and pre-operative handling	
Capture/obtain fish using least injurious and stressful means	Oldenburg et al. 2011
Monitor water quality	Oldenburg et al. 2011
Monitor fish health	Oldenburg et al. 2011
Minimize handling to reduce injury and stress	Portz et al. 2006; Harmon 2009; Oldenburg et al. 2011
Use water conditioners	Harnish et al. 2011
Clean tools, electronic tag and surgical suite in preparation for surgery	Mulcahy 2003; Harms and Lewbart 2000; Chomyshyn et al. 2011; Harms and Lewbart 2011; Mulcahy 2011
Anesthesia and surgery	
Anesthetize fish and transfer to surgery suite	Ross and Ross 2008; Carter et al. 2011
Perform laparotomy (incision)	Wagner et al. 2011
Insert electronic tag	Wagner et al. 2011
Use antibiotics if advisable	Mulcahy 2011
Close incision	Mulcahy 2003; Wagner et al. 2011
Post-operative care and release	
Resuscitate fish as needed	Oldenburg et al. 2011
Monitor water quality	Oldenburg et al. 2011
Monitor fish health	Oldenburg et al. 2011
Minimize handling to reduce stress and injury	Portz et al. 2006; Harmon 2009; Oldenburg et al. 2011
Use water conditioners	Harnish et al. 2011
Release fish at time identified based on study objectives, scientific knowledge and fish health	Oldenburg et al. 2011
Follow-up	
Submit necessary reports to animal care committee and regulatory agencies	NA
Reflect on process to inform future study (what can be improved and incorporated into SOP and future training)	Cooke et al. 2011a, b
Disseminate findings that include adequate detail to enable replication of study	Thiem et al. 2011

Note that the surgical process includes much more than just the surgery itself and this is reflected in the scope of the special issue. References bolded represent the papers in the special issue that address the different phases of the tagging process. This table assumes that it has already been decided that some form of electronic tag technology is the best means of addressing the study objective(s) and that intracoelomic implantation has been chosen as the means of tagging down some of the barriers that appear to limit interactions with veterinarians, Harms and Lewbart (2011) suggest that it is useful to recognize the relative strengths and deficits of the two groups to enable successful collaborations. In assembling this special issue it was important to the editorial team to include a veterinary perspective given that engaging veterinary consultation for electronic tag implantation surgeries in fish can be a mutually beneficial experience for the researcher and the veterinarian, with dividends in data quality and welfare of the research subjects.

The third paper recognizes that the care of fish before and after surgery is critical to the outcome of the procedure. Oldenburg et al. (2011) summarize the sources of stress and injury for fish and their potential negative effects during pre- and post-surgical holding. The authors examine negative aspects of handling, air exposure, water quality, and holding density, and provide recommendations to ameliorate their potential negative influences. Literature related to specific dynamic action, gastric evacuation, and post-absorptive energy use are also examined and related to pre- and post-surgical holding. The review indicates the variability in study locations and facilities available for holding fish and suggests the pre- and post-surgery holding factors that should be prioritized.

Harnish et al. (2011) examine the importance of water conditioners for use during the process of tagging fish to decrease disturbance to the mucus layer. The authors examine the role of the mucus layer and the negative implications of its disturbance. The types of water conditioners available and the mechanism for protecting the mucus layer are also explored. They reviewed studies that examined the effects of water conditioners on fish and provide recommendations for its use in tagging procedures.

Carter et al. (2011) examine the use of tricaine methanesulphonate (MS-222) for surgical implantation of transmitters and handling of fish associated with implantation. They examine the role of anesthesia, how users can protect themselves while using this chemical, how it should be stored, and the ambiguity in the state of knowledge in this area. In addition, the authors review how this anesthetic works and provide guidance on dosage and the length of exposure. One critical aspect of the use of MS-222 is its proper use so that fish are not overexposed and damaged. Carter et al. (2011) examine the mechanisms associated with overexposure to this anesthesia and precautions of its administration. It is worth noting that for the purpose of the special issue we did not dwell on anesthesia because it is covered in depth elsewhere. However, it is worth noting that there is need for zero-withdrawal anesthetics as well as additional research on other means of sedating or restraining fish for surgery including electroanesthesia.

Chomyshyn et al. (2011) identified that aside from a study by Wagner et al. (1999) examining wound healing in rainbow trout (*Oncorhynchus mykiss*) treated with or without betadine, there have been no scientific evaluations of aseptic techniques and their benefits. To address this data gap, the authors conducted two experiments on a model species (bluegill, *Lepomis machrochirus*) related to infection control during the intracoelomic surgical implantation of electronic tags in fish. In their first experiment they evaluated the consequences of water entering the incision during tag implantation. Their second experiment examined variation in surgical sterility, from non-sterile to the highest grade of sterility. Chomyshyn et al. (2011) used a variety of endpoints (i.e., mortality, incision healing, physiology [glucose], condition [plasma protein, hepatosomatic index], and health [health assessment index]) to determine if differences existed between the treatments. Although the authors did not detect differences in the surgical outcome of fish in either experiments, they still maintain it is best to avoid introducing water into the incision during surgery, and recommend that fish surgeons work with veterinarians to develop surgical protocols that attempt to balance logistical concerns with sterility in field settings while still maintaining a high quality of animal care.

Wagner et al. (2011) offer a review of surgical implantation techniques for electronic tags. The authors emphasize the importance of considering fish size when selecting surgical implements, incision length, transmitter placement, suture material, and needle type to reduce fish discomfort, minimize tissue damage, and to expedite wound healing. Particular procedures in which human error commonly occurs (i.e., suturing) are highlighted. Wagner et al. (2011) suggest optimal surgical methods for juvenile salmonids based on published literature, and argue the need for standardized procedures. Practical considerations for field-based surgeries are provided in reference to tool selection and sterilization. Given that optimal procedures are not known for all steps in the surgical process, the authors provide suggestions for future studies.

Mulcahy (2011) provides a useful contribution on the use (and mis-use) of antibiotics when conducting intracoelomic implantation of electronic tags in fish. Of particular concern is the fact that the use of single dose antibiotics in this context are of unproven value and this carries with it the potential for the development of antibiotic resistance in bacteria and the alteration of the immune response of the fish. Moreover, Mulcahy (2011) makes a compelling case that antibiotic use during electronic tag implantation must conform to drug laws and regulations; including the requirements for withdrawal times before human consumption is a possibility. Clearly there is need for additional research on antibiotics for surgical implantation of electronic tags in fish.

Loher and Rensmeyer (2011) provide an empirical assessment of physiological responses of Pacific halibut (*Hippoglossus stenolepis*) to different configurations of surgical tag implantation, as well as a review of internal tagging methods employed in studies of flatfishes. The authors argue that while the use of externally- attached pop-up archival transmitting (PAT) tags has become commonplace with the International Pacific Halibut Commission for investigating migration and spawning behaviors, there are a number of questions that cannot be answered using PAT technology (e.g., ontogenetic changes in behavior), but rather are better suited to data storage tags surgically implanted in the fish. Given the need to recover the tag to retrieve the data, Loher and Rensmeyer (2011) carefully consider encapsulation of the tag as a limitation to tag recovery, and contrast the use of fully internal tags versus those with externally-projecting light stalks. The authors encourage all researchers using tagging technology to conduct holding experiments of appropriate length and scope to quantify the potential for tissue encapsulation (and possibly tag expulsion) given the longevity of modern tag technology. Indeed, this contribution emphasizes the need to evaluate surgical techniques on a wide range of fish species given the immense variation in anatomy, morphology and biology.

Unlike the majority of other papers in this special issue, the contribution by Thiem et al. (2011) focused on empirical studies that used intracoelomic implantation to tag fish for biological study rather than to evaluate tagging effects per se. They argue that with a growing number of studies that involve surgical implantation of electronic tags, it is essential to be able to evaluate the methods used. Only when the methods are transparent, clear and complete may readers undertake a complete and informed assessment of a given study. The objective of the study by Thiem et al. (2011) was to quantify the level of "completeness" or "repeatability" of surgical procedures reported in tagging studies over the last 20 years. The authors reviewed a random sample of articles from 1990 to 2009 where electronic tags were surgically implanted in fish aimed at characterizing trends in data reporting. They revealed that the majority of studies failed to report basic information related to the surgical procedures used which would make it challenging to repeat a study. Some study information was consistently well reported such as the tag size and dimensions, the type of anaesthetic used and the location of incisions. In contrast, the type of suture knots, duration or level of anaesthesia, and precautions taken to minimize infection were consistently left out of the methods section of most telemetry studies. Their analysis was confounded by the large proportion of studies that cited other sources for their surgical methods. Although such an approach is valid, Thiem et al. (2011) found numerous instances where the paper cited did not contain adequate details, making it even less clear as to what methods were used in the current study. To that end, Thiem et al. (2011) recommend that future electronic tagging studies include minimum reporting standards which they presented in their paper. Increasing the detail of reporting has the potential to improve the quality of data presented, minimize welfare and ethical concerns and allow transparency for study repeatability. Moreover, transparent methods will enable researchers to determine the extent to which it is possible to make inter-study comparisons.

Bridger and Booth (2003) published a review where they detail the literature associated with attachment of telemetry tags to fish and covered a variety of approaches including gastric, external, intracoelomic and urogenital. In recognition that intracoelomic tagging approaches were preferred for most applications, there have since been numerous studies on various aspects of the surgical procedures.

Indeed, it is that body of literature that served as the basis for the recommendations that emanated from the various papers contained in this special issue. In the final paper for the special issue, Cooke et al. (2011b) conducted a quantitative literature review where they summarized the trends in 108 peer-reviewed electronic tagging effect studies focused on intracoelomic implantation. The objective of their paper was to summarize the entire body of peer reviewed literature related to the intracoelomic implantation of electronic tags in fish to characterize the existing body of work and to identify where research gaps still exist. The authors revealed that to date, almost all of the studies have been conducted in freshwater, typically in laboratory environments, and have focused on biotelemetry devices rather than archival loggers. The majority of studies have focused on salmonids, cyprinids, ictalurids and centrarchids, with a regional bias towards North America, Europe and Australia. Most studies have focused on determining whether there is a negative effect of tagging relative to control fish, with proportionally fewer that have contrasted different aspects of the surgical procedure (e.g., methods of sterilization, incision location, wound closure material) that could advance the discipline. Some of the more common endpoints used were mortality, growth, healing and tag retention. Relatively few studies addressed sublethal endpoints such as swimming ability, predator avoidance, physiological costs, or fitness.

Based on their synthesis, the authors developed a detailed research agenda specific to different tag types, species, and environments. Not surprisingly, it was quite evident that in a relative sense, the most was known about implantation of freshwater fish, particularly juvenile salmonids, with comparatively little known about tagging of marine fish. Cooke et al. (2011b) also developed a series of generalized guidelines intended to elevate the science of intracoelomic implantation. In particular, they suggested that future studies would benefit from (1) rigorous controlled manipulations based on statistical designs that have adequate power, account for inter-individual variation, and include controls and shams, (2) approaches that transcend the laboratory and the field with more studies in marine waters, (3) incorporation of knowledge and techniques emerging from the medical and veterinary disciplines, (4) addressing all components of the surgical event, (5) comparative studies that evaluate the same surgical techniques on multiple species and in different environments, (6) consideration of how biotic factors (e.g., sex, age, size) influence tagging outcomes, and (7) studies that cover a range of endpoints over ecologically-relevant time periods. To our knowledge, the research agenda and proposed framework for future studies is the first such attempt to collate and direct research on the important topic of intracoelomic implantation.

Conclusions

This compilation of peer reviewed papers represents the first such attempt to evaluate all available science related to intracoelomic implantation of electronic tags in order to provide practitioners with knowledge that has the potential to improve the surgical outcome. The compilation is comprehensive and addresses all phases of the implantation process. The need for this compilation was obvious. There were a number of critical issues related to animal welfare, professionalism, standardization, and data quality (see Table 2) that needed to be addressed in order to elevate the science and practice of intracoelomic electronic tag implantation. Failure to do so (see Table 2) has the potential to have a number of negative consequences including reductions in funding for electronic tagging studies, loss of public, scientific and legal credibility, introduction of bias, and animal welfare impairments. We believe that this compilation is the first step to doing so and there are a number of strategies including greater incorporation of veterinary skill (Harms and Lewbart 2011), training (Cooke et al. 2011a) and more transparent and complete reporting of methods (Thiem et al. 2011) that should have immediate benefit. What is also clear is that continued research is needed to further elevate the practice of electronic tag implantation in fish in order to ensure that the data generated are relevant to untagged conspecifics (i.e., no long-term behavioral or physiological consequences) and the surgical procedure does not impair the health and welfare status of the tagged fish. The research agenda provided by Cooke et al. (2011b) identifies many opportunities for future research on this topic. Indeed, there are many aspects of the implantation process for which we simply no nothing or only know very little

Table 2 Summary of key general issues related to the need for advancing intracoelomic implantation of electronic tags in fish with an overview of the benefits of doing so and the risks associated with failure to do so

Issue	Benefits of advancing the science and practice of tagging	Risks of failure to advance science and practice of tagging
Fish welfare	Improvements in tagging techniques are consistent with maintaining welfare status	Biosecurity concerns with fish that could be in poor condition after handling
	Fish welfare is consistent with ensuring animals in good health and condition	Institutional animal care and use committees could restrict procedures and demand adoption of best practices
Professionalism	Provides researchers with credibility to address public and legal scrutiny	Failed surgeries/studies could lead to reductions in funding or negative media reports
Standardization	Would enable longitudinal analyses or cross-study analyses	Difficult to make comparisons and evaluate literature
Data quality	Management actions must be based on reliable data that reflects untagged conspecifics	Management decisions based on unreliable data could lead to significant economic, social and environmental costs and erode confidence in tagging studies
	Tagging studies of threatened species are critical and require that best practices are used	Research permits may not be issued for work on imperiled species if the tagging effects are not well-developed and tested

for a given taxa or environment. Nonetheless, this compilation represents an exhaustive summary of all available literature which should serve as a valuable resource for those conducting intracoelomic electronic tag implantation in fish.

Acknowledgments We thank Alison Colotelo for kindly providing comments on this introductory paper. The following referees kindly evaluated the papers considered for this special issue: Tim Clark, Thomas Grothues, Erica Eliason, Jesse Trushenski, Tom Binder, Sarah McConnachie, Daniel Mulcahy, Chris Vandergoot, Martyn Lucas, Craig Bihun, Tony Goldberg, Cory Suski, Greg Gaulke, Eric Hockersmith, Caleb Hasler, Edd Brooks, Alison Collins, Chris Holbrook, Brendan Ebner, Katrina Cook, Craig Harms, Marie-Laure Acolas, Katherine Deters, Adam Daniel, Jim Boyd, Brian Graeb and Brenton Zampatti.

References

Arnold G, Dewar H (2001) Electronic tags in marine fisheries: a 30-year perspective. In: Sibert JR, Nielsen JL (eds) Eletronic Tagging and Tracking in Marine Fishes. Kluwer Academic, Dordrecht, pp 7–64

Block BA (2005) Physiological ecology in the 21st century: Advancements in biologging science. Integr Comp Biol 45:305–320

Bridger CJ, Booth RK (2003) The effects of biotelemetry transmitter presence and attachment procedures on fish physiology and behavior. Rev Fish Sci 11:13–34

Brown RS, Carlson TJ, Welch AE, Stephenson JR, Abernathy CS (2009) Assessment of barotraumas from rapid decompression of depth-acclimated juvenile Chinook salmon bearing radiotelemetry transmitters. Trans Am Fish Soc 138:1285–1301

Carter KM, Woodley CM, Brown RS (2011) A review of tricaine methanesulfonate for anesthesia of fish. Rev Fish Biol Fish. doi:10.1007/s11160-010-9188-0

Chomyshyn L, McConnachie SH, Cooke SJ (2011) Evaluation of water entry into the coelom and different levels of aseptic technique during surgical implantation of electronic tags in freshwater fish. Rev Fish Biol Fish. doi:10.1007/s11160-010-9189-z

Cooke SJ (2008) Biotelemetry and biologging in endangered species research and animal conservation: relevance to regional, national, and IUCN Red List threat assessments. Endanger Species Res 4:165–185

Cooke SJ, Wagner GN (2004) Training, experience, and opinions of researchers who use surgical techniques to implant telemetry devices into fish. Fisheries 29(12): 10–18

Cooke SJ, Wagner GN, Brown RS, Deters KA (2011a) Training considerations for the intracoelomic implantation of electronic tags in fish with a summary of common surgical errors. Rev Fish Biol Fish. doi:10.1007/s11160-010-9184-4

Cooke SJ, Woodley CM, Eppard MB, Brown RS, Nielsen JL (2011b) Advancing the surgical implantation of electronic tags in fish: a gap analysis and research agenda based on a review of trends in intracoelomic tagging effects studies. Rev Fish Biol Fish. doi:10.1007/s11160-010-9193-3

Cooke SJ, Hinch SG, Wikelski M, Andrews RD, Wolcott TG, Butler PJ (2004) Biotelemetry: a mechanistic approach to ecology. Trends Ecol Evol 19:334–343

Harmon TS (2009) Methods for reducing stressors and maintaining water quality associated with live fish transport in tanks: a review of the basics. Rev Aqua 1:58–66

Harms CA, Lewbart GA (2011) The veterinarian's role in surgical implantation of electronic tags in fish. Rev Fish Biol Fish. doi:10.1007/s11160-010-9185-3

Harms CA, Lewbart GA (2000) Surgery in fish. In: Bennett RA (ed) Veterinary clinics of North America: exotic animal practice. Saunders, New York, pp 759–774

Harnish RA, Colotelo AH, Brown RS (2011) A review of polymer-based water conditioners for reduction of handling-related injury. Rev Fish Biol Fish. doi:10.1007/s11160-010-9187-1

Hart LG, Summerfelt RC (1975) Surgical procedures for implanting ultrasonic transmitters into flathead catfish (*Pylodictis olivaris*). Trans Am Fish Soc 104:56–59

Jepsen N, Koed A, Thorstad EB, Baras E (2002) Surgical implantation of telemetry transmitters in fish: how much have we learned? Hydrobiologia 483:239–248

Loher T, Rensmeyer R (2011) Physiological responses of Pacific halibut, *Hippoglossus stenolepis*, to intracoelomic implantation of electronic archival tags, with a review of tag implantation techniques employed in flatfishes. Rev Fish Biol Fish. doi:10.1007/s11160-010-9192-4

Lucas MC, Baras E (2000) Methods for studying spatial behavior of freshwater fishes in the natural environment. Fish Fish 1:283–316

Mellas EJ, Haynes JM (1985) Swimming performance and behavior of rainbow trout (*Salmo gairdneri*) and white perch (*Morone americana*): Effects of attaching telemetry transmitters. Can J Fish Aquatic Sci 42:488–493

Mulcahy DM (2003) Surgical implantation of transmitters into fish. ILAR Journal 44:295–306

Mulcahy DM (2011) Antibiotic use during the intracoelomic implantation of electronic tags into fish. Rev Fish Biol Fish. doi:10.1007/s11160-010-9190-6

Oldenburg EW, Colotelo AH, Brown RS, Eppard MB (2011) Holding of juvenile salmonids for surgical implantation of electronic tags: a review and recommendations. Rev Fish Biol Fish. doi:10.1007/s11160-010-9186-2

Portz DE, Woodley CM, Cech JJ Jr (2006) Stress-associated impacts of short-term holding on fishes. Rev Fish Biol Fish 16:125–170

Ramstad K, Woody CA (2003) Radio tag retention and tag-related mortality among adult sockeye salmon. N Am J Fish Manage 23:978–982

Ross LG, Ross B (2008) Anesthetic and Sedative Techniques for Aquatic Animals. Blackwell Publishing, Ames, IA, p 222

Sibert JR, Nielsen JL (2001) Electronic tagging and tracking in marine fisheries. Proc Symp Tagging and Tracking Marine Fish Electronic Devices, Kluwer, Dordrecht

Summerfelt RC, Smith L (1990) Anesthesia, surgery, and related techniques. In: Schreck CB, Moyle PB (eds) Methods for fish biology. American Fisheries Society, Bethesda, MD, pp 213–272

Thiem JD, Taylor MK, McConnachie SH, Binder TR, Cooke SJ (2011) Trends in the reporting of tagging procedures for fish telemetry studies that have used surgical implantation of transmitters: a call for more complete reporting. Rev Fish Biol Fish. doi:10.1007/s11160-010-9194-2

Thorstad EB, Økland F, Heggberget TG (2001) Are long term negative effects from external tags underestimated? Fouling of an externally attached telemetry transmitter. J Fish Biol 59:1092–1094

Wagner GN, Cooke SJ (2005) Methodological approaches and opinions of researchers involved in the surgical implantation of telemetry transmitters in fish. J Aquat Anim Health 17:160–169

Wagner GN, Stevens D, Harvey-Clark C (1999) Wound healing in rainbow trout following surgical site preparation with a povidone-iodine antiseptic. J Aquat Anim Health 11:373–382

Wagner GN, Cooke SJ, Brown RS, Deters KA (2011) Surgical implantation techniques for electronic tags in fish. Rev Fish Biol Fish. doi:10.1007/s11160-010-9191-5

Winger PD, Walsh SJ (2001) Tagging of Atlantic cod (*Gadus morhua*) with intragastric transmitters: effects of forced insertion and voluntary ingestion on retention, food consumption and survival. J Appl Ichthyol 17:234–239