Training, Experience, and Opinions of Researchers Who Use Surgical Techniques to Implant Telemetry Devices into Fish

ABSTRACT

Intraperitoneal implantation of telemetry devices in fishes has become commonplace in fisheries science, yet little is known about the training and experience of practicing fish surgeons. We used a survey to characterize the training, experience, and opinions of researchers who use surgical techniques to implant telemetry devices in fishes. The experience level of the 177 respondents varied from 0 to 25 years of experience and 5 to 5,000 fish surgeries, and it was apparent that there was no consistent method of training in surgical techniques, with many of the respondents indicating they learned from trial and error. Very few of the respondents had been formally tested to assess their level of surgical competency, although the majority recognized that surgical experience was important and believed that a minimum level of experience should be required prior to engaging in fish surgery. Respondents identified a need for more effective training materials and perhaps some levels of international standards. The consensus of respondents was that the most effective surgical training would include coupling theoretical instruction/workshops with hands-on mentoring. We suggest that workshop materials (i.e., curricula and manuals) should be developed by a diverse group of surgeons with experience operating on fish. These materials must be peer reviewed, the courses should be accessible and affordable to all fisheries students and professionals, and the results need to be evaluated to determine if the program is achieving learner outcomes. Furthermore, a formal venue for individuals who conduct surgery on fish is needed to exchange ideas, and to link novices with appropriate mentors. Information derived from this study will provide a starting point for understanding issues associated with fish telemetry surgery and enable development of effective training materials for future and practicing fish surgeons.

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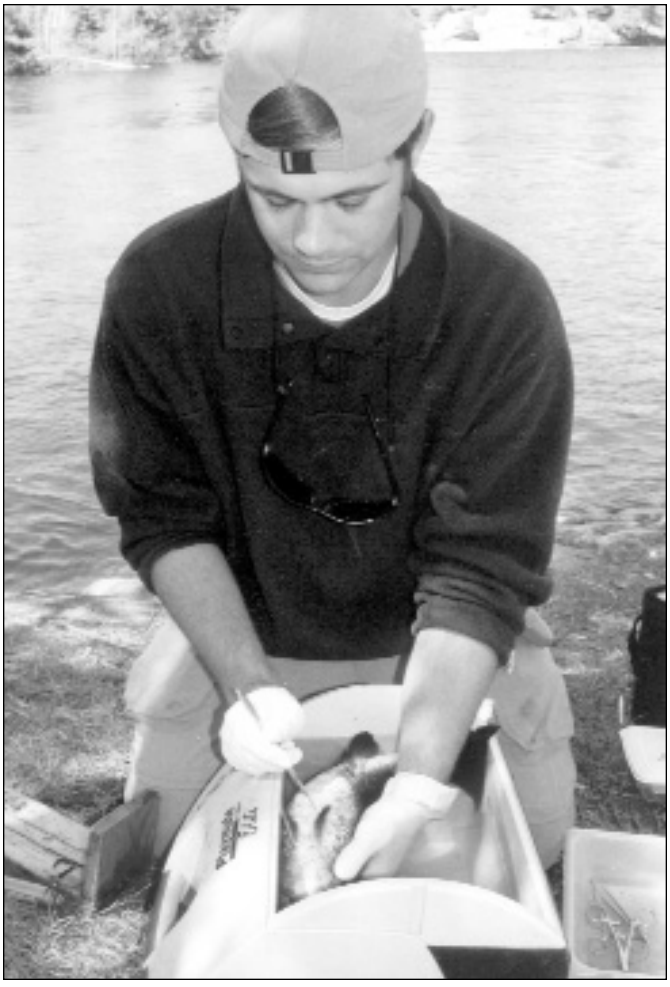
Introduction

Surgical procedures are becoming increasingly common in basic, clinical, and applied fisheries science in both laboratory and field conditions (Summerfelt and Smith 1990; Stoskopf 1993a,b; Harms and Lewbart 2000; Murray 2002; Borski and Hodson 2003; Mulcahy 2003b). The most common type of surgical application in fish is intraperitoneal implantation of devices such as telemetry transmitters, data loggers, and passive integrated transponders (Mulcahy 2003b; Stoskopf 2003; Cooke et al. 2004b). Data derived from use of these surgically implanted devices has provided a wealth of information on activity, movement, swimming speeds, energy use, habitat use, and survival (e.g., Winter 1996; Lucas 1999; Lucas and Baras 2000; Cooke et al. 2004a). However, few empirical studies have been performed to test or develop surgical techniques for fishes, even though a basic tenet of this research is that the surgical procedure or the presence of the transmitter should not significantly alter animal behavior, physiology, and survival. Interestingly, most assessments of surgical procedures that do exist tend to focus on understanding the physical presence of the transmitter (e.g., Peake et al. 1997; Adams et al. 1998; Brown et al. 1999; Paukert et al. 2001; see reviews in Bridger and Booth 2003; Mulcahy 2003b; Thorsteinsson 2002) rather than detailed examinations of the surgical procedures used to implant the device (but see Hart and Summerfelt 1975; Thoreau and Baras 1997; Wagner and Stevens 2000; Wagner et al. 2000; Cooke and Bunt 2001; Jepsen et al. 2002).

In medical and veterinary science, experience of the surgeon and the volume of procedures conducted have been deemed important in the outcome of surgical procedures (Califf et al. 1996). An expanding body of literature suggests that despite receiving formal surgical instruction and clinical experience, veterinarians and physicians still exhibit significant differences in surgical aptitude (Freund et al. 1999). Research into this topic has grown, reflecting genuine care and concern for the well-being of patients and an increase in professional responsibility (Califf et al. 1996). Furthermore, there has been a greater emphasis on the development and testing of different surgical procedures. We suspect that the level of training and experience among individuals that conduct intraperitoneal implantation surgeries on fishes is highly variable, primarily due to the lack of standardized training opportunities and assessment tools.

This variability in experience, and probably in expertise, suggests great variation in the study outcome simply due to surgical competency. To date, there is only one published report on the effects of surgical experience on outcome in fish surgery (Cooke et al. 2003). Although the results were preliminary and the study was not designed to rigorously address that issue, Cooke et al. (2003) did yield the first empirical evidence that the experience of a fish surgeon can affect the speed and precision of surgical procedures, and the outcome of the study (i.e., survival and "normal" behavior).

Greater emphasis is being placed on fish welfare as institutional animal care and use committees (IACUCs) expand their focus beyond current research guidelines for mammals and birds (e.g., Canadian Council on Animal Care, United States Interagency Research Animal Committee) to include other vertebrates (DeTolla et al. 1995; see discussion in Mulcahy 2003a). In some cases, individual IACUCs have attempted to regulate or standardize procedures for fisheries research. However, because most fish telemetry research is not performed by veterinarians and occurs under field conditions, it has been difficult to develop guidelines that are useful and appropriate for fisheries scientists (Mulcahy 2003a,b). Furthermore, there seems to be much variation between the standards employed by different agencies, jurisdictions, and employers. Professional fisheries societies including the American Fisheries Society, American Institute of Fisheries Research Biologists, the American Society of Ichthyologists and Herpetologists, and the Fisheries Society of the British Isles have developed guidelines intended to improve the welfare of fish used in research (ASIH et al. 1987, 1988; AFS et al. 2004; FSBI 2002). Although these general guidelines include sections on surgical implantation of telemetry transmitters, there is very little detailed or standardized information concerning the development of guidelines for training and regulation of fish surgery (Mulcahy 2003a). This is particularly surprising considering that there are some documented examples of negative consequences arising from surgery on fish (see Bridger and Booth 2003; Mulcahy 2003b). Basic information on the education, type of surgical training, skill development and maintenance strategies, and experience levels of practicing fish sur-



Surgical procedures are sometimes conducted in remote sites using simple field apparatus. Here, a fish surgeon is making an incision on a smallmouth bass.

Surgical procedures can also be conducted inside using more elaborate surgical suites. Here, a surgeon is implanting a transmitter into an Atlantic salmon.

geons will provide a starting point for understanding issues associated with fish telemetry surgery.

The primary purpose of this study was to characterize the training and experience of researchers who use surgical techniques to implant telemetry transmitters in fish, and to obtain their opinions concerning appropriate training. We used an online survey instrument to obtain responses from individuals of all experience levels who engage in surgical implantation of telemetry transmitters in fish. This strategy enabled us to collect what may be the first data that will characterize the fish surgery community and provide insight and opinions on fish surgery and training. We believe that this information will be useful for developing more effective guidelines and training materials for fish surgery by professional organizations, as well as government agencies and IACUCs. The ultimate goal is to improve surgical proficiency in order to minimize negative effects of surgical procedures, ensure that data from tagged individuals are representative of the larger untagged population, and to improve the welfare of tagged fishes.

Survey Design

We designed a survey that was intended for individuals who used surgical procedures to implant telemetry devices intraperitoneally (including passive integrated transponders, radio transmitters, acoustic transmitters, and data loggers) in fishes. We used an online program to design a custom survey instrument that was hosted on a commercial server (www.surveyconsole.com). Invitations to participate in the survey (including an access code and instructions) were distributed to potential participants via e-mail. We targeted individuals known to participate in fish telemetry studies by extracting names from recent primary literature (using Fish and Fisheries Worldwide). We also searched the American Fisheries Society Annual Meeting website from 2002 and 2003 to identify other potential participants who may not have published their work. A list of participants for the 4th Conference on Fish Telemetry in Europe also was acquired. Using web-searching tools, we located additional individuals involved in fish telemetry (e.g., from the FAO Telemetry Website). In total, we targeted approximately 300 individuals who had engaged in some form of fish telemetry. Finally, the invitation to participate in the survey was circulated using three list-servs (Fishfolk, Fisheries Ecology, and Biotelemetry). Due to the wide distribution, we cannot speculate on response rates or assess the size of the entire population of fish surgeons. We encouraged recipients to pass along the survey to other appropriate personnel. As such, we were forced to leave access to the survey unrestricted. The system did log IP addresses, which enabled us to monitor for patterns of abuse or intentional bias. As we were content with the level of participation after 35 days and because it was not possible to determine who had already completed the survey, we did not circulate reminders. However, we did contact several individuals in North America and Europe who indicated they had received the survey multiple times from different sources (including passing among colleagues), suggesting that the survey reached many individuals that conduct intraperitoneal surgical implantations on fish.

The entire survey consisted of 43 questions, 22 of which we report on here, and took an average of 1,046 seconds to complete. Other questions detailing specifics of surgical methodology (e.g., different suture materials, anesthetics, etc.) are reported separately (i.e., Wagner and Cooke In Press). We posed a number of questions and also asked those surveyed to respond to a number of statements.

Results

A summation of the findings is reported below. Headings reflect the questions asked or statements provided to respondents.

Survey Respondent Characteristics

In total, we logged 177 responses from individuals who completed the entire survey. In the instructions, we restricted the study to those who actually conducted the intraperitoneal surgical implantation of telemetry devices in fishes. Thus, when characterizing the respondents, we are also de facto characterizing for the first time the characteristics of individuals that conduct surgical implantation of intraperitoneal devices in fishes. Overall, we received responses from 17 countries. The majority of the respondents were from North America (62.4% United States, 20.8% Canada) and Europe (Table 1). Only a small number of responses were received from other regions (Table 1), despite the fact that we attempted to distribute the survey beyond North America and Europe.

The majority of the respondents identified their primary current employment as government (37.7%), academic (25.6%), or student (17.6%). Fewer participants indicated that they worked for a consulting company (12.0%) or nongovernmental organization (4.0%). An additional 3.0% of respondents classified their primary employment as "other."

All respondents had completed some level of higher education, ranging from technical college to

Table 1. Geographical distribution of fish surgery survey respondents (N=171).

Country	Percentage of total responses
North America	83.2
Europe	13.2
Australasia	2.4
Africa	0.6
South America	0.6

veterinary college. The majority of respondents had some form of university education, with M.Sc. (34.5%) and Ph.D. (33.0%) level surgeons being more common than baccalaureate level (23.9%). Only a small percentage of participants had DVM or MD training (4.0%) or technical college training (4.6%).

When asked to characterize their surgical ability on fish, the majority of the respondents (56.7%) considered themselves to be competent, followed by 30.9% as expert, and even fewer as novice (12.4%). There was a consistent positive trend between the experience level of individuals and the amount of time they had been conducting fish surgeries (Figure 1a), the number of surgeries they performed (Figure 1b), and the number of fish species with which they had experience (Figure 1c). Thus, there does seem to be some validity to the ability of surgeons to self-report their own level of ability, presuming that greater experience in terms of volume, time, and number of species implanted translates to ability. However, some individuals who have conducted a large number of surgeries over many years still do not consider themselves as "experts," whereas, some surgeons who have conducted few surgeries in a short period of time do consider themselves to be "experts." It is possible that some of the respondents conducted their research many years ago and have not stayed current or engaged in fish surgery in some time, leading to some individuals with years of experience who still do not consider themselves "experts." Also, not all individuals have the confidence and dexterity to become competent gifted surgeons despite years of experience or large volumes of surgeries.

Respondents also were asked to identify the fish species or family upon which they most frequently conducted surgeries. Overwhelmingly, salmonids were the most frequently identified group of fishes (Table 2). Interestingly, significantly more effort was directed towards freshwater fish than marine fish.

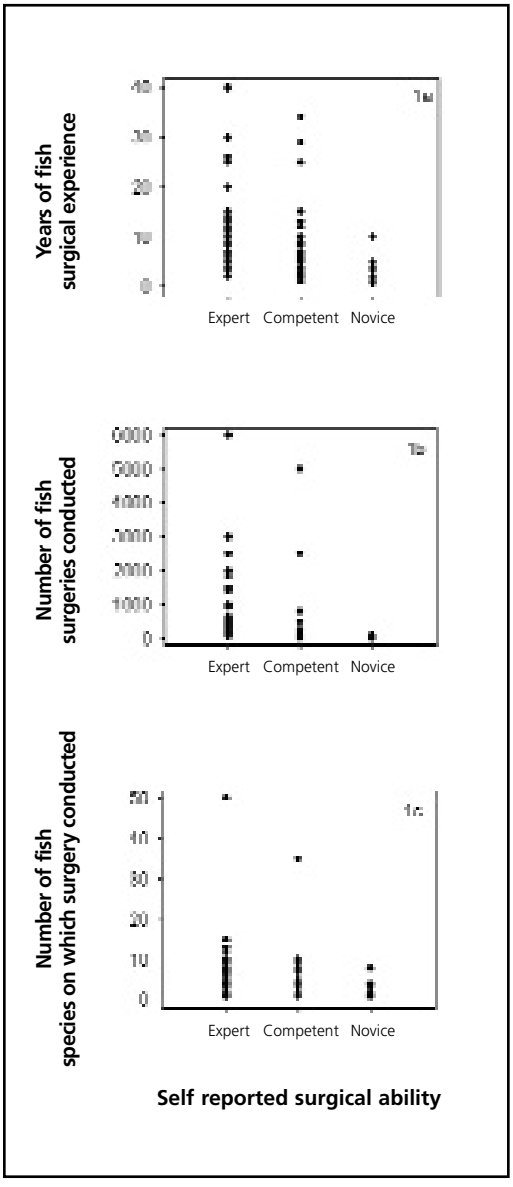


Figure 1. Number of years for which an individual had been conducting fish surgeries relative to their self-reporting of surgical ability

(a). In all cases, there were significant differences in years of experience among self-reported surgical ability (ANOVA with Tukey HSD, $F=17.73$, $P<0.001$; Mean ± SD years, Expert 10.6 ± 7.7, Competent 5.5 ± 5.8, Novice, 2.4 ± 2.2). Number of fish surgeries conducted relative to self-reporting of surgical ability

(b). In all cases, there were significant differences in surgical volume among self-reported surgical ability (ANOVA with Tukey HSD, $F=15.54$, $P<0.001$; Mean ± SD volume of fish surgeries, Expert 791 ± 1028, Competent 181 ± 553, Novice, 27 ± 23). Number of different species upon which fish surgeries conducted relative to self reporting of surgical ability

(c). In all cases, there were significant differences in the number of fish species upon which surgery conducted among-self reported surgical ability (ANOVA with Tukey HSD, $F=14.62$, $P<0.001$; Mean ± SD number of fish species, Expert 7.2 ± 6.9, Competent 3.2 ± 3.7, Novice, 2.1 ± 1.6).

Table 2. Fish families most commonly used for intraperitoneal surgical implantation of fishes as identified by practicing fish surgeons (N=167). For instances where there were fewer than 4 records for a specific family, fish were categorized as "miscellaneous marine" or "miscellaneous freshwater." Additionally, the elasmobranchs are not teleost fishes and are categorized more generically.

Fish family	Percentage of total responses
Salmonidae	37.0
Acipenseridae	10.2
Centrarchidae	9.0
Miscellaneous marine fishes	7.8
Miscellaneous freshwater fishes	6.6
Cyprinidae	6.6
Percidae	5.4
Moronidae	4.2
Gadidae	3.0
Esocidae	3.0
Elasmobranchs	2.4
Ictaluridae	2.4
Catostomidae	2.4

Some surgeons have attempted to maintain sterile surgical conditions but this is challenging when in the field. Here a surgeon uses a drape in a sterile surgical suite while implanting a transmitter into a rainbow trout.

Do you work in a jurisdiction or for an employer that requires some minimum level of surgical training or competency to conduct fish surgery?

The majority of respondents (60.6%) work in a jurisdiction or for an employer that does not require a minimal level of training or proficiency prior to conducting fish surgery. Another reasonably sized component was unsure (11.4%), while only 28.0% answered "yes" to the question.

These findings were somewhat surprising considering the apparent increased emphasis on animal welfare issues, which has been evidenced in Canada and the United States through growing interest in university-administered IACUCs. Although academic and some government agencies (i.e., state, provincial, federal fish and wildlife agencies) are required to participate in national animal care programs, those individuals actually engaged in fish surgery typically have the perception that no minimum level of training or competency is required. Others responded that they do have to document proficiency, perhaps highlighting variation in how federal animal care guidelines are executed. These observations are based only on the U.S. and Canadian responses because of sample size. This is not to say these surgeons or their supervisors do not impose such standards, but there are rarely government-sanctioned minimum requirements.

One of the more common responses was that surgeons had to consult IACUCs regarding a specific protocol. Often this included a veterinarian or other appropriate official within an IACUC observing the surgical approaches used on fish and then providing guidance and eventual approval to work independently. Most often, however, approval of protocols was based on review of written statements indicating familiarity with the species and the procedure proposed. In most cases approval required some type of instruction in the procedure by someone who had experience, though in novel procedures and procedure development the use of a trained surgeon was generally required. Some individuals indicated they had to demonstrate competence in technique and speed on non-living specimens coupled with survival of trial or training organisms in the laboratory. In Europe in particular, government agencies regulate surgical activity on all vertebrates including fish (e.g., U.K. Home Office). In Iceland, the Fish Disease Officer must approve all fish surgeons.

Table 3. Method of learning surgical procedures on fish as reported by 171 fish surgeons. Respondents were able to identify more than one technique.

Method of learning surgical procedures	Percentage of total responses
Observation	24.6
Mentoring	23.5
Literature	23.3
Trial and error	15.3
Professional development workshop	3.9
Part of degree program	2.7
Specialized course	2.1
Other	4.7

How did you learn to do fish surgery?

The three most common ways respondents in our survey learned to perform fish surgery were from observation, mentoring, and the literature (Table 3). Surprisingly, 15% identified trial and error as a learning strategy. Very few respondents actually learned fish surgery as part of a professional development workshop, specialized course, or part of academic degree requirements (Table 3). This likely reflects the general lack of workshops or courses either offered or accessible to aspiring fish surgeons. For the open-ended responses, several participants indicated they learned from video or from the Internet. Almost all respondents chose multiple responses indicating that even those who relied on the literature, for example, may have coupled their reading with mentoring. There is undoubtedly more variation in responses than would be observed if the same question was posed solely to physicians or veterinarians who have professional bodies that regulate how surgeons learn and develop their skills.

Have you taken any university or college courses for credit that included instruction on surgical techniques?

Only 12% of respondents participated in university-level course work that included instruction on surgical techniques, and of those, only half included experience specifically focused on fishes. The majority (88%) of respondents had not participated in any academic credit-based courses that included instruction on surgical techniques. Some schools with veterinary programs now include graduate course options in "surgery for research" that is specifically designed for those not involved in a professional degree program. However, these courses are relatively new and are unlikely to include modules or content on fishes. We anticipate that there will be an increase in formal academic instruction on fish surgery, but it will likely be focused at several schools with large fisheries and veterinary programs.

Have you ever taken a workshop or course on fish surgery?

The majority (80.5%) of fish surgeons have not participated in a workshop or course on fish surgery. Some surgeons did participate in workshops or courses on fish surgery and were able to observe demonstrations and practice themselves (6.9%). An equal number of respondents only received hands-on practice (6.9%) and few only observed demonstrations (4.6%). Only two indi-

viduals took such a course or workshop that only included lecture material.

Continuing education course offerings/workshops at a professional conference would satisfactorily train future fish surgeons.

In general, respondents were in agreement (52.7% agree, 10.8% strongly agree) with the statement that continuing education course offerings or workshops at professional conferences could satisfactorily train future fish surgeons. Some respondents were neutral to this idea (18.6%). The remaining 17.9% of respondents were in disagreement with this statement. Some individuals suggested that materials currently delivered in workshops are either outdated or wrong, having been based on dogma rather than thorough experimentation, collation of literature, and principles of veterinary science.

A web portal such as the FAO Telemetry Website could provide enough information to train fish surgeons.

The Food and Agriculture Organization (FAO) of the United Nations developed and launched a website in June 2003 to provide a "comprehensive overview of the use of telemetry in studying and managing fish populations" (www.agsci.ubc.ca/gbi/FAO%20Fish%20Telemetry/). Although at present the site only has a cursory overview of surgical techniques for fish, this may be expanded in the future as indicated by the longer-term goals of the project. When queried as to the potential of a web portal such as this to serve as a resource for training surgeons, the results were mixed. Overall, more respondents disagreed (41.0%) that a web portal could provide enough information to train fish surgeons than agreed (16.3%), with 35.5% being neutral to the idea. Few respondents selected strongly disagreed or strongly agreed. Although there is general apprehension to the idea, the Internet could still serve as a resource for communication among fish surgeons. This could provide a venue for exchange of information on surgical techniques, species-specific insights, and provide opportunities for less experienced surgeons to identify and connect with potential mentors.

Have you been formally tested or evaluated to determine the level of your surgical proficiency?

The majority (93%) of fish surgeons surveyed have not been formally tested or evaluated to determine their level or surgical proficiency. Considerably fewer individuals were assessed with respect to fish (6.5%) and only one individual had only been evaluated on another animal.

Surgical experience is important when conducting fish telemetry research.

More than 92% of respondents agreed or strongly agreed that surgical experience was important for conducting fish telemetry research. Several respondents were neutral (6%) and only 2% of respondents disagreed or strongly disagreed with that statement.

A minimum level of experience or training should be required before engaging in fish surgery for a formal study.

The majority of respondents agreed (47.9%) or strongly agreed (30.5%) that a minimum level of training or experience should be required prior to engaging in fish surgery. Some respondents were neutral (11.4%) to this statement, while 8.4% of respondents disagreed and only 1.8% strongly disagreed.

On how many fish did you practice before the first fish that you used in a formal telemetry study?

Most respondents practiced on between 1 and 5 (45.1%) or 6 and 10 (18.9%) individuals, with fewer respondents reporting 11 to 20 (10.9%) or 20 or more (12.5%) practice subjects. A number of individuals did not practice at all (12.6%) before engaging in their first telemetry study. This result was unexpected considering that practice seems to be a logical means of improving one's skills and improving fish survival.

Overhead view of a smallmouth bass being implanted with a radio transmitter.

There is a need for international standards for fish telemetry surgery.

Responses to this statement varied considerably with the most common response being neutral (41.2%). Roughly equal numbers of participants either agreed (24.9%) or disagreed (22.4%) and strongly agreed (6.0%) or strongly disagreed (5.5%).

Several individuals responded strongly to this question, indicating there is already too much regulation associated with fisheries research. However, many of the respondents stated that some minimum standards are needed to ensure that fish exposed to surgery have a reasonable chance of recovery and survival. The responses to this question seem to conflict with those of the previous question in that most fish surgeons seem to agree

that a minimum level of training and experience should be required. This disparity between the realization that minimum levels of training are required coupled with a low desire for international standards may be symptomatic of a general apathy with the status quo. Change seems to be required but it would appear that fish researchers do not want to be subjected to more regulations or standardization.

Surgery on fish should be restricted to veterinarians with experience working on fish.

The majority of respondents to the survey strongly disagreed (59.4%) or disagreed (35.8%) with this statement. Several individuals were neutral (3%) and only 3 individuals agreed or strongly agreed with this statement. The response to this question must be tempered with the realization that the majority of the respondents are not trained veterinarians, but do conduct surgery on fishes. It is fair to say that when provided the opportunity to elaborate on any of the questions that were answered, the most responses were directed towards this question. Interestingly, a self-identified veterinarian provided some of the most balanced insight. This individual stated, "As a veterinarian, I strongly feel that veterinary consultation is valuable for any fish telemetry implant study to ensure that a high standard of care is maintained. I do not, however, presume to think that only veterinarians are competent to perform the surgeries. I have seen some darned fine implantation surgeries performed by well-trained graduate students. I always learn something from the interaction with fisheries researchers, and feel that they and the fish also benefit from veterinary input."

There were many comments directed toward veterinarians suggesting lack of training or experience in working on fish or in field conditions. Not all veterinarians will have experience working on fish, but some of the general principles of animal welfare and surgery technique are broadly applicable to all vertebrates. Furthermore, there are a growing number of veterinary curricula that include training in aquatic animal medicine. Those individuals who expressed concern about involving veterinarians in fish surgery reported that they did so because of the possible inflation of research costs, difficulty in scheduling/coordinating, and the perception that most veterinarians have little or no experience in fish surgery.

What type of surgical training materials do you believe would be most helpful?

The most useful types of training materials identified by respondents were mentoring in a lab where fish surgery is conducted, continuing education courses or workshops at conferences, or a handbook (Table 4). A web portal and academic instruction were thought to have some value. Interestingly, few participants believed that sessions presented by IACUCs or other government bodies would be helpful. The most common open-ended suggestion was video or CD.

Discussion

Based on the results of this survey, as well as the open-ended information provided by respondents, it is our belief that the most effective training technique would be to couple mentoring and course work to provide both theoretical (fundamentals) and practical experience. Perhaps one advantage of a standardized course would be to ensure that participants are informed of the full range of techniques with a focus on care for the fish. This type of course would provide participants with the confidence and knowledge to then approach individuals with specific expertise on a study organism or type of surgery to obtain more detailed mentoring. Some respondents indicated that the most useful training is obtained by contacting others in the field who have conducted surgery on the species of interest and can provide insights into the requirements for this species. Techniques often are very different among species and therefore cannot be adequately taught in standardized formats. At some level, complete standardization of procedures may also reduce experimentation and development of new techniques, which would be an undesirable outcome.

One of the biggest limitations in relying upon delivery of materials at conferences is that many of the future surgeons may be students who do not attend because they are not involved with societies or a project that involves telemetry. A handbook and video instruction from a conference/workshop coupled with mentoring may be the best for situations where students (or those in developing nations; see Baras et al. 2002 for discussion of a general fish biotelemetry workshop designed for biologists in developing countries) require the information but do not have the opportunity to attend courses/workshops themselves. It is also important that courses/workshops not be viewed as a financial windfall for the course instructors. These courses must be accessible and affordable to all who

Table 4. Method of learning surgical procedures on fish that were identified as being most effective for training future fish surgeons as reported by 171 fish surgeons. Respondents were able to identify more than one technique.

Method of learning surgical procedures for training future fish surgeons	Percentage of total responses
Mentoring in a laboratory	26.6
Continuing education courses/workshops at professional conferences	22.1
Handbook	17.5
Academic instruction	12.6
Web portal	12.0
Sessions provided by animal care councils or government	5.1
Other	4.0

need them, including students, recent graduates and individuals working in developing nations.

Conclusions and Recommendations

We believe there is general consensus among respondents to our survey that fish surgery requires specialized training. However, at present, there seem to be few formalized opportunities to obtain such training. There are occasional workshops led by fisheries professionals on the topic of fish surgery, or more commonly telemetry workshops that include a module on surgery, but typically these are based on the personal experience of one or two individuals. Although this type of experience is useful and worthy of sharing (e.g., see Jepsen et al. 2002), the collective knowledge of many individuals from diverse backgrounds coupled with the delivery of peer-reviewed materials may be more effective. In fact, a working group consisting of a number of individuals with diverse backgrounds, training, and experience should be tasked with developing a comprehensive and balanced course including manuals and presentation materials that could be used for training around the globe. These materials should be peer reviewed to ensure that the curriculum and materials are accurate, comprehensive, and current. Furthermore, any curriculum that is developed must have a clear set of learning outcomes as well as an evaluation framework to determine if the curriculum is effective in the attainment of the desired outcomes. This would be an iterative process that would require frequent updating and refinement to ensure that the latest advances are incorporated into training.

Such "in-class" experience should be supplemented with mentoring in the laboratory of someone proficient in surgical techniques, ideally on the same (or related) organism that one wishes to conduct surgery upon. Considering the diversity of fishes and environments around the world, it is very important to provide interchange between fish surgeons and discuss the new, as well as already proven, surgical methods. To facilitate greater communication among researchers, we also recommend using a web portal, such as the FAO telemetry website, as an engine for dialogue. Such a site could serve as a resource for individuals embarking on telemetry projects by providing contact information for prospective mentors.

We also encourage potential fish surgeons to consult with others who have experience working with a given species or environment and veterinarians. Open dialogue with veterinarians, who can learn more about fish while the researcher learns about veterinary and surgical techniques, can only help to promote improved lateral transfer of knowledge and skill. This in no way means that fish surgeries should be restricted to veterinarians, but more generally that veterinarians should be consulted. In our opinion, we believe that fish surgeons can only benefit from interaction and consultation with veterinarians, given the opportunity. Ideally this type of collaboration will lead to improvements in the outcomes of the surgeries and the studies. The same can be said for communication with IACUCs where there needs to be greater interaction and understanding among fish surgeons and IACUC members (Mulcahy 2003a).

Participants voiced a concern that the results of the study would be used to enact some new class of regulation that further restricts trained and knowledgeable fish biologists from doing their research. Our purpose was indeed to explore issues associated with fish surgery, but doing so in a way to provide opportunity for increased specific training opportunities to result in improvements in fish welfare and fisheries research. At present, there is a recognized need for training, but little structure to address this need. For example, the newly released AFS guidelines for the use of fishes in research (AFS et al. 2004) suggest that "personnel should be appropriately trained in specific tag implantation" without further explanation on what constitutes being "appropriately trained." The generality of these guidelines may reflect the fact that specific instructions and definitions are typically the responsibility of institutional entities. As IACUCs increase the rigor required when dealing with lower vertebrates such as fishes to avoid public (and political) criticism regarding animal welfare, it is crucial to have some standards for the basic level of skills required for conducting surgeries. Indeed, this is supported by our survey results with the majority of respondents acknowledging that surgical experience is important and that there should be some minimum level of training prior to engaging in fish surgery. Based on the apparent lack of confidence in the ability of IACUCs to train future fish surgeons (as identified in this survey), the onus may lie with the more experienced fish surgeons (working with professional societies) to develop such materials. Because the quality of data derived from a study is directly based upon the assumption that the surgical procedure does not result in mortality or long-term negative consequences, fisheries scientists should find the development of training materials to be a valuable tool for both refining the techniques of practicing fish surgeons, and the training of future ones.

A smallmouth bass implanted with a radio transmitter is shown immediately prior to release.

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