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RESEARCH PAPER

Trends in the reporting of tagging procedures for fish telemetry studies that have used surgical implantation of transmitters: a call for more complete reporting

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Abstract The intracoelomic surgical implantation of telemetry transmitters in fish is becoming the "standard" tagging approach for most field telemetry studies. Subsequently, efforts must be made to ensure the welfare of the fish are maintained and that fish do not experience significant mortality or sublethal impairments in health, behavior or physiology as a result of surgical procedures. Therefore, it is essential to adequately report information relating to all aspects of the surgical procedure to enable the reader to make an accurate interpretation of study results. We conducted a quantitative literature review aimed at characterizing trends in data reporting by examining a sample of fish telemetry studies published in peer-reviewed outlets during the last 20 years. We used a repeatability score, based on 16 predetermined criteria, to evaluate the reporting of surgical procedures in telemetry studies. The majority of studies failed to report basic information relating to the surgical procedures used. Repeatability scores were highly variable between studies and ranged from 0–93.8%. No single study provided complete information (mean repeatability score = 50.7%) and repeatability showed no trend over time. Some study information was consistently well reported (e.g. tag size and dimensions, the type of anaesthetic used and the location of incision). 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. Our review was confounded by the large proportion of studies that cited other sources for their surgical methods, many of which themselves lacked complete information. We recommend that future electronic tagging studies that involve intracoelomic implantation include the minimum reporting standards presented in this paper. Increasing the detail of reporting will improve the quality of data presented, minimize welfare and ethical concerns and allow transparency for study repeatability.

Keywords Telemetry · Fish · Surgical implantation · Tagging effects · Reporting

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Introduction

The underlying assumption of all electronic tagging studies (i.e., both biotelemetry and biologging) is that the tagging procedure and burden of the device itself does not alter the behavior, health, condition or survival of the individual and that therefore the behavior of tagged individuals is representative of untagged conspecifics. In light of this assumption and given the increasing use of electronic tagging in field studies (e.g. Lucas and Baras 2000; Block 2005; Cooke 2008), a solid understanding of tagging effects is required (see reviews by Bridger and Booth 2003; Cooke et al. 2011). Comprehensive reviews of electronic tag implantation procedures exist in the literature (e.g. Mulcahy 2003), including those specific to each component (see Table 1) and species-specific procedures for a number of species (e.g. eels (*Anguilla anguilla* L.), Baras and Jeandrain 1998; channel catfish (*Ictalurus punctatus*), Carmichael 1991; Hart and Summerfelt 1975; bluegill (*Lepomis macrochirus*), Knights and Lasee 1996; tilapia (*Oreochromis aureus*), Thoreau and Baras 1997; sea lamprey (*Petromyzon marinus)*, Lowartz et al. 1999).

The surgical implantation of electronic tags into the peritoneal cavity of fish is a common technique and is generally regarded as the most appropriate for the long term retention of tags (Jepsen et al. 2002). Alternative tag attachment techniques used less frequently and generally of use for short term studies include external attachment, or gastric and ovipositor insertion (see reviews by Lucas and Baras 2000; Bridger and Booth 2003). Even though intracoelomic surgical implantation is the most appropriate technique for long-term tag retention, the method is inherently more invasive than other attachment procedures and generally involves sedation, complex surgical procedures and, in some cases, longer handling times than other methods. Consequently, intracoelomic implantation has the potential to have both lethal and sublethal impacts on fish if performed incorrectly or without appropriate training.

Collectively, there is general agreement on best practice for some procedures (e.g. monofilament sutures are better than braided sutures for closing incisions), but for others, no firm consensus exists (e.g. which anaesthetic to use). In rare cases, best practices are emphasized in the literature without debate (e.g. using anaesthetic is better than not). Regardless of which procedure is least harmful to the fish, it is evident that the choices made by a surgeon do matter. As knowledge of tagging effects emerges, it should be possible to evaluate the results of past electronic tagging studies with regard to the methods used. To make comparisons it is important that methods are consistent, clear and complete for all studies that involve the surgical implantation of electronic tags. Transparent methods enable readers to undertake a complete and informed assessment of a given study. Additionally, because best practices and methods are not standardized and vary by species, researchers often look to the literature to develop their surgical techniques (Cooke and Wagner 2004). However, according to a survey completed by Wagner and Cooke (2005), only 34% of fish researchers performing electronic tagging surgeries feel that reporting surgical method in the current literature is adequate. The objective of this study was to quantify the level of "completeness" or "repeatability" of surgical procedures reported in tagging studies over the last 20 years. To do this, we reviewed a random sample of articles from 1990–2009 where telemetry tags were surgically implanted in fish. We focused on radio and acoustic telemetry and excluded passive integrated transponder tagging as many studies employed tag injection by syringe and excluded biologgers given that relatively few field studies that use such technology have relied on intracoelomic surgical implantation until very recently. Nonetheless, the conclusions emanating from this paper are relevant to all electronic tagging procedures that involve intracoelomic implantation. By extracting information from these articles we were able to identify: (1) whether researchers as a whole report enough details of surgical procedures to accurately repeat the surgery, (2) the aspects of the surgical procedure that were consistently poorly reported, and (3) whether there were temporal trends in the rigour of reporting. Although we expected studies to generally exhibit poor repeatability, we also expected reporting and subsequent repeatability to improve over time given the growing use of this technology and improvements in knowledge through tagging effects studies.

Methods

In December 2009, we conducted a Boolean literature search in ISI's Web of Science using a combination of the topics fish* and telem*, where telem* was refined with the keywords radio*, acoustic*, or ultrasonic*. We further refined search results by year

Table 1 Justification of criteria (based on potential effects on behavior and/or condition of fish) used to determine the repeatability of surgical methods for field studies that implanted electronic tags into fish

Criteria	Factors for consideration	Potential consequences	References
Anaesthetic (type, concentration and duration)	Inadequate/overdose concentration; anaesthetics may themselves be stressors; some aesthetic may be more effective than others	Increase in blood cortisol and glucose; increased susceptibility to infection	Wagner et al. (2002, 2003), Sink et al. (2007)
Gill irrigation	Air exposure	Depressed ventilation rates	Davis and Parker (2004), Gingerich et al. (2007)
Reducing infection	Non-sterility; value of using antibiotics	Infection	Whittem et al. (1999), Jepsen et al. (2002), Mulcahy (2003)
Tag size/ dimension	Weight and buoyancy compensation; importance for laterally compressed, elongated and juvenile fishes	Loss of short-term and/or long-term swimming performance; tag loss; increased metabolic rate	Winter (1983), Adams et al. (1998), Brown et al. (1999), Lefrancois et al. (2001), Jepsen et al. (2002), Mulcahy (2003), Lacroix et al. (2004)
Location of incision	Damage to vascular anatomy; tag retention; exposure of inner coelom	Infection; tag loss	Schramm and Black (1984), Clapp et al. (1990), Wagner and Stevens (2000), Mulcahy (2003)
Length of incision	Excess pressure during insertion; increased sites for bacteria	Infection; tag loss	Mulcahy (2003)
Suture type	Integrity of closure; increased sites for bacteria	Infection; tag loss	Prince and Maughan (1978), Petering and Johnson (1991), Kaseloo et al. (1992), Haeseker et al. (1996), Thoreau and Baras (1997), Block et al. (1998), Bunnell et al. (1998), Lowartz et al. (1999), Starr et al. (2000), Wagner et al. (2000), Wagner and Stevens (2000), Jepsen et al. (2002), Mulcahy (2003), Cooke et al. (2003), Koster and Crook (2008)
Number of sutures	Integrity of closure; increased sites for bacteria	Infection; tag loss	Wagner et al. (2000), Mulcahy (2003)
Type of knots	Integrity of closure; increased sites for bacteria	Infection; tag loss	Tera and Aberg (1976), Tera and Aberg (1977)
Duration of surgery	Prolonged exposure to stressful experience; longer duration of anaesthesia	Magnification of all effects of surgery	Cooke et al. (2003)
Pre- and post-holding duration and conditions	Temperature and oxygen; density of fish; acute handling; time before release	Increase in blood cortisol; increased oxygen consumption; reduction in lysozymes, thrombocytes and lymphocytes in the blood; increased susceptibility to infection	Strange et al. (1977), Pickering et al. (1981), Pickering and Pottinger (1987), Mock and Peters (1990), Cooke et al. (2000), Jepsen et al. (2002), Mulcahy (2003), Wagner and Cooke (2005)

(1990–2009) and subject area: fisheries, marine, freshwater biology, oceanography, environmental sciences, ecology, zoology, biology, and water resources. We further refined search results by document type, with only peer-reviewed articles published in English retained. Following search refinements, we compiled a list of 2,816 articles. We briefly reviewed each article to ensure that it involved surgical implantation of telemetry tags. We excluded methodological studies and reviews such as surgical and tagging effects studies. Articles were sorted by publication year and author, assigned a unique number and randomized for each year group. The first 20 relevant articles (unless 20 articles weren't available for that year) within a given year were retained for data extraction.

Sixteen surgical criteria (Table 1) were pre-determined for the purposes of making comparisons between studies, based on review of available literature and expert opinion, and thus represent the minimum information needed to evaluate and repeat a surgery. Inclusion of other factors not considered here may also warrant consideration (e.g. use of water conditioners, temperature at tagging or tag density in water), however, were not used in our analyses. Articles were evaluated based on reporting the presence or absence (1 or 0, respectively) of each of these criteria and subsequently used in the analysis. General study information (e.g. study location, species used, whether or not a veterinarian was consulted and reference to approval by an animal care committee) was also collected from each article. It is important to note here that if an article explicitly stated that they did not perform a procedure then a score of 1 was still assigned as they were deemed to have reported on the category. When an article cited additional sources for further information regarding surgical methods, cited articles were obtained, subjected to the same scoring process and later added to the database as a separate analysis. If a cited article could not be located (books and non-peer-reviewed outlets were excluded), or included a review where multiple tagging procedures were presented, then we removed the original article from the database ($n = 39$), resulting in an eventual sample size of 247 articles. Articles that used citations for reporting methodological detail received a "before" and "after" value based on the extraction of methodological detail from the cited work. However, we considered those articles separately for reasons discussed below. Where reporting categories were not relevant to an article (e.g. concentration of anaesthetic when none was used), scores were adjusted accordingly. Linear regression was used to examine trends in reporting of surgical procedures over time. Test groups were considered significantly different at a level of $P < 0.05$, with data visually examined for normality and homogeneity of variance using histograms and plots of residuals prior to analysis.

Results

General study information

The articles reviewed comprised 168 radio telemetry studies, 76 acoustic telemetry studies, and three combined radio-acoustic studies. Single species studies comprised the majority of studies (89.5%), followed by two (9.7%), three (0.4%) and five (0.4%) species studies. Most studies were conducted in freshwater (76.5%) followed by marine (15%) or estuarine (5.3%) or a combination of environments (3.2%). Surgeries were predominantly undertaken in the field (59.5%), and to a lesser extent a hatchery or laboratory (13.4%) or a combination of the two (2.8%). However, 24.3% of studies didn't specify a surgery location. Capture methods were reported in 83.8% of studies but water temperature at capture, tagging or recovery was reported in only 21.5% of studies. Assessment studies to verify that there were no adverse affects of tagging procedures were reported in 7.7% of articles and an additional 11.3% of articles cited assessment studies published elsewhere. Reference to an animal care committee was reported in 12.1% of studies and animal care project numbers were provided in 4.9% of articles. Only 0.8% of studies indicated that veterinarians were consulted prior to conducting surgery. The number of surgeons conducting surgery was reported in 0.4% of studies, the level of surgical training was not mentioned in any study and analysis was never undertaken to determine the effect of using different surgeons as a covariate in analysis. Fish-tag weight ratios in air were not always reported (some articles did not report fish weight and/or tag weight), however, where they were reported or able to be calculated manually, 53% of tags did not exceed 2% of fish body weight and 75.7% did not exceed 3% ($n = 115$, mean $2.41 \pm 0.20\%$, range 0.008–13.75%).

Trends in citing surgical methodology from past studies

Of the 247 articles selected for extraction of surgical information, 107 of these cited other sources for some or all aspects relating to surgical procedures and were consequently analyzed separately. Articles that cited an additional source for further details of some aspect of surgical procedure or study information exhibited a general trend to report less detail in all 16 surgical reporting categories (see 'before', Table 2) as opposed to those that did not cite other studies. This was less prevalent for core study information such as tag size and dimensions. Typically, articles provided a citation for surgical details and subsequently excluded further information. Indeed, it was not uncommon for authors

Table 2 The proportion of published articles reporting specific details of the surgical procedure used to implant electronic tags into fish

Reporting category	Percentage of articles reviewed (%)			
	Article does not cite other sources for surgical methods	Article cites other source for surgical detail		
		Before	After	Difference
Preholding conditions	38.1	27.1	57.9	30.8
Type of anaesthetic	76.4	47.7	90.7	43
Duration of anaesthesia	23.2	14.3	58.1	43.8
Anaesthetic concentration	57.2	31.4	83.8	52.4
Gill irrigation	39.3	19.6	68.2	48.6
Reducing infection	32.9	15.9	61.7	45.8
Tag size	85.0	73.8	93.5	19.7
Tag dimensions	75.0	59.8	86.0	26.2
Incision location	61.8	24.8	81.3	56.5
Incision length	54.3	23.4	79.4	56
Suture type	52.9	29.0	77.6	48.6
Number of sutures	53.6	19.6	75.7	56.1
Type of knots	2.2	1.0	27.5	26.5
Duration of surgery	34.3	17.8	51.4	33.6
Recovery conditions	56.4	47.7	83.2	35.5
Duration of recovery	67.1	54.2	85.0	30.8

Articles are divided into those that provide no citation for further methodological detail and those that do. Where an article cites further information, reporting scores are presented as before (information reported in the original article) and after (information presented in the citation and incorporated into the score). Articles are pooled from 1990–2009

to report *'surgical procedures were identical to xx, with the exception that…(some aspect was modified)'*. In some cases, articles also provided a citation for further details and then proceeded to report some of these details. New scores which were updated to include information retrieved from cited sources are presented for each reporting category in the 'after' column of Table 2. In the interest of maintaining objectivity, we assumed that authors citing other studies for methodological detail followed all procedures precisely. However, while some aspects of particular techniques appear directly transferable (e.g. location of incision and type of suture), other aspects may be study specific (e.g. duration of anaesthesia, duration of surgery or duration of recovery). By updating our scores using cited articles, these criteria were improved by 44, 34 and 31% respectively. Indeed, scoring appeared to be artificially inflated (see 'after' Table 2) for articles that cited other studies in comparison to those that did not. Given our uncertainty in the legitimacy of transferring scores between studies, further results focus only on studies that did not cite other sources for details.

Trends in reporting and repeatability of surgical methodology

Repeatability scores were highly variable between studies and ranged from 0–93.8%. No single study provided complete information and on average repeatability scores were poor (50.7 ± 1.9%). Repeatability scores did not follow a trend over time ($R^2 = 0.001$, $F_{1,\ 118} = 0.128$, $P = 0.721$) (Fig. 1). A summary of individual reporting characteristics for the remaining 140 articles is presented in Table 2. Two studies clearly reported that anaesthetic was not used to sedate fish prior to surgery (Jordan et al. 2006; Pitman and Parks 1994). One study reported that no preholding of fish occurred prior to surgery (Schaefer and Fuller 2005). Some study information was consistently well reported, including tag size (85%) and dimensions (75%), the type of anaesthetic used (76.4%) and the

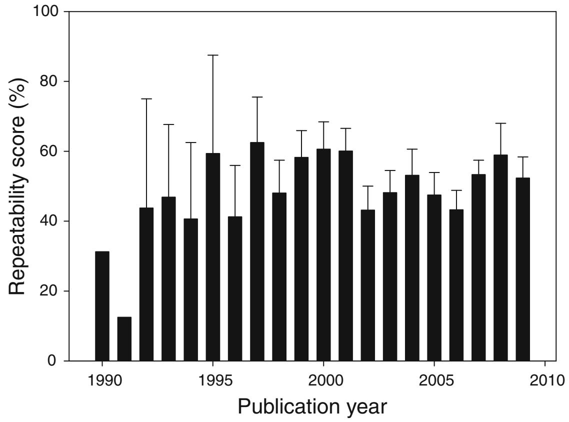

Fig. 1 Trends in repeatability of surgical methods used to implant electronic tags into fish (based on 16 evaluated categories for each publication). *Note* sample sizes are low (<6 articles per year) prior to 1998

location of incisions relative to the long axis and midline (61.8%). In contrast, only 2.2% of studies reported the type of surgical knots used to close incisions, 23.2% of studies reported the duration or level of anaesthesia reached and 32.9% of studies reported that precautions were taken to minimize infection. Of the 46 studies that reported undertaking procedures to reduce infection, 47.8% reported sterilising tags (e.g. Pitman and Parks 1994; Thorstad et al. 2000), 34.8% reported sterilising instruments (e.g. Nack et al. 1993; Thorstad et al. 2000), 28.3% reported swabbing of the incision site (e.g. Bauer and Schlott 2004; Kelly et al. 2007) and 39.1% reported administering some form of antibiotic (e.g. Vehanen and Lahti 2003; Able and Grothues 2007). Only one scoring criteria (incision length) exhibited a significant decrease over time ($R^2 = 0.489$, $F_{1,\ 10} = 9.571$, $P = 0.011$) and no criteria showed significant improvements in reporting over time (Table 3).

Table 3 Trends in the reporting of surgical details over time (1998–2009, $n = 120$)

Reporting category	R^2	$F_{1,\ 10}$	P
Preholding conditions	0.257	3.47	0.092
Type of anaesthetic	0.015	0.154	0.703
Duration of anaesthesia	0.023	0.233	0.640
Anaesthetic concentration	0.045	0.470	0.508
Gill irrigation	0.005	0.052	0.825
Reducing infection	0.261	3.535	0.089
Tag size	0.081	0.883	0.370
Tag dimensions	0.001	0.008	0.931
Incision location	0.049	0.511	0.491
Incision length	**0.489**	**9.571**	**0.011**
Suture type	0.124	1.411	0.262
Number of sutures	0.000	0.005	0.947
Type of knots		–	
Duration of surgery	0.322	4.755	0.054
Recovery conditions	0.010	0.099	0.760
Duration of recovery	0.006	0.063	0.807

Only published telemetry field studies not citing other publications for further surgical details were used in the analysis. Linear regressions deemed significant at $P < 0.05$ are indicated in bold

Discussion

The proper and complete reporting of surgical details is crucial to enable researchers to assess and/or replicate the results of telemetry-based studies. In general, we found that the majority of studies did not provide sufficient information to evaluate or replicate procedures. These results support Wagner and Cooke's (2005) finding that surgical procedures are poorly reported in the literature. A number of implications may result from this ubiquitous problem of poor reporting. Firstly, new surgeons cannot use peer-reviewed literature as a source of information on surgery methodology if the details are not reported. Secondly, interpretation of data or findings generated by telemetry studies cannot be evaluated in the context of the procedures used. In many situations considerable debate exists concerning the value of certain tagging procedures. For example, Mulcahy (2003) suggested that the use of nonsterile surgical instruments for the implantation of transmitters would be an inhumane act, which should not be performed. Although, it seems that the actual practice of sterilization may not be prevalent due to the challenges of keeping a sterile environment in the field (Wagner and Cooke 2005). We found that only one-third of studies reported use of sterilization procedures and to date there has been no direct study of the effects of different sterilization procedures on the outcome of surgical procedures on fish (see Cooke et al. 2011). This may prove to be an important area of research in the future and full reporting of these procedures will enable retrospective evaluations of previous studies.

A second example demonstrating the importance of reporting tagging procedures relates to fish to tag weight ratios. The commonly used “2% rule” (Winter 1983) has little empirical evidence, yet is still commonly reported in telemetry studies. Brown et al. (1999) demonstrated that transmitters ranging from 6–12% of the fish’s body weight did not adversely affect the swimming performance of rainbow trout; however, only short term swimming performance was measured and not the long-term physiological consequences. Therefore, more research is needed on species specific guidelines for tag weight thresholds in long term studies. In the future, it may be realized that the commonly used guideline of 2% is either conservative or liberal. Previous telemetry study results should be evaluated in the context of new found knowledge and this can only be done if tagging procedures are adequately reported.

Only a small number of articles reported (7.7%) or cited (13.3%) assessments of tagging effects. In some cases, assessments and/or multiple tagging events resulted in a modification of procedures in response to poor survival or tag retention (e.g. Haeseker et al. 1996). The majority of tagging effects studies are short term (Cooke et al. 2011), but tagging effects may occur over a wide temporal scale. These effects are particularly hard to detect (except for mortality) unless the individual can be recaptured (e.g. Jepsen et al. 2002). Some species also appear particularly troublesome to tag. For example, Daniel et al. (2009) reported that expulsion of dummy tags implanted in common carp (*Cyprinus carpio*) occurred 15–362 days after surgery and that anchoring tags to the pelvic girdle did not improve retention. Others have reported complete mortality for the same species and technique (e.g. Økland et al. 2003). There is certainly a need to report failed experiments so that others can learn from them, however, this occurs infrequently (Mulcahy 2003).

Only one study that we reviewed reported the number of surgeons used (Hanson et al. 2007) and no studies used surgeon as a factor in analysis. This was a surprising result considering Wagner and Cooke (2005) identified that 62% of practicing fish surgeons believed that using individual surgeon as a covariate when analyzing data obtained from a study using multiple surgeons was important. Further, this is an important issue considering that the level of surgical experience can directly influence the results of a study (e.g. Cooke et al. 2003). The level of surgical training or experience was not mentioned in any article analysed in this study, and veterinarians were reported to be consulted in only two articles. This is not surprising given that the majority of practicing fish surgeons receive no formal training, rarely consult veterinarians and do not regularly practice (Cooke and Wagner 2004; Wagner and Cooke 2005).

We predicted that reporting of surgical procedures would generally improve over time. This was based on the assumption that improvements in knowledge through an increased number of tagging effects studies (Cooke et al. 2011) combined with an increasing use of telemetry as a research and management tool (e.g. Lucas and Baras 2000; Cooke 2008) would transfer to peer-reviewed literature through improved reporting; this was not the case. One problem with our analysis was that many researchers cited other articles for further details of surgical procedures. While repeating proven techniques is a logical and efficient means of deciding upon the correct tagging procedure to use, citing a previous study as a means of reporting tagging procedures causes a number of complications. For example, citing hard-to-find literature (e.g. grey literature or theses) for surgical details can result in the inability of the reader to fully assess or repeat the methods used. Further, multiple citations can result in incorrect interpretation of the methodological technique used, particularly when the cited studies use different techniques from one another (e.g. Curry et al. 2006). Telemetry tagging reviews were also cited as a justification for a particular technique, or to provide further methodological detail, however, these generally present various surgical techniques and discuss the appropriateness of each one. In all cases the reader is left to make a number of assumptions. Detailing all aspects of tagging methods may be restricted due to perceived or actual limitation on journal space (Ebner 2009). However, we contend that at a minimum the 16 criteria listed in this paper should be reported for repeatability and interpretation of results in future studies.

While our analysis largely demonstrates that reporting of surgical details is poor, a number of excellent reporting examples exist in the literature (e.g. Koed et al. 2000; Økland et al. 2003; Uglem et al. 2008). We suggest a template to incorporate the 16 reporting criteria used to assess repeatability of surgical methods in the present study. An example of such a summary could be as follows: *Following a holding period of xx (hours or days) in net pens at the point of capture (temperature and gear type) to ensure no adverse effects of capture method, each individual was placed in an anaesthetic bath (type and concentration) of river water until operculum rate became slow and irregular (2–4 min). Following length and weight measurements, the fish was placed in a V-shaped surgical cradle and supplied with a continuous flow of water for gill irrigation. The transmitter (model, weight and dimensions) which represented X% (min and max) of the body weight of the fish in air and X% (min and max) in water was inserted into the body cavity through a 2 cm mid-ventral incision, posterior to the pelvic girdle. Incisions were closed with two independent monofilament absorbable sutures (model) tied with a double surgeons knot and the same surgeon performed all surgeries. All surgical equipment, including the transmitter, was sterilized (method) between each surgery. The incision site was not swabbed, however antibiotics (type) were administered (method) to each fish post-operatively. The duration of each procedure took 1–2 min. Fish were placed individually in net pens until they regained equilibrium (4–6 min) and released 1–2 h after surgery*. This short paragraph provides information relevant to interpretation of the outcome of surgery (and hence the study), and contains all of the basic information that other researchers need to assess or repeat the study. We recommend that, where possible, detailing the techniques adopted from other studies would eliminate confusion and promote transparency. We also suggest adoption of more complete reporting standards for surgical implantation of electronic tags given the increased use of telemetry (and biologging technology) and increased knowledge of the effects of different surgical procedures on outcome, in light of animal welfare issues, and ability to interpret and replicate studies.

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