2016-03

Ten practical realities for institutional animal care and use committees when evaluating protocols dealing with fish in the field

Cooke, SJ

10.1007/s11160-015-9413-y
Reviews in Fish Biology and Fisheries
Springer Science and Business Media LLC

Rev Fish Biol Fisheries (2016) 26:123–133
DOI 10.1007/s11160-015-9413-y

POINT-OF-VIEW

Ten practical realities for institutional animal care and use committees when evaluating protocols dealing with fish in the field

Steven J. Cooke · Alexander D. M. Wilson · Chris K. Elvidge · Robert J. Lennox · Niels Jepsen · Alison H. Colotelo · Richard S. Brown

Received: 6 August 2015 / Accepted: 22 November 2015 / Published online: 27 November 2015

Abstract Institutional Animal Care and Use Committee's (IACUCs) serve an important role in ensuring that ethical practices are used by researchers working with vertebrate taxa including fish. With a growing number of researchers working on fish in the field and expanding mandates of IACUCs to regulate field work, there is potential for interactions between aquatic biologists and IACUCs to result in unexpected challenges and misunderstandings. Here we raise a number of issues often encountered by researchers and suggest that they should be taken into consideration by IACUCs when dealing with projects that entail the examination of fish in their natural environment or other field settings. We present these perspectives as ten practical realities along with their implications for establishing IACUC protocols. The ten realities are: (1) fish are diverse; (2) scientific collection permit regulations may conflict with IACUC policies; (3) stakeholder credibility and engagement may constrain what is possible; (4) more (sample size) is sometimes better; (5) anesthesia is not always needed or possible; (6) drugs such as analgesics and antibiotics should be prescribed with care; (7) field work is inherently dynamic; (8) wild fish are wild; (9) individuals are different, and (10) fish capture, handling, and retention are often constrained by logistics. These realities do not imply ignorance on the part of IACUCs, but simply different training and experiences that make it difficult for one to understand what happens outside of the lab where fish are captured and not ordered/purchased/reared, where there are engaged stakeholders, and where there is immense diversity (in size, morphology, behaviour, life-history, physiological tolerances) such that development of rigid protocols or extrapolation from one species (or life-stage, sex, size class, etc.) to another is difficult. We recognize that underlying these issues is a need for greater collaboration between IACUC members (including veterinary professionals) and field researchers which would provide more reasoned, rational and useful guidance to improve or maintain the welfare status of fishes used in field research while enabling researchers to pursue fundamental and applied questions related to the biology of fish in the field. As such, we hope that these considerations will

S. J. Cooke (✉) · C. K. Elvidge · R. J. Lennox
Fish Ecology and Conservation Physiology Laboratory, Department of Biology and Institute of Environmental Science, Carleton University, 1125 Colonel By Drive, Ottawa, ON K1S 5B6, Canada
e-mail: steven_cooke@carleton.ca; Steven.Cooke@carleton.ca

A. D. M. Wilson
School of Life and Environmental Sciences, Deakin University, Waurn Ponds, VIC, Australia

N. Jepsen
National Institute of Aquatic Resources, Technical University of Denmark, Silkeborg, Denmark

A. H. Colotelo · R. S. Brown
Pacific Northwest National Laboratory, U.S. Department of Energy, Richland, WA, USA

be widely shared with the IACUCs of concerned researchers.

Keywords Animal care · Ethics · Field research · Welfare

Introduction

Institutional Animal Use and Care Committees (IACUCs; also known as ethics review and animal care committees in some jurisdictions) serve a vital role in scientific research. Early efforts of IACUCs focused primarily on research involving mammals at academic institutions, whether in on-campus holding facilities or at agriculturally-oriented research facilities like experimental farms. As a result, the theory underlying IACUC activities largely grew out of veterinary practices and principles that were developed for husbandry of mammals, particularly companion and farm animals (Broom 2011). Today, IACUCs are tasked with ensuring compliance with local, regional and national guidelines as they engage with researchers. Research activities span the laboratory-field realm and can involve cultured, domesticated and wild animals representing a diverse range of primarily vertebrate taxa including rodents, birds, reptiles, fishes and even some invertebrates (cephalopods, decapods). Yet, the many fundamental differences between laboratory- or campus-based biomedical and/or agricultural research and field studies on wild animals may be largely unaddressed or ignored (Sikes and Paul 2013).

This issue has received significant attention in recent years (but see Orlans 1988), particularly with respect to the application of IACUC principles to research involving wild animals in field settings (Curzer et al. 2013; Wallace and Curzer 2013; McMahon et al. 2012; Stoskopf 2003). A focal point of this discourse centers around the lack of interaction and collaboration between field researchers and veterinarians (Wargo Rub et al. 2014; Cattet 2013). As ecologists working with wild and hatchery-reared fish under both laboratory and field settings, we routinely interact with IACUCs. While we certainly respect the oversight process and value the important role of IACUCs in ensuring that animal welfare principles are upheld (Bayne 1998), we also encounter a number of challenges and misunderstandings when interacting with IACUCs regarding field work on fish. These challenges tend to be common among researchers irrespective of their institutional affiliation, geographic location or nationality. The purpose of this brief document is to raise a number of issues that are repeatedly encountered by field researchers working on fish. We suggest that these challenges should be taken into consideration by IACUCs dealing with projects that entail the examination of fish in their natural environment or other field settings. We present these perspectives as ten practical realities along with their implications for establishing research protocols. While we recognize that some of these perspectives are also relevant to researchers working on fish in laboratory environments, most of the examples presented here are specific to field settings.

Ten practical realities

Reality 1: fish are diverse

An important consideration in fish research and animal care is that fish are by far the most diverse vertebrate taxon (Helfman et al. 2009). With more than 32,800 species classified (Froese and Pauly 2015), there are more species of fish than mammals, amphibians, reptiles and birds combined. Together with this diverse taxonomy is perhaps an even greater diversity of body morphology and anatomy, as fish come in all shapes and sizes with a wide range of body plans and structural features. Moreover, fish occupy the full spectrum of aquatic habitats requiring very different environmental and physiological tolerances in e.g. marine versus freshwater and in extreme environments ranging from hot springs to hypersaline water and to extreme depths in the abyss. Fish demonstrate a diverse array of behaviours, including elaborate reproductive strategies such as diadromy and prolonged parental care and foraging strategies from filter feeding to piscivory and even parasitism. As examples, fishes vary in size from the smallest known vertebrate (*Paedocypris* spp., adult total length <10 mm) inhabiting acidic peat swamps in Borneo, to the world's largest fish, the whale shark (*Rhincodon typus*, adult total length >12 m). This diversity in form and habitat represents a significant research challenge for fish biologists because it is difficult or impossible to create generalized standard operating procedures (SOPs) for fish capture, handling, tagging, surgeries, and other routine procedures. These SOPs are important components of the animal care system, facilitating the use of common or repetitive procedures in research. Although SOPs have the potential to be highly relevant for facilitating field research, the differences in morphology, physiology and behaviour among fish species mean that procedures described in an SOP for some species are entirely unsuitable for others, even if they are closely related. Indeed, different life history stages or reproductive states within the same species often respond differently to standardized procedures. Fish also vary in their holding requirements in terms of aeration, pH, salinity, turbidity and feeding preferences, responses to anaesthetics, possibilities for tagging or marking due to differences in body structure and likelihood of recovering from any experimental manipulations—although this last point is heavily mediated by the body condition and physiological tolerances of individuals. While the usefulness and value of SOPs in animal research is indisputable in some instances, including laboratory studies of mammalian species that are relatively similar in anatomy and handling/welfare needs, or to ensure standardized handling of model fish species like zebrafish (*Danio rerio*), they are not so consistently applicable to wild fish. Thus, a higher degree of flexibility is needed in written SOPs than is currently permitted under most animal care protocols (Sikes et al. 2012). SOPs should be written broadly enough to recognize the generalities common across species while avoiding specifics like stating exactly where a tag will be placed that make current SOPs invalid or only applicable in certain contexts. Alternatively, a form of SOP could be developed that provides a multi-course option plan permitting flexibility between a broader suite of acceptable options for techniques and procedures to be used at the discretion of the researcher. This step would facilitate and standardize many aspects of fish research and still be accountable through IACUC permissions and stated procedures for clear-cut follow-up in the project summaries.

Reality 2: scientific collection permit regulations may conflict with IACUC policies

When working on fish in the field, researchers may be required to obtain a scientific collection permit from natural resource management agency(ies), although this is not necessarily the case in all jurisdictions. Such permits enable researchers to use various capture gears that may not be available to the general public, like electrofishing, as well as to collect fish of species, sizes or from locations that would otherwise be restricted. A notable exception to the permitting requirements exists when collaborating with American Tribes or Canadian First Nations who, in some cases, are exempted from oversight from both governmental and IACUC bodies. Failure to secure the required permits for projects that do not involve collaborations with indigenous organizations can lead to various legal actions including seizure of equipment, fines and even arrest and imprisonment. The mechanisms by which animal care protocols are enforced differ greatly from the law enforcement model used for scientific collection permits. Animal care committees operate through their ability to terminate funding and professionally sanction offenders, usually at the institutional level. In many cases, approved animal care protocols are at odds with the legal edict of scientific collection permits. This is particularly relevant in the context of using mortality as an endpoint in the field. For example, if an individual fish appears moribund (e.g. loses equilibrium, demonstrates erratic swimming behavior) during the course of a study, the animal care protocol would typically require that individual to be euthanized. Although this might be sensible in a laboratory setting, most scientific collection permits would require the same fish to be released if the approved sampling method was described as non-lethal as a fish that is moribund at the time of release may yet recover sufficiently to reproduce or serve as prey to natural predators. This fundamental difference in philosophy has to do with natural resource agencies focusing on *populations* as the unit of management while IACUCs focus on the welfare of *individuals*. In such cases, researchers are legally bound by their scientific collection permit to release injured fish but the contradiction of their institutional requirements may leave them in difficult circumstances. Some natural resource agencies are beginning to request that approved animal care protocols be shared when submitting permit requests, although this remains far from the norm and often the persons within natural resource agencies that examine animal care issues are different from those that actually grant the permits. In most instances, there is simply an acknowledgement from both IACUCs and resource management agencies that each must, in turn, gain the appropriate approvals from the opposite governing body. As summarized by Paul and Sikes (2013), the permit system for working with wild animals is complex and does not always parallel the requirements of institutional animal care protocols.

Reality 3: stakeholder credibility and engagement

Unlike laboratory-based research, field research often involves extensive interactions with members of the public and various groups of stakeholders. These entities hold vested interests in the species and location under study and/or the question(s) being addressed. For those researching fish in the field, collaborating with stakeholders is often—if not always—a necessity. For example, fishers are often recruited with varying degrees of formality by researchers to collect data on species of recreational or commercial interest via online or hard-copy surveys (e.g. Cooke et al. 2000) or logbooks (Cotter and Pilling 2007). In other cases, anglers are hired or recruited as volunteers to catch fish on behalf of researchers for scientific purposes. Donaldson et al. (2012) recruited anglers to capture fish as part of a catch-and-release study on sockeye salmon after receiving criticism from both angling and research communities when fish had been collected by researchers or where fishing had been "simulated" (see Cooke et al. 2013a). At times, researchers are invited aboard commercial fishing boats (e.g. Raby et al. 2015) or to fishing tournaments (e.g. Suski et al. 2004) to collect data. In the case of commercial fishers, their activities generally consist of harvesting fish and delivering them directly to onboard holds where they suffocate on ice—a clear departure from the treatment of animals mandated of researchers by IACUCs. An accompanying research team would be poorly received if they were to anaesthetize and pith every fish that they handled for blood, tissue or scale samples, thereby rendering the sampled fish of no commercial value to the fishing crew. Conversely, large quantities of valuable data on fish stocks collected during commercial activities may be unusable if the treatment and handling of harvested fish does not comply with IACUC protocols. Collaborations with researchers from other nations may also result in the incorporation of data obtained through techniques that may be deemed sub-optimal to individual IACUCs.

There are also cultural norms that need to be acknowledged and respected when conducting research alongside stakeholders. This is due to the recognition that not all individuals handling or interacting with fish (to be included in research) will have formal animal care training. This should not constrain collaborative research because there are many benefits of involving stakeholders—including children—with hands-on science (i.e. citizen science; Silvertown 2009). In Florida, research teams have built programs that combine public engagement and outreach with long-term population monitoring of sharks. For example, some activities include schoolchildren assessing the eye reflexes of the sharks while the animals are being restrained by research staff. This can allow the collection of data while providing high-level engagement, which builds appreciation for both sharks and the research being performed on them (N. Hammerschlag, University of Miami, Personal Communication). Understanding and respecting cultural and societal norms is a reality for stakeholder engagement when working with wild animals.

Reality 4: more is sometimes better

While every effort is often made to minimize the number of animals used in field research (typically a requirement for IACUC protocols), it is nonetheless sometimes necessary to use higher numbers of animals in order to achieve management standards or judicially mandated relevance. For example, in the Columbia River Basin (CRB) of the Pacific Northwest of the United States, evaluations of the survival of juvenile salmonids passing downstream through hydroelectric dams in the Federal Columbia River Power System are frequently conducted using active telemetry methods. Many of the salmon and steelhead populations within the CRB are listed for protection under the US Endangered Species Act (ESA). Due to ESA protection, US federal regulations currently require that performance standards of 96 and 93 % survival per dam are met for spring and summer migrating fish, respectively (Skalski et al. 2014). In addition, these results must be estimated with a standard error $\leq$1.5 %. To meet such precision requirements virtual paired-release models are typically used, where fish implanted with transmitters are released several kilometres upstream of the hydroelectric dam, in the tailrace, and downstream of the dam. To attain the prescribed low variance within the results of these models, the sample sizes can exceed hundreds or thousands of fish per release location depending on detection probabilities and survival estimates for fish released upstream and downstream of each dam (Skalski et al. 2010). Failure to meet the precision requirements can result in the need to repeat the study, requiring additional resources (e.g. fish, finances) in a following year. Therefore, it is imperative that sufficient sample sizes are used in these studies to meet the regulatory requirements.

Social science surveys conducted in the Fraser River Basin (see Young et al. 2013) have revealed that managers often fail to act on data generated by researchers since the sample sizes tend to be small (particularly in telemetry studies or physiological sampling), making it difficult to scale any observed effects to the population level with the required certainty. Animal care committees should be aware that legal and management requirements sometimes dictate sample size needs. Implicit within this is recognition that the number of individuals used in a study may exceed what is suggested by statistical power analyses focused on ecological or biological questions to achieve relevance to management strategies or comply with legal requirements.

Reality 5: anaesthesia is not always needed

Anaesthesia serves an important purpose in fisheries research. The use of anaesthetics enables researchers to perform invasive or prolonged activities that require the animal to be immobilized, thereby protecting both fish and researcher (e.g. Ross and Ross 1999). However, anaesthesia itself represents a major physiological challenge for fish (or, indeed, any animal; Iwama et al. 1989) and may influence the behaviour of focal fish after it has regained equilibrium. This can potentially lead to post-release predation, feeding impairments and biased experimental results (e.g. Wargo Rub et al. 2014).Whenever a fish is captured and handled, no matter how delicately, the animal will mount a physiological stress response (Barton and Iwama 1991). There is some indication that anaesthetic applied to a stressed fish can mute this response (Iversen et al. 2003) but it is unclear if there is any benefit from doing so given that the acute stress response is adaptive for fish exposed to challenging situations. As researchers begin to work on a growing diversity of species across the globe, they are presented with a number of challenges when applying anaesthetics. In the case of large animals like sharks or sturgeon, the amount of handling needed to get fish into an appropriate vessel to administer anaesthesia would require large machinery and brute force in addition to large quantities of anaesthetics. Cold-water and Arctic fish can take hours to emerge from even small doses of anaesthesia due to exceedingly slow temperature-dependent metabolic rates. It is well-recognized that pre- and post-operative care is as important to survival and recovery as the surgical procedure itself. However, for fish in the field, the ability to provide post-operative care is limited to the time that the individual fish needs to recover from anaesthesia. We are not suggesting that anaesthesia be entirely avoided, as it is essential to completing invasive and lengthy surgeries; however, it should not be the default for all procedures. By keeping fish in well-oxygenated water with ample circulation that matches ambient conditions, such as in a foam-lined trough (e.g. Cooke et al. 2005), many fish remain sufficiently calm to enable minimally invasive procedures such as measurement, phlebotomy, external tagging and fin clipping. This general method for external tagging of adult salmon is used routinely in Scandinavia, where it has repeatedly proved a superior method to anaesthesia with minimal adverse effects on the fish (Thorstad et al. 2000, 2003, 2014). When tagged this way, fish remain vigorous and can be released immediately without having to deal with clearance of the anaesthetic and any associated lingering behavioural or cognitive impairments. As we discuss below, this also eliminates the possibility of anaesthetics being ingested by organisms—including humans—consuming released fish. Apart from the value of anaesthetics in restraining fish for more lengthy procedures, their utility in shorter procedures is further diminished by the possibility that fish may not feel pain (Rose et al. 2014), or at least not in the same sense as other vertebrates. The use of anaesthesia needs to be carefully balanced with considerations of the biology and ecology of a given species and the study objectives.

Reality 6: prescribe with care

Fish that are used in field studies present unique considerations for the use of antibiotics and anaesthetics. Most fish that are used in field studies are released back into their natural environment following non-lethal collection of data (e.g. size, tissue samples) and/or the affixation or implantation of transmitters for telemetry studies. One consideration is that the effects of treatment with antibiotics or anaesthetics are largely unknown for most species of fish, and administration of such chemicals may impair the behaviour, survival, and fecundity of sampled individuals and their offspring (Mulcahy 2011; Berejikian et al. 2007). These effects may differ within species depending on the life history stage of individuals and the environmental conditions they are subject to. Furthermore, animals in natural environments are at risk of predation from other animals or humans, placing any consumers of fish that have been treated with antibiotics, analgesics or anaesthetics at risk for exposure to potentially harmful chemicals. In a hypothetical scenario, it is not difficult to imagine the media headlines and public outcry if fish that had been treated with an opiate-based analgesic were released into the water in an area where they could be harvested. Regulatory bodies, often linked to health and food safety such as the Canadian Food Inspection Agency and the United States Food and Drug Administration, may impose lengthy withdrawal periods before fish treated with certain chemicals can be released back into their natural environment (Mulcahy 2011). However, most anaesthetics, analgesics and antibiotics have not been studied with respect to human or food safety and it is consequently illegal to use them on wild fish in many jurisdictions. Careful evaluations prior to the use of any chemicals or drugs on fish in field studies are essential to their safe usage. Quite simply, the effects of many chemical treatments on fish and their predators—including humans—remain poorly understood and require further study before they are administered in natural settings. Similar concerns about human health and safety have led to the adoption of rubber or plastic coated PIT tags in studies involving commercially harvested fish species with the intention of reducing the chance of injury should a tag accidentally end up on a dinner plate (McKenzie et al. 2006).

Reality 7: field work is inherently dynamic

An important consideration in fish research is the need to conduct certain types of studies under field settings to confer ecological relevance. Often these studies require a certain level of flexibility from researchers, because it can be difficult to be certain of the presence and abundance of a particular species prior to the onset of fieldwork. Animal care/ethics permissions are often submitted long in advance of a planned project but conditions can often vary over much shorter timescales. When conducted internationally, these projects can involve substantive costs to the researcher (travel and accommodation costs for research team, equipment/boat rentals, necessary collection permits and licenses, among others) that cannot be recouped if the study becomes unfeasible. The current standards of IACUC planning, however, do not provide acceptable alternatives to deal with unforeseen complications in animal availability. For example, submission of generalized IACUC proposals listing several (similar) species as potential organisms of interest risk being perceived as taking a shotgun approach based on poor or inadequate planning. Often, however, this is the only way to increase the likelihood of a successful project outcome when changing conditions require onsite troubleshooting. By listing several species that are similar in their needs and are equally relevant to the research question(s), researchers can still inform animal care committees of their planned activities but also ensure that they will be able to achieve their immediate goals should plans go awry. Conversely, some sampling methods, particularly passive ones like netting, may yield substantially higher numbers of fish than authorized or desired. We advocate that IACUCs take these factors under advisement and allow increased flexibility in the planning stages of projects, which in combination with generalized SOPs and post-project reviews still provide the necessary levels of accountability and oversight to ensure animal ethics concerns and needs are being addressed.

Reality 8: wild fish are wild

In stark contrast to controlled laboratory conditions, wild fish are constantly faced with ecological uncertainty stemming from a number of sources. Temporal variability in predation risk (Lima and Bednekoff 1999), intra- and interspecific competition and aggression (Tilman 1982), direct and indirect interactions with novel (introduced) species (Lockwood et al. 2013)as well as variation in the physical environment arising from both natural (climate) and anthropogenic sources (e.g. water extraction, damming, pollution;

Schindler 2001) are all well-documented stressors. Indeed, along with over-exploitation of commercial stocks, these factors have been identified as the greatest threats to the persistence of wild fish populations (Maceda-Veiga 2013). Fish species in general typically display the characteristics of r-strategists (Gadgil and Solbrig 1972) in their production of large numbers of offspring with low likelihood of individual survival. In some cases, inter-annual recruitment or survival may be as low as 1 % (Cunjak and Therrien 1998). While the relative contributions of the different sources of mortality outlined above remain unknown or only established in particular systems, the fact remains that survival is far from certain for wild fish over any timescale. We are not suggesting that a cavalier attitude towards field-based sampling should be adopted; rather, this is an attempt to contextualize any population-level effects of responsible scientific research as negligible in comparison to other factors influencing mortality in most instances.

Reality 9: individuals are different

Sampling wild populations inherently involves measuring variations between individuals. Laboratory experiments using captive fish, by contrast, often involve model species obtained from breeding colonies or domesticated strains with individuals being inherently similar, as they have been selected, bred and reared for the purpose of experimentation or for characteristics amenable to aquaculture. These homogeneous properties limit the ecological relevance of experiments involving similar individuals and highlight the need to conduct field research on wild individuals representing a range of genotypes and phenotypes to fully explore ecological systems and conservation problems (Lawton 1998). At the same time, intraspecific variation introduces considerable uncertainty when working with wild fish and quantifying the responses of individuals to experimental manipulations, as individual differences in behaviour are often correlated with metabolic demands and activity levels (Careau et al. 2008). Unpredictable environmental conditions affect individual physiology at several different scales; for example, the stress history of an individual fish can significantly influence its response to experimental manipulations (O'Connor et al. 2014). Intraspecific variation also complicates the establishment of consistent endpoints for experiments—a key requirement of IACUCs. Because fish of different behavioural types or repertoires have different behavioural or physiological trajectories (i.e. exhaustion and recovery times), benefits of establishing common endpoints for all individuals, particularly those leading to euthanasia or administration of anaesthetics, must be carefully considered in individual contexts.

Reality 10: logistics of fish capture, handling, and retention

Whereas laboratory experiments usually draw from established breeding colonies and husbandry protocols for maintaining available and accessible fish for experiments (e.g. Lawrence 2007), fish are not often readily accessible for field research. Conducting research and experiments on wild fish therefore requires specialized knowledge of where and when to capture fish as well as the equipment necessary for capture including nets, traps, trawls, electricity or hook-and-line (Hayes et al. 1996). Although there are benefits and drawbacks associated with each of these methods, they all inevitably cause some degree of physiological stress (Pankhurst 2011) and potentially physical injury. Fortunately, a large body of literature exists from recreational fisheries and commercial bycatch data that has the capacity to advance fish capture and handling practices. Recreational fisheries research has demonstrated the importance of handling fish with wet hands, minimizing air exposure, and restricting sampling activities during periods of extreme water temperatures(Cooke and Suski 2005; Arlinghaus et al. 2007).These findings can aid researchers in collecting fish while minimizing the physiological disruptions they experience.

Capture and handling protocols that significantly impact the physical and physiological condition of wild fish are not useful to the researcher, nor are they justifiable from an animal care perspective. After capture, fish destined to be tagged or manipulated in any way must be retained in some type of holding chamber during the experiment. Alternatively, holding may be necessary for facilitating recovery from treatment or capture prior to release, particularly when anaesthetic is administered; in both cases, holding periods are inherently stressful (Oldenburg et al. 2011; Portz et al. 2006). Even when fish are in poor physiological condition due to complications arising during capture, handling or experimental manipulation, discretion is necessary to determine whether holding is beneficial (Robinson et al. 2013; Jepsen et al. 2002) and what particular holding conditions are optimal. Although in situ or semi-natural pens often represent ideal holding facilities, externalities including abiotic (e.g. wind, tide) and biotic (e.g. predation) conditions must be considered in real-time when selecting the best housing methods for captured fish.

Synthesis and conclusions

With increasing anthropogenic stressors on wild fish populations, it is imperative to study and monitor the impacts of human population growth and activity levels on a variety of fish species (Stoskopf 2003). This is particularly relevant to fish given that aquatic ecosystems are among the most threatened (Jenkins 2003; Ricciardi and Rasmussen 1999) and fish are among the most imperiled taxa (Richter et al. 1997).Wild fish deliver many important ecosystem services (Holmlund and Hammer 1999) in addition to anthropocentric services such as being fished recreationally for leisure (i.e. catch-and-release) or harvested for consumption. As such, many stakeholders relate closely with fish through some level of consumptive or non-consumptive exploitation (e.g. Cooke et al. 2013b). Fish have immense cultural and spiritual value in diverse human communities (Holmlund and Hammer 1999) and provide economic livelihoods and sustenance for some of the most impoverished peoples on the planet (Brown et al. 2014; Young et al. 2013). Many fish populations are actively managed by natural resource agencies that monitor the people, habitats or the fishes themselves. Maintaining the diverse values that fishes have to humans, while also maintaining their welfare, is one amongst many powerful examples of, at times, competing interests. Nonetheless, it is frequently the case that what is beneficial for the welfare of individual fish is also beneficial for fish populations (Diggles et al. 2011; Arlinghaus et al. 2009) and connects fish welfare and animal care concerns to population levels and ecosystem services.

The contemporary research community has an ever-expanding toolbox for the study of wild fish in their natural environment. For example, electronic tags that can be affixed to or implanted in fish (e.g. Hussey et al. 2015; Cooke et al. 2004) to point-of-care devices that enable blood physiology analyses to occur on the river bank (Stoot et al. 2014), mobile ultrasound units to sex fish (Evans et al. 2004), analyses of scales, slime or fin tissue to detect isotopic signatures (for trophic ecology: Church et al. 2008) or ascribe genetic pedigree (Wasko et al. 2003), or simple assessment of fish condition via reflex responses (Davis 2010). There are also a growing number of tools that do not require the researcher to physically handle the fish such as hydro-acoustics (Rudstam et al. 2012), underwater videography (Struthers et al. in press; Mueller et al. 2006), eDNA (Lodge et al. 2012) and the extraction of cortisol from water samples (Ellis et al. 2004). Although such tools hold much promise, they will never entirely replace traditional fish sampling and handling for monitoring or research. We certainly advocate for continued innovations related to the development of non-invasive approaches for studying wild fish, but recognize at the same time that much can be gained from lethal sampling (but see Hammerschlag and Sulikowski 2011; Heupel and Simpfendorfer 2010). These sampling innovations also emphasize the need for continued engagement with veterinary professionals and IACUC participants to both refine these practices and serve to inform future decisions and procedures on the part of the IACUC committees.

When one reflects on the key points made in this paper, they nearly all relate to misunderstandings of the realities of working on fish in the wild. This does not imply ignorance, but simply different training and experiences that make it difficult for one to understand what happens outside of the lab where fish are captured and not ordered/purchased/reared, where there are engaged stakeholders, and where there is immense diversity in size, morphology, behaviour, life-history and physiological tolerances such that development of rigid SOPs or extrapolation from one species (or life-stage, sex, size class, etc.) to another is difficult. We recognize that underlying these issues is a need for greater collaboration between IACUC members (including veterinary professionals) and field researchers (see Wargo Rub et al. 2014; Harms and Lewbart 2011). This would provide more reasoned, rational and useful guidance to improve or maintain the welfare status of fishes used in field research while enabling researchers to pursue fundamental and applied questions related to the biology of fish in the field. To that end, one should question what is needed to help IACUCs and veterinarians learn more about working on wild fish. An obvious potential solution to this is inviting IACUC members to gain first-hand experience by joining researchers in the field. Such visits do not need to be carried out in the context of additional inspections, but rather, simply represent an opportunity to learn about and participate in fieldwork. Such experience may provide for such personnel an appreciation of the realities of working on wild fish under natural conditions. Of course, this may not always be possible, but an alternative approach would be to visually record field procedures (e.g. with a video camera) and show them to IACUCs. General presentations (not on a specific protocol, but more generally on the challenges and realities of fieldwork on fish) to IACUCs can also be useful for providing context. Inclusion of field-oriented researchers on IACUCs as well as the committees that create policies and guidelines would also be extremely helpful in this regard (e.g. AFS Guidelines for Use of Fish in Research: Jenkins et al. 2014). Such approaches are much more effective than simply trying to extrapolate lab-based practices to field settings (e.g. DeTolla et al. 1995). Ultimately, better synergy between IACUCs and field-based researchers during the development of animal care protocols will improve the utility of protocols from a welfare perspective while maximizing the relevance of the protocol to researchers in the field.

We encourage field researchers to share this paper with their IACUC—indeed, that is the target audience for this article. Veterinarians and other IACUC members have much to offer in terms of understanding and contributing principles of animal health and welfare. However, there is also a need to recognize that in practice, not all traditional veterinary principles translate directly to wild animals and the governing legal bodies around the world that provide scientific collection permits for field work on animals.

Acknowledgments S.J. Cooke is supported by the Natural Sciences and Engineering Research Council of Canada, Ocean Tracking Network Canada, and the Canada Research Chairs program. We thank and appreciate the comments and assistance we have gained from our experiences with IACUCs at our home institutions. It is those interactions and our mutual appreciation of the challenges of working on wild animals that inspired us to produce this manuscript. We also thank three referees for providing useful input on the manuscript.

References

Arlinghaus R, Cooke SJ, Lyman J, Policansky D, Schwab A, Suski C, Sutton SG, Thorstad EB (2007) Understanding the complexity of catch-and-release in recreational fishing: an integrative synthesis of global knowledge from historical, ethical, social, and biological perspectives. Rev Fish Sci 15:75–167

Arlinghaus R, Schwab A, Cooke SJ, Cowx IG (2009) Contrasting pragmatic and suffering-centred approaches to fish welfare in recreational angling. J Fish Biol 75:2448–2463

Barton BA, Iwama GK (1991) Physiological changes in fish from stress in aquaculture with emphasis on the response and effects of corticosteroids. Ann Rev Fish Dis 1:3–26

Bayne BL (1998) The physiology of suspension feeding by bivalve molluscs: an introduction to the Plymouth "TROPHEE" workshop. J Exp Mar Biol Ecol 219:1–19

Berejikian BA, Brown RS, Tatara CP, Cooke SJ (2007) Effects of telemetry transmitter placement on egg retention of naturally spawning captively reared steelhead. N Am J Fish Manage 27:659–664

Broom DM (2011) A history of animal welfare science. Acta Biotheor 59:121–137

Brown RS, Colotelo AH, Pflugrath BD, Boys CA, Baumgartner LJ, Deng ZD, Silva LGM, Brauner CJ, Mallen-Cooper M, Phonekhampeng O, Thorncraft G, Singhanouvong D (2014) Understanding barotrauma in fish passing hydro structures: a global strategy for sustainable development of water resources. Fisheries 39:108–122

Careau V, Thomas D, Humphries MM, Reale D (2008) Energy metabolism and animal personality. Oikos 117:641–653

Cattet MR (2013) Falling through the cracks: shortcomings in the collaboration between biologists and veterinarians and their consequences for wildlife. ILAR J 54:33–40

Church MR, Ebersole JL, Rensmeyer KM, Couture RB, Barrows FT, Noakes DL (2008) Mucus: a new tissue fraction for rapid determination of fish diet switching using stable isotope analysis. Can J Fish Aquat Sci 66:1–5

Cooke SJ, Suski CD (2005) Do we need species-specific guidelines for catch-and-release recreational angling to conserve diverse fishery resources? Biodiv Conserv 14:1195–1209

Cooke SJ, Dunlop WI, Macclennan D, Power G (2000) Applications and characteristics of angler diary programmes in Ontario, Canada. Fish Manage Ecol 7:473–478

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

Cooke SJ, Crossin GT, Patterson DA, English K, Hinch SG, Young JL, Alexander R, Healey MC, Van Der Kraak G, Farrell AP (2005) Coupling on-invasive physiological and energetic assessments with telemetry to understand inter-individual variation in behaviour and survivorship of sockeye salmon: development and validation of a technique. J Fish Biol 67:1342–1358

Cooke SJ, Donaldson MR, O'Connor CM, Raby GD, Arlinghaus R, Danylchuk AJ, Hanson KC, Hinch SG, Clark TD, Patterson DA, Suski CD (2013a) The physiological consequences of catch-and-release angling: perspectives on experimental design, interpretation, extrapolation, and relevance to stakeholders. Fish Manage Ecol 20:268–287

Cooke SJ, Lapointe NWR, Martins EG, Thiem JD, Raby GD, Taylor MK, Beard TD Jr, Cowx IG (2013b) Failure to engage the public in issues related to inland fishes and fisheries: strategies for building public and political will to promote meaningful conservation. J Fish Biol 83:997–1018

Cotter AJR, Pilling GM (2007) Landings, logbooks and observer surveys: improving the protocols for sampling commercial fisheries. Fish Fish 8:123–152

Cunjak RA, Therrien J (1998) Inter-stage survival of wild juvenile Atlantic salmon, *Salmo salar* L. Fish Manage Ecol 5:209–223

Curzer HJ, Wallace M, Perry G, Muhlburger P, Perry D (2013) Environmental reseach ethics. Environ Ethics 35:95–114

Davis MW (2010) Fish stress and mortality can be predicted using reflex impairment. Fish Fish 11:1–11

DeTolla LJ, Srinivas S, Whitaker BR, Andrews C, Hecker B, Kane AS, Reimschuessel R (1995) Guidelines for the care and use of fish in research. ILAR J 37:159–173

Diggles BK, Cooke SJ, Rose JD, Sawynok W (2011) Ecology and welfare of aquatic animals in wild capture fisheries. Rev Fish Biol Fisher 21:739–765

Donaldson MR, Hinch SG, Raby GD, Patterson DA, Farrell AP, Cooke SJ (2012) Population-specific consequences of fisheries-related stressors on adult sockeye salmon. Physiol Biochem Zool 85:729–739

Ellis T, James DJ, Stewart C, Scott AP (2004) A non-invasive stress assay based upon measurement of free cortisol released into the water by rainbow trout. J Fish Biol 65:1233–1252

Evans AF, Fitzpatrick MS, Siddens LK (2004) Use of ultrasound imaging and steroid concentrations to identify maturational status in adult steelhead. N Am J Fish Manage 24:967–978

Froese R, Pauly D (2015) FishBase. World Wide Web electronic publication. www.fishbase.org, version (02/2015)

Gadgil M, Solbrig OT (1972) The concept of r- and K-selection: evidence from wild flowers and some theoretical considerations. Am Nat 106:14–31

Hammerschlag N, Sulikowski J (2011) Killing for conservation: the need for alternatives to lethal sampling of apex predatory sharks. Endanger Spec Res 14:135–140

Harms CA, Lewbart GA (2011) The veterinarian's role in surgical implantation of electronic tags in fish. Rev Fish Biol Fisher 21:25–33

Hayes DB, Ferreri CP, Taylor WW (1996) Active fish capture methods. American Fisheries Society, Bethesda, pp 193–220

Helfman G, Collette BB, Facey DE, Bowen BW (2009) The diversity of fishes: biology, evolution and ecology. Wiley, New Jersey

Heupel MR, Simpfendorfer CA (2010) Science or slaughter: need for lethal sampling of sharks. Conserv Biol 24:1212–1218

Holmlund CM, Hammer M (1999) Ecosystem services generated by fish populations. Ecol Econ 29:253–268

Hussey NE, Kessel ST, Aarestrup K, Cooke SJ, Cowley PD, Fisk AT, Harcourt RG, Holland KN, Iverson SJ, Kocik JF, Mills Flemming JE, Whoriskey FG (2015) Aquatic animal telemetry: a panoramic window into the underwater world. Science 348:1255642

Iversen M, Finstad B, McKinley RS, Eliassen RA (2003) The efficacy of metomidate, clove oil, Aqui-S and Benzoak as anaesthetics in Atlantic salmon (*Salmo salar* L.) smolts, and their potential stress-reducing capacity. Aquaculture 221:549–566

Iwama GK, McGeer JC, Pawluk MP (1989) The effects of five fish anaesthetics on acid-base balance, hematocrit, blod gases, cortisol, and adrenaline in rainbow trout. Can J Zool 67:2065–2073

Jenkins M (2003) Prospects for biodiversity. Science 302:1175–1177

Jenkins JA, Bart HLJ, Bowker JD, Bowser PR, MacMillan JR, Nickum JG, Whitledge GW (2014) Guidelines for use of fishes in research—revised and expanded. Fisheries 39:415–416

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

Lawrence C (2007) The husbandry of zebrafish (*Danio rerio*): a review. Aquaculture 269:1–20

Lawton JH (1998) Ecological experiments with model systems: the ecotron facility in context. In: Resetaritis WJ, Bernardo J (eds) Experimental ecology: issues and perspectives. Oxford University Press, New York, pp 170–182

Lima SL, Bednekoff PA (1999) Temporal variation in danger drives antipredator behavior: the predation risk allocation hypothesis. Am Nat 153:649–659

Lockwood JL, Hoopes MF, Marchetti MP (2013) Invasion ecology, 2nd edn. Wiley-Blackwell, Oxfofd, p 466

Lodge DM, Turner CR, Jerde CL, Barnes MA, Chadderton L, Egan SP, Pfrender ME (2012) Conservation in a cup of water: estimating biodiversity and population abundance from environmental DNA. Mol Ecol 21:2555–2558

Maceda-Veiga A (2013) Towards the conservation of freshwater fish: Iberian Rivers as an example of threats and management practices. Rev Fish Biol Fisher 23:1–22

McKenzie JR, Diggles B, Tubbs L, Poortenaar C, Parkinson D, Webster K, Miller N (2006) An evaluation of a new type of plastic-coated PIT tag for tagging snapper (*Pagrus auratus*). N Z Fish Assess Rep 2006(8):40p

McMahon CR, Harcourt R, Bateson P, Hindell MA (2012) Animal welfare and decision making in wildlife research. Biol Conserv 153:254–256

Mueller RP, Brown RS, Hop H, Moulton L (2006) Video and acoustic camera techniques for studying fish under ice: a review and comparison. Rev Fish Biol Fisher 16:213–226

Mulcahy DM (2011) Antibiotic use during the intracoelemic implantation of electronic tags into fish. Rev Fish Biol Fisher 21:83–96

O'Connor CM, Norris DR, Crossin GT, Cooke SJ (2014) Biological carryover effects: linking common concepts and mechanisms in ecology and evolution. Ecosphere 5:art28

Oldenburg EW, Colotelo AH, Brown RS (2011) Holding of juvenile salmonids for surgical implantation of transmitters: a review and recommendations. Rev Fish Biol Fisher 21:35–42

Orlans FB (1988) Field research guidelines: impact on animal care and use committees. Scientists Center for Animal Welfare, Beltsville, pp 1–23

Pankhurst NW (2011) The endocrinology of stress in fish: an environmental perspective. Gen Comp Endocr 170:265–275

Paul E, Sikes RS (2013) Wildlife researchers running the permit maze. ILAR J 54:14–23

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

Raby GD, Hinch SG, Patterson DA, Hills JA, Thompson LA, Cooke SJ (2015) Mechanisms to explain purse seine bycatch mortality of coho salmon. Ecol Appl 25:1757–1775

Ricciardi A, Rasmussen JB (1999) Extinction rates of North American freshwater fauna. Conserv Biol 13:1220–1222

Richter BD, Braun DP, Mendelson MA, Master LL (1997) Threats to imperiled freshwater fauna. Conserv Biol 11:1081–1093

Robinson KA, Hinch SG, Gale MK, Clark TD, Wilson SM, Donaldson MR, Farrell AP, Cooke SJ, Patterson DA (2013) Effects of post-capture ventilation assistance and elevated water temperature on sockeye salmon in a simulated capture-and-release experiment. Conserv Physiol 1:cot015

Rose JD, Arlinghaus R, Cooke SJ, Diggles BK, Sawynok W, Stevens ED, Wynne CDL (2014) Can fish really feel pain? Fish Fish 15:97–133

Ross LG, Ross B (1999) Anaesthesia of fish I and II. Anaesthetic and sedative techniques for aquatic animals, 2nd edn. Blackwell Science Ltd., Oxford, pp 58–94

Rudstam LG, Jech JM, Parker-Stetter SL, Horne JK, Sullivan PJ, Mason DM (2012) Fisheries acoustics. Fisheries Techniques, 3rd edn. American Fisheries Society, Bethesda

Schindler DW (2001) The cumulative effects of climate warming and other human stresses on Canadian freshwaters in the new millennium. Can J Fish Aquat Sci 58:18–29

Sikes RS, Paul E (2013) Fundamental differences between wildlife and biomedical research. ILAR J 54:5–13

Sikes RS, Paul E, Beaupre SJ (2012) Standards for wildlife research: taxon-specific guidelines versus US Public Health Service policy. BioScience 62:830–834

Silvertown J (2009) A new dawn for citizen science. Trends Ecol Evol 24:467–471

Skalski JR, Townsend RL, Steig TW, Hemstrom S (2010) Comparison of two alternative approaches for estimating dam passage survival of salmon smolts. N Am J Fish Manage 30:831–839

Skalski JR, Eppard MB, Ploskey GR, Weiland MA, Carlson TJ, Townsend RL (2014) Assessment of subyearling chinook salmon survival through the federal hydropower projects in the mainstem Columbia River. N Am J Fish Manage 34:741–752

Stoot LJ, Cairns NA, Cull F, Taylor JJ, Jeffrey JD, Morin F, Mandelman JW, Clark TD, Cooke SJ (2014) Use of portable blood physiology point-of-care devices for basic and applied research on vertebrates: a review. Conserv Physiol 2:cou011

Stoskopf MK (2003) All of the world is a laboratory. ILAR J 44:249–251

Struthers DP, Danylchuk AJ, Wilson ADM, Cooke SJ (2015) Action cameras: Bringing aquatic and fisheries research into view. Fisheries 40:502–512

Suski CD, Killen SS, Cooke SJ, Kieffer JD, Philipp DP, Tufts BL (2004) Physiological significance of the weigh-in during live-release angling tournaments for largemouth bass. Trans Am Fish Soc 133:1291–1303

Thorstad EB, Økland F, Finstad B (2000) Effects of telemetry transmitters on swimming performance of adult Atlantic salmon. J Fish Biol 57:531–535

Thorstad EB, Økland F, Kroglund F, Jepsen N (2003) Upstream migration of Atlantic salmon at a power station in the River Nidelva, Southern Norway. Fish Manage Ecol 10:1–8

Thorstad EB, Foldvik A, Lo H, Bjørnå T, Stensli JH (2014) Effects of handling adult sea trout (*Salmo trutta*) in a fishway and tagging with external radio transmitters. Boreal Environ Res 19:408–416

Tilman D (1982) Resource competition and community structure. Princeton University Press, Princeton

Wallace MC, Curzer HJ (2013) Moral problems and perspectives for ecological field research. ILAR J 54:3–4

Wargo Rub AM, Jepsen N, Liedtke TL, Moser ML, Weber EPS (2014) Surgical tagging and telemetry methods in fisheries research: promoting veterinary and research collaborations. Am J Vet Res 75:402–416

Wasko AP, Martins C, Oliveira C, Foresti F (2003) Non-destructive genetic sampling in fish: an improved method for DNA extraction from fish fins and scales. Hereditas 138:161–165

Young N, Gingras I, Nguyen VM, Cooke SJ, Hinch SG (2013) Mobilizing new science into management practice: the challenge of biotelemetry for fisheries management, a case study of Canada's Fraser River. J Int Wildl Law Policy 16:331–351