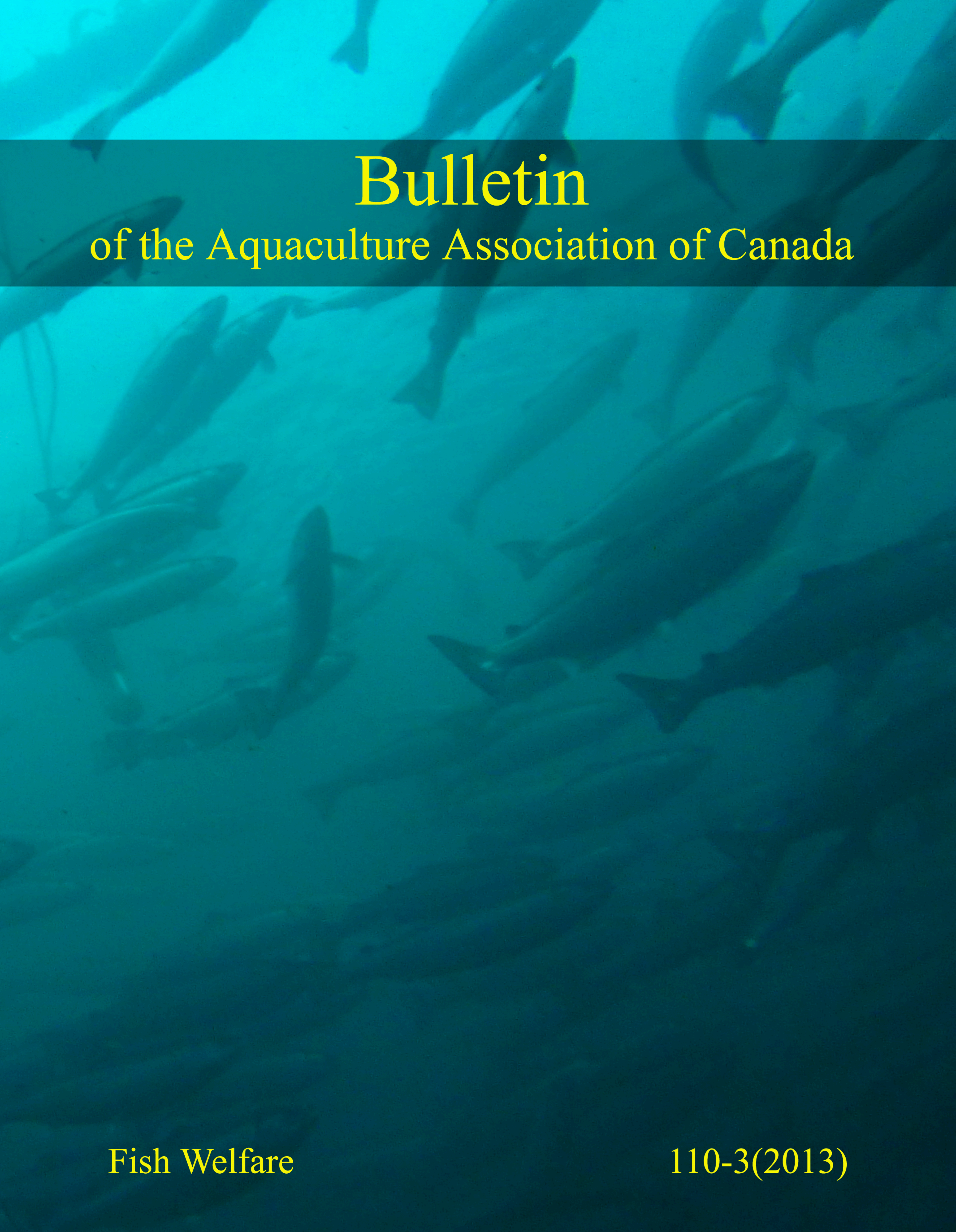


Bulletin

of the Aquaculture Association of Canada

Fish Welfare

110-3(2013)

Bulletin
de l'Association aquacole du Canada
110-3

Vous pouvez recevoir le *Bulletin* en vous y abonnant pour la somme de 60$ par année ou en devenant membre de l'Association aquacole du Canada (AAC), organisme à but non lucratif. Pour de plus amples renseignements, communiquez avec l'Association aquacole du Canada, 16 Lobster Lane, St-Andrews (Nouveau-Brunswick), Canada E5B 3T6 [tél.: 506 529-4766; téléc.: 506 529-4609; courriel: aac@dfo-mpo.gc.ca; site Internet: http://www. aquacultureassociation.ca]. La cotisation s'élève à 100$ par personne (50 $ pour les étudiants et les retraités) et 300$ pour les sociétés. Le *Bulletin* est répertorié dans les *Résumés des sciences aquatiques et halieutiques* (ASFA) et le Zoological Record. Envoi de publication – Enregistrement n° 40065445. Tout changement d'adresse doit être notifié à l'AAC. En cas de non-livraison, prière de retourner à l'AAC. Port de retour payé.

ISSN 0840-5417
Imprimé par Taylor Printing Group Inc., Fredericton, N-B

Bulletin
of the Aquaculture Association of Canada
110-3

The *Bulletin* is available through subscription ($60 per year) or as a benefit of membership in the Aquaculture Association of Canada, a nonprofit charitable organization. For membership information contact: Aquaculture Association of Canada, 16 Lobster Lane, St. Andrews, N.B., Canada E5B 3T6 [telephone 506 529-4766; fax 506 529-4609; e-mail aac@dfo-mpo.gc.ca; website http://www.aquacultureassociation.ca]. Annual dues are $100 for individuals ($50 for students and seniors) and $300 for organizational. The *Bulletin* is indexed in Aquatic Sciences and Fisheries Abstracts (ASFA) and the Zoological Record. Mailed under Canada Post Publications Mail Commercial Sales Agreement No. 40065445. Change of address notices and undelivered copies should be mailed to AAC. Return postage guaranteed.

ISSN 0840-5417
Printed by Taylor Printing Group Inc., Fredericton, NB

Cover: Photograph courtesy of Cooke Aquaculture Inc. Inside a Cooke Aquaculture salmon cage off Grand Manan Island, New Brunswick.

Contents

Fish Welfare in Aquaculture Workshop

November 16th, 2012, St. Andrews, NB

Workshop Introduction

TJ Benfey

In the last sixty years, the importance of aquaculture as a source of fish for human consumption ('fish farming') has increased dramatically, representing 34% of global fish production in 2010 compared to less than 2% in 1950[1]. Global capture fishery harvests peaked in 1996 at 81.2 million mt and have since been in slow decline, standing at 75.3 million mt in 2010[2]. This points to capture fisheries being at, or even beyond, their sustainable limits, and comes at a time when the unprecedented increase in human population size makes increasing food production critical for human nutrition and global security. Aquaculture has therefore become, and will remain, a critical requirement for providing aquatic food resources. And indeed, harvests of farmed fish have more than doubled since capture fisheries have gone into decline, from 16.9 million mt of farmed fish produced in 1996 to 39.2 million mt in 2010[3].

"Salmon farming is a well-established and regulated industry in Canada that benefits from an appreciation by industry leaders that the best product comes from healthy animals grown under conditions that minimize stress."

In Canada, Atlantic salmon (*Salmo salar*) dominates fish farm production. The Canadian capture fishery for this species peaked in the mid-1970s at only 2,500 mt per year, and has yielded less than 150 mt per year for the last decade[4]. Farming of this species, which began in the late 1970s as wild stocks went into decline, now accounts for over 30,000 mt of fish in Atlantic Canada and, together with Pacific salmon, another 70,000 mt in British Columbia[5]. The Canadian salmon farming industry was valued at $691 million in 2010, representing 75% of total Canadian aquaculture production value[5]. Salmon farming is now the principal employer in many rural communities in coastal British Columbia, New Brunswick, Nova Scotia and Newfoundland.

Salmon farming is a well-established and regulated industry in Canada that benefits from an appreciation by industry leaders that the best product comes from healthy animals grown under conditions that minimize stress. Attention is therefore paid to continuous improvement in farm management and fish health practices. This same approach has historically been used for all livestock production, but a combination of consumer pressure and a better appreciation of the link between animal welfare and product quality have more recently led to a greater focus on farmed animal welfare. An outcome of this has been the establishment of groups such as the National Farm Animal Care Council, through which government agencies, farmers associations, veterinarians and the animal humane movement collaborate on addressing farm animal welfare issues that individual organizations could not easily do on their own[6]. However, the NFACC limits itself to terrestrial farm animals and there is no equivalent for aquatic animals in Canada. (Although the National Aquatic Animal Health Program does consider animal welfare, this is only with respect to the prevention, control and eradication of aquatic animal diseases.)

The growth of the aquaculture industry has led to increased consumer awareness of farmed fish in the market place and the need for agreed-upon standards for their production, including standards that address the treatment of farmed fish prior to slaughter (i.e., fish welfare). Although such husbandry standards are already in place at the farm/company level, and some aspects such as maximum stocking densities are regulated conditions of licence, it is within this context of public scrutiny that the aim of this 1-day workshop was to bring together experts in various aspects of the science, regulation and management of fish welfare in aquaculture, to determine the need for research to better understand and provide for the welfare of farmed fish. This was done through a series of state-of-the-art presentations (morning session) followed by a facilitated discussion of research gaps and priorities (afternoon session), with a focus on salmon aquaculture in Canada. The workshop was held on November 16, 2012, at the Fundy Discovery Centre (Huntsman Marine Science Centre, St. Andrews, New Brunswick). Exactly 100 people attended the morning session and 47 of them (mostly industry representatives and university faculty) stayed on for the afternoon session.

"Although such husbandry standards are already in place at the farm/company level, and some aspects such as maximum stocking densities are regulated conditions of licence, it is within this context of public scrutiny that the aim of this 1-day workshop was to bring together experts in various aspects of the science, regulation and management of fish welfare in aquaculture…"

Funding to support the workshop came principally through a Partnership Workshops Grant from the Natural Sciences and Engineering Research Council of Canada (NSERC), with additional financial support from the Réseau Aquaculture Québec (RAQ) and the New Brunswick Community College (NBCC). As well, substantial in-kind contributions were made by the Aquaculture Association of Canada and the Huntsman Marine Sciences Centre. I am grateful to the many people who helped with obtaining the funding for this workshop and its organization: Betty House and Pam Parker (Atlantic Canada Fish Farmers Association), Caroline Graham (NBCC), Sharon McGladdery (Fisheries and Oceans Canada – St. Andrews Biological Station), Céline Audet and Renée Gagné (Université du Québec à Rimouski), Bill Robertson, Ashley Simpson, Amber Garber and Jim Cornall (Huntsman Marine Science Centre) and Catriona Wong and Gail Ryan (Aquaculture Association of Canada).

The workshop was followed on November 17 by a half-day student-focused workshop at the NBCC's St. Andrews campus, to take advantage of the expertise of the invited speakers from the previous day. Approximately 30 people attended, mostly students from l'Université du Québec à Rimouski, NBCC and the University of New Brunswick. Funding for this satellite workshop came from a separate NSERC grant (CREATE), with additional support from RAQ and NBCC.

This Bulletin provides a summary of the November 16th workshop, with papers from four of the six morning presenters and a summary of the afternoon session. I would like to thank all those who contributed their time to make this workshop a success: the invited speakers, most of whom stayed on for the Saturday session, Bill Robertson for facilitation of the afternoon session and timely production of a summary document, all those who participated in the afternoon discussion and Gregor Reid for putting together this document.

Author

Tillmann Benfey is a Professor of Biology and Director of Animal Care at the University of New Brunswick (Fredericton) and a former President of the AAC.

References

1. Benfey, T.J. 2011. Aquaculture: a sustainable future for aquatic food production. Canadian Journal of Zoology 89(7): v-xii.

2. DFO 2012. 2010 Canadian Aquaculture Production Statistics (tonnes). Fisheries and Oceans Canada (http://www.dfo-mpo.gc.ca/stats/aqua/aqua10-eng.htm) (accessed July 2012).

3. FAO 2012. Global Capture Production 1950-2010. UN Food and Agriculture Organization, Fisheries and Aquaculture Department (http://www.fao.org/fishery/statistics/global-capture-production/query/en) (accessed July 2012).

4. FAO 2012. Global Aquaculture Production 1950-2010. UN Food and Agriculture Organization, Fisheries and Aquaculture Department (http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en) (accessed July 2012).

5. ICES 2011. Report of the Working Group on North Atlantic Salmon (WGNAS), 22–31 March 2011, Copenhagen, Denmark. (http://www.ices.dk/reports/ACOM/2011/WGNAS/wgnas_2011_final.pdf)

6. NFACC 2011. Advancing Animal Care and Addressing Market Expectations: Meeting Challenges and Seizing Opportunities. National Farm Animal Care Council (http://www.nfacc.ca/pdfs/nfacc/NFFAC_Prospectus2011.pdf).

Do you believe that fish can feel pain???

E D Stevens

Don Stevens

The goal of this article is to discuss the problem of 'pain' in fish and also to talk about 'pain killers', more properly referred to as analgesics. This is an important issue because there are currently hundreds of articles in non-scientific magazines and also some writers who recommend that analgesics be used with fish. Let me be absolutely clear at the outset regarding my position on this issue: I am opposed to any and all uses of analgesic drugs in fishes because very little is known about their actions and side effects.

Do you believe that fish can feel pain???

The title of this article poses a question in a way that is usually posed by the media when they interview me about the topic of 'pain' in fish. There are two problems with the question as stated this way. The first concerns the word 'believe' because a belief is something we accept as true in the absence of evidence. However, my job as a scientist is to seek evidence to support arguments, not to believe in stories told by advocates of one position or another. There are a number of advocates who strongly believe that fish can feel pain in the absence of evidence. I am a proponent of 'evidence-based' medicine.

"Let me be absolutely clear at the outset regarding my position on this issue: I am opposed to any and all uses of analgesic drugs in fishes because very little is known about their actions and side effects."

The second problem with the question as stated concerns the word 'pain', which is defined by the IASP (International Association for the Study of Pain) as an unpleasant sensory and emotional experience[1]. This definition was meant for humans and it creates problems when we try to adapt or use it when talking about other animals. Because many researchers use this definition, the problem of 'pain in fish' changes to the problem of 'emotional experience in fish'. Thus, many of the proponents of the idea that fish can feel pain have changed their focus to try to show that fish can have an emotional experience.

My goal here is not to belabour this point regarding 'emotional experience in fish', but I think it is important to at least mention what is meant by the phrase. 'Emotional experience' implies consciousness, and consciousness has many meanings. But what it means in the present context is a general awareness of place (where I am relative to where I have been), time, self and an abstract ability to represent the perceptual, emotional, motivational, cognitive and motor states being processed moment by moment[2]. This definition alone should make it clear that scientists trying to prove consciousness in fish have a big challenge. My favorite comment on this issue is one attributed to Derbyshire: "We may feel sorry for the salmon, but the more important question is, Does the salmon feel sorry for itself?" (paraphrased)[3, 4].

Throughout this article I will make a number of points to support my position that analgesics should not be used in fish except by scientists who are trying to study this problem.

The topic is controversial, and it is important to respect the opinion of others

POINT #1. My first point is OPINIONS VARY. When I gave my talk at this workshop, the first thing I did was to survey the audience with the question in the title of this paper, in order to get their opinion on the topic. And, as at most meetings when I survey the audience, not everyone agreed. When we asked the same question to sports fishermen in the southern United States they are inclined to answer no. On the other hand, when we asked the question to an audience of environmentalists they usually all respond in the affirmative. Even the official statements by animal care organizations in different countries vary considerably (Table 1).

Table 1. The official position of organizations concerned with animal care differs considerably from country to country

<u>Canadian Council on Animal Care</u> "With this debate in mind, the guidelines include a working definition of pain in fish: fish pain is a response to a noxious stimulus that results in a change in behaviour or physiology and the same noxious stimulus would be painful to humans." [5]
<u>Fisheries Society of the British Isles</u> "Our working position is that fish have the capacity to perceive painful stimuli and that these are, at least, strongly aversive."[6]
<u>American Fisheries Society</u> "We recommend that researchers pay careful attention to controlling and minimizing physiological stress, because this will eliminate most nociceptive behavioral responses by fish that some observers may interpret as pain"[7].

These official statements use some words that require further definition. A **<u>noxious</u>** stimulus is one that is damaging to tissues, or at least potentially damaging. There are four categories of noxious stimulus: high temperature (touching a hot stove), low temperature (putting your hands into an ice bath), acid (getting vinegar or any other type of acid on a cut) and high pressure or force (hitting your thumb with a hammer). A **<u>nociceptor</u>** is a receptor preferentially sensitive to a noxious stimulus or to a stimulus that would become noxious if prolonged. Just as the receptors in our eyes are specialized to detect light and those in our ears are specialized to detect sound, we have specialized receptors to detect noxious stimuli. These are called nociceptors and are different from touch receptors because they are specialized to detect extreme stimuli: hot not just warm, ice cold not just cool, high force not just a touch.

What is meant by 'pain' has changed over time and continues to change

POINT #2. My second point is that the definition of pain has changed and continues to change with time. It is only in the last 15 or 20 years that analgesics have been used with the newborn. It was not that long ago, for example, that local anaesthesia was not used during circumcision and I expect that most males reading this will wince at the thought of the removal of a large chunk of foreskin with no analgesic. Similarly, the use of analgesics by veterinarians has increased markedly in the last 20 years. We have to appreciate that as a society our opinions change with time, and this includes the way that we think about pain in animals.

Where do you draw the line – what organisms can feel pain?

POINT #3. My third point concerns how we think about pain in different organisms. Each of us draws the line at a different place; we believe that animals above the line feel pain whereas those below do not. We might also rearrange the order of animals in the adjacent list (Table 2). What is important here is that each of us needs to think about a list like this and where we would draw the line and why. Why do we hold a different view about lobsters and sea-lice when they are closely related crustaceans with essentially identical nervous systems? Scientists consider that amongst the invertebrates, the tunicates have a nervous system most closely related to ours, but mussel farmers consider them a pest and make considerable effort to kill them.

Table 2. Where do you draw the line? Which of the animals below can 'feel pain'?

humans
monkeys and apes
pet mammals (dogs and cats)
farm mammals (cows and pigs), zoo animals
pest mammals (rats), hunted mammals (deer and moose)
pet birds (budgies)
farm birds (chickens)
pest birds (starlings), hunted birds (ducks and geese)
reptiles
cute tropical lizards, pet turtles
big poisonous snakes, crocodiles
frogs, toads, salamanders
pet fish (guppies)
farmed fish (salmon)
pest fish (invasive Asian carp), lamprey
tunicates
octopus
arthropods
lobster that we eat
shrimp that we feed to our aquarium fish
sea lice, mites, ticks, cockroaches, locusts, carpenter ants, mosquitoes
butterflies
worms in our garden
worms in our gut, worms on a fishhook
farmed mussels and clams
jellyfish
tomatoes
bacteria

Two types of pain sensing systems: fast and slow

My fourth point concerns the different types of specialized nerve fibers responding to noxious stimuli. In the simplest scheme of things, there are two types of physiological pain: fast and slow. It is important to understand that these are two completely separate systems with separate detectors or nociceptors and separate nerve fibers that go to different regions in the spinal cord with unique different connections within the spinal cord and go to different parts of the brain. The fast type (A-Delta fibers) conduct a nerve impulse very rapidly to the spinal cord that results in a rapid reflex motor response that is immediate and unconscious. For example, if we touch a hot stove then we withdraw our hand even before we know that it was painful. The slow type (C-fibers) conduct the nerve signal much more slowly to the spinal cord and then to the brain and are associated with our awareness of the fact that we touched the hot stove. By far the majority of nerve fibers (usually more than 80%) in humans are C-fibers, whereas in fish they constitute a trivial minority (usually less than 5%)[8, 9]. The condition called 'human congenital insensitivity to pain' occurs in people with less than 30% C-fibers; these patients have a diffuse insensitivity to injury[10, 11]. Those who argue that fish are not aware of pain would argue that fish lack sufficient C-fibers to be aware of the pain. On the other hand, those who argue that fish are aware of pain claim that the role of A-Delta and C-fibers is different in fish and humans.

POINT #4. My point here is that we don't know which of these points of view regarding the role of A-Delta and C-fibers is correct.

Nociceptors in fish

Next I will consider the whole 'pain' system from the nociceptor to the brain. What do we know about nociceptors in fish? All of the scientific evidence points to trout having nociceptors with properties very similar to those in mammals[(12)]. This is not really unexpected, because even worms and insects have similar nociceptors. The one thing that we know is different with regards to nociceptors in fish and mammals is that mammals have cold nociceptors whereas no one has been able to demonstrate the presence of cold nociceptors in any fish. **This has important welfare implications because the commercial fishing practice of live chilling or icing would not stimulate nociceptors and thus would not be 'painful'.**

"People who argue that fish are not aware of pain will say 'of course fish cannot feel pain because they do not have a cortex'. People who argue that fish are aware of pain will say that this function is carried out by a different part of the fish's brain."

Modulators of nociceptor responses

POINT #5. My next point is that nothing is known about the modulators of nociceptors in fish. Any textbook diagram describing the pain system in humans will show a diagram of the skin and list the many chemicals that influence how nociceptors respond to a noxious stimulus. About 25 modulators of nociception in humans are known and much is known about how and where they act. Absolutely nothing is known about any of these modulators in fishes. The reason this is important is that many analgesics that you are familiar with do not act directly on nociceptors or do not act directly on your brain. Rather, they act by interacting with modulators. For example, aspirin and Advil® inhibit the synthesis of prostaglandins and this, in turn, alters the response of nociceptors. Before recommending the use of drugs in fish that act on modulators, I argue that we should know if those modulators are present and have a similar function in fish.

Is the fish brain big enough or complex enough to 'feel pain'?

POINT #6. My next point concerns the structure of the brain. We know that in general the brain of a mammal is 10 times larger than that of a similarly sized fish. For example, a 200 gram rat has a brain 10 times larger than a 200 gram salmon. In addition, the anatomy of the brain in the adult is very different and it develops very differently. The cortex, which is important for awareness of pain in humans, is absent from the fish brain. People who argue that fish are not aware of pain will say "of course fish cannot feel pain because they do not have a cortex". People who argue that fish are aware of pain will say that this function is carried out by a different part of the fish's brain. I argue that we don't know the answer to this question. Similarly, we know that humans have about 100,000,000,000 neurons or brain cells whereas fish have fewer; a human has five to 10,000 brain cells for every brain cell that a fish has. We don't know how many brain cells are required for awareness of pain.

POINT #7. My next point concerns the 'pain' pathway. The A-delta fiber or C-fiber nerve that goes from the nociceptor in your skin to the spinal cord makes a connection with other nerve cells within the spinal cord. These connections between nerve cells (called synapses) work via the secretion of chemicals (called transmitters) from one cell that bind to special proteins (called receptors) on the receiving neuron in the spinal cord. There are many different types of transmitters and receptors, and these are extremely well studied in mammals. There are absolutely no studies of connections between neurons involved in the nociceptive pathway in fishes. The reason that this is important is that many analgesics, morphine for example, have as one of their main actions the stimulation or inhibition of the action of transmitters or of blocking the receptors at these synaptic connections between neurons in the spinal cord.

Analgesics are not approved for use in fishes

POINT #8. My next point is that no analgesics are officially approved for use in fishes by any organization and therefore should not be used.

What is known and not known about analgesics in fishes?

When my laboratory started to do experiments concerning analgesics in fish, we decided to focus on morphine because it is the gold standard to which other analgesics are compared and because it is still very commonly used in human medicine, especially for treatment of cancer pain.

Pharmacodynamics of morphine in fishes

First let us consider pharmacodynamics and efficacy of morphine in fishes. Efficacy refers to the capacity to produce a desired effect, in this case the capacity for morphine to decrease the effects of a noxious stimulus. Pharmacodynamics refers to the way in which efficacy changes over time. For example, if you have a headache and you don't take any medication then the pain will remain relatively constant. However, if you take a drug that is efficacious then the pain will gradually decrease. The drug will remain effective for some time and then its effectiveness will diminish as the drug is metabolized. In addition, the decrease in pain will be greater with a larger dose of the drug because there is a dose-response effect.

Very little is known about the pharmacodynamics of morphine in fish, but there are several studies concerning its efficacy. One study in particular brought this topic of pain in fishes to the forefront[13]. This was one of the early studies by Dr. Sneddon

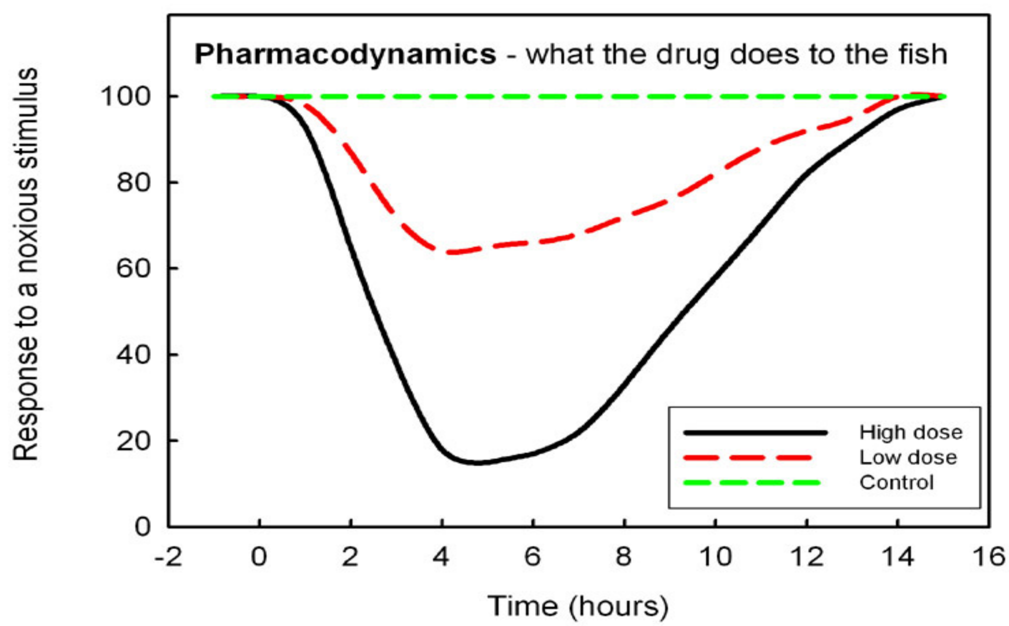


Figure 1. Pharmacodynamics of morphine in fish

when she was doing her graduate degree with Dr. Braithwaite. She used an injection of acetic acid (vinegar) into the face region (she refers to it as the lips of the trout) as the noxious stimulus and then recorded the behaviour of the fish. One of her key observations was that the fish refused to eat for about 180 minutes after the noxious stimulus, whereas the control fish resumed eating in about 80 minutes. However, if she gave the fish morphine prior to the noxious stimulus, then the fish resumed eating in about 80 minutes, just like the control fish. The results of this study were very widely reported in many newspapers and magazines and on many websites. However, there are two important points to note about this study. The first is that she used an extremely large dose, 300 mg/kg, a dose so large that it would be lethal to any mammal on the planet and enough to kill about 100 humans. The second point is that when Newby attempted to replicate Sneddon's experiment, all of the fish in her study ate immediately[14, 15]. That is, they ate when they were first tested 15 minutes after being injected with noxious stimulus. Sneddon's study was important not because it was great science, but rather because it made the question regarding 'fish pain' topical and newsworthy. It made others, including me, think more carefully about the problem.

Efficacy of morphine in fishes

POINT #9. Rainbow trout can tolerate huge doses of morphine, but we don't know how they are able to tolerate these huge doses or what it means. Most studies show that morphine does change the response of fishes to a noxious stimulus but the doses used or required to have an effect are much larger than those used in mammals.

Table 3. Summary of studies examining the efficacy of morphine in fishes

Noxious Stimulus	Dose (mg/kg)	Effect	Fish	Authors
Electric shock	30 (on brain)	Yes	Goldfish	Ehrensing et al.[16]
Electric shock	10 (in water)	Yes	Goldfish	Jansen et al.[17]
Electric shock	10 IV	Yes	Trout	Jones et al.[18]
Acetic acid	300 IM	Yes	Trout	Sneddon et al.[13]
Acetic acid	40 IP	Yes	Flounder	Newby et al.[19]
Acetic acid	6 IP	Yes	Zebrafish	Correia et al.[20]
Heat	40 IM	Acute-No 2 hours later-Yes	Goldfish	Nordgreen et al.[21]

IV= intravenous, IM = injected into the muscle, IP= injected into the abdominal or peritoneal cavity

There are a number of other studies that have looked at the efficacy of morphine in fish. In general, the results from all of these studies taken together suggest that morphine does reduce the effect of noxious stimulus (Table 3; Fig. 2).

Pharmacokinetics or metabolism of morphine in fishes

Pharmacokinetics is the study of the metabolism of drugs; that is, what the 'animal does to the drug' rather than what the 'drug does to the animal'. There have been about five studies concerning the pharmacokinetics of morphine in fishes, carried out in winter flounder, goldfish, rainbow trout adapted to sea water, and rainbow trout adapted to fresh water (Fig. 3). These studies show that the metabolism of morphine is different in different species of fishes, but in general they showed that the metabolism is much slower than in mammals[22-24].

POINT #10. The metabolism of morphine differs in different species of fish and is much slower in fish than in mammals. The importance of this is that the concentration in the blood remains above the effective level for about 10 times longer than it would in a mammal. We do not know how or why this is the case.

Analgesics other than morphine

A few other analgesics have been studied in fish with mixed results. Chervova, a Russian scientist, has reported that some experimental opioids are efficacious in fishes[25-28]. Tramadol is the only drug that she has tested that is available to veterinarians in Canada. Sneddon's group reported that neither buprenorphine (an opioid) nor carprofen (an NSAID) were effective, but that lidocaine injected at the site of the noxious stimulus was effective[29]. Others have tested ketoprofen and butorphanol, and neither was effective [30].

POINT #11. Some analgesics appear to be effective in fish and others do not, and we do not have any understanding of why some are effective and others are not. That is, there is no understanding of what it is about fishes that makes them respond to some drugs but not others.

Side effects

When considering the use of any drug in any animal, it is extremely important to know something about side effects. Table 4 shows the side effects of some analgesics that have been tested in fish.

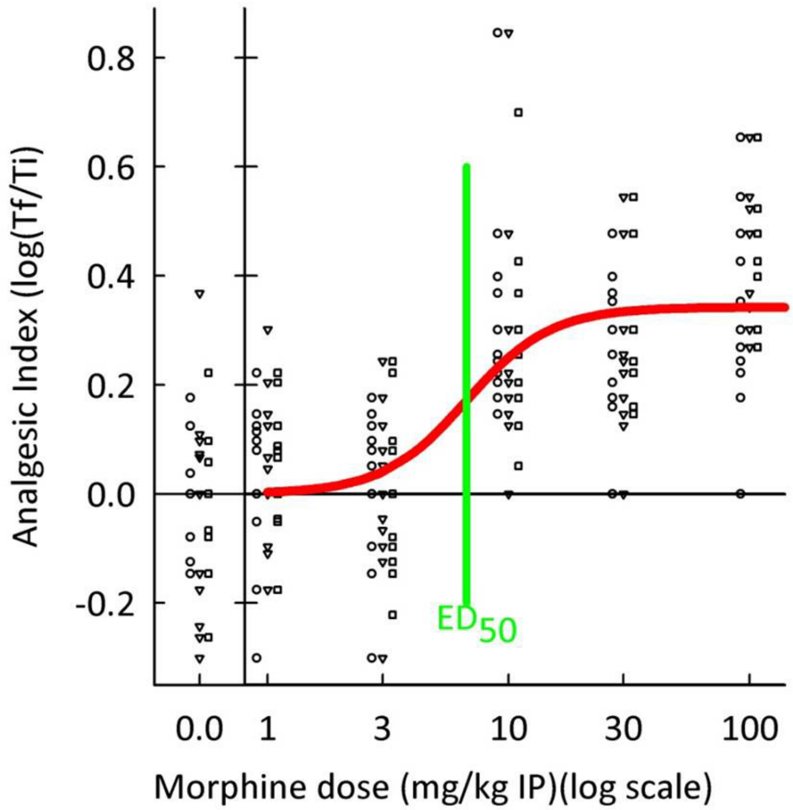


Figure 2.The dose-dependent effect of morphine as an analgesic in fish (adapted from (19)). The graph illustrates two main points: there is a great deal of variation among individuals and, in general, there is an increase in analgesic effect with an increase in dose of morphine. Each point represents a test on a separate fish. In this test, the authors used rainbow trout, about 60 grams, and used an electric shock to the face as a noxious stimulus.

Table 4. Side effects of analgesics in fish

Analgesic	dose	Side effect
Morphine	300 mg/kg	Surprisingly, no side effects. No change in swimming behaviour or feeding[13, 14]
Morphine	30 mg/kg	Increase in heart rate, lasted for days[19]
butorphanol	1 mg/kg	Tilapia died[30]
butorphanol		Koi did not die, not efficacious[30]
sidnophen		Not efficacious, fish died[26]
analgin		Not efficacious, fish died[26]
morphine	various	If given a choice, fish choose to be in water that contains morphine[31]

Problems in the literature

All of the foregoing was an attempt to convince you that not much is known about analgesics in fish. There is another issue that needs mentioning: the issue of problems in the literature. There are three problems that I want to mention here[32]. The first is faith-based research. Some persons writing about 'fish pain' have an agenda and they are quite clear and open about it: they want to convince everyone that fish can feel pain and can suffer. This makes for bad science because scientists need to be objective and not have any preconceived notions regarding the outcome of experiments. The most obvious example of this problem concerns sea-lice. Alexandra Morton and her colleagues have a clear agenda and one wonders whether any of their 'research' concerning sea-lice is objective and unbiased.

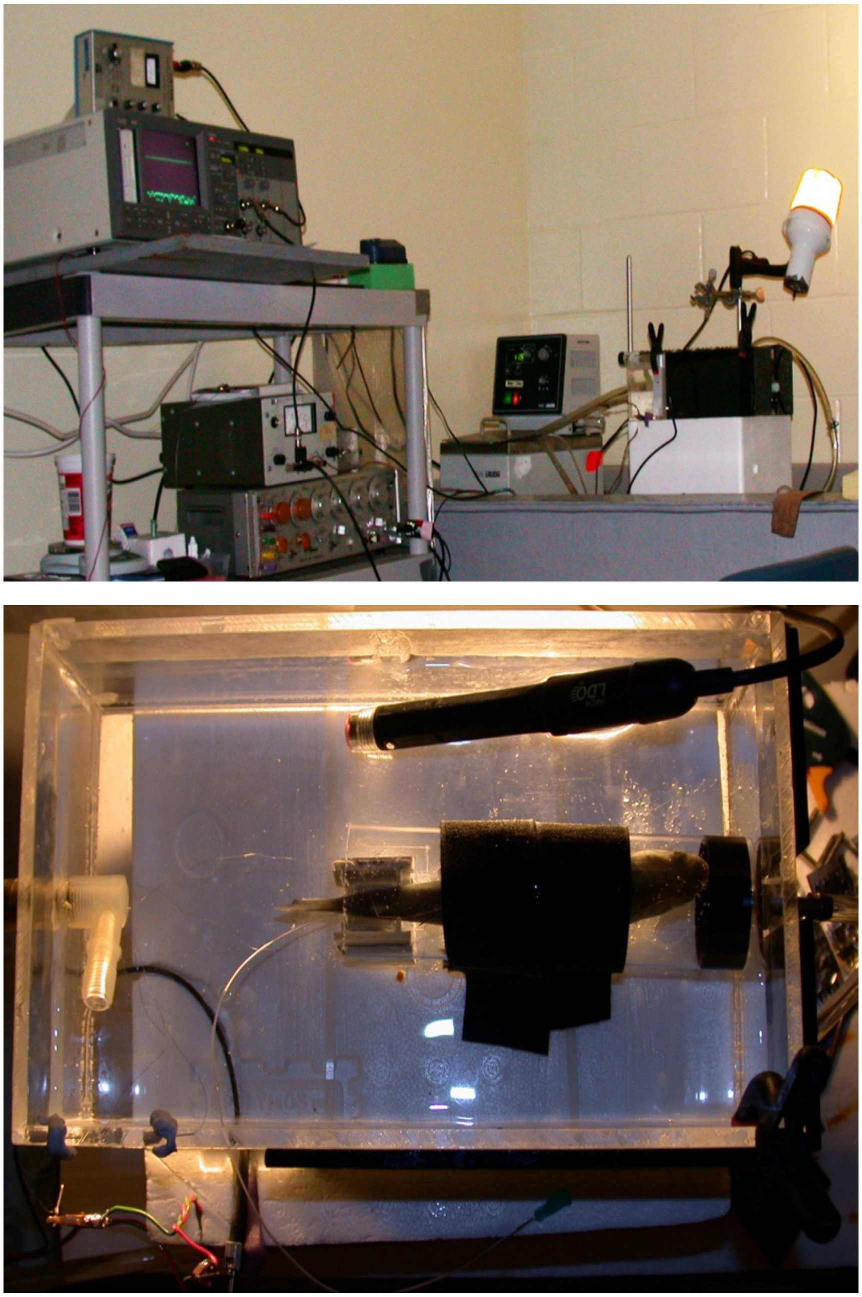


Figure 3. Equipment used to estimate the analgesic effect of morphine in rainbow trout. The top photo shows the whole setup with the fish in the black box on the right. The bottom photo shows the trout constrained to stay within a plastic tube for the test.

The second is ignoring or failing to discuss negative results. For example, Sneddon reported that acid-injected fish sometimes "rubbed" their mouths against the gravel, but the venom-injected fish did not and concluded that "mouth rubbing" was due to pain[13]. Why did the venom-injected fish that also were "experiencing pain" not perform this behaviour? Although the negative results were reported, they were not discussed at any length and were dismissed or completely ignored in subsequent discussions by those with an agenda.

The third is called HARKing[32], which refers to Hypothesis After Results are Known. Science is usually done by having a hypothesis, making a prediction based on this hypothesis and then testing the prediction. The HARKing problem occurs when people do the reverse; that is, create the hypothesis after doing the experiment. For example, observing that a change in respiration rate or spending more time on the bottom half of the tank after a noxious stimulus and then inferring that these changes can be used to measure 'fish pain'. Thus, in addition to the genuine problems discussed in points 1 to 11 above, we must also be cognizant of the veracity of what is argued in the literature.

Relevance of the 'fish pain' issue to fish farming and conclusion

Let me conclude by suggesting that there may be some circumstances during fish farming that may stimulate nociceptors. These include deformities that make it difficult to swim, crowding that may lead to fin biting, vaccination that leads to adhesions, grading and/or sea-lice that may lead to wounds, and during slaughter. However, during these circumstances I recommend that we avoid speculation about what the fish is 'feeling' and focus on objective metrics, i.e., things that we can actually measure. For example, behaviour, feeding, growth, and reproduction of brood stock can all be objectively measured. We need to measure what can be measured objectively rather than guessing how 'angry, happy, anxious, afraid, depressed or frustrated' the fish is 'feeling'. Details of the arguments concerning 'pain' in fishes have recently been addressed in a book by Dr Braithewaite[(33)] and a large review paper by Rose[(34)].

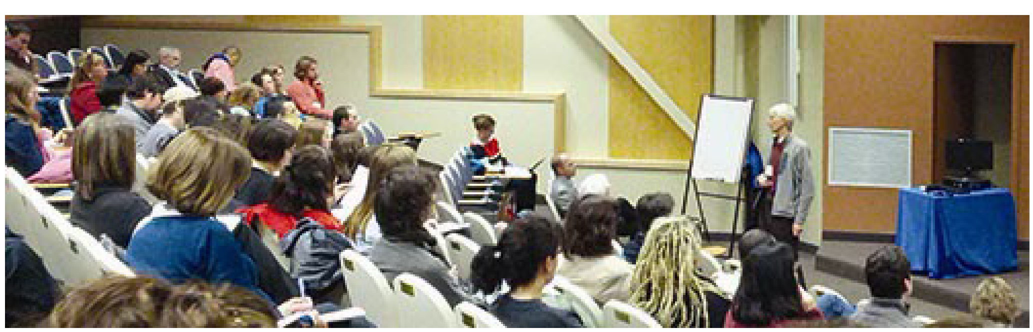
And lastly, as I said at the outset, I argue that at present, it is not appropriate to use analgesics in fish, especially in fish raised for human consumption.

Acknowledgements

I would like to thank the many students (Nat Newby, Sarah Jones, Angela Douglas, Glenn Wagner, Jake Robinson), colleagues and co-authors (Chris Harvey-Clark, Mike Wilkie, Bob Balahura, Ana Correia, Pascal Vachon, Francis Beaudry) that have participated in our experiments and others who have helped in understanding the meaning of 'pain' in fish (Gilly Griffin at CCAC, Jana Sawynok, Craig Mosley, Bob Frank, Tor Horsberg, Janicke Nordgreen, Lilly Chervova, John Burka, Jon Spears, Luis Bates).

Author

E. Don Stevens is Professor Emeritus of Integrative Biology at the University of Guelph and Adjunct Professor in Biomedical Sciences at the Atlantic Veterinary College.



References

1. IASP. *IASP Pain definitions*. [1 May 2005]; Available from: http://www.iasp-pain.org/defsopen.html.
2. Nussbaum, D. and K. Ibrahim, *Neuronal function is necessary but not sufficient for consciousness: consciousness is necessary for will.* Front Integr Neurosci, 2012. **6**: p. 103.
3. Mameli, M. and L. Bortolotti, *Animal rights, animal minds, and human mindreading.* J Med Ethics, 2006. **32**(2): p. 84-9.
4. Derbyshire, S.W. *Fishing for theories*. 2003 [cited 2012 30 Nov 2012]; Available from: http://www.spiked-online.com/articles/00000006DD91.htm.
5. Canadian_Council_on_Animal_Care, *CCAC guidelines on: the care and use of fish in research, teaching, and testing*. 2005, Ottawa, Canada: Canadian Council on Animal Care.
6. FSBI, *Fish welfare briefing paper 2*. 2002, Fiseries Society of the British Isles.
7. American_Fisheries_Society, *Guidelines for the use of fishes in research*. 2004, American Fisheries Society: Bethesda, Maryland, USA.
8. Roques, J.A., et al., *Tailfin clipping, a painful procedure: Studies on Nile tilapia and common carp.* Physiol Behav, 2010. **101**(4): p. 533-40.
9. Sneddon, L.U., *Anatomical and electrophysiological analysis of the trigeminal nerve in a teleost fish, Oncorhynchus mykiss.* Neurosci Lett, 2002. **319**(3): p. 167-71.
10. Guo, Y.C., et al., *Congenital insensitivity to pain with anhidrosis in Taiwan: a morphometric and genetic study.* Eur Neurol, 2004. **51**(4): p. 206-14.
11. Rosemberg, S., S.K. Marie, and S. Kliemann, *Congenital insensitivity to pain with anhidrosis (hereditary sensory and autonomic neuropathy type IV).* Pediatr Neurol, 1994. **11**(1): p. 50-6.
12. Ashley, P.J., L.U. Sneddon, and C.R. McCrohan, *Nociception in fish: stimulus-response properties of receptors on the head of trout Oncorhynchus mykiss.* Brain Res, 2007. **1166**: p. 47-54.
13. Sneddon, L.U., *The evidence for pain in fish: the use of morphine as an analgesic.* Applied Animal Behaviour Science, 2003. **83**: p. 153-162.
14. Newby, N.C. and E.D. Stevens, *The effects of the acetic acid "pain" test on feeding, swimming, and respiratory responses of rainbow trout (Oncorhynchus mykiss).* Applied Animal Behaviour Science, 2008. **114**: p. 260-269.
15. Newby, N.C. and E.D. Stevens, *The effects of the acetic acid "pain" test on feeding, swimming, and respiratory responses of rainbow trout (Oncorhynchus mykiss): A critique on Newby and Stevens (2008) - Response.* Applied Animal Behaviour Science, 2009. **116**(1): p. 97-99.
16. Ehrensing, R.H., G.F. Michell, and A.J. Kastin, *Similar antagonism of morphine analgesia by MIF-1 and naloxone in Carassius auratus.* Pharmacol Biochem Behav, 1982. **17**(4): p. 757-61.
17. Jansen, G.A. and N.M. Greene, *Morphine metabolism and morphine tolerance in goldfish.* Anesthesiology, 1970. **32**(3): p. 231-235.
18. Jones, S.G., et al., *The dose-response relation for the antinociceptive effect of morphine in a fish, rainbow trout.* J Vet Pharmacol Ther, 2012. **35**(6): p. 563-70.
19. Newby, N.C., A.K. Gamperl, and E.D. Stevens, *Cardiorespiratory effects and efficacy of morphine sulfate in winter flounder (Pseudopleuronectes americanus).* Am J Vet Res, 2007. **68**(6): p. 592-7.

20. Correia, A.D., S.R.Cunha, Scholze M. and E.D. Stevens, *A Novel Behavioral Fish Model of Nociception for Testing Analgesics*. Pharmaceuticals 2011. **4**(4): p.665-680; doi:10.3390/ph4040665
21. Nordgreen, J., et al., *Thermonociceptions in fish: effects of two different doses of morphine on thermal threshold and post-test behaviour in goldfish (carassius auratus).* Applied Animal Behaviour Science, 2009.
22. Newby, N.C., et al., *Pharmacokinetics of morphine in fish: winter flounder (Pseudopleuronectes americanus) and seawater-acclimated rainbow trout (Oncorhynchus mykiss).* Comp Biochem Physiol C Toxicol Pharmacol, 2006. **143**(3): p. 275-83.
23. Newby, N.C., et al., *Pharmacokinetics of morphine and its metabolites in freshwater rainbow trout (Oncorhynchus mykiss).* Journal ov Vet. Pharmcol. Therap., 2008. **31**: p. 117-127.
24. Newby, N.C., M.P. Wilkie, and E.D. Stevens, *Morphine uptake, disposition, and analgesic efficacy in the common goldfish (Carassius auratus).* Canadian Journal of Zoology, 2009. **87**(5): p. 388-399.
25. Chervova, L.S., *Nociception and fish behavior.* Veprosy-Ikhtoiologii, 1997. **37**: p. 106-111.
26. Chervova, L.S., *Pain sensitivity and behaviour of fishes.* Journal of Ichthyology, 1997. **37**(1): p. 98-102.
27. Chervova, L.S. and D.N. Lapshin, *Opioid modulation of pain threshold in fish.* Doklady Biological Sciences, 2000. **375**: p. 590-591.
28. Chervova, L.S. and D.N. Lapshin, *Behavioral control of the efficiency of pharmacological anesthesia in fish.* Journal of Ichthyology, 2011. **51**: p. 1126-1132.
29. Mettam, J.J., et al., *The efficacy of three types of analgesic drugs in reducing pain in the rainbow trout, Oncorhynchus mykiss.* Applied Animal Behavior Science, 2011. **133**: p. 265-274.
30. Harms, C.A., et al., *Behavioral and clinical pathology changes in koi carp (Cyprinus carpio) subjected to anesthesia and surgery with and without intra-operative analgesics.* Comp Med, 2005. **55**(3): p. 221-6.
31. Shelford, V.E., *The reactions of goldfish to certain habit forming drugs - the use of the gradient tank.* Journal of the American Pharmaceutical Association, 1918. **7**: p. 597-603.
32. Browman, H.I. and A.B. Skiftesvik, *Welfare of aquatic organisms: is there some faith-based HARKing going on here?* Dis Aquat Organ, 2011. **94**(3): p. 255-7.
33. Braithwaite, V. *Do Fish Feel Pain*? 2010. Oxford University Press, Oxford.
34. Rose, J. D., et al., *Can fish really feel pain*? 2013. Fish and Fisheries. epub doi: 10.1111/faf.12010

Gilly Griffin

CCAC guidelines for animals used in science – can these inform welfare practices for production animals?

G Griffin

Abstract

The Canadian Council on Animal Care (CCAC) publishes guidelines on the care and use of animals for scientific purposes. In general these guidelines tend to be more stringent than one would typically see in an agricultural or aquaculture setting. In carrying out its mandate, the CCAC acts in the interests of the people of Canada, and it is clear that the public in general expects a higher standard of care to be given to research animals than currently afforded to animals used for food production. Standards that are set for scientific purposes, however, can form the basis for industry standards. Where the public has a concern for the welfare of animals raised for food, the intention for the standards is the same – minimization of any potential for pain and distress and provision of an environment that enables a good quality of life for the animals.

Introduction

"…it is likely that the welfare of fish raised for food will become more of a concern in the future."

Public concerns regarding practices in the agricultural industry grew out of the concern about large scale agricultural operations and de-personalization of the production systems. These concerns include contamination of meat products and the impact of large scaling farming on the environment, as well as the welfare of the individual animals involved. With the increasing growth of the aquaculture industry, it is likely that fish farms will experience similar public scrutiny. At present, the concerns of the public are focused on the impact of fish farms on the environment and the potential contaminants in fish products[(1)]. However, it is likely that the welfare of fish raised for food will become more of a concern in the future.

The use of animals for scientific purposes has been under heavy public scrutiny for many years. Organizations responsible for overseeing the use of animals in science, such as the Canadian Council on Animal Care (CCAC), have addressed public concern and the concerns of researchers that they be permitted to carry out their knowledge generation and testing activities, through the development of standards. In general, these standards aim to minimize pain and distress for animals used for scientific purposes and to provide a living environment that affords a good quality of life for the animals, given the constraints of the research setting. The *CCAC guidelines on: the care and use of farm animals in research, teaching and testing*[(2)] provided a starting point for the development of industry Codes of Practice, in particular for dairy cattle. Similarly, the *CCAC guidelines on: the care and use of fish in research, teaching and testing*[(3)] could form the basis for development of welfare standards for aquaculture. Key to good welfare standards is the ability to assess the welfare of the animals, and this CCAC guidelines document provides a list of parameters for welfare assessment in a research setting, which could also be used as a basis for suitable parameters in industry.

Canadian Council on Animal Care

The Canadian Council on Animal Care is Canada's national peer review agency, responsible for setting and maintaining standards for the ethical use and care of animals in science. It was established in 1968 to ensure that the use of animals for research, teaching and testing purposes employs optimal care according to acceptable scientific standards. It was also established to promote knowledge, awareness and sensitivity to the relevant ethical principles concerning the use of animals in science.

At the time that the CCAC was established, there was an increasing use of animals in biomedical research and a growing public concern about their use, given the increasing understanding of animals' capacity to suffer pain and distress. This was not only the case in Canada; in 1966, the US Congress enacted Public Law (P.L.) 89-544, known as the Laboratory Animal Welfare Act(4), to regulate dealers who handle dogs and cats, as well as laboratories that use dogs, cats, hamsters, guinea pigs, rabbits or nonhuman primates in research. Increasing public concern was also being expressed in Europe and in the UK, despite the 1876 Cruelty to Animals Act(5), requiring that scientists be licenced to carry out experiments. Following a study to determine the most appropriate mechanism to oversee the use of animals in Canada, a peer-review system was developed to act in the interest of the people of Canada in ensuring that any use of animals is ethical and that their welfare is supported as far as possible, in line with Canadian societal values. The CCAC peer review system was also developed to address the scientists' concerns that they be permitted to carry out their legitimate activities.

"The policies and guidelines of the CCAC recognize that good animal welfare and good animal science go hand in hand."

The overarching *CCAC policy statement on: the ethics of animal investigation*(6) requires that any use of animals has a benefit to humans, animals or the environment. For the CCAC, the basis of the ethic of animal experimentation relies heavily on the principles of humane science, first enunciated by Russell and Burch in 1959, in response to public concern about the harm caused to animals in experiments(7). This is spelled out for the CCAC in its fundamental policy statement, and essentially says that animals should only be used where necessary, that the number of animals used should be appropriate to meet the goals of the experiment, and that any potential pain and distress should be minimized as far as possible. These principles are commonly known as the Three Rs: Replacement, Reduction and Refinement. Other CCAC documents are formulated under this framework to provide assistance to investigators and members of animal care committees (which oversee animal based work at their institutions) to balance the well-being of animals with the legitimate goals of research. The policies and guidelines of the CCAC recognize that good animal welfare and good animal science go hand in hand.

Public Attitudes

It is interesting that public attitudes towards the use of animals in science tend to mirror the application of the Three Rs. In general, people tend to take a pragmatic approach, in that they support the use of animals only when there are no alternatives, and as long as pain and distress are minimized[8]. In addition, according to the work of a previous CCAC research fellow Elisabeth Ormandy and others, people are more supportive of research when they know that a system involving standards and assurance of compliance with those standards is in place[9] .

The study carried out by Ormandy et al. asked specific questions of the 415 participants to establish attitudes towards species sentience, genetic modification and regulations of animal-based research. Participants were asked "Do you believe that the following species can experience pain, suffering, happiness and pleasure?" Table I shows the response rate for three species for the responses 'totally agree' and 'mostly agree' (the other possible responses, 'neutral', 'mostly disagree' and 'totally disagree', are not shown here). If the two responses of 'totally agree' and 'mostly agree' are combined, perhaps not surprisingly, 93% of participants agreed that dogs can experience pain, suffering, happiness and pleasure. More surprising was the finding that if these two responses are combined for mice and for fish, 45% of participants agreed that each of these species have the capacity to experience pain, suffering, happiness and pleasure.

Table 1: Respondents believing that animals can experience pain, suffering, happiness and pleasure

Species	Totally agree	Mostly agree
dogs	85%	8%
mice	16%	29%
fish	10%	35%

The study was designed to determine the extent to which participants would be willing to let an animal-based research study for skin cancer proceed, depending whether it was carried out in mice or fish, and whether it involved a genetically-engineered animal model or a skin cancer model developed through subjecting the animals to chemical mutagenesis. An interesting finding was that 65% of participants were opposed to chemical mutagenesis in fish, on the grounds that it might be a painful experience for the animals[9].

From the above study, it would seem that at least for the research setting, public attitudes to the use of fish are not so different from attitudes towards the use of mice. These focus around minimizing any pain and distress for the animals, through assurance of compliance with ethical standards.

Setting Standards

As with any of its standard setting activities for the care and use of animals in science, the CCAC acts in the interests of the people of Canada. Development of any CCAC guidelines document starts with the identification of sound scientific evidence. Scientific evidence is then considered in the light of expert opinion, the "regulatory framework" within which CCAC operates (not just government regulations, although clearly CCAC guidelines need to respect legal requirements, but also the CCAC compliance framework), and consideration of what we know about Canadian societal concerns (Fig. 1).

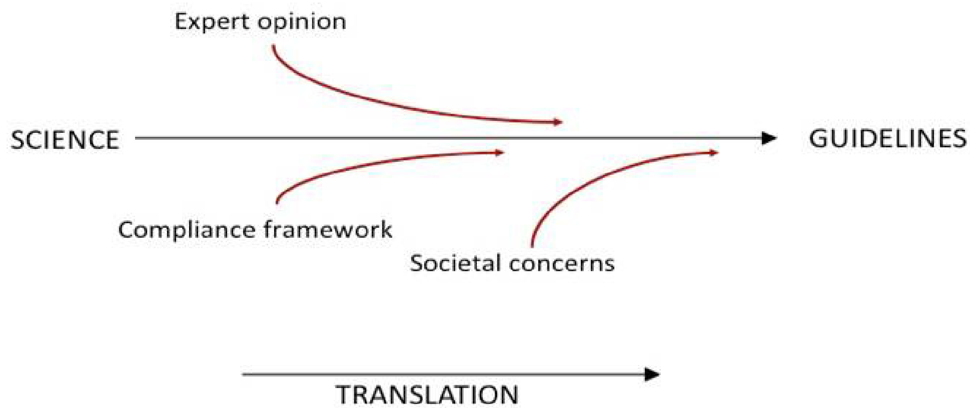


Figure 1: Knowledge translation for standard setting. Scientific evidence is translated to practical guidelines by taking into consideration expert opinion, the compliance framework within which the guidance must operate and public concerns about the particular topic at hand.

Although in some instances animals may experience pain, distress or other forms of suffering as a consequence of being a research subject, those involved in any scientific practice aim to minimize any harms to animals as far as possible. This is important for scientific purposes, as data from animals that are stressed is not as scientifically sound: there may be greater variability, and the effects of circulating stress hormones can have a large impact on physiological parameters. However, investigators and animal care staff also want to provide good animal welfare as their moral responsibility to those animals involved in their studies.

A number of different definitions of animal welfare exist, however, arguably one of the clearest is described by David Fraser in his book "Understanding Animal Welfare"[10]. He states that to experience a good welfare state animals should:

1) Be healthy and thriving;
2) Have the ability to do things they are strongly motivated to do; and
3) Enjoy life – experience positive states and have negative states minimized.

The CCAC guidelines set standards outlining conditions for animals to experience good welfare, balanced with the constraints required to meet scientific objectives, as approved by local ethics committees. This is the work of the CCAC Guidelines Committee and the various subcommittees formed to develop CCAC guidelines.

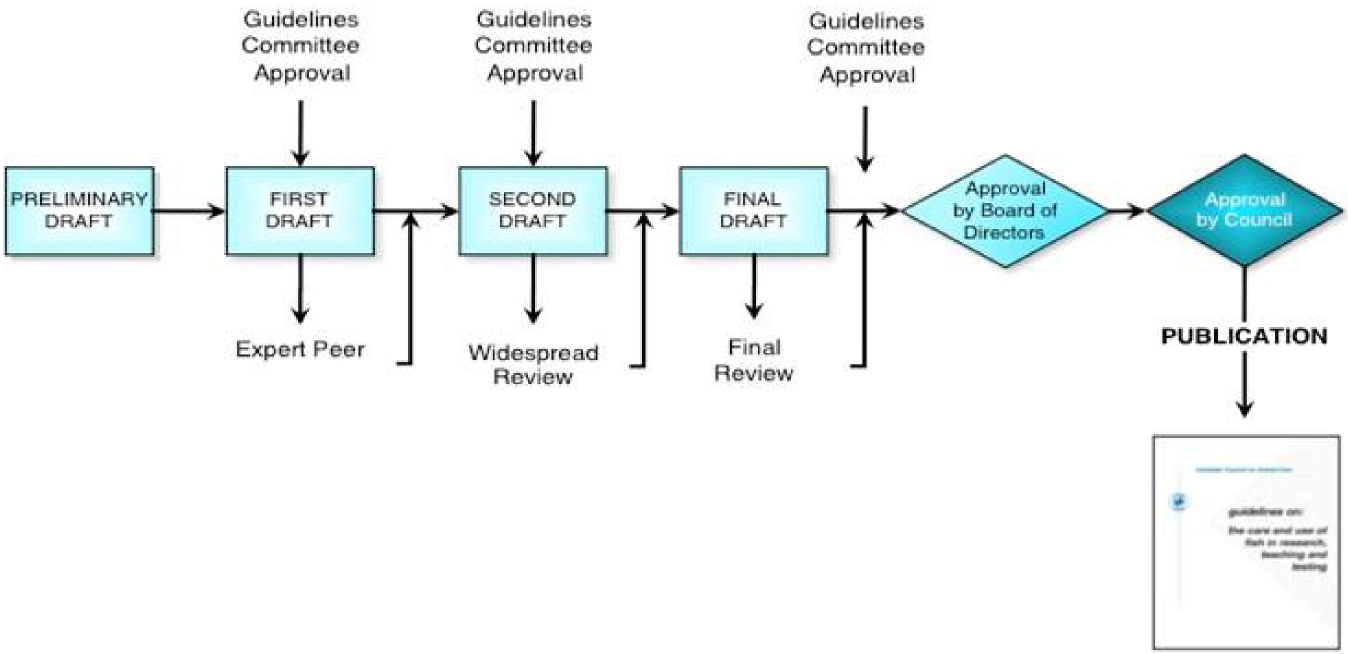


Figure 2: The CCAC Guidelines development process. The CCAC has developed a considerable number of guidelines in this manner, which can be found on the CCAC website (www.ccac.ca).

The process of guidelines development is lengthy, as shown in Figure 2: there are at least three review stages involving experts in the area of the guidelines document under development, as well as any stakeholders who might be affected by the new or revised guidelines.

CCAC Guidelines on: the care and use of fish in research, teaching and testing

In 2005, the *CCAC guidelines on: the care and use of fish in research, teaching and testing*[3] was published. In developing this guidelines document, the CCAC subcommittee on fish set out to both support the leadership role that Canadians play in fish research and ensure that the welfare of fish is carefully considered when they are kept and used for scientific purposes. The difficulty of this task for the members of the subcommittee can perhaps be best summarized by a quote from a 2002 Fisheries Society of the British Isles briefing paper, which states that "The scientific study of welfare is at an early stage compared to work on other vertebrates and a great deal of what we need to know is yet to be discovered"[11]. The subcommittee members felt that it was important to have some understanding of fish perception, and in particular, whether fish can experience pain, because it may have an influence on the considerations of how these animals should be managed.

The subcommittee reviewed the available literature on the subject (for example see references 12 and 13). The subcommittee also sought additional expert advice, and identified "fish pain" as a knowledge gap to the Natural Sciences and Engineering Research Council (NSERC), with the recommendation that NSERC consider funding some of the studies required to support the guidelines document. In addition, one of the subcommittee members also carried out additional research studies, with a view to understanding the effects of analgesics in fish[14, 15].

After all the deliberations, the subcommittee decided on a precautionary approach. The *CCAC guidelines on: the care and use of fish in research, teaching and testing* recognize that "Fish have the potential to experience pain and manipulations that provoke stress or avoidance/escape behaviour may be causes of distress … Researchers have an obligation to mitigate or minimize potential pain and distress whenever feasible … This is consistent with good scientific practice"[3]. This approach is, of course, not only consistent with good scientific practice, but also addresses societal concerns that fish may experience pain and distress. Having taken this decision, the subcommittee was then able to move forward and carve the guidelines within this framework.

"Fish have the potential to experience pain and manipulations that provoke stress or avoidance/escape behaviour may be causes of distress … Researchers have an obligation to mitigate or minimize potential pain and distress whenever feasible …"

The CCAC guidelines cover the following topics: aquatic facilities; facility management, operation and maintenance; capture, acquisition and transport; husbandry; health and disease control; experimental procedures; euthanasia; and disposition. Many of these topics are also relevant to fish being held for aquaculture purposes. In fact, one of the challenges in developing the guidelines was the broad spectrum of research activities that needed to be covered, including aquaculture research and biomedical research. For example, aquatic environments are very different for zebrafish used for developmental toxicity purposes than for Atlantic salmon used to test a drug to treat sea lice. In addition, much of what fish prefer as housing environments is unknown. The guidelines therefore took a performance approach where possible: "Aquatic environments should be designed to meet the normal behavioral drives of fishes in terms of shelter, social grouping, overhead cover and lighting. Each species should be housed at a density that optimizes the well-being of the fish while meeting experimental parameters … However … In some cases the ideal environment will have to be developed using performance-based criteria such as growth rate".

The subcommittee also tried to give some overall guidance concerning assessment of the welfare state of fish. A table of possible signs that can be used is included, with the categories of physical appearance, measurable clinical signs, unprovoked behaviour, and provoked behaviour.

International harmonization

At the same time as the *CCAC guidelines on: the care and use of fish in research teaching and testing*[3] was under development, other guidance for the use of fish for research purposes was being developed in other countries. The US American Fisheries Society was developing the *Guidelines for the use of fishes in research*[16] and the Council of Europe was revising *Appendix A to the European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes*[17], including species specific provisions for fishes. The approach of the US guidelines focused on minimizing stress for fish in research, based on the review by Rose[12], asserting that fish do not have the neuroanatomical structures necessary to experience pain; whereas the Council of Europe, based on the intention that the European Convention "applies to any animal used or intended for use in any experimental or other scientific procedure where that procedure may cause pain, suffering, distress or "…lasting harm [and where] '*animal*', unless…" otherwise qualified, means any live non-human vertebrate, including free-living and/or reproducing larval forms, but excluding other foetal or embryonic forms", decided that *ipso facto* fish have the capacity to experience pain. These two approaches and the manner in which the CCAC reconciled its own position, given the diverging opinions in different countries, has been discussed by Gauthier and Griffin[18]. Suffice it to say, that it is important to establish international harmonization of standards, as Canadian research needs to be able to compete in the increasingly global market.

"General acceptance by the public of the current killing methods used in harvesting wild fishes or in recreational angling … the public appears to be willing to accept these killing methods for food production but not when fishes are used for research."

The Norwegians have a strong research interest in fish welfare, given the role aquaculture plays in the Norwegian economy. The Norwegian Consensus Platform for Replacement, Reduction and Refinement of animal experiments was quick to pick up the *CCAC guidelines on: the care and use of fish in research, teaching and testing*[3], and hosted two meetings to consider harmonization of research practices. Good practices in fish research and reports from the meetings can be found at: http://oslovet.veths.no/dokument.aspx?dokument=153.

Research standards versus production standards

In developing the guidelines document, the CCAC subcommittee on fish also recognized that the public has very different standards. "General acceptance by the public of the current killing methods used in harvesting wild fishes or in recreational angling … the public appears to be willing to accept these killing methods for food production but not when fishes are used for research."[3]. In addition, for research, teaching, and testing use of any animal, including fish, more emphasis is likely to be placed on individual well-being than is generally accepted for the commercial harvesting or production of animals for food. This can be seen as recognition that when animals are placed in an artificial environment to serve human ends, there is an additional burden of responsibility to care for their well-being.

In 2009, the CCAC published the *CCAC guidelines on: the care and use of farm animals in research, teaching and testing*[2]. During the process of developing this guidelines document, similar issues were discussed as with the fish guidelines. In particular, institutions using farm animals in research and teaching were concerned about the guidelines setting standards of a higher level than might be found in a typical farm setting, such as for standard husbandry practices of dehorning and castration. The CCAC subcommittee on farm animals decided that research and teaching institutions had opportunities to explore and implement good practices, and that students should graduate fully aware of current good practices. In addition, the subcommittee wanted to be assured that studies would be carried out in facilities and according to procedures recognized as good practices, emphasizing that good animal welfare and good science go hand in hand. Nonetheless, in cases where research must be directly aligned with current industry practices, the guidelines also permit a lesser standard of practice, provided there is adequate justification.

Interestingly, soon after the C*CAC guidelines on: the care and use of farm animals in research, teaching and testing*[2] was published, the newly formed National Farmed Animal Care Council put in place a revised Code development process that was not dissimilar to the CCAC guidelines development process. As with the CCAC guidelines development process, where review of the literature and consideration of other guidelines documents already available is a key first step, the Dairy Code development process had clearly considered statements made in the *CCAC guidelines on: the care and use of farm animals in research, teaching and testing*[2]. For example, for calves, the CCAC guidelines document states: "Bedding must be added or replaced regularly in order to keep the calves clean and dry. Calves should not lie on bare wooden or concrete floors", and the Dairy Code of Practice states: "Calves must have a bed that provides comfort, insulation, warmth, dryness and traction. Bare concrete is not acceptable as a resting surface". While this recommendation might not be considered particularly contentious, some recommendations made in the Code concerning standard husbandry practices were far more progressive in supporting good animal welfare, particularly in light of the criticism that the CCAC had received for having strong guidelines for the use of pain control. For calves undergoing disbudding procedures, the CCAC guidelines document states: "Disbudding and dehorning are painful and stressful procedures, and effective pain control methods must be used", and the Dairy Code of Practice states "Pain control must be used when dehorning or disbudding".

"As the public becomes more aware of the aquaculture industry there is likely to be increasing attention paid to the welfare of fish being raised for food."

Conclusion

As the public becomes more aware of the aquaculture industry there is likely to be increasing attention paid to the welfare of fish being raised for food. Public attitudes to the use of animals in research have focused attention on ensuring that pain and distress is minimized, that standards are in place and that compliance with those standards is assessed regularly. While the public likely expects a higher standard of care for animals used for research purposes than for animals raised for food, the *CCAC guidelines on: the care and use of fish in research, teaching and testing* [3] offer a good starting point for the development of industry standards.

Author

Gilly Griffin, Guidelines and Three Rs Programs Director, Canadian Council on Animal Care (1510-130 Albert St., Ottawa, ON K1P 5G4; ggriffin@ccac.ca)

References

1. Griffin G. Science and governance issues in aquaculture animal welfare. In: Culver K, Castle D, editors. Aquaculture, Innovation and Social Transformation New York, NY: Springer; 2008. p. 35-49.
2. Canadian Council on Animal Care – CCAC. CCAC guidelines on: the care and use of farm animals in research, teaching and testing. Ottawa ON: CCAC; 2009. p. 135.
3. Canadian Council on Animal Care – CCAC. CCAC guidelines on: the care and use of fish in research, teaching and testing. Ottawa ON: CCAC; 2005. p. 87.
4. United States. United States Code Title 7 Agriculture - Chapter 54 - Transportation, Sale, and Handling of Certain Animals. Washington DC: Office of the Law Revision Counsel of the United States House of Representatives; 1966.
5. United Kingdom. The Cruelty to Animals Act. 39 & 40 Vict, Public Acts, c 77: Parliament of the United Kingdom; 1876.
6. Canadian Council on Animal Care - CCAC. CCAC policy statement on: ethics of animal investigation. Ottawa ON: CCAC; 1989.
7. Russell WMS, Burch RL. The Principles of Humane Experimental Technique. London UK: Special edition published by Universities Federation for Animal Welfare - UFAW, 1992; 1959.
8. Nuffield Council on Bioethics. The Ethics of Research Involving Animals. London: Nuffield Council on Bioethics,; 2005.
9. Ormandy EH, Schuppli CA, Weary DM. Factors affecting people's acceptance of the use of zebrafish and mice in research. Alternatives to Laboratory Animals. in press.
10. Fraser D. Understanding Animal Welfare: The Science in its Cultural Context. Vancouver: Wiley-Blackwell; 2008.
11. Fisheries Society of the British Isles - FSBI. Fish Welfare Briefing Paper 2. Sawston, Cambridge; 2002.
12. Rose JD. The neurobehavioral nature of fishes and the question of awareness and pain. Reviews in Fisheries Science. 2002; **10**(1): 1-38.
13. Braithwaite VA, Huntingford FA. Fish and welfare: do fish have the capacity for pain perception and suffering? Animal Welfare. 2004; **13**: S87-S92.
14. Newby NC. Investigation of the pharmacokinetics and effects of morphine in fish [MSc]. Guelph ON: University of Guelph; 2006.

15. Newby NC, Mendonça PC, Gamperl K, Stevens ED. Pharmacokinetics of morphine in fish: Winter flounder(*Pseudopleuronectes americanus*) and seawater-acclimated rainbow trout (*Oncorhynchus mykiss*). Comparative Biochemistry and Physiology, Part C. 2006; **143**: 275-83.
16. American Fisheries Society - AFS. Guidelines for the Use of Fishes in Research. Bethesda MD: AFS; 2004.
17. Council of Europe. Appendix A of the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (ETS No. 123) Guidelines for Accomodation and Care of Animals (Article 5 of the Convention); 2006 2006/09/15/.
18. Gauthier C, Griffin G. Using animals in research, testing and teaching. Revue scientifique et technique Office international des epizooties. 2005; **24**(2): 735-45.

Victoria Braithwaite

What do we mean by fish welfare and what can we do to promote it?

V. Braithwaite and F. Huntingford

Over the last decade there has been a change in the perception and concern for welfare in fish, particularly with regard to the fish that we rear in aquaculture[1]. Much of the discussion is now focused around the ways we can implement good welfare strategies and what kinds of factors we should monitor to achieve this[2,3]. In this review, we consider what we mean by welfare for animals in general and then consider how this might relate to fish. One of the primary goals of animal welfare is to minimize the suffering associated with the way we rear and handle farmed animals. So in a discussion of fish welfare we need to consider whether suffering is a meaningful concept for fish. To explore this, we use some recent examples of complex cognition in order to highlight the kinds of decisions that some fish are capable of and then discuss what this may reveal about their emotions and awareness. Finally, we turn to how we can assess factors that influence fish welfare and how these can be used to inform us about the welfare state of the fish we rear on farms.

"One of the primary goals of animal welfare is to minimize the suffering associated with the way we rear and handle farmed animals. So in a discussion of fish welfare we need to consider whether suffering is a meaningful concept for fish."

What does welfare refer to?

Animal welfare can be defined a number of different ways, but perhaps the most widely used definition is the one created by the Farm Animal Welfare Council[4]. This was devised to provide a framework of welfare for terrestrial farm animals and is often referred to as 'The Five Freedoms'. For good animal welfare, the list proposes that animals should have:

1. Freedom from hunger and thirst - by ready access to fresh water and a diet to maintain full health and vigor.
2. Freedom from discomfort - by providing an appropriate environment including shelter and a comfortable resting area.
3. Freedom from pain, injury or disease - by prevention or rapid diagnosis and treatment.
4. Freedom to express normal behaviour - by providing sufficient space, proper facilities and company of the animal's own kind.
5. Freedom from fear and distress - by ensuring conditions and treatment which avoid mental suffering.

Broadly speaking the list can be divided into three categories of welfare. The first considers how an animal functions; its hunger level or its health for example. Others relate to the animal's ability to lead a natural life; the capacity to express normal behaviour. And finally, consideration is given to the animal's feelings, such as avoiding pain and distress. These categories are rather different in the way that they approach welfare. Function-based approaches consider whether an animal can adapt to its environment; is it in good health, with all its biological systems working? Nature-based approaches are more concerned with whether the animal can meet its behavioural needs. The feelings-based approach, on the other hand, considers whether the animal is free from negative experiences (e.g., pain, fear or hunger) or, alternatively, does it have access to positive experiences (e.g., social companionship).

Different groups of people prefer different approaches. For example, scientists and practitioners tend to be more comfortable with the function-based approach as this relates to factors that are often measured within the farming context. We take samples to measure the health status of the animals we rear, or we can observe the animals and see if they are walking or, more relevant for aquaculture, swimming normally. The public, however, typically prefer feelings-based and to some extent nature-based approaches to welfare. This is because the public tend to be more concerned with whether the animal is content and not in a state of distress. Such concepts are much harder to work with for two reasons. Firstly they are difficult to measure, but secondly from the perspective of fish farming (Fig. 1), we need to ask how relevant are they for fish?

"The public, however, typically prefer feelings-based and to some extent nature-based approaches to welfare. This is because the public tend to be more concerned with whether the animal is content and not in a state of distress."

Figure 1. A Norwegian salmon farm.

Can the term 'welfare' be applied to fish?

Is it possible to determine whether fish have the capacity to suffer from, or conversely, to enjoy experiences? A number of researchers have tried to address this from opposite directions. Taking a top-down approach, some have explored whether fish have the neural systems that are involved with feelings and emotions in mammals. Others have taken a bottom-up approach and use the behaviours of fish to demonstrate complex cognitive abilities that can only work if the fish has some form of awareness about its situation.

Taking the bottom-up approach first, are there examples of complex behaviour that indicate some level of awareness in fish? In fact there are several that could be given, but for the purposes of this article we will highlight some recent work that relates to the behaviour and the decisions made by cleaner wrasse. Cleaner fish provide an important service for many different fish species, by removing small ectoparasites that have attached themselves to the skin and gills of a host fish. Some species of cleaner fish will establish cleaning stations these are specific places where client fish can come to have their parasites removed. The service is so sought after that at times client fish will wait in line for their turn to be cleaned. This sets up a rather interesting situation where client fish can watch cleaners interact with other clients and so they can gauge how well the cleaners perform. Why should performance matter? Well it turns out that cleaner fish are not always honest – they are not just after the ectoparasites. In fact, cleaner fish much prefer to feed on the protein-rich mucous on the skin of the client fish because this is more nutritious than ectoparasites. So in between nipping off the ectoparasites, the cleaner fish sometimes take a bite of the client's flesh and get a meal of mucous that way. It is quite obvious when this happens because the client fish visibly jolt when the cleaners bite them [5].

To determine whether client fish can discriminate among cleaner fish based on their propensity to cheat, Pinto and colleagues[6] set up an experiment where observer client fish could watch different cleaners interacting with their clients, but the observing fish were behind one-way mirrors and so were not visible to the interacting cleaners and clients. The researchers scored how many jolts different cleaner fish caused and then looked to see if this affected where the observer client fish spent their time. And yes, it did: observing client fish were much less likely to associate with cleaners that had caused more jolting.

"Do these experiments tell us that fish have the capacity for emotions and feelings? No they do not – at least not directly. But this is largely because understanding what it is like to be another animal is a really hard thing to do."

In a clever extension of this study, Pinto and colleagues[6] went on to see whether cleaner fish will cheat less often if there is an audience. For this experiment they now ran two kinds of trial, ones where a cleaner and client could see that they were being watched, and ones where there was no bystander observing. Interestingly, the cleaner fish did alter their biting rate – their clients showed less jolting when the cleaner was aware that it was being watched.

Together, these two experiments suggest that both cleaner and client fish are capable of making complex, situation-dependent decisions. Client fish observe the cleaner fish perform and this allows the clients to make informed decisions about which cleaner they will select. Similarly, cleaner fish modulate their decision to cheat based on whether potential clients are watching them. All in all, quite a sophisticated set of relations.

Do these experiments tell us that fish have the capacity for emotions and feelings? No they do not – at least not directly. But this is largely because understanding what it is like to be another animal is a really hard thing to do. Even in humans this is a difficult thing to achieve. For example, one cannot truly know what it is like for another person to experience the sensation of pain. In the case of humans, we have the capacity to share our experiences through language, and while we cannot feel the sensations that another is experiencing directly, we can empathize through verbally discussing it. But this problem takes on a whole new dimension when we try to understand the feelings experienced by animals – with no shared language how can we ever know what they are aware of? Some philosophers and scientists suggest that it is something we just cannot understand with our current level of knowledge of the how the brain works[7,8]. However, returning to the cleaner fish and their clients – what the experiments do reveal is that the fish have some level of awareness that influences their decisions, and perhaps this awareness suggests that fish may be aware of other kinds of information such as their affective, or emotional state.

Let's turn now to looking at the capacity for fish to suffer from a top-down approach. Here we can start to explore specialisations in the fish brain and look at what kinds of system these support. Fish have a brain that follows the same pattern as other vertebrates. They have a forebrain, midbrain and hindbrain. These different areas control different functions. The hindbrain, for example, is involved with several motor actions and some forms of simple learning such as stimulus-response learning where a particular signal is learned to predict a specific outcome, rather like Pavolv's dogs learning that a bell predicts the arrival of food.

Of more relevance to the issue of whether fish are aware of their emotional state are the roles played by areas within the forebrain. The forebrain consists of a number of discrete regions that are involved in processing and integrating different kinds of information. We know this because of experiments that use surgical lesions to very precisely damage areas of the brain. After the fish recover from the surgery, tests can determine what kinds of information the fish can or can no longer process. Using this technique, two critical areas have been distinguished: one that processes the sequence in which events occur (this more complex learning and memory is the sort that the client and cleaner fish will be using) and another that is associated with learning to avoid negative experiences. These structures are considered to be functionally similar to the mammalian hippocampus and amygdala, respectively. The presence of these two areas has been used to infer capacities for fear and suffering in fish because these structures help to support these processes in mammals.

"Good welfare measures are ones that can readily and reliably be made within the commercial setting."

Such arguments by analogy have been criticized in terms of their use as evidence for fish suffering because they only provide an indirect measure. However, if we take the top-down and bottom-up evidence together, a more compelling picture emerges of an animal that has a brain with specialized capacities that support adaptive, complex decision making. While still not explicit evidence of a capacity for suffering *per se*, it does indicate that at least some fish species are cognitively competent and so perhaps do warrant the benefit of the doubt when it comes to considering their welfare needs.

How can we measure welfare in fish held in culture systems?

Assessing the welfare of terrestrial farm animals involves direct observations or measurements, which is obviously harder to do for fish [9]. So how can we quantify the welfare of the fish that we farm? The methods currently adopted typically fall into three categories: assessments that focus on (i) physical condition, health and growth, (ii) physiological status, and (iii) behavioural status [10].

Good welfare measures are ones that can readily and reliably be made within the commercial setting. One measure of physical condition that has recently been shown to be a useful indicator of welfare status assesses the quality of different fins [11]. Fin erosion can have a significant impact on fish quality and work showing that fins are innervated with pain receptors[12] suggests that damaged fins are likely to generate pain responses. Furthermore, damage to the quality and size of the fin area could have a negative impact on fish welfare given the important role played by the fins in keeping the fish in the right posture and helping the fish to move. Using an index based on various images and descriptions, fish can be assessed quickly to assign a fin damage score[13] .

Similarly, good health can be promoted by determining when and how different kinds of injury occur. Having identified the risk factors that contribute to injury occurrence, steps can be taken to prevent or minimize these kinds of injury from arising. Noble et al.[14] discuss this approach for injuries to the eyes, skin and fins of farmed fish. Injuries that arise through abrasions during handling can be reduced by decreasing the number of direct interactions with fish. For example, fish that are being graded can be pumped into different cages rather than being netted and moved manually, knowing that vacuum pumps generate fewer injuries than turbine pumps. Fish grading can also be achieved passively by getting fish to swim through mesh netting set to different sizes. In general, knotless nets also lead to fewer overall skin injuries. So, several changes to current practices can provide effective ways of reducing the risk of different kinds of injury.

"Behavioural indicators of fish welfare are also being developed for commercial farm settings."

Similarly, we can use physiological measures to gain an understanding of the current state of the fish. For example, oxygen probes can measure the rate of oxygen consumption of fish maintained in tanks. Rapid changes to the level of oxygen consumed can provide an early indication of stress. A recent experiment by Folkedal and colleagues[15] used this measure to look at the response of juvenile Atlantic salmon parr to a sudden change from a constant light schedule to a 12-hour light,12-hour dark schedule. What the authors found was that oxygen consumption rate increased rapidly and remained high for several days after the change in schedule.

Direct measures of the stress hormone cortisol can also reveal the stress status of fish. Because fish excrete cortisol across their gills, the general production of cortisol by groups of fish can be measured non-invasively and so water-borne assays of cortisol provide a measure of stress state [16]. Even though this assay is non-invasive, the levels of cortisol still need to be measured in a lab, so the assay is not as direct as a behavioural observation. A recent paper, however, has suggested that colouring and pigmentation patterns on the skin of both rainbow trout and Atlantic salmon correlate with stress responsivity. Typically fish with more black pigmented spots are less stress responsive than non-spotted fish. Thus colouration patterns may provide a simple, effective way of assessing farmed fish stress physiology phenotype without needing a specific measure of cortisol[17].

Behavioural indicators of fish welfare are also being developed for commercial farm settings. Underwater cameras can be used to look for altered swimming patterns[18]. Although not widely used, looking for patterns of stereotypical swim paths could be informative about the general welfare state of the fish. Stereotypies, which are repeated patterns of behaviour with no obvious value, have been used to indicate poor welfare status for zoo and other terrestrial animals, but they have not been widely used on fish farms yet. An earlier study with African catfish, however, does suggest that this could be a useful early indicator of poor welfare in farmed fish[19]. Another simple, yet effective, behavioural assay relates to feed intake rate. One of the early signs of stress in fish is a reduction in appetite, and thus a drop in feed consumption can be used to signal early stages of stress[3]. The use of self-operated (demand) feeders (Fig. 2) can readily show changes in feed intake rate as the rate of feeder triggering goes down when the fish feed less.

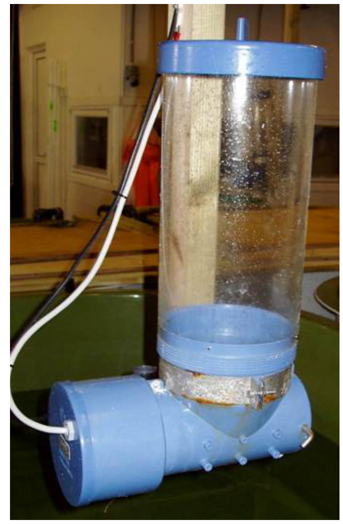


Figure 2. A self-feeder used to train hatchery fish to operate a wire pulley to deliver small quantities of food after each successful pull.

Thus there are a range of indicators that provide measures for farmed fish welfare status. Although the three different approaches were discussed separately above, on-farm measures could combine these different approaches to gain a broader overview of the welfare status of fish.

Conclusion

While the field of fish welfare is at a relatively early stage, there are several aspects of terrestrial farm animal welfare that can be borrowed and adapted to help create good and appropriate welfare guidelines for fish. A number of welfare related measures are already available for fish, particularly those held in captivity. Some of these are more readily applied than others, but our current state of understanding would just seem to be a starting point. Current interest and focus on fish welfare suggests that new welfare indicators will continue to be discovered. In many cases the people most likely to recognize these are the people who work most closely with the fish and therefore quickly recognize subtle changes in behaviour.

Authors

Victoria Braithwaite is a Professor of Fisheries and Biology at Pennsylvania State University. Felicity Huntingford is an Emeritus Professor of Functional Ecology at the University of Glasgow.

References

1. Huntingford FA, Adams C, Braithwaite VA, Kadri S, Pottinger TG, Sandoe P, Turnbull JF. 2006. Current issues in fish welfare. *J Fish Biol* 68:332–372.
2. Braithwaite, VA. 2010. *Do Fish Feel Pain?* Oxford: Oxford University Press.

3. Martins, C. I. M., Galhardo, L., Noble, C., Damsgård, B., Spedicato, M. T., Zupa, W., Beauchaud, M., Kulczykowska, E., Massabuau, J-C., Carter, T., Planellas, S. R. and Kristiansen, T. (2012) Behavioural indicators of welfare in farmed fish. *Fish Physiol Biochem* 38:17–41.
4. Fraser D. 2008 *Understanding Animal Welfare: The Science in its Cultural Context.* UFAW Animal Welfare Series. Wiley Blackwell.
5. Bshary R & Côte´ IM. 2008. New perspectives on marine cleaning mutualism. In: Fish Behaviour (Magnhagen ., Braithwaite VA, Forsgren E, Kapoor BG., eds). Science Publishers, Enfield, pp. 563—592.
6. Pinto A, Oates J, Grutter AS, Bshary R. 2011. Cleaner wrasses Labroides dimidiatus are more cooperative in the presence of an audience. *Curr. Biol.* 21: 1140-1144.
7. Nagel T. 1974 What is it like to be a bat? *Philos. Rev.* 83:435-450.
8. Dawkins MS. 2012. *Why animals matter: Animal consciousness, animal welfare, and human well-being*. Oxford: Oxford University Press.
9. Weary DM, Niel L, Flower FC, Fraser D. 2006. Identifying and presenting pain in animals. *Appl. Anim. Behav. Sci.* 100: 64-76.
10. Dawkins MS. 2006. A user's guide to animal welfare science. *Tr. Ecol. Evol.* 21:77-82.
11. Noble C, Mizusawa K, Suzuki K, Tabata M. 2007 The effect of differing self-feeding regimes on the growth, behaviour and fin damage of rainbow trout held in groups. *Aquaculture* 264:214–222.
12. Roques JAC, Abbink WA, Geurds FB, van de Vis HA, Flik G. 2010. Tailfin clipping, a painful procedure: Studies on Nile tilapia and common carp. *Physiol Behav* 101:533–540.
13. Hoyle I, Oidtmann B, Ellis T, Turnbull J, North B, Nikolaidis J, Knowles TG. 2007. A validated macroscopic key to assess fin damage in farmed rainbow trout (*Oncorhynchus mykiss*). *Aquaculture.* 270:142–148.
14. Noble C, Cañon Jones, H.A, Damsgård B, Flood MJ, Kjell Ø, Midling KØ, Roque A, Sæther BS, Yue Cottee S. 2012 Behavioural indicators of welfare in farmed fish. *Fish Physiol Biochem* 38:17–41.
15. Folkedal O, Torgersen T, Nilsson J. Oppedal F. 2010, Habituation rate and capacity of Atlantic salmon (*Salmo salar*) parr to sudden transitions from darkness to light *Aquaculture* 307: 170-172.
16. Ellis T, James JD, Sundh H, Fridell F, Sundell K, Scott AP. 2007. Non-invasive measurement of cortisol and melatonin in tanks stocked with seawater Atlantic salmon. *Aquaculture.* 272: 698–706
17. Kittilsen S, Schjolden J, Beitnes-Johansen I, Shaw JC, Pottinger TG, Sørensen, C, Braastad, BO, Bakken, M, Øverli Ø. 2009 Melanin-based skin spots reflect stress responsiveness in salmonid fish. *Horm. Behav.* 56: 292–298.
18. Stien LH, Bratland S, Austevoll I, Oppedal F, Kristiansen TS. 2007. A video analysis procedure for assessing vertical fish distribution in aquaculture tanks. *Aquacult. Eng.* 37:115–24.
19. Almazán-Rueda P, Schrama J W, Verreth, JA J. 2004. Behavioural responses under different feeding methods and light regimes of the African catfish (*Clarias gariepinus*) juveniles. *Aquaculture* 231: 347–359.

Fish Welfare in Closed Containment Systems

R.D. Moccia

Richard Moccia

The welfare status of captive livestock is an important determinant of society's overall acceptance of farming practices, and of agrifood production systems in general. Unlike those animal species used in terrestrial agriculture, there is still a paucity of scientific information concerning the welfare of intensively farmed fish. Fish production in some countries has come under criticism by humane societies and animal welfare and activist groups, as well as by more mainstream sectors. Closed-containment technologies have been touted as a solution to many contemporary issues facing the aquaculture industry including the prevention of escapement and better control over water use and wastewater/nutrient discharge. But, do these technologies present any issues relevant to the welfare of fish raised within them? This paper will examine this question from a variety of perspectives including: high density rearing, health management protocols, risk management, maximized feeding strategies to produce very rapid growth, harvest techniques and genetic manipulation, to name a few. The unique attributes of these practices in closed containment systems may impact fish welfare in both positive and negative ways. Insight into these issues will be provided by examining the latest scientific developments that may help to better define those acceptable captive conditions in which farmed fish live. This paper attempts to address the practical and scientific overlays between fish welfare, systems design and production technology, and to look at these issues from an economic, social and ethical issues in raising fish using closed containment technologies.

One of the challenges, of course, is that we all have different definitions of both fish welfare and closed containment. As outlined in other papers within these proceedings, we talk about different things when we describe 'fish welfare'. There is a need to recognize both the breadth of the definitions and applied use of the term fish welfare. My goal is to try to give some sense of those extremes in definitions, some sense of the evolution of the thinking around fish welfare and the related ethical issues, and perhaps even some sense of where we might be going in comparison to the evolving terrestrial industries that are perhaps a few years ahead of us.

"One of the challenges, of course, is that we all have different definitions of both fish welfare and closed containment... my goal is to try to give some sense of those extremes in definitions, some sense of the evolution of the thinking around fish welfare and the related ethical issues..."

If you think it's not important I'll tell you a tiny little story. I've been the official spokesman for the University of Guelph for the last three years on our Enivropig project. The University of Guelph actually trademarked and licensed a genetically modified pig. It has a promoter gene from a mouse and a bacterial gene that together produce phenotypic expression of phytase enzyme production in the salivary glands of the pig, which normally does not occur. When these pigs eat diets with previously non-digestible forms of phosphorus, they are able to utilize this nutrient and produce 60% less phosphorus in their manure and urinary waste. So, it's an environmentally friendly pig if you will! It seemed like a good solution to reduce phosphorus production from terrestrial hog farming by 50 to 60%. But over the last three years the greatest engagement in discussion with the public at large, students and the academic community has been around the ethical and welfare issues of genetic modification in a pig developed putatively to solve an environmental problem. So the accomplishment of developing a new production technology was trumped by societal and market issues surrounding the welfare aspects of the technology.

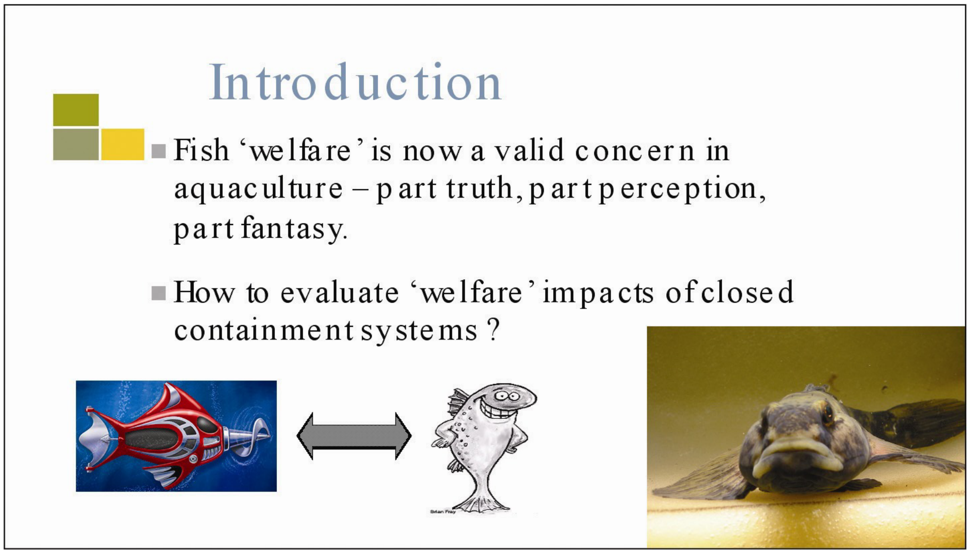


Figure 1. Fish welfare as fact or fantasy?

It is important to debate the principles of fish welfare and regard the fact that it is now a valid discussion point related to aquaculture. It's part truth, it's part public perception and part of it is fantasy as well. And it's really important to distinguish between what's fact, what's known in the scientific and other credible literature, and what's pure fantasy in terms of how we're dealing with fish welfare in captive populations. The other challenge is to try to put this discussion into the context of how we would evaluate various forms of production technologies and various systems from an actual fish welfare perspective, particularly closed containment technologies. And that was the challenge of this presentation. So, I want to take a quick look at trying to recapture some of the concepts presented in earlier papers in these proceedings, and give you the extremes of thinking about these issues because my goal was to try to present extremes of thinking and open up everybody's thinking to this particular issue.

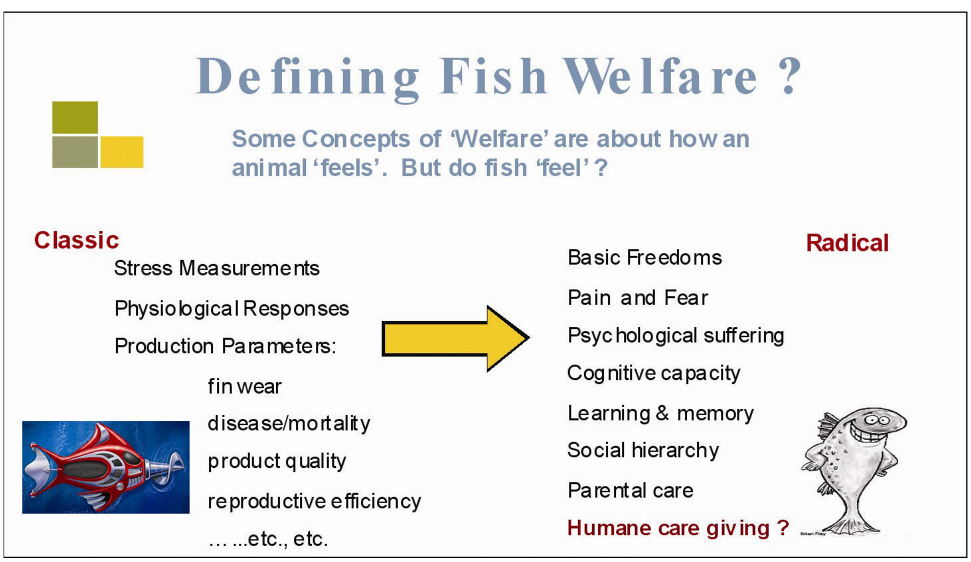


Figure 2. Extremes in definitions of fish welfare

Figure 2 represents extremes in thinking about fish welfare. The classic view (on the left hand side) is that fish welfare over the last thirty years has been primarily about stress management, so it's been about measuring physiological response, cortisol levels for example. When we started farming fish around the world, fish welfare was used by stockmen years and years ago, and it related primarily to production parameters and production performance only. Everything from as simple as a little bit of fin wear, to disease outbreaks, mortality issues, management of product quality at the farm and at the consumer's table, things like reproductive efficiency and everything else, were considered to be measures, either direct or surrogate, of fish welfare in captive populations. That's been the classic application of the definition of fish welfare, and most of us around the aquaculture industry would say, "yes, that's what I think of as fish welfare".

On the right hand side of the figure is the evolving (and some refer to it as kind of the radical) thinking about fish welfare. But it's not so radical depending on where you are and who you're talking to. It includes things such as trying to take scope of the basic freedoms of animals: freedom to express normal behaviour, freedom from starvation and thirst, freedom from suffering and pain, those kinds of things. And it also asks a fundamental question about whether fish can feel pain. This topic is covered elsewhere in these proceedings. And can a fish suffer in a true 'psychological' context as humans and other higher vertebrates do? And does a fish possess the advanced cognitive capacity such that we need to consider whether it has an inherent right or not to be cared for from a humane perspective? So humane caregiving really is not just about production capacity, but it might also be about management of the various possibilities for psychological and other forms of suffering in advanced vertebrate animals.

"None of you would likely deny that dogs have emotions and feel fear and pain and suffering, are happy and are sad, but it is a tough question to answer where fish are in that evolving spectrum from simple to complex organism"

Now, we don't deny that humans can psychologically suffer, and that we have emotions and we feel fear and pain and everything else. Somewhere between a plasmid and on up to the other end of the spectrum of humans is the evolution of those capacities in other animals. None of you would likely deny that dogs have emotions and feel fear and pain and suffering, are happy and are sad, but it is a tough question to answer where fish are in that evolving spectrum from simple to complex organisms. And of course a fish is not just a fish either, because a fish can be everything from the most primitive sharks and rays and hagfishes, up to the most advanced cichlids and species that show parental care, long-term care of young, complex mating behaviours and many other forms of behaviours which we would typically associate with an animal that has a significant level of cognitive capacity. A wide range of evolutionary development occurs within those thirty to forty thousand species ranges of fishes still living on the planet. So I liked Dr. Braithwaite's comment that as we look to develop aquaculture on many new species, we maybe need to develop a different set of thinking paradigms about different species of fish.

The other problem, of course, is this closed containment issue. So what is it? I also wanted to zone in on these production technologies and try to go from the most open system (Fig. 3), which would be the equivalent of sea ranching where there's really not much human intervention into the actual growth or care of the fish, to the other end of the extreme which is really the goldfish bowl where you have virtually 100% control and total containment capacity. We're getting to the point now in recirculation systems where we're up to 99.8% recirculation and high efficiency with production practices that will influence fish welfare in the captive populations. And so, I will examine the technology as it relates to welfare issues and how the technology might actually drive changes in thinking about welfare.

Figure 3. Open vs. closed containment

The other political back story of course to all this, is that there already is a movement to look at land-based fully closed containment as being better for the welfare of the fish. And this is also being used as a strategy to attempt to move cage aquaculture onto land in closed containment. And so the reasonable question to be asked is: Is the welfare of fish in closed containment any better, worse or the same as it is in open water cages? Then maybe it is or it isn't a factor in driving those decisions.

Accordingly, I wish to examine some of the major welfare issues that impact fish in captivity and therefore influence the caregiver's role in managing them. Water and environmental quality obviously represent significant differences between open-water culture and highly closed containment (Fig. 4), particularly in the management of basic water quality parameters – ammonia nitrogen, nitrate, nitrite, carbon dioxide – things which are almost never problematic in open-water culture systems yet may be significant issues in closed containment.

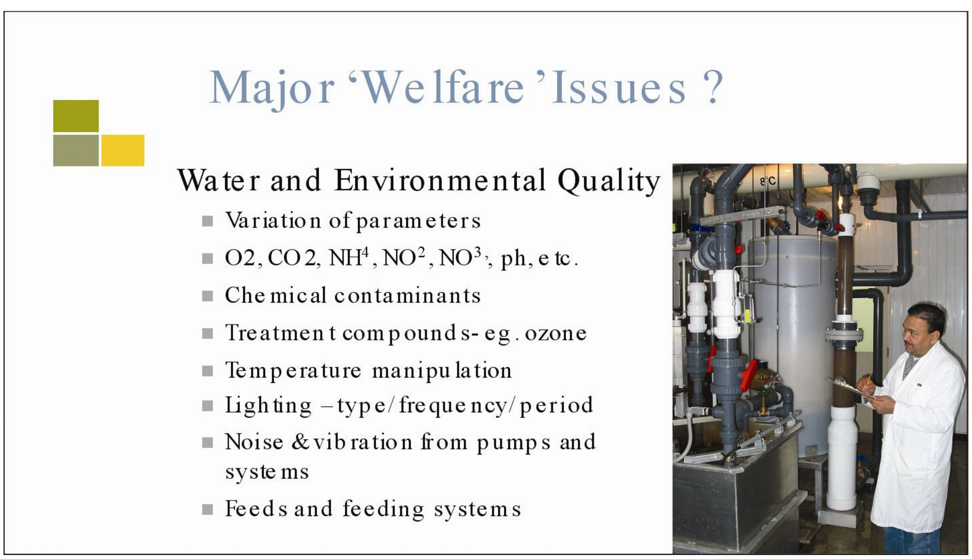


Figure 4. Issues in closed containment: water and environmental quality

Most closed-containment technologies also only manage and mitigate nitrogenous and other forms of waste. They don't deal with other forms of xenobiotics, pheromones, small metabolite substances that might end up in the water, and the unknown influencing factors of those things on large populations of fish. Chemical contaminants and treatment compounds, of course, in closed containment are very different than they are in open-water culture. We have the ability to maintain and manipulate temperature in closed-containment systems that we don't have in open-water culture, and you'll see later that this will present perhaps issues around risk management and mitigation in the event of system failures. One of the big challenges in my opinion with recirculation systems is what happens when something goes wrong, and the welfare concerns of very large populations of animals in captivity are immediately put in jeopardy due to the potential for system crashes and technology failure.

Something as simple as lighting: types and frequency and photoperiod of lighting systems are very important in closed containment and you don't see the equivalent of that really in open-water systems. We know that many fish have the visual acuity to see the vibrational frequency of some of the low frequency fluorescent lighting, and this can cause behavioural perturbations in fish. We are lucky now in having high-frequency electronic ballasts that go up to ten or twenty thousand flickers per second, so you're getting beyond some of those kinds of issues, but something as simple as lighting type and frequency need to be considered from a welfare perspective. We have recirculation systems where we have significant issues with noise and water vibrations from pumping systems and other system control factors inside closed containment, and these are almost unrecognized as an issue from a fish's perspective. But they can be issues for the fish. I always thought it was funny that we ignore vibration, because fish are one of the most delicately and perfectly designed animals to detect vibrations in water. They have lateral lines that are exquisite neurological organs to do just that, and yet we almost disregard completely vibrations from continuous sources like pumps and everything else in closed systems. Feed and feeding systems as well. Significant differences in both our land-based containment versus open water need to be understood.

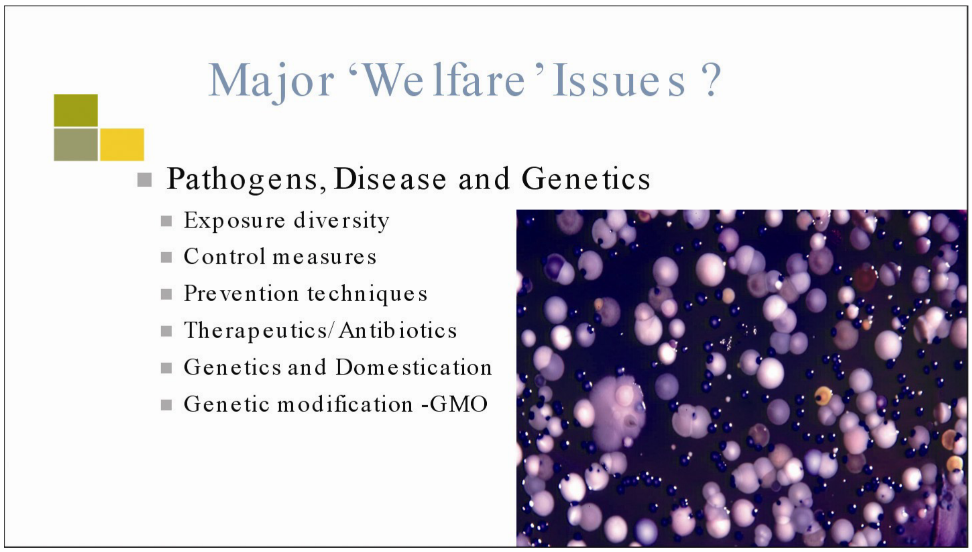
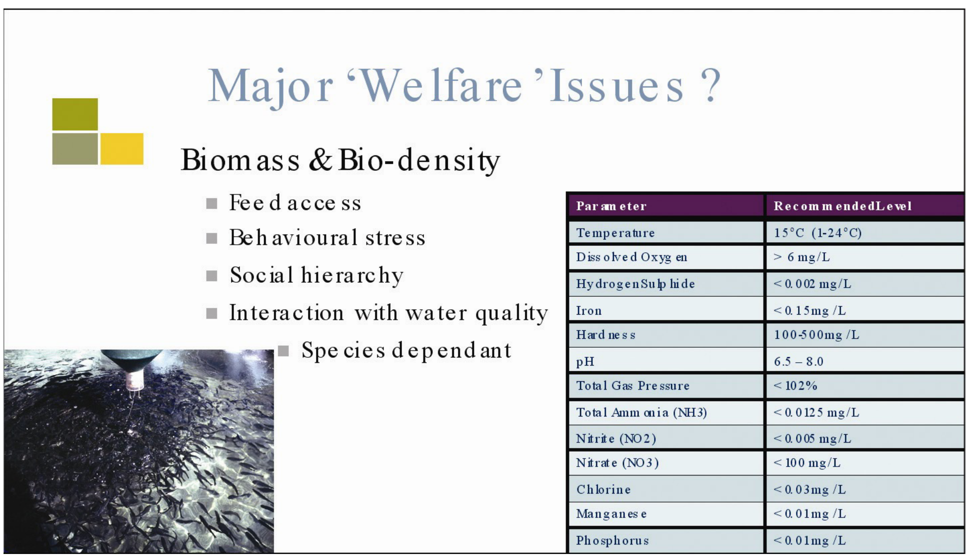


Figure 5. Issues in closed containment: pathogens and disease

Other major welfare considerations that we need to examine are the spectrum of issues around fish pathogens, health management, disease control and genetics (Fig. 5). Clearly land-based technologies have an ability to control pathogens and external parasites much more than open-water systems, but they also bring with them a measure of challenges in maintaining that quality over time. Use of antibiotics and other therapeutants in closed containment is a significant issue, particularly with today's technology of biofiltration and the challenges of very, very high biodensities which are almost necessary to ensure economic efficiency in closed containment.

Genetics and domestication also play a major role in the debate about fish welfare. I would argue that a simple analogy would be trying to keep a wild canine in captivity versus a domesticated dog: they would be not similar at all in terms of their desire to seek freedom, their stress response to captive containment and everything else related to their welfare. One is a direct result of domestication and genetic selection over time, and this actually alters the way an animal behaves to a captive culture environment. That's significant, because when we draw parallels to the terrestrial livestock industries – poultry, hog, dairy and beef – you're using animals which are highly, highly domesticated over time for a captive farming environment. And so there are sometimes analogies that work looking at terrestrial agriculture and other times they don't. Largely we're still working with essentially pretty wild fish because we haven't been farming them that long in Canada. Our genetic selection has only gone over now maybe a couple of dozens of generations, not really a long time in terms of genetic selection and breeding. This will increasingly play a role when looking at welfare issues.



Parameter	Recommended Level
Temperature	15°C (1-24°C)
Dissolved Oxygen	> 6 mg/L
Hydrogen Sulphide	< 0.002 mg/L
Iron	< 0.15mg /L
Hardness	100-500mg /L
pH	6.5 – 8.0
Total Gas Pressure	< 102%
Total Ammonia (NH3)	< 0.0125 mg/L
Nitrite (NO2)	< 0.005 mg/L
Nitrate (NO3)	< 100 mg/L
Chlorine	< 0.03mg /L
Manganese	< 0.01mg /L
Phosphorus	< 0.01mg /L

Figure 6. Issues in closed containment: biodensity

I referred earlier to genetic modification in the pig. As you know we also have that in fish right now, with the production of rapidly growing fish by having promoter genes and growth hormone genes which essentially produce an animal that can grow four to five to six times faster than a non-transgene, and you might look at that and say, well, from a production point of view that might be great if I can grow fish faster to market. But there are social and ethical issues around using genetically modified animals, environmental issues and efficacy of the technology, but one of the other issues that's never really been considered much is whether there is a welfare issue to producing a fish that grows so fast, well beyond the domain of its normal evolutionary growth potential. Again, there are welfare issues that are emerging that require and new directions in our research objectives and general thinking.

I talked about biomass and biodensity issues in closed containment (Fig. 6). One of the challenges of course is that, except for managing broodfish and other very high value fish, production technologies to produce food size fish in closed containment generally require very high biodensities relative to what you would see in a cage operation. And those high biodensities bring a whole spectrum of other kinds of problems and associated issues, and not just with water quality. For example, you have to deal with higher CO_2 production with high biomass, and you have other issues with high biomass in tanks, but they also present other challenges to managing fish culture from the perspective of managing social hierarchy perhaps, considered from a behavioural point of view. Other authors in these proceedings have described stereotypies in low density situations that are obliterated in high density, and that's partly because you essentially can disaggregate social hierarchies and dominance-submissive behaviour when you go to fairly high densities. There's no way for an animal to be dominant where you have very, very high biodensities inside of a tank. And if you've raised fish like Arctic charr, for example, you know that they appear to do very well in quite high biodensities relative to other species in farming. So there are species-specific factors that influence what's acceptable from both a classical welfare definition as well as perhaps the more right-end or 'radical' side. So there's a species dependency for us to discuss here as we move the industry and its production technologies forward.

We also need to consider harvesting, transportation and slaughter as other areas of concern from the management of fish welfare (Fig. 7). One of the great things that I have seen is this transition is the move to using dead-bolt and percussion stunning to kill fish, and to move away from the old CO_2 kill tanks. Percussion stunning is a much more humane form of slaughter compared to CO_2 kill tanks. One of the other advantages to percussion stunning is that it produces a much better quality product that goes to the processing plant and then to the consumer. And the take home message here: there's win-wins a lot of times with using technology to solve problem which can enhance product quality and also can improve welfare.

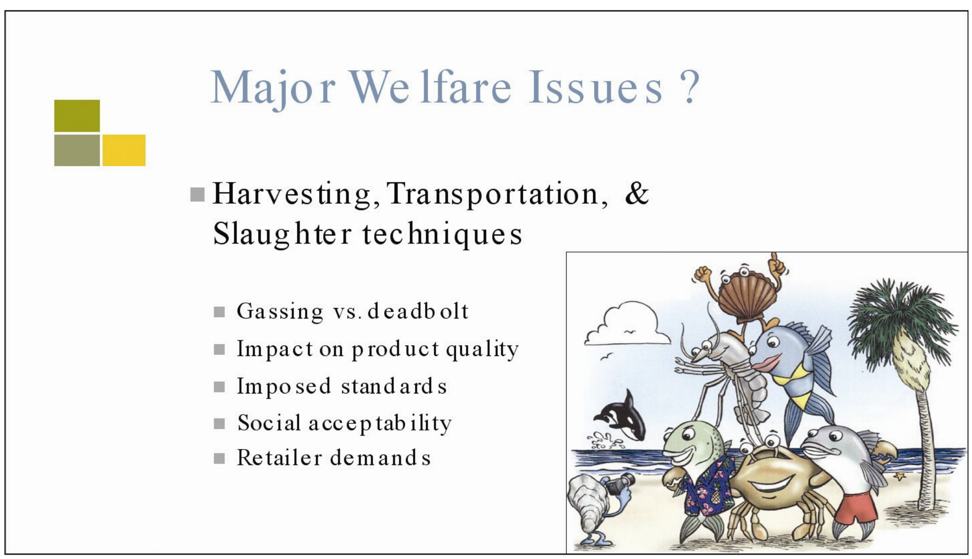


Figure 7. Issues in closed containment: harvesting and grading

There's no question that all farm animals get killed at the end of their life. I was in a huge debate with a group from the United States – you might have seen me in the newspapers because I made every major newspaper in continental North America – because we had nine Enviropigs left at the end of our trial and we had decided to euthanize them. There were several groups in the States that wanted us to adopt them out. You know, they wanted to adopt out a genetically modified pig and put it somewhere where you have no control over it. In the end, which I didn't really think was a good idea from the University's point of view, we did euthanize them, but it actually raised this whole issue about whether it's humane to allow the animal to live to the end of its normal life and all the issues that go along with it or whether it's humane to euthanize it earlier on in its life, and which one is actually better or worse from a humane care point of view. Dr. Hammell spoke about that from an ecosystem management point of view, where we may allow fish to go for extended periods of time in very debilitated states of morbidity and health because we want to manage environmental control by not using chemical compounds which might alleviate pain and suffering in the fish, assuming that they might do that.

Of course we all know that there's an emergence now of thinking around social acceptability and demands from retailers to meet welfare standards in livestock. Companies like McDonalds are driving social and welfare standards in their poultry suppliers. Fish retailers are doing exactly the same thing around the world. And so again, although they might be motivated by satisfying a consumer concern over animal welfare rather than really having a true concern for the farm animal itself, they are actually driving decision making, driving technology and concerns for welfare, perhaps for all the wrong reasons, it doesn't matter, but the challenge is for us to attempt to address it with good solid science and sound decision making about appropriate technologies and production practices (Fig. 8).

Figure 8. Welfare can be a function of rearing system

Well, trying to wrap up a little bit, looking at some of the commonalities in issues between closed containment and open water rearing, trying to make the point that the degree of concern about welfare issues will be influenced by the technology and the production system that's used. Closed containment obviously has a great ability to have a very high level of control over water quality (Fig. 9). It essentially prevents escapement and largely eliminates environmental impact there. We're not sure whether at some point there will be an issue about wild fish and welfare concern for them, that's certainly a problem with transgenics. One of the regulatory hurdles on genetic modified animals is if they escape and they transfer their exotic genes to the native populations, and that alters natural behaviour, feeding systems, responses of a wild animal which has adapted to its environment since the last ice age or whatever, and we need to reconcile if this is a welfare concern from an environmental perspective.

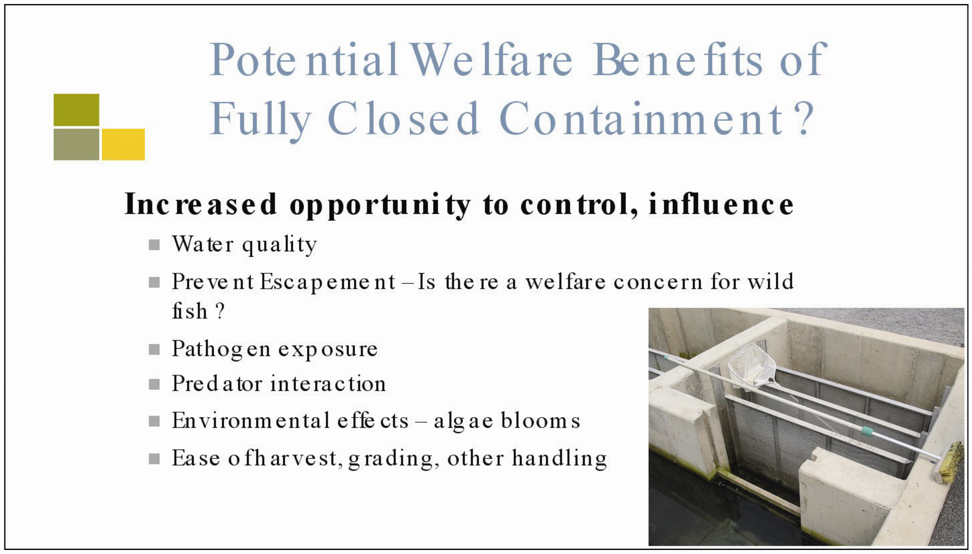


Figure 9. Welfare benefits in closed containment

Control over pathogen exposure is both an asset and a liability in my opinion in closed containment. In most cases we can significantly reduce the exposure of fish to many different pathogens, but at other times, once you do have a pathogen problem in closed containment, it becomes very challenging to deal with effectively and you'll see in a minute one of my big issues with recirculation systems will be with our risk mitigation strategies.

Lastly, the ease of harvesting, grading and other handling may represent welfare issues in closed containment. Earlier speakers showed some great photos of the challenges of trying to harvest, grade and stun fish in an open, cage culture environment. The pictures were nice but when the wind's blowing forty knots and the sleet's falling, it's not for the faint of heart for both the fish and the care handler. One of the other problems of course, in closed containment, is the overlay on cost effectiveness of the technology to make it welfare friendly. I'm not necessarily saying it has to be coping with or managing around the psychological aspects, because I'm not sure those are even valid concerns in most cases, but biodensity is a big limiting factor for production efficiency and economics in this particular technology. And so in order for closed containment systems to be

Figure 10. Welfare challenges in closed containment

economical, you need to have high biodensities, and high biodensities will trigger a number of different kinds of potential welfare issues (Fig. 10). It's an interesting example of how the technology overlay on environmental controls actually then presents questions around welfare, rather than necessarily solves these issues.

Risk of system failure? This is the last point there is to discuss as one of the welfare challenges of closed containment. Risk, of course, is a difficult concept to understand in of itself. It's not just about something going wrong. Risk really is an aggregate of the probability of something going wrong or negative event occurring, coupled with the relative degree of harm of that event (Fig. 11). A nuclear power plant, for example, has incredibly, incredibly low risk of something going wrong, but when it does, it's a catastrophically negative event. So, risk of a power plant failure will be one type of issue. Other situations like nutrient contamination from a farm, which happens a lot, but has a relatively low impact and the 'harm' is usually short lived and transient. So, managing risk from a welfare perspective is also a significant consideration. In highly closed containment systems one of the challenges is managing what to do when something goes wrong. Are there sufficient redundant systems in place in filtration, water back-up systems, emergency power supplies, all the things that are built into the technology now which add to the cost to mitigate welfare issues when something goes wrong? When it's working everything's great, fish welfare is high level, but when something goes wrong you're stuck with this decision: at what point should you actually euthanize all the animals to prevent long-term suffering and morbidity in them because of system problems. So risk mitigation is another issue that needs to be factored in when considering closed containment technologies.

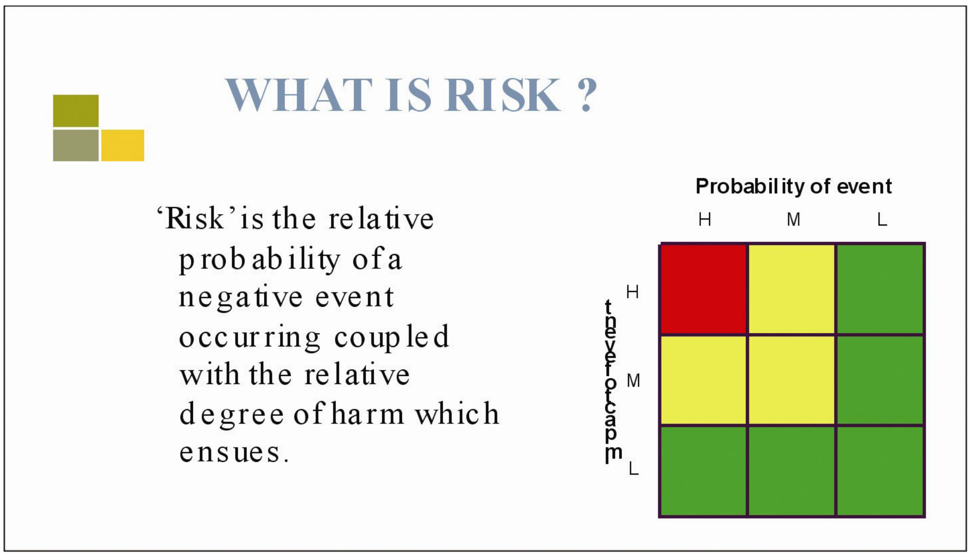


Figure 11. How to define risk?

To wrap up then, the challenges in decision making are tied to determining if closed containment is better for the welfare of the fish compared to open water, cage culture systems. One of our problems, as stated by all presenters at this workshop, is that there really is a lack of quantitative and objective welfare assessment tools to use, and we've been moving in some of the debate to very anthropocentric views and perspectives on decision making, which in my opinion is inappropriate and dangerous. When you look at a fish, when you poke it and it swims away, your naturally tendency might be to think, "oh it felt pain and it's trying to escape", when you may be observing a purely a reflexive response. Maybe good or bad example here, but you get the idea that increasingly we are debating in a much more anthropocentric vein about issues of welfare.

There is little or no appreciation for the notion of 'acceptable' levels of risk or impact, both by people who are proponents as well as opponents of fish welfare, and there is also a lack of weighting criteria for those welfare indices which do exist. For example, is it more important for a fish to have freedom to swim around or to have better water quality, and do fish get bored, and if they do is there environmental enrichment that's necessary – yes or no? I'm not making value statements on this, I'm just telling you that that's the range of the thinking that's going on right now about how we're viewing fish in captivity. My point about that is that we also need to look at weighting criteria from a welfare point of view, that some of them are important and some of them maybe are not, and you can't use anthropocentric bases for it.

Lastly, I think there is a broad range of research opportunities here. I believe we can actually be pragmatic and focussed in the kind of research that we do that's meaningful to the aquaculture industry. Some of the things can be quite esoteric obviously in research, but I think there are a number of things that really need to be undertaken now. We can learn a lot from some of the terrestrial industries. That's a hog operation pictured below (Fig. 12), as well as a layer-poultry operation in the middle, and some countries have actually adjusted the size of cages for laying hens purely from a welfare perspective. They need to have adequate space to be able to stand up, turn around and move around. If you're managing a laying operation, then that means you can have fewer laying hens in the same barn that you had before. And this is just an analogous example to biodensity issues in aquaculture. Then, of course, there are these extraneous external factors that come in about others who are establishing standards. Michael Szemerda refereed to sustainability standards, organic standards and other things which actually will drive technology decisions, perhaps for all the wrong reasons. So, it's worthwhile to at least take scope on the evolving thinking around that.

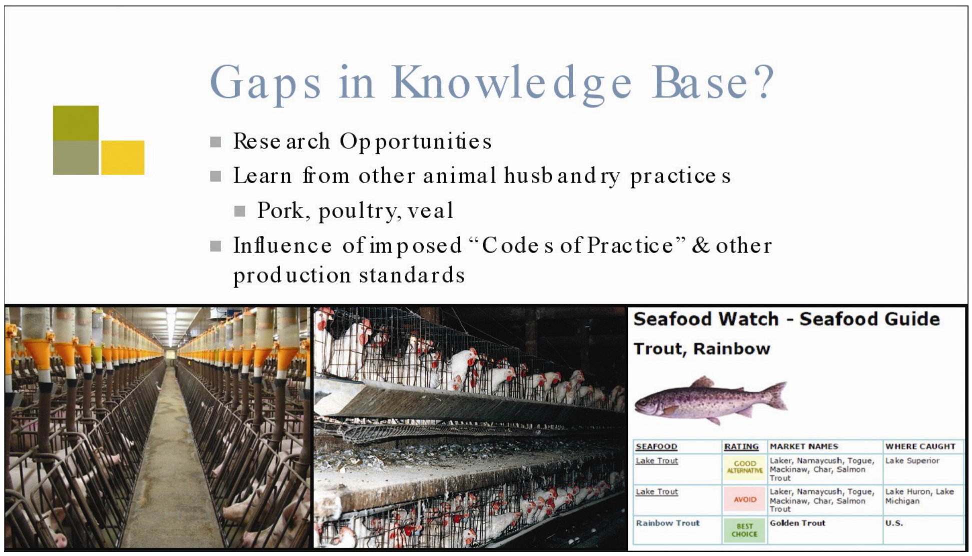


Figure 12. Gaps in Knowledge Concerning Welfare Issues

And finally, a few take home messages (Fig. 13). ***I encourage all of you, no matter where you sit in this philosophical discussion, to at least give***

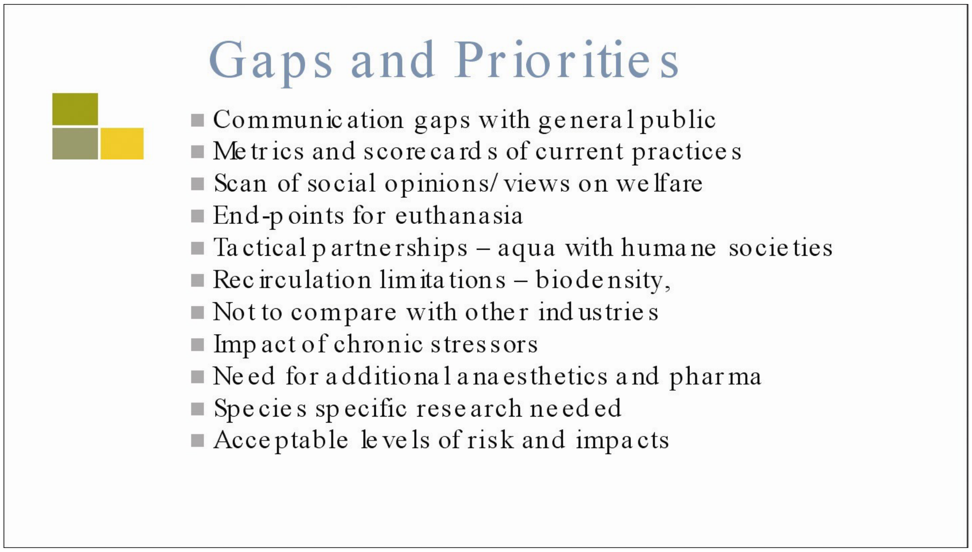


Figure 13. Gaps and priorities for future research containment

some objective thought to a more holistic view of animal welfare that I have tried to present here. I don't think fish are just purely a mechanistic animal that is just a stimulus-response machine. Neither do I think that are they fully cognitive at the same level as humans and higher vertebrates, either in my personal opinion or in most researcher's opinion, but for sure they are somewhere in the middle. Wherever you draw the line will be a challenge for all of us as we move forward, but this presentation was simply an attempt to try to open up your thinking and to get us all to at least see the challenge ahead that we've got to figure out exactly where we are going to draw that line in the middle and link welfare concerns to production technologies. There's no question, and it's not anything to be ashamed of, that we have to link welfare to environmental and economic factors as well. We do that in every other form of terrestrial agriculture, so again, we need to be up front about that environmental and economic issues play into welfare management in captive fish populations. In my thinking, it is really just another external cost of production that needs to be considered.

And so this workshop and the debate that will follow it, I think, is an excellent forum to open up our thinking and broaden people's paradigms about animal welfare and our responsibilities as the primary caregivers of farmed fish.

Author

Rich Moccia currently holds both research and senior executive cross-appointments at the University of Guelph, where he has been employed since 1987. He is the Associate Vice-President of Research for the Strategic Partnerships portfolio, as well as a Professor in the Department of Animal and Poultry Sciences. He is committed to industry-relevant research, education and extension service, and publishes across a wide variety of disciplines.

Selected References

1. Chandroo, K.P., S. Yue, and R.D. Moccia. 2004. An Evaluation of Current Perspectives on Consciousness and Pain in Fishes. Journal of Fish and Fisheries. 5: 281-295.

2. Chandroo, K.P., I.J.H. Duncan and R.D. Moccia. 2004. Can Fish Suffer? Perspectives on sentience, pain, fear and stress. Journal of Applied Animal Behaviour Science, 86: 225-250.
3. McFarlane, W.J., K.F. Cubitt, H. Williams, D.Rowsell, R.D. Moccia, R. Gosine and R.S. McKinley. 2004. Can feeding status and stress level be assessed by analyzing patterns of muscle activity in free-swimming rainbow trout (*Oncorhynchus mykiss* Walbaum) ? Aquaculture 239: 467-484.
4. Cooke, S.J., K.P. Chandroo, T.A. Beddow, R.D. Moccia and R.S. McKinley. 2000. Swimming Activity and Energetic Expenditure of Captive Rainbow Trout, *Oncorhynchus mykiss* (Walbaum), Estimated by Electromyogram Telemetry. Aquaculture Research. 31(6):495-506.
5. Chandroo K.P, R.D. Moccia, and R.S. McKinley. 2000. Utilization Of Physiological Telemetry To Monitor The Behavioural Responses Of Rainbow Trout, *Oncorhynchus mykiss* (Walbaum), To Captive Culture Conditions. Bulletin of Aquaculture Association of Canada. 99(4):34-36.

Knowledge gaps in aquaculture fish welfare: a discussion

This dialog was held on November 16, 2012, chaired by Tillmann Benfey and facilitated by W.F. (Bill) Robertson

Michael Szemerda

1.Direction

Objective

- To identify knowledge gaps of significant importance to the Aquaculture Sector that require further investigation, specific to fish welfare

Agenda

- Ground rules about Group Discussion
- Functional Issue Assessment
- Next steps

Roles

- Expect full participation
- Require professional courtesy

Results

- Document discussion

2. General Discussion (key points)

- Keynote speakers from the morning session provided a wide range of perspectives on animal welfare, with a focus on fish in captivity.
    - Dr Victoria Braithwaite spoke about the research on pain perception in fishes
    - Dr Don Stevens spoke about the effectiveness of analgesics in fishes
    - Dr Gilly Griffin provided an overview of the work done by the Canadian Council on Animal Care
    - Mr Michael Szemerda gave an overview of the fish culture practices for farmed Atlantic salmon
    - Professor Rich Moccia looked at issues relating to intensive recirculating land based systems versus open net pen systems
    - Dr Larry Hammell gave an overview of fish handling practices in different parts of the world.
- The discussion by the group was centred around farming practices for Atlantic salmon. It was understood that these current practices may not translate to other species (non-salmonid fishes). It was also understood that the discussion did not cover welfare issues pertaining to fish that are not farmed (i.e., sport fishing and commercial harvest of wild fish).

Rich Moccia

- There was general agreement that the perceived and accepted standards of care (Public Attitude) for "wild caught" fishes is very different from those of farmed fish. This difference may be a marketing opportunity.
- There was no consensus on the definition of an acceptable level of welfare (indices) nor what constitutes acceptable level of risk to farmed fish. These tend to be value based. There was agreement that fish – in particular farmed Atlantic salmon – can display changes in behaviour (distress) due to pathogens, physical trauma, and changes in the rearing environment (water temperature, light intensity, oxygen concentrations, presence of predators, etc.). Intuitively the group felt that there are humane ways to treat fish in captivity.
- There was no consensus on a definition of pain in fish. Pain is perceived as real in the context of public perception.
- Although developed for livestock and not necessarily well suited for fish, the 5 Freedoms could be a starting point for creating a list of relevant criteria to apply to farmed salmon. These are (as defined by Wikipedia):
    - Freedom from hunger or thirst by ready access to fresh water and a diet to maintain full health and vigour
    - Freedom from discomfort by providing an appropriate environment including shelter and a comfortable resting area
    - Freedom from pain, injury or disease by prevention or rapid diagnosis and treatment
    - Freedom to express normal behaviour by providing sufficient space, proper facilities and company of the animal's own kind
    - Freedom from fear and distress by ensuring conditions and treatment which avoid mental suffering
- Actual practices that create distress are difficult to define. For example, it is not uncommon to observe one individual (or a small number) in a population of fish that can be seen as failing. Not all changes in behaviour are a result of distress. These may simply be animals in a population that are not going to thrive. These individuals create critical decision points (risk management) for the farmers. When does the farmer treat, harvest, destroy the population based on the distress of the individual? There is a need to develop risk management "end points".
- It is generally not understood by the public at large that the survival of farmed Atlantic salmon from hatch to harvest is far greater than in nature.
- The Aquaculture sector in Canada employs excellent Standard Operating Practices (SOP's) when dealing with animal care. If the animals are not properly handled throughout their lifecycle, the impact flows right to the bottom line of the farming operation. Aquaculture farms are monitored, measured and inspected.

Industry Attendees

- Keng Pee Ang (Kelly Cove Salmon)
- Ian Armstrong (Aqua Pharma)
- Steve Backman (Skretting)
- Bev Bacon (RDI Strategies)
- Bryan Bosien (Snow Island Salmon)
- Chris Bridger (AEG)
- Jason Collins (Fish Vet Group)
- Stacy Fielding (Kelly Cove Salmon)
- Kathleen Frisch (Mainstream Canada)
- Danielle Goodfellow (Aquaculture Assoc. of NS)
- James Hoare (Fish Vet Group)
- Jason Holmes (Northeast Nutrition)
- Betty House (Atlantic Canada Fish Farmers Assoc.)
- Elizabeth Jones (Admiral Fish Farms)
- Mark Kesselring (Northern Harvest Seafarms)
- Alastair McNeillie (Solvay Chemicals)
- Hugh Mitchell (AquaTactics Fish Health)
- Robin Muzzerall (Gray's Aqua Farms)
- John O'Halloran (Aquaculture Veterinary Services)
- Hernan Pizarro (Fish Vet Group)
- Don Rainnie (Consultant)
- Amanda Smith (SIMCorp)
- Michael Szemerda (Cooke Aquaculture)
- Robert Taylor (Snow Island Salmon)
- Paul Tonita (Novartis Animal Health Canada)
- Jessica Whitehead (SIMCorp)

University (NSERC-eligible) Attendees

- Céline Audet (UQAR-ISMER)
- Tillmann Benfey (UNB Fredericton)
- Mairi Best (Laurentian University & Univ. of Victoria)
- Kurt Gamperl (Memorial University)
- Larry Hammell (UPEI Atlantic Veterinary College)
- Simon Lamarre (Université de Moncton)
- Tyson MacCormack (Mount Allison University)
- Rich Moccia (University of Guelph)
- Don Stevens (University of Guelph & UPEI)

Victoria Braithwaite

- Most of the larger salmon producing companies as well as most of the large buyers of farmed fish participate in one of several certification programs that are now available. These programs audit the practices of the farming system and provide a score based result.
- Current aquaculture practices are based on a model of continuous improvement. Fish (growth, survival, etc), feed (formulation and ingredient sources), farming/harvesting/processing equipment are constantly being improved to provide better performance and ultimately better economic returns.
- The indices currently used for assessing animal welfare on farms are observational and performance based. Quantitative and objective metrics focus on results from measuring key water quality parameters (i.e., temperature and oxygen) as well as observations on schooling behaviour, feeding behaviour, growth rates and reproductive success of salmonids. These may need to be modified when dealing with farmed, non-salmonid fishes.
- There was agreement that there is a link between the welfare of the animals and the environmental conditions that they are exposed to. Ideal rearing conditions (water chemistry, space, nutrition, etc.) usually result in better performance, and lower stress levels are implied.
- Land based systems usually require very high bio-densities to provide an economic return. These high densities do not allow for “normal” behaviour in fishes and may run counter to accepted standards of welfare. In addition, the water reconditioning systems that are currently employed may require changes in disease management practices critical to the well being of the populations of fish.
- Animal breeding programs currently select fish for “best performance under farmed conditions”. This is a form of continuous improvement but too new to be domestication. The actual number of generations in captivity is much lower than in traditional agriculture. There is scope for increased research into quantitative parameters that might be practical at the farm level (cortisol concentrations in water as an indicator of stress, sentinel animals followed within cages using telemetry for cardiac function and other physiological parameters, etc).
- Further, there is little research on the impact of long term, chronic stressors on the populations of fish being farmed. There are a series of observations with respect to certain locations that have been in continuous production showing signs of decline (lower productivity).
- Tools for assessing welfare should be based on reducing stress responses in farmed fish and in sync with CCAC guidelines. Farms, as a general rule, do not report on their welfare standards even though these are very high given the number, size and quality of fish that make it through the farming cycle. There was discussion about creating a welfare index (report card) on the sector as a whole. For example, the majority of Atlantic salmon farmed in Canada today are harvested using percussion stunning.

- There is still limited access to chemicals (vaccines, pathogen treatments, etc.) in Canada that will allow farming practices to improve the welfare of the fish. Some vaccines currently in use can cause adhesions in the body cavity of salmonids, and this requires attention.
- Short discussion on the approval process related to chemicals. Clove oil and AQUI-S used as the example of a chemical approved for use in other jurisdictions (including other sectors in Canada) but not for food fish production.
- Ana Espejo (UNB Research Office) provided an overview of the type of funding programs available to support partnerships between researchers and industry, should the group conclude that there are research questions arising from the discussion. Other institutions in other jurisdictions would have access to similar programs.

Other Attendees

- Victoria Braithwaite (Penn State University)
- Karen Coombs (NB-DAAF)
- Ana Espejo (UNB Office of Research Services)
- Amber Garber (Huntsman Marine Science Centre)
- Caroline Graham (NB Community College)
- Gilly Griffin (Canadian Council on Animal Care)
- Tim Jackson (NRC – IRAP)
- Shelley King (Genome Atlantic)
- Sharon McGladdery (Fisheries & Oceans Canada)
- Joanne Power (Fisheries & Oceans Canada)
- Bill Robertson (Huntsman Marine Science Centre)
- Gail Ryan (Aquaculture Association of Canada)

Pam Parker

Sharon McGladdery

3. Functional Issue Assessment

Issue Assessment	How is it being manifested?	Why is it happening?
Absence of quantitative and objective welfare assessment metrics to determine when an endpoint for euthanasia is reached. This may be influencing the effectiveness of fish health management practices.	Individual (dark, lethargic, emaciated) fish can sometimes be seen in fish culture systems (tanks, net pens, ponds). These animals may be left alive despite signs of distress, and may be a source of infection to other fish.	Risk management decisions tend to be based on farm experience and the observations of the general population as a whole within a fish culture system. There is no one set of metrics. An individual fish not performing well is not always viewed as an indicator of how the rest of the population is doing. The industry does not use a sentinel animal model. Individual fish (poor performers) are often removed from the population as soon as practical. The timing of harvesting for an entire population of fish is usually dictated by market conditions
Standard Operating Practices (Procedures) for farmed salmonids are not well understood by the general public. This may be a communication function. There are no score cards on welfare practices for farmed or wild-caught fishes. There are currently no active partnerships between the Aquaculture sector in Canada and recognized animal welfare organizations.	There appears to be different tolerance levels for the practices associated with handling wild-caught species of commercial importance (crabs, lobsters, swordfish, cod, herring, etc.), as compared to those accepted for farmed salmon or farmed trout. Game fish seen jumping out of the water after being hooked by an angler elicits a different response from the viewing public than a live salmon being sluiced down a stunning chute. Aquaculture associations do not have a history of working with animal welfare/humane societies on establishing SOP's for fish farms and/or public education.	There are regional and ethnic differences to the public attitude toward harvesting fishes. The Aquaculture Sector does not report farming practices in terms of "animal welfare". There are no comparisons with wild fish. There is a general view that individually hooked game fish do not feel any pain and that the jumping behaviour is associated with a majestic display of vigor (not distress). Aquaculture producers tend to sell their products to seafood buyers and not directly to the general public. The details about the farming practices are not always passed along in the process.

Issue Assessment	How is it being manifested?	Why is it happening?
There are limited numbers of treatments available (approved for use) for fish farmers to use when managing the vectors of disease. Broodstock programs are still relatively new compared to other agriculture animal programs. Domestication as a means of selecting for disease resistance is just beginning.	Access to compounds that help control sea lice infestations on farmed salmon or trout in the marine environment are highly regulated and limited in number. In-feed treatments such as emamectin benzoate (marketed as *SLICE*®) seem to be losing their effectiveness in some areas. Other products including hydrogen peroxide, Salmosan, AlphaMax and Calicide are based on an emersion bath treatment and are expensive and logistically difficult to apply. Further, it takes a long time to bath-treat a farm of fish. Some of the vaccines currently in use demonstrate adhesions in the body cavity of the fish.	The Canadian Pest Management Regulatory Agency (PMRA) of Health Canada is responsible for the approval process and takes a long time in their decision making because of the risk to non-target organisms – including lobster stocks. There is a regulatory component and a social component to approving the use of pesticides in ocean net pens. Environmental impacts appear to trump fish health. The regulatory burden in Canada is very high and therefore the investment in developing alternative treatments by the supply companies is reflective of this. Breeding programs take a long time to show heritable gains.
Land-based closed-containment systems are being proposed as a solution to concerns about environmental impacts of open net-pen systems. The bio-densities proposed are very high Little is known about the long term effect of chronic stress on fish populations.	Numerous panels have been convened recently on the state of the art on land-based closed-containment systems. The bio-densities that these systems are being designed to carry is very high. There are few data on the impact of these densities or on the impact of the filtration systems that do not recondition all of the water parameters. There are numerous pilot-scale systems currently being built or already operational.	These land-based systems are being touted as an alternative to open net pen systems and are being positioned as virtually impact free (as it pertains to organic loading of receiving waters, escapees and the use of chemicals). These high intensity recirculation systems are expensive to construct and operate and therefore require high production densities to make economic sense. There is interest from ENGO's and Regulatory Agencies to test this concept as a possible solution to the current impacts of aquaculture.

4. Next Steps

- Summarize the key points from the group discussion and make it available for editing
- Find a group of interested parties who will evaluate the functional issues identified and prioritize them with the aim of creating a position paper. The following people have volunteered to be part of the initial interested parties group.
  - Tillmann Benfey – University of New Brunswick
  - Larry Hammell – UPEI Atlantic Veterinary College
  - Rich Moccia – University of Guelph
  - Amber Garber – Huntsman Marine Science Centre
  - Tyson McCormack – Mount Allison University
  - Simon Lamarre – Université de Moncton
  - Robin Muzzerall – Admiral Fish Farms
  - Hugh Mitchell – Aqua Tactics Animal Health
  - Kurt Gamperl – Memorial University
  - Michael Szemerda – Cooke Aquaculture
  - Tim Jackson – NRC-IRAP
- Identify what will be needed to pull together a position paper – including but not limited to the need to include a social science component and finding the best funding mechanism.

Caroline Graham and Larry Hammell

Funding opportunities to support R&D partnerships, with a focus on New Brunswick

A Espejo

Ana Espejo

Abstract

As part of the workshop session that focused on identifying knowledge gaps specific to fish welfare in aquaculture (see preceding article), a presentation was made by the University of New Brunswick's Office of Research Services that outlined funding opportunities to support research and development partnerships to address such knowledge gaps. Although the emphasis was on funding available to New Brunswick applicants, many of the programs identified were regional (Atlantic) or national in scope.

Presentation Slides


Office of Research Services (ORS) Mandate
• Link between the university and funders
• Support researchers in meeting their goals
• Facilitate/support collaboration/ initiatives
• Facilitate knowledge transfer
• Provide financial support services
• Ethics / animal care and other regulatory responsibilities
The Power of Passionate Minds
UNB RESEARCH


Research and Development Partnerships
These partnerships can take a variety of forms:
•Short term or long term
•Basic research, applied R&D, testing or technical services
•Solely directed by a university researcher or directed in collaboration with company researchers
•Deliverable – report, proof-of-concept device, improvements to and existing technology, etc.
The Power of Passionate Minds
UNB RESEARCH

Funding Programs

- NSERC – Natural Sciences and Engineering Research Council
- NBIF - New Brunswick Innovation Foundation
- IRAP – Industrial Research Assistance Program
- ETF – Environmental Trust Fund
- SSHRC – Social Sciences and Humanities Research Council
- MITACS - http://www.mitacs.ca/

The Power of Passionate Minds

UNB RESEARCH

NSERC

- Partnership Workshop Program – up to $25,000 to fund workshops for building new collaborations between Canadian academic researchers and the industry and government receptor community that will result in future economic, environmental or societal benefits to Canada. http://www.nserc-crsng.gc.ca/Professors-Professeurs/RPP-PP/PWG-SAP_eng.asp

The Power of Passionate Minds

UNB RESEARCH

NSERC

- Interaction Grant Program - up to $5,000 to support expenses associated with travel and meetings in order to allow academic researchers to establish contact with one or several companies. http://www.nserc-crsng.gc.ca/Professors-Professeurs/RPP-PP/Interaction-Interaction_eng.asp

The Power of Passionate Minds

UNB RESEARCH

NSERC

- Engage Grant Program – up to $25,000 to support a 6 month research and development project aimed at addressing a company-specific problem. Foster new collaborations so no previous or existing relationship. Company owns IP. http://www.nserc-crsng.gc.ca/Professors-Professeurs/RPP-PP/Engage-Engagement_eng.asp

The Power of Passionate Minds

UNB RESEARCH

NSERC

- Collaborative Research & Development Program – Projects 1 to 5 years for focused projects with specific short- to medium-term objectives, as well as discrete phases in a program of longer-range research. Industrial cash must be at least half NSERC request with other half as in-kind. IP agreement required. http://www.nserc-crsng.gc.ca/Professors-Professeurs/RPP-PP/CRD-RDC_eng.asp

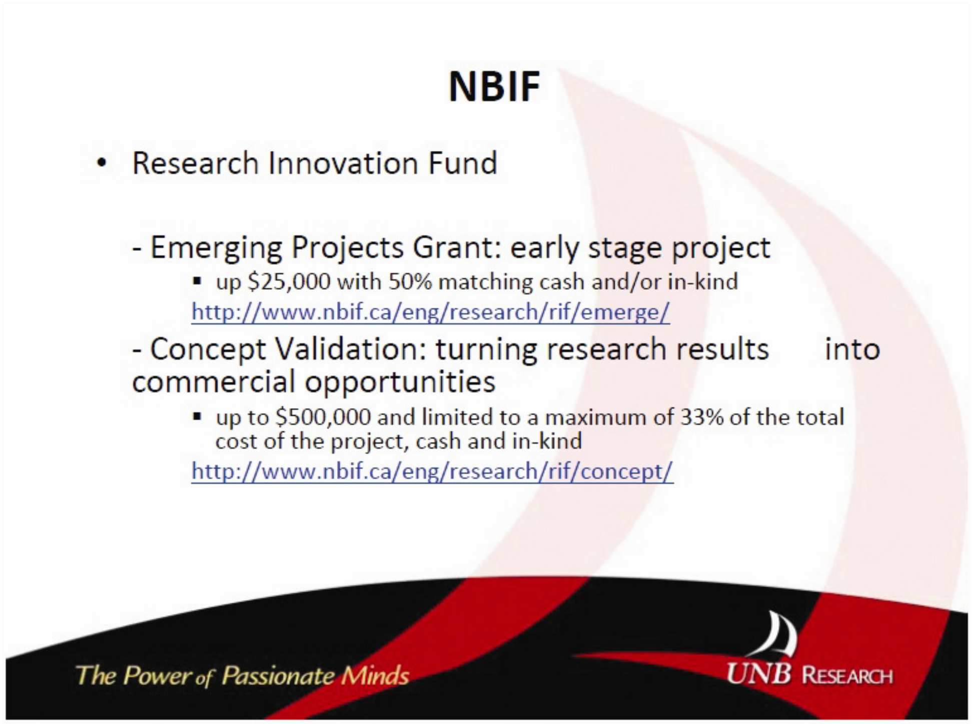
The Power of Passionate Minds UNB RESEARCH

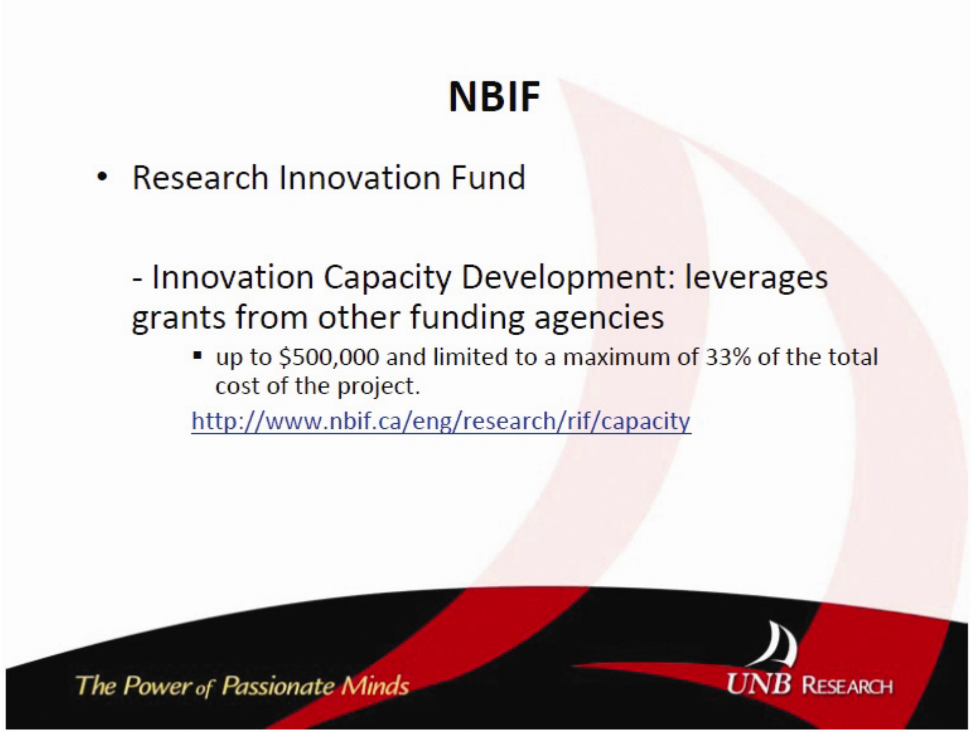
NBIF

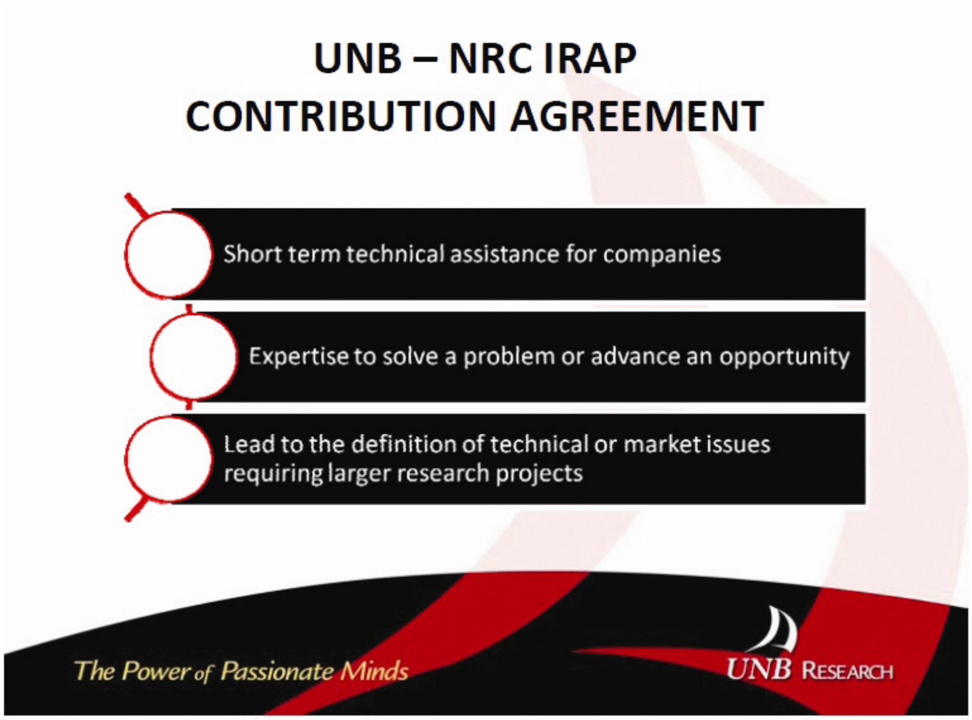
- All projects must fit within their Strategic Industries:
  - Energy & Environmental Technologies
  - Knowledge & ICT
  - Life Sciences
  - Value-added Natural Resources
  - Advanced Manufacturing

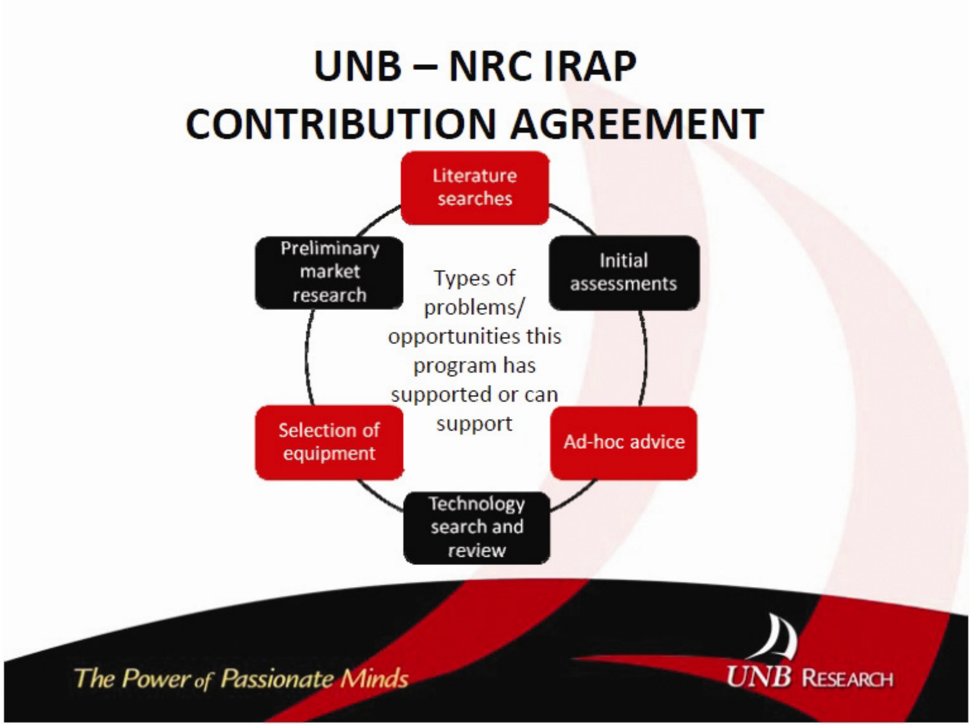
http://www.nbif.ca/eng/about/industries/

The Power of Passionate Minds UNB RESEARCH


NBIF
• Research Innovation Fund
- Emerging Projects Grant: early stage project
▪ up $25,000 with 50% matching cash and/or in-kind
http://www.nbif.ca/eng/research/rif/emerge/
- Concept Validation: turning research results into commercial opportunities
▪ up to $500,000 and limited to a maximum of 33% of the total cost of the project, cash and in-kind
http://www.nbif.ca/eng/research/rif/concept/
The Power of Passionate Minds
UNB Research


NBIF
• Research Innovation Fund
- Innovation Capacity Development: leverages grants from other funding agencies
▪ up to $500,000 and limited to a maximum of 33% of the total cost of the project.
http://www.nbif.ca/eng/research/rif/capacity
The Power of Passionate Minds
UNB Research


UNB – NRC IRAP
CONTRIBUTION AGREEMENT
Short term technical assistance for companies
Expertise to solve a problem or advance an opportunity
Lead to the definition of technical or market issues requiring larger research projects
The Power of Passionate Minds
UNB RESEARCH


UNB – NRC IRAP
CONTRIBUTION AGREEMENT
Literature searches
Initial assessments
Ad-hoc advice
Technology search and review
Selection of equipment
Preliminary market research
Types of problems/ opportunities this program has supported or can support
The Power of Passionate Minds
UNB RESEARCH

NB ETF

- Eligibility: Community groups, NB municipalities, non-profit NB organizations, and institutions furthering sustainable development
- Funds projects under one of these categories
  - Protection
  - Restoration
  - Sustainable Development
  - Conservation
  - Education
  - Beautification

http://www2.gnb.ca/content/gnb/en/services/services_renderer.13136.html

The Power of Passionate Minds UNB RESEARCH

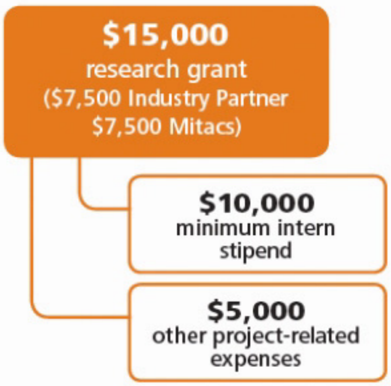
SSHRC

- Connection Grants – 1 year grants between $7,000 & $50,000 to support events and outreach activities geared toward short-term, targeted knowledge mobilization initiatives. Foster opportunities to exchange knowledge and to engage on research issues of value to those participating.

  http://www.sshrc-crsh.gc.ca/funding-financement/programs-programmes/connection_grants-subventions_connexion-eng.aspx

The Power of Passionate Minds UNB RESEARCH

Accelerate: Funding – One Internship Segment



- Open to graduate students and postdoctoral fellows
- Intern spends ~ 50/50 time at the company/university
- Travel subsidies may be available to interact with partners outside the local area
- Industry contribution may qualify for SR&ED tax credits

Accelerate: Eligibility & Timeline

- Open to graduate students and postdocs
  - Masters students can do up to 2 internship segments
  - PhD students and Post-docs can do up to 4 internship segments
  - Note: students are limited to 4 internships per lifetime
- Each internship is a 4-month duration
  - Funds must be spent within 6 months of the internship start date

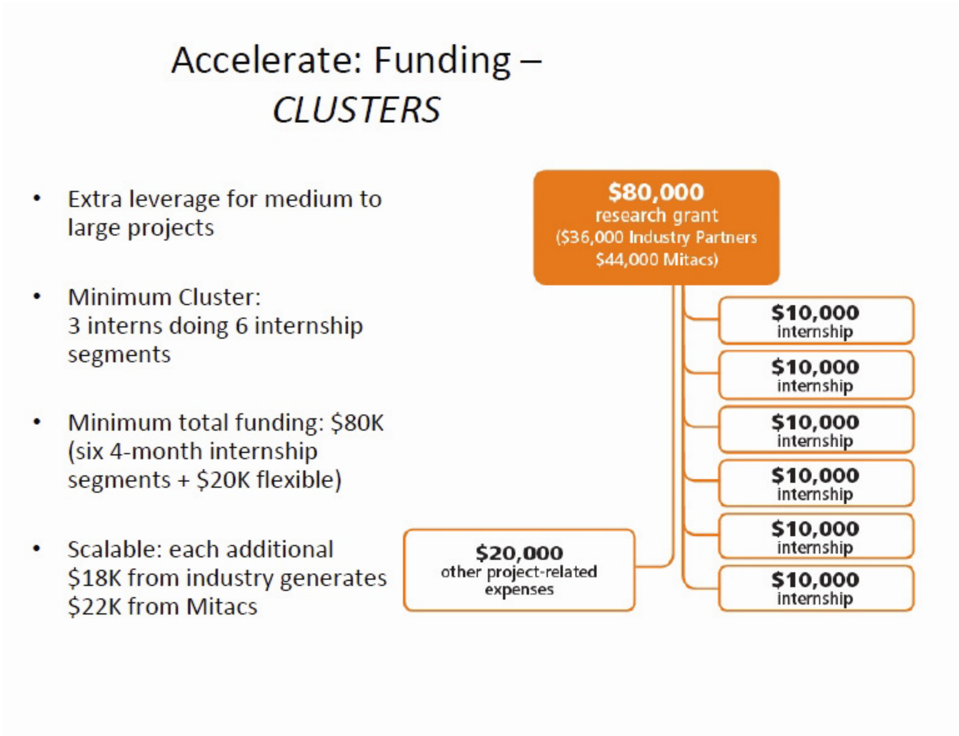
Accelerate: Application Process

- Application forms are short and simple to complete
- Non-competitive award
- No application deadlines; projects can begin anytime
- Peer-reviewed by internal and external experts
- Most proposals are reviewed within 6 weeks of submission
- International students are welcome
- Full support of the Mitacs during project development, draft preparation, and after submission

Accelerate: Eligible Industry Partners

- **Eligible:** For-profit company / business of any size with a facility in Canada where the intern can spend time on-site or in field research
  - Domestic or foreign-owned
  - Eligible organisations may also include:
    - Crown Corporations
    - University spin-offs
    - First Nations Development Corporations
    - Industry associations
- **Ineligible:** Hospitals, NGOs, municipalities, government agencies, university spin-offs in same room as founding "lab"

www.mitacs.ca



Author

Ana Espejo is the Manager of Pre-Award Services in the Office of Research Services at the University of New Brunswick.