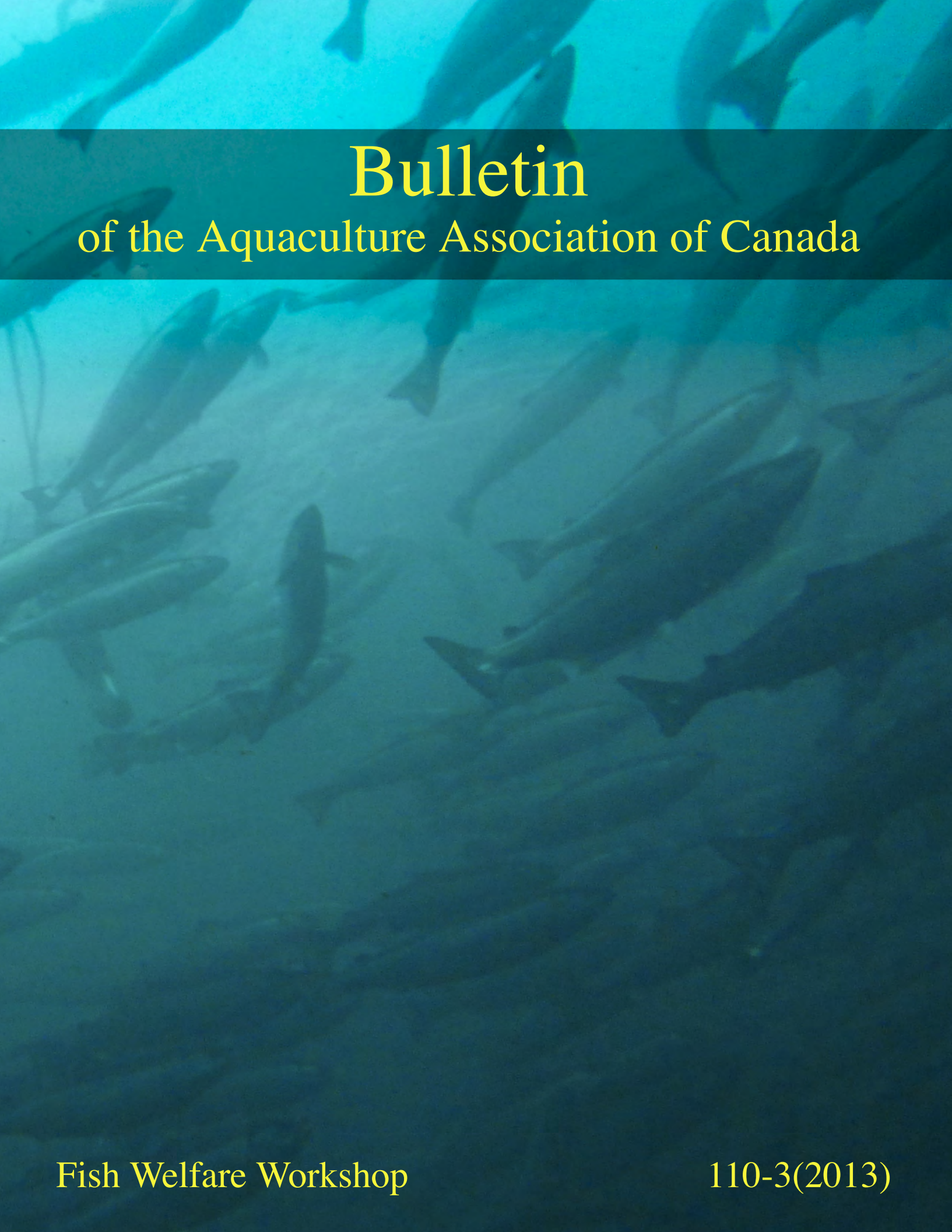

Bulletin

of the Aquaculture Association of Canada

Fish Welfare Workshop

110-3(2013)

Bulletin
de l'Association aquacole du Canada
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ISSN 0840-5417
Imprimé par Taylor Printing Group Inc., Fredericton, N-B

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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

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.

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

"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..."

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.

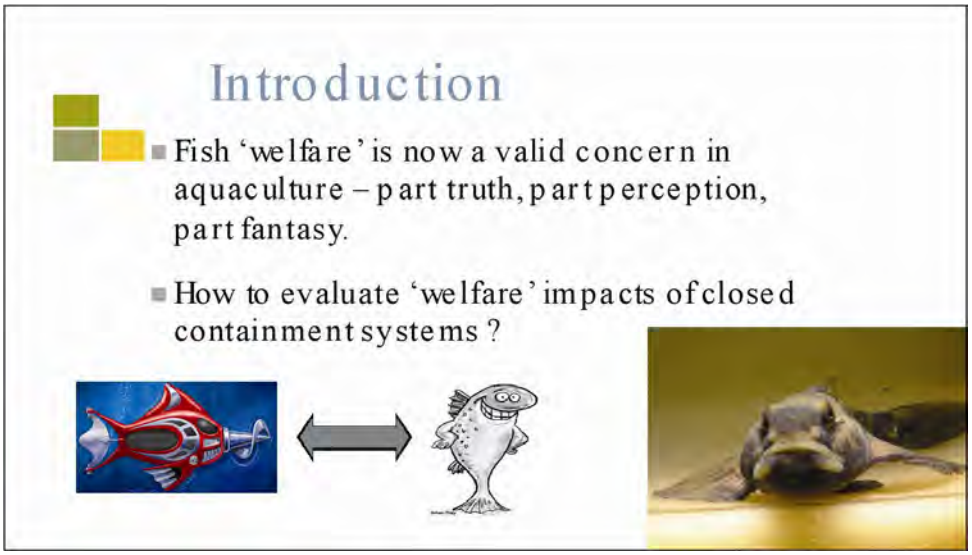

Figure 1. Fish welfare as fact or fantasy?

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.

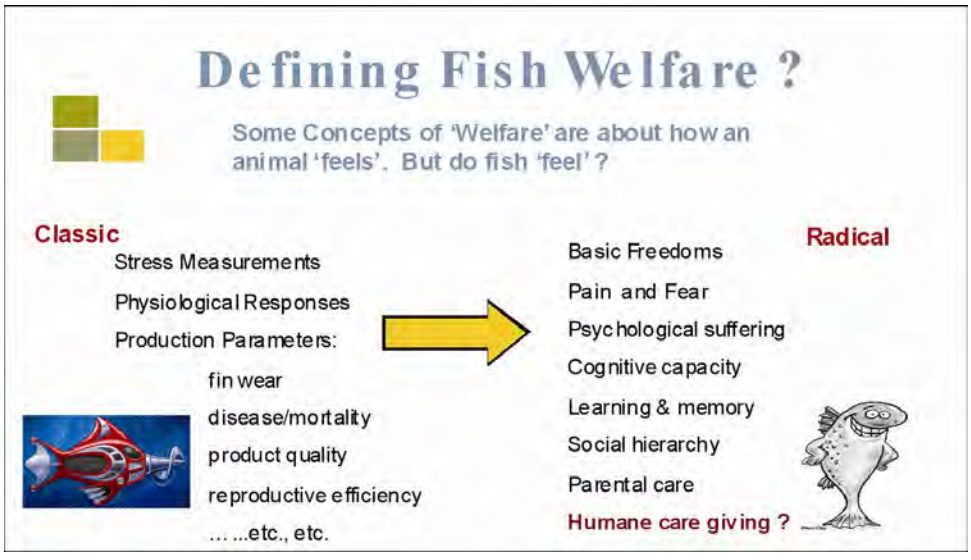

Figure 2. Extremes in definitions of fish welfare

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.

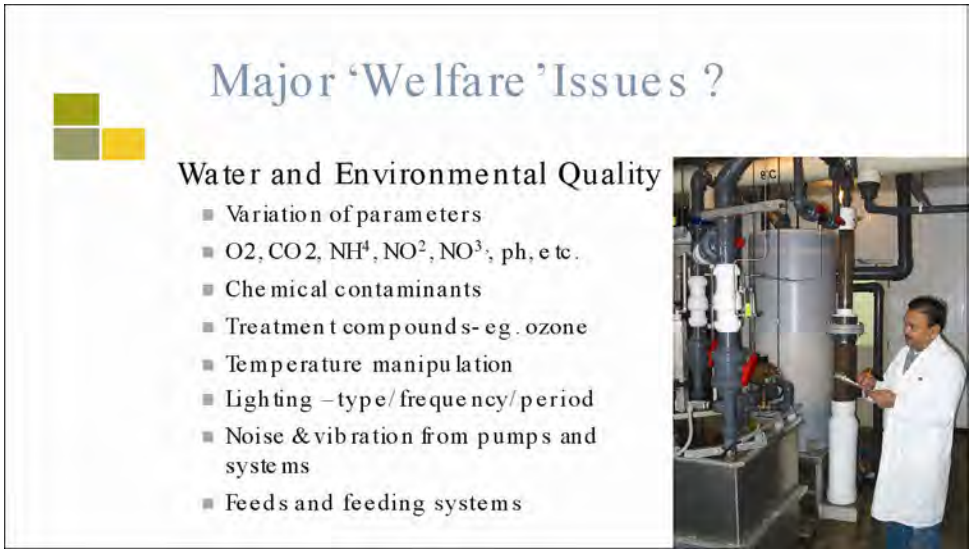

Figure 4. Issues in closed containment: water and environmental quality

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.

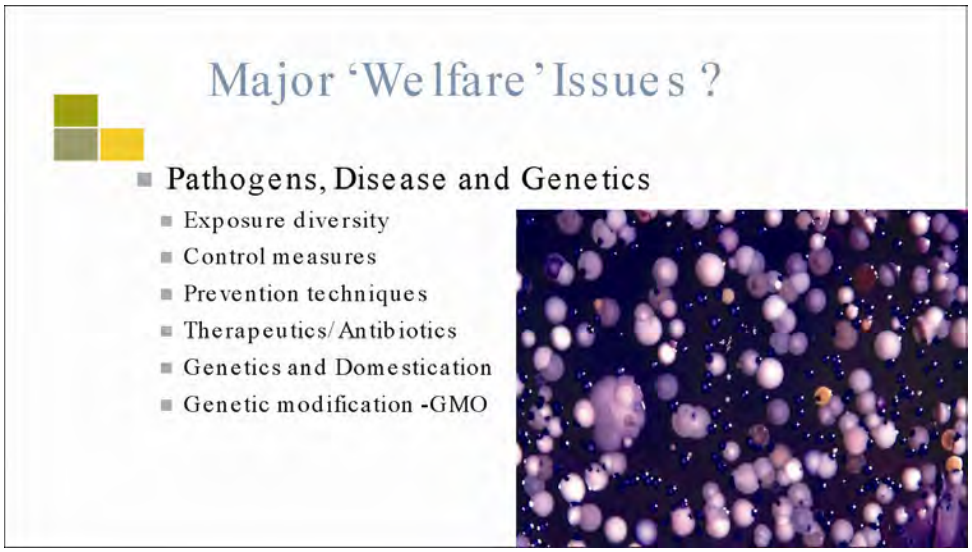

Figure 5. Issues in closed containment: pathogens and disease

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.

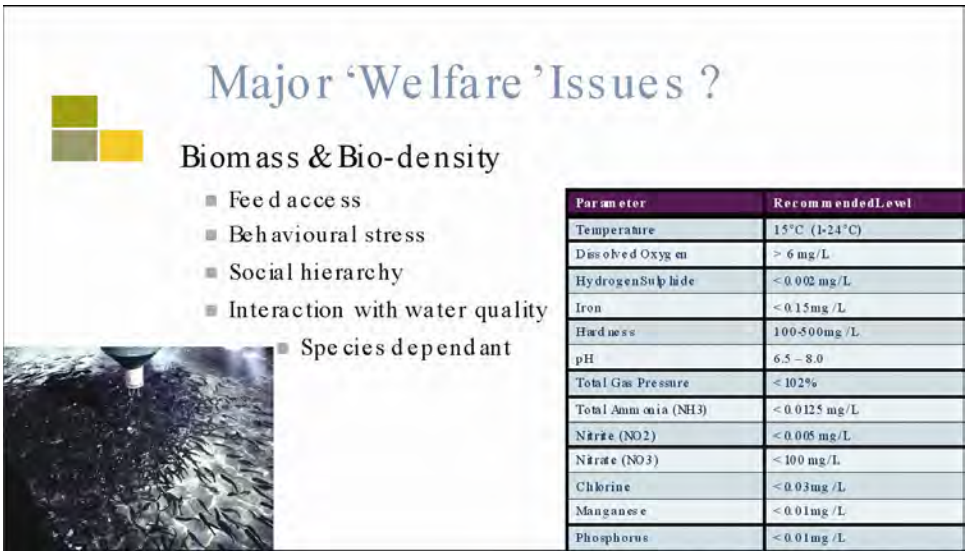

Figure 6. Issues in closed containment: biodensity

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.

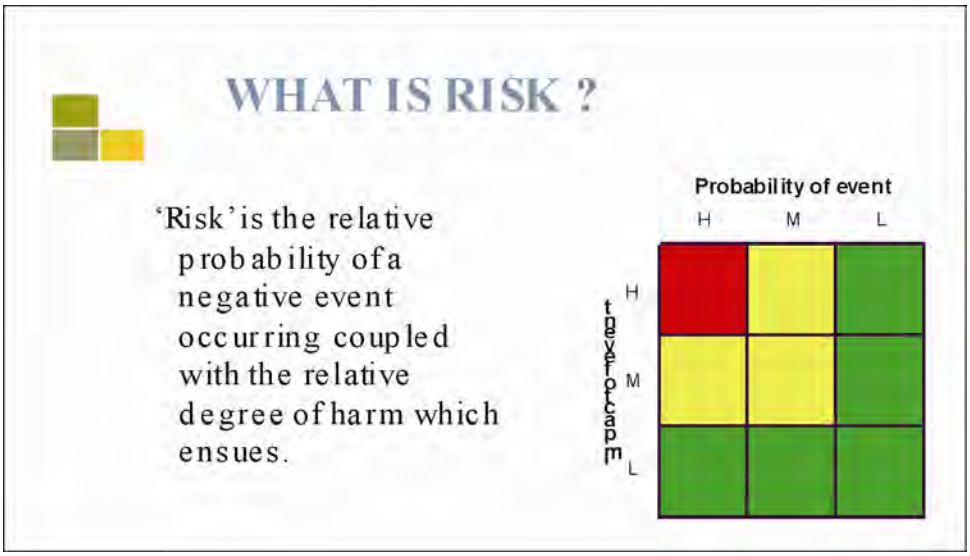

Figure 11. How to define risk?

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.

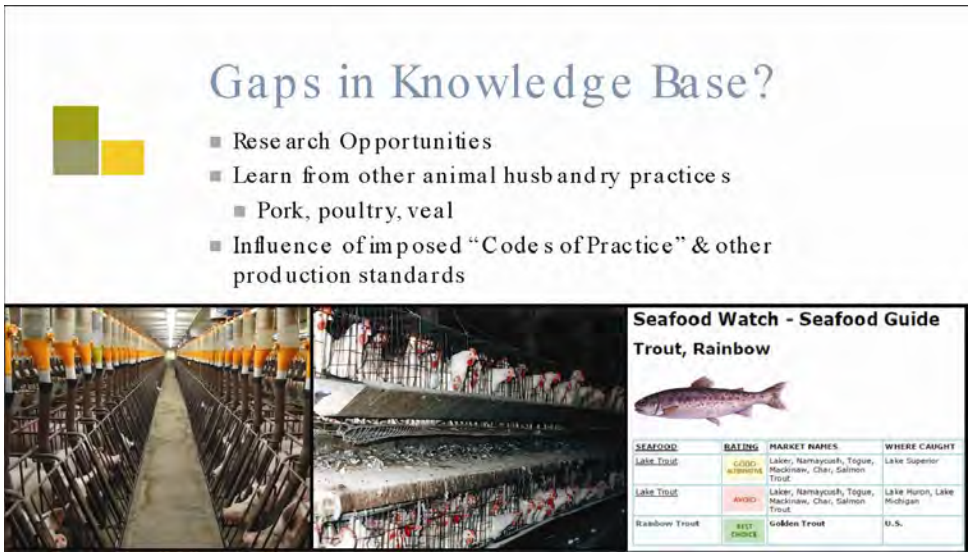

Figure 12. Gaps in Knowledge Concerning Welfare Issues

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.

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