Securing Sustainable Economic Prosperity

Aquaculture Canada 2007

Edmonton, Alberta

Proceedings of Contributed Papers & Second National Freshwater Symposium

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23-26 September 2007

É. Boucher
A. Vickerson
C. Couturier

editors

Aquaculture Canada [OM] 2007 and Canadian Freshwater Symposium - Proceedings of Contributed Papers of the 24th Annual Meeting of the Aquaculture Association of Canada, Edmonton AB, September 23 - 26, 2007

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Proceedings of Contributed Papers & the Second National Freshwater Symposium

Conference Keynote

Aquaculture Canada 2007 - Contributed Papers

Canadian Freshwater Symposium 2007 - Contributed Papers

President's Report
Rapport du Président

Aquaculture Canada^{OM} 2007, the annual meeting of the Aquaculture Association of Canada (AAC), was held in Edmonton, Alberta from September 23rd to the 26th at the Shaw Conference Centre and was co-hosted by Alberta Agriculture and Rural Development, the Alberta Aquaculture Association, and the Interprovincial Partnership for Sustainable Freshwater Aquaculture Development (IPSFAD). I would like to thank each of our co-hosts for their valuable contributions of funds and support which allowed us to organize such a wonderful meeting. The successful hosting of such a large conference by a strictly volunteer organization such as the AAC requires a major influx of funds and I would like to acknowledge all of the organizations that contributed money to the cause, most especially our *diamond* (Agriculture & Food Council of Alberta, Agriculture and Agri-Food Canada, Alberta Agriculture and Rural Development, Canadian Aquaculture Industry Alliance, Fisheries and Oceans Canada, Genome Atlantic) and *gold* (Aquaculture Centre at the University of Guelph, Atlantic Provinces Council on the Sciences, Grieg Seafood, IPSFAD, Réseau Aquaculture Québec, La Société de Recherche et de Développement en Aquaculture Continentale) sponsors.

Organizing an Aquaculture Canada^{OM} event requires a lot of dedicated work from a plethora of people and I would like to acknowledge the efforts of all the members of our Local Organizing, Sponsorship, Program, Student Affairs, and Communications Committees (see complete list of committee members in this issue). I would be remiss in not highlighting the efforts of a few select people that went above and beyond the call of duty. I want to especially thank Linda Hiemstra, our conference and tradeshow organizer, for all her tremendous hard work in planning, organizing, and implementing both the conference and tradeshow. I don't know what I would have done without her! Grant Vandenberg, IPSFAD President, was instrumental in pulling together the Second National Freshwater Symposium and securing funding. We certainly could not have had the success we did without the devoted efforts of Eric Hutchings, member of the Local Organizing and Program Committees. He worked on almost every aspect of the organization of this conference and tackled every job we threw his way with gusto! Chris Hendry, Program Committee Chair, developed a highly informative and exciting line up of scientific and technical presentations (the following year after his Presidency and organizing his own Aquaculture Canada^{OM} conference, I might add). I would also like to thank Cyr Couturier, Sponsorship Chair, for his guidance and securing funding and product donors. Also, I would like to acknowledge Master Promotions Ltd. for overseeing conference registration and Bill Hirsche, Janet Smalley, and Janice Wilson from Alberta Agriculture and Rural Development for logging many an hour at the conference registration desk and serving the delegates in a courteous and friendly manner. I am also appreciative of the efforts of Emily Louden, who solicited many items for the silent auction and worked onsite to ensure that the tradeshow ran smoothly. Finally, I must gratefully acknowledge the diligent and tireless efforts of Susan Waddy and the AAC Home Office in St. Andrews for all of their efforts with both the conference and the day-to-day running of the Association.

The conference theme this year, ***Securing Sustainable Economic Prosperity***, spoke to the need for the Canadian aquaculture industry to maintain or increase financial profitability (economic sustainability) while ensuring environmental integrity (environmental sustainability) and safeguarding public support (social sustainability). These are three keys required to assure the future success of the Canadian aquaculture industry and a number of special sessions and speakers were organized to address these particular topics at Aquaculture Canada^{OM} 2007.

Approximately 220 delegates attended the annual conference and tradeshow, which was the 24th annual meeting of the AAC and the first held in the Canadian Prairies. The province of Alberta – which is in the Canadian interior – is not typically known for its aquaculture production, but there is a burgeoning freshwater-based industry developing in the Prairie provinces. Part of the provincial economic boom, Alberta aquaculture has over 100 commercial producers (most with sophisticated indoor recirculation facilities) realizing CAD $10 million annually in revenue from 730 tonnes of cultured fish such as trout, tilapia, eel, buffalo fish, and triploid grass carp (2005 Alberta provincial statistics).

This year, Aquaculture Canada[OM] 2007 partnered with IPSFAD to host the Second National Freshwater Symposium (the first being held at Aquaculture Canada[OM] 2004 in Quebec City, Quebec), which focused on issues relevant to the Canadian freshwater aquaculture industry. A number of special sessions were organized for the symposium, including: fish nutrition, feeds, and feeding; environmental aspects of freshwater cage farming; diversification of freshwater production; fish health management in freshwater aquaculture; and aquaponics. Dr. Grant Vandenberg, Laval University, was the organizer of this special symposium and I would like to thank him and Eric Boucher (IPSFAD Project Coordinator) for developing such a productive and highly informative session. The Second National Freshwater Symposium was a big part of our conference this year and contributed hugely to our overall success.

The conference keynote speaker was the Honourable A. Brian Peckford, former Premier of the province of Newfoundland and Labrador and currently a consultant to the oil and gas industry in British Columbia. In his riveting presentation entitled *"The Challenge to Develop Aquatic Resources to Secure Economic Prosperity while Maintaining Social Approval"*, Mr. Peckford described how lessons learned from other resource-based industries – such as the oil and gas industry – can be applied to the sustainable development of the aquaculture industry in today's and tomorrow's world (see text of speech in this issue and http://aquaport.ca/projects/AC07.htm for the webcast). One of Mr. Peckford's key recommendations to the Canadian aquaculture industry was to do a better job at self promotion. He suggested establishing a small group – comprised of individuals from science, industry, and public relations – that would travel throughout Canada, hitting all the major media outlets, to promote our industry. A very good idea indeed!

Our two plenary speakers at this year's conference were Dr. Rebecca Goldburg (Environmental Defense Fund) and the Honourable David Anderson (former member of cabinet and current Director of the Guelph Institute of the Environment). Dr. Goldburg gave a fascinating presentation entitled *"Creating an Industry Model for Addressing Environmental Issues and Achieving Business Benefits"* where she summarized some of Environmental Defense's recent work with market-leading corporations in which they strive to make significant progress on various environmental issues while creating benefits for industry. One of the key messages that I took away from her presentation was that environmental stewardship can actually increase a company's bottom line in terms of profitability. Mr. Anderson spoke elegantly about the political debate surrounding Canadian aquaculture and the development of policies to regulate the industry in his presentation entitled *"Public Concerns and Policy Development for Aquaculture"*.

This year's recipient of the AAC Research Award of Excellence was Professor Rich Moccia (Professor and Director, Aquaculture Centre, University of Guelph). Professor Moccia has been involved in Canadian aquaculture for nearly 30 years and has conducted research in such varied areas as applied nutrition, aquatic and fish health, ecotoxicology, environmental impact assessment, reproductive and growth physiology, and animal welfare studies related to captive aquatic livestock. He has been a very student-centred educator during his career, advising 32 students in either MSc or PhD programs and participating in the committees of over 100 other graduate students. A more detailed biography of Professor Moccia is presented in this issue, but needless to say, he is most deserving of this award. For his presentation, Professor Moccia gave an interesting overview of his career in aquaculture, focusing mostly on the students and colleagues with whom he has worked with over the years.

This year's conference also included a vibrant tradeshow – with over 25 companies, industry associations, and government/academic departments present – and an eye-opening industry tour. The tour took conference delegates to two local recirculation facilities: Smoky Trout Farm (near the city of Red Deer), which is a cold-water trout producing company, and MDM Aqua Farms Ltd. (Rumsey, Alberta), which produces high-quality tilapia in a warm-water recirculation system that makes use of aquaponics to produce a variety of vegetables. I would like to thank Mark McNaughton and his family for organizing the tour of MDM Aqua Farms Ltd. (and for the absolutely fabulous lunch!) and Dan and Max Menard for the tour of Smoky Trout Farm.

A number of social events were also organized for the conference, including the President's Reception, the Joe Brown Barbeque in Support of AAC Students, the Genome Atlantic Reception, the Conference Banquet, and the annual AGM Luncheon. A large part of the success of these social events hinges upon the quality and quantity of food served and we were fortunate enough to have some first rate products (cultivated under marine, freshwater, and terrestrial conditions) donated. I would like to thank all of the food donors for their generous support of Aquaculture Canada[OM] 2007 (a complete list of companies that donated product is presented in this issue). I would also like to thank Chef Simon Smotkowicz and his team at the Shaw Conference

Centre for creating some absolutely wonderful meals! A special acknowledgement goes to David McCallum (BC Shellfish Growers Association) and Peter Egger (Aquafarms 2000 Inc.) for shucking wonderful BC oysters all night at the opening reception. I am also appreciative of the tremendous efforts of Martin Linlove and Ed Pilecki at the Shaw Conference Centre for logistical arrangements at their facility. In addition, I would like to thank Ray Kavinta, Convention Services Manager for The Westin Edmonton, for providing our delegates with such wonderful rooms and service at the conference hotel.

The barbeque in support of AAC students was held at a local Edmonton bar (The Rose & Crown Pub) and was a huge success, bringing in $2,498 from the silent auction for the Student Endowment Fund (SEF) and hosting the first ever Canadian Aquaculture Idol contest (a huge hit). This was the second highest revenue ever brought in through the silent auction in the history of AAC conferences! Thanks are expressed to the chef and staff (especially Dean Chambers) at the Rose & Crown and to all the auction donors for generously giving up various items for the SEF silent auction (a complete list of donors is presented in this issue). I would also like to acknowledge Terralynn Lander, members of the AAC Student Affairs Committee, and various Alberta volunteers for all of their hard work in pulling together an absolutely wonderful event. It was a memorable occasion!

Genome Atlantic sponsored a fantastic reception in the absolutely spectacular Hall D (overlooking the Edmonton River Valley) of the Shaw Conference Centre. I would like to thank Genome Atlantic, especially Jill Murrin and Shelley King, for organizing and sponsoring this wonderful event. Fantastic entertainment at the conference banquet was supplied by Edmonton Tourism's Festival City Road Show (presented by TransAlta) and included four diverse acts from the local Edmonton area – a Japanese drumming group, an aerial artist, a jazz group, and a high-energy reggae band. Jennifer Christenson and Chris Foster at Edmonton Tourism are thanked for arranging for the amazing show, which was one of the highlights of the conference for me. I would also like to acknowledge Bob Dunham, also with Edmonton Tourism, for initially showing us around Edmonton and helping with preliminary arrangements for the conference.

To conclude, I would like to thank the AAC membership and the Board of Directors for a great 10-month term as your President. A lot of hard work goes into running the Association behind the scenes and I gratefully acknowledge all the support and efforts of the other AAC officers and directors. I know that I certainly learned a lot during my presidency and I appreciate the experience that I was granted. As I write this, Aquaculture Canada[OM] 2008 has come and gone and we have had another very successful conference. Congratulations to Alistair Struthers, our Past President, and all of his conference and program committee members for pulling together a wonderful event in Saint John, NB. I look forward to the development of the Association over the next year under the leadership of our new President, Debbie Martin-Robichaud. She is already busy with arrangements for Aquaculture Canada[OM] 2009 to be held in Nanaimo, BC. Please make plans to attend this fine city next spring (May 10-13, 2009) for what is shaping up to be a fantastic event. You won’t want to miss it! See you there.

Chris Pearce

AAC President, 2006-2007

Aquaculture Association of Canada – Research Award of Excellence 2007
Association Aquacole du Canada – Prix d'Excellence en Recherche 2007

Richard D. Moccia

Associate Vice-President Research (Agrifood and Partnerships)

Professor and Director, Aquaculture Centre, University of Guelph

Richard Moccia currently holds research and senior management cross-appointments at the University of Guelph, where he has been employed since 1987. He is the Associate Vice-President of Research (Agrifood and Partnerships), as well as Director of the university's Aquaculture Centre and the Alma Aquaculture Research Station – both centres of excellence dedicated to the development of aquaculture science and technology. Rich also holds a faculty appointment as a Professor of Aquatic Science in the Department of Animal and Poultry Sciences and is the Chair of the MSc Aquaculture Program. Professor Moccia has been an enthusiastic member of the Canadian aquaculture sector for nearly 30 years. His career activities have always had a strong focus in research, as well as in education and extension service, in various capacities within the aquatics and fisheries sectors in Canada. Rich is a very student-centred educator, and has advised 32 students in either MSc or PhD programs, and has participated in the committees of over 100 other graduate students. His research career began in the mid-1970s, examining thyroid goiter and neoplasia in Great Lakes fish, using fish and birds as biological sentinels of ecosystem effects and environmental degradation. Rich's more recent research has been directed at industry-related problems and he has dedicated himself primarily to applied studies related to the enhancement of the commercial success of the fish farming industry. These studies are highly varied and span such areas as: applied nutrition, aquatic and fish health, ecotoxicology, environmental impact assessment, reproductive and growth physiology and animal welfare studies related to captive aquatic livestock. Professor Moccia has published widely in journals such as Science, Cancer Research, Journal of Wildlife Disease, Aquaculture, Aquaculture Nutrition, Aquaculture Research, Fish and Fisheries, Environmental Biology of Fishes and many others. Prior to his university career, Rich was President of the Ontario Aquaculture Association, as well as Research Director and Vice-president of an aquaculture technology and fish production company which he co-founded. He also established and ran a private consulting company, which was dedicated to helping farmers with fish health and water quality issues. Rich Moccia was also a founding member of two private-sector, national aquaculture lobbying groups, including the predecessor to CAIA, and was instrumental in helping to position the industry within the government's mandate during the early years of the industry's commercial development in Canada. Professor Moccia is also the holder of a Distinguish Professorial Teaching Award (2002) and a Distinguished Extension Service Award (2004). In his spare time he is an avid hockey player, scuba diver, hiker and coach of minor league sports.

Rich Moccia receives the 2007 AAC Research Award of Excellence from Chris Pearce, AAC President.

AC07 Student Affairs Report

Student Affairs and Events / Affaires étudiantes

The AAC is pleased to have sponsored travel for the following six students to attend the conference and AGM:

Guillaume Dagenais – *Université Laval;* Erin Friesen – *University of British Columbia*; Matthew Liutkus – *University of New Brunswick, Saint John*; Melanie M. Mamoser – *University of Victoria* Joanne Power – *University of New Brunswick, Fredericton*; Michelle Wetton – *University of Manitoba*

Student Travel Awards were sponsored by the Atlantic Provinces Council for the Sciences Aquaculture Committee and the Canadian Aquaculture Industry Alliance.

Best Oral Presentation (Erin Friesen, UBC, left photo) and Best Poster Presentation (tie)(Thomas Ho, UBC, right photo) and Kris Osuchowski (tie)(no photo). Awards were sponsored by the Aquaculture Centre, University of Guelph and Aqua Health, and were presented by Prof. Rich Moccia.

Joe Brown BBQ in Support of AAC Students / le BBQ aquacole –

Conference participants came together at the annual Joe Brown BBQ which was held at the historic Rose and Crown Pub a couple of blocks from the Shaw Conference Centre. Opened in 1978, the Rose and

Crown was Edmonton's home to the famous, infamous, and downright local. Waylon Jennings, Johnny Cash, Rick Moranis, and Tom Jones have all joined the rousing sing-a-longs and quaffed quantities from the great selection of beer and scotch. This year the BBQ featured the first ever Aquaculture Idol contest! The BBQ was combined again this year with an auction in support of the AAC Student Endowment Fund (SEF).

Aquaculture Canada^{OM} 2007 – Committees

Aquaculture Canada^{OM} 2007 – Comités

Executive Committee

Chair: Chris Pearce (AAC President) – Fisheries and Oceans Canada
Cyr Couturier – Fisheries and Marine Institute of Memorial University
Chris Hendry – Newfoundland and Labrador Department of Fisheries and Aquaculture
Linda Hiemstra (AC07 Conference Organizer) – Mel Mor Science

Program Committee

Chair: Chris Hendry – Newfoundland and Labrador Department of Fisheries and Aquaculture
Linda Hiemstra (AC07 Conference Organizer) – Mel Mor Science
Eric Hutchings – Alberta Agriculture and Rural Development
Mark McNaughton – Alberta Aquaculture Association
Rich Moccia – Aquaculture Centre, University of Guelph
Jason Nichols (AAC Webmaster) – Marine Institute of Memorial University
Mia Parker – Grieg Seafood
Chris Pearce (AAC President) – Fisheries and Oceans Canada
Rod Penney – Canadian Food Inspection Agency
Alistair Struthers – Canadian Food Inspection Agency
Grant Vandenberg – Université Laval

Local Organizing and Sponsorship Committees

Chair Organizing Committee: Chris Pearce (AAC President) – Fisheries and Oceans Canada
Chair Sponsorship Committee: Cyr Couturier – Fisheries and Marine Institute of Memorial University
Chris Hendry – Newfoundland and Labrador Department of Fisheries and Aquaculture
Linda Hiemstra (AC07 Conference Organizer) – Mel Mor Science
Eric Hutchings – Alberta Agriculture and Rural Development
Terralynn Lander – Fisheries and Oceans Canada
Mark McNaughton – Alberta Aquaculture Association
Alistair Struthers – Canadian Food Inspection Agency
Grant Vandenberg – Université Laval

Communications Committee

Chair: Linda Hiemstra (AC07 Conference Organizer) – Mel Mor Science
Tim DeJager – co3 Consulting
Eric Hutchings – Alberta Agriculture and Rural Development
Chris Pearce (AAC President) – Fisheries and Oceans Canada
Joy Wade – Fisheries and Oceans Canada

Aquaculture Canada^{OM} 2007 – Partners and Sponsors
Aquaculture Canada^{OM} 2007 – Partenaires et Commanditaires

Co-Hosts

- Aquaculture Association of Canada
- Alberta Agriculture and Rural Development
- Alberta Aquaculture Association
- Interprovincial Partnership for Sustainable Freshwater Aquaculture Development

Diamond Sponsor ($5,000+)

- Agriculture & Food Council of Alberta and Agriculture and Agri-Food Canada, Advancing Canadian Agriculture and Agri-Food (ACAAF) Program
- Alberta Agriculture and Rural Development, Agri-business Expansion Program
- Canadian Aquaculture Industry Alliance, Canadian Agriculture and Food International Program
- Fisheries and Oceans Canada, Aquaculture Collaborative Research and Development Program
- Genome Atlantic

Gold Sponsor ($1,000-$4,999)

- Aquaculture Centre, University of Guelph
- Atlantic Provinces Council on the Sciences
- Canadian Aquaculture Industry Alliance
- Grieg Seafood
- Interprovincial Partnership for Sustainable Freshwater Aquaculture Development
- Réseau Aquaculture Québec
- La Société de Recherche et de Développement en Aquaculture Continentale

Silver Sponsor ($300-$999)

- Alberta Pulse Growers
- Saskatchewan Pulse Growers

Food Sponsors/Donors

- Agassiz AquaFarms
- Alberta Elk Commission
- Aquaculture Centre of Excellence, Lethbridge College
- Bay Enterprises Ltd.
- BC Shellfish Growers Association
- Cooke Aquaculture Inc.
- Cunningham's Scotch Cold Smoking
- en Santé Orchard & Winery
- Global Aquaculture Consultants
- Icy Waters Ltd.
- Lakeland Wild Rice

- MDM Aqua Farms Ltd.
- North America Tilapia
- Pentlatch Seafoods Ltd.
- Taylor Shellfish Canada
- Thundering Ground Bison Ranch
- Wild West Steelhead

Silent Auction Donors

- Ackenberry Trout Farms
- Alberta Agriculture and Rural Development
- Alberta Aquaculture Association
- Alberta Elk Commission
- Alberta Food Processors Association
- Atlantic Genome
- Atlantic Veterinary College
- Ben’s Beef Jerky & JT Foods Co.
- Canadawide Scientific
- Canadian Aquaculture Industry Alliance
- Champion Petfoods Ltd.
- Chris Pearce
- Cooke Aquaculture Inc.
- Corey Aqua
- COWS Ice Cream
- Delta Saint John
- Eric Hutchings
- Field Stone Fruit Wines
- Fisheries and Oceans Canada, Pacific Biological Station
- Fundy Textile & Design Ltd.
- Genome Atlantic
- Hilltop Maple Products
- Hoskin Scientific Ltd.
- IMP
- Jack Taylor
- Jay Parsons
- Joe Brown Family
- Lakeland Wild Rice Ltd.
- Lammle’s Western Wear & Tack
- Leckie’s Lakefish Net & Twine
- Lethbridge College
- Linda Hiemstra
- Marine Institute of Memorial University
- Mark's Work Wearhouse
- Marmot Basin Ski Hill, Jasper
- MDM Aqua Farms Ltd.
- Mike Strong / Maria Buzeta
- Nancy House
- Newfoundland Aquaculture Industry Association
- PEI Dirt Shirt & No White Dogs
- Peter Chettleburgh
- Quarter Master Marine
- Rainbow Net & Rigging Ltd.
- Rene Trudel – Korite International Ltd.
- Rich Moccia
- Rockport Flour Mills Inc. & Tree of Life Canada
- Rockport Hutterite Colony
- The Rose & Crown Pub
- Shawn Chase
- Shawn Robinson
- Smoky Trout Farm
- Susan Waddy
- UNB Fredericton
- UNB Saint John
- United Farmers of Alberta (UFA) Co-op
- UPEI Bookstore
- Victor Chrapko – en Santé Orchard & Winery
- Western Freshwater Aquaculture Association
- Westin Edmonton
- Wolfhead Smokers Ltd.
- World Aquaculture Society

Aquaculture Association of Canada – Board of Directors 2006/2007
Association Aquacole du Canada – Conseil d'administration 2006/2007

Aquaculture Canada^{OM} 2007 – Keynote Address
Aquaculture Canada^{OM} 2007 – Discours Programme

Honorable A. Brian Peckford, P. C.

"My trade is to say what I think." Voltaire

Personal

I grew up in rural Newfoundland in the 1950s and 1960s.

I worked as a university summer student from 1961 to 1966 with the provincial department of social services in various parts of rural Newfoundland, especially isolated regions of the island and Labrador.

I salmon fished in Labrador and worked briefly in the logging industry.

I taught high school in rural Newfoundland.

My grandfather was a fisherman for 50 years and went to the seal hunt for 49 years. It is reported that he had the first motorized boat in Newfoundland's inshore fishery. In other words, he embraced new technology while developing a natural resource.

I visited a salmon farm on the Norwegian coast in 1976 and in the 1990s worked on a consulting basis for an Icelandic Aquaculture Enterprise.

Additionally, as some of you know, I was Minister of Mines and Energy in Newfoundland from 1976 to 1979. What some of you may not know is that during part of that time I was also Minister of Rural Development.

And, of course, I served as Premier from 1979 to 1989.

And the Government that I led introduced Newfoundland's first Aquaculture Act in 1987.

Introduction

I have been asked to speak on The Challenge to Develop Aquatic Resources to Secure Economic Prosperity while maintaining social approval. And, of course, I am to do that within the context, however loosely or tightly defined, of your theme of Securing Sustainable Economic Prosperity. This may be a tall order, but I guess if I define the terms at the outset, then I can move on.

I am not an ideologue.

While I love literature, philosophy, and economic history, and learn from them, I am not inextricably wedded to this or that point of view. I have leanings, but find fixed positions, ah…too fixed.

In the pursuit of everyday matters I am a practical person. I am impatient and like to make decisions.

I like balance.

I was very involved in getting offshore oil and gas development going off Newfoundland and Labrador. At the same time, I created the First Department of Environment.

I was very involved in getting the large, bankrupt (at the time the largest bankruptcy in Canadian history) Come by Chance refinery restarted. At the same time, I introduced the first legislation of its kind in the province to establish wilderness and ecological reserves.

Nor am I an alarmist!!!

I do not believe that the evidence supports a view that we are heading for an unsupportable population, that ecological disaster is just around the corner, or that pollution is getting worse. Acid rain had minimum effect on trees and DDT should never have been banned, contributing to the death of millions of African lives.

It is undeniable that on the earth in 1900 one could expect to live to age 30.

Today it is 67.

As Lomborg (Bjørn Lomborg, page 352, The Skeptical Environmentalist) says, “Children born today – in both the industrialized world and developing countries – will live longer, and be healthier; they will get more food, a better education, a higher standard of living, more leisure time and far more possibilities without the global environment being destroyed.”

Neither do I believe in many of the narrow definitions given to the words “sustainable” or “the precautionary principle” by the United Nations and other international bodies. Philosophically, Jeremy Betham (The Works of Jeremy Betham, J. Bowring, 1843, page 321) may have said it best when he exclaimed, “Can it be conceived that there are men so absurd as to prefer the man who is not to him who is.”

Discussion

Development of all types is a part of the human condition. And responsible development provides improvement to that condition.

Resource development is very much a part of Canada’s development as a nation. Without it our present standard of living would be third world. And let’s hope that future development will include, as it seems to now, aquaculture as an integral part of that. However, it is likely that it will not happen automatically.

Here are a few actions/initiatives that, as I look back, guided the early years of success in getting offshore oil and gas on the development radar in a positive way that may have some relevance to our subject today.

1. Pro active or being out front. Before the first major discovery was made and announced, the provincial government was talking about offshore oil and gas, and doing something about it. For example, a document entitled Heritage of the Sea was prepared that went to every household explaining both the jurisdictional issues but, as well, explaining some of the technical aspects of the industry. A Petroleum Directorate was established in the Department of Mines and Energy with real people who knew a lot about offshore oil and gas and regulations concerning offshore were promulgated.

2. Champions. Early on there were public champions for offshore oil and gas development. They included especially the Minister of Mines and Energy, but not exclusively. Key members of the petroleum directorate elaborated and were out in public advancing the issue. And a pro-active industry association was formed that was of great assistance in its advocacy.

3. Science. Great reliance was given to science and facts of offshore oil and gas exploration and development. Studies were done by local reputable scientific bodies. For example, a then established scientific agency known as NORDCO completed a study on fixed platforms as a mode of production.

4. Constant reference to success stories in other jurisdictions. Newfoundland was lucky that Norway and the U.K. had preceded it in offshore production and, given their Atlantic setting, the province was able to use real concrete examples of positive results in employment, research and development, education, royalties, and real local positive benefits in Aberdeen, Shetland Islands, and Stavanger.

5. When discoveries did occur, and commercial production was viable, a certain and definite framework was in place federally and provincially to see that an orderly process of public hearings to examine all aspects of the development occurred; that is an Atlantic Accord detailing of principles and leading to legislation.

Now it is true that the setting in Newfoundland of the late 1970s and early 1980s was more conducive to development, given the province’s economic circumstance, than in some other Canadian jurisdictions, that it was highly focused and that it was centered in one place. Yet there were the doomsayers, both within the political class and generally, who saw this as either another corporate grab, environmental devastation, or a sure way to destroy the fishery. David Suzuki even blessed us with a visit with the CBC and their collective negativity in tow. Even as late as 1990, when the Hibernia project got the green light, there were serious doubters like a prominent local economist who said it would do nothing to help the average Newfoundlander and a Calgary oil analyst who said even more money would be needed. Of course, both have proven to be wrong, and they were the experts. Surprisingly, they are still active and described as experts today.

However, I submit that a number of new developments have significantly changed the landscape.

The growth and intense irrational alarmism of the environmental movement and the anti-globalization movement have affected the resource development industry in ways that were not present years ago, either delaying reasonable development or, in some cases, seeing such developments cancelled altogether. And what is most tragic in all this environmental alarmism is the politicizing of science that has resulted. Both the IPCC Reports and the Kyoto process are ripe with policy guised as science. Predictions are seen as fact, correlation is seen as causation and complexity is given little attention. Political words like "majority" and "consensus" are erroneously used in a scientific context. As Dr. Fred Singer, former director of the U.S. Weather Satellite Service, atmospheric physicist, and professor emeritus of environmental sciences at the University of Virginia has observed:

"Unlike in politics, majority does not rule. Rather, every advance in science has come from a minority that found that observed facts contradicted the prevailing hypothesis. Sometimes it took only one scientist. Think of Galileo and Einstein."

Listen to a recent comment from Freeman Dyson, professor of physics at the Institute of Advanced Study at Princeton University:

"In the modern world, science and society often interact in a perverse way. We live in a technological society, and technology causes political problems. The politicians and the public expect science to provide answers to the problems. Scientific experts are paid and encouraged to provide answers. The public does not have much use for a scientist who says, 'Sorry, but we don't know'. The public prefers to listen to scientists who give confident answers to questions and make confident predictions of what will happen as a result of human activities. So it happens that the experts who talk publicly about politically contentious questions tend to speak more clearly than they think. They make confident predictions about the future, and end up believing their own predictions. Their predictions become dogmas which they do not question. The public is led to believe that the fashionable scientific dogmas are true, and it may sometimes happen that they are wrong."

Additionally, the role of First Nations, as a result of several Supreme Court of Canada decisions, has changed forever how development is to occur on land in which First Nations have or think they have an interest.

So we need to clearly define and agree to our "present reality".

Parenthetically, the doom and gloom associated with the Alarmist movement is hardly new. To hear some, you would swear it was a very recent concept. Let me remind them that there is an Assyrian tablet, many thousands of years old, on which is written, "Our earth is degenerate in these latter days…" and the notion of the past was so good often implied in the alarmists rhetoric is ever present. The Scottish philosopher, David Hume, exclaimed in 1754, "The humor of blaming the present and admiring the past is strangely rooted in human nature and has an influence even on persons endued with the profoundest judgment and most extensive learning."

The first component of the new reality is, as I have already alluded, environmental alarmism. Michael Crichton was one of the first to coin the phrase "environment as a religion" in a courageous speech in 2003. Here is part of what he said that I think bears repeating:

"Today, one of the most powerful religions in the Western World is environmentalism. Environmentalism seems to be the religion of choice for urban atheists. Why do I say it's a religion? Well just look at its beliefs. If you look carefully, you see that environmentalism is in fact a perfect 21st century remapping of traditional Judeao-Christian beliefs and myths. There is an initial Eden, a paradise, a state of grace and unity with nature, there's a fall from grace into a state of pollution as a result of eating from the tree of knowledge, and as a result of our actions there is a judgment day coming for us all. We are all energy sinners, doomed to die, unless we seek salvation, which is now sustainability. Sustainability is salvation in the church of the environment, just as organic food is its communion, that pesticide free wafer that the right people with the right beliefs imbibe."

This zealotry found practical, local expression in our country this year with the conviction of an environmentalist in the Supreme Court of BC of defamation for written statements made about a salmon farming enterprise. The judge found that the guilty party "withheld facts" and "was motivated by actual malice".

The second component of the new reality is the utter failure of the mass media to respect facts, context, science and reason. We see it every day. Almost daily, people give me a certain position on an issue of the day and I respond, "Do you know this to be true?" or "Do you have some independent information to support that position?" "Oh yes, yes…it was just on the radio or TV or I just read it in the paper." John Stossell, of the ABC News program 20/20, says in his book *Myths, Lies and Downright Stupidity* that "when it comes to science and economics, and putting life's risks in perspective, the media does a dismal job." He goes on to describe his first myth: "The media will check it out and give you the objective truth." Reality: "Many in the media are scientifically clueless and will scare you to death." He speaks of the insiders' joke about newscasts, "If it bleeds, it leads." Daniel Boorstin, in his brilliant essay entitled "A Flood of Pseudo Events" (from the book *Hidden History*), describes in depth the profound changes that have taken place in the presentation of events and so-called information to the public – how the usual easy distinction between sham and reality is no longer an easy one and that the people's preference for sham over reality is now complete. Let me quote:

"The American citizen thus lives in a world where fantasy is more real than reality, where the image has more dignity than its original. We hardly dare face our bewilderment because our ambiguous experience is so pleasantly iridescent, and the solace of belief in contrived reality is so thoroughly real. We have become eager accessories to the great hoaxes of the age. Theses are the hoaxes we play on ourselves."

And more often than not the media are on the side of the anti-development and anti- globalization forces and almost celebrate the pseudo-scientific rampant alarmism.

Take a recent example in BC where an escape of some Atlantic salmon from a farm brought the following headline: "Salmon escape raises alarm over open net cages". The story does not substantiate the headline!!! The only source quoted is an environmental group opposed to open net-cage farming. Using a source that is clearly prejudiced surely discounts the objectivity of the story. Does this prove that the use of the word "alarm" was justified? Of course not!!! The Globe and Mail carried stories and pictures last year about a certain aquaculture enterprise using outdated information and never once talked to the enterprise involved. This type of lazy, unprofessional journalism has infected the fourth estate and cheapens its vital role in a free and democratic society.

Here is what we are up against: The American Opinion Research Inc. in 1993 asked reporters to answer the following question: "Which of the following sources do you use most for data and information about the environment?" For all media it was 25% from environmental activist groups, 8% from academics, universities and professional journals, 3% business or industry executives or press releases, and 1% company or industry publications. And, of course, since then it has not improved.

A third component of our Canadian reality is that the power structure of our federation has changed. Where once there were relatively clear lines of authority and jurisdiction among the three levels of government we now have a more asymmetrical federalism where responsibilities are blurred. Of course, this has allowed for each level of government to multiply the sources of its involvement and cause overlapping, duplication and often confusion. This has been exacerbated in recent times with all levels of government in a frenzy to show their environmental bona vides. A recent application in BC for aquaculture activity sees at least 15 separate pieces of legislation coming into play and innumerable regulations.

A fourth interesting development is the apparent different ways the aquaculture industry is viewed in different parts of the country. Using governments' identification, it is interesting to note that the three Maritime provinces and Newfoundland and Labrador have the word "aquaculture" as a part of the name of their Fisheries Departments. On the other hand, the province that has the most aquaculture activity, British Columbia, does not have a Fisheries Department, Fisheries and Aquaculture being subsumed in the Department of Agriculture and Lands and shown as a division of the Department and the Federal Government, whose involvement is substantial right across the nation, uses the term Fisheries and Oceans Canada with aquaculture a division of it. This seeming east pro-development profile versus a west ambivalent profile finds itself further manifested in Newfoundland's (and Nova Scotia's) approach to offshore oil and gas exploration versus British Columbia's approach, with the former now producing 50% of Canada's sweet crude (without any significant environmental incident from 10 years of production and almost 40 years of exploration involving over 600,000 square miles of continental shelf, twice the area of this Province) and the latter's offshore still under moratoria. What's in a name? What's in a word? However one wants to spin it, it says something. What do we use words for?

I have spent some time defining the landscape, since unless we get the reality clear it will be impossible to effectively deal with it.

I listed earlier, some concepts and factors that assisted in getting development going in offshore Newfoundland in the 1980s and, of course, some of these are still operative today in your context. Let me now add to some of these and elaborate on some already mentioned.

Ideas and Recommendations

1. Governments. Given the increased role of governments and their inter-connected authorities it seems to me an imperative to develop more streamlined processes for advancing the industry. This is always talked about in many fields of government involvement and timid attempts are made from time to time. Sometimes the attempts get more complicated than the processes one is trying to simplify. I don't know if this is a particular Canadian phenomenon or not, but somehow ways and means must be found to respect safety, the environment, the public and still get to a decision in a timely manner. It was one of the things that most frustrated me in government and since. But, you know, there is way and here is an example. In the Atlantic Accord that I helped finalize, which was the framework to govern all exploration and development of hydro-

carbons on the continental shelf, there was a process of 270 days specified for projects, which would involve a Commissioner and panel and public hearing. And this was like aquaculture – a joint federal/provincial matter. And what do I mean by 270 days? The Accord says, and I quote, “Not more than 270 days shall elapse between the receipt of the plan by the Board and its decision with respect to the plan.” I am talking about projects costing billions of dollars in the North Atlantic.

I realize that there are memos of agreement between the federal government and the provincial governments, but often within each government, departments to whom referrals are made do not move in concert with the lead department and much time, energy, and money by an applicant is made chasing down responses needed for their application. A super government coordinator (one for both governments) seems to be needed and obligatory time frames, to which department and agencies must adhere or face penalties like frozen budgets for a few years.

2. Science, research and development. Nothing trumps good science and, as I said earlier, nothing is as destructive as politicized science. In aquaculture we are seeing a lot of those opposed to the industry using the latter type. This is perhaps the most important subject for the future of aquaculture. What is needed is independent science of the kind Crichton describes:

“In essence, science is nothing more than a method of inquiry. The method says an assertion is valid and merits universal acceptance only if it can be independently verified. The impersonal rigor of the method means it is utterly apolitical. A truth in science is verifiable whether you are black or white, male or female, old or young. It’s verifiable whether you like the results of the study or you don’t.”

Now, it seems to me that what has been happening too often in today’s aquaculture world is that those who are negative and alarmist with bits of science or biased “science” make statements, usually with highly-charged rhetoric, that are carried by a gullible and lazy press and in no time become fact. Those on the other side are slow to respond, often have poor spokespersons or say nothing at all. I am afraid if this is to be reversed then research institutions/universities must become very much a part of the debate. In almost all fields these days, scientists and think tanks are speaking out and providing reason and intellectual rigor in the public square. Proponents and governments are seen as biased and, while they can and must continue to do their part, support from the research and scientific community is vital. And, in matters of crucial public policy, it does not behoove those in academia to espouse silence in the name of independence. They must speak to where the science has led them. I note from my research that attempts are being made to establish some independent information on the web in a project called Aqua Port. This is to be commended and while it is mainly targeted at those in the industry it must also become a portal for the public to learn.

In addition, I think you will agree that there is a difference between science and R&D or pure and applied research as it relates to aquaculture. There are ongoing biological questions that must be studied and resolved that may not see any change to a bottom line any time soon, and there are other more practical questions of sighting, materials, feed, etc. that depend on innovation and applied R&D.

We are not very good when it comes to R&D in this country. Listen to this statement: “Canada’s R&D infrastructure is not well aligned with requirements for upgrading. Too much R&D spending takes place through government laboratories. The links between publicly funded research institutes and industry are poorly developed. The supply of highly qualified personnel may be inadequate for future research needs.” This statement was made in 1991, 16 years ago (Michael Porter study). Let me give you a further statement: “Canada scored a D grade on innovation, 4th to last in a seventeen country comparison.” This statement was made in June, 2007 (Conference Board of Canada). It looks like little has happened in 16 years. R&D reminds me sometimes of foreign aid –there seems that there is a lot of money spent, but I am unsure how much is going to the right places for the right projects. Of course this leads to my third point.

3. Collaboration. Equally important in your field is the importance of collaboration. For R&D to be effective there needs to be tremendous collaboration between industry, government and academia. The C.D. Howe Institute – in a paper this year on Innovation, Competition and Growth – made the following point:

“Without sacrificing academic values that sometimes conflict with commercial interests, Canadian universities should continue to develop ties with private enterprise, to see that innovation turns into adopted technologies.”

Now I am not a part of the aquaculture industry and I have not had a chance to fully explore this area in depth. I note that the Aquaculture Collaboration Research and Development Program of DFO seems to be working. The Strategic Review of 2005 of this program was positive on the program. I do not know how it has worked since then. The amount of money, however, seems meager to me. And I am unsure how agencies like the Aquaculture Alliance and Aqua Net are working. I sense that there are problems. Just let me say this. Without an integrated approach to science and pure and applied R&D (*i.e.* government, industry and academia across the nation), the lack of progress made generally across the nation, as described by the Conference Board just mentioned, is likely to apply to your sector as well over the coming years. Some questions have to be asked: Are present collaborative efforts across the country in R&D sufficient? If not, what needs to be done to correct this? Is there need for a small national body to properly co-ordinate the R&D projects? Is there a need to ensure appropriate balance between pure and applied research? Are funds being fairly distributed across the nation?

4. Industry action. Given the more blurred nature of governmental responsibilities, it is even more imperative than ever that applicants/investors understand completely the power structure of the governments politically – the policy process; who really is in charge, politically and bureaucratically; where are the buttons to push and how and when to push them. One of the big surprises for me, when I first entered business consulting, was the degree of ignorance that existed in business as to how governments actually worked. Of course, the larger the government, the more tangled the process is likely to be. Hence, a lot of my consulting was informing clients of how to deal with governments. It seems that in the east the understanding of the government process and how to weave through the government maze is more efficient than in the west. Additionally, the industry needs quick response time and more pro-active actions concerning its activities and a major commitment to R&D.

5. I have left the best for last. PR, marketing and getting out the message!!!!

It seems that, looking from the outside, few in the public at large have much appreciation for aquaculture and that what little they might have is negative. Now I was encouraged that my perceptions had validity when I read the results of research commissioned by Fisheries and Oceans Canada and placed on their website entitled "Qualitative Research Exploring Canadians' Perceptions, Attitudes, and Concerns Towards Aquaculture". Here are a few quotes from that study:

"Overall, findings reveal a great deal of consistency across regions, and respondent types. Top of mind awareness of aquaculture was generally low, with pockets of greater familiarity and particular understandings in the coastal areas."

"It is clear that the minds of respondents are dominated by doubts and fears about food safety and environmental safety, primarily brought on by negative media coverage and to a lesser degree, by personal observation of environmental degradation."

"Negative perceptions seemed to fall along a continuum, moving from east to west, with the east tending to be positive, the central areas of Ontario and Quebec took on more of a neutral tone, and pockets of the west showed a stronger negative bent."

If you believe my description of our reality, and in light of the other things I have said, I would be concerned that the negativity so prevalent in the west will find its way to the east. The image needs to be improved. And if you are to get governments to move in the long run on a consistent basis, a more informed and hence supportive populace will be necessary.

I am reminded of my involvement with perhaps the only international pro-sealing campaign on record. In the late seventies the federal government, after intense pressure from Newfoundland, agreed to try and stem the negative tide on the east coast seal hunt. I was somehow cajoled (no one else could be found to do it) in heading up this monster and to travel with a group of PR professionals and some scientists around the world. We went to Washington and many of the western European capitals preaching the gospel of a humane and necessary fishery, holding press conferences, talking to governments and other organizations. From Good Morning America to the BBC, we carried our message.

Perhaps short of a swat team, I would recommend the following for the aquaculture sector:

A. A national PR campaign be launched. Hopefully all stakeholders would contribute financially.

B. A small, dedicated, articulate working group would be established.

C. This group would consist of representatives of government, industry and science –three would be ideal.

D. They would have on call other qualified, identified individuals to act as a resource to provide backup when needed.

E. The campaign would be launched and explained at a national press conference in Ottawa.

F. Then beginning either in Victoria or St. John's this group would travel to every provincial capital, holding a press conference to further explain and elaborate on what was said at the national press conference and give that province's involvement in aquaculture and its importance, etc.

G. The group would try and get on as many radio open-line shows as possible and meet with the editorial boards of the newspapers in that capital and with the most influential columnists in that capital or province .

H. The group would also meet with relevant provincial ministries, research institutes and universities.

I. Meetings with national papers' editorial boards (National Post and the Globe and Mail and national magazines like McLean's).

J. A first class website that can be referenced in all press conferences and made understandable for the ordinary citizen.

I am sure you get my drift. Obviously there are other details (a follow-up permanent PR strategy would be imperative) that would need to be worked out.

Now, this might be too radical for some, but I see no other way for your sector to get the public's and governments' attention to the extent that the people become better informed and that governments are willing to actively embrace this sector as one of the components of economic policy for the future.

After this, life will never be the same.

The sector will be active not reactive, as is the case now.

Solid science will be seen as an integral part of the public perception of the sector, as opposed to the one-sided part science of alarmists who oppose you.

You will have a more informed media and populace, although it will have to be constantly fed, as your opponents are now doing.

You will have a significantly better chance of seeing the sector grow and prosper.

Conclusion

Michael Porter, of the Harvard Business School, did a study on Canadian competitiveness in 1991 that was financed by The Business Council on National Issues and the Government of Canada. One of the more prominent recommendations was:

"Build on Canada's regional strengths. Many government policies in Canada have put a higher priority on economic diversification than on competitive advantage. A different concept of regional and industrial development is needed, one that focuses on building industry clusters where they already have established or nascent strengths."

Surely one of these clusters is aquaculture.

And the UN says aquaculture will continue to grow globally.

And Fisheries and Oceans Canada says Canada has the potential to be in the top three global competitors in aquaculture production.

We have got a lot of work to do, so let's get on with the job.

Appendix

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A Poverty of Reason: Sustainable Development and Economic Growth. *Wilfred Beckerman*

The Skeptical Environmentalist: Measuring the Real State of the World. *Bjørn Lomborg*

The Intellectuals. *Paul Johnson*

But Is It True?: Citizen's Guide to Environmental Health and Safety Issues. *Aaron Wildavsky*

State of Fear. *Michael Crichton*

<u>Hidden History: Exploring Our Secret Past</u>. *Daniel J. Boorstin*

Myths, Lies, and Downright Stupidity. *John Stossel*

Conference Board of Canada website

C.D. Howe Institute website

Fisheries and Oceans Canada website

Aquaculture Association of Canada

Websites on aquaculture of all the provincial governments

FAO of the United Nations website

Other aquaculture websites in Canada and abroad

Canada at the Crossroads. Study by Professor Michael Porter and Monitor Company

Is Scallop (*Placopecten magellanicus*) Aquaculture and Enhancement Economically, Viable in the Gulf Region?

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In the Gulf Region, various aspects of scallop aquaculture and enhancement have been studied since the early 90's. Projects were launched with industry partners, federal and provincial governments along with many funding agencies regarding the sea scallop (*Placopecten magellanicus*). Only recently has sufficient data been accumulated to predict the economical viability of the activities in question, however these predictions have not been tested.

OVERVIEW OF GULF REGION INVESTIGATIONS

In the Gulf Region, there is a commercial scallop fishery and there are slightly over 700 licence holders. For management purposes, the Region is separated into Scallop Fishing Areas (SFA) 21A, 21B, 21C, 22, 23 and 24 (Figure1). In the late 60's and early 70's, the commercial scallop landings peaked but have been low since then. The low landings do reflect the reduced population density of scallops in the Gulf Region. Scallop aquaculture and enhancement studies began in the early 90's as a reaction to this decrease. Projects were developed and conducted by the industry, the federal and provincial governments. Industry partners include: Botsford Professional Fishermen's Association, Maritime Fishermen's Union, Northumberland Strait Diversification Sea Scallop Research Group, and Gulf NS Bonafide Fishermen's Association**.** Also, Universities such as: Memorial University, University of New Brunswick, Université de Moncton and St. Francis Xavier University, were implicated in many projects. Agencies that funded the various projects include: Atlantic Canada Opportunities Agency (ACOA), Antigonish Regional Development Authority (ARDA), Aquaculture and Fisheries Research Initiative Inc. (AFRI), PEI Atlantic Shrimp Corp Inc. (PEIASC), New Brunswick Training Group Inc. (NBTGI), National Research Council (NRC) and Industrial Research Assistance Program (IRAP).

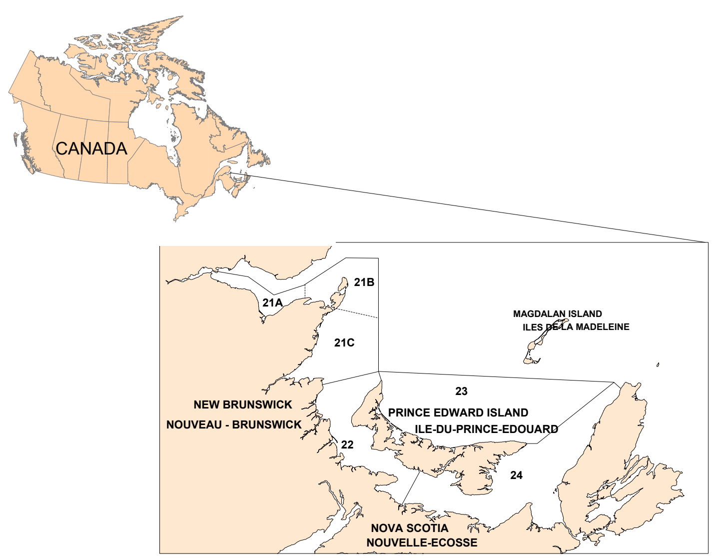

Figure 1. Scallop Fishing Areas 21A, 21 B, 21C, 22, 23 and 24 in the Gulf Region.

Major hurdles were overcome before attaining the knowledge we have today. Locating the ideal scallop spat collection sites required many years of investigation. We utilised the Japanese collector bags. However, we developed a long line technique and anchoring system more suitable to our environment. Scallop enhancement and culture investigations conducted in the Gulf Region also involved the transfer of Japanese know-how. We have successfully enhanced sections of existing scallop beds but have not been able to create new beds. The first harvest was conducted in 2006 on a 1 Km^2 section that had been seeded in 2001. The value of the harvest was nearly $8K and estimates predict that the harvest of the next 1 Km^2 section will yield $16K. The research investment was about $20K for each 1 Km^2 seeded. The local corporation of fish harvesters are confident that they can reduce the cost and make a profit. Presently, a project has been launched to transfer the knowledge acquired from research to the local corporation, in hopes to incorporate enhancement activities in the management strategies of the commercial scallop fishery.

We have tried imported culture gear such as the Chinese lanterns and the pearl nets. Also, we experimented with oyster tables and Aquamesh™ cages using Vexar™ bags. Aquamesh™ is a plastic coated wire mesh that is often used to make lobster traps. Vexar™ bags are black plastic rectangular mesh bags that are often used in oyster culture. The Aquamesh™ cages are constructed to hold 4 or 5 Vexar™ bags (Figure 2). Pecten UPM/MFU Inc. also created their own lanterns using Aquamesh™ and Vexar™, calling them Pekten lanterns.

Figure 2. Aquamesh™ cage

Great losses of gear and time were encountered during many investigations. However, we presently feel that we have mastered most techniques. Preliminary calculations, using the data obtained through research studies, indicate that a marginal profit could be achieved if scallop aquaculture was commercially practiced in the Gulf Region. The grower would need to target an annual production of at least 1 million scallops. Start up cost would be approximately $1.3M and there would be no income for the first three years. The enterprise would employ 9 people for 22 weeks and would require a 2 Km^2 (200 ha) culture site with suitable environmental parameters.

An ongoing challenge is the social management of the activities. All the studies were done on a small scale. Results indicate that economical viability can be achieved if activities were to be conducted at a much larger scale. However, management strategies required to test the activities on a larger scale need to be put in place.

Stress in Eastern Oyster (*Crassostrea virginica*)

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The Eastern oyster (*Crassostrea virginica*) is an important commercial species in the Maritimes and is a candidate for aquaculture in Newfoundland. The present study evaluated the stress responses of farmed oysters held under different storage conditions: 1) fed, 2°C water, 2) unfed, 2°C water, 3) fed, 10°C water, 4) unfed, 10°C water, and 5) air storage (2-4°C)(control). Stress levels were measured using the Neutral Red Retention Assay (NRA), and by measuring condition index and glycogen content of the oysters in each treatment as independent indices of stress. Glycogen content was not related to Neutral Red Retention times, suggesting different stress response mechanisms from these indices. Condition index did not appear to be related to stress levels based on NRA or glycogen. Oysters lost weight in all treatments; however, the levels of stress based on NRA were lower in all treatments compared to control animals. Wet storage appears to reduce the stress response in oysters, with the least stress experienced in oysters held in conditions most closely approximating ambient seasonal temperatures (2-4°C). The NRA appears to be a useful indicator of stress for post-harvest holding conditions in Eastern oysters, however further studies on the seasonality of the response are needed to confirm these findings.

INTRODUCTION

Global aquaculture production of *Crassostrea virginica* is increasing and the species is a candidate for aquaculture activities in Atlantic Canada. Seasonal and short-term environmental changes can induce stress in bivalves, as can farm management activities such as seed grading, or live holding in post-harvesting periods (Harding *et al.* 2004). These stressors may result in reduced product shelflife and quality, lowering the value to the producer. An important aspect of stress management in bivalve aquaculture is early recognition of stress. The Neutral Red Assay (NRA) has been shown to be a useful and sensitive indicator of cellular stress levels in bivalves (Lowe *et al*., 1995a). Stress also appears to be correlated to seasonal episodes of mortality in different species of bivalves. Soletchnik *et al*. (2006) suggested that carbohydrate anabolism contributes to the physiological stress that leads to mortality events. The objectives of the study were to evaluate stress responses in eastern oysters (*Crassostrea virginica*) to post-harvest holding conditions using the NRA and evaluate if stress responses measured by NRA are correlated to glycogen content in tissues of eastern oysters.

MATERIALS AND METHODS

Oysters – live oysters (65-75 mm shell length) were obtained from a commercial supplier, shipped chilled by air (7 days), and placed in a refrigerator at 2°C for a few days until assigned to treatments.

Experiment #1 – wet storage: 4 groups of 55 oysters were held at different water temperatures and food levels for 4 weeks: Group 1- 2°C, Fed; Group 2- 2°C, Unfed; Group 3- 10°C, Fed; Group 4- 10°C, Unfed. 10 oysters were sampled from each treatment at days 0, 15 and 30 and Neutral Red Retention Time (Lowe *et al*. 1995a, Hauton *et al.* 2001) and growth (weight, length, and condition index) were measured. Glycogen (mg/g) content was measured at days 0 and 30 using the Glucose (GO) Assay Kit (Sigma-Aldrich), a colorimetric glucose oxidase/peroxidase for glucose measurement as described in Burton *et al.* (2000).

Experiment #2 – dry storage: 100 oysters were held in moist air at 2-4°C for 21 days and then split in two groups, one group put back in sea water at 2-3°C and fed for 15 days and the second group allowed to remain in dry storage the remaining 15 days. 10 oysters per treatment were sampled at days 0 and 21 and 35. Neutral Red Retention Time, survival, glycogen and tissues (weight and condition index) were measured.

Fed oysters were given a mixture of cultured phytoplankton (*Chaetoceros muelleri, Isochrysis galbana*) every second day, equivalent to 1-2% of wet body weight.

RESULTS

Neutral Red Retention Time: All 4 oyster holding treatments in Experiment #1 showed lower stress levels than the Control (ANOVA, p>0.05, Figure 1A). Stress levels did not vary within a treatment from Day 15 to Day 30 of holding (Fig. 1A).

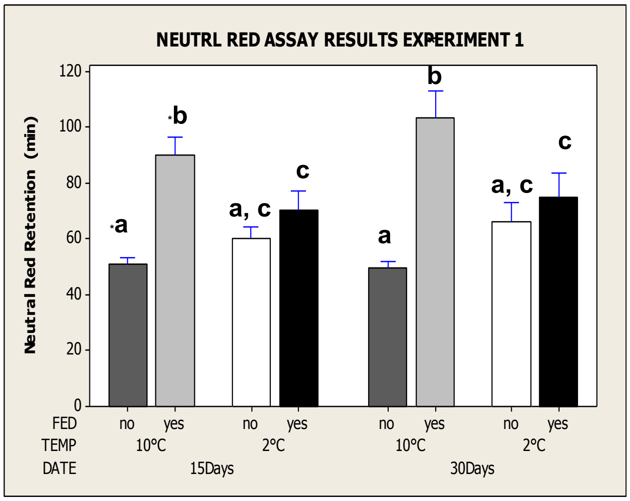

Figure 1: Neutral Red Retention Time in Experiment #1. The higher the value, the lower the cellular stress response. Common letters indicate no significant difference among treatments.

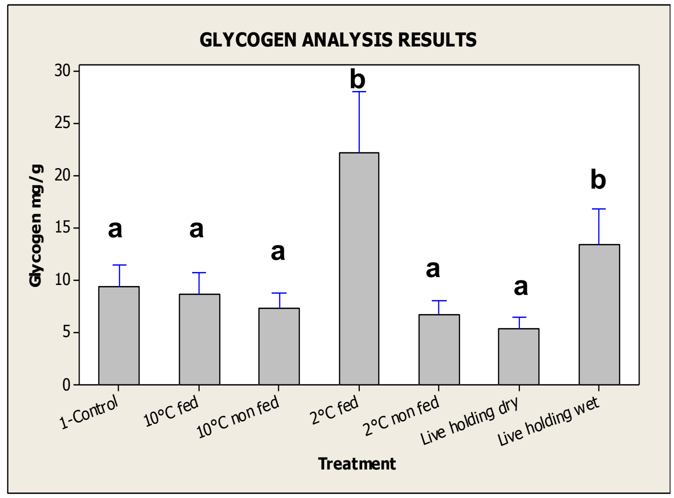

Figure 2: Glycogen results for oysters grouped for both Experiments 1 and 2. Common letters indicate no significant difference among treatments (Tukey b, p>0.05). Bars represent the mean ± S.D, n=10 oysters.

Temperature and day of sampling did not affect the stress response, however food level was significant (ANOVA $p<0.05$, Fig. 1A). Tukey's test showed that fed oysters were less stressed than the unfed oysters at both temperatures ($p<0.001$).

Oysters sampled after 21 days of dry storage were more stressed than Control oysters or oysters reconditioned in seawater for 2 weeks. The oysters held in dry storage for 5 weeks were not statistically different than oysters reconditioned for 2 weeks in wet storage ($p>0.05$, Tukey b).

Growth: Oysters held in wet storage had significantly lower condition indices after 30 days of storage, and all groups held in wet storage had significantly lower condition than control oysters held in dry storage ($p<0.001$, Tukey b). Oysters in group 1 in Experiment #2 had a lower condition index after being reconditioned in wet storage for 2 weeks, than the control group in dry storage for 3 or 5 weeks.

Glycogen analysis: Oysters held at 2°C in wet storage and fed presented the highest glycogen content ($p= 0.002$), and this comparable only to the oysters held for 3 weeks dry storage and reconditioned for 2 weeks (Fig. 2). All other oyster groups (fed, unfed, wet, or dry storage) had significantly lower glycogen content. Glycogen content, Neutral Red Retention Time and oyster condition index were not correlated (Pearson r, $p>0.05$).

DISCUSSION AND CONCLUSIONS

Fed oysters were generally less stressed than unfed oysters (dry or wet storage). Followed the initial stress of transport to the lab, stressed oysters (less than 60 min NRRT) recovered rapidly under wet storage conditions.

The lower condition index in fed oysters in the experiments, compared to the controls, may be explained by excess food levels and the lack of acclimation of the oysters to wet holding conditions. In this respect, the condition index results are in disagreement with the neutral red results, as they denote sub-optimal conditions for oysters held in wet storage during winter compared to the control oysters held in dry (air) storage.

The use of glycogen as a stress indicator in eastern oyster is questioned as no relationship between the two was found. Glycogen remains a good indicator of the general health of oysters; however, it may be correlated to seasonal mortalities in this species. Low wet storage temperatures (2°C, fed) with food were better environmental conditions for the oysters based on maintenance of glycogen levels.

Prolonged periods of dry storage (i.e., more than 2 weeks) may unduly stress oysters and reduce glycogen content. If longer periods of dry storage are considered by industry, a reconditioning period of a few weeks in cold water supplemented with a food source may improve oyster quality.

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The Grass Carp and Tilapias as Biological Control Agents and their Role in Aquaculture for Food Security

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Many problems related to decrease of water flow, sedimentation and harboring the vectors of water-borne diseases, are associated with heavy infestations of aquatic weeds, especially in irrigation canals of agricultural schemes. The grass carp and several species of tilapias are used as biological control agents for aquatic weeds and associated disease vectors. This paper highlights the problems of weed infestations in irrigation canals and lakes, accounts for the biology of the grass carp and tilapias, and their roles in both, biological control of aquatic weeds and aquaculture for food security.

AQUATIC PLANTS OR WEEDS, THEIR PROBLEMS AND METHODS OF CONTROL

In any aquatic habitat, high inputs of nutrients, particularly phosphorous and nitrogen, combined with large areas of clear, shallow water, inevitably lead to excessive growth of algae and aquatic plants (emergent, floating, submersed and rooted plants). Aquatic plants form the basis of the food chain but their excessive growth causes acute problems:

- slow down water flow, increase sedimentation and evaporation loss in irrigation canals;

- impede navigation and recreational activities in reservoirs and lakes;

- harbor the intermediate hosts of human vector-borne diseases like Bilharzia snails;

- enhance mosquito production by protecting its larvae from wave action and predatory fish;

- interfere with aquaculture practices in dugout ponds and open water cage culture;

- cause oxygen depletion and deterioration of water quality.

Excessive aquatic weed growth can be controlled by the following methods**:**

- mechanical method through hand labor and/or machinery;

- chemical method through use of herbicides;

- biological control which involves living organisms to control an animal or plant pest(1,2).

Biology, structural feeding adaptations and breeding of weed-eating fish species

1) Grass carp, *Ctenopharyngodon idella* (Valenciennes, 1844)

The Chinese grass carp “Waan Ue” or White Amur (Fig. 1) belongs to the minnow family, *Cyprinidea*, and unlike other carps, has no barbels at the edge of its mouth. It occurs naturally in the Amur River that forms the border between China and Russia and flows into the Pacific Ocean. It tolerates a wide range of temperature 0-38C, salinity up to10 ppt and extremely low dissolved oxygen level. It has a lifespan of 12-20 years, a weight up to 50 kg and a length of more than one meter. It has a broad head and soft fleshy lips on a toothless mouth. As a “grazer”, it feeds from top downward “mowing” off the vegetation rather than rooting up and mudding the bottom like the common carp, *Cyprinus carpio*. Weeds are sucked into its throat where “pharyngeal teeth” on long arches occur in two rows, the upper with two small teeth and the lower with strong comb-like teeth, 4 on the right and 5 on the left pharyngeal bone. These structures grind food against a hard, horny pad beneath the lower skull (Fig. 2). Juvenile up to 3 cm total length feed on plankton but larger sizes feed exclusively on vegetation. Because it has a short digestive system and no enzymes for cellulose digestion, it eats weeds up to 3 times its body weight daily. About 65% of the eaten weeds are digested and the remainder ejected as dense pellets which act as “green manure” for the water body. Normally, males mature at two years while females a year later. Fecundity is very high, about 730,000 eggs in a fish weighing 3.5 kg. A female spawns naturally only in long, fast-flowing rivers with fluctuating water levels but do not breed in captivity. This problem was solved by induced breeding (hypophysation) producing diploid carps (1,3,4). To avoid possible adverse effects on the aquatic environment, U.S. grass carp breeders produced in 1983 triploid sterile grass carp by physically shocking fertilized eggs with heat, cold or hydrostatic pressure

(1,3,5,6). In 1963, grass carp was introduced into Stuttgart, Arkansas, from Malaysia by the U.S. Fish and Wildlife Service in cooperation with Auburn University, mainly for weed control. In 1987, Duncan Lloyde introduced grass carp into Alberta, Canada from Florida to control weeds in irrigation canals and farm ponds. In 1975, Thomas George introduced the grass carp into Sudan from India for biological control of weeds in irrigation canals and pond polyculture (1,6,7).

Figure 1. The grass carp, *Ctenopharyngodon idella*, with an oblong body, a broad head and soft fleshy lips on a toothless mouth which has no barbels on its edge (Photo by TT George).

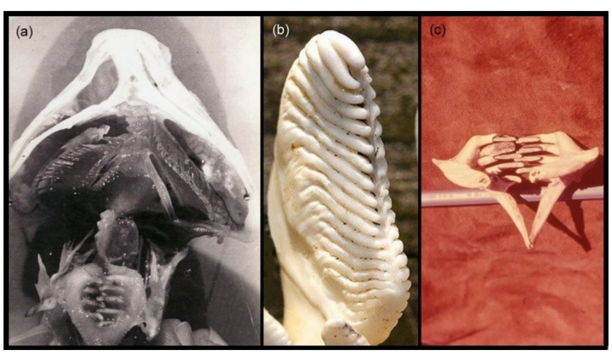

Figure 2. Lower view of grass carp skull (a) showing position of the horny pad (b) and pharyngeal teeth (c) (Photos by TT George).

2) Tilapia or Tilapias

Tilapia, a group of about 100 species known as St. Peter's Fish, Miracle Fish, etc., belong to the Family *Cichlidae* of the Tribe *Tilapiine* and one of three main genera: *Tilapia*, *Sarotherodon*, or *Oreochromis*. Unlike other bony fishes, *Tilapia* has a single nostril on either side of its snout. It is generally more herbivorous, hardy, disease resistant, lives up to ten years and tolerates a wide range of physical and chemical conditions: temperature 8-42C, salinity 42 ppt and extremely low dissolved oxygen level. It has a terminal protractile mouth, jaws armed with teeth and two sets of bones in its pharynx, a complex of three in the roof and a pair on the floor united into a single triangular bone whose upper surface is covered with teeth (Fig. 3). Food passes between the upper and lower pharyngeal bones to be crushed before passed to the stomach and then to a very long, coiled intestine. Sexual maturity is a function of age, size, and environmental conditions. In larger lakes, tilapias mature at a later age and larger size than the same species farmed in ponds.They are sexually dimorphic (larger males) and are either substrate brooders (genus *Tilapia*), or bi-parental (genus *Sarotherodon*) or maternal mouth-brooders (genus *Oreochromis*). Substratum species have smaller eggs than mouth-brooders and deposit them in rows of 15-25 cm long on solid surface as much as 7000 eggs while mouth-brooders have larger eggs of about 2000 eggs and incubate them in the mouth. All-male tilapias are produced by manual sexing (hand culling) or hormonal sex-reversal or through hybridization and genetic selection. In USA, exotic tilapias are used in aquatic weed control programs and also, for food in intensive recirculating systems. Ontario was the first Province in Canada to introduce *O. niloticus* in 1995 from Egypt by Gary Chapman, Northern Tilapia Inc., mainly for food in indoor intensive recirculating systems; later, it was introduced in Alberta and British Colombia for the same purpose (8,9,10).

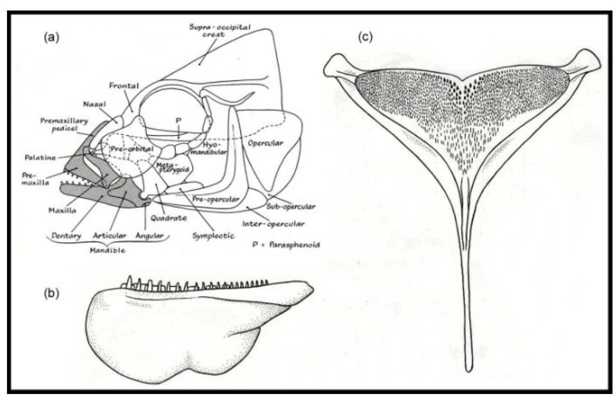

Figure 3. Diagrammatic view of tilapia skull (a) showing teeth on the mouth jaws and separately, two sets of bones in the pharynx: a complex of three on the roof (b) and a pair on the floor (c) united into a single triangular bone whose upper surface is covered with teeth (Diagrams from Fryer and Iles 1972).

Important application results of grass carp and tilapias as biological control agents

In 1972, Bailey stocked about 350,000 fish in over 100 USA lakes (total area 50,000 acres) and noticed no detrimental effects on natural fish populations and in some cases, the populations were improved (7). All tests in Alberta, Canada, did not find important diseases in grass carp populations. Grass carp has to eat 48 g vegetation to produce 1 g gain in weight. The amount of weed eaten is related to water temperature, fish size, and numbers. Feeding is limited below water temperature 13 C, moderate between 13-18 C and optimum between 18-26 C. It consumes 5% its body weight/day at 13 C and 48% at 18-25 C. Small fish 25-40 cm consume more feed (35-50% body weight/day) than larger fish 45 cm (20-30% body weight/day). Stocking rates vary with the type and density of vegetation to be controlled but generally, 10-15 fish/acre in a small pond and 10-20 fish/acre in larger vegetated areas (1,3,6). Removal of vegetation by grass carp helps to crush the intermediate snail hosts of *Bulinus* and *Biomphalaria* spp. which transmit the vector *Schistosoma* of *Bilharzia* and also, eat the larvae of malaria transmitting mosquitoes and further expose them to be eaten by predatory fish (1,11).

Chemical control is expensive ($ 200-$600/acre/year) and water gets polluted. Mechanical is another short-term solution but is about twice as costly as chemical control and can disrupt the fishery. In Alberta, John Derksen reported that 707 liters of the chemical Magncide H, at a cost of $ 7975, are required to treat just a 3 km of canal flowing at a rate of 5.66 m^3/s while control by mechanical methods were estimated to cost $3144 /day (6). It was confirmed that biological control by grass carp is far less expensive, less labor intensive, and better for long-term weed management than chemical and mechanical methods. Combination of biological and mechanical is more effective than mechanical alone. In brief, the advantages of using grass carp as biological control are: longevity of the method once it has become established; constant feeding activity against the growing weeds; low long-term costs; high effectiveness on some aquatic plants; excellent potential for conversion of weed to useful protein product (1,3).

Tilapia rendalli and *Tilapia zillii* are voracious feeders on aquatic macrophytes and vascular plants and when stocked in dams of 2-3 hectares in Kenya, eradicated the weeds in three years. *Oreochromis spilurus spilurus*, when used in a large-scale field trial by the World Health Organization (WHO) and the Ministry of Health in Somalia, controlled the larvae of *Anopheles* mosquitoes and significantly reduced malaria; besides, it cleaned the water, crystal clear. But, *T. zillii* when introduced intentionally in the lower Colorado River to control aquatic vegetation, it endangered native fish species by eating their eggs and juveniles (11,12).

Role of grass carp and tilapias in aquaculture for food security

Grass carp was introduced in more than 50 countries and is one of the top four most cultured fish species in the world. Tilapia is the most important fresh / marine cultured food fishes, introduced in more than 150 countries. It is the second most important group of farmed fish after carp and most widely grown of any farmed fish. Most production comes from Asia (China) and Latin America (Ecuador, Costa Rica and Honduras). Both grass carp and tilapia species are significant contributors to food security, especially for lower income people in developing countries. In polyculture with other major carps, grass carp contributed more than 76% of total carp aquaculture production and 60.7% of the world fish aquaculture production. In bi-culture with shrimp, catfish, trout, or with hydroponic for lettuce, tomatoes and cucumbers, or integrated with agriculture including livestock rearing, tilapia enhanced production significantly. Rice–tilapia culture contributed to aquaculture and helped farmers reduce use of environmentally damaging pesticides (1,9,13). Because tilapia has a fine-tasting, white, flakey meat and relatively low cost, its world aquaculture production increased rapidly and reached 2,348,656 tonnes in 2006 (14). In Canada and USA, intensive re-circulating systems played a big role in providing live tilapia to consumers (9).

CONCLUSION

Aquatic weeds in irrigation canals and other waterways pose a significant problem in many parts of the world and constitute a substantial drain on the agro-economy of developing countries in particular. Use of grass carp and tilapia can successfully and economically control aquatic weeds, larvae of malaria transmitting mosquitoes and snails of bilharzias; besides, can also result in improved supply of protein in rural communities and in pond bi-culture or polyculture integrated with other farming activities. The production of triploid sterile grass carp is a great scientific achievement because it has alleviated the concern of possible adverse effects on the aquatic environment. But, the use of *T. zillii* for weed control is strictly regulated in southern USA to avoid its invasive negative impacts on the native fish species. However, introduction of grass carp or tilapia should be a last resort after completing risk analysis. The economic benefit of using them as exotic species will often outweigh known risks, especially if the indigenous species cannot be used as biocontrols and lack market potential. Thus, prohibiting use of these species will have a cost, which is shortage of available food, loss of protein and health benefits, rural development, employment, and foreign exchange earnings. Therefore, emphasis should be on prudence to strike a balance between ecological risks and possible benefits because just prohibiting the use of these exotic species will be a lost opportunity to establish commercial aquaculture with its concomitant benefits (1,15).

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Wild and Farmed Fish, their Nutritional Value and Role of Aquaculture for World Food Production

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This paper reports on the scientific facts about the nutritional value of wild and farmed fish as compared to beef, pork and chicken; their stand with respect to cholesterol, omega-3s and the allegations made against farmed fish species, in particular, salmon. Furthermore, the roles of aquaculture in world food production and that of the Government of Canada with respect to NAAHP and HACCP, are highlighted.

Fish nutritional value: "Eat Fish, Live Better"

Physicians and dietitians regularly suggest fish for healthy eating at least twice a week because of their exceptional nutritional value (1). Wild and farmed fish have the same nutritional value and both are superior to beef, pork, and chicken. Fish meat is one of the best sources of high-quality protein and also, vitamins A, B, D and minerals such as calcium, phosphorous, iron, copper, selenium and iodine(2). Fish protein is made up of long-chains of small subunits called amino acids and that is why fish meat contains the essential amino acids which cannot be manufactured by human body but must be ingested in the diet, namely: *Arginine, Histidine, Lysine, Leucine, Isoleucine, Valine Methionine, Phenylalanine, Threonine*, and *Tryptophan*(3). Besides, fish protein is low-fat and easier to digest than that of other meats because fish meat has very little connective tissue and shorter muscle fibers(4). It is a more efficient source of energy for human body than carbohydrates but to avoid its side effects when burned, sufficient amounts of complex carbohydrates must be consumed to prevent the body using protein for energy(5). Moreover, the fats of fish, unlike that of other meats, are unsaturated fatty acids that lower blood cholesterol level and triglycerides (fats) in human body and reduce incidence of cardiovascular disease; but, fish liver oils, unlike fish oils, contain high levels of cholesterol and vitamins A and D which are harmful in large quantities(1). Levels of low-density lipoprotein (LDL) or "bad" cholesterol are lowered by intake of dietary fibers such as fruits, vegetables, grains, nuts, seeds which speed up its breakdown in the liver(6). Also, updated scientific analysis corrected the unfair reputation about shellfish (molluscs and crustaceans) raising cholesterol levels as they are low in calories, total fat, saturated fat, have little or no effect on the plasma cholesterol and are good sources of omega-3 fatty acids(7).

Omega-3s are long-chain polyunsaturated fatty acids (n-3 PUFA) found almost exclusively in fish, particularly fatty fish such as salmon, trout, tuna, mackerel, herring, sardines and also, shellfish or fish oils; smaller amounts are found in some plants and plant oils. They occur in three forms: ALA, the short-chain *alpha linolenic* acid and the long-chain, EPA and DHA, *eicosapentaenoic* acid and *docosahexaenoic* acid respectively. DHA and EPA are totally absent from plant sources but ALA is found in flax, walnuts, canola and soybean oils. They are proved to be scientifically vital for human health from the cradle to the rocker. DHA, in particular, is most important for the development of human brain and retina of the eye. It is essential because fats make up more than 60% of the human brain and nervous system, and a considerable part of that is DHA; it is incorporated into the brain during fetal development and the first two years of life. Besides, omega-3s make blood clotting more difficult, improve heart beats and prevent the build up of "plaque" on artery walls (atherosclerosis) which cause heart attack and stroke. Also, they reduce: heart disease by lowering blood fats and pressure; levels of blood sugar and damage to kidney that occurs in some insulin-dependent diabetics; the development of Alzheimer's disease in senior citizens; certain inflammatory diseases such as arthritis and psoriasis; risk of some types of cancer; and various forms of depression. Therefore, eating dietary fiber, fresh fish and shellfish is extremely important for human health. Fish and shellfish lose their nutritional value if they are not chilled immediately after being caught or eaten fresh(1,8,9).

Farmed-versus-wild salmon debate, irresponsible allegations and the scientific facts

Canadian salmon farmers, wild salmon harvesters and some opportunist environmentalists have been locked in a shameful battle over a decade debating on which tastes better or is more environmentally friendly. Some of the irresponsible allegations against farmed salmon are: friends do not let friends eat farmed salmon because they are contaminated with PCBs (polychlorinated biphenyls) that cause cancer, injected with chemical dyes to color their flesh pink, treated with antibiotics and transfer diseases and parasites to wild stocks, etc. Accordingly, the scientific facts are as follows. Farmed and wild salmon, milk, cheese and butter contain traces of PCB's far below what is considered a risk to human health. There are no significant differences in PCB's levels between wild and farmed salmon and their levels are well below Health Canada and U.S. FDA current guidelines of 2000 ppb; they have never been reported to cause cancer in humans. Artificial chemical dyes are the same carotenoids (*xanthophylls*) that make wild salmon, shrimp, and crab pink. In nature, they are produced as *canthaxanthin* and *astaxanthin* by plankton in the water food chain and can be synthesized artificially. They are not injected in farmed salmon but used as additives in fish feed to give a pink color and in poultry to give the skin and egg yolk a brighter yellow color. Health Canada, Canadian Food Inspection Agency (CFIA) and U.S. Federal Drug Agency (FDA) certify the safety use of dyes. Also, local and international authorities do not have evidence to prove or disprove that farmed salmon transfer pathogens and parasites to wild salmon. Besides, lice and Infectious *Hematopoetic Necrosis* (IHN) were identified before salmon was cultured in Canada's coastal waters. Actually, research results indicate that farmed salmon are at a higher risk of contracting a disease from wild fish than vice versa. According to DFO, the reasons for fish to become susceptible to disease are fluctuations in water temperature, water level or salinity, natural physiological changes that the fish undergo when salmon migrate from salt to fresh water and abundance of populations. However, antibiotics are used for farmed salmon only when prescribed by a veterinarian to cure an infection and are used only for a short duration of 5-14 days. Now, antibiotics are used very seldom in farmed salmon since vaccines have been developed for most diseases. Moreover, the aquaculture industry is strictly regulated by provincial and federal authorities, and there are various regulations and guidelines designed specifically to manage the health of both farmed and wild fish (10, 11).

Role of NAAHP and HACCP Fish Health Programs

Sustainable farmed and wild fish are significantly threatened by disease. As a member of the World Organization for Animal Health (OIE) and Food and Agriculture Organization (FAO) and signatory to the Code of Conduct for Responsible Fisheries, Canada adopted a National Aquatic Animal Health Program, NAAHP, which is a science-based regulatory program designed to meet international aquatic health management standards to protect Canadian aquatic resources (wild and farmed) from serious infectious diseases and maintain competitive international market access. In the Spring of 2005 budget, the Government of Canada, announced a $59 million for implementation of NAAHP by the Canadian Food Inspection Agency (CFIA) and Fisheries and Oceans (DFO) which come under the Ministers of Agriculture and Agri-Food and Fisheries and Oceans respectively. Also, Canada adopted another program, HACCP or Hazard Analysis and Critical Control Point, which is an internationally recognized, science-based approach to ensure food safety. Thus, NAAHP and HACCP fish inspection systems will contribute to the industry's worldwide reputation for exporting high quality fish products and assuring the Canadian consumers of safe farmed quality. To further reduce the incidence and severity of disease impacts, the Canadian Aquaculture Industry (CAIA) continues to invest in the development of disease prevention strategies (e.g. vaccines), alternative treatments, healthy and well-balanced feeds and good production practices(12,13).

Role of aquaculture in world food production

World demand for seafood is sky-rocketing while capture fisheries has already reached a maximum sustainable yield of about 95 million tonnes since 1980 because over-fishing, degradation of coastal marine-freshwater ecosystems and habitats caused dramatic declines in global catches. About 90 % of the oceans' population of edible fish like cod, halibut and tuna has been cut off due to high technology in global fishing, using sonar and satellite combined with extremely long fishing nets. As a result of the status quo, aquaculture has emerged as the "blue revolution" of the present and future, an environmentally friendly production system that farms over 210 species of finfish, molluscs, crustaceans and seaweeds and supplies large quantities of low-price food fish (Fig. 1). Its production has increased at an average compounded rate of 8.8 per cent per year since 1970, compared with only 1.2 per cent for capture fisheries and 2.8 per cent for terrestrial meat production systems. Now, it is the fastest growing food production sector in all regions of the world except sub-Saharan Africa. It yields about 60 million tonnes annually and accounts for 43% of the world's fish supply for direct human consumption. It is expected to fill a gap of 50-80 million tonnes of fish and seafood which capture fisheries will not supply on a sustainable basis beyond the 95 million tonnes per year. Over 90% of global aquaculture production comes from Asian countries with almost 74% originating from China alone where most farmed fish and shellfish are grown in traditional small-scale systems that benefit local communities and minimize the environmental impact(11,14).

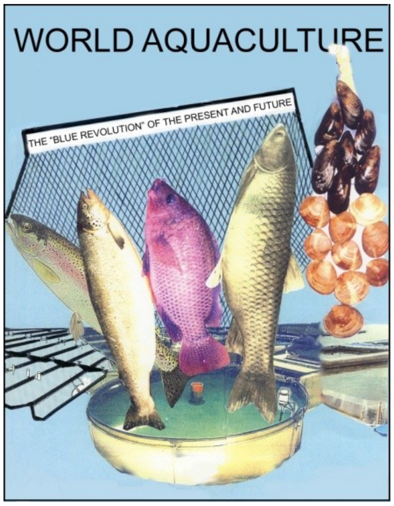

Figure 1. A collage highlighting the “Blue Revolution” of World Aquaculture which farms over 210 species in a variety of aquatic land-based and off-shore culture systems (Art by TT George).

CONCLUSION

The world’s eminent researchers and nutrition institutions recommend that people should eat fish twice a week because of their exceptional nutritional value. It is high time to educate the public more about the benefits of fish (farmed and wild) and the supporting scientific facts through regular programs on the national TV and newspapers. Now, increasing emphasis is placed on enhanced enforcement of regulations and better governance of aquaculture in order to supplement the shortage of fish supply from capture fisheries, satisfy consumer demand and contribute to the nutritional security of the poor in many developing countries where fish provides more than 50% of the annual protein intake(14). For these reasons, the Kyoto Declaration on Aquaculture at the First International FAO Technical Conference on Aquaculture in 1976, Kyoto, Japan, urged all governments of the world to give high priority to aquaculture development in national planning and also, the international financing agencies to recognize aquaculture as a priority sector for investment and provide adequate financial support for aquaculture in developing countries (15). In response to this declaration and because Canada has the longest coastline, the largest offshore economic zone, the largest freshwater system, and the world’s greatest tidal range(12), The Hon. Brian Tobin, Ex-Minister, Fisheries and Oceans (DFO), released in 1995 on behalf of the Government of Canada, the Federal Aquaculture Development Strategy(16) in Halifax at Prince George Hotel (Fig. 2). Another country which has a tremendous potential for aquaculture development is Sudan, the largest country in Africa with an area of 2.5 million sq. km, a coastline of 720 km on the Red Sea, over 6,500 km of river waters (Blue and White Niles), an appropriate climate and unpolluted waters for raising warm-water aquaculture species year-round(17,18).Yet, this potential has still to be recognized and promoted through the Government’s National Plan and the private sector(19). Similarly, Governments of other countries especially, those in sub-Saharan region with great natural potentials,(14) should recognize and promote aquaculture development so that it can play an effective role in global food security by supplementing the already declining wild stocks from capture fisheries.

Figure 2. The Hon. Brian Tobin, Ex-Minister, DFO when released the Canadian Federal Aquaculture Development Strategy at Prince George Hotel,Halifax, on February 6, 1995 (Photo by TT George).

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The Centre for Integrated Aquaculture Science (CIAS) and the Linkages to Policy Development within Fisheries and Oceans Canada

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Fisheries and Oceans Canada (DFO) is a science-based government department with its policies and management decisions founded on science generated information. In an effort to strengthen national coordination of aquaculture research within DFO, the department established the Centre for Integrated Aquaculture Science (CIAS). The CIAS facilitates effective policy by coordinating research activity that generates the necessary information to inform, influence, stimulate, and enable sound policy and decision making. The success of the CIAS to support policy will continue to depend on the ability of researchers to understand the knowledge gaps for sound policy, as well as the individual relationships among researchers and policy makers.

INTRODUCTION

The Centre for Integrated Aquaculture Science (CIAS) is a national, "virtual" centre of research expertise within Fisheries and Oceans Canada (DFO) that has a focus on identifying, implementing, and coordinating an effective and efficient national and inter-regional research program that addresses relevant DFO aquaculture needs and priorities.

As stated in the Terms of Reference of the CIAS, which was formally accepted in February 2007, the Centre has five major objectives:

1. Develop an awareness within the DFO Science community of the aquaculture related objectives and priorities of the department, including emerging issues that require a science response;
2. Identify, implement, and coordinate national and inter-regional research activities that address the relevant departmental aquaculture needs and priorities;
3. Identify new capacities and expertise required to address existing and emerging aquaculture science issues;
4. Facilitate inter- and cross-laboratory partnerships as required to address DFO aquaculture science priorities in an effective and efficient manner, and within an integrated research framework; and
5. Communicate within DFO science and to its clients (i) the priority needs for DFO aquaculture science, (ii) the science activities being conducted to meet those needs, and (iii) the results of those activities.

The CIAS is one of ten Centres of Expertise (COEs) established within DFO Science as part of DFO science renewal initiative.[1] The COEs were established to increase collaboration, co-ordination, alignment, and focus of research within key activity areas; aquaculture was identified as a key area for DFO Science, and therefore the CIAS was established. Through this process, DFO is striving for improved research coordination among regions, strengthened research capacity that is better aligned with departmental aquaculture priorities, and stronger integration between management priorities and research direction.

The overarching goal of research within the CIAS is to achieve "Ecosystem Friendly Production" within the aquaculture sector in Canada. This goal supports the regulatory and enabling responsibilities of DFO pertaining to aquaculture, as well as the broader government objective of ecosystem-based management. It also supports a policy environment that enables the sustainable development and management of the aquaculture sector in Canada.

CIAS STRUCTURE AND ACTIVITIES

The CIAS has a broad scope of potential research ranging from ecosystem impacts of aquaculture activities, effects of enzootic pathogens, genetic and ecological interactions of wild and cultured species, and alternate strategies for culturing aquatic organisms that enhance production while minimising risk of impact to the surrounding ecosystem. This broad scope of research necessitates a broad range of researchers and capacities; hence, the CIAS incorporates all the DFO research laboratories across Canada.

The foundation of the CIAS is the individual researchers within the regional DFO labs where the research planning and implementation is carried out. The national and inter-regional coordination and oversight of these research activities is the responsibility of the CIAS management structure, which consists of the Secretariat, Board, Science Committee, and Theme Groups. The Secretariat consists of the CIAS Director, Fred Page, and the Manager, Edward Kennedy, both of whom are located at the St. Andrews Biological Station in St. Andrews, NB. The Secretariat is responsible for the overall coordination of the CIAS activities, preparing annual reports and work plans, and strengthening the integration of departmental policy and decision makers with the research community that supports their activities. The Board consists of the CIAS Director and Manager, DFO Science managers from every DFO region across Canada (i.e. Newfoundland, Gulf, Maritimes, Quebec, National Capital Region, Central and Arctic, and Pacific regions), and managers from the internal client groups (i.e., Aquaculture Management Directorate, Habitat Management, and Oceans Directorate). The Board is responsible for setting the overarching priorities, objectives, and activities for the CIAS, as well as reviewing and recommending annual reports and work plans to the National Science Directors Committee (NSDC) for approval. The Scientific Committee, although not yet formally established, will consist of DFO researchers across Canada representing the various aquaculture disciplines, and will be responsible for identifying the most appropriate research activities to address the priority needs and issues of DFO policy and decision makers. The Theme Groups will be transitory forums focused on carrying out the necessary research within a specific area.

The CIAS, as well as the other COEs, reports to the DFO National Science Directors Committee (NSDC). Every year, the CIAS must submit its work plan for approval to the NSDC, which includes consideration of research funding from the NSDC for high priority research projects.

The basis of the CIAS work plan consists of the research plan developed in response to the priorities of the department. These priorities result from consultations with the internal clients (i.e., AMD, HM, and OD), as well as with the researchers within DFO regional laboratories. The work plan attempts to balance the priority research needs of the internal client with the available research capacity and funding to address these priorities. Another important aspect of the work plan is communication of research results to the internal clients. This communication and feedback (via workshops, newsletters, informal discussions, etc.) is essential to address knowledge gaps and support sound policy and decision making pertaining to aquaculture management within DFO. In the future, the CIAS will be exploring opportunities to build linkages with stakeholders external to DFO, such as other federal and provincial government departments and agencies, academic institutions, and industry to ensure the research plan of the CIAS is relevant to the needs of the Canadian aquaculture sector.

INTERACTIONS WITH POLICY

DFO is a science-based department meaning its policies and decisions are supported by sound science, including those pertaining to aquaculture. In fact, the Aquaculture Policy Framework makes reference to ensuring departmental aquaculture activities are based on the best available science.[2] Hence, the CIAS research activities need to be relevant to, and support, the aquaculture policies and decisions being made by the department. Ensuring relevance to policies and decisions requires close interaction between the research community and government policy makers. The CIAS is tasked with facilitating and strengthening this interaction, and through its management structure as well as its targeted research outputs, the CIAS will aim to inform, influence, stimulate, and enable aquaculture policy and decision makers within DFO.

The CIAS is influenced by policy in that the major activities and focus of the Centre is guided by the key policies of DFO, such as the Aquaculture Policy Framework, Ecosystem Based Management Policy, Environmental Framework for Aquaculture Risk Management, and the DFO Science Five Year Research Plan. In addition, the overarching direction of the CIAS is determined by the key science policy and decision makers in DFO, specifically the Departmental Management Committee, Science Management Board, and the National Science Directors Committee.

The CIAS also influences policy in that the Centre enables interaction between researchers and policy and decision makers which, in turn improves communication between science and policy managers, and helps identify research that can reduce the uncertainties and knowledge gaps that exist in the policy and decision making process. The CIAS also provides a recognized and condoned route for providing relevant and potentially influential research results and perspectives into DFO policy forums. This can help make policy developers aware of potential consequences of prospective policies, and lead to other potential policy options for addressing a priority need or issue.

The future success of the CIAS in influencing policy will depend on continued strong relations with the aquaculture policy and decision makers within DFO. There needs to be a continued willingness on their part to receive newly generated information, as well as researcher willingness to generate and provide new information relevant to DFO aquaculture policy and decisions. Thus, the CIAS and its body of researchers must make the effort to understand the nuances of the policy and political processes so the relevant science information can be delivered.

SUMMARY

The CIAS structure, in particular the CIAS Board, enables close interaction between science and policy. A result of this close interaction is relevant research to address the key challenges and needs of aquaculture policy and decision makers. By being strategic in focusing limited research resources and capacity on issues of relevance to DFO, the CIAS will continue its success on bridging the needs between science and policy.

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Primary and Secondary Antibody Responses to Immunisation with Single Antigens and *Aeromonas salmonicida* bacterin in Atlantic salmon, *Salmo salar* L.

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The development of immunological memory in relation to antigen-type was examined in Atlantic salmon. Immunological memory is a necessary physiological response for achieving long-term protection through vaccination. In this 25 week study, we compared primary and secondary antibody responses of individually tagged juvenile salmon immunised with three non-adjuvanted preparations: i) recombinant TapA, an *A. salmonicida* pilin subunit protein and putative thymus-dependent antigen; ii) purified *A. salmonicida* strain A449 lipopolysaccharide (LPS), a thymus-independent antigen; and, iii) a bacterin suspension of formalin-killed *A. salmonicida* strain A449 cells. ELISA results showed that primary antibody responses to rTapA or LPS were synchronized while bacterin responses were heterogeneous. Immunological memory followed secondary immunisation with rTapA, but not LPS. These results are consistent with memory-inducing properties of thymus-dependent and thymus-independent antigens, respectively. The secondary response of bacterin-immunised salmon to *A. salmonicida* also lacked evidence of memory, thus resembling a thymus-independent, LPS -driven response. These results suggest that commercial bacterin-based vaccines may not induce memory responses from the immune repertoire of Atlantic salmon.

INTRODUCTION

An important property of an effective vaccine is its ability to confer long-term protection against a pathogen. This is achieved through the development of immunological memory to specific antigens. It is well-known that the fish immune system includes memory responses, although they are generally weaker than those reported for mammals (Arkoosh & Kaattari, 1991).

In this study we examined the memory response of Atlantic salmon to the fish pathogen and aetiological agent of furunculosis, *Aeromonas salmonicida* subsp. *salmonicida*. Commercial vaccines for furunculosis are commonly, if not all, in the form of adjuvanted bacterins (suspensions of killed *A. salmonicida*). In order to assess the memory-inducing ability of a bacterin vaccine, we compared bacterin administration to immunisation with single *A. salmonicida* antigens predicted to produce: i) a classical thymus-dependent (T_D) and thus memory-inducing response, and, ii) a thymus-independent (T_I), non-memory-inducing response. The putative T_D- and T_I- antigens chosen for this study were a recombinant form of TapA, a pilus subunit protein (Boyd et al., 2008), and lipopolysaccharide (LPS), respectively. The T_D- or T_I character of the bacterin immune response determines the potential for immunological memory and thus long-term physiological protection through bacterin vaccination.

METHODS

The experiment was performed at the Aquatron facility of Dalhousie University (Halifax, NS). Animal work adhered to Canadian Council of Animal Care guidelines. Cultured Atlantic salmon (St John River strain) were obtained from a Nova Scotia farm certified under Canadian Fish Health Protection regulations. Fish were stocked in 100 L fibreglass tanks each equipped with an aeration source and a supply of dechlorinated municipal water (12 to 14°C). Fish experienced a constant artificial photoperiod (14L:10D) and were fed 1-2% body mass at least once per day.

Individual fish were tagged intra-muscularly with passive integrated transponders (AVID, Canada) four weeks in advance of the experiment. All fish were blood sampled for a preimmune reference sample then immunised two weeks later with one of four different treatments. Treatment groups were represented by two replicate tanks of 17-19 individually tagged salmon (mean starting body mass ~100g). One tank was examined for the primary immune response, the other was sampled for the secondary immune response. Experimental treatments were delivered without adjuvant in either Tris- or phosphate-buffered saline, thus removing adjuvant-associated depot and non-specific stimulatory effects. Treatment groups were as follows:

rTapA - 50μg purified recombinant protein per 100 g body mass

LPS - 50μg purified *A. salmonicida* A449 strain LPS per 100g body mass

Bacterin (BAC) - 100 µl of OD_{600} 1.0 suspension of formalin-killed *A. salmonicida salmonicida* strain A449 grown in iron-depleted conditions (120µM 2,2′dipyridyl in TSB; 17°C).

PBS – SHAM injections of 100 µl of phosphate-buffered saline solution

Methods for the cloning and expression of TapA and for the purification of LPS, both isolated from *A. salmonicida salmonicida* strain A449, are given elsewhere (Boyd et al., 2008; Wang et al., 2007)

Fish were serially blood sampled over time, primary response tanks were sampled at 20, 40 and 60 days post-primary immunization (dppi). Secondary immune response tanks were blood sampled at 60 and 136 dppi, then the fish received a secondary immunisation at 158 dppi with a blood sample occurring 20 days later (178 dppi). Subsets of fish in the PBS control group received primary injections of experimental treatments at 158 dppi (n=5 per treatment) in order to serve as controls for the secondary immune response (PBS-Treat); a set of 4 fish remained as sham injected controls (PBS-PBS).

Specific indirect ELISAs were optimised for each treatment. Duplicate plasma dilutions were incubated for 2 h at room temperature. Salmon antibodies were detected using commercially available antibodies including an HRP-conjugate; o-phenylenediamine dihydrochloride substrate (Sigma) was used for colorimetric detection. Changes in optical density (450nm) were analysed kinetically and maximal rates of reaction (V_{max}) values determined for each well. Specific antibody titers were determined as the last plasma dilution with a $V_{max} > 2x$ the preimmune V_{max} at the same dilution. Temporal changes in mean specific antibody titers were compared non-parametrically using the Kruskal-Wallis one-way ranked ANOVA with pairwise comparisons by Mann-Whitney tests.

RESULTS AND DISCUSSION

Changes in specific antibody titers over time were statistically significant for the three experimental treatment groups (P<0.001). Primary responses to single purified antigens (rTapA and LPS) were synchronized among individuals with statistically significant peak titers occurring at 20 dppi. Titers decreased thereafter in these treatment groups. Bacterin-immunised fish also demonstrated a significant specific antibody response following primary immunization, but the response was not synchronised among individuals which resulted in similar mean titer levels between 20 and 60 dppi.

Secondary immunisation with rTapA produced an increase in mean specific antibody titer that was significantly greater than the primary immune response, including that observed for PBS-secondary immunization controls injected at 158 days (Figure 1).

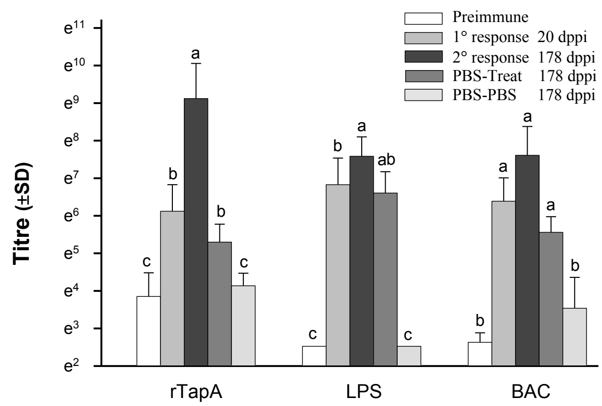

Figure 1. Mean (±SD) specific antibody titers following immunization with the non-adjuvanted experimental and control treatments. Results shown for each group represent: preimmune levels prior to immunization; primary (1°) antibody response at 20 dppi; secondary (2°) antibody response at 178 dppi (20 days after secondary immunization); primary response of PBS control fish immunized at 158 dppi (PBS-Treat); and, the response of double sham injected control fish (PBS-PBS). Statistical analyses were performed for each group separately, means labeled with the same letter are not significantly different (*P*>0.05).

This increased response indicates the presence of immunological memory typical of a T_D- antigen. In contrast to the results for rTapA, immunological memory was not seen for either the LPS- or bacterin-immunised groups (Figure 1). Primary and secondary immune responses were statistically similar, which was the expected response from injection with a T_I antigen such as LPS. The T_I-like secondary response of bacterin-immunised salmon prompted additional testing of their plasma in an LPS ELISA. The results demonstrated that the bacterin response was in fact LPS-dominated (data not shown). Moreover, a significant correlation was seen between V_{max} values determined in bacterin and LPS ELISAs (Pearson correlation coefficient=0.909, P<0.001).

In summary, immunological memory was clearly seen in response to a T_D antigen, but not in response to either a T_I antigen or a bacterin. Ultimately, the results question whether bacterin vaccines can confer adequate long-term physiological protection beyond the adjuvant depot effect. Bacterin vaccines may not utilize the capacity for immunological memory inherent in the salmon antibody response. Future vaccines should include T_D antigens in order to exploit this capacity.

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Cage Culture Characteristics of Juvenile Atlantic halibut (*Hippoglossus hippoglossus*)

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Atlantic halibut (*Hippoglossus hippoglossus*) is an "alternative" aquaculture species being evaluated to complement salmon aquaculture in Atlantic Canada. Significant progress has been made on improving hatchery production of juveniles, but a number of biological issues remain to be addressed in advancing sea-cage culture. This study focuses on determining the optimal size for transfer to sea cages, the effect of sex and sexual maturation on growth, and how malpigmentation changes with growth, over time. Growth and mortality rates of three different size grades of individually tagged fish have been monitored over the past two years on a commercial site in the Bay of Fundy. Early analysis indicates a probable decrease in malpigmentation over time. In continuing this work, it is hoped that the knowledge base on culturing halibut in Atlantic Canada will be strengthened, and that the halibut aquaculture industry in Atlantic Canada will be brought a step closer to economic viability.

INTRODUCTION

Declining wild stocks (DFO, 2004) and high market price make Atlantic halibut a good candidate for aquaculture. With the extensive competition within the salmon aquaculture industry in recent years, it is important that alternative species, such as halibut, be considered to complement this successful industry. Species diversification would make better use of the vast human and physical resources available in Canadian coastal communities, take advantage of high market prices for this species, and reduce the impact of high-density monoculture on disease transmission. A collaborative project is currently underway in Atlantic Canada, wherein a number of academic, government, and financial institutions are working together with industry to develop the knowledge and techniques necessary to make halibut cage culture feasible in the Bay of Fundy. To address some important issues related to halibut cage culture, this study is designed to answer the following questions: 1) at what size should halibut be transferred from a hatchery to a cage setting? 2) what is the effect of sex upon the growth of halibut in cage culture? and 3) how do malpigmentation patterns change with growth? This paper outlines research progress to date and how this research will help develop Atlantic Canada's halibut cage-culture industry.

MATERIALS AND METHODS

In December 2005, 50,000 juvenile halibut were transferred from a hatchery in Nova Scotia to a commercial cage grow-out site in Lime Kiln Bay near St. George, New Brunswick. Prior to transfer, approximately 200 of each of three size classes (<250g, 250-500g, and >500g) were tagged at the hatchery using Floy tags attached in a loop around the operculum. Having the fish tagged allowed the tracking of individual fish in cages over the study. All tagged fish were collected by divers in the spring (May) and fall, (October or November) of 2006 and 2007, for measurement of weight, length and width. Each fish was also sexed (ultrasound: Martin-Robichaud and Rommens, 2001) and recorded digital photographs were taken of malpigmented individuals. An image analysis program, Image Pro Plus, was used to determine the percent coverage of malpigmentation on each fish.

RESULTS

Halibut transferred at sizes of 500g and greater grew faster than those introduced at smaller sizes (Fig. 1A). The growth rates of the three size grades were significantly different at $\alpha = 0.05$. Each size grade benefited from the summer growing season each year, indicated by greater increases in size between spring and fall samplings, compared to winter periods between fall and spring. As is the case with many other marine finfish species, Atlantic halibut display a difference in the rate at which females and males grow in sea-cage culture (Fig. 1B). The size difference between the two sexes was significantly different ($\alpha = 0.05$) over all samplings, and increased with time.

Change in percent malpigmentation in relation to fish size over time indicates that as the fish get larger the malpigmentation pattern on the dorsal side decreases (Fig. 2).

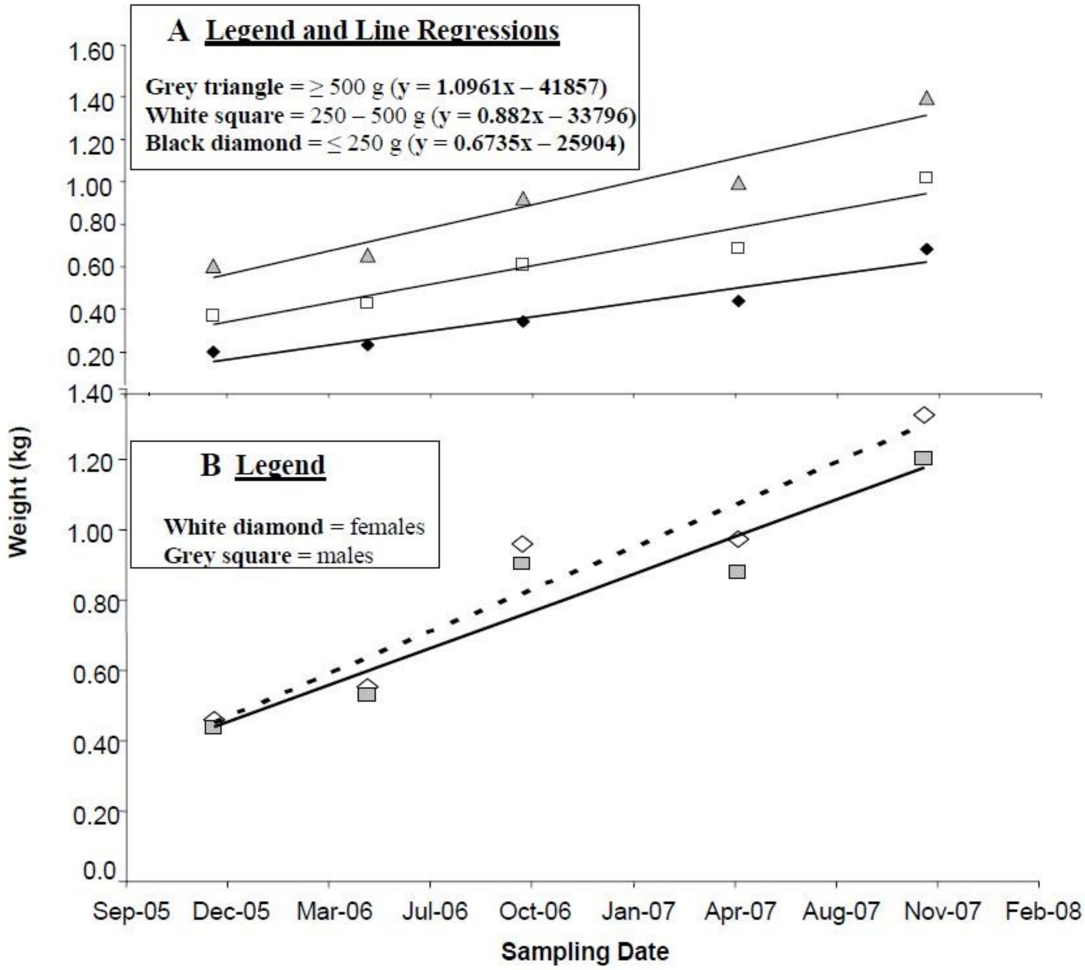

Figure 1. Growth of Atlantic halibut reared in cages for two years. A) Comparisons of size grades. B) Comparison of males and females.

DISCUSSION

Although all size classes of juvenile halibut transferred to sea cages benefited from seasonally available, optimal temperatures, those over 500 grams at entry grew the fastest. This may be why most Norwegian cage operations do not introduce Atlantic halibut to cages until they are about 500 g (Jonsson, A., 2006 pers. comm.). Although larger juveniles are more expensive, they may be more economical in the long run as it may take less time for these larger fish to reach harvest size. Larger fish may also tolerate transfer and cage conditions better than smaller juveniles and have less prevalence of eye problems and a lower mortality rates. Other aspects of this study will be evaluating this possibility.

Female halibut grow faster than males in sea cages in Atlantic Canada similar to that reported for Atlantic halibut in Norway (Bjornsson, 1994). Production of all-female stocks for halibut culture should therefore be beneficial to commercial fish farmers. This can be achieved using indirect feminization (Hendry *et al.*, 2003).

Malpigmentation may decrease the market value of halibut being sold whole. However, our study indicates that malpigmentation patterns (those patterns of white appearing on the dorsal region of a halibut where dark pigmentation would normally appear) decreases over time on fish reared in sea cages. This is important information for halibut farmers, since previously there was no indication that malpigmentation declined during growth. Early nutritional deficiencies are considered a key factor in malpigmentation of halibut juveniles and recent improvements in hatchery nutrition have decreased its prevalence.

The results of this study provide practical information useful for optimizing cage culture protocols for rearing Atlantic halibut. Continued growth studies, together with the monitoring of feeding practices and fish behaviour, will improve the knowledge base for halibut aquaculture to ensure an economically feasible industry in Atlantic Canada.

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Recent Developments and Challenges for Open-Water, Integrated Multi-Trophic Aquaculture (IMTA) in the Bay of Fundy, Canada

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An open-water IMTA project in the Bay of Fundy is successfully making the transition from an experimental to a commercial scale. Recent amendments to the Canadian Shellfish Sanitation Program now allow the culture of blue mussels in proximity to salmon cages and 18 mussel rafts, with a 500 MT production capacity, have been deployed to date. An expected kelp harvest of close to 120 MT wet weight from 16 rafts is expected this year. However, several challenges need to be overcome for open-water IMTA to optimize sustainability. It is the ratio of nutrient releasing fed biomass (*e.g.* fish) to the nutrient converting biomass of co-cultured extractive species in their respective biomitigating niches that largely influence nutrient recovery efficiency; not necessarily the physical/spatial scale of any one component. Consequently, rearing extractive species at scales complementary to the upper-trophic fed species presents novel challenges. 'Trial and error' learning approaches are largely unavoidable, due mainly to new husbandry and site design. Appropriate culture scale of extractive species necessary to optimize nutrient recovery, and spatial deployment to facilitate husbandry and harvest access, become major design considerations. Each species within the system also has unique temporal and spatial culture requirements, adding further complexity. Continuous site evolution and unpredictable dynamics are typical of commercial operations and present unique challenges for model validation. Nevertheless, some modelling approaches, like Monte Carlo simulation, can generate a likelihood of outcomes based on 'partial data' thereby providing practical estimates until validation can occur at 'fully evolved' commercial sites. Implications from model simulations are discussed.

INTRODUCTION

Integrated Multi-Trophic aquaculture (IMTA) is a practice where the by-products of one cultured species become the nutritional inputs for another. The nutrient wastes from an upper trophic fed species (*e.g.* fish) typically augment the natural food supply to lower trophic, organic extractive (*e.g.* filter feeders, deposit feeders) or inorganic extractive species (*e.g.* seaweeds) [1,2,3]. Co-cultured species in IMTA should be more than just biofilters; they should be harvestable commodities. If optimally designed and managed, IMTA sites will foster sustainability though economic diversification and will reduce the overall nutrient load to the environment. A conceptual IMTA site schematic is illustrated in figure 1.

A six year IMTA pilot project (funded by AquaNet, the Canadian Network of Centres of Excellence for Aquaculture) clearly demonstrated 'proof of concept', with mussels and kelps grown in proximity to salmon cages having increased growth rates ranging from 19 to 53 % and 46%, respectively. Levels of contaminants in co-cultured species were non-detectable or well below the Canadian Food Inspection Agency (CFIA), the US Food and Drug Administration (FDA), and the European Community Directives guidelines [4,5]. Successful 'proof of concept' in a pilot project, however, does not automatically ensure that the co-culture species can be practically cultured at scales necessitated by modern day commercial aquaculture production. This challenge spawned the genesis of a five year project (funded by the Atlantic Canada Opportunities Agency) beginning in 2006, tasked with advancing R&D in consort with IMTA commercialization. The following is a brief update on some project aspects, focusing mainly on production and nutrient recovery considerations. Disease, contaminant, economic and health aspects are beyond the scope of this update.

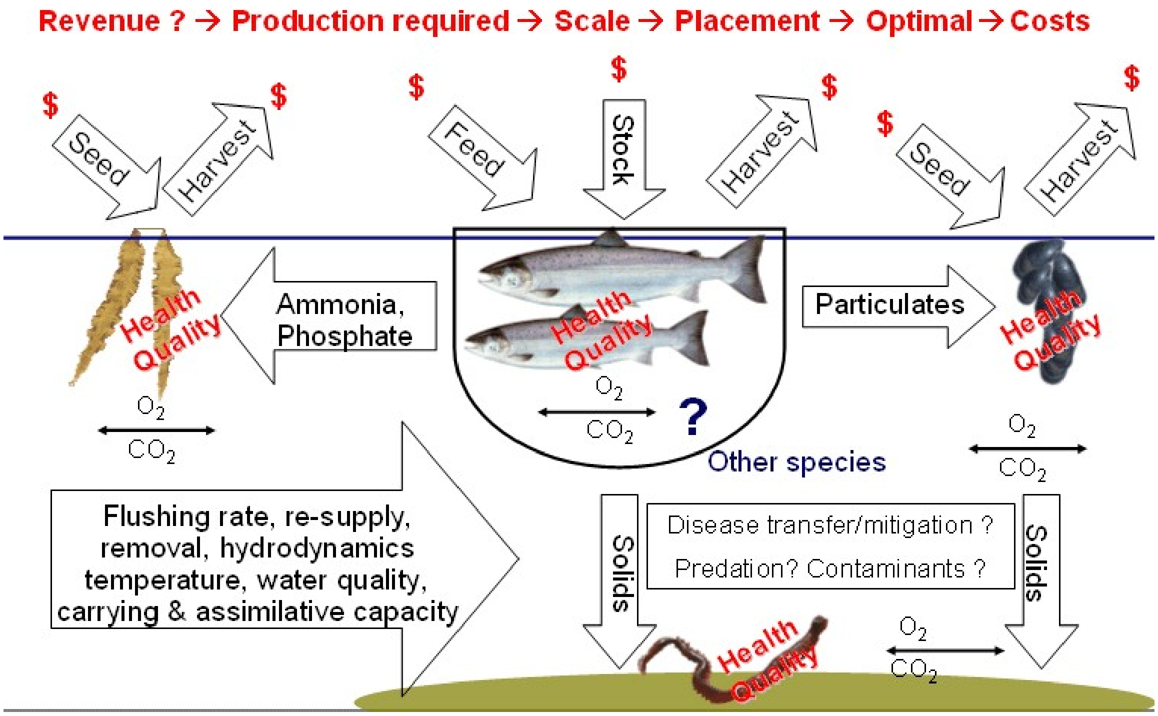

Figure 1. Conceptual diagram of a commercial IMTA site illustrating key management, design and functional considerations.

Production

Mussels and kelps cultured at the IMTA sites in the Bay of Fundy can now be sold commercially, though harvesting is dependent on season and biotoxin activity. Recent amendments to the Canadian Shellfish Sanitation Program permit the sale of blue mussels cultured in proximity to Atlantic salmon cages, provided that an appropriate IMTA management plan has been implemented [(6)]. To date, 18 mussel polar circles are deployed at IMTA sites, with an anticipated production value of 500 MT. An expected kelp harvest of close to 120 MT wet weight from 16 rafts is expected this year. Other co-culture species such as deposit feeders are presently being test cultured, but are not slated for commercial production at this time.

Temporal considerations

Temperatures which promote peak growth rate, feed consumption and consequent waste generation for Atlantic Salmon, occur during late September in New Brunswick waters [(7)]. The grow-out period for the kelps, *Saccharina latissima* and *Alaria esculenta*, occurs from November to May-July, depending on the applications [(8)]. Colder winter temperatures reduce salmon grow rates by several fold, resulting in the lowest relative nutrient loading of the year [(7)]. It can, however, be argued that a portion of the organic deposits takes time to mineralize back into inorganic nutrients trapped in sediments, which need some turbation (biological or physical) to be bioavailable to seaweeds. Consequently, nutrients accumulation in the ecosystem and nutrient absorption by seaweeds can be partially uncoupled in time. If kelps are the only inorganic extractive co-cultured species at the sites, there will be little opportunity to recover loaded inorganic nutrients during the time of the year they are absent from the sites. Trials with the red alga dulse (*Palmaria palmata*) are presently underway as a means of expanding the deployment times of inorganic extractive species.

Blue mussel grow-out in New Brunswick is typically two years, although this time may be reduced somewhat at IMTA sites due to accelerated growth rates [(9,10)]. Fish culture at salmon aquaculture sites as legislated in New Brunswick is a maximum of three consecutive years, requiring a minimum of one year fallowing as a disease preventative measure [(11)]. This has implications for staggered culture times of blue mussels. Mussels deployed in year two of the site occupation by salmon would not benefit from salmon particulates in their second year of culture. It is also uncertain at this time whether mussels would need to be included in the fallowing rotation [12].

Spatial considerations

Ideally, filter feeders and inorganic extractive species should be placed in optimal locations and at optimal densities to intercept the maximal cross sectional area of suspended and soluble nutrients 'plumes' exiting the salmon cages. Polar Circle salmon cages used in the Bay of Fundy vary in diameter, but are typically 10 m deep [13]. Kelps are not cultured below a depth of 4-5 m at IMTA sites due to sunlight attenuation. Unless under conditions of vertical upwelling, would soluble nutrients advecting from the bottom half of the salmon cages be likely intercepted by kelps. Moreover, kelps deployed immediately adjacent to salmon cages experience 'dusting' by salmon fine particulates, which could affect their photosynthetic rates. This is remediated by placing mussel rafts immediately adjacent to the salmon cages and deploying the kelp rafts beyond this. This order also benefits the mussels since the close proximity increases the opportunity to intercept the 'deposition cone' of particulates.

The present system of mussel culture also has some vertical restrictions. Continuous sock 'loops' do not exceed 7 m depth at this time, largely due to practical harvesting and buoyancy issues. Areal loading of settleable solids below the fish cages is also a consideration under investigation for placement of deposit feeders which will need to be suspended below cages or off the bottom. Research in these aspects is ongoing.

Different deployment strategies for existing species or the addition of new species may be necessary to fully capitalize on the vertical and horizontal distribution of nutrients exiting fish cages; but the culture of additional species must be balanced with the need to facilitate adequate water exchange. This raises the issue of oxygen uptake/production, and nutrient loading/removal rates relative to proximity, water movement and culture densities within a site lease area. One method to quantify this may be to investigate ratios of fed to extractive biomass per area (and volume), under given hydrodynamic conditions. However, investigation of this aspect may require considerable production of co-cultured species at scales complimentary to that of the fed species, and that scale of production has not yet been reached.

One element not to be overlooked is the ease of access for species husbandry and harvesting. Boat access is a significant design consideration for raft and cage placement at the surface. Eventually, the addition of deposit feeders will necessitate either mid-water suspension or bottom deployment of trays or cages. This suggests additional cables will traverse the water column with existing mooring and buoy lines. The potential for submarine congestion is significant and warrants due consideration, for site design and diver safety. The implementation of IMTA practices, where all extractive 'niches' are facilitated, will require a complete re-designing of aquaculture sites and their operational grid.

Nutrient recovery efficiency

In order to measure the success of IMTA and ultimately develop a metric of environmental sustainability, some assessment of nutrient recovery efficiency is required. Modelling an IMTA system is one approach. Management necessities and 'trial and error' learning approaches to new husbandry result in continual evolution of IMTA sites, making it difficult to predict what is occurring at any given time. Such aspects make validation of modelling estimates very difficult. Nevertheless, some modelling approaches, like Monte Carlo simulation, can generate a likelihood of outcomes based on 'partial data', thereby estimating probable outcomes until validation can occur at 'fully evolved' commercial sites.

A modelling exercise was undertaken using a mass balance nutritional approach [14] considering food consumption, digestibility (or uptake of soluble nutrients in kelps), and retention of nutrients as partitioned by proximate composition (*i.e.* proteins, lipids, minerals, nitrogen free extract, phosphorus). The model was executed in Excel™ coupled with @RISK™ software to accommodate known and estimated input distributions for Monte Carlo simulation.

Growth data of IMTA kelps and mussels collected from the initial pilot-project were used. Data distributions of proximate composition, nutrient digestion, retention and 'probability of capture' by deposit feeders were generated from literature values and preliminary lab studies. A range of species and species biomass were run in the simulations. Such simulations acted as a means to accommodate input uncertainty and identify variables that most affect the system. Some obvious and not-so obvious modelling outcomes were identified by this exercise. Only the conceptual results are discussed below.

The modelling results demonstrated that the IMTA system can be quite complex in its interactions and therefore, it is not possible to report a general 'mitigation' or nutrient recovery value for an IMTA system. It is the ratio of nutrient releasing fed biomass to the nutrient converting biomass of co-cultured extractive species in their respective biomitigating 'niches' that largely influence nutrient recovery efficiency; not necessarily the physical/spatial scale of any one component. Each co-cultured species cannot exploit nutrients beyond its 'niche', given its particular spatial, temporal and consumptive requirements. Consequently, nutrient recovery efficiency also becomes a function of system biodiversity; analogous to a natural ecosystem. IMTA design must therefore consider how these species function together in combination. This is made apparent upon examination of nutrient and energy cascades in an IMTA system. Blue mussels for example, may capture small salmon particulates and natural seston, but indigestible portions will be defecated as mussel faeces. Ammonia will also be generated via protein catabolism. The solid and soluble waste products from the mussels may then require recovery by other species in the system, and these species will also generate their own respective waste products. It is therefore essential that co-cultured species have more than good nutrient 'capture ability'; they must be able to digest and convert 'lost nutrients' to biomass, for ultimate removal (*i.e.* harvest) from the system. Proper species selection, in conjunction with 'nutrient and energy cascade' modelling, can help ensure that the addition of co-cultured species results in a net increase of nutrients recovered, and not lost.

One of the overreaching outcomes of the modelling exercise was that the bulk of the nutrient load from a fish farm is sequestered in the heavier settleable solids, not accessible to the co-cultured species presently grown at the IMTA sites. This has served as an impetus to pursue a variety of deposit feeder species to develop culture techniques below the salmon cages. Several sub-projects on this aspect are already underway.

CONCLUSION

Most of the aforementioned challenges cannot be thoroughly anticipated or studied in laboratory or pilot scale projects only and, consequently, emphasizes the need for scientific research and commercial IMTA site development to progress in a concerted manner. With this approach in mind, current project priorities include: increase in kelp and mussel production and other species of seaweeds and filter-feeders; development of appropriate 'large-scale' deposit-feeder culture, and continued data collection for model development.

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Managing Mussel, *Mytilus* spp. Seed Health: The Effects of Brine, Lime and Acetic Acid Antifouling Treatments and Transport on Mussel Seed Performance

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Transferring mussel seed from collection sites to grow-out sites can subject seed to unique and multiplicative stressors (e.g. long transport times and treatments for mitigating the spread of marine invasives) that could compromise the health and subsequent performance of the seed. Batches of mussel seed (20*3 replicates) were subjected to the following antifouling treatments, either before (30-s seawater rinse or no rinse), or after a 15-h simulated storage/transport period: 4% lime (fresh water solvent), 4% lime (salt water solvent), 4% acetic acid, or 300 ppt brine (30-s. dip). Seed was then placed in re-circulation raceways and the number of mussels attached via byssal threads was determined following 24, 48 and 72 hrs. Seed treated with lime (fresh or salt), or acetic acid, that was not rinsed prior to transport/storage, had the poorest performance (lowest survival and attachment). Acetic acid was the most potent treatment with rinsing still resulting in significantly reduced attachment. Brine treatments did not differ significantly from the control. Brining offers the most flexibility, without compromising early performance, however, its efficacy, with respect to mitigating the spread of potential marine invasives, needs further study. Future research will address the long-term performance of seed exposed to such treatments.

INTRODUCTION

The mussel culture industry in eastern Canada faces the challenge of locating easily accessible, high quality mussel seed stocks that can be collected and transferred to grow-out sites. This process, however, could facilitate the spreading of marine invasive species that can have devastating impacts on aquaculture and the environment. It is believed that treating seed, by chemical and/or physical means, can greatly help reduce the risk of transferring invasive species (Forest and Blakemore, 2006). In order for seed transfers to be viable for industry, transfer time, storage method, and treatment method must adhere to the following: 1) cause minimal disruption to operations, 2) not negatively affect the health of the stock, 3) be 'environmentally friendly,' 4) effectively eliminate the viability of any potential invasive species (Carver et al. 2003; Sharp et al., 2006; Forest and Blakemore, 2007).

The goal of this study was to determine the short-term performance of seed subjected to chemical treatments in conjunction with a simulated 15 hr storage/transport period. Understanding how seed is able to cope with these unique and multiplicative stressors will give a better idea of what treatments/conditions are best suited for use by industry, as well as direct future field experiments. The two main objectives of this study include: 1) To evaluate the effect of brine, lime, and acetic acid treatments on short-term performance of seed, as measured by attachment via byssal threads. 2) To evaluate the effect of treating mussels, before (with and without a seawater rinse) or after a transport/storage period, on short-term performance of seed, as measured by attachment via byssal threads.

MATERIALS AND METHODS

Batches of mussel seed (20*3 replicates) were dipped in the following chemical, antifouling treatments for 30-s, either before (30-s agitated seawater rinse or no rinse), or after a 15-h simulated storage/transport period ($4^{o}C$, 100% humidity): 4% lime (fresh water solvent), 4% lime (sea water solvent), 4% acetic acid (vinegar), or 300 ppt brine. The control group was exposed to a 15-h simulated storage/transport period, but received no chemical treatment. Treated seed was then placed in 4 litre buckets, which were then completely submerged in re-circulation raceways ($10^{o}C$, 32 ppt salinity). Only mussel that were actively producing byssal threads were used. The number of mussels gapping (mortalities), unattached, and attached via byssal threads was determined following 24, 48 and 72 hrs (Forest and Blakemore, 2006).

It should be noted that while conducting these experiments the seed was in a pre-spawning period, and hence was at a medium to high level of stress, as measured via the Neutral Red Assay (Neutral Red Retention time < 30 min) (Harding et al. 2004). Future research will evaluate the temporal response of seed to chemical treatments and thus at different levels of stress.

RESULTS

Brine treatments did not differ significantly from the control over the 72 hrs of recovery (ANOVA, p>0.05) (Fig. 1).

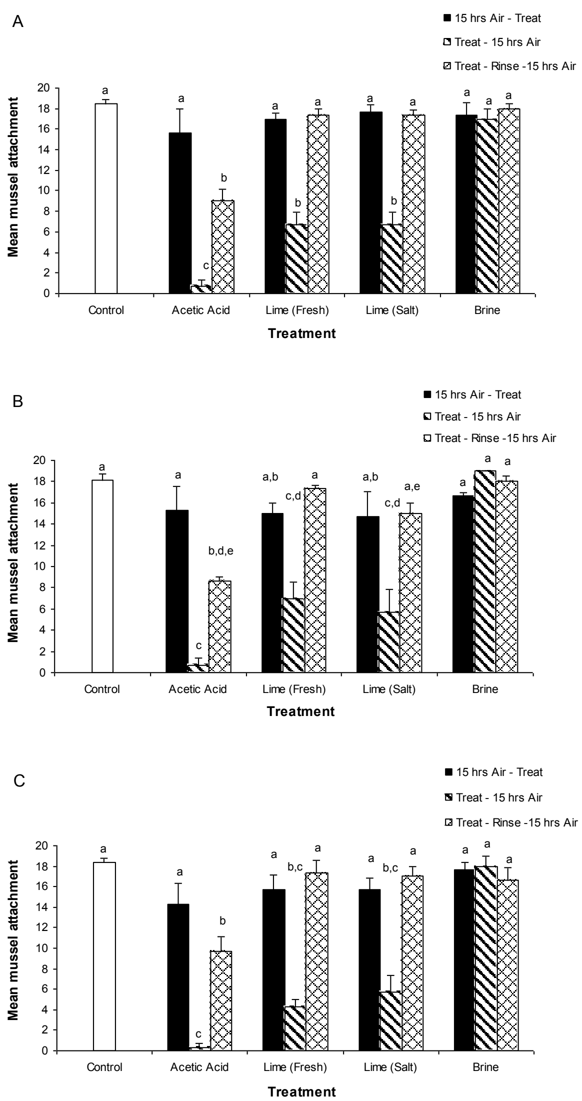

Figure 1. Mean mussel seed attachment (n = 20×3 replicates), A) 24 hrs, B) 48 hrs, C) 72 hrs, after acetic acid (4%), lime (fresh water solvent), lime (salt water solvent), and brine (300 ppt) treatments. Treatments were performed before (rinse and no rinse) and after a period of 15 hours of air exposure (4^{o}C, 100% humidity), (mean ± S.E.). Common letters indicate no significant difference among treatments (e.g. Tukey's b, p>0.05).

Similarly, lime (fresh and seawater solvents) treatments did not differ significantly from the control, except for the *treat (no rinse) – storage/ transport* treatment (ANOVA, p< 0.001 for both solvents, post-72 hrs) (Fig. 1). Without rinsing, ~ 25% of mussels were gapping (mortality), 25% unattached and 50% attachment, for both solvents, following 72 hrs.

Acetic acid was the most potent treatment with, *treat (no rinse) – storage/transport,* resulting in ~ 75% gapping (mortality), 23% unattached and 2% attachment, followed by, *treat (rinse) - storage/transport,* resulting in ~ 33% gapping (mortality), 18% unattached and 49% attachment. The *15 hrs air exposure - treat*, however, was not significantly different from the control (ANOVA, p>0.05) (Fig. 1).

DISCUSSION/CONCLUSION

The treatment methods investigated differed in their influence on the short term performance of seed. Results after 24 hrs were similar to those after 48 and 72 hrs, suggesting that if seed was able to recover, it did so within the first 24 hrs of recovery.

Brining offers the most flexibility, without compromising early performance. Liming should only be done if seed is rinsed in seawater immediately thereafter, either before or after transport. Performances of seed exposed to either freshwater or saltwater solvents were not significantly different, thus, the freshwater solvent may be of greater potency (e.g. greater osmotic gradient) to marine fouling species, without compromising the health of the seed. Acetic acid as a means of routine prevention of transfer is unlikely given the high mortality rate, however, acetic acid has been of some benefit for treating already established marine fouling species (Carver et al., 2003, Sharp et al., 2006).

With respect to mitigating the spread of potential invasive species, the efficacies of these treatments need further study. Future research will address the long-term performance (e.g. growth rate, condition indices) of seed exposed to such treatments.

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Canadian Freshwater Symposium - Contributed Papers

An Innovative Approach to Sustainable Freshwater Aquaculture Development in Canada: The Inter-Provincial Partnership

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Freshwater aquaculture in Canada includes more than 700 operations that produce more than 10,000 metric tonnes of output annually with a farm-gate value of approximately $70 million. Located in every province of the country, most operations are land-based facilities utilizing ponds, tanks and/or raceways. Additionally, approximately one dozen cage culture operations located in lakes and reservoirs account for more than 45% of total production. Trout and charr are the principal production species. Globally, Canada ranks a distant 13th in total freshwater trout and char output; however, given our natural resource base and other strategic advantages, this level of output is not commensurate with the opportunity and potential that exist. Growth has been forestalled due largely to concerns regarding the environmental and social sustainability of aquaculture. The Inter-Provincial Partnership for Sustainable Freshwater Aquaculture Development (IPSFAD) was established to facilitate research, development and commercialization (RDC) partnerships among Canadian and international experts to implement projects aimed toward resolving industry-identified challenges and helping the sector to realize its potential. Since its founding in 2001, IPSFAD has been a positive factor in freshwater aquaculture development. The first Action Plan was instrumental in securing industry buy-in and successfully coordinated and prioritized R&D efforts. The feed trails implemented under the second Action Plan have been a major success, resulting in the development and utilization of high-performance diets for trout and providing the sector with an exciting 'green' edge. These new-formula diets represent an important and growing market share since they simultaneously improved fish growth and reduce the environmental footprint of fish farm operations. The third Industry Action Plan reflects industry consensus regarding pertinent needs and challenges related to the major impediments affecting the acceptance, productivity and sustainability of the freshwater aquaculture industry in Canada. A major focus of the Action Plan is the Canadian Model Aqua-Farm Initiative, which will integrate results from all components of prioritized RDC projects into a standard, efficient operational design. As a direct result, Canadian freshwater aquaculture producers will be more competitive, more sustainable and better positioned to develop our inherent potential and take advantage of the opportunities that exist in all regions of this country.

KEYWORDS

Industry-driven research, development and commercialization; partnerships, freshwater aquaculture development

INTRODUCTION

Aquaculture encompasses a variety of activities in land-based systems, in freshwater lakes and in Canada's marine coastal zone. In 1986, Canadian aquaculture production amounted to only 10,488 tonnes, valued at $35 million. The value of aquaculture production increased at an average annual rate of 17.7% between 1986 and 2006, when output reached 171,829 tonnes valued at $912 million. Today, four species dominate production: salmon 68.7%, blue mussels 13.9%, oysters 7.3% and trout 2.9% (1).

The value and economic potential of freshwater aquaculture in Canada was thoroughly assessed in 1999 when 9,784 tonnes of freshwater fish were produced having a value of $69.6 million (2). In 2002, some 785 freshwater aquaculture ventures produced approximately 10,132 tonnes of product (3). The majority of these operations are land-based facilities where fish are reared in ponds, tanks and/or raceways. There are also approximately one dozen cage culture operations located in lakes and reservoirs. Although vastly out-numbered, cage culture operations account for more than 45% of total freshwater aquaculture output in Canada.

Salmonid species account for more than 88% of the production tonnage and 70% of the value of freshwater aquaculture in Canada (Table 1). The majority of the output (80%) consists of fish for human consumption while the remainder is produced for stocking private and public waters. Ontario and Quebec are the dominant producers of freshwater fish in Canada, followed by Saskatchewan, Alberta and New Brunswick. More than 1,260 full-time jobs have been created by this sector - some 900 direct employment positions and approximately 360 indirect jobs in the aquaculture supplies and services sector.

Globally, European nations are the major producers of trout and charr in freshwater systems; particularly France, Italy, Turkey, Spain and Denmark. Combined, these five countries produce more than 170,000 tonnes of trout per year in freshwater systems. Canada ranks a distant 13th in total trout and char output, behind countries such as Columbia, Iran and Japan. Considering Canada's freshwater resource base and other strategic advantages, the current level of output is not commensurate with the opportunity and potential that exists for freshwater aquaculture development in Canada. Furthermore, Canada's freshwater aquaculture sector is well-positioned to benefit from the following competitive advantages:

- Plentiful resource base (i.e. water supplies, low cost energy, etc.);
- Industry experience, expertise and desire to support sustainable development;
- Substantial export potential with proximity to the U.S. market which is increasingly dependent on imported seafood;
- Increasing global demand for fish and seafood due to population growth, increased affluence and the recognized health benefits of the products;
- A considerable potential and need for agricultural diversification and latent infrastructure to support development; and
- The potential to increase private sector participation in stocking public waters for fisheries enhancement.

Freshwater aquaculture in Canada, however, is not capitalizing on these inherent advantages and opportunities. In fact, growth in the sector has been forestalled for several years, due largely to concerns (real and perceived) regarding the environmental and social sustainability of aquaculture, which have resulted in an 'unofficial' moratorium on industry expansion in several regions of the country. Therefore, any expansion in the Canadian freshwater aquaculture sector is dependent upon the development of knowledge, technologies and practices to address and resolve such challenges.

Table 1: Relative abundance of freshwater aquaculture species produced in Canada – 2002 [2].

Species	Tonnage	Percent
Rainbow trout	7,684	76%
Brook trout	1,200	12%
Arctic char Tilapia Lake trout Brown trout Others	1,248	12%
TOTAL	10,132	100%

INTER-PROVINCIAL PARTNERSHIP FOR SUSTAINABLE FRESHWATER AQUACULTURE DEVELOPMENT IN CANADA

In recognition of this challenge, in 2001, a joint effort was undertaken between the Society for Research and Development for Continental Aquaculture (SORDAC) Inc., the Quebec Aquaculture Network (RAQ), and Fisheries and Oceans' Office of the Commissioner for

Aquaculture Development (OCAD). Recognizing common interests and objectives, the Ontario industry also engaged in the exercise, followed by freshwater producers in Western Canada. This consortium solicited the views and participation of the major players in the Canadian freshwater aquaculture industry regarding challenges and constraints facing the sector and resulted in formation of the Inter-Provincial Collaborative R&D Initiative for Sustainable Freshwater Aquaculture (the Initiative). The Initiative is national in scope and brings together several internationally-recognized experts into a collaborative framework of industry, academic and government interests that enriches and stimulates the overall Initiative. It is a unique opportunity to pool expertise and resources and to focus them around a primary cause; namely, fostering the sustainable development of freshwater aquaculture. The Initiative established research, development and commercialization (RDC) partnerships among Canadian experts to carry out specific projects related to the issues voiced by industry stakeholders. This approach generated consensus on industry priorities, identified pertinent RDC expertise, sought out synergies between various players and reduced duplication of efforts. In 2003, the first national meeting was held in association with the Aquaculture Association of Canada (AAC) in Victoria, BC. At the 2004 annual meeting of the AAC in Québec City, the Initiative hosted a national symposium to address a wide range of issues regarding freshwater aquaculture development and published Proceedings.

Mission, Objectives & Approach

In 2006, the Initiative became a registered not-for-profit organization – the Inter-Provincial Partnership for Sustainable Freshwater Aquaculture Development (IPSFAD) - with headquarters in Quebec City, QC. IPSFAD remains industry-driven and includes regional representation on its Board of Directors.

Mission

To promote sustainable development of freshwater aquaculture in Canada.

Objectives

1. *Create consensus regarding applied research, development and commercialization (RDC) priorities identified by industry.*
2. *Promote applied research, development and commercialization projects and assemble required research and/or technology transfer expertise for execution.*
3. *Foster the establishment of necessary synergies among various players while avoiding duplication of work and making optimal use of resources.*
4. *Organize and seek funding for projects that result directly from priorities identified by industry.*

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FIRST INDUSTRY ACTION PLAN - 2002

The first Industry Action Plan, submitted in January 2002, focused largely on projects related to nutrition. It was decided that this area was likely to have the most significant impact in the shortest time period. Projects were targeted toward developing more efficient diets to optimize animal performance and minimize environmental impacts. The following statements present a concise summary of results from the first Industry Action Plan.

- Salmonidae demonstrated compensatory growth following fasting with no significant morphological effects, however, there was no economic rationale to support fasting.
  - Lead researcher: Pierre Blier – Univ. du Québec à Rimouski
  - Industry partners: SODIM, RAQ

- Inoculation of fish meal with bacteria prior to feed manufacturing significantly increased the apparent digestibility coefficient of P in diet ingredients of animal origin, thereby providing a potential means to reduce the environmental effects of under-utilized phosphorus in feeds.
  - Lead researcher: Grant Vandenberg – Université Laval
  - Industry partners: Martin Mills, Philom Bios Inc., Bois Clair Fish Farm inc., SORDAC inc.

- Encapsulation of microbial phytase to improve phosphorus digestibility in salmonid diets proved ineffective since the encapsulated phytase was not heat-stable and lost efficacy during the feed manufacturing process.
  - Lead researcher: Grant Vandenberg – Université Laval
  - Industry partners: BASF Canada, Martin Mills, SORDAC inc.

- Incorporation of phase-feeding to alternate between phosphorus-deficient and phosphorus-replete diets reduced phosphorus emission to less than 2 kg total phosphorus per tonne of fish produced, and less than 1 kg dissolved phosphorus per tonne of fish produced without adversely influencing growth.
  - Lead researcher: Grant Vandenberg – Université Laval
  - Industry partners: Martin Mills, Pisciculture Bois Clair Inc.

- Low-phosphorus diets were found to have no adverse impact on the normal functioning of immune response in salmonid fishes. Survival and disease resistance were not impaired by low-phosphorus diets.
  - Lead researcher: Carl Uhland – University of Montréal
  - Industry partners: AquaSolutions, Inc., AVC Inc., RAQ

- A new model has been developed to project the behaviour of different forms of phosphorus typically found in aquaculture diet ingredients. The model, which has been validated, is accurate for a number of aquatic species.
  - Lead researcher: Dominique Bureau – University of Guelph
  - Industry partners: AquaCage Fisheries Ltd

- Diets formulated to produce less solid organic wastes were found to reduce faecal output by 10%, improve feed conversion by 8% and reduce BOD per tonne of fish produced without reducing growth rate or increasing feed cost. Results were immediately incorporated into commercial diet production.
  - Lead researcher: Dominique Bureau – University of Guelph
  - Industry partners: AquaCage Fisheries Ltd, Martin Mills

- The Initiative sponsored a National Freshwater Aquaculture Symposium in Victoria, BC (2003) at which research and technology transfer requirements were identified and prioritized, leading to the second Scientific Action Plan.
  - Lead: Eric Gilbert, DFO – Ottawa & Rich Moccia, Guelph University
  - Industry partners: AquaNet, SORDAC inc., AAQ

The total cost of the projects implemented under the first Industry Action Plan was $1.4 million, of which $1.0 million was provided by Fisheries & Oceans Canada's Aquaculture Cooperative Research & Development Program (ACRDP). Additional funding was provided by SORDAC inc. and SORDIM inc.

SECOND INDUSTRY ACTION PLAN - 2004

In 2004, industry's RDC requirements and priorities were re-evaluated and a second Industry Action Plan was developed. The renewed focus continued to address nutritional requirements while aspects of waste management, farm management and environmental carrying (assimilative) capacity were added. The following statements present a concise summary of results from the Second Industry Action Plan.

- The Initiative coordinated two missions to Denmark during which Canadian producers, government officials and other stakeholders gained a better understanding of Danish technologies and practices introduced to reduce

the environmental effects of aquaculture. These initiatives, based on an extensive applied research and technology transfer exercise, generated an enabling policy framework for aquaculture expansion of freshwater aquaculture in Denmark.
  - Lead: Eric Gilbert, DFO; Sylvain Lareau, AAQ
  - Industry partners: AAQ, OAA, Cedar Crest Trout Farm, Pisciculture des Alléghanys, Ferme piscicole des Bobines, Pisciculture Val-des-Bois, Canadian Aquaculture Systems Inc., Les consultants Filion et Hansen

- During the mission to Denmark, it was discovered that Danish diets were superior to salmonid diets conventionally available in Canada. Moreover, Canadian feed manufacturers believed that producers were unwilling to pay the increased cost for better diets. Therefore, the Initiative coordinated a research program to comparatively evaluate Canadian and Danish diets. Canadian feed manufacturers provided their traditional (old-formula) diets and some companies also manufactured new-formula, higher quality diets for the evaluations. The research was conducted in university laboratories (University of Guelph, Université Laval) as well as on commercial farms. The university studies established scientific credibility for the project while the on-farm trials were intended to demonstrate practical results to producers. In 2004/2005, the diets were tested at land-based facilities in Québec and Ontario and, in 2006, the program was extended to cage culture (Saskatchewan) and recirculation (Alberta) facilities. The university and on-farm studies produced consistent results, demonstrating that, in terms of feed conversion ratios (FCR) and kilograms of total phosphorus released per tonne of fish produced (kgTP/tfp), the Danish diets generally performed best overall. It was also discovered, however, that the FCR generated using the new-formula Canadian diets was between 8% and 25% better than that realized using the old-formula diets. Similarly, the amount of phosphorus discharged per tonne of fish produced was 9% to 45% less than that generated using the old-formula diets. The new-formula diets are now domestically available and command an important and growing market share. Producers recognize the inherent benefits of these more expensive, but more efficient feeds.
  - Lead: Grant Vandenberg, Université Laval, Éric Gilbert, DFO, Eric Boucher, IPSFAD.
  - Industry partners: SORDAC inc., SODIM inc., Pisciculture des Alléghanys, Ferme piscicole des Bobines, Pisciculture de Marinard Aquaculture, Pisciculture Mont-Tremblant, Pisciculture Val-des-Bois, Pisciculture de Marinard Aquaculture, Alberta Aquaculture Association, Wild West Steelhead, Ackenberry Trout Farms, Smoky Trout Farm, Corey Feed, Skretting, Martin Mills, Unifeed, EWOS

- The commercial, environmental and physiological performance of brook trout fed a low-phosphorus, high-energy new-formula Canadian diet has identified improved diet formulations specifically for brook trout.
  - Lead researcher: Grant Vandenberg, Université Laval
  - Industry partners: Pisciculture des Alléghanys

- The Initiative sponsored a National Symposium on Freshwater Aquaculture in association with the 2004 annual meeting of the Aquaculture Association of Canada in Québec City and published Proceedings of the symposium.
  - Lead: Eric Gilbert, DFO; Daniel Stechey, Canadian Aquaculture Systems, Inc.
  - Partners: AAC, AAQ, NOAA, OAA, SORDAC inc., University of Guelph

The total cost of the projects implemented under the second Industry Action Plan was $500,000 of which $250,000 was provided by Fisheries & Oceans Canada's Aquaculture Cooperative Research & Development

Program (ACRDP). Additional funding was provided by SORDAC inc., the Industrial Research Assistance Program (NRC-IRAP) and the Office of the Commissioner for Aquaculture Development (OCAD).

THIRD INDUSTRY ACTION PLAN – 2007-09

In the autumn of 2006 and early winter of 2007, the IPSFAD coordinated five 1-day workshops with industry and government stakeholders to solicit input regarding those RDC initiatives deemed to be most pertinent to industry development and to once again update and prioritize sectoral challenges and opportunities. Meetings were held in Alberta (stakeholders from Saskatchewan and Manitoba participated in the Alberta meeting.), Québec, British Columbia and Ontario, and a pan-Atlantic meeting was held in New Brunswick.

The workshops successfully identified stakeholder perspectives on the fundamental RDC issues in each region, including identification of specific project objectives. Consolidation of stakeholder input from these meetings is the foundation for a renewed three-year Industry Action Plan that will serve as a coordinating instrument for sustainable freshwater aquaculture development throughout Canada from 2007-2009. Unquestionably, the IPSFAD's third Industry Action Plan is industry driven. It builds upon its predecessor, using similar approaches, and addresses a broadened range of themes related to sustainable freshwater aquaculture development in Canada.

To consolidate resources and effort in those areas where interests, challenges, needs and opportunities are similar, 32 of the 49 issues identified in the regional workshops have been re-classified into 16 RDC initiatives within six thematic groups:

- Fish Health Management
- Nutrition
- Broodstock Management
- Alternative Species and Practices
- Canadian Model Aqua-Farm Initiative
- Cage Culture

Each of these themes is clearly within the purview of the IPSFAD. The 17 issues identified in regional workshops that are not reflected in the Action Plan are largely not within the scope of activities that could be undertaken by the IPSFAD; nevertheless, their omission from the IPSFAD Action Plan does not diminish their importance to regional aquaculture development. It is for this reason that five separate regional workshop summaries have been produced, thus preserving the full scope of regional needs, challenges and opportunities.

Based on stakeholder input, the RDC Themes outlined in the Action Plan are fundamental to industry development; however, within each theme, the issues are not necessarily static. It is recognized that the Action Plan must maintain a degree of flexibility to address emerging issues. Therefore, it is conceivable that the Board of Directors may, from time to time through the life of the Action Plan, recommend new initiatives based on the evolving requirements to advance sustainable freshwater aquaculture development.

Within the six themes, specific RDC projects have been outlined. All parties are invited to participate in their areas of expertise. The order of the themes presented below is immaterial as no attempt has been made to further rank the overall importance of the issues either between or within groups.

Approach

In pursuit of its Mission to promote sustainable development of freshwater aquaculture in Canada, the Action Plan is an important tool that will guide the IPSFAD toward meeting its Objectives for 2007-2009. The Plan reflects industry and stakeholder consensus regarding those research, development and commercialization issues requiring priority attention. It facilitates the implementation of RDC initiatives in the freshwater aquaculture sector.

The process of identifying and prioritizing key RDC issues on a national basis consolidates needs and enables a cooperative, synergistic approach to the development of solutions. Moreover, with the rationale and priority already established, parties need only to assemble the required research and/or technology transfer expertise for execution. Sponsoring (funding) agencies, therefore, need only to focus on whether proposals are well structured with a scientific team having the necessary experience and expertise to deliver meaningful results and whether the budget is commensurate with the proposed work plan and will generate value.

Beyond leading development of the Action Plan, the IPSFAD's Board of Directors and its Scientific Coordinator can facilitate the process of identifying and securing funding and other resources necessary for project implementation. In some instances, it may be beneficial for the IPSFAD to participate in or even to lead the implementation process by structuring project proposals, applying for funding and/or being directly involved in project execution. It is important to recognize, however, that all parties are invited to develop and submit proposals for RDC initiatives in support of the IPSFAD's objectives and Action Plan to advance sustainable freshwater aquaculture development in Canada.

Theme 1 - Fish Health Management

Increased emphasis on disease prevention strategies is required as a first line of defence against disease and to reduce the necessity for veterinary intervention. Presently, the understanding and implementation of biosecurity measures at commercial aquaculture ventures is not commensurate with the state of knowledge in the area. More effective biosecurity measures are required to reduce operational risk, to promote a healthy public image and to sustain inter-provincial / international trade.

The principal diseases that impart an economic impact on the culture of freshwater salmonids include cold water disease (*Flavobacterium psychrophilum*), columnaris disease (*Flexibacter columnaris*), furunculosis (*Aeromonas salmonicida*), infectious pancreatic necrosis virus (IPN) and fungal disease (e.g. *Saprolegnia*). Recently, viral hemorrhagic septicemia virus (VHSV) has been identified in the Great Lakes watershed, including Lake Huron, representing a potentially serious threat to the aquaculture sector. Disease management strategies including access to approved therapeutic agents for these specific pathogens are essential to industry development. Restricted access to approved antibiotics, non-antibiotic therapeutic agents (i.e. for control of external pathogens) and anaesthetics for use with aquaculture species is a constraint.

To facilitate fish health management, a comprehensive understanding of pathogen movement in relation to commercial aquaculture is required. That is, we must gain a better understanding of the epidemiology of disease - how disease travels between farms. As a fundamental component of the National Aquatic Animal Health Program (NAAHP), DFO and CFIA should be encouraged to pursue this exercise to facilitate increased fish health management in the sector.

Fish Health Management Projects

- *Project 1:* Develop Best Management Practices (BMPs) for Fish Health that incorporate standard operating procedures (SOPs) and technologies for biosecurity and aquatic health for land-based and cage culture operations, based on CFIA and NAFTA requirements, including:
    - facility design and operational management (animal husbandry, density, fish handling, etc.);
    - site access controls
    - routine monitoring and reporting requirements
    - control and management of water supply(ies);
    - management of mortalities;
    - written Fish Health Management Plans for each farm site; etc.

- *Project 2:* Evaluate the pathogenicity of VHSV to commercial strains of rainbow trout, brook trout and arctic charr and develop effective management and treatment solutions, as required.

- *Project 3:* Identify and prioritize those antibiotics, non-antibiotic therapeutic agents (e.g. for control of external pathogens) and/or anaesthetics required for effective management of cold water disease, columnaris, furunculosis, fungal disease and, if necessary, VHSV. Comparatively evaluate potential products based on their efficacy in fish farming and their likelihood for Canadian regulatory approval, and develop a business case to support product registration. Products available for use in aquaculture in other jurisdictions or that are approved for use in Canada in other sectors should be given priority.

- *Project 4:* There is an urgent need to identify a suitable replacement for malachite green, which was widely used as a disinfectant to treat external ectoparasites but which has been banned for use in food fish production.

- *Project 5:* Provide scientific support to advance regulatory approval of identified antibiotics, non-antibiotic therapeutic agents (e.g. for control of external pathogens) and/or anaesthetics for use with commercial aquaculture species.

Theme 2 - Nutrition

In spite of the considerable progress made in conjunction with IPSFAD's first two Action Plans, additional effort is required to further advance the efficiency and environmental sustainability of aquaculture diets. As a major cost factor, and the principal source of waste by-products, more efficient diets and improved feeding strategies can significantly affect the overall economic and environmental performance of aquaculture operations. Producers require high-quality, cost-effective diets. Furthermore, nutritional technologies have advanced to the point where 'designer' feeds can now be produced to meet specific production requirements at different stages in the lifecycle of the fish.

As in other areas of aquaculture, innovation in nutritional technology has surpassed the scope of existing legislation. The Canadian *Feeds Act* requires that labels on aquaculture feed specify the actual percentage of phosphorus in the feed with a guaranteed concentration between 1.0% and 2.5% and within a tolerance limit of plus or minus 20%. This is greater than the required concentration of phosphorus for salmonid fishes and precludes development of more environmentally sustainable diets.

Nutrition Projects:

- *Project 6:* IPSFAD will continue to support Canadian feed companies in their efforts to develop higher performing diets with reduced environmental impacts. Such initiatives should include:
  - improved performance (FCR, growth rate) with reduced phosphorus discharge;
  - denser fecal pellets that more-readily settle out of the water column for use in land-based and recirculation systems;
  - improved protein retention in large rainbow trout (i.e. >1.5 kg);
  - improved broodstock diets to enhance gamete quality in rainbow trout;
  - improved diets specifically for brook charr.

- *Project 7:* Prepare the necessary scientific documentation/rationale to support a formal request by fish farming and/or feed industries for a regulatory amendment that would enable lower phosphorus content in aquaculture diets.

- *Project 8:* Improvements in feeding strategy and feed delivery can also contribute significantly toward enhanced environmental sustainability in the sector. Reliance on standard feed charts to calculate rations remains a common practice, even though it has been proven to be inefficient. Improved methods to calculate feed rations are required and must reflect the high-energy diets used in the industry and the operational conditions at fish farms.

Theme 3 - Broodstock Management

Today, commercial rainbow trout broodstock populations exist throughout Canada; however, it is fair to say that these populations have not been properly genetically evaluated. Additionally, some producers source eggs from a major U.S. supplier. In the absence of any effort to enhance the quality of Canadian trout broodstock, long-term reliance on existing suppliers may impose undue risk on the sector.

Furthermore, substantial economic gains could be attained through genetic selection to enhance the quality and performance of captive strains of rainbow trout produced in the Canadian aquaculture sector. Within the sector, it is recognized that there are two avenues to achieve genetic improvement: (1) short-term gains induced through the introduction of identified commercial strains from other jurisdictions; and (2) long-term gains attained from the introduction of a wider genetic base from feral and/or captive populations and implementation of a selective breeding program to target desirable traits, including growth, disease resistance, late maturation, yield, etc.

Broodstock Management Projects:

- *Project 9*: Develop a national broodstock program to develop enhanced performance in rainbow trout, specifically targeting improved fillet yield, enhanced growth rate and greater tolerance to warm-water conditions. Additional rainbow trout strains should be sought from local and/or imported stocks, taking into consideration the genetic characteristics (performance) of the target strains and their disease profile.

Theme 4 - Alternative Species & Practices

The potential exists to diversify the freshwater aquaculture sector by developing alternative species for commercial culture, provided that markets exist and that the current state of technology is at an applied stage of development. In doing so, however, it is essential to evaluate and prioritize potential new species to avoid the risk associated with the exploration of too many species, thus diluting efforts so thinly that it becomes difficult to generate meaningful advances.

Canada's traditional agricultural sector has considerable under-developed potential for rural economic development in the form of experienced farmers with a desire and willingness to engage in new ventures, a rural infrastructure and labour pool, as well as biophysical, economic and market assets to exploit. Aquaculture presents an opportunity to help diversify and stabilize traditional agriculture; however, a tangible plan is required to bring this concept to fruition.

Diversification Projects:

- *Project 10*: Identify and prioritize those species (domestic and exotic) that offer the best opportunities for industry diversification based on market and production capacities in keeping with regional interests. For identified target species, develop core technologies and practices to establish commercial culture operations (e.g. systems technologies, water quality requirements, nutritional requirements, broodstock development, etc.) Following this prioritization exercise, IPSFAD will continue to support developmental efforts to advance the identified species.

Theme 5 – Canadian Model Aqua-Farm Initiative (Land-Based)

'Farmers' often develop agri-business ventures by observing other operations, acquiring a basic understanding of operational and investment requirements, and then constructing their own facility. Throughout Canada, however, there is no standard aquaculture model to emulate. Moreover, existing aquaculture ventures are decidedly variable in design and performance and thus there are few fundamental benchmarks for productivity or efficiency. The development of a standardized farm model, which addresses all of the basic production, economic, environmental and regulatory aspects of commercial aquaculture in a design that is efficient, effective and sustainable would be a milestone in Canadian aquaculture.

The Canadian Model Aqua-Farm Initiative (CMAF) is a long-term process that will require several years to develop and implement. The first step in this process is to agree upon the basic design guidelines and principles for such a facility. Once the conceptual framework for the CMAF initiative is agreed upon, the next major undertaking will be to establish a model farm / demonstration farm to apply and validate the concepts for environmental sustainability and economic success. Thereafter, knowledge pertaining to the design and management of the CMAF will be available to those individuals or corporations intending to develop freshwater aquaculture in Canada.

Canadian Model Aqua-Farm Initiative (Land-Based) Projects:

- *Project 11:* Coordinate an 'experimental farm' design workshop at which leading authorities on the design, operation, management and regulation of land-based aquaculture systems in Canada and elsewhere would meet to develop the principles and design concept for a 'Canadian Model Aqua-Farm.' Workshop delegates would provide collective expertise to review and discuss all aspects of the operation, including: rearing unit design, hydraulics, solid waste management, biofiltration, gas exchange, fish health management, production planning, systems management and control, waste disposal, environmental controls, etc.

- *Project 12:* Construct a Canadian Model Aqua-Farm for aquaculture development to 'demonstrate' industry potential. Evaluate all inputs and outputs, including:
    - Fish
    - Feed
    - Other direct inputs (e.g. labour, electricity, etc.)
    - Costs
    - Environmental Management (water and nutrients)
    - Regulatory Components

Specific initiatives to be targeted within the CMAF program include, but are not limited to:

- Development of effective and efficient sludge dewatering systems
- Improved technologies for tertiary treatment of soluble wastes
- Standard design and operational protocols for pond aquaculture, including:
    - » optimum dimensional ratios (e.g. LxWxD, bottom slope) for fish production and handling and for water exchange;
    - » hydraulic flow rates for optimal growth and effective flushing;
    - » pond management strategies, etc.
    - » Design and management for reducing P output
- Development of effective protocols for determination of the assimilative (carrying) capacity of an aquaculture operation and its receiver
- Development of consistent and practical environmental compliance standards
- Evaluation of the theoretical utilization (digestibility) and waste production from the most common diets used in Canadian freshwater aquaculture to establish base line standards for environmental modelling. For each diet, projection of the anticipated output of waste metabolic products, including:
    - » Total suspended solids;
    - » Dissolved and particulate phosphorus;
    - » Dissolved and particulate nitrogen;
    - » Biochemical oxygen demand
    - » Fecal matter characterisation (cohesion, density, etc.)
- Development of options for effective on-site concentration and stabilization of aquaculture manure, including potential uses for this agricultural by-product that could generate additional revenue for producers

- *Project 13*: BMPs (Codes of Practice) effectively combine science, technology, economics, management and common sense to reduce or prevent adverse environmental effects of a defined activity. Comprehensive BMPs also serve to enhance operational effectiveness, environmental performance and the social licence of aquaculture ventures. As part of the process to establish standard procedures through the CMAF initiative, comprehensive BMPs should be developed to provide overall management direction that will ensure responsible development through:

- recommended practices at the farm level that help to ensure industrial responsibility (e.g. routine inspection of animal health; record-keeping; mortality disposal; environmental monitoring; etc.);
- practical, economically sound, specific guidelines to help farmers avoid or minimize risks to operations, the environment, the general public and consumers;
- promotion of attitudes and behaviours that support sustainable development; and
- establishment of industry performance standards that provide a reference for monitoring and compliance.

Theme 6 - Cage Culture

Canada's lakes and rivers constitute an extraordinary freshwater resource that is unparalleled in the world. Furthermore, the federal and provincial governments have invested extensively in the development of dams, diversion structures, reservoirs and canals in support of irrigation for our traditional agriculture sector, for flood control and for hydro-electric generation. This natural and man-made resource base is vastly under-utilized for aquaculture. Regulatory authorities often contend that there is insufficient science to establish effective cage culture policy. Furthermore, due to the absence of waste treatment systems in cage culture operations, critics argue that the sector benefits from external diseconomies, suggesting that producers gain from the use of public resources at a private cost that is less than the social cost associated with their use. Additional knowledge, therefore, is required to supplement available science that will facilitate sound planning and decision-making with respect to cage aquaculture.

Cage Culture Projects:

- *Project 14*: Augment knowledge regarding sediment and benthic science and monitoring requirements, including:
  - Development of effective models to characterize sediments beneath freshwater cage aquaculture operations;
  - development of practical surrogates to project complex physical, chemical and biological interactions;
  - identification of fundamental decision criteria and thresholds to support effective risk management and a practical decision-making framework;
  - further evaluation of site fallowing as a site management strategy; and
  - development of appropriate site decommissioning protocols.

- *Project 15*: Refine practical and effective water quality modelling, monitoring and reporting requirements.

- *Project 16*: Develop effective models to project the assimilative capacity of freshwater bodies to support cage aquaculture.

CONCLUSION

Since its founding in 2001, IPSFAD has been a positive factor in freshwater aquaculture development. The first Action Plan was instrumental in securing industry buy-in and successfully coordinated and prioritized R&D efforts. The feed trails implemented under the second Action Plan have been a major success, resulting in the development and utilization of high-performance diets for trout and providing the sector with an exciting 'green' edge. These new-formula diets represent an important and growing market share since they simultaneously improved fish growth and reduce the environmental footprint of fish farm operations.

The Third Industry Action Plan of the Inter-Provincial Partnership for Sustainable Freshwater Aquaculture Development in Canada reflects industry consensus regarding pertinent needs and challenges related to the major impediments affecting the acceptance, productivity and sustainability of the freshwater aquaculture industry in Canada. Through implementation of the research, development and commercialization initiatives outlined in the Action Plan, it is envisaged that industry prosperity will increase and that a more collaborative, interdisciplinary approach will emerge amongst those stakeholders engaged in freshwater aquaculture research, development and technology transfer. A major focus of the Action Plan is the Canadian Model Aqua-Farm Initiative, which will integrate results from all components of prioritized RDC projects into a standard, efficient operational design. As a direct result, Canadian aquaculture producers will be more competitive, more sustainable and better positioned to develop our inherent potential and take advantage of the opportunities that exist in all regions of this country.

ACKNOWLEDGMENTS

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The Canadian Model Aqua-Farm Initiative

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'Farmers' often develop agri-business ventures by observing other operations, acquiring a basic understanding of operational and investment requirements, and then constructing their own facility. Throughout Canada, however, there is no standard land-based aquaculture model to emulate. Moreover, existing aquaculture ventures are decidedly variable in design and performance and thus there are few fundamental benchmarks for productivity or efficiency. The development of a standardized farm model, which addresses all of the basic technological, production, financial, environmental and regulatory aspects of commercial aquaculture in a design that is efficient, effective and sustainable would be a milestone in Canadian aquaculture. The results of a March 2007 workshop to discuss design and production concepts related to a standardized Canadian Model Aqua-Farm are presented. The technological concepts agreed upon at this workshop provide considerable insight into the design and development of full-scale model farm projects for further evaluation and refinement. The IPSFAD will continue to coordinate this effort with the guidance and assistance of a CMAF Project Management Team. Based on the conceptual designs for several Canadian Model Aqua-Farm projects, next steps in the process include working with prospective developers, conduct pre-feasibility assessments of the conceptual designs to confirm the projected productivity, performance, and environmental effects of the system and to project efficiencies at the minimum economic scale. Thereafter, the conceptual designs will be adjusted accordingly to meet financial and environmental objectives. This step will be completed in early 2008 and includes the requirements for a comprehensive environmental and economic performance measurement and reporting (benchmarking) program that can be used to improve productivity and sustainability within the freshwater aquaculture sector. The final step will be to prepare detailed designs and proceed to the construction phase to establish the first Canadian Model Aqua-Farm ventures for comprehensive monitoring and evaluation.

KEYWORDS

Model farm, freshwater aquaculture

INTRODUCTION

Freshwater aquaculture output in Canada pales compared to that of many European countries. Collectively, France, Italy, Germany, Britain and Denmark produce more than 170,000 tonnes of trout in freshwater systems. In fact, with only 10,000 tonnes of annual production, Canada ranks a distant 13th among the world's trout-producing nations. This is not commensurate with Canada's inherent potential, particularly considering that the freshwater aquaculture sector is well-positioned to benefit from the following competitive advantages:

- Plentiful resource base (i.e. water supplies, low cost energy, etc.);
- Industry experience, expertise and desire to support sustainable development;
- Substantial export potential with proximity to the U.S. market which is increasingly dependent on imported seafood;
- Increasing global demand for fish and seafood due to population growth, increased affluence and the recognized health benefits of the products;
- A considerable potential and need for agricultural diversification and latent infrastructure to support development; and
- The potential to increase private sector participation in stocking public waters for fisheries enhancement.

Freshwater aquaculture in Canada, however, is not capitalizing on these inherent advantages and opportunities. In fact, growth in the sector has been forestalled for several years in most regions of the country, due largely to an unofficial moratorium imposed because of real and perceived challenges regarding the environmental and social sustainability of aquaculture, the lack of design and operating standards with industry benchmarking and the absence of a coordinated federal-provincial policy and regulatory framework. Expansion within the freshwater aquaculture sector, therefore, is dependent upon development and implementation of a strategic approach to generate the knowledge, technologies and practices necessary to resolve these challenges.

The Inter-Provincial Partnership for Sustainable Freshwater Aquaculture Development (IPSFAD) was established in 2001 to promote sustainable development of freshwater aquaculture in Canada. The principal objectives of this national, private, not-for-profit organization are to create consensus regarding applied research, development and commercialization (RDC) priorities identified by industry; and facilitate implementation by fostering synergies among producers, researchers and governments. IPSFAD also helps to organize and seek funding for projects that result directly from priorities identified by industry.

IPSFAD's third Industry Action Plan (2007-09) reflects industry and stakeholder consensus regarding research, development and commercialization issues requiring priority attention. The Action Plan was developed using stakeholder input garnered through five regional workshops in which the challenges and opportunities pertaining to sustainable freshwater aquaculture development were identified and prioritized. The concept of developing a land-based Canadian Model Aqua-Farm was initially presented in IPSFAD's second Action Plan (2004-06)[1] and was subsequently outlined in further detail at the 2004 annual meeting in Quebec City[2]. The Canadian Model Aqua-Farm initiative is now the core component of IPSFAD's third Industry Action Plan (2007-09)[3].

The Danish Model Farm Program

For a relatively small country with limited freshwater resources, Denmark is among the world's leading trout suppliers, producing more than 31,000 tonnes of trout annually from freshwater land-based operations – more than 3-times total Canadian output.

During the 1990s, however, Danish aquaculture fell under considerable public scrutiny due to environmental issues regarding water use and effluent phosphorus, which resulted in a moratorium on further industry development. These environmental pressures forced the Danes to re-examine their operations in an effort to reduce water consumption, improve the quality of discharged effluent and decrease the total cost of production. With more than $3 million in government investment over several years, and through the cooperative efforts of industry, government and other stakeholders, the Danish Model Farm Program thoroughly researched and verified all system components, inputs and outputs in economic and environmental terms. New technologies and practices related to all aspects of commercial aquaculture were developed, including feed manufacturing and feeding strategies, farm management strategies, the introduction of recirculation systems to conserve water and energy and development of standardized and recognized technological, economical and environmental performance metrics.

The program is based on an innovative yet simplistic design implementing concrete raceway systems and employing a series of air lift systems that serve to simultaneously oxygenate and strip carbon dioxide and move water. As the water moves through the raceways, sludge cones located in settling zones remove a large percentage of solid wastes, which are stored for intermittent land application. At the end of the raceways, water is treated to remove remaining suspended material (via mechanical filtration) and ammonia is removed with a deep-welled, moving-bed biofilter. Effluent water is drained through a constructed wet-land to remove remaining organic matter, dissolved phosphorus and nitrate, prior to its release.

The resulting novel approach to land-based aquaculture has enabled further industry expansion and has improved prosperity in an environmentally sustainable manner - permitting the efficient production of trout with minimal environmental impact in terms of nutrient loading and water requirements. Furthermore, the Danish Model Farm Program has been recognized and accepted by industry, government and other stakeholders, thus facilitating the regulatory review and approval of applications for new aquaculture development.

THE CANADIAN MODEL AQUA-FARM INITIATIVE

'Farmers' often develop agri-business ventures by observing other operations, acquiring a basic understanding of operational and investment requirements, and then constructing their own facility. Throughout Canada, however, there is no standard land-based aquaculture model to emulate. Moreover, existing aquaculture ventures are decidedly variable in design and performance and thus there are few fundamental benchmarks for productivity or efficiency. The development of a standardized farm model, which addresses all of the basic technological, production, financial, environmental and regulatory aspects of commercial aquaculture in a design that is efficient, effective and sustainable would be a milestone in Canadian aquaculture.

Building upon the Danish experience, the CMAF initiative will adapt the latest knowledge and technological innovations to the Canadian context to develop a 'model farm' that incorporates the latest innovations in terms of nutrition and feeding strategy, fish health management, design of infrastructure and equipment, water conservation and utility, manure processing and management, production management and operational practices and standards to maximize both financial and environmental performance. Furthermore, once thoroughly assessed and documented, farm inputs and outputs will become recognized as standards and will be more readily accepted by authorities, thus facilitating site application and approval processes. By incorporating a modular approach, the CMAF can be easily duplicated, bringing standardization to industry practices and performance.

In essence, the CMAF will lead to established norms and baseline standards pertaining to the biological, technological, financial and environmental sustainability of aquaculture. A fundamental component of success will be the participation of provincial and federal regulatory officials in the environmental assessment of these technologies so that aquaculture applications based on the 'Canadian Model Aqua-Farm' will be recognized, understood and accepted by the authorities. Once achieved, these standards can form the basis for establishment of 'smart regulation' within the sector.

It is envisaged that the initial model farm projects would also serve as demonstration and development farms where individuals could go to learn about aquaculture and participate in workshops and/or skills training programs, thus greatly facilitating technology transfer and dissemination.

Design and Production Concepts

In March 2007, the IPSFAD assembled a group of approximately two dozen recognized national and international authorities on the design, operation, management and regulation of land-based aquaculture systems to develop design and production concepts for the CMAF. This group met for two days to review and discuss all aspects of the farm, including: rearing unit design, hydraulics, solid waste management, biofiltration, gas exchange, fish health management, production planning, systems management and control, waste disposal, environmental controls, etc. The objective of the meeting was to generate ideas and strategies regarding the scope and nature of an innovative yet simplistic design for a Canadian Model Aqua-Farm. The advantages and disadvantages of available technologies and practices were reviewed and discussed in an effort to identify a preferred approach for the CMAF. For those issues where consensus could not be attained regarding the most appropriate technologies and practices, strategies to address and resolve such issues were identified. The meeting concluded with an outline of 'next steps' for applied research, development and commercialization to establish a successful Canadian Model Aqua-Farm initiative.

Scope

Species: Salmonids
Salmonids were selected as the culture species of choice since, among commercially cultured species, these fishes are the most sensitive to adverse culture conditions. Therefore, a system capable of supporting salmonids should be capable of supporting other, less demanding species.

Product: Food Fish
Since food fish have the lowest per unit cost, the facility should be designed to produce food fish at a commercial scale. Moreover, the principal thrust of industry expansion and the greatest market opportunities derive from the production of food fish. A system capable of supporting commercial food fish production should also be capable of supporting production of fingerlings, stockers, etc.

Scale: Minimum Economically Sustainable Size
The underlying objective of developing the CMAF is to enable industry expansion. It is imperative, therefore, that the venture is economically sustainable and thus the minimum size necessary to achieve financial autonomy must be targeted. It is estimated that this is likely to be in the range of 100 to 200 metric tonnes of production per year. In keeping with conventional industry practices, this scale may be most economically achieved by developing the CMAF in modules having approximately 50 to 100 tonnes capacity.

In the interest of conserving water resources and enabling economical climate (temperature) control, a water recirculation rate of 98% should be targeted in the design, based on flow rate (i.e. for every 100 Lpm of water circulating through the system, 98 Lpm shall be recirculated while 2 Lpm of new water is introduced).

Principles

1. The CMAF must be industry-driven. This means that it must be profitable, be environmentally

sustainable, uphold fish welfare requirements, facilitate industry expansion, earn social licence from consumers and other stakeholders, and support effective communications.

2. Intellectual Property associated with the CMAF shall be open and publicly accessible.
3. Stakeholder engagement in the development of the CMAF is encouraged and welcome. In particular, government regulatory agencies (regulatory design and management) and economic development agencies (regional infrastructure and support) are to be engaged at an early stage of the initiative. Other stakeholders are to be engaged at an appropriate time, after the core industry, government, and research groups have established the fundamental parameters for the initiative.

Design Concepts

A fundamental part of the March 2007 workshop was open dialogue and exchange of information pertaining to the conceptual design of the Canadian Model Aqua-Farm. The various components of system design and management were discussed and consensus was reached pertaining to the most practical options available for further consideration in a subsequent pre-feasibility conceptual design stage. It was not the objective of the workshop to develop a detailed design but, rather, to identify the most practicable technologies and practices that should, in concept, be utilized in the model farm.

Rearing Unit Design

Three basic rearing unit designs were discussed – raceways, circular tanks and Swede-style (semi-square) tanks. To facilitate a comparison between these designs, nine key parameters that influence the performance of fish culture in these units were outlined; however, they were not prioritized. These are described below. Although 'cost' is a key parameter that must be considered, it was decided that cost factors would be better addressed during the economic assessment phase of the conceptual design.

Space Efficiency	The capacity to effectively utilize the available space within the footprint of a conventional building or cover.
Flexibility	The ability to remove tanks if necessary to accommodate a change in capacity or configuration.
Fish Distribution	The likelihood of attaining uniform fish distribution throughout the rearing unit.
Labour Efficiency	The ability to effectively manage the fish (e.g. sorting, grading, harvest) within the rearing unit.
Hydraulics	The efficient and relatively homogeneous movement of water through the rearing unit.
Energy Consumption	The amount of energy required to move water though the rearing unit.
Water Quality	The ability to maintain a high-quality rearing environment based principally on hydraulic flow rates and patterns.
Biosecurity & Fish Health	The ability to effectively manage fish health within the system.
Ability to Cover	The practicality and economics of covering the rearing units to provide protection from the elements for the fish and the employees.

The three rearing unit designs were compared by ranking their performance within each of the nine parameters. The rearing unit that was perceived to perform best was ranked 1st and the unit with the worst perceived performance was ranked 3rd. The comparative rankings are presented in Table 1. Overall, circular tanks received the lowest total score, suggesting that they offer the best combination of factors for intensive aquaculture. Circular tanks scored highest for flexibility, fish distribution, hydraulics, water quality and biosecurity / fish health. Raceways scored highest for space efficiency, labour efficiency, energy consumption and ability to cover. Swede-style tanks did not rank highest in any category, suggesting that they provide an acceptable compromise in most categories but are ideal in none.

After considerable discussion it was agreed that, at this time, it would be ill-advised to select circular tanks as opposed to raceways (or vice versa) for the conceptual Canadian Model Aqua-Farm since further analysis is required to determine which system would be most practical. Therefore, for the following categories, it was necessary to consider both rearing unit designs in the discussion.

Hydraulics

Raceways

Low-head (i.e. low energy) systems were recommended. It was noted that the Danish Model Farm raceways utilize air-lift pumping to achieve 90% to 95% oxygen saturation within a system that operates at approximately 20 cm of total head. Nitrogen saturation and accumulation of dissolved carbon dioxide are not chronic problems in the Danish system. As an alternative to air-lifts, multiple low-head submersible pumps should also be considered for circulating water through the system, which would allow for the incorporation of low-head oxygenation technology.

Circular Tanks

Efficient submersible or flooded-suction pumps were the preferred option for circular tank systems in a 'pump-once' configuration.

Suspended Solids Control

Raceways

It was agreed that effective solids control in raceways could be best managed with a combination of (1) settling cones installed at regular intervals in the floor of the raceways to collect and remove large (> 100 µm) particles and (2) micro-sieve filtration to capture smaller particles. Other aspects of solids control that were considered to be important included feed formulation to generate diets that produce dense, cohesive faecal pellets and management of fish densities and hydraulic flow rates to facilitate self-cleaning within the rearing units by carrying the solid wastes to the sludge cones.

Circular Tanks

Circular tanks having a diameter-to-depth ratio of 3:1 to 4:1 and employing a Cornell-style double drain configuration were considered practical. The underflow rate (proportion of water flowing out the bottom drain) should be between 10% and 30% of total tank flow. Underflow water containing the majority of the solids generated within the system should be directed to micro-sieve filters for solids removal, either with or without pre-concentrators (e.g. swirl separators, radial flow clarifiers). Proper inlet design is considered important to maintaining efficient hydraulics within the tank. A total hydraulic retention time (exchange rate) of 30 to 60 minutes is considered optimal.

Biofiltration

Among the various biofilter designs available, three were considered acceptable for the Canadian Model Aqua-Farm: (1) moving bed filters; (2) micro-bead filters; and (3) fluidized bed filters. These three filter designs were compared using four functional parameters – capital cost, operational cost, simplicity and efficiency. As for the rearing unit designs, the three biofilter designs were ranked best through worst for each parameter (Table 2). Among the three biofilter designs, the micro-bead filter presents the most practical combination of functional factors. Moreover, they are the most economical from both capital and operating perspectives.

Raceways

Moving bed and micro-bead biofilters were proposed as feasible options for raceway culture systems.

Circular Tanks

All three biofilter designs were proposed as feasible for circular tank culture systems.

Table 1: Perceived rank of raceways, circular tanks and Swede-style tanks by nine functional parameters.

Functionality	Raceways	Circular Tanks	Swede-Style Tanks
Space Efficiency	1	3	2
Flexibility	3	1	2
Fish Distribution	3	1	2
Labour Efficiency	1	2	3
Hydraulics	3	1	2
Energy Consumption	1	2	3
Water Quality	3	1	2
Biosecurity & Fish Health	3	1	2
Ability to Cover	1	3	2
Total of Ranked Scores	**19**	**15**	**20**

Table 2: Perceived rank of moving bed, micro-bead and fluidized bed biofilters by four functional parameters.

Functionality	Moving Bed Biofilter	Micro-Bead Biofilter	Fluidized Bed Biofilter
Capital Cost	3	1	2
Operating Cost	2	1	3
Simplicity	1	2	3
Efficiency	3	2	1
Total of Ranked Scores	**9**	**6**	**9**

Dissolved Gas Management

Raceways

For raceway systems, a preference was stated for the use of aeration to maintain dissolved oxygen levels appropriate for the concentration of fish in the units. In intensively aerated systems, the concentration of dissolved carbon dioxide typically does not reach levels that are chronically detrimental to the fish; however, a carbon dioxide mass balance should be conducted to confirm each particular application. In those cases where liquid oxygen is necessary to facilitate removal of soluble nitrogen from source water, the use of a side stream oxygen injection system (e.g. down-flow contact chambers or cones) to pre-treat incoming water should suffice.

Circular Tanks

In circular tank systems, the use of liquid oxygen injection is regarded as standard technology. Based on those design parameters already discussed for circular tanks, a typical system would entail the following process flow:

MICRO-SIEVE FILTRATION → PUMPING → BIOFILTRATION → CO_2 STRIPPING → O_2 INJECTION → CULTURE TANKS

Oxygenation in such systems can generally be economically achieved using low-head oxygen contactors (LHO). Often, ozone (O_3) is introduced into the LHO with oxygen. Ozone is an effective oxidizing agent that provides a disinfection function and also breaks down long-chain hydrocarbons and proteins to facilitate water quality management.

Heating / Cooling, Buildings & Infrastructure

It is envisaged that approximately 80% of the potential CMAF installations in Canada would be enclosed within a building or structure to protect the system from the elements and to facilitate environmental control. Regional snow loading requirements, in compliance with building codes, would largely determine the type and cost of building or cover to be employed. The economics of the different building types will be a determining factor and must include a cost-benefit analysis of heating and/or cooling options.

Fish Health Management

It is recognized that the CMAF will have a comprehensive operational Fish Health Management Plan in place governing all aspects of operations. From a facility design perspective, the principal factors governing fish health management relate to the quality of the incoming water supply and the quality of the fingerlings stocked into the system. For those operations utilizing a surface water source, disinfection of the water supply using ozone and/or ultraviolet irradiation at dosage rates sufficient to control the known pathogens of concern is necessary. Depending on the quality of the water, groundwater supplies may need to be similarly pre-treated for pathogen control.

Within the operating system, it may also be advisable to incorporate ozonation. For raceway systems, this could be accommodated in a side-stream configuration with standard oxygen contacting equipment (see dissolved gas management, above). In circular tanks systems, this can be achieved in the LHO or other oxygenation equipment.

Fish Handling & Containment

At the envisaged scale of 100 to 200 tonnes of production per year, labour costs will be a significant economic factor in the CMAF. It will be necessary, therefore, to develop efficient fish handling systems for inventory management, grading and harvesting. Facility design features that allow for *in situ* sorting, grading and relocation of fish between rearing units are preferable to techniques that require removal of fish from the water.

Given that the CMAF is intended to be an intensive recirculation facility, it is also preferable to have a purge tank incorporated into the system for post-harvest conditioning of the fish prior to sale. Effective fish containment technologies are also required. The CMAF should utilize a three-stage process to ensure that fish cannot escape from the facility. Typically, this would consist of triple screening with at least one of the screens being passive in operation (not relying on electricity) and having a fish-free zone between the last two control points.

Solid Waste Collection & Disposal

Following solids-liquid separation, it is essential to concentrate and stabilize waste solids for disposal. Rapid dewatering is essential in freshwater systems since it reduces the amount of phosphorus that leaches into the solute. Concentration of sludge can be effectively achieved using sludge drying beds, sedimentation or mechanical filtration (belt filters) either with or without polymer addition to facilitate flocculation. Solid wastes can be removed for distribution on arable land during the frost-free growing season or utilized as an ingredient in composting operations. The clarified solute may be disposed of into a municipal sewer, pumped over arable land for irrigation or released into a receiving body of water provided it meets the effluent discharge standards. Due to the high concentration of soluble nutrients that is common in the solute, it may be necessary to discharge this wastewater through an artificial wetland.

Monitoring & Control Systems

In intensive recirculating aquaculture systems, it is essential to employ active monitoring and control systems to avert potential catastrophic losses. The following systems should be targeted for monitoring:

- Water level & flow
- Oxygen concentration
- Water Temperature
- Building security
- Electrical supply
- Back-up power systems
- Redox potential (with O_3)
- Ozone-in-air sensors
- Auto. Feeding systems

Among these systems, several require active monitoring with alarm functions and mandated human intervention to address and resolve the situation that triggered the alarm. These are water level and flow, oxygen concentration, electrical supply and ozone-in-air sensors. Additionally, these four systems also require automatic back-up systems that are activated according to a programmed response following the alarm situation.

CONCLUSION

The technological concepts agreed upon at the March 2007 Canadian Model Aqua-Farm workshop provide considerable insight into the design and development of full-scale model farm projects for further evaluation and refinement. The IPSFAD will continue to coordinate this effort with the guidance and assistance of a CMAF Project Management Team. Next steps in the process include:

- Based on the conceptual designs for several Canadian Model Aqua-Farm projects, work with prospective developers to conduct pre-feasibility assessments of the conceptual designs and confirm the projected productivity, performance, and environmental effects of the systems and project efficiencies at the minimum economic scale. Adjust the conceptual designs accordingly to meet financial and environmental objectives. This step will be completed in early 2008 and includes the

- requirements for a comprehensive environmental and economic performance measurement and reporting (benchmarking) program that can be used to improve productivity and sustainability within the freshwater aquaculture sector.

- Prepare detailed designs and proceed to the construction phase to establish the first Canadian Model Aqua-Farm ventures for comprehensive monitoring and evaluation.

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Status and Outlook for Freshwater Aquaculture in Canada: Regional Perspectives

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Over the last five years, the number and output of freshwater aquaculture operations has declined, from more than 10,200 tonnes in 1999 to approximately 8,339 tonnes with a farm-gate value of $44 million in 2006. Salmonid species still account for more than 91% of the production tonnage and 89% of the value of freshwater aquaculture in Canada. Ontario (46.8%), Quebec (17.5%) and Saskatchewan (14.6%) are the dominant producers of freshwater fish in Canada, followed by Alberta (7.5%), New Brunswick (7.1%), British Columbia (3.2%), Yukon Territory (1.4%), Prince Edward Island (1.4%) and Nova Scotia (0.3%). There is no freshwater aquaculture production in Newfoundland and Labrador (aside from smolt production which is not included in this assessment). It is estimated that more than 1,000 jobs are created by freshwater aquaculture throughout Canada. Throughout all regions of Canada, there is considerable opportunity and potential to advance freshwater aquaculture by taking advantage of our plentiful biophysical resource base and capitalizing on our proximity to strong seafood markets. Challenges to further aquaculture development are two-fold. Throughout the country, the absence of an enabling policy and regulatory framework for sustainable aquaculture is a principal constraint to further land-based and cage aquaculture development. The principal technical challenges include the need to improve the genetic quality of commercial brood stock populations to yield better performing fish, implementing better fish health management strategies and continuing efforts to develop more efficient diets. The Canadian Model Aqua-Farm initiative, a program to develop a standardized, efficient recirculating aquaculture system, is widely regarded as a harbinger of further growth and development in the Canadian freshwater aquaculture sector.

KEYWORDS

Freshwater aquaculture, production tonnage and value, employment

INTRODUCTION

The value and economic potential of freshwater aquaculture in Canada was thoroughly assessed in 1999 when 9,784 tonnes of freshwater fish were produced having a value of $69.6 million[1]. In 2002, some 785 freshwater aquaculture ventures produced approximately 10,132 tonnes of product[2]. At the time, the majority of these operations were land-based facilities where fish are reared in ponds, tanks and/or raceways. There were also approximately one dozen cage culture operations located in lakes and reservoirs. Although vastly out-numbered, cage culture operations accounted for more than 45% of total freshwater aquaculture output in Canada in 2002.

Over the last five years, the number and output of freshwater aquaculture operations has declined. In 2006, total production of freshwater aquaculture species was approximately 8,339 tonnes with a farm-gate value of more than $44 million (Table 1). Salmonid species still account for more than 91% of the production tonnage and 89% of the value of freshwater aquaculture in Canada (Table 1). The majority of the output consists of fish for human consumption while the remainder is produced for stocking private and public waters. Ontario (46.8%), Quebec (17.5%) and Saskatchewan (14.6%) are the dominant producers of freshwater fish in Canada, followed by Alberta (7.5%), New Brunswick (7.1%), British Columbia (3.2%), Yukon Territory (1.4%), Prince Edward Island (1.4%) and Nova Scotia (0.3%). There is no freshwater aquaculture production in Newfoundland and Labrador (aside from smolt production which is not included in this assessment). Almost 800 jobs (not FTEs) are reported in the sector from those provinces and territories that collect freshwater employment statistics (Table 2). Based on industry output, it is estimated that more than 1,000 jobs are created by freshwater aquaculture throughout Canada.

Of the 733 freshwater aquaculture licences issued in 2006, 703 were for land-based operations and 30 were for cage culture operations (Table 3). The latter were located in British Columbia (18), Ontario (11) and Saskatchewan (1). It is estimated that cage culture accounts for 54% of total freshwater aquaculture output in Canada.

Table 1: Canadian freshwater aquaculture tonnage and value ($000) by region in 2006.

	Atlantic	Quebec	Ontario	Western	Canada
Tonnage					
Rainbow Trout	5	617	3,800	1,638	6,060
Brook Trout	300	758	10	0	1,068
Arctic Charr	280	60	10	131	481
Tilapia	0	0	75	255	330
Enhancement (stockers)	0	na*	0	14	14
Other	145	25	5	211	386
Total	730	1,460	3,900	2,249	8,339
Value ($000)					
Rainbow Trout	21	2,561	15,770	6,919	25,270
Brook Trout	2,700	6,822	90	0	9,612
Arctic Charr	2,520	540	90	1,179	4,329
Tilapia	0	0	413	1,490	1,902
Enhancement (stockers)	0	na*	0	126	126
Other	1,595	275	55	1,008	2,933
Total Farm-Gate Value	6,836	10,198	16,418	10,721	44,172
Contribution to Provincial Economy**	588	70,000	60,000	400	130,988

Table 2: Canadian freshwater aquaculture employment by region in 2006

Labour (#)	Atlantic	Quebec	Ontario	Western	Canada
Direct	32	na	180	260	489
Indirect	36	na	200	35	292
Total	68	na	380	295	781

Table 3: Number of Canadian freshwater aquaculture licences by region in 2006.

Permits / Licences (#)	Atlantic	Quebec	Ontario	Western	Canada
Land-Based	137	140	103	204	703
Cage Culture	0	0	11	19	30
Total	137	140	114	223	733

While producers in the Canadian freshwater aquaculture sector share many of the same objectives, production strategies and policy environments, regional differences exist. The following sections of this report discuss the status and outlook of freshwater aquaculture from four

perspectives: Western Canada (British Columbia, Alberta, Saskatchewan, Manitoba and Yukon Territory), Ontario, Quebec and Eastern Canada (New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador).

Western Canada (BC, AB, SK, MB, YK)

Status

The freshwater aquaculture sector in Western Canada is relatively small and fragmented, although Saskatchewan has one of the largest freshwater cage culture operations in the country for production of rainbow trout. Industry fragmentation, and the vast geography of the region, makes it difficult for producers, suppliers, government personnel and other stakeholders to share practical information and expertise for the benefit of the entire sector and region.

Total freshwater production in 2006 was 2,249 tonnes (Table 1). Saskatchewan accounted for the largest proportion of this total followed by Alberta, British Columbia, Yukon Territory and Manitoba. Approximately ¾ of all production is rainbow trout, followed by tilapia (~11%), other species including grass carp and walleye (~9%) and Arctic charr (~6%). More than 95% of total production is for food fish with the balance being produced for fee-for-fishing and stock enhancement. It is estimated that these ventures support more than 295 jobs in the sector (Table 2). Among the four western provinces and the Yukon Territory, 204 land-based and 19 cage culture licences were issued in 2006 for freshwater aquaculture (Table 3).

Opportunities

Western Canada has an opportunity to utilize a greater proportion of its surface and groundwater supplies to further develop commercial aquaculture. Furthermore, the farming culture is conducive to aquaculture development as opposition to aquaculture due to user-group conflict is not commonplace in this region which is accustomed to livestock production. Current trends in the agri-food industry are forcing the agriculture sector to enhance productivity and produce more affordable, higher quality and safer foods, leading to consolidation amongst farming operations. Today, there are fewer and larger farms than in years past. Such consolidation is having a negative impact on the sustainability of family farms and is compromising the survival of rural communities and traditional ways of life. Aquaculture has been identified as one method to augment total output on family farms, particularly in decommissioned hog and PMU barns, which present an opportunity to establish aquaculture clusters in the region[3].

Western Canadian fish producers are well-positioned to service central and western North American markets by taking advantage of efficient distribution systems for food products that already exist throughout the region. Owing to the multi-cultural fabric of many western cities, the potential also exists to diversify the freshwater aquaculture sector by culturing alternative species to service ethnic markets in search of premium quality, live products, much of which is presently imported from the United States.

Challenges / Constraints

“Farmers’ develop agri-business ventures by observing other operations and then constructing their own venture. Throughout the country, including Western Canada, there is no proven aquaculture model to follow and existing ventures are highly variable in design, scale, performance and profitability. Not surprisingly, therefore, it has been difficult to generate awareness regarding opportunities for aquaculture development and thus attract new players into the sector. Furthermore, in the absence of a cluster of producers, the vast geography of the region is not conducive to small-scale operations.

The absence of a standardized approach to aquaculture development also presents policy and regulatory challenges since each proposed venture triggers an entirely new review process for government officials. Permit application and licensing processes, which are long, laborious and expensive, are exacerbated by the absence of clear and enabling aquaculture policy. Most of the western provinces have supportive Agricultural agencies but taciturn Fisheries and/or Environmental agencies. Taken collectively, these challenges make it difficult to secure investment and working capital to finance aquaculture operations.

Western producers already engaged in the sector face similar challenges to producers in other regions. More efficient diets, better performing strains of trout and technologies to help reduce the overall cost of production are among their greatest challenges. In some areas, particularly BC, producers must also battle a general negative perception regarding commercial aquaculture due to media campaigns sustained by anti-aquaculture NGOs targeting the west coast marine salmon farming industry. The latter is one part of a larger marketing challenge faced by a small, fragmented sector, which must identify means for cooperative efforts aimed at growing the sector in western Canada so that collectively they all prosper by being part of a larger cluster of producers.

Outlook

Aquaculture is a small industry with considerable potential for expansion in western Canada given the biophysical resource base and farming culture of the region. Achieving this potential, however, requires that the scope and scale of aquaculture development in the region be quantified such that an effective strategy can be established to foster industry development and to provide governments with an incentive to support aquaculture. Existing producers and some government agencies in the region have concluded that development of a Canadian Model Aqua-Farm supported by an enabling policy framework is fundamental to overcoming the challenges to further growth in the sector.

Ontario

Status

Among Canadian provinces, Ontario has the largest output of freshwater aquaculture products. Rainbow trout is the principal species produced, accounting for more than 97% of the Ontario industry's total output. Minor species produced include tilapia, Arctic charr, brook trout, smallmouth and largemouth bass, walleye and cyprinid baitfish. Aside from tilapia, charr and brook trout, however, these minor species are more developmental than commercial. The production of brook trout and bass occurs at approximately 60 land-based operations and is primarily targeted to pond stocking and recreational fishing markets[4]. Charr production is limited to only a few farms and the species shows no signs of growth. Since peaking at 7 operations in the late 1990s, tilapia production has decreased considerably and today most of the value from this sector is derived from the export of fingerling-sized fish.

Total trout production in Ontario was approximately 3,800 tonnes in 2006, having a farm-gate value of more than $15.7 million (Table 1). In total, other species production was only about 100 tonnes. More than 180 direct jobs have been created (Table 2) at the 103 land-based and 11 cage culture operations (Table 3) while an additional 200 jobs exist in the related aquaculture supplies and services sector. Overall, the economic contribution of aquaculture in Ontario is estimated to be approximately $60 million annually.

Opportunities

Ontario's vast inland water supplies and the Great Lakes basin suggest that this province could increase its total aquaculture output many times over in both land-based and cage culture operations. Public awareness and opposition to aquaculture development, however, is often formulated from biased media messaging developed by anti-aquaculture interest groups that rely on select information which is portrayed in a manner to shape public opinion and influence government decisions. Objective information regarding sustainable aquaculture development is required to foster sustainable development.

Challenges / Constraints

The absence of an enabling policy and regulatory framework for sustainable aquaculture is a principal challenge to further land-based and cage aquaculture development in Ontario. Land-based operations face increased surveillance and enforcement measures that add considerable expense. For cage culture operations, regulatory authorities contend that there is insufficient science to establish effective cage culture policy; necessitating additional knowledge to supplement available science and facilitate sound planning and decision-making with respect to cage aquaculture. The sector also faces several technological challenges, for instance:

- Substantial economic gains could be attained through genetic selection to enhance the quality and performance of captive strains of rainbow trout produced in the Ontario aquaculture sector.
- Fish health management is also an important challenge. Three principal diseases impart an economic impact on rainbow trout culture in Ontario: cold water disease (*Flavobacterium psychrophilum*), columnaris disease (*Flexibacter columnaris*) and furunculosis (*Aeromonas salmonicida*). Recently, viral hemorrhagic septicemia virus (VHSv) has been identified in the Great Lakes watershed, representing a potentially serious threat to the Ontario aquaculture sector.
- As feed represents the largest cost in trout production, and it is the principal source of metabolic wastes, further research is required to

enhance the efficiency and effectiveness of aquaculture diets.

- The understanding and implementation of biosecurity measures at commercial aquaculture ventures is not commensurate with the state of knowledge in the area. More effective biosecurity measures are required to reduce operational risk and to promote a healthy public image.

Outlook

Moccia and Bevan[4] offer the following perspective on the sector – "The aquaculture industry in Ontario is facing a very difficult and volatile future. This situation is mostly a result of internal factors that constrain its growth, rather than foreign competition, effectively limiting more successful market penetration, and thus reducing profitability and discouraging new investment. [Currently], the Ontario industry is languishing in one of its worst periods in the last decade. The major constraint to Ontario's aquacultural development remains the complex and confusing legislative, regulatory and policy barriers that confront cage aquaculture expansion in the public waters of the Great Lakes, where 80% of Ontario's market size fish production occurs. In spite of the many impediments to growth, Ontario's aquacultural potential remains intact with a strong market, a highly skilled workforce, and an abundant infrastructure of goods and services that would drive much needed expansion given the appropriate legal framework."

Quebec

Status

Aquaculture in Québec dates back to 1857 when sport fish species (mainly Atlantic salmon and brook trout) were produced for enhancement of rivers where stocks had become depleted. It wasn't until the 1970s that commercial production of farm-raised food fish began in Québec; production was 45 tonnes in 1976. Brook trout and rainbow trout are the principal species raised for human consumption. Financial incentive programs made available by the Government of Québec in 1980, 1986 and 1992 fostered significant growth in the sector. Production peaked at 2,200 tonnes in 1999, the same year that the provincial government introduced more stringent environmental guidelines governing the sector[5]. As a direct result of these new guidelines, production has steadily declined to only 1,460 tonnes in 2006 (Table 1). Reduced total phosphorus in fish farm effluents and water conservation measures were the basis of the tougher environmental standards.

Today, production serves two principal markets – (i) fish for stocking ponds and lakes and (ii) fish produced for direct human consumption. While the number of producers growing fish for the stocking market has remained somewhat stable, the number of producers growing fish for direct human consumption has been in decline for the past decade. During this time, five (5) major producers have discontinued operations. Since peaking in 1998-99 the number of fish ponds has declined substantially. In 2006, the province issued only 126 aquaculture licences (Table 3), down from 187 licences in 1999. Brook trout is the main culture species accounting for more than half of total output, followed by rainbow trout (Table 1). Together, these two species represent 94% of total output; the balance consists of Arctic charr and other species (brown trout, lake trout, perch, bass and hybrids. Production is allocated largely to stock enhancement (60%), followed by food fish (33%) and fee-for-fishing operations (7%)[5]. Quebec does not collect employment statistics for the freshwater aquaculture sector; however, a study to compile this data is to be completed in 2008.

Opportunities

Québec has abundant natural resources to support further aquaculture development and strong markets exist for stock enhancement and food fish. Moreover, technical assistance and financial incentives are available from the lead provincial government agency, Ministère d'Agriculture, pêcheries et l'alimentation Québec (MAPAQ).

Challenges / Constraints

Not unlike other regions of the country, Québec's regulatory framework presents a cumbersome and expensive environmental approval process with little certainty regarding the outcome. Furthermore, due to the enhanced environmental performance standards imposed in 1999, the level of investment required to launch a new aquaculture venture is high. Another principal challenge is to locate development sites where the receiving body of water has sufficient flow to accommodate the fish farm effluent. In many receivers, the background level of phosphorus is already too high to enable aquaculture development. Coupled with the inherent risks in the sector, these challenges make financing difficult to secure.

In spite of the considerable progress made in conjunction with IPSFAD's first two Action Plans, additional effort is required to further advance the productivity and environmental sustainability of aquaculture. Technological solutions must be developed to improve the efficiency and effectiveness of water recirculation systems to further reduce water consumption and facilitate effluent treatment. Continued efforts are also required to improve aquaculture diets. Specific measures to adjust dietary ingredients to increase waste (faecal) cohesion and facilitate solid waste removal are necessary to meet long-term regulatory targets. Similarly, more efficient feeding strategies are also required. Once solid wastes are removed from process waters, technologies are required to enhance the concentration and stabilization of aquaculture manures so that practical alternative uses for this organic waste material can be developed.

In many ways, the culture of fish in ponds has not evolved beyond the basic technologies and practices used a generation ago. New technologies and standards for pond aquaculture are required to improve the overall performance of this sub-sector of Québec's aquaculture industry. Improvement of pond culture technologies and practices is a fundamental component of the STRADDAQ (see below). For all operations, there is a need to place increased effort on disease prevention strategies as a first line of defence against disease and to reduce the necessity for veterinary intervention.

Outlook

Looking ahead, Québec's aquaculture industry must evolve in a radical departure from its past development. To conform to the new, more restrictive, environmental standards, operations must utilize improved water treatment systems to reduce their environmental impact on receiving bodies of water and recirculation technologies will be required to conserve ground water and surface water resources. In recognition of this challenge, however, the Strategy for Sustainable Development of Freshwater Aquaculture in Québec (STRADDAQ) was launched in 2004. The plan was agreed to by the Quebec Ministries of the Environment (MENV) and Agriculture, Fisheries and Food (MAPAQ) and the Aquaculture Association of Québec (AAQ) to reduce the discharge of total phosphorus (TP) from land-based aquaculture ventures by 40%, from approximately 7.2 kilograms TP per tonne of fish produced today to only 4.2 kilograms TP per tonne of fish produced within ten years. The agreement pertains only to those fish farms producing more than 5 tonnes of fish annually; however, this group represents approximately 50 farms that account for 92% of Québec's total aquaculture output[6]. The phosphorus reduction target is to be achieved by a combination of efforts involving better diets and nutrition, enhanced farm management strategies and infrastructure renewal. *Aquablue* is a financial assistance program that has been agreed to by the STRADDAQ committee (MAPAQ, MENV, AAQ). Under the program, MAPAQ will provide up to 70% of the funding required to improve the environmental performance of fish farms, up to $800,000 per farm. Projects could include installation of solids settling facilities or micro-screen filtration, conversion of ponds to more efficient tanks and/or raceways, sludge handling equipment, 'smart feeding' systems, etc. Financial support is available on a one-time basis per farm site requiring that the full review and implementation plan be developed as an initial exercise; however, a second round of funding is may be acquired if project goals are not fully attained.

In spite of these developments, the future of the Québec aquaculture sector is uncertain. The average age of producers today is 55 years and it is increasingly difficult to attract young people into an industry facing regulatory uncertainty. As a result, existing producers have only limited opportunity to sell their operations and thus the number of farms continues to decline. There is evidence, however, that the STRADDAQ initiative is beginning to reverse this trend.

Eastern Canada (NB, NS, PEI, NL)

Status

Freshwater aquaculture in Atlantic Canada is entirely land-based. Among the provinces, output is greatest in New Brunswick (590 tonnes), followed by Prince Edward Island (119 tonnes) and Nova Scotia (21 tonnes). There is no freshwater aquaculture production in Newfoundland and Labrador (except for salmon smolt production which is not included in this review). Total output from the region was 730 tonnes in 2006 (Table 1). Approximately 68 jobs were supported by this industry (Table 2) at 137 licenced operations throughout Atlantic Canada (Table 3)

In the Atlantic region, the majority of the production is almost equally divided between brook trout and Arctic charr. Sturgeon and rainbow trout are also produced commercially in the region. It is difficult to segment the production data by species since charr and sturgeon data are included amongst "Other Species" for confidentiality. Total freshwater production in the region has declined over the past decade.

Opportunities

As in other regions of Canada, an optimism exists that total freshwater aquaculture can increase considerably in Atlantic Canada. Not unlike the perspective in Western Canada and Quebec, it is perceived that the development of a modular land-based production system that incorporates proper monitoring, biosecurity and stock traceability in an efficient recirculating system, would address the current gap that exists between those that want to pursue aquaculture and those who require more certainty. Producers are also interested in diversifying their output through other species such as sturgeon and brook charr x Arctic charr hybrids.

Challenges / Constraints

Throughout Central and Western Canada, rainbow trout is the predominant culture species for a variety of biological and economic reasons. In Atlantic Canada, however, rainbow trout, a naturalized non-native species, accounts for a very small proportion of total output due to policy constraints imposed out of concern for wild populations of native salmonid fishes.

Among the species cultured, producers feel that substantial economic gains could be attained through genetic improvement in brood stock populations. For Artic charr (*S. alpinus*) in particular, performance has been highly inconsistent with the two primary strains used in the sector. Further broodstock and/or hybrid (Arctic x brook charr) development has been suggested. Producers of sturgeon are concerned that the species is listed as endangered under C.I.T.E.S. and by the US Fish and Wildlife Service which affects international trade; an issue due to the small domestic market for sturgeon meat and caviar.

Producers also feel that sectoral growth is hampered by the lack of a standard production system that is both environmentally sustainable and economically viable. Efforts to develop a system that minimizes the environmental footprint by conserving water and reducing the discharge of organic metabolic wastes are essential to industry growth in Atlantic Canada.

Outlook

Innovative technologies and practices are required to stimulate a second wave of aquaculture development in a manner that is financially and environmentally sustainable. Increasing standardization in facility design and operation could also lead to improvement in the regulatory framework governing aquaculture. In this regard, the Canadian Model Aqua-Farm initiative is viewed as a harbinger of further growth and development in the region. If anticipated policy changes governing the culture of rainbow trout in Atlantic Canada come into effect, substantial gains could be achieved in a relatively short period of time.

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Lupin and Low Tannin Faba Bean as Potential Feed Ingredients for Aquaculture

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From 2004-2006, lupin (*Lupinus angustifolius*) and low tannin faba bean (*Vicia faba minor)* were investigated for agronomic adaptability and nutritional attributes for food and feed. Lupin had never been grown commercially in Western Canada. Faba bean had been grown before, however, these cultivars contained higher levels of tannin and were late maturing. The range in yield of lupin and low tannin faba bean in small plot trials across years and locations was 2092 to 3486 $kg \cdot ha^{-1}$ and 4601 to 6981 $kg \cdot ha^{-1}$, respectively. Both crops were shown to be higher in protein compared to field pea with whole seed values of 29 to 40 % for lupin and 26 to 31 % for low tannin faba bean. Limited testing as a feed ingredient indicated that both grains could be incorporated into farmed salmon diets. One report on faba bean concentrate concluded that low tannin faba bean values for salmonid feed formulation was roughly equivalent to corn gluten meal, however, maximum inclusion levels for salmon diets will have be to determined if this feed comes onto the market on a commercial scale. De-hulling of lupin and air classification (fractionation) of both lupin and low tannin faba bean were studied to improve utilization and increase market potential.

KEYWORDS
Lupin, low tannin faba bean, feed ingredient, nutritional attributes, uses, yield, protein

INTRODUCTION

In 2002, Alberta Agriculture and Food's Industry Development Sector changed the approach to project management. An analysis to determine market feasibility and potential was required before agronomic research trials could be conducted. Lupin and low tannin faba bean were two high protein grain legume crops that were in the preliminary stage of investigation for adaptability to the Alberta environment. Lupin had never been grown commercially in Western Canada. Faba bean had been grown before, however, these cultivars contained higher levels of tannin and were late maturing. A number of private industry experts (Marv Anderson and Associates. 2003, Mercantile Consulting Venture (Marlene Boersch, Anthony Temple). 2004, Trimension Group (Ray Rondeau). 2002) were hired to assess the market potential for lupin and low tannin faba bean.

PRODUCTION AND USES

i) Lupin

Globally there are three important *Lupinus* species; *Lupinus albus* (white), *Lupinus luteus* (yellow) and *Lupinus angustifolius* (blue). Commercially available lupin which is used for human and livestock consumption are 'sweet' types which contain low levels of alkaloids. Sweet lupin varieties contain 0.01 - 0.03 % alkaloids compared to the 'bitter' lupins which contain 0.8-0.9 % alkaloids. Alkaloids, when administered to mammals, produce striking physiological effects such as paralysis and elevated blood pressure. Of the three species, only *Lupinus angustifolius* is traded to any extent internationally and Australia is the world's largest lupin producer, exporting some 1,000,000 tonnes annually.

World wide lupin is used extensively in livestock rations as a high protein and energy source. As well, our market intelligence indicated that lupin was being used as a feed ingredient in farmed fish rations in Australia and that fish feed manufacturers worldwide were interested in this crop as a potential new feed ingredient. Soy meal and canola are the main current plant protein options for aquaculture feed, but soy has less than desirable nutritional qualities and needs to be imported into Western Canada. According to the literature, lupin has exceptional qualities for fish feed including high protein content, low levels of anti-nutritional factors (phytic acid, saponins, lectins and trypsin inhibitors), high phosphorous digestibility and retention, and valuable pelleting qualities. The aquaculture industry growth was pegged at 8-10 % (compared to 1-2 % for traditional animal species) annually worldwide.

In addition to aquaculture demands, a collaborative effort with private industry discovered a new use for lupin in the cosmetics and personal-care sector. Companies have become increasingly concerned by potential allergens associated with traditional protein extracts (e.g. wheat, soy, nuts etc). However, lupin protein has unique functional properties, making it an ideal choice in cosmetic and personal healthcare formulations. Through a patented process a sweet lupin peptide extract is manufactured without chemically modifying the protein, thereby producing an all natural extract. This extract was launched worldwide in spring 2007.

The range in yield of lupin in small plot trials across years(2004-2006) and locations in Alberta was 2092 to 3486 kg·ha^{-1}. Currently, there are less than 100 acres of commercial production of lupin in Alberta. Pedigreed seed production (the multiplying of seed) of the cv. Arabella has just begun.

ii) Low tannin faba bean

Globally there are three important Vicia faba varieties; Vicia faba var. major, Vicia faba var. equina and Vicia faba var. minor. Vicia faba var. major (broadbean) is large seeded with a 1000 kwt (kernel weight) > 800g. Vicia faba var. equina (horsebean) and Vicia faba var. minor (tickbean) are smaller seeded, with a 1000 kwt ranging from 200 to 800g. Additionally, faba bean species may broken down further based on the presence of two genes : gene zt (zt1 or zt2) which determines the tannin content and gene zv which determines the vicine and convicine contents. Faba bean with only the zt1 or zt2 gene are referred to low or zero, however, if the genes zt1 or zt2 and zv have been incorporated into the plant, they are described as double low or double zero. In Europe, these double low or double zero types have been trademarked as Fevita®. It should be noted that the term faba bean may be used interchangeably with fava bean and broadbean in other parts of the world.

Low tannin faba bean, as the name implies, has a substantially reduced level of tannins (approximately 1% or less) in the seed. Tannins are phenolic compounds of plant origin and give the seed an astringent (bitter) taste. Digested tannins have the ability to precipitate proteins resulting in the inactivation of gut enzymes, giving tannins their anti-nutritional role. In monogastric species, such as hogs and poultry, tannin containing seed will cause feed consumption issues (palatability), affect digestion, and increase days to market.

Feed is the biggest input cost in raising hogs. Currently the protein needs of the hog industry are being met through imported soy meal. Low tannin faba bean, grown locally, could drastically reduce the processing and transporting costs and increase the competitiveness of the Alberta hog industry. Zero-tannin faba bean has a slightly lower protein content compared to soy, but unlike soybean that requires the removal of excess oil and a mechanized reduction of antitrypsic factors, faba can be used as whole seed and does not require processing for hogs. It also has a high lysine content, which may promote more efficient use of protein and reduce the nitrogen surplus excreted in animal urine.

Additionally, research breaking the whole seed into various fractions such as the hulls, protein and starch have created interest in other applications. Similar to lupin, the concentrated low tannin faba bean protein fraction may replace a portion of the plant protein in fish diets. Soy meal and canola have less than desirable nutritional qualities and soy needs to be imported.

The range in yield of low tannin faba bean in small plot trials across years (2004-2006) and locations was 4601 to 6981 kg.ha-1. Currently, there are between 5,000 and 10,000 acre of commercial low tannin faba bean in Alberta. Pedigreed seed production of cv. Snowbird has now expanded across the prairies and into eastern Canada.

OVERALL BENEFITS

Nitrogen is by far the most important nutrient for crop growth, and the nutrient most required in the largest quantity by all crops. Lupin and low tannin faba bean belong to a group of plants called legumes. Legumes form a symbiotic relationship with certain bacteria known as rhizobia found in root nodules and as a result these plants fix their own nitrogen from the air. As well, the not fully understood "rotational effect" (nonnitrogen) of a grain legume crop on the crop following results in an increased yield, quality and reduction in nutrient requirements. The reduction in nitrogen fertilizer use in the year of growing the legume and in the year following the legume leads to a reduction in greenhouse gases, thus, minimizing the "energy foot print".

Compared to cereal and oilseed crops grain legumes only need a fraction of the usual amounts of manufactured fertilizers. This reduces greenhouse gas emissions associated with the *production* of fertilizer, *transportation* of fertilizer, and *application* of fertilizer (fertilizers are applied with tractors that burn fossil fuels). Moreover, 80% of the grain legume crops in Alberta are grown in a reduced tillage system, meaning fewer tillage passes in the field, again further lessening the impact of agricultural practices on the environment.

When the overall energy consumption in the production of legumes (including pesticides, fertilization, mechanization) is weighed against other crops, it is approximately half that of a wheat crop or most other non-fixing crop. Consequently, the increased use of the grain legumes will significantly reduce greenhouse gas emissions from cropping systems. This includes reduced CO2 emissions, as well as, N2O, CH4, NO and NO2 emissions at the different steps of manufacturing and application of products.

Another environmental impact of excess manufactured fertilization is the eutrophication of aquatic ecosystems. Eutrophication is the increase of chemical nutrients (usually nitrogen and phosphorous) in an eco system. Commonly this occurs in water bodies receiving excess nutrients in runoff. The addition of nutrients stimulates algal blooms which deplete oxygen in the water and subsequently causes the death of fish and other animals in the water body, throwing the whole ecosystem off balance.

Rations containing de-hulled lupin, when compared to other grains such as soybean or animal proteins, have a higher phosphorous digestibility and retention, thereby lessening eutrophication. Likewise, the practice of reduced tillage in grain legumes production means less soil erosion into streams, rivers and lakes. As phosphorous is tightly bound to soil particles, this further reduces the amount of phosphorous entering the aquatic environment.

Finally, grain legumes are a natural fit in the consumer movement towards a healthier lifestyle and disease prevention. They are high in complex carbohydrates including fiber and resistant starch, as well as protein, minerals, vitamins, and phyto chemicals. As a source of these components, grain legumes can offer many benefits for nutrition, health, and chronic disease prevention including cholesterol and blood lipid lowering, improved blood glucose control, and promotion of satiety.

RESEARCH FINDINGS 2004-2007

There has been substantive research in Alberta on lupin and zero tannin faba bean over the last three years. The areas studied include; genetics, seeding rate and date, germination and vigour, inoculants, fertility, nitrogen fixation, weed control, disease, seed treatments, harvest aids, silage, compositional analysis, feeding, and processing. Due to time constraints, the remainder of this paper will focus on findings relating to compositional analysis and processing. The following section on compositional analysis derived from Strydhorst et al, 2007. ACIDF #2004C012R. Chapter 7.

i) Compositional Analysis

Seed of cv Snowbird tannin-free faba bean, cv Arabella narrow-leafed lupin, and cv Cutlass field pea were analyzed to quantify and compare their nutrient and mineral profiles. Seed samples were collected from six different site years and samples reflected a combination of four different agronomic practices. The nutrient profile was assessed by measuring protein, fat, fiber, and total digestible nutrients. Measurements of gross energy, digestible energy, metabolizable energy, net energy of feed, nitrogen free extract, nonstructural carbohydrates, and neutral detergent fiber were used to assess the energy and carbohydrate profiles of the samples. The mineral composition was assessed by measuring the ash, Ca, Mg, P, K, Na, and salt content.

Growing environment significantly affected the measured parameters. Seed composition was slightly affected by agronomic practices. Lupin seed was characterized by a high protein (36%), fat (5.7%), fiber (15.3%), ash (3.4%) content, but low non-fiber carbohydrate content. Faba bean seed had an intermediate nutrient and mineral profile between lupin and pea. The protein, fat, fiber, ash content of faba bean was 28%, 1.4%, 8.9%, and 3.1%, respectively. Pea seed had the lowest protein (23%), fat (1%), fiber (6.5%), and ash (2.7%) content of the three pulses studied. However, pea seed had a high non-fiber carbohydrate content compared to lupin and faba bean. Despite large differences in the nutrient composition, there were only minor differences in the energy profiles of the three pulse seeds.

Lupin (cv. Arabella)

Lupin seed had the highest protein (36%) fat (5.7%), fiber (15.3%), NDF (25.6%), ash (3.4%), Ca (0.37%), Mg (0.20%), P (0.43%) content, compared to faba bean and pea. The protein content of lupin seed was 28.6% and 56.4% greater than the protein content of faba bean and pea seed, respectively. Lupin had 5.2 and 4.1 times greater fat content compared to pea and faba bean, respectively. The lupin fiber content was 2.4 and 1.7 times greater than the fiber content of pea and faba bean. The ash content of lupin seed was 27% greater then pea seed and 9% greater than faba bean seed. The high protein, fat, fiber, and mineral content of lupin seed gives it a unique nutrient and mineral profile that may make lupin suitable for specialty products which cannot be produced from pea or faba bean seed. The high protein, fat, and fiber seed content of lupin seed is balanced by a lower non-fiber carbohydrate content. Lupin seed contains only 47% and 55% of the NSC found in pea and faba bean, respectively, and 59% and 67% of the NFE found in pea and faba bean, respectively. Despite having a lower carbohydrate content, lupin seed has a similar to slightly greater energy profile to pea seed and faba bean seed as indicated by its GE, DE, ME, and NEF.

Compared to Australian grown lupin seed, Canadian lupin seed is 12.4% higher in protein (increase of protein from 32.01 to 35.98%), 10.7% higher in GE and, 24.7% higher in ash. This is balanced by Canadian lupin having a slightly lower fat content (Table 1). A price premium may be paid for Canadian lupin based on its higher protein content.

Low tannin faba bean (cv. Snowbird)

Faba bean seed has a mean protein content of 28%, fat content of 1.4%, fiber content of 8.9%, NSC content of 53.4%, and an ash content of 3.1%, giving it an intermediate nutrient and mineral profile between lupin and pea. Compared to faba bean grown in Australia, Canadian faba bean has a higher protein, fat, fiber, NDF, GE, ash, Ca, Mg, K, and Na content but lower P content. Some of these differences may be attributed to different growing conditions and cultivars used in the two countries. The higher quality of Canadian grown faba bean, may command a price premium.

Table 1. Comparison of the nutrient and mineral composition of 'Arabella' lupin, 'Snowbird' faba bean, and 'Cutlass' field pea seed grown at Barrhead, Devon, and Lacombe, AB in 2004 and 2005 (Petterson *et al.* 1997). *Values are compared to previously published data on soybean meal NFE, DE, ME, NE_F, and TDN are expressed as Mcal kg^{-1} DM and all other parameters are expressed as a % of the total DM .*

Nutrient or Mineral Parameter	**Lupin** (AB, Canada)	**Lupin** (Australia)	**Pea** (AB, Canada)	**Pea** (Australia)	**Faba Bean** (AB, Canada)	**Faba Bean** (Australia)
Protein	35.98	32.01	23.01	23.16	27.96	24.12
Fat	5.74	5.90	1.01	1.12	1.41	1.25
Fiber	15.34	15.35	6.47	5.94	8.87	8.41
NDF	25.63	23.53	12.27	13.26	14.11	12.79
NSC	29.28	-	61.04	-	53.42	-
NFE	39.55	-	66.86	-	58.66	-
GE	4.86	4.39	4.40	4.01	4.48	4.01
DE	4.10	-	3.88	-	3.91	-
ME	3.21	-	3.16	-	3.13	-
NE_F	1.99	-	1.86	-	1.85	-
TDN	90.24	-	88.47	-	87.84	-
Ash	3.38	2.71	2.66	2.49	3.09	2.7
Ca	0.37	0.22	0.09	0.07	0.15	0.11
Mg	0.20	0.16	0.13	0.12	0.15	0.10
P	0.43	0.30	0.33	0.40	0.35	0.38
K	0.91	0.80	1.03	0.82	1.14	0.98
Na	0.02	0.04	0.02	<0.01	0.06	0.01
Salt	0.06	-	0.06	-	0.15	-

Low tannin faba bean (cv. Snowbird)

Faba bean seed has a mean protein content of 28%, fat content of 1.4%, fiber content of 8.9%, NSC content of 53.4%, and an ash content of 3.1%, giving it an intermediate nutrient and mineral profile between lupin and pea. Compared to faba bean grown in Australia, Canadian faba bean has a higher protein, fat, fiber, NDF, GE, ash, Ca, Mg, K, and Na content but lower P content. Some of these differences may be attributed to different growing conditions and cultivars used in the two countries. The higher quality of Canadian grown faba bean, may command a price premium.

ii) Processing Work

In the competitive world of feed ingredients, doing the least amount of processing possible is paramount as additional processing increases costs, lowers margins, and drives the end product price above competing feed ingredients. In the case of lupin, the hull contains a high proportion of fiber and removing the hull decreases total crude fibre by approximately 5 % and increase total protein by 4-5%. Fish feed manufacturers indicate that fibre is not desirable as an ingredient and a de-hulled lupin product would be preferred. One of the challenges in the protein market, is that many of the products on offer are by-products of other processes which put lupin and low tannin faba bean at a distinct disadvantage. Although there maybe nutritional and environmental advantages to using lupin and low tannin faba bean as feed ingredients, it appears $/unit of protein plays one of the largest roles in the decision by purchasers to include the ingredient in the ration or not.

Investigations into de-hulling and the fractionation of the whole lupin and low tannin faba bean (air classification) of both were made at the Canadian International Grains Institute (CIGI) in Winnipeg, POS (Protein, Oil and Starch) Pilot Plant Corp in Saskatoon, Hosokawa Micron Powder Systems, New Jersey, USA and Alberta Agriculture and Food, Bio-Industrial Technology Branch, Edmonton, Alberta.

From our limited research, de-hulling of lupin and low tannin faba bean appeared to be mechanically feasible with a number of commercial de-hulling machines available; Codema (Maple Grove, Minnesota), Buhler (Minneapolis, Minnesota) and Forsbergs (Thief River Falls, Minnesota). The only challenge of note was immature green lupin seeds which proved difficult to de-hull.

Air classification is a physical separation process by which the protein and starch are separated through centrifugal force based on their respective densities. Protein is inherently finer than starch, thus the more coarse (higher density) that is removed from the product, the higher the protein content of the fines will be. De-hulled lupin, low tannin faba bean and yellow pea were tested at Hosokawa Micron Powder Systems. Initial protein contents of the de-hulled grain were 42% for lupin and 27% for low tannin faba bean. Tests found that air classification of lupin proved more difficult than low tannin faba bean due to the higher fat content of the seed. The higher fat content resulted in a build up at the classifier wheel which caused the product to become coarser. A switch to a different model of equipment with no classifier wheel, but rather two pin rotors opposed, was made to grind the product.

The highest protein achieved for lupin was 56.1% with a fines yield of 38 % at a total throughput of 231 lbs/hour. The best results for highest fines yield and both protein and fines yield was achieved with a 54.8 % protein, 59.5 % fines yield and a throughout of 290 lbs/hour.

The highest protein achieved for low tannin faba bean was 62.5 % with a fines yield of 19.5 % at a total throughput of 385 lbs/hour. The highest fines yield was 46.4% with a protein content of 51.2 % and a throughput rate of 207 lbs/hour. For low tannin faba bean, the best results for both protein and fines yield was achieved with a 60.8 % protein, 31.5 % fines yield and a throughout of 219 lbs/hour.

iii) The Reality of Economics

Private companies are reluctant to invest dollars in the building of an industry without a substantial and stable commercial acreage base to draw from. Growers are unlikely to risk growing a crop for which no market has been established. Lupin had never been grown commercially in Western Canada. Faba bean had been grown before, however, these cultivars contained higher levels of tannin and were late maturing. Based on limited large scale field trials for lupin and a small but growing commercial acreage for low tannin faba bean, cost of production estimates have been put together for these crops (Tables 2 and 3) (Chaudhary, 2007).

Table 2. Estimated Costs and Returns for Lupin Production, 2007.

			$ / Acre
(A)	Crop Sales		
	Yield per Acre (tonne)	1.09	
	or 40 bushels/acre or 2400 lbs/acre		
	Price per tonne ($)	270.00	
	Gross return		**294.30**
(B)	Variable Costs		
1	Seed and seed treatment		53.29
2	Fertilizer		9.21
3	Chemicals		34.35
4	Hail / Crop Insurance		4.18
5	Trucking & Marketing		0.00
6	Fuel		11.38
7	Repairs - Machinery		8.53
8	Repairs - Building		1.03
9	Utilities & Misc. Expenses		7.54
10	Custom Work & Specialized Labour		0.29
11	Operating Interest Paid		0.00
12	Paid Labour & Benefits		9.14
13	Unpaid Labour		9.40
	Total variable costs		**148.34**
(C)			
1	Cash/Share Rent & Land Lease		0.00
2	Taxes, License & Insurance		4.85
3	Equipment & Building a) Depreciation		28.56
	b) Lease Payment		0.00
4	Paid Capital Interest		9.03
	Total capital costs		**42.44**
(D)	**Cash costs (B+C-B13-C3)**		**127.27**
(E)	**Total production costs (B+C)**		***190.78***
(F)	**Gross margin (A-D)**		**167.03**
	Return to investment		**112.55**
	Return to equity		**103.52**

Notes:
1) Targeting a return to equity of ~ $100/acre
2) Price of lupin $7.35/bushel or 12.25 cents/lb is required due to lower yield than faba bean and seed treatment requirement
3) Trucking, marketing, cash rent have not been included
4) De-hulling of the product would add another $30-$50/tonne
5) Trucking to Vancouver would add $30/tonne

Lupin yields substantially less than low tannin faba bean, therefore to receive a similar gross per acre, the price per bushel will have to be higher. Using average of 40% for protein, and ~$300/tonne the $/unit cost of protein lupin to produce the crop is $7.50 per unit of protein. This does not include de-hulling and transportation cost to the coast. There are efficiencies to be gained in higher volumes in processing and transportation that will not be realized until the industry grows in scale.

Table 3. Estimated Costs and Returns for Fababean Production, 2007.

			$ / Acre
(A)	Crop Sales		
	Yield per Acre(tonnes)	1.4	
	(lbs.) or 50 bu/acre or 3100 lbs/acre		
	Price per lb. ($)	0.09	
	Gross return		**279.00**
(B)	Variable Costs		
1	Seed		33.13
2	Fertilizer		9.46
3	Chemicals		34.51
4	Hail / Crop Insurance		4.28
5	Trucking & Marketing		**0.00**
6	Fuel		11.37
7	Repairs - Machinery		8.68
8	Repairs - Building		0.94
9	Utilities & Misc. Expenses		7.60
10	Custom Work & Specialized Labour		0.30
11	Operating Interest Paid		0.01
12	Paid Labour & Benefits		9.01
13	Unpaid Labour		9.20
	Total variable costs		**128.49**
(C)			
1	Cash/Share Rent & Land Lease		**0.00**
2	Taxes, License & Insurance		4.89
3	Equipment & Building a)Depreciation		30.45
	b)Lease Payment		**0.00**
4	Paid Capital Interest		9.03
	Total capital costs		**44.37**
(D)	**Cash costs (B+C-B13-C3)**		**127.27**
(E)	**Total production costs (B+C)**		*172.86*
(F)	**Gross margin (A-D)**		**151.73**
	Return to investment		**115.17**
	Return to equity		**106.14**

NOTES:
1) Targeting a return to equity of ~ $100/acre
2) Price of low tannin faba bean is lower compared to lupin due to higher yield and no seed treatment cost
3) Price received for fababeans is $5.50/bu or 9 cents/lb
4) Trucking, marketing, cash rent have not been included

The recent subsidization in the US of bio-fuels (ethanol and bio-diesel) have increased production of these fuels and driven grain prices to all time highs. The price of competing crops in the rotation also determines whether growers will grow the crop or not.

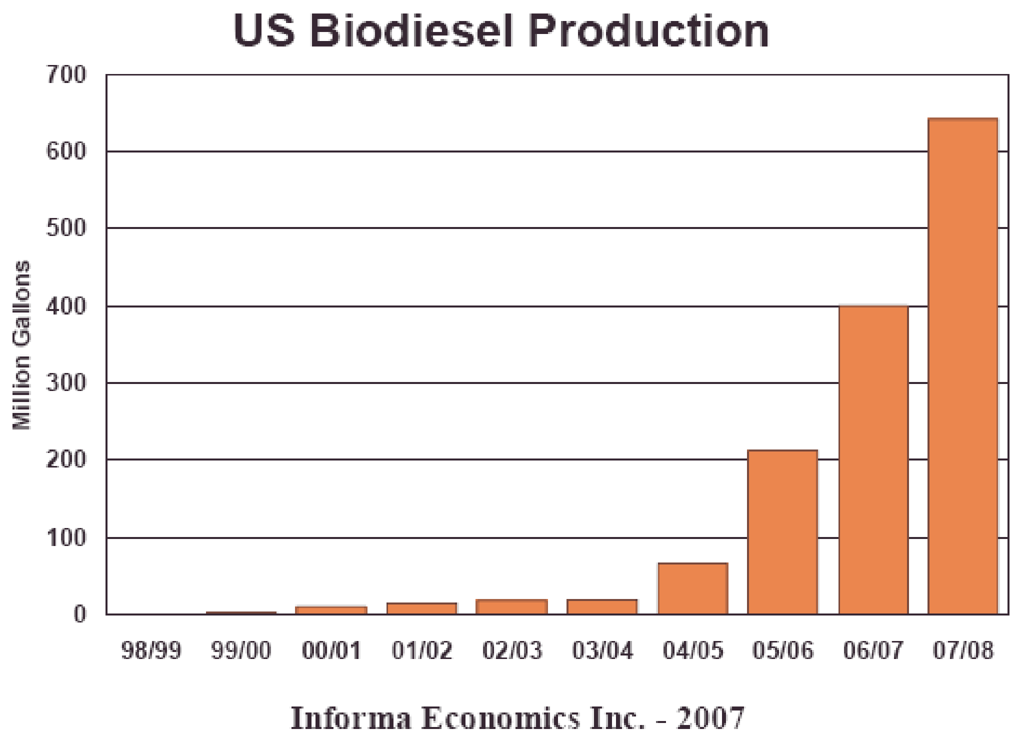

Figure 1. Production of bio-diesel in the US.

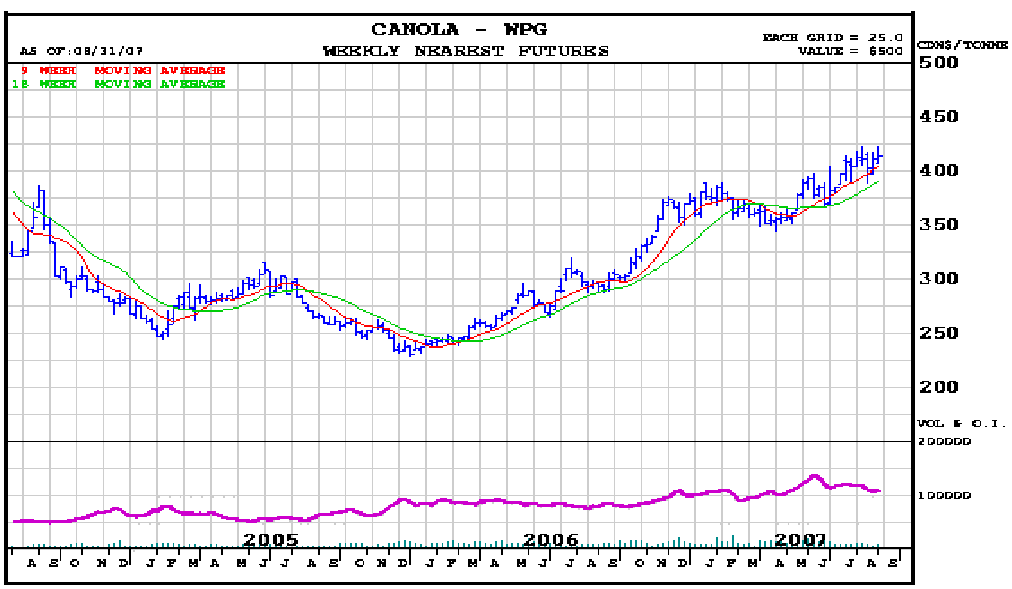

Figure 2. Canola-WPG Weekly Nearest Futures.

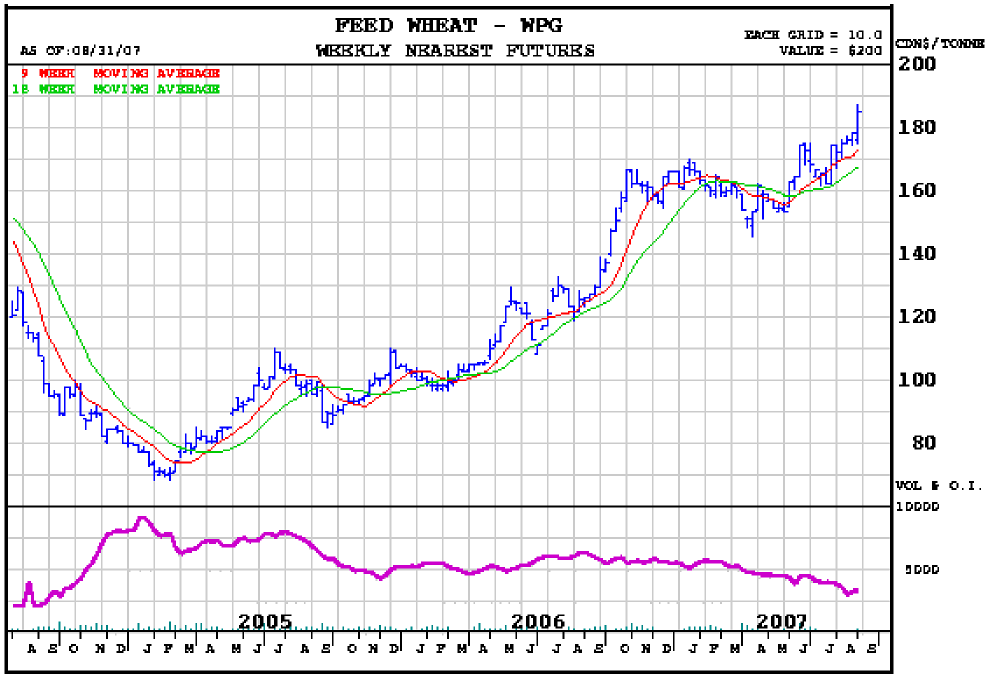

Figure 3. Wheat-WPG Weekly Nearest Futures.

(Source; Winnipeg Commodity Exchange 2007)

Canola and wheat would be the two mostly likely crops growers would include in the crop rotation, and the gross return per acre would likely have to comparable (most likely higher) before commodity substitution into lupin and low tannin faba bean would occur. This is partly because lupin and faba bean have not been grown extensively on the prairies.

CONCLUSIONS

Based on the research conducted to date by Alberta Agriculture and Food and our partners, a solid foundation has been laid to which these two grain legume crops could grow and develop. Numerous aspects of lupin and low tannin faba bean production have been studied, and there are practical, viable solutions for growers wanting to produce these two crops. Grain legumes have many nutritional (for all species including humans) and environmental benefits for society. Preliminary work on processing of both crops has shown some very promising results. The challenge will be to provide a price competitive product that the customer is wanting and able to afford.

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Opportunities for Western Canadian Pulse Crops in Aquafeeds

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Historically fishmeal has been the most important protein source in commercial aquatic feeds. However, annual growth of greater than 10% per year has put increasing pressure on fishmeal supplies. Expansion of aquaculture production in the future will be dependent on lowering the inclusion rate of marine products in aquafeeds and replacing them with plant based protein sources. Peas and faba beans in their native forms are too low in protein (22 and 28% respectively) and too high in starch (approximately 45% for both crops) for use in most aquafeeds. However, both crops may be converted to protein concentrates economically using air classification. These ingredients may be further improved through crop breeding programs to improve the chemical composition of the crops and reduce levels of antinutritional factors such as tannins. The combination of improved varieties and crop processing may lead to a desirable new protein sources for the aquafeed industry.

KEYWORDS

Field peas, faba beans, rainbow trout

INTRODUCTION

Aquaculture is the fastest growing sector of food animal production in the world today. Aquaculture has experienced a compounded average increase in production of 8.9% since 1970 as opposed to capture fisheries which have increased by only 1.4% and terrestrial animal production by a mere 2.8% (1). The use of fish and fish products is important for human consumption as well as a feed source for aquaculture diets. However, wild populations of fish are not limitless and that demand will soon exceed supply (2). Alternative sources of fish production will be required to meet this demand, aquaculture being the most feasible method.

A reliable source of feed ingredients to be used in aquafeeds may be the largest problem associated with aquaculture. Without a reliable feed source, there is no future for the aquaculture industry. Currently, fish meal and fish oil are essential as aquafeed ingredients and are depended on by the aquaculture industry. However, the demand for fishmeal and fish oil will soon exceed supply (2). The need for a new feed source increases daily. Using plant sources as feed ingredients in aquaculture could reduce the demand for fish meal and fish oil. In the long run, plant ingredients may also be a cheaper and more dependable source of feed ingredients, depending on the cost of the plant product and any further processing required. The use of plant sources in aquafeeds also offers a potential market for feeds grown in Saskatchewan and the other prairie provinces, giving the prairies a foothold in the global aquafeed market and increasing the value of Western Canadian feed ingredients.

Replacing fishmeal with plant proteins has proven a difficult nut to crack. Soybeans are the principal source of protein in diets fed to terrestrial farm animals accounting for approximately 75% of protein fed in animal diets. The natural assumption is that soybeans should therefore easily and economically replace fish meal in salmonid diets. Soybean meal contains approximately 48% crude protein and with the addition of methionine has an excellent balance of essential amino acids. However, a host of studies have reported that inclusion rates of greater than 20-30% soybean meal results in decreased weight gains and increased conversion rates (3,4). This effect has been attributed to the presence of antinutritional factors in plant protein, particularly SBM (5-8). High dietary levels of SBM cause pathological changes in the intestinal mucosa described by Baeverfjord and Krogdahl (9) as "non-infectious subacute enteritis in the distal intestine". This pathology is associated with shortening of intestinal folds (equivalent of villi in terrestrial animals), thickening and infiltration of the lamina propria with inflammatory cells, alteration in enterocyte structure and shortening of the microvilli (10). More recently, Sanden et al. (11) fed Atlantic salmon diets containing 12.5% full fat SBM for an 8 month period and observed elevated levels of proliferating cell nuclear antigen in distal small intestinal enterocytes and morphological changes, which together suggested an increased rate of enterocyte turnover. Increased enterocyte turnover is a well-established component of the intestinal inflammatory response in terrestrial animals and likely accounts for the reduction in brush border digestive enzyme activity observed in Atlantic salmon fed diets containing SBM (12).

These effects have been attributed to the presence of antinutritional factors (ANFs) present in soybean meal. Heat labile ANFs, including trypsin inhibitor and lectins, can be eliminated or reduced by a heat treatment during the normal processing of SBM (13). Heat stable ANFs present in SBM include non-starch polysaccharides (NSP), saponins, phytate, phytoestrogens and protein antigens (14). These factors must be removed from soybean meal by fractionation or inactivated in some other way. Soybean protein concentrates and isolates are lower in heat stable ANFs and may be used at higher inclusion rates than soybean meal. However, they are cost prohibitive ($1500-3000 per tonne). Clearly soybeans are not final solution to replacing fish meal in salmonid diets.

FIELD PEAS

Field peas are grown widely with a total world production of 11.7 million metric tonnes (15). Canada is the largest producer and exporter of dry peas in the world. On average, Canada produces approximately 20% of the world's peas and accounts for 50% of the world pea exports. Approximately 70% of Canada's pea production is in Saskatchewan. This has made the development of new, high-valued markets for peas a priority in Saskatchewan. Aquaculture feeds are seen as a very desirable market opportunity for peas and pea products.

Peas are relatively low in protein and contain only 23% crude protein on average with the typical amino acid balance for pulses-high lysine and low methionine content (Table 1). Peas also differ significantly from soybeans in that they are low in lipid (1%) and high in starch (47%). In terms of nutrient digestibility, pea protein has an apparent digestibility coefficient (ADC) of 0.91 in rainbow trout while energy and dry matter digestibility 0.55 and 0.42 respectively. Whole dry peas are therefore a poor nutritional fit for salmonid diets due to the low protein content and low energy digestibility. In terms of ANFs, peas contain many of the same ANFs as soybeans including heat labile ANFs (trypsin/chymotrypsin inhibitors and lectins) and heat stable ANFs (phytic acid, condensed tannins, saponins, antivitamins and protein antigens (legumin and vicilin)) antinutritional factors which reduce their nutritional value to fish (6,16,17). However, the level of these compounds tends to be lower in peas than in soybeans (18). This may give peas a significant advantage over soybeans in aquafeeds if their nutritional liabilities could be overcome.

The nutritional properties of peas for aquafeeds may be improved by processing. Extrusion of raw whole peas significantly improves starch and energy digestibility in rainbow trout from 0.00 to 0.96 and 0.55 to 0.78 respectively (19). This is due gelatinization of starch and break down of starch granule matrix structure (19). Protein ADCs in rainbow trout were increased from 0.91 to 0.94 by extrusion. This is a common pattern for nearly all processing methods applied to peas; energy and dry matter digestibilities are markedly increased while protein digestibilty is only modestly improved.

Pea protein concentrate

The nutrient value of peas for salmonid diets may be further improved by fractionation to create pea protein concentrate. Peas have a significant advantage over soybeans in that pea protein concentrate can be manufactured using a relatively cheap, dry processing method: air classification. This process consists of fine grinding peas to an average particle size of 80 microns using a pin mill followed by separation of particles by density in an airstream (15). The denser fraction contains the bulk of the starch and fibre while the lighter fraction contains the bulk of the protein. Pea protein concentrate prepared by air classification averages from 47-55% crude protein depending on the starting material and the separation conditions. The typical nutrient compositions of pea starch and protein concentrates are shown in Table 1.

Table 1. The nutrient composition as percentage of dry matter of peas and pea protein concentrate (Parrheim Foods, Saskatoon SK) ([19]).

	Raw Whole Peas	Pea Protein Concentrate	Pea Starch Concentrate
Dry Matter	92.5	86.8	90.8
Crude Protein	21.2	50.2	6.8
Ether Extract	1.4	4.1	0.6
Ash	3.0	6.4	1.27
Crude fibre	6.3	2.0	6.2
Starch	47.0	7.4	73.0
ADC Dry matter	0.42	0.84	nd
ADC Gross Energy	0.55	0.87	nd
ADC Crude protein	0.91	0.95	nd

The energy and dry matter digestibilities of pea protein concentrate in rainbow trout are significantly increased from 0.55 to 0.87 and 0.42 to 0.84 respectively (19), while the protein digestibility of pea protein concentrate ranged from 0.82 to 0.95 (19-22).

Economic feasibility of pea protein concentrate in aquafeeds

As previously stated, soybean protein concentrate or isolate are presently too expensive for use in aquaculture. This is because these products are produced using aqueous or ethanol extraction which requires an expensive drying step. Pea protein concentrate differs in that it is produced by a dry process: air classification. Because no water or solvents need to be removed, the energy costs of this process are relatively low. However, air classification also produces pea starch at nearly 2 times the amount of pea protein. Currently, there are markets for pea starch that will support the kinds of tonnages that would be produced in pea protein became widely used in aquafeeds. This results in pea protein bearing the total cost of the starting material and the processing resulting in a product costing $700-900 per tonne. If a market could be developed for pea starch, the cost of pea protein could be considerably reduced. The development of the ethanol industry in Western Canada might be that market.

The expansion of the ethanol industry in the United States in the last 10 years has been remarkable. Production has increased more than four-fold from 4.2 billion litres in 1996 to 18.4 billion litres in 2006 (23). Canadian production has lagged behind but a significant growth in ethanol production is forecast to triple to 650 million litres by 2010 (23). Canadian production of ethanol will be based on the fermentation of wheat in Western Canada, however, other feedstocks may be used including pea starch concentrate. Pea starch concentrate has several advantages over wheat as an ethanol feedstock. It is higher in starch and it is already ground to the small particle size required prior to saccharification in the fermentation process. Providing a market for pea starch would significantly decrease the cost of pea protein concentrate making it competitive with soybean meal and corn gluten meal in aquaculture diets.

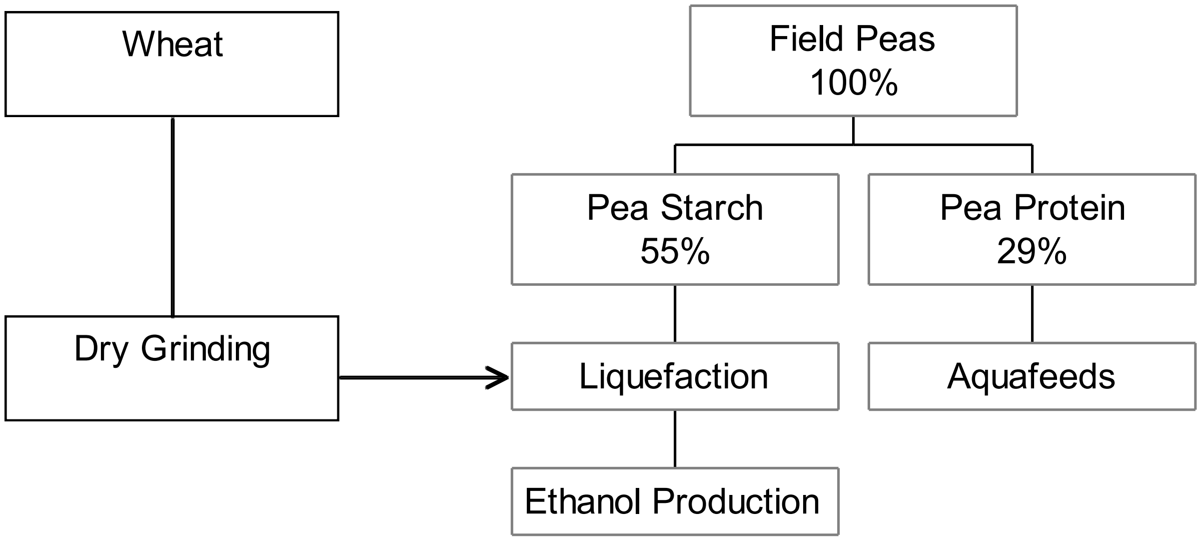

Figure 1. Ethanol production using pea starch concentrate.

FABA BEANS

Faba beans have been around for a long time and have been "the crop of the future" since the 1970s. Faba beans are high in protein (28-31%; Table 2) and are one of the highest nitrogen fixing crops currently in production. Western Canadian production of faba beans peaked at 15,000 tonnes in 2000 and dropped to 11,000 tonnes in 2004. This is a crop with a lot of potential in aquaculture diets but there are several factors that constrain its use. Currently grown varieties of faba beans contain a host of ANFs which must be removed by breeding programs or processing. Faba beans contain high levels of tannins, vicine, convicine and phytate which reduce protein and mineral digestibility in animal diets. Eurpean varieties with zero levels of tannins, vicine and convicine have recently become available under the name Fevita and these varieties have significantly improved nutrient digestibility in animal studies. Jansman et al. (24) fed low and high tannin faba beans to swine and reported that low tannin faba beans had 9% greater apparent ileal crude protein digestibility than high tannin faba beans.

The nutrient profile of faba beans can be improved by processing as well as genetic selection. Air classification may be used to create faba bean protein concentrate that contains 60-65% crude protein making it a very desirable feed ingredient for replacement of fish meal. Recent work in my laboratory examined the nutrient digestibility of normal and low tannin faba beans (Snowbird) and faba bean protein concentrate (Parrheim Foods, Saskatoon SK) in rainbow trout (25). The experiment was designed as a 2 x 3 factorial design with 2 levels of heat treatment (none or autoclaved for 20 min at 121^{o}C/15 psi) and 3 faba bean products (normal tannin, low tannin and faba bean protein concentrate). The ADC of crude protein was significantly increased in the low tannin faba beans compared to the normal tannin variety ($P < 0.05$) but there were no differences in dry matter or energy ADCs. The faba bean protein concentrate had significantly improved dry matter, crude protein and gross energy digestibility compared to the 2 faba bean meals. Heat treatment had no effect on digestibility. These results are similar to those seen for peas and indicate that faba bean protein concentrate is a desirable ingredient for aquaculture feeds.

Table 2. Chemical composition (% DM basis) of normal and low tannin faba bean meals and faba bean protein concentrate ([25]).

	Normal Tannin Faba Bean	Low Tannin Faba Bean	Faba bean protein conc.
Dry matter	86.3	88.3	90.2
Crude Protein	34.6	29.8	64.4
Crude Fat	2.0	2.5	2.3
Tannins	1.4	0.8	0.8

Table 3. Apparent digestibility coefficients of faba bean products with and without heat treatment in rainbow trout ([25]).

	Dry matter	Crude protein	Gross energy
Faba bean product			
Normal Tannin	0.21[a]	0.71[a]	0.29[a]
Low Tannin	0.32[a]	0.80[b]	0.37[a]
Faba bean protein concentrate	0.68[b]	0.86[c]	0.69[b]
SEM	0.12	0.02	0.18
Presence or absence of heat treatment			
Cooked	0.40[a]	0.79[a]	0.44[a]
Uncooked	0.41[a]	0.79[a]	0.46[a]
SEM	0.02	0.01	0.01
P value			
Faba bean product	<0.01	<0.01	<0.01
Heat treatment	0.89	0.83	0.72
Interaction	0.12	0.19	0.04

[abc]Means within columns with the same superscript are not significantly different ($P < 0.05$)

Economic feasibility of faba bean protein concentrate in aquafeeds

While faba beans appear similar in their nutritional properties, they differ markedly in terms of their attractiveness to the aquafeed industry. First, the supply of faba beans in Western Canada is small and varies widely from year to year. This makes the development of a processing industry for the crop difficult. Second, the varieties presently being grown contain high levels of ANFs. While low tannin varieties are now available, zero tannin, vicine and convicine varieties must be developed for the growing conditions in Western Canada. Recently a group was formed to create a Canadian faba bean industry strategy and the development of a consistent supply of low ANF varieties of faba beans a principal goal in this strategy. Faba beans also stand to benefit from the expanding ethanol industry since faba bean starch would have a market that would help support the cost of fractionation. Clearly, peas and faba bean protein concentrates have the right nutritional specifications and economics for the aquafeed industry. However, we must make these products available in consistent quantities to develop the market for these ingredients.

ACKNOWLEDGMENTS

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The Development of Alternate Species for Aquaculture: An East Coast History and Perspective

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This Power Point presentation provided a history (1996 to present 2007) and perspective on the development of alternate species for aquaculture in Atlantic Canada. Research on the culture of species other than salmon has been ongoing in public laboratories generally post-1990. A public/private focus on commercialization began around 1995. Despite significant advances in all aspects of the culture of a variety of species a self-sustaining and viable industry producing these species has not yet developed on the east coast. This presentation discussed some of the reasons for this commercialization failure to-date and provides suggestions for a public/private strategy to develop a viable industry.

KEYWORDS

Alternate species, Atlantic Canada, perspective.

PRESENTATION

A General History in Atlantic Canada

For many years public laboratories in Atlantic Canada have worked to better understand the biology and handling of a number of species with perceived potential for aquaculture. In 1996 an Alternate Species Program was established (Chang, 2001). This was a Federal/Provincial/Industry initiative focused on the commercial development of six species: Haddock (Melanogrammus aeglefinus), Atlantic halibut (Hippoglossus hippoglossus), Winter flounder (Pseudopleuronectes americanus), American eel (Anguilla rostrata), Striped bass (Morone saxatilis) and Sturgeons (Acipenser brevirostrum, A. oxyrhynchus). The five year program was funded with various combinations of support including $1 million of federal public money plus industry and additional federal and provincial personnel and program contributions.

During this highly successful period of focused research and development, three species were developed to the point of being considered pre-commercial: halibut, haddock and sturgeon while eel proceeded with a previous focus on wild harvest and holding and the culture of flounder was considered marginally viable at best. Development of cod culture was initiated and advanced separately from the Alternate Species Program.

When the Alternate Species Program ended in 2001, initiatives on haddock, halibut and sturgeon as well as cod continued with a combination of industry money and public program money from various sources. The public contribution was generally the initiative of individual researchers drawing on existing program money rather than as a coordinated public strategy.

In 2004 there was a collapse of activity in two key species: haddock and cod while halibut and sturgeon struggled on by private initiative coupled with some public contribution.

Status of the Technology Today

Today, in 2007, the status of alternate species culture in Atlantic Canada is generally as follows:

Sturgeon: Commercial (Tank Culture)
$4-5 M annual sales, 10+ PY (Person Years employment); Private initiative

Halibut: Commercial (Hatchery) - Developmental (cage and tank culture), $3-4 M annual sales, 30-35 PY
Both public and private initiatives ongoing;
Key focus on reducing juvenile costs and evaluating cage culture

Cod: Pre-Commercial Sales? Primarily public/private initiative with focus on genomics research;
Key focus on reducing juvenile costs and selective breeding to improve grow-out performance

Haddock: Pre-commercial – Inactive, $0 sales
NB Provincial lab maintaining F3+ brood stock;
Key focus on reducing juvenile costs; selective breeding to improve grow-out performance and improved low fat, high energy feeds

Why has Alternate Species Development Foundered?

Alternate species development has foundered for the following key reasons:

1. The private sector has not driven the agenda
    a. There is a lack of private investment for aquaculture and in particular for developmental species
    b. The industry was unable to maintain the 1996-2001 developmental momentum
        i. The salmon industry was not generating sufficient profits post 2001 to encourage investment in alternate production
    c. Private investment has focused on the tried and true Atlantic salmon
        i. Investment in alternate species is speculative
    d. Alternate species offers opportunities for expanded site utilization, for disease rotation and a hedge in periods of depressed salmon prices…areas where industry is unlikely to assume a lead role

2. There have been no programs or public initiatives in place since 2001 either specific to or fitting alternate species development
    a. The public contribution has derived from existing programs and been driven by the initiatives of individual persons in the public sector
    b. Public R&D funding is directed primarily to Research in public labs and universities
        i. Private projects generally require repayment while public programs are grants

From Concept to Commercial – the 4 Stages

The question now arises: how do we develop a new species for aquaculture. This is a relatively long and costly process: from concept to commercial there are 4 stages as outlined following:

1. Selection of the Species
    a. This can be a lengthy process of market, technical and economic analyses. In Atlantic Canada it is generally a matter of selecting from the three or four species that will perform in the temperate climate, have previously been researched in public facilities, for which significant information already exists and for which a long market history exists.

2. The Research Stage
    a. The focus here is on three growth stages
        i. Brood stock handling and spawning including maturation timing manipulation
        ii. Hatchery production of juveniles; from eggs to post-metamorphosed juveniles
        iii. Small scale grow-out of juveniles to harvest, process and market
    b. There is likely a history of ongoing research in a university and/or government lab
    c. Technical competence which can be built upon is likely available in the public service
    d. The technology will need a business perspective to advance
        i. Is likely advancing sideways
        ii. Production targets need to be set…and will likely be met by stimulated personnel

3. The Technical Development Stage
    a. This is the most reasonable point of entry of industry in a public-private partnership
    b. The repeatability and reliability of the juvenile supply from hatcheries should be tested
    c. The trials should include processing, sales and market analysis
    d. The problems of scale-up should be identified
    e. A brood stock should be established and photoperiod manipulation requirements must be met
    f. A series of annual lots on a pilot or semi-commercial scale should be grown-out to market
        i. Until cost targets are met
        ii. Until diseases are contracted and addressed
    g. Brood stock should be advanced through enough generations to meet commercial initiation criteria and to allow determination of heritability gains

4. The Business Development Stage

a. This is where an investor:
   i. Determines if the species can be profitable (see Cost Model section following)
   ii. Partners with an ongoing research program
   iii. Establishes firm juvenile production and cost targets
   iv. Plans the grow-out through to market
   v. Plans to be in the business for the long term: through thick and thin. This requires financing to be solid and with some flexibility

The Cost Model

A critical step in any private investment and development program is the Cost Model. Prior to any industry investment a cost model should be developed. This answers the questions:

1. Can the fish be produced profitably
2. Can production cost targets be met e.g. haddock and cod juveniles @ $ 0.20 as a reasonable starting point
3. Can the selling prices, volumes and market expectations be met e.g. deliver consistently over a planned seasonal time frame
4. Keys to meeting the Cost Model are:
   a. Don't kid yourself
   b. Project a reasonable case scenario

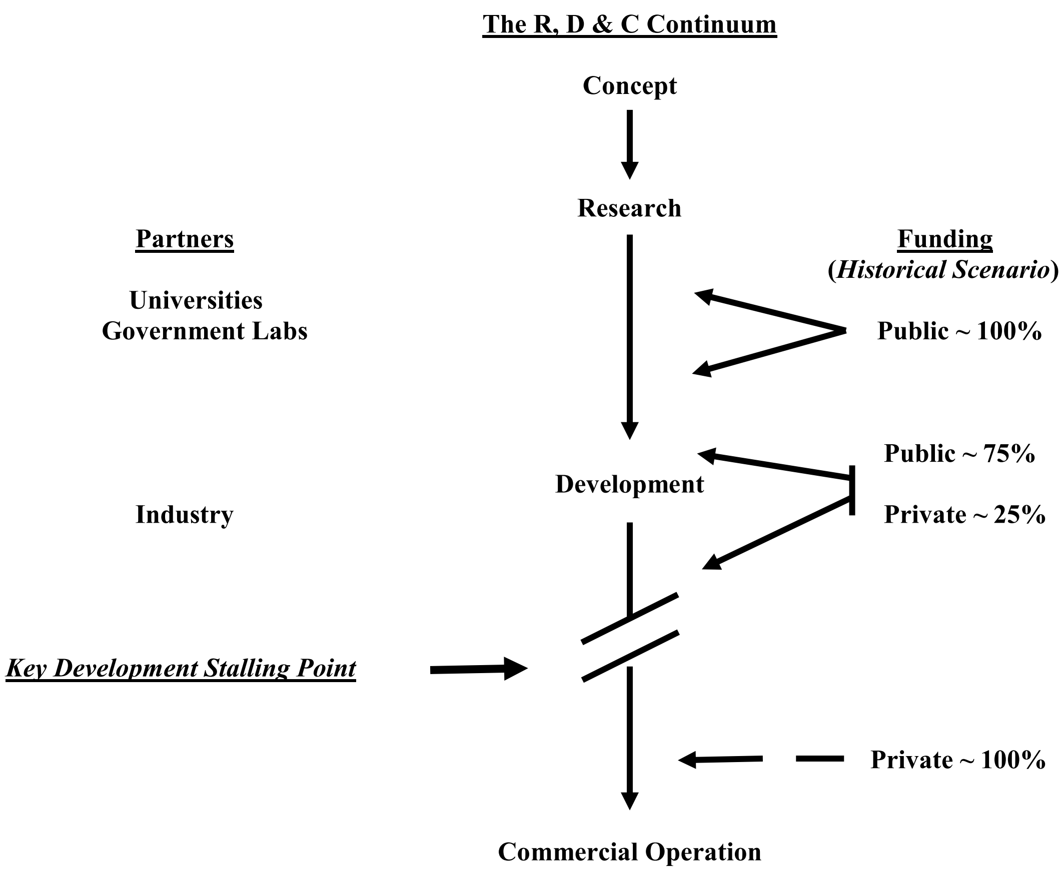

Figure 1. Outlines of the flow from Concept to Research to Development and eventually to a Commercial Operation.

How Do We Drive Commercial Development?

Now the question arises: how do we drive Alternate Species Commercial Development? The following steps are a suggested approach.

1. Establish a public/private planning committee

  a. Representatives must be technically competent decision makers with a history of involvement in or with the industry and technology
  b. Members should be able to make decisions in a competent and timely manner
  c. The committee should report to decision makers in federal and provincial government since public support will be critical for an industry to be developed

2. Rationalize the public effort
   a. This includes an analysis of the benefit of all public spending in related areas
   b. Public expenditures on culture of alternate species should be focused on the national effort
   c. Strict timelines and targets should be established
      i. The previous Alternate Species Program clearly demonstrated that targets would be met by motivated and accountable public and private partners.

3. Establish a program to make conditionally repayable public money available for private commercial proposals on alternate species development
   a. The proposals should be evaluated by the planning committee for recommendations to the appropriate public minister
   b. The key basis of proposal evaluation should be the likelihood of commercial success

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SWOT-Based Technique for New Species Development – An Evaluation and Planning Model

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A 4-phase process for evaluation, development and commercialization of new candidate species for aquaculture has been developed based on the application of SWOT Analysis (Strengths, Weaknesses, Opportunities, Threats) within key functional areas. SWOT Analysis has been selected as the fundamental approach to the model because it is a robust, strategic tool that requires reflection on a broad range of considerations which can influence the success of a project. When conducted thoroughly, a SWOT Analysis will reveal key strengths to build upon and opportunities to exploit while simultaneously focusing attention on those areas where improvement is necessary and where external factors may impose additional constraints to be addressed. The SWOT approach guides the compilation of necessary information in a way that enables development of structured response plans to resolve underlying critical issues that must be addressed to generate the intended results. The 4-phases of the model include: Preliminary Evaluation of Species (Market & Basic Biology); Species Selection & Commitment (Applied Research); Testing and Validation (Pilot Project); and Verification & Technology Transfer (Commercialization). By reviewing the SWOT analysis on a regular basis, stakeholders will be able to track progress on the development of the species, enabling the Research, Development & Commercialization Plan to remain current.

KEYWORDS

Aquaculture, new species development, model, SWOT

INTRODUCTION

"*The success of [Atlantic salmon and blue mussel aquaculture] in a region beset by economic problems and where funding is available for economic development has given an impetus to the search for new-candidate species to culture. The result, however, has not been encouraging. Already there have been a number of ill-conceived and very costly projects, and while some new species do indeed show promise, others have only a low probability of success, and may not have been considered at all except that they have become the political 'flavour of the month.' In some instances the motivation to culture a new species may be driven partly by a measure of naïvety or even opportunism, the desire perhaps to try something new and different. Unfortunately, this is happening at a time when the Atlantic coastal communities are experiencing unparalleled economic and social hardships and can ill-afford any misguided projects. Besides wasting public funds they cause harm by raising false expectations that success is just around the corner. They also compete with commercially viable culture operations for the limited funds available for research and technology development and the establishment of appropriate infrastructure. Failure of these new ventures can bolster the all too common perception in some financial circles that aquaculture is a high-risk activity with only limited prospect of contributing to economic development*." (Drinnan 1995). This passage, from Cold Water Aquaculture in Atlantic Canada, underscores the necessity to apply a rational and strategic approach to new species development.

Successful development of alternative species to support expansion of commercial aquaculture is dependent, to a large degree, upon successful integration of knowledge regarding culture technologies and husbandry practices; that is, the successful integration of biology and engineering to create the necessary conditions for the successful production of the species. Technical feasibility, however, reflects only one component of successful new species development and, alone, will not necessarily translate into commercial viability. Production economics, processing and market dynamics, environmental and socio-economic factors must also be favourable.

Because sustainable production of a "new species" may require an initial phase of 3 to 10 years of targeted effort, practical pursuit of alternative species for commercial aquaculture development is dependent upon a coordinated and focused research, development and commercialization initiative. A need exists to rationalize the species selection and commercial development process to identify potential candidate species and define those steps necessary to make commercial production practicable. Hence, an effective model to facilitate the evaluation of species and to outline the necessary RDC processes for commercial aquaculture development is required. The advantages associated with a rational, planned approach to industry diversification warrant the effort to develop such a model. Through methodical planning, the following benefits can be attained:

- Co-ordination of Effort – defining objectives and roles enables movement as a unit toward a common goal with increasing efficiency;
- Reduced Uncertainty – by looking to the future, planning initiatives anticipate change in the economic and socio-political environment and clarify decision alternatives in response to change;
- Reduced Redundancy – when objectives and roles are well defined, overlapping and wasteful activities can be avoided;
- Facilitated Control – by establishing goals and objectives, performance can be evaluated with respect to the desired level of achievement; and
- Enhanced Performance – although not guaranteed, data have proven that formal planning processes consistently out-perform less organized and/or *ad hoc* approaches.

Success in aquaculture, therefore, is not necessarily species-specific. Rather, the application of a rational RDC model to guide development of alternative species for commercial cultivation will greatly enhance the chances for successful industry diversification by assuring that all pertinent issues are identified and addressed. Moreover, such a model should be constructed around the principles of Strategic Opportunism[1] - "*the ability to remain focused on long-term objectives while staying flexible enough to solve the day-to-day problems and recognize new opportunities*".

[1] Dr. Peter Saul, Strategic Consulting Group, Spit Junction, NSW, Australia

It is envisaged that diversification of production species in aquaculture will facilitate further expansion, stability and profitability within the Canadian aquaculture industry and should allow the Canadian aquaculture industry to capture a larger share of the expanding global market for cultured fish and shellfish. A comprehensive model is needed that targets preferred species based on a comprehensive list of qualifiers so that, in time, cost-effective industry sub-sectors are established, leading to (i) market expansion; (ii) spreading of risk; (iii) increased industry efficiency and (iv) industry expansion.

LESSONS FROM EXPERIENCE

In the process of developing a new model for identification of potential candidate species for aquaculture development and an appropriate RDC process to bring the species from conceptualization through to commercialization, it is important to understand past experiences in the area and take advantage of lessons learned. As noted, several 'new' aquaculture species have been targeted for commercialization in Canada to varying degrees of success. Key personnel in the Canadian aquaculture industry and research community who were associated with the development of these species were interviewed to gain a better appreciation of the thinking and processes behind the selection and development of several of these alternative species. Attention was focused on four species in particular – Atlantic salmon, haddock, geoduck and Japanese (Pacific) scallop. This retrospective look at attempts to develop new aquaculture species in Canada yielded two fundamental conclusions. First, patient capital provided by governments is required to bridge the knowledge and innovation gaps from the early developmental stages through to the commercialization phase. Second, the development process can be expedited by targeting species that use the same (or similar) infrastructure as existing aquaculture products (for example, finfish that can use the salmon farming infrastructure).

THE RDC PROCESS FOR NEW SPECIES DEVELOPMENT

Several authors (Alvial & Manriquez 1999, Bascuro & Abellan 1999, Durant 2006) concur that there are three principal phases in the new species development process: (1) initial identification, evaluation and selection of target species, (2) implementation of research initiatives to resolve biological and technological challenges, and (3) development of pilot-scale and/or commercial operations.

Table 1 outlines some of the fundamental issues typically addressed in each of these three phases of the new species RDC process. It is important to note that these phases are not necessarily cumulative - that is, they do not have to proceed in a strict order; however, it is logical and probable that the process would proceed from phase-to-phase. Within each phase, though, there is likely to be considerable overlap in the delivery of research and development initiatives. A fundamental question, however, is how to gauge the readiness to move on to the next phase of development?

Fundacion Chile found that the application of this managed approach to new species development generates several key advantages which ultimately foster successful industry development and diversification. Foremost, the process produces skilled and trained managers and technicians who are then able to administer the commercial and technical aspects of the new ventures. Additionally, the nature of the new-species process results in active and focused cooperation between private sector companies, research institutions and governments (Alvial and Manriquez 1999).

The Initial Species Selection Phase

Given the number of potential finfish and shellfish species that could be developed for commercial aquaculture, a preliminary screening step is required to narrow the focus to a subset of species that, according to a defined set of parameters, would appear to be practicable. Basic biological factors (e.g. size, growth, behaviour), marketability and geography (native, naturalized or exotic) are typically used to evaluate species in this phase of the selection process (Table 1). At this stage of the process, it is possible that several candidate species will meet the preliminary screening objectives and warrant further consideration for commercial aquaculture development. Depending on the number of candidate species and the availability of resources (expertise, time and money) to conduct further evaluations, it may be necessary to further prioritize these species based on a more thorough analysis which incorporates biological, technological and/or socio-economic factors.

Table 1: Research, development and commercialization phases in the pursuit of new species for commercial aquaculture, noting some of the more typical issues and challenges addressed in each Phase. (Modified from Basurco & Abellan 1999).

Species Selection Phase	Research Phase	Pilot & Commercial Phase
Markets ▪ Prices, product form (e.g. fresh, frozen, portions), distribution ▪ Major buyers ▪ Competition (e.g. fisheries, imports) ▪ Consumer preferences Basic Biology ▪ Size, growth rate, fecundity, age at maturation ▪ Temperature range ▪ Behaviour in captivity Geography ▪ Native, naturalized, exotic	Reproduction ▪ Controlled spawning Early Rearing ▪ Larval / juvenile management and nutrition On-Growing ▪ Nutritional requirements ▪ Optimal environmental parameters (e.g. temperature, photoperiod, water quality) Culture Conditions ▪ Rearing density, exchange rates, current, etc. Animal Health ▪ Disease management ▪ Veterinary practices	Pilot Studies ▪ Verification of production requirements (e.g. feed conversion, survival, stocking density, growth modelling) ▪ Compilation of operating costs (e.g. feed, labour, power, other direct and indirect expenses) Risk Assessment ▪ Risk identification, mitigation techniques and management Market Research ▪ Expected market price ▪ Market acceptance of product Technology Transfer ▪ Communications, workshops, publications, demonstration farms, etc.

The Research Phase

Once a species has been selected, a research program must be developed to outline the principal biological, technological and production challenges to be addressed. At this stage of the development process, constraints to commercial cultivation are often related to reproductive and nutritional biology and animal health (Table 1). In the research plan for the species, it is also important to identify the logical research partners based on a reconciliation of capacities and expertise with the research requirements. For instance, university researchers typically offer expertise in basic aspects of biology such as reproduction, nutrition, and animal health, whereas field research stations are more adept at conducting applied research to determine optimal culture conditions, feeding practices, systems design requirements, etc. Furthermore, efficiency, effectiveness and timeliness necessitate that a planned and coordinated process be established with a comprehensive communications plan to minimize duplication and overlap.

The Pilot-Scale and Commercialization Phase

Moving beyond the laboratory, the purpose of a pilot project is to experimentally and systematically evaluate all aspects of production and operations in a simulated commercial setting. In doing so, the current knowledge, understanding and application of production technologies are verified. At times, the need for additional experimentation may be revealed and portions of the new species development process will revert to the research phase for further review.

Pilot-scale trials are typically designed to last for a finite period of time (generally 2-5 years) and are conducted at a scale of at least one-tenth of full-scale production. Implementation often involves public resources (including funding and professional expertise), the research community and industry (either as individual companies or via industry associations). In some situations, once the technology has been verified, pilot facilities continue to operate as applied research, development and training centres.

The objective of the pilot phase is to yield practical information regarding the basic techniques required for commercial culture and to provide an indication of anticipated performance of the species. Survival, feed conversion, growth rates and stocking densities are often emphasized in pilot projects since these factors are significant to productivity and, ultimately, to the evaluation of costs for juveniles, feed, labour, management, veterinary services, etc. During the pilot phase of development, production practices and performance will be verified, technical requirements will be confirmed and operational manuals can be drafted. As well, the technical staff will become well-trained in the production of the new species and should be capable of transferring their knowledge to industry practitioners.

For those candidate species for which juveniles are available in commercial quantities, that demonstrate successful early rearing and on-growing, have acceptable survival rates and feed efficiencies, the logical progression is to advance to commercial-scale development, which generally involves three additional steps: (1) more in-depth market research and planning; (2) detailed economic analyses and business planning; and (3) technology transfer.

The 4-phase approach for working through the new species model is illustrated in Figure 1. Following each phase of the process, it must be decided whether the species warrants further investment in research, development and commercialization. Decision Factors are presented to facilitate the decision-making process associated with determining whether sufficient knowledge and experience have been developed to enable the species to advance to the next phase of the RDC process.

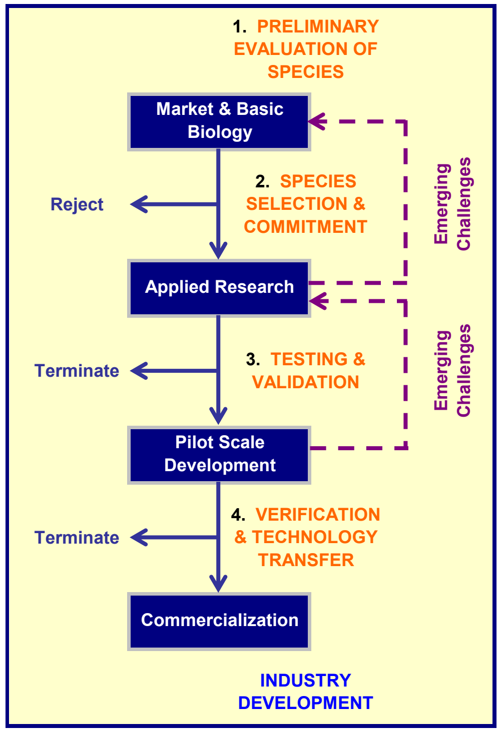

Figure 1: A proposed 4-phase process for evaluation, development and commercialization of new candidate species for aquaculture.

CONCEPTUAL NEW SPECIES EVALUATION MODEL

Based on the informational requirements discussed above, and upon consideration of historical review processes (Table 1), a conceptual new species evaluation model has been proposed. In comparison with other models, the proposed 4-phase 'New Species Model' is more comprehensive in that it:

- facilitates the preliminary review of potential alternative species;
- guides the selection process for those candidate species that warrant further development;
- outlines specific areas requiring investment in research, development and/or commercialization initiatives;
- provides 'decision factors' to indicate when a species is ready to move on to subsequent phases in the RDC process; and
- presents a review mechanism that readily enables the status of a candidate species to be re-evaluated and updated on a regular basis.

The model is based foremost on the application of SWOT Analysis within four main functional areas. As such, users of the model will require a fundamental understanding of the species and its intended application in aquaculture since thorough knowledge and exercise of judgement are prerequisite for using the model. Unlike some models, the proposed model does not rely on 'convenient' numeric scores since the application of such quantification measures likely implies a degree of accuracy or precision that does not necessarily exist, particularly given that the application is for 'new' species.

SWOT Analysis has been selected as the fundamental approach to the model because it is a robust, strategic tool that requires reflection on a broad range of considerations which can influence the success of a project. The SWOT acronym refers to the Strengths, Weaknesses, Opportunities, and Threats involved in a project. Strengths and weaknesses are internal considerations for which means to impose control and direction can be potentially developed. Opportunities and threats, however, are factors that are external to the project but which must, nevertheless, be considered in the planning and development process since they have a real capacity to influence success or failure.

When conducted thoroughly, a SWOT Analysis will reveal key strengths to build upon and opportunities to exploit while simultaneously focusing attention on those areas where improvement is necessary and where external factors may impose additional constraints to be addressed. It is a comprehensive approach to Pro/Con techniques. In short, the SWOT approach guides the compilation of necessary information in a way that enables development of structured response plans to resolve underlying critical issues that must be addressed to generate the intended results – the essence of new species development.

Strengths:

- What advantages does the candidate species have for commercial aquaculture (i.e. why is it being considered as a good candidate)?

Weaknesses:

- What needs to be improved or resolved before the species can be commercially cultured?
- What areas of technology and expertise are lacking in the sector to develop the species?

Opportunities:

- What opportunities exist to transfer knowledge or technology for the species from other jurisdictions where research, development or commercialization precedes progress in Canada?
- What opportunities exist to transfer knowledge or technology from other similar species to the candidate species?

Threats:

- What external factors may compromise the capability to successfully culture and market the candidate species in an environmentally and economically sustainable manner?

The information for the SWOT analysis comes from a variety of sources; including but not limited to interviews with experts and experienced personnel, literature reviews and scenario planning. Where information is unknown or uncertain it should be identified and interpretation of the analysis judged accordingly. To facilitate completion of the exercise, the fundamental issues to be addressed within each of the four functional areas have been presented in a standard SWOT template (Table 2). Additionally, it is important that all questions be answered since any one factor may be sufficient to preclude successful development of a candidate species. Consequently, the factors have not been prioritized.

Table 2a: SWOT Analysis template for evaluation of candidate species for commercial aquaculture development – Market Factors.

MARKET FACTORS	
<u>STRENGTHS</u> ▪ Issue	<u>OPPORTUNITIES</u> ▪ Issue
<u>WEAKNESSES</u> ▪ Issue	<u>THREATS</u> ▪ Issue
<u>Product Analysis</u> ▪ What are the current product forms? ▪ What is the market price of various product forms? ▪ Does the product fill a vacant market opportunity or does it augment an existing supply? ▪ What is the species' fillet yield / product yield? ▪ Will the product generate new demand (e.g. grow the total market) or cannibalize existing demand (e.g. provide better value and/or service)? <u>Competitor Analysis</u> ▪ What are the alternative sources for the product? ▪ What is the volume of product currently produced? From where? ▪ What are the strengths and weaknesses of competing products? ▪ How are competitors likely to react to increased production from aquaculture? ▪ What are the strengths and weaknesses of competing companies? ▪ Do competitors have power to influence market decisions? ▪ Do competitors have capacity to increase production? By how much? <u>Market Characteristics</u> ▪ What is the present demand for the product? ▪ What factors will influence demand for the product positively and negatively? ▪ What is the projected demand for the product into the foreseeable future? ▪ How is the market segmented with respect to the product (i.e. are there identifiable market segments based on physical product differences, consumer differences, geography, etc.)? ▪ Can existing markets be segmented to secure a competitive advantage? ▪ Can the product be extended into markets beyond its current / traditional use (i.e. horizontal diversification using different product forms)? <u>Consumer Analysis</u> ▪ What benefits do consumers seek from the product? Can they be provided? ▪ How will consumers compare the product with other similar products? ▪ What risks do consumers perceive in the product? ▪ Will consumers expect / require additional services? ▪ What do consumers know about the product? ▪ Where do consumers buy the product? Are these outlets accessible? ▪ Who currently uses the product? Why do they buy it? ▪ Who are the principle buyers of the product on a commercial scale? ▪ How will this product satisfy buyers' needs?	

Table 2b: SWOT Analysis template for evaluation of candidate species for commercial aquaculture development – Production Factors.

PRODUCTION FACTORS	
<u>STRENGTHS</u> ▪ Issue	<u>OPPORTUNITIES</u> ▪ Issue
<u>WEAKNESSES</u> ▪ Issue	<u>THREATS</u> ▪ Issue

<u>Morphology</u>
- What is the record landing for the species (i.e. maximum attainable size)?
- What is the target production weight for the species?
- Is the target production weight between 25% and 40% of the maximum weight?

<u>Physiology</u>
- What are the acceptable and critical ranges of important biophysical variables that will permit growth and survival of the species?
- As temperature increases, when does the species become subject to unacceptable levels of stress?
- What is the age of the species in the wild at the target harvest size?
- Due to temperature control, optimal feeding and good husbandry, what is the anticipated age of the species at harvest under culture conditions?

<u>Behaviour</u>
- Does the species display territorial or otherwise aggressive behaviours within its population?
- Is the species a social, schooling species that is accustomed to being in close proximity to others of its kind?
- Is there evidence that the species' level of aggression increases or decreases as densities increase?
- Can the species be handled for routine shipment, grading, vaccination, etc. without imposing excessive stress or mortality?

<u>Geography</u>
- Are the climatic and general biophysical conditions in the region suitable for the candidate species?
- Is the temperature profile within the tolerance limits for the species?
- Does the water supply have sufficient thermal units (degree days) to promote economical growth rates?
- Is the candidate species being introduced or transferred to the region?

<u>Seedstock Supply / Reproduction / Domestication?</u>
- Can commercial quantities of fry or spat be readily obtained on a consistent, reliable basis? From where?
- Is the broodstock population genetically sound (i.e. having an effective breeding number)?
- To what extent is the reproduction of the species able to be controlled?
- Can knowledge be transferred from a more developed, similar species?
- What is the fecundity of the species? / What is the egg size?
- At what age does the species typically reach reproductive maturity?
- Can broodstock be effectively conditioned to produce high quality gametes?
- Can gametes readily be stripped for artificial fertilization?

<u>Nutrition</u>
- Are the nutritional requirements of the species understood and documented at each critical life stage?
- Have commercial diet formulations been developed for the species? Can diets be obtained?
- For species requiring live feed, is the technology available to enable production of the necessary live feed species in commercial quantities?
- Does the species readily accept commercial diets at all life stages?
- For bivalve species can sufficient nutrition be obtained from primary productivity and at culture sites?

<u>Animal Health</u>
- Have the bacterial, viral and parasitic pathogens afflicting the species been reviewed and documented?
- What are the implications of these pathogens should an outbreak occur?
- Have veterinary practices (i.e. diagnostic tests, biosecurity protocols and/or control measures) been developed for these pathogens with the candidate species or for other similar species?
- Does the species respond well to standard treatment regimens?
- Are known pests and pathogens of concern present in the local environment?

Table 2c: SWOT Analysis template for evaluation of candidate species for commercial aquaculture development – Socio-Political & Environmental Factors.

SOCIO-POLITICAL & ENVIRONMENTAL FACTORS	
STRENGTHS ▪ Issue	**OPPORTUNITIES** ▪ Issue
WEAKNESSES ▪ Issue	**THREATS** ▪ Issue

Competition

- Will commercial cultivation of the candidate species be perceived as competition for an existing industry?
- How are competitors likely to react?
- Do competitors have power to influence or shape policy decisions?
- Will culture of the species create potential marine or land use conflicts with other users or industries?

Fisheries & Environmental Policy

- Will the candidate species require a risk assessment according to the National Policy on Introductions and Transfers of Aquatic Organisms and/or provincial I&T policies?
- Will it be necessary to secure seedstock and/or broodstock from wild fisheries resources in accordance with the policy on Access to Wild Aquatic Resources as it applies to Aquaculture?
- Will commercial culture of the species potentially result in opportunities for wild products to be harvested or traded outside of fisheries management controls?
- Will the commercial culture of the candidate species potentially result in negative environmental impacts that cannot be avoided or mitigated through culture practices?
- Will commercial culture of the species result in requirements for unique policy requirements (e.g. First Nations consultation, conflicts with *Species at Risk Act* listed species, etc.)

Infrastructure

- What implications does the candidate species impose for infrastructure and industrial development support in the region? Is existing infrastructure sufficient to enable industrial development with the new species? What is currently in place? What else may be required?

Table 2d: SWOT Analysis template for evaluation of candidate species for commercial aquaculture development - Economic Factors.

ECONOMIC FACTORS	
STRENGTHS ▪ Issue	**OPPORTUNITIES** ▪ Issue
WEAKNESSES ▪ Issue	**THREATS** ▪ Issue

- What are the principal direct costs and efficiencies associated with production of the species?
- What is a likely range for cost for production (cost of goods sold) under commercial production?
- What is a likely minimum scale for successful commercial culture of the species?
- What is the anticipated cost structure (Variable Cost : Fixed Cost Ratio) for production of the candidate species? High fixed costs imply that profitability will be sensitive to volume.

How are experience effects likely to influence production costs and market pricing as the sector grows?

Preliminary Evaluation of Species (Market & Basic Biology)

The purpose of the preliminary evaluation of species is to narrow the list of potential candidates to a manageable number for more detailed review. Although preliminary in nature, this should not be regarded as a cursory overview since Type I (selecting a poor candidate) and Type II (rejecting a good candidate) errors at this stage can be costly in terms of effort, investment, lost time and/or lost opportunity.

The following Market, Production and Socio-Political factors outlined in the SWOT analysis template are recommended for review at this stage of the species assessment: Product Analysis; Competitor Analysis; Morphology; Physiology; Behaviour; Geography; Fisheries & Environmental Policy.

Decision Factors

- Does the species, and the proposed product types, fill an existing demand (retail, food service, other)?
- Does the market demand have a seasonality to it? Is this due to the influx of wild caught supplies?
- Is the capacity for competitors to increase supply or decrease price detrimental in terms of future ability to remain competitive?
- Are the size and growth rate of the species able to provide the products required on a timely basis?
- Does the behaviour of the species appear suitable for commercial culture conditions?
- Are the habitat requirements of the species suitable for commercial culture?
- Is cultivation of the species socially and ecologically feasible in the region?
- Can cultured product be sufficiently identified from wild fishery harvests through traceability or other programs?

Species Selection & Commitment (Applied Research)

For the short list of species approved in Phase 1, the entire SWOT analysis must be completed. Thoroughness in the collection and compilation of data and information at this stage of the process will focus further efforts and enhance the efficiency and effectiveness of the RDC process.

The principal output from the evaluation model at this phase of the review process will be an RDC Plan for the species. Using information from the SWOT analysis, a species profile can be developed with key sectors of the profile describing the product and market potential for the species (opportunities) as well as the basic attributes that make it a good candidate for commercial culture (strengths). Moreover, outlining and reporting these advantages will further justify its selection for on-going development. From the weaknesses and threats components of the SWOT analysis, the underlying issues that need to be addressed to advance the species to the status of commercial culture will be identified and an action plan for applied research can be prepared. For each identified research and development issue, the action plan should specify: Challenges to be addressed; Research & development objectives; Potential RDC partners in the project; Potential leadership for the project; Estimate of time frame for completion of the project; and Estimate of the budgetary requirement for the project.

Decision Factors

- Is the scope of the RDC Plan realistic given the resources available to complete the applied research and development program?
- Are the necessary partners committed to supporting the development of the species?
- Are there regulatory barriers that impede current development? (e.g. shellfish harvesting in the Bay of Fundy)
- Are there public infrastructure issues that require resolution? (e.g. access to the water, year round road access, etc.)
- Are regional economic development policy, necessary program support and the regulatory framework conducive to support commercialization of the species – i.e. required biotoxin, disease or food safety monitoring programs?

Testing and Validation (Pilot Project)

The objective of the pilot project is to evaluate all aspects of production and operations in a simulated commercial setting. Emphasis should be placed upon evaluation of survival, feed conversion, growth rates and stocking densities and economic data should be compiled to quantify the cost for juveniles, feed, labour, management, veterinary services, etc.

Decision Factors

- Has the applied research program been unable to resolve one or more critical challenges that would suggest the species be terminated from further development?
- Has sufficient progress been made to suggest that juveniles will be available from hatchery or fishery stocks to support a pilot scale initiative?
- Are the nutritional requirements for the species sufficiently understood such that prepared diets can be formulated in sufficient volume to support the pilot project if required?
- Are the basic system design requirements sufficiently understood to warrant pilot-scale evaluation? (Comparison of system requirements may be a valid pilot scale initiative).

Verification & Technology Transfer (Commercialization)

If the species appears ready to advance, the fundamental components of this phase of the RDC initiative are to prepare a detailed Business Plan to support commercialization of the species, conduct further market research and develop a Market Strategy in support of the Business Plan and develop a Technology Transfer Program to facilitate dissemination of information and knowledge to the private sector.

Decision Factors

- Are juveniles available or does technology exist to consistently produce juveniles in sufficient quantity to support commercialization of the species?
- Have survival, growth rate and productivity been demonstrated to be commercially sustainable?
- Is a commercial diet readily available for the species if required?
- Have the risk factors been addressed and an acceptable risk management plan developed?
- Do any significant challenges remain that are likely to compromise successful transition to commercial culture?
- Do the economics of the species support commercialization?
- Is the projected ROI in keeping with expectations?

CONCLUSION

This 4-phase approach will enable key stakeholders to clearly identify and evaluate the strengths and opportunities that a potential culture species offers. At the same time, it will also identify specific areas where further research, development and/or commercialization efforts are required. Additionally, by reviewing the SWOT analysis on a regular basis, stakeholders will be able to track progress on the development of the species and the RDC Plan can remain current.

ACKNOWLEDGMENTS

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Global Tilapia Production and Markets – 2007

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Tilapia is the second most important farmed fish after the carps and is the most widely grown of any farmed fish. World tilapia production was 2,348,656 mt in 2006. Tilapia production in China (>1.3 million mt) exceeds the total combined production of all other countries. Consumption of tilapia in the U.S. has steadily increased from 0.3 lb/capita in 2000 to 1.0 lb/capita in 2007 and currently ranks in fifth position after shrimp, tuna, salmon and pollock. Consumption of tilapia in the U.S. was equivalent to 368,295 mt live weight in 2006. The majority of tilapia consumed in the U.S. is imported in the form of fresh fillets (23,101 mt), frozen fillets (74,381 mt) and whole frozen fish (60,772 mt) based on 2006 data. U.S. tilapia production supplies approximately 9,000 mt for the live fish market. The value of tilapia imported to the U.S. was US$482,743,000 in 2006. Demand is increasing for stricter food safety standards, higher quality and value-added tilapia products, improved packaging and environmental safeguards. Growth in market demand is projected for all tilapia product forms, especially frozen meals. Worldwide tilapia production and sales are expected to maintain their upward trend.

KEYWORDS

Tilapia, production, marketing, processing, price

INTRODUCTION

The tilapias, several closely related species in the genus *Oreochromis*, have become the second most popular farmed fishes after the carps on a global basis. World tilapia production has grown by 7 to 10% per annum over the last 20 years and has reached 2,348,656 mt in 2006. Production increases in tropical countries in Asia, Latin America and Africa have minimized price increases while demand has grown in the major markets of the US, EU, China, as well as in the producing countries themselves (Figure 1.) Expansion of up to 10% per year is anticipated in coming years with global production of 3,000,000 mt per year likely for 2010. Tilapias have passed the salmonids in global production and consumption and should eventually surpass the carps. While this may take 20 years or more, the continued rapid increase in tilapia culture and consumption along with the relatively static condition of the carps make this scenario fairly certain.

In 2006, tilapia grew to become the 5th most popular seafood in the US (Table 1). In 2006, US consumption of tilapia represented 368,295 mt (810,249,000 lbs) as live weight equivalent. This represents a per capita consumption of processed tilapia of 1.0 lbs, just behind that of catfish (0.97 lbs per capita). The four leading seafood products in the US are shrimp (4.4 lbs per capita), tuna (2.9 lbs), salmon (2.0 lbs) and pollock (1.6 lbs).

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CHINA

Domestication and production of tilapia has taken a quantum leap forward in China in recent years (Figure 2). China currently produces one half of the global supply and consumes one quarter. With 2005 consumption of 456,000 mt and production of 978,000 mt, tilapia are grown and eaten in virtually every province. However, the southern province of Guangdong leads with almost half of all production, and much of the fish for export. The neighboring provinces of Hainan, Fujian and Guangxi are also major producers. In addition to being the world's biggest producer of tilapia, China is also the world's biggest market, with more than half of the production being sold domestically. The majority of fish for domestic markets are still sold live to local restaurants. However, as the standard of living increases in China and with large numbers of women in the workforce, value-added, processed fish products, including fillets, are starting to find market demand in grocery stores. Within China there is also an effort to increase demand for a second reason. When the highest quality products are exported and lower quality and smaller size fish are sold in domestic markets, the industry is at risk of accusations of dumping. The rapid improvement in the Chinese standard of living has tempered this situation. Domestic tilapia prices increased from 12 RMB/kg ($1.50/kg) to 15 RMB/kg ($1.90/kg) from 2004 to mid-2006. This price approaches the average price of $2.17/kg average price paid for exported whole frozen tilapia in 2005.

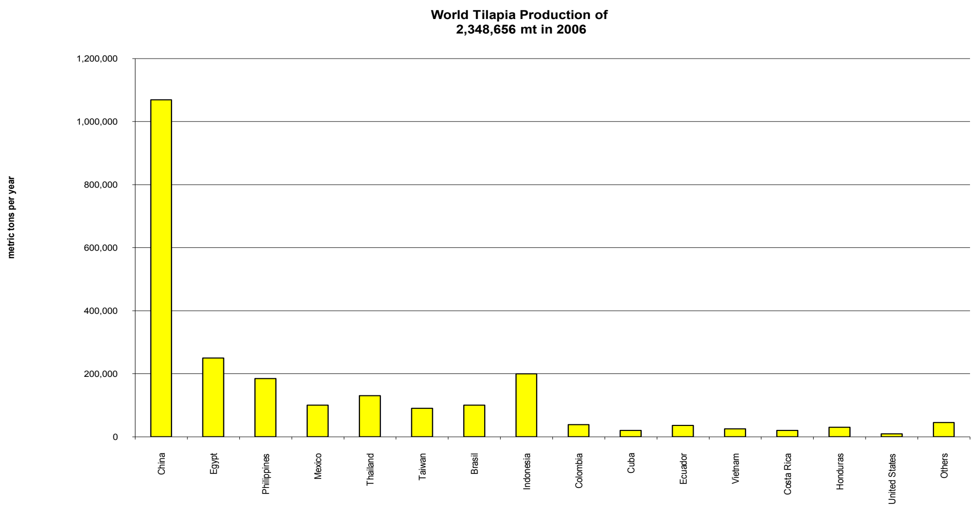

Figure 1. The major tilapia producing countries.

Table 1. Consumption of seafood in the US (in pounds per capita).

2000	2001	2002	2003	2004	2005	2006
Tuna 3.5	Shrimp 3.4	Shrimp 3.7	Shrimp 4.0	Shrimp 4.2	Shrimp 4.1	**Shrimp 4.4**
Shrimp 3.2	Tuna 2.9	Tuna 3.1	Tuna 3.4	Tuna 3.4	Tuna 3.1	**Tuna 2.9**
Pollock 1.6	Salmon 2.0	Salmon 2.0	Salmon 2.2	Salmon 2.2	Salmon 2.4	**Salmon 2.0**
Salmon 1.5	Pollock 1.2	Pollock 1.1	Pollock 1.7	Pollock 1.7	Pollock 1.5	**Pollock 1.6**
Catfish 1.1	Catfish 1.1	Catfish 1.1	Catfish 1.1	Catfish 1.1	Catfish 1.0	**Tilapia 1.0**
Cod 0.8	Cod 0.6	Cod 0.7	Cod 0.6	**Tilapia 0.7**	**Tilapia 0.8**	**Catfish 0.97**
Clams 0.5	Clams 0.5	Crabs 0.6	Crabs 0.6	Cod 0.6	Crabs 0.6	**Crabs 0.66**
Crabs 0.4	Crabs 0.4	Clams 0.5	**Tilapia 0.5**	Crabs 0.6	Cod 0.6	**Cod 0.51**
Flatfish 0.4	Flatfish 0.4	**Tilapia 0.4**	Clams 0.5	Clams 0.5	Clams 0.4	**Clams 0.44**
Scallops 0.3	**Tilapia 0.4**	Flatfish 0.3	Scallops 0.3	Scallops 0.3	Scallops 0.3	**Scallops 0.31**
Tilapia 0.3						

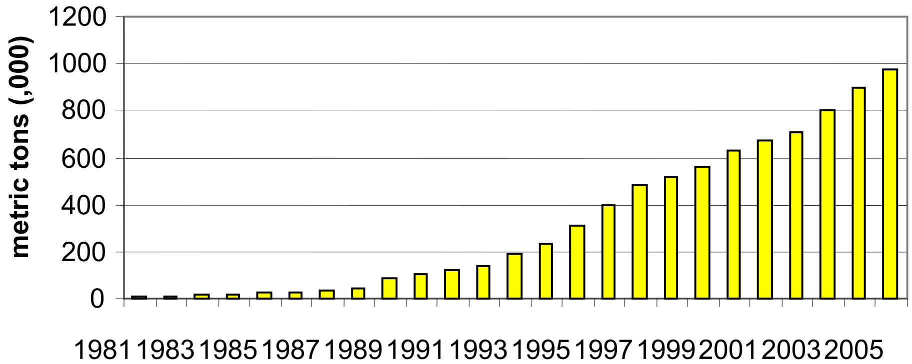

Figure 2. Production of tilapia in China.

In recent years, China has earned a reputation as a producer of low cost frozen fillets for export. These fillets are exported to North American and European markets, but the US is by far the biggest export market for Chinese tilapia. However, this is a recent phenomenon. In 1998, whole frozen tilapia accounted for more than 90% of Chinese tilapia exports. While the volume of whole frozen fish exports has increased a hundred fold, the volume of frozen fillets has increased a 1000 fold. Of course the fillet volume represents 3 times as much in live fish weight. In total the live fish harvested for export represent around 45% of the national production. Chinese exports for 2006 to the US are expected to exceed 95,000 metric tons (Table 2).

The tilapia industry in China is also evolving rapidly. The quality and variety of products being offered to markets has improved, as well as the packaging. At the same time we are beginning to see more privatization in all aspects. The old model of Chinese tilapia production started with large-scale, state-supported hatcheries, several producing 100s of millions of fry and fingerlings per year. These were distributed to hundreds of thousands of small farmers who grew the tilapia in ponds, cages, and rice paddies. At harvest the fish were collected in all manner of trucks and transported to processing plants. The processors were a mix of old and new plants, some converted from other food products and other designed specifically for tilapia processing. Much of the product was shipped to Taiwan and repackaged there for eventual export.

By 2006, we saw changes in all aspects. Several private hatcheries were opened and some state hatcheries were converted to cooperatives. Most hatcheries in China report using a hybridization of GIFT strains of Nile Tilapia (*Oreochromis niloticus*) crossed with Blue Tilapia (*O. aureus*). This cross typically yields a high percentage of male fry. Small farms still make up the vast majority of producers. Rice paddies, farm ponds and cages in reservoirs and rivers account for virtually all tilapia production. Vertically integrated farms with multiple ponds or recirculation systems are rare, but are being encouraged. Intensification, however, has been steady; more ponds now utilize mechanical aeration, most fish are fed pelleted diets, and fish are sampled for off flavor while still in ponds or cages. Depuration is becoming more common before harvest. Transportation to the processing plant has also improved. Stake bed trucks with canvas sides, emptied by hand, have been replaced with fish haul tanks with aerators and chutes to quickly transfer fish without handling.

Table 2. Exports of tilapia products from China to the United States.

	1998 (mt)	1999 (mt)	2000 (mt)	2001 (mt)	2002 (mt)	2003 (mt)	2004 (mt)	2005 (mt)	2006 (mt–est.)
Fresh Fillets	<1	38	59	191	844	856	<1	<1	<1
Frozen fillets	38	749	1,810	2,529	6,026	15,857	28,086	44,121	54,932
Whole frozen	435	4,940	11,622	10,870	19,615	23,762	31,781	30,884	39,530

The greatest improvements have been in the processing plants. Government support in the form of low cost land and loans helped spur the industry, but investment capital from Taiwan and foreign partnerships is supporting the newest plants. These plants meet HACCP and ISO standards and incorporate state of the art design, equipment, sanitation, and packaging.

Even the government promotion arm has evolved. The China Aquatic Products Processing and Marketing Association (CAPPMA) is still a department within the Ministry of Agriculture. However, in the early days the CAPPMA represented the entire industry and promoted tilapia in a generic manner. Today, the Association develops contacts on a global basis (representing the industry at seafood shows, posting a website, and promoting improved farming and processing techniques. CAPPMA encourages individual processing companies to develop their own marketing programs, brands, and labels. The Association also supports a bi-annual tilapia technology and trade conference. This series has brought together academic expertise along with production, processing and marketing personnel from across China and the rest of the world.

New products and packaging are promoting additional demand on an international basis to match the increased domestic demand. Butterfly versions with bones removed and new re-sealable packages of IQF fillets are driving restaurant and grocery sales respectively (Figure 3).

Figure 3. Butterfly tilapia with bones removed.

EUROPE

The rapid rise in US consumption is now being replicated in Europe. The EU appears to be on track to follow American trends as tilapia products are found more frequently across the continent. European consumption of tilapia has closely followed the path taken by the US. Early market segments were Asian and African immigrants familiar with the fish from their homelands. Then tilapia started to appear in up-scale restaurants looking for high quality fresh product to substitute for wild fish unavailable due to over fishing or seasonality. Club stores and hypermarkets have followed with frozen products. Europe lacks the large number of chain "casual dining" establishments that are common in the US. Adoption of tilapia consumption in the multitude of small cafes across Europe will probably take a longer time, but will likely occur over the next ten to twenty years.

PRODUCTION

The vast majority of tilapia farming occurs in tropical and sub-tropical countries with abundant supplies of warm water and low cost labor. China, Southeast Asia, the Middle East, South and Central America, and Southern Africa are all major producers and consumers of tilapia products. Egypt, the Philippines, Mexico, Colombia, Cuba, and Brazil are each major producers, but their domestic demand is so strong, their exports have been minimal. Interestingly, each has been a focal point of research and development that has driven the industry forward.

Egypt is now the second biggest producer of tilapia with very strong domestic markets. Egypt's proximity to Europe suggests that there is a strong potential for exports. Most of the other countries in the Middle East also produce tilapia ("boulti" in Arabic). In the Gulf region, temporary workers from the Philippines and the Indian sub-continent are significant consumers. Tilapia consumption in the Philippines has grown to the point that it is considered a staple of the diet and is one of the items that determines the consumer price index. Strains of tilapia developed in the breeding programs at the Freshwater Aquaculture Center on Luzon have been distributed around the world and include the GIFT, EXCEL, and YY or Genetically Male Tilapia. These strains and other populations derived from them are used in additional programs throughout China, South and Southeast Asia and the Americas.

The major exporting countries can be loosely grouped by the main product forms they offer. China, with Taiwan, is the world's major supplier of whole frozen tilapia. Indonesia, Thailand, and China along with Taiwan, supply frozen fillets to North American and EU markets. Ecuador, Honduras, and Costa Rica are the major suppliers of fresh fillets to the North American market. Zimbabwe and Jamaica supply significant amounts of fresh fillets to European markets.

North America and the EU also support significant markets for live tilapia. Although much smaller in scope than frozen or fresh, the live markets are supplied by local farms that transport fish directly to restaurants and grocery stores. Most of these outlets cater to immigrant communities, especially Asian, Hispanic and Africans, who were familiar with tilapia from their home countries. Most of the product from these farms is trucked live to restaurants and grocery stores that display live fish for customers to select. This has been the most lucrative market for the grower, minimizing handling and processing costs while returning the best price.

Whole frozen fish, primarily Chinese imports, have appealed to immigrants of limited financial means looking for low cost fish products. Fresh fillet imports have been absorbed by the restaurant trade, especially the casual dining trade. Frozen fillets have also found strong markets in the club stores and hypermarkets. Re-sealable bags containing one or two kilos of individually wrapped, quick frozen fillets, are especially popular (Figure 4). The packages allow the consumer to select any number of fillets for preparation and then to return the balance back to the freezer.

Tilapia farms have become economically successful for several key reasons. The foremost is the substantial progress that has been achieved through traditional selective breeding programs in several countries. These programs are often staffed with highly trained female biologists in the Philippines, Thailand and Brazil. These scientists, who might not be given such responsibilities in more established industries, often supervise a staff of male workers and administer complex genetics programs receiving international financial support. Another reason for tilapia's popularity is that no religious, national or cultural groups are known to have any taboos or restrictions directed towards tilapia.

Rapid progress has also been achieved in developing cost effective commercial diets for tilapia. As an herbivore-omnivore, tilapia can be fed with diets containing little or no fish meal. Diets with 30% protein, derived from plant materials, have proven to be cost effective for most farms.

Another advantage is the preference shown by many professional chefs for tilapia. Up-scale restaurants often prefer to receive whole fish on ice that will be prepared by the chef. The wait staff are usually instructed in the details of how the tilapia are farmed locally, delivered daily, along with general facts of tilapia including their Biblical role as the fish of the "Miracle of the Loaves and Fishes", as the native fish in the Sea of Galilee, and the favorite fish of "green groups" based on its low trophic level, feeding on plant materials and farmed with a grain fed diet.

An important growth area for tilapia is the value-added market. In the EU and North American markets, pre-breaded fillets, loin cuts, and fillets stuffed with shrimp and crab are appearing in club stores and groceries. These products, mostly prepared in the producing country, capture additional value for the processors and increase the variety available to the consumer. A number of upcoming magazine articles in food and health magazines will further drive North American demand in 2008 and beyond.

PRICES

As tilapia products have become commodities, the prices in general have declined slightly over the last ten years (Figure 4). When we consider the additional processing, improved packaging and other added costs to the processor and farmers, and factor in inflation, the real price to farmers and processors has seen a significant decline. It is only through increased efficiencies and cost cutting that profits have been maintained. These trends can be expected to continue for the foreseeable future. Tilapia prices will increasingly be compared to beef, chicken and pork rather then just to other seafood items.

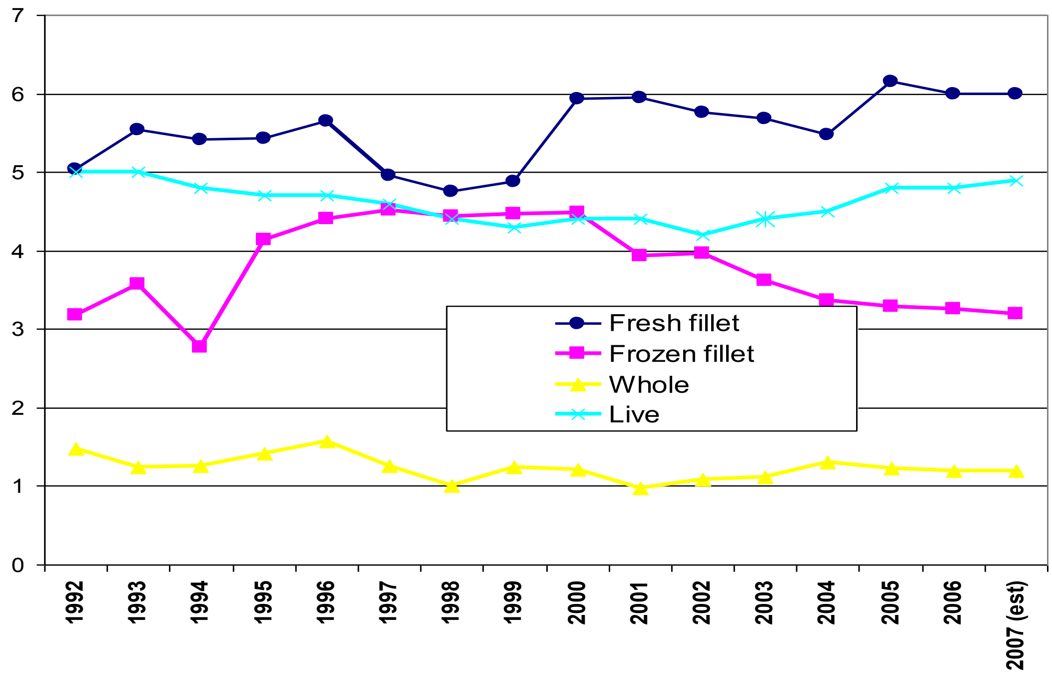

Figure 4. Tilapia product prices (US$/kg).

CONCLUSIONS

As tilapia continues to rise as the single most important food fish in the world, we should pause to consider the lessons learned.

1. US, Canadian, European and many Asian producers have focused their production and marketing on the high end, high profit markets of live fish or fresh whole fish on ice delivered directly to the markets.
2. North American and foreign producers have collaborated to maintain high standards and reputations for all tilapia products.
3. Foreign producers and commercial importers have collaborated to market tilapia in both generic ways that also benefited live fish producers while also developing branded products that differentiated the imported tilapia.
4. The term "tilapia" has been used by all parties as the generally regarded common name. Efforts to substitute a different common name have failed.
5. Growth in US demand is now being followed by European growth in demand. Vastly increased production in Southeast Asia and Latin America, has managed to feed demand and reduced the cost of product to the consumer.
6. Demand is increasing for stricter food safety standards, higher quality and value-added tilapia products, improved packaging and environmental safeguards.

Naturally Grown Tilapia Fish and Certified Organically Grown Herbs and Vegetables Using Aquaponics

Myles Harston

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There are several problems that accompany current procedures for supplying food to the marketplace:

First are the nagging concerns surrounding the use of genetic modification, hormonal manipulation and the use of antibiotics in the animals' food supply.

Second is the concern of pollution. Both wild caught and farm raised are affected. There are widely publicized concerns with the farm-raised fish that are raised extreme polluted conditions.

Some of the sources of the pollutants are the fishes' own excrement, farm chemical runoff, manufacturing waste and heavy metals that affect outdoor aquaculture and fish caught in the natural water including the ocean. Many traditional aquaculture facilities discharge huge amounts of excrement in their wastewater that is very high in nitrogen, which ends up in our natural waterways. These pollutants, added to the excess nitrogen from farmer's petroleum based nitrogen fertilizers, pesticides and herbicides, empty into the waterways and aquifers in North America and contribute to the Dead Zone in the Gulf of Mexico, which now measures, alarmingly, over 10,000 square miles. There are 200+ dead zones worldwide, which contribute to the up-take of contaminants that are taken up by the wild caught fish. Heavy metals such as mercury continue to build up in carnivorous fish such as tuna, salmon and cod.

http://www.nytimes.com/2008/01/23/dining/23sushi.html?_r=1&ref=health&pagewanted=print&oref=slogin

http://www.foxnews.com/story/0,2933,328850,00.html

http://www.nytimes.com/2007/12/15/world/asia/15fish.html?ex=1198386000&en=4aeb3394bbf6b59f&ei=5070&emc=eta1

Third is the problem that fresh produce has very long distances and extended amounts of time taken to deliver the food of products to the market place. The supply trucks contribute to air pollution as they travel great distance to deliver their products. Western Illinois University states that the average distance food travels before it reaches stores in Illinois and before the consumer buys it is 1,500 miles. The extra time and distance contribute to lower quality product. Because time and distance affect these products, the use of modified atmosphere procedures to store the foods such as formaldehyde, Nitrogen gas and Carbon Monoxide gas has become the norm.

Fourth, most vegetable farming operations presently use large amounts of water and chemicals for the growth of their products. These operations can significantly diminish water supplies, and also contaminate the water supply with chemicals that also compromise the foods we eat.

Aquaponics is one of the most viable solutions to all of these problems. Aquaponics is the combination of growing fish (aquaculture) and herbs and vegetables in water (hydroponics) in the same water system. Because Aquaponics can be done in a greenhouse, it may be located closer to major markets, so transportation expenses and emissions are reduced. At AquaRanch Industries, we specialize in fresh naturally grown tilapia fish and organic certified fresh grown herbs and vegetables. We begin this process with our own breeders so that we can spawn our own fish. This ensures that the fish we produce are not artificially, genetically or hormonally manipulated. AquaRanch starts with potable water and grows all the fish indoors in a controlled environment. This guards against the pollutants that are so rampant in our natural waterways. AquaRanch uses a proprietary filtration system to separate the fish waste from the water so that the fish are not swimming in their own excrement. After the primary filtration, the water flows to the grow beds where the herbs and the vegetables are grown. The roots of the plants hang down in the water and serve two purposes. First the roots directly take up nitrogen and other nutrients produced by the fish. Second, the roots act as a substrate for beneficial bacteria to break down harmful ammonia and nitrites to a less toxic form of nitrogen called nitrates. The fish are grown in round tanks so that a current can be maintained to stimulate the fish to swim against the current. This swimming activity creates a firm texture to the fish, which is more natural than a dormant pond raised fish. The amount of water that is discarded for cleaning purposes is far less than traditional aquaculture and is directed to the outdoor gardens as a tremendous source of nutrients for the garden produce. As a note; the fish are called naturally grown because the USDA currently has no designation for organic certification of fish.

The AquaRanch grow beds provide a barrier between the top of the plant and the root system, which hangs down in the nutrient rich water. The fish provide all the nutrients except for a few trace minerals. The plants grown are Organic Certified; therefore only organic certified pest control methods are used including biologicals like ladybugs and spiders. Weed control is not needed in this environment.

AquaRanch sells wholesale to grocery stores and from our Flanagan, Illinois location, as well as through farmers markets and Community Supported Agriculture, (CSA)'s. When you think of AquaRanch, think fresh and healthy! We have a continuous year around supply of naturally grown tilapia which we sell either whole or as fillets that we compliment with organic certified, site-grown gourmet lettuce, a variety of herbs, tomatoes, cucumbers, squash, sweet potatoes, potatoes, broccoli, and various varieties of peppers. Add to that our own signature Basil Vinaigrette dressing, and you can set your next dinner table with ease.

Visit us on the web at www.aquaranch.com or call us at 815-796-2978 for more information.


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