Aquaculture Canada[OM] 2005

Proceedings of contributed papers

AAC Special Publication No. 10

Navigating Forward: New Directions for Food Safety, Quality and Social Diversification

St. John's, NL
3-6 July 2005

C.I. Hendry
editor


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Aquaculture Canada[OM] 2005 – Proceedings of the Contributed Papers of the 22nd Annual Meeting of the Aquaculture Association of Canada, St. John's, NL, July 3-6, 2005.

Aquaculture Association of Canada Special Publication Number 10, 2006.

C.I. Hendry, editor

ISBN 0-9694597-9-3

Printed by Taylor Printing Group Inc., Fredericton, NB

Printed in Canada

Front cover: Logo designed by Di Dabinett. Inside front and back covers: Photos courtesy of Cynthia McKenzie, Alistair Struthers, and Natalie Hamilton-Gibson.

Aquaculture Canada^{OM} 2005

July 3-6, 2005
Delta St. John's Hotel and Convention Centre
Proceedings of Contributed Papers

President's Report

This must have been one of the shortest presidencies of the Aquaculture Association of Canada (AAC), from 18 October 2004 (end of the 21st Annual Meeting) to 6 July 2005 (end of the 22nd Annual Meeting): 8.5 months!

After sending a few thank you letters for the Aquaculture Canada^OM 2004 conference in Québec, it was time to prepare for the Aquaculture Canada^OM 2005 conference in Newfoundland. It started with the first Aquaculture Association of Canada (AAC)/Newfoundland Aquaculture Industry Association (NAIA) teleconference on November 13, 2004. NAIA and the Newfoundland and Labrador Department of Fisheries and Aquaculture were the co-hosts of AC05, and it was a pleasure working with them: thanks Mike Rose, Lynette Carey, Victoria Hamlyn, Brian Power and Brian Meaney! We had our first joint Organizing and Program Committee meeting in St. John's, NL, on December 13, 2004. We then had 5 Program Committee, 5 Organizing Committee, and 3 Sponsorship Committee teleconference calls in 6 months, along with innumerable emails and telephone calls (record on June 27: 58 emails in and 26 out). I would like to thank the members of the Organizing and Program Committees for their support, Melissa Struthers for her very professional and pleasant work as Conference Coordinator, going beyond the call of duty set forth in her contract, Chris Hendry as Programme Chair, Alistair Struthers for his many Program/website talents, Susan Waddy and Chrissy McGregor for standing as solid pillars of the AAC Office, and the very precious and experimented institutional memory we are lucky to still have with us, Cyr Couturier. Due to the Halifax airport fiasco, Chrissy McGregor was unable to reach St. John's and Natalie Hamilton-Gibson was able to stand at and manage the AAC booth on a last minute request: thanks for all your help, Natalie! Thanks also to our sponsors (sorry, "contributing partners" to be Ottawaly correct!), all the volunteers, without whom this meeting would not have been possible, and, of course, the proverbial hospitality of the Newfoundlanders!

This year, Aquaculture Canada^OM 2005 took place concurrently with NAIA's Cold Harvest™ Trade Show, making it the largest aquaculture event of the year in Canada. The programme combined an International Cod Symposium and the Second International Mussel Forum, with special sessions and contributed paper sessions from researchers, students, and industry and government representatives on current issues facing the aquaculture sector. It was a highly informative and enjoyable event. The theme for Aquaculture Canada^OM 2005 was "Navigating forward: New Directions for Food safety, Quality and Social Diversification". This underlined the need for inter-disciplinary and innovative teamwork, and co-operation among all users of our aquatic resources, to enable a prosperous and diversified aquaculture industry and research community in the appropriate environmental, economic and social climate. The promotion and discussion of business, technology, and science pertinent to the different types of finfish, shellfish and seaweed culture was a key objective of this meeting. All are interconnected as was so nicely reflected in the wonderful and colourful logo of this year's meeting, designed by local artist Di Dabinett.

This year's plenary speaker was Dr. Patrick Moore. His itinerary from Greenpeace to GreenSpirit made his presentation unique because of the breadth of experience included in it. Moreover, because of his experience, Dr. Moore is in a position to comment on controversial topics in an unparalleled way that nobody else could have the authority to do so. His comments were thought provocative and refreshing. In a way, he was preaching to the converted, but his message should be broadcasted further. People need to hear such a message from somebody who has been full circle from confrontation to consensus building and has a unique insider opinion on the evolution of the environmental movement.

Mr. Louis Deveau was this year's recipient of the AAC Honorary Lifetime Achievement Award. In his lively style, he told us the history of Acadian Seaplants Limited from the beginning to where it is today, including why it is the success story we, the seaweed guys, know it is, even though it is, unfortunately, not known well enough in the "animal side" of the aquaculture sector! Acadian Seaplants Limited is a diversified manufacturer of innovative and high quality seaweed products obtained from the harvesting of natural beds and a land-based seawater tank cultivation system. Louis Deveau shared with us many lessons learned over 35 years, which apply to all the different types of aquaculture, and gave us wise advice based on the remarkable entrepreneurial itinerary in his life.

Dr. John Castell, the recipient of the AAC Research Award of Excellence gave us an overview of his career and the path it followed with his legendary sense of humour and simplicity. From his beginning at the DFO's Halifax Fisheries Research Laboratory in 1970 to his retirement at the St. Andrews Biological Station in 2002, he worked on a wide variety of aquatic organisms with an impressive number of undergraduate and graduate students, postdoctoral fellows and colleagues. Through the years, he served on many editorial positions in different journals, and was very involved in the WAS (president in 1989-1990) and ICES Working Groups. Dr. Castell founded Castell Aquaculture Nutrition Consulting in 2004 and has been a volunteer advisor with the Canadian Executive Services Organization.

After you have been involved in deciding which people will be “screeched in” at the Banquet (however, not having complete control over the list… how did I end up on the stage, Melissa?!), what the colour of the conference bag will be, and which session will be on Tuesday afternoon, you realize that your time as President is pretty much up, especially when you have just wrapped up one conference in order to start another one…! No time to reflect on the future of the aquaculture sector in Canada! Maybe, this reinforces the importance that the Past-Presidents Advisory Council should have. The Past Presidents, not being involved in the details of the next annual conference, should be the think tank for the AAC and be involved in the visioning exercise. As Past President, I am now charged with recharging the battery of this venerable Council and get all its accumulated wisdom out.

Fortunately for me, these 8.5 months have been relatively calm on the controversy front through the media. No large PCB story, but the aftermath of this media coup. However, we had to deal with an industry undergoing tremendous restructuring, especially on the East coast, in a difficult economic and social climate while it continues to mature.

On the Association side of things, the Board of Directors had to deal with an accumulated deficit over 2003 and 2004. We had constructive discussions on membership fee rates, attracting more participants to our annual meetings by strategically choosing the time and place of these events and delivering a stimulating programme, in conjunction with other conferences when possible. We have also been rethinking the ways of operating our Committees. At the present time, almost all the committees are made up of different combinations of Board members, either as *ex officio* members or just Committee members, and staff. There are several problems with this practice: 1) some Board members are overcommitted to too many Committees, 2) always the same faces/same ideas does not bring new blood to the table, but 3) this new blood needs training.

Getting AAC members, who are not members of the Board, involved in Committees is also an excellent recruitment tool for the Association: the ones who will get “hooked” on AAC matters/issues, will then become the trained Board members of tomorrow. Our new President, Chris Hendry, has been following up on this recommendation and some committees are getting their “transfusion”! Please, do not hesitate to contact him if you want to volunteer and take a more active role in the AAC. I do not regret my involvement with the AAC, even as not coming from the main stream (you know, this seaweed guy!): it has been a fantastic networking opportunity and has matured my views on aquaculture.

The year 2005 also saw the creation of the long talked about AAC electronic newsletter “Watermark”. Thanks to Chrissy McGregor and David Rideout for their energy in turning an electronic newsletter project into a reality.

Thank you all for your hard work, dedication and convivial spirit that you have brought to the AAC. I hope to continue to work with the AAC as a Past President who will not have to decide whether we need 3, 4, or 5 reserved tables for the banquet and, consequently, will have time for the bigger questions, i.e. how can we build a prosperous and sustainable aquaculture sector?

We are now in good hands with our new President, Chris Hendry. Chris’ involvement with the AAC is a remarkable itinerary: he came to the Board while a student, representing the interests and issues of this important component of our membership very well, became a dedicated Programme Chair and Editor of the Proceedings of our Annual Meetings, and it was a pleasure to pass on the gavel of the AAC to him last July.

Thierry Chopin
AAC President 2004-2005

Honorary Lifetime Achievement Award

Louis E. Deveau, PEng, LLD (Hon), OC

Louis Deveau is the Chairman and Founder of Acadian Seaplants Limited, a seaweed manufacturing, cultivation and processing company specializing in value-added products developed for global agri-chemical, animal feeds, food ingredients including health, beauty and brewery markets and cultivated marine plants for the Asian food market. Mr. Deveau was born in Salmon River, Nova Scotia. He obtained a BA at Ste. Anne's University in Church Point, Nova Scotia in 1953 and his BEng at the Technical University of Nova Scotia (now Dalhousie University) in 1957. His innovative involvement in the economic development of marine resources in the Maritime Provinces dates to 1961. At that time he worked for the Federal Department of Fisheries for six years and was responsible for developing the snow crab and shrimp industries in the Maritime Provinces. Mr. Deveau ventured into the seaweed industry over 35 years ago and has dedicated his life to it. He was recruited by Marine Colloids of Rockland, Maine, USA, and from 1967-1989 he held positions as President of Marine Colloids Canada Ltd.; President of Philippine Marine Inc., Manila; President of Gel Mex, Mexico; and Vice-President of Marine Colloids Inc. His responsibility for the worldwide procurement of seaweeds for processing into carrageenan led him to circle the world numerous times. During this period, he spearheaded the development of an entirely new industry – seaweed farming in the Philippines and Malaysia, which today is a major industry in these countries. In 1980, Louis Deveau acquired the Canadian assets of Marine Colloids, Canada from its US parent and in 1981 Acadian Seaplants Limited was born. Since then, Mr. Deveau has invested continuously in the development of innovative cultivation and manufacturing technologies and new product and market development. His strategy of innovation has transformed Acadian Seaplants from a one customer, one product company into a diversified, fully-integrated organization, processing wild seaweeds into value-added agricultural products, animal feeds, food ingredients for the health, beauty and brewery industries and the cultivation and processing of seaweeds for the Asian food market. Louis Deveau's association with seaweed started as a youngster on the Acadian French Shore of Nova Scotia's Baie Ste. Marie. He discovered at an early age that seaweeds are an excellent source of nutrients for plants, noticing that his father would spread "goemon de roche" (the Acadian term for seaweed found on the rocky shoreline) on the crops he grew in the family vegetable garden. Years later, Louis would develop innovative, high quality, value-added products processed from seaweeds and create a seaweed industry in Atlantic Canada. Today, Mr. Deveau's company is comprised of four product divisions: Food Science, Animal Science, Plant Science and Food Ingredients Divisions. He operates five major manufacturing and cultivation facilities in Nova Scotia, New Brunswick and Prince Edward Island from a corporate office in Dartmouth Nova Scotia. Acadian Seaplants products are marketed and sold in over 70 countries around the world.

Louis Deveau (Acadian Seaplants Limited, L) receives the 2005 AAC Lifetime Achievement Award from Dr. Thierry Chopin, AAC President.

Research Award of Excellence

John D. Castell, PhD

Dr. Castell is Scientist Emeritus at the St. Andrews Biological Station of the Department of Fisheries and Oceans. Born April 19, 1943 in Guelph Ontario where his Father taught at OAC, he completed his BSc (Hon) in Biochemistry at the Dalhousie University in 1964. He was Dr. Robert G. Ackman's first graduate student completing his MSc in Lipid Chemistry at Dalhousie University September 1965. He completed his PhD in Food Science and Technology from Oregon State University in 1970. His Postdoctoral Fellowship was spent under Dr. Orvill Privitt at the Hormell institute at the University of Minnesota. He joined DFO's Halifax Fisheries Research Laboratory in December of 1970 as a Research Scientist. He served as Head of the Disease and Nutrition Section from 1983 to 1988. His research has involved studies of a wide variety of aquatic organisms including both North American lobsters (*Homarus americanus*) and spiny lobsters (*Panulirus argus*) in Cuba, rainbow trout (*Oncorhynchus mykiss*), Atlantic salmon (*Salmo salar*), Chinese shrimp (*Penaeus chinensis*), American and European oysters (*Crassostrea virginicus* and *Ostrea edulis*), European crayfish (*Asticus asticus*), just to name a few of the species. This research would not have been possible without the efforts of many undergraduate, graduate students, postdoctoral fellows, and colleagues at DFO, Dalhousie University, University of Moncton, the Agricultural College of Nova Scotia, the Nova Scotia Technical College, Memorial University of Newfoundland, the University of New Hampshire, the University of Maine at Orono and the University of New Brunswick the aquaculture industry and research institutes around the world. Dr. Castell served on the Editorial Advisory Board Associate Editor for the *Journal of the World Aquaculture Society* 1983-1986, Member of Editorial Advisory Board for Aquaculture 1984-1992, Associate Editor for the *Journal of Aquariculture* 1979-Present, and Associate Editor for the *Journal of Tropical Aquaculture* 1985-present. Dr. Castell was instrumental in the establishment of the International Working Group on Crustacean nutrition and served as Editor of *Crustacean Nutrition Newsletter* 1983-1992. He has served on the Board of Directors of World Aquaculture Society from 1984 until 1991, including a term as president 1989 to1990. He served on several ICES Working Groups and chaired the ICES Working Group on Marine Fish Culture from 1999 until retirement in 2002. Appointed to US National Academy of Science, National Research Council, Committee on Animal Nutrition, Subcommittee on Warmwater Fish, 1981-1983. He serves as an Adjunct Professor at Dalhousie University, the Nova Scotia Agricultural College and University of New Brunswick and founded Castell Aquaculture Nutrition Consulting in 2004. Dr. Castell was appointed Canadian Consultant to International Development Research Centre's (IDRC) Cuba (Langosta) Project 1982-1985. This was a three year cooperative international assistance project to improve live holding and processing of the spiny lobster in Cuba. He was Canadian Consultant to IDRC's China (*Penaeus chinensis*) Project 1986-1991. He is also a volunteer advisor with Canadian Executive Services Organization and has been involved in aquaculture projects in China 2001 and Panama 2003.

Dr. John Castell (Fisheries and Oceans Canada, R) receives the 2005 AAC Research Award of Excellence from Chris Hendry, AAC President-Elect.

AC05 Student Affairs Report

Student Presentations

This year we were pleased to host 32 student presentations; 15 oral presentations and 17 poster presentations. Overall, the student presentations were of excellent calibre, covering a range of interesting topics. **M. Guillame Werstink** (ISMER-UQAR) was awarded best oral for his presentation "Applying GIS and that analytic hierarchy process on seafarming spatial assessments in the Magdalen Islands (Quebec),", sponsored by University of Guelph Aquaculture Centre and CAIA. Special mention was given to **Terralynn Lander** (UNBSJ) for her contributed paper "Effects of Atlantic salmon (*Salmo salar*) aquaculture on the reproductive cycle of the blue mussel (*Mytilus edulis*) in the Bay of Fundy, New Brunswick." Best poster presentation was awarded to **Meredith Hutchison** (UNB) for her presentation "Public participation GIS as a 'Push' technology for disseminating aquaculture information to stakeholders" also sponsored by University of Guelph Aquaculture Centre and CAIA. **Stephanie Lynn Synard** (UPEI) earned a special mention for her poster entitled "Structural alterations of haemocytes affected with haemic neoplasia (HN) in soft shell clams, *Mya arenaria*." Winners of the both the oral and poster presentation awards have contributed papers in this issue. Thank you and congratulations to all of the exceptional student presenters.

Following AC04, the format for judging student presentations was revisited. This year the student presentations were subject to a new judging scheme which hopefully left students with a positive feeling after attending and contributing to this year's scientific program. The judging procedures will be reviewed by the Student Affairs Committee and the committee will determine if further improvements can be made. With that said, a huge thank you goes to all the judges who participated in evaluation of student presentations. Your time and efforts are invaluable to the student evaluation process.

Student BBQ

The annual student BBQ is known for its relaxed atmosphere for conference participants to mingle and enjoy local customs and cuisine. This year was no exception with the BBQ being held at O'Reilly's Irish Pub in the heart of famous George Street. The venue was perfect for a taste of Newfoundland culture and hospitality with members of the of the Irish Descendants providing the entertainment, followed by the "Screeching-in" of some of our notable participants.

One of the largest draws to the student BBQ and a major contributor to the AAC Student Endowment Fund (SEF) is the silent auction. Again this year, it went off with resounding success. A variety of donations including framed prints, textbooks, mugs, t-shirts, fleeces, gift baskets and baseball hats helped to raise over $1000 dollars for the SEF. This of course would not be possible without the generosity of our sponsors:

ACE Aquaponics, Aquaculture Association of Canada, Blackwell Publishing, Dive Newfoundland, Ed Roche Fine Art, EWOS, Holland Nurseries, Hoskin Scientific, Lambs, Laura Halfyard, Marine Institute, Mickey Quinn's, Newfoundland Aquaculture Industry Association, New Zealand Mussel Industry Council, Northern First-Aid, Novartis, Ocean Quest Adventure Resort, O'Reilly's, PEI Aquaculture Alliance, PEI Department of Agriculture, Fisheries and Aquaculture, Pretty SAFE Enterprises, UNBSJ

Student Travel

This year the SEF offered travel awards totalling $3040 to the following 13 students:

Paula Moreno-Silva (Catholic University of Valparaiso), Dulce Martins (University of Porto, Portugal), Catherine Gaudreau and Arianne Savoie (UQAR), Aaron Bennett, Terralynn Lander, Kelly Barrington and Bill Martin (UNBSJ), Meredith Hutchison (UNBF), Stephanie Synard (UPEI) and Nicole Brun, Leah Lewis and Carla Walbourne (Dalhousie University)

Again this year, much gratitude is extended to Terralynn Lander for organization of student involvement with AV logistics. A superb job of allowing the smooth running of presentations and sessions was seen again this year.

Finally, we hope you will join us in Halifax, NS for AC06.

Submitted by the Student Affairs Committee
Jason Mullen, Carla Walbourne, Rod Penney, Daphne Munro

Aquaculture Canada^{OM} 2005 Committees

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Thierry Chopin – AAC President and Conference Chair, University of New Brunswick, Saint John
Chris Hendry – Program Chair, AC05, NL Department of Fisheries and Aquaculture
Melissa Struthers – Conference Coordinator, Struthers and Associates
Chrissy McGregor – Registration and Aquaculture Association of Canada
Brian Power – Trade Show Coordinator, Newfoundland Aquaculture Industry Association
Mike Rose – Newfoundland Aquaculture Industry Association
Cyr Couturier – Marine Institute of Memorial University
Brian Meaney – NL Department of Fisheries and Aquaculture
Geoff Perry – Department of Fisheries and Oceans
Frank Handrigan – Atlantic Canada Opportunities Agency
Marc Kielley – Canadian Centre for Fisheries Innovation

Program Committee

Chris Hendry – Program Chair, AC05, NL Department of Fisheries and Aquaculture
Thierry Chopin – President, Aquaculture Association of Canada, Univ. of New Brunswick, Saint John
Alistair Struthers - Webmaster and contributed papers, Marine Institute of Memorial University
Lynette Carey – Newfoundland Aquaculture Industry Association
Rod Penney – Department of Fisheries and Oceans
Chris Brown – National Research Council of Canada – Industrial Research Assistance Program
Joe Brown – Memorial University of Newfoundland
Duane Barker – Marine Institute of Memorial University of Newfoundland
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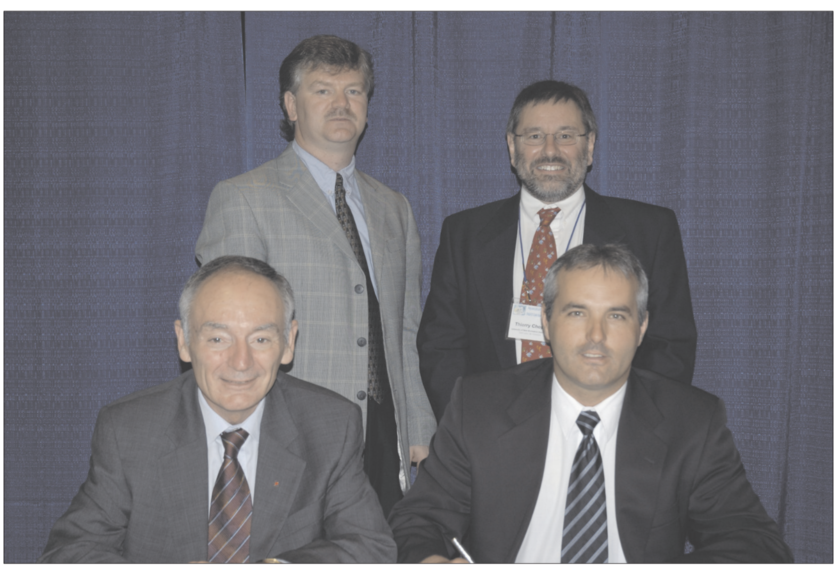

During the conference opening, Hon. Trevor Taylor (seated, R), NL Minister of Fisheries and Aquaculture, proclaimed July 4-10, 2005 Aquaculture Week in Newfoundland and Labrador. Accompanying Minister Taylor at the table is Larry Murray (Deputy Minister, Fisheries and Oceans Canada), and (from back L-R) Mike Rose (Executive Director, Newfoundland Aquaculture Industry Association), and Dr. Thierry Chopin (President, Aquaculture Association of Canada).

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In Memoriam

Dr. Joseph A. (Joe) Brown

On Sunday, September 4, 2005, the Aquaculture Association of Canada lost a dear friend, colleague, and mentor. Joe Brown passed away suddenly at his home in Shoe Cove, Newfoundland. A Past President of AAC, Joe was a colourful, vibrant, and cheerful staple to every AAC conference and other aquaculture-related meetings, both in Canada and worldwide. His professional relationships were all sincere, illustrated by the large network of colleagues that also called him a friend. His contributions to aquaculture are countless and outstanding, all the while he was one of the most approachable – and recognizable – figures in his field. In addition, Joe's commitment to students was unprecedented.

After graduating from high school in Grey, Maine, Joe came to Canada and completed a BSc degree at St. Francis Xavier University in 1968. He then served for two years in the US army at the invitation of Uncle Sam, after which he took advantage of the opportunity afforded by the GI Bill and began graduate studies at Memorial University of Newfoundland. At Memorial he initially worked with Dr. John Lien on seagull behaviour but soon became interested in the behavioural ecology of fish. Under the guidance of Dr. John Green, Joe studied aggression and territoriality in the arctic shanny, and received his MSc degree in 1976. Following two years working as a farm labourer, laboratory demonstrator and museum curator in Nova Scotia, Joe joined Dr. Patrick Colgan's research group at Queen's University and was awarded the PhD degree in 1983 for his thesis on the behavioural ontogeny of centrarchid fish. He remained at Queen's for a further year as a postdoctoral research fellow, mentored by Dr. Peter Johansen, before returning to Memorial in 1984 to rejoin Dr. Green's laboratory as a Research Associate. Joe was appointed to the faculty of the Ocean Sciences Centre (then the Marine Sciences Research Laboratory) in 1985, and was promoted to the rank of Professor in 2000. He recently served a term as Associate Director and also a period as interim Director.

Joe's terms of reference on appointment were to set up a strong research programme in his field, the behavioural ecology of fish, and to use this as a platform to support the emerging aquaculture industry in the Province. He applied himself to this task with considerable energy and enthusiasm, and over the next twenty years established himself as one of Canada's leading researchers in fish behaviour and an outstanding figure in aquaculture related research, authoring or co-authoring over a hundred articles in scientific journals as well as numerous reports and contributions to scientific conferences and workshops. Joe was one of those marine scientists who recognised the potential of fish farming to complement capture fisheries, and was totally committed to research and development in finfish aquaculture. His work on rearing the Atlantic cod has been instrumental in taking cod farming to the developmental stage in the field, and he was actively pursuing this research at the time of his death. Joe made sure that his aquaculture work was not conducted in the ivory tower, always seeking commercial applications for his research, and he worked closely with many partners in the private sector and government agencies. His ability to acquire research funding from a myriad of sources was legendary. He was an excellent communicator, a skill that he fully exploited as a tireless advocate of fish farming. Joe was frequently sought out by the media, and enjoyed a high profile both inside and outside the university.

Joe travelled widely, visiting Norway, Sweden, Brazil, Malawi, and many other places, working with colleagues on theoretical and applied problems in fish behaviour and aquaculture while sharing new cultures and making lifelong friends. Although his work had a significantly international dimension, it was at home in Newfoundland and Labrador that Joe was most content, doing what he could to assist the aquaculture industry at both the provincial and the national level. His efforts and achievements were recognised through awards from the Canadian Centre for Fisheries Innovation (Researcher of the Year, 1998) and the Aquaculture Association of Canada (Research Award of Excellence, 2001), and in 2002 the Canadian Foundation for Innovation formally recognised him as one of Canada's leading aquaculture scientists.

It was as an advisor and mentor of students, however, that Joe made his most enduring contribution. He was devoted to them, both undergraduates and graduates, and they to him. Students flocked to join his group, and his large "stable" of graduate students became one of the pillars of the Ocean Sciences Centre. He attracted many international students, especially from developing countries. He always had time for students, both in the laboratory and outside, and they were a central part of his lively social life. He encouraged them to attend scientific meetings, and made it possible for them to travel. Joe enjoyed teaching and played a leading role in several graduate programmes at Memorial, especially the MSc in Aquaculture and the MSc and PhD in Biology and in Cognitive and Behavioural Ecology.

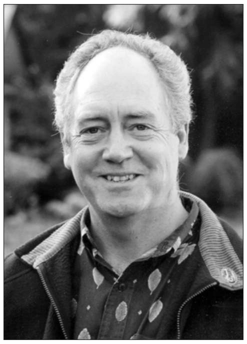
To his colleagues, Joe was a tireless, consummate "team player" who did not shirk administrative tasks, serving on numerous departmental and university committees as well as those of national research programmes such as AquaNet. He was President of the Aquaculture Association of Canada, Chair of the Ecological and Behaviour Section of the Canadian Society of Zoology, and sat on numerous review boards and panels. He played a major role in the establishment and operation of the Aquaculture Research and Development Facility at Memorial, which was no mean achievement, since it required close and effective liaison between the academic, government and private sectors.

Joe will be sadly missed, not only by his family but also by his wide circle of friends, colleagues, students, and former students. His work, his friendships, and his love of life will be his legacy.

The Dr. Joe Brown Scholarship has been established to honour Joe's memory. Donations, which are tax-deductible, can be sent to the Dr. Joe Brown Scholarship Fund, Alumni Affairs and Development, Memorial University of Newfoundland, St John's, NL, A1C 5S7. Online donations can be made at *www5.mun.ca/dir/viking.gv020.p001* (taken from *www.mun.ca* and following the links to "Alumni Affairs" and "Ways to Donate"). In the information box, state "Dr. Joe Brown Scholarship" and give your name and address to expedite the tax receipt.

Dr. Ray Thompson
Ocean Sciences Centre

Aquaculture - The Future of Healthy Protein and Oil for a Growing Population



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Since its beginnings in the 1980s, salmon farming has been under a relentless attack in British Columbia, and to a lesser extent in other parts of the world. The opposition comes from a coalition of commercial wild salmon interests, environmental groups, the political left, boaters, and tourism operators. Let's look at the laundry list of complaints activists are making daily against what I believe is one of the cleanest industries on the planet, producing the healthiest food in the world.

"Salmon farms are polluting the ocean with fish waste"

Activists compare salmon farms to "cities of 500 000 people dumping their raw sewage" into the environment. The primary reason for concern about untreated human waste is disease transfer, not the waste itself. For centuries before sewage was treated, diseases like cholera and tetanus were transmitted by water that was contaminated with human waste. Once human waste is treated and sterilized it is a perfectly good fertilizer, and fish waste is no different except that there are no diseases that can be transmitted from fish to people. Fish waste consists of carbon, oxygen, hydrogen, potassium, nitrogen, phosphorous, calcium, iron, zinc, and the other nutrients essential for life.

It is possible to have too much of a good thing. If a fish farm is situated in shallow water where there is no tidal flushing and the farm is heavily stocked it can cause the form of pollution know as eutrophication, or simply too many nutrients. Excess nutrients cause excess plankton (algae) growth, depleting the water of oxygen when the plankton die, causing fish kills and reduced productivity. One of the best features of fish farms is that they are self-regulating for this concern. If a salmon farmer pollutes the water at the farm site, it is the fish in the pens that will suffer the most harm. Fish living outside the pens can swim away but the farm fish must live or die in an enclosed area. They are somewhat like the proverbial canary in a coalmine in that they would suffer first, the farmer would go broke, and the pollution would end.

If a farm is properly located where there are strong tidal currents, the nutrients are dispersed widely and actually increase the productivity of the area. It is no secret that prawn and crab fishermen often set their traps close to fish farms due to the abundance of marine life in their vicinity. What would I do with a wheelbarrow full of fish waste? I'd spread it on my vegetable and flower gardens; knowing it would make them grow faster and produce more food and blooms.

In this case the activists are employing the propaganda of using negative and foul-smelling words like sewage and waste, as if fish waste is some kind of toxic chemical when it is actually beneficial. In the great food chains of life, one species' waste is another species' food. Three cheers for fish poop!

"Farmed salmon may escape and pollute the wild salmon and even take over from the wild fish"

To cut to the chase I sum this one up with, "Some people are more worried about which fish are mating up a river than where their own kids are at night." The concern is that if a farmed fish escapes and mates with a wild fish that the offspring will be inferior and will not be able to compete in the wild. Then there is another concern that if a farmed fish escapes it will overpower the wild fish and displace it, thus creating an inferior stock of fish. They can't have it both ways, however. Either the farmed salmon are inferior and won't be able to compete, or they're superior and will outcompete. In fact the critics are wrong on both counts because in the wild the rule is the survival of the fittest. If the escaped farm fish really were more fit, then it would deserve to survive. King and silver salmon from the north Pacific have adjusted to the Great Lakes and thrive there. Rainbow trout from the Pacific Northwest – British Columbia in particular – are now well established in lakes and rivers around the world. People are generally happy with this because they like to catch and eat the salmon and trout.

Most of the farmed salmon grown in British Columbia and Washington State are Atlantic salmon. It isn't possible for them to breed with Pacific salmon so there is no genetic concern like there is in Norway and Scotland where farmed Atlantic escapees could breed with their wild cousins. But activists fear that Atlantic salmon might become established in the Pacific and displace the native species. After 15 years during which time thousands of Atlantic salmon have escaped there is no evidence that they have become permanently established. This is likely to remain the case as there have been many attempts around the world to establish Atlantic salmon outside their natural range and all have failed. It would appear that Atlantic salmon are difficult, if not impossible, to transplant.

Even if Atlantic salmon did become established would it be such a bad thing? There are already eight species of salmonids in Pacific Northwest rivers and they don't "displace" each other. Maybe a ninth species would simply add to biodiversity. The oyster farming industry in the Pacific Northwest is based upon the cultivation of Japanese oysters in the ocean. In some warmer inlets they have become established as self-perpetuating populations. In other words, they have become naturalized and it seems to me that this is a pretty natural state of affairs. There is no evidence that the Japanese oysters are displacing native species of shellfish.

In Norway and Scotland activists charge that escaped Atlantic salmon will wipe out the wild stocks. They neglect to mention that the reason salmon farming was invented in Norway was because the wild salmon had been so badly overfished there weren't enough to satisfy the demand. If anything, the salmon farms allow some of the fishing pressure to be taken of the wild stocks so that they might rebuild. In a recent agreement Greenland has stopped commercial fishing for Atlantic salmon with financial support from Denmark and the US. Hopefully this will increase ocean survival so that more fish will return to spawn in their native rivers in Europe and the Atlantic coast of North America.

"Salmon are fed large amounts of antibiotics that spread into the sea"

During the early years of salmon farming it was common to medicate the fish fairly regularly to control a number of diseases to which they were susceptible. Today, antibiotics are used very seldom because vaccines have been developed for most diseases. When compared to chicken and hog farming, there is no comparison. Whereas these livestock are on low-dose antibiotics for more than 50% of their lives, only 3% of salmon feed is medicated. Many salmon farms are now completely antibiotic-free and some are able to qualify for "organic" status.

It is truly amazing that activists can put such a negative spin on the use of modern medicine in animal husbandry. It is perfectly reasonable for veterinarians to prescribe medication for diseased livestock, and reasonable to use low-dose antibiotic feed to promote rapid and healthy animal growth. These practices are partly why our agriculture is so productive today. Sure it would be nice if there were no diseases in this world, but such a world is a fantasy that is unlikely ever to be real.

"Salmon farms spread disease to wild fish"

The anti-fish-farm set give people the impression that salmon farms are somehow manufacturing diseases and then spreading them to wild fish. In fact the reverse is true. All the diseases that farm fish get are from the wild. Farm fish go into the ocean disease-free and sometimes contract the diseases that are natural in the waters around them. If the disease outbreak is severe, they can be treated and cured, unlike wild fish that get disease and transfer it to both other wild fish and to farm fish.

"Salmon farms are spreading sea lice to wild fish, causing their populations to plummet"

This is the claim that anti-salmon activists are pursuing most aggressively today. It is a completely trumped-up fabrication but that doesn't stop them from repeating it so often that the media, and thence the public, believe it.

The story goes like this: Sea lice, which are slightly parasitic relatives of shrimp and crabs, attach themselves to farmed salmon and breed on them so prolifically that they become a reservoir for infecting wild fish swimming by. Lice from salmon farms attack pink salmon, in particular, which have a very small juvenile stage, when they come out of the rivers and go to sea. In 2002 a large run of pink salmon that returns to spawn in rivers near the Broughton Archipelago on British Columbia's central coast crashed to less than 10% of its previous size. This is blamed on sea lice.

It is a great story for the activists, as it argues that the fish farming industry is a direct threat to the wild salmon populations. Whereas the aquaculture industry argues, correctly in my view, that farming helps take the pressure off wild stocks by providing a farmed product; the activists now have an argument that suggests the opposite is the case. Let's examine the facts.

There is no actual direct evidence that lice from salmon farms are harming wild salmon stocks. The crash of 2002 was clearly a natural phenomenon caused by overpopulation in the 2000 and 2001 returning spawners. They simply ate themselves out of house and home and collapsed. This pattern occurs in most populations of wild species; it is a typical boom-and-bust cycle. The activists never mention that the 2000 and 2001 pink salmon populations were the highest recorded since records have been kept. They don't mention that salmon farms were already established for 15 years before the crash occurred. And they certainly don't talk about the fact that in a number of years before salmon farms existed on the coast that the populations were even lower than in the crash year of 2002. And you can be doubly sure that they will never volunteer the fact that in 2003, 2004, and 2005 the population has rebounded, quickly coming back to a level that is higher than the 50-year average for the region. Meanwhile the activists continue to claim that sea lice from salmon farms are "threatening wild pink salmon with extinction."

The media has been particularly irresponsible in its reports on this subject. It seems quite obvious that they enjoy helping to create the myth, rarely if ever presenting the facts listed above. I have been around controversial environmental issues a long time so I know you can't always just blame the media. In this case, however, I believe it is justified.

There can be no doubt that salmon farms, sea lice, and wild salmon all exist in the ocean. Sea lice do attach themselves to farmed salmon, and a percentage of wild pink salmon fry do have sea lice on them as they pass by salmon farms. So where are the sea lice coming from? It turns out that salmon have been infested with sea lice long before there were any salmon farms. It is now known as a result of government-funded research that sea lice are present in the billions on many other species of fish besides salmon. Sticklebacks, which are abundant near the outlets of the streams from which pink salmon come down, are loaded with lice. They and other wild species are the most likely source of sea lice that attach to the wild salmon. This same research has found no evidence that the lice that are on the wild salmon are causing any damage to the population. Yet hysteria seems to rule the day.

Researchers have now developed a treatment for sea lice on farmed salmon called SLICE. It is a medication that is put in the salmon feed and it kills the lice. Activists are now campaigning against the use of this medicine; even though it has been approved by health and environment authorities in many countries. This is typical; they are against the lice, claiming they will exterminate wild salmon, and then they are against the cure even though there is no evidence of harmful side effects.

"The feed for farmed salmon contains fishmeal and oil from wild fish. This results in a "net loss" of protein for a hungry world because it takes 2-3 pounds of wild fish to make a pound of farmed salmon"

It is true that a portion of the feed for farmed salmon is fishmeal and oil from wild fish. The omega-3 fats in fish oil are essential for good health in salmon and other farmed fish. But it is not true that the use of these products results in a net loss of protein for consumers. When you think about it, why would fish farmers be so stupid as to employ a system that made less food for people? The fact is they don't; aquaculture produces more food for people or it would not make any sense. A recent independent study done for the European Union Research Director concluded, "Globally the efficiency of consuming fish directly and eating animals fed on fishmeal and fish oil is about the equal. Feed conversion figures for salmon suggest that it is more efficient to consume salmon derived from aquaculture than wild caught fish."

Fishmeal and fish oil are derived from three main sources; the scraps from processing wild and farmed seafood, undesirable fish that are caught incidentally while fishing for other species, and anchovies caught off the coast of Peru. The anti-salmon farm brigade focuses all their attention on the anchovy fishery, a well managed and sustainable harvest that lands five million tons per year, or about 5% of the global wild seafood catch. The gist of the activist criticism is that salmon farmers are taking food from the mouths of poor Peruvians and producing food for affluent consumers in rich countries. And by feeding the fishmeal and oil made from anchovies to salmon there is a net loss of protein as it takes two to three pounds of anchovies to make one pound of salmon. It's a great story about corporate greed and abuse of poor people but there isn't a speck of truth to it.

First, not even poor people want to eat a regular diet of anchovies. We do have to take people's tastes into account. It may well increase the food supply if we all ate algae paste three meals a day but that isn't likely to become a fad any time soon. Second, anchovies spoil very quickly after they are caught: that is why they are usually canned in oil with a lot of salt. Some people, I included, enjoy the occasional one on a Caesar salad. But the only other way to keep them for a reasonable time is to freeze them. There simply isn't a market for five million tons of frozen anchovies. That is why they are converted to meal and oil. If people actually wanted to eat them as anchovies there would be a market for them and they would not be rendered down. Food fish always command a higher price than fish that go into rendering plants. I suppose one could argue that the government of Peru should buy all the anchovies and give them, and a deep-freeze, and the power to run it, to the poor. As it is, the export of anchovy meal and oil is one of Peru's largest income earners. It probably does the people of Peru more good to bring in foreign currency that it would to make the people eat five million tons of anchovies every year. Yet the activists, and even some wooly-headed academics, continue to argue this point.

Whatever your thoughts on developing countries and poor people, it sure doesn't make sense to blame salmon farmers for keeping Peruvians down on the farm. And only about one-third of the world's fishmeal and oil is consumed by aquaculture; the majority is fed to chickens and pigs. Why? Because it's good for their health just like it's good for our health. As aquaculture grows, it will consume a larger share of these feeds because fish have better conversion rates so fish farmers can afford to outbid land-based farmers. Eventually the limited supply of fishmeal and oil will become a constraint to the growth of aquaculture. That's why a tremendous amount of research is now focussed on partly or completely replacing fishmeal and oil with substitutes such as soybeans and other crops grown in abundance on land. Already a genetically enhanced soybean has been engineered to produce omega-3 oils. This and other innovations will eventually revolutionize the human diet and the diets of our domestic animals, with positive results all around for health and nutrition. We will come back to this subject later.

"Salmon are fed artificial chemical dyes to make them look pink like wild salmon"

This is one of the most preposterous allegations, but it is always repeated in the activist rant against aquaculture. Again it is simply the use of propagandist language - turning a good thing into a toxic threat - that gives consumers the impression that farmed salmon is somehow "artificial."

It is true that naturally occurring chemicals called carotenoids are added to salmon feed and this is what gives the salmon their distinctive colour. They are, in fact, the same carotenoids that make wild salmon pink. They come through the food chain from the plankton that produce them in the first place. These same carotenoids are also what make shrimp and crabs pink and that is why shrimp farmers add them to their feed as well.

It is also a fact that these carotenoids – astaxanthin and canthaxanthin to be exact – are produced synthetically to be used as additives in the feed of fish and poultry (to give the skin and egg yolks a brighter yellow colour) and as colorants in and on a wide variety of foods. These carotenoids are good for human health and are essential nutrients for salmon. They are powerful antioxidants and if you "Google™" them you will see that they are sold as health food supplements and sunless tanning treatments.

Carotenoids are what make carrots orange (and they are good for our eyesight), daffodils yellow, and prepared meats pink rather than gray. Adding them to food for nutritional or aesthetic reasons is perfectly safe, and in many cases, beneficial. It is no different from adding vitamin C to fruit juice as a dietary supplement, and yes, vitamin C (ascorbic acid) is also made synthetically and is no different from the "natural" vitamin C produced in citrus fruits. Should products with added vitamin C be labelled "contains the artificial chemical ascorbic acid?"

"Farmed salmon contain high levels of cancer-causing PCBs and dioxins"

Enter the classic food scare world complete with images of pregnant women and babies threatened by toxic chemicals in their cuisine. It is a fundraiser's delight and millions are spent on orchestrated media campaigns to make sure the scare is spread far and wide. How about some facts?

Yes, farmed salmon contain minute traces, in the parts per billion (equal to one penny out of $10 000 000), of PCBs and dioxins. But so do milk, cheese, butter, beef, chicken, and pork. The levels of these chemicals in all these foods are so far below what is considered a risk to health that it isn't worth talking about; though it is worth fear-mongering in order to fabricate campaigns, make media headlines and bring in the big grants and donations.

Interestingly, scientists have new evidence that some long-lived chemicals that have been thought to be man-made pollutants, such as polybrominated diphenyl ethers (PBDEs) used as flame-retardants in furniture and clothing, actually have significant natural sources. Most of the PBDEs found in the blubber of a stranded True's beaked whale found in Virginia in 2003 were found to be of natural origin. The natural sources of the PBDEs found in the whale are still unknown, they only know it isn't from human activity. Even more important from a health perspective is the fact that these natural chemicals likely explain why whales, humans, and other animals have enzymes that are able to break down PCBs, PBDEs, and other pollutants. That's why, from a health perspective, the parts per billion of these chemicals in our foods are of no health consequence. If they were, so would be the thousands of other natural toxic chemicals present in tiny amounts in our foods.

This is a story of conspiratorial proportions with politicians, lobbyists, fishermen, charitable foundations, and activist groups all lined up to deliver the knockout punch to salmon farming. Yet farmed salmon sales continue to go up and one must admire the intelligence of the consumer who sees through the hype and buys one of the healthiest foods in the market.

In September 2004 the journal *Science* carried a report that concluded that farmed salmon had higher levels of PCBs than wild salmon. The activist scientists who did the research were paid by the Pew Charitable Trust, an advocacy group based in Philadelphia with billions in assets – a legacy from the Sun Oil Corporation. Coincidentally the advisory board to Pew included a former governor of Alaska and a representative of the Alaska seafood industry. It just so happens that the main competition for "wild" Alaskan salmon sales in the US is farmed Chilean and British Columbian salmon (we will get to why I put "wild" in quotations in a bit). Other powerful figures to wade into this campaign are Alaskan Governor Frank Murkowski and his daughter, Alaskan Senator Lisa Murkowski. The *Science* article made headlines around the word while salmon farmers watched and wept. The whole episode was framed as an issue of a threat to health posed by farmed salmon. The fact that wild salmon was also shown to contain PCBs, although supposedly at lower levels, was not even noticed in the media reports; farmed was toxic and wild was safe.

On September 3, 2003, the "Netscape News," attributing the New York Times and Reuters, proclaimed that farmed salmon was "contaminated with high levels of cancer-causing chemicals" when PCBs have never been shown to cause cancer in humans even at thousands of times the levels found in salmon and other foods. The story should have read, "contain extremely low levels of chemicals that have never been shown to cause cancer in humans." But that doesn't make a very good headline; not like the word "contaminated" which has about as much scientific meaning as "loaded" or "full of it" as in BS.

There were a number of fundamental flaws in the *Science* article. The wild salmon they selected included species like pink salmon that have much lower fat content than farmed Atlantic salmon. Because PCB and other fat-soluble contaminants concentrate in fat, it is predictable that pink salmon, which are not farmed because they are not as desirable as Atlantic salmon, would have lower PCB content. But they also have lower omega-3 fat content and are therefore not as effective in preventing heart attacks as farmed Atlantic or wild king (Chinook) salmon, both of which have similar high (good) fat content

An even more glaring shortcoming of the *Science* paper was that it failed to reference two previous studies that provided examples of wild salmon that contained higher PCB levels than farmed salmon. One of these reports analyzed the famed Copper River sockeye salmon from southeast Alaska. It is usually the first fresh wild salmon on the market, appearing in stores in May, so it commands a high price. The report, done by the environmental organization The Circumpolar Conservation Union showed that Copper River sockeye contained about five times the level of PCBs in farmed salmon. Another well-known report demonstrated that wild king and silver (Coho) salmon in Puget Sound, Washington, contained two to three times the levels of PCBs found in farmed salmon. Both these reports were widely circulated among interested parties before the Science article was published yet no mention was made of them. Selective sampling of salmon and selective omission of previous studies equal a biassed report.

Nowhere in the science article or in any of the anti-aquaculture literature is there a mention of the fact that the average North American consumer ingests about eight times as much PCBs from beef and about three times as much from milk as they do from eating farmed salmon. Yet all the warnings are about salmon and the facts are ignored.

The fact is there are so many benefits from eating salmon, and so little risk, that it makes sense to eat it regularly. The American Heart Association categorically states that eating oily fish like salmon reduces the risk of a fatal heart attack by 50 percent or 400 out of 100 000. The Environmental Protection Agency, which tends to exaggerate risk by orders of magnitude, estimates that eating farmed salmon more than one a month will result in one additional cancer in 100,000 people in a 70-year life span. I make that 400 to one for a regular feed of salmon, pretty good odds in my book.

And it's not only the American Heart Association that thinks this way. The World Health Organization, the Food and Drug Administration, Health Canada, and the Council on Science and Nutrition all recommend increasing our intake of seafood, particularly oily fish, as a way of improving our health. It is deeply ironic that the activist's campaign against salmon farming puts people who listen to them at greater risk than if they just ignored the scare tactics and ate more salmon.

"In order to save the wild salmon we should boycott farmed salmon and only eat wild salmon"

Whoever thought up this lunatic idea should get the Nobel Prize for anti-logic. How can you save wild salmon by eating more of them? Yet a whole gaggle of groups has succeeded in convincing activist chefs, restaurant owners, and consumers that a boycott of farmed salmon will somehow be good for wild salmon. Of course, the deadly sea lice fabrication comes in handy here. Get rid of the salmon farms and wild salmon will no longer be decimated by the lice from the farms. As if the fishermen are not "decimating" the wild salmon, oh no, they are just "harvesting" them, a nice term for "killing."

Every year, tens of millions of wild salmon are killed by commercial, sport, and aboriginal fisheries just as they are about to go up rivers and spawn. This is somehow twisted into being "good" for the wild fish. If you ask me what's good for the fishery is not necessarily what's good for the fish. I am not opposed to fishing for wild salmon but there is no doubt that fishermen are impacting their numbers far more than fish farmers.

It is interesting that the anti-aquaculture set has aligned themselves with commercial wild fishing interests. Obviously the wild fishery is against aquaculture; it is a direct competitive threat. It doesn't cost as much to grow a farmed salmon as it does to catch a wild one, chasing around burning fuel in big boats. Of course this is why people began to farm plants and animals on the land 10 000 years ago; it is more efficient than hunting and gathering.

So why are so-called environmentalists siding with the people who are killing the wild salmon? Partly it is a romantic notion about going back to a time when brave men went to sea and sometimes died trying to earn a living and bring food to hungry villagers. Partly it is an opportunistic move to play upon the public's notion of this romantic theme. In fact there is nothing romantic about risking your life and maybe capsizing and drowning in an angry sea. Just ask the widows.

But the single biggest driver is the competition for sales in fish stores from Los Angeles to New York. Many environmental campaigns today are simply piggybacking on trade disputes, competition for market share, and anti-globalization agendas. Salmon farming just happens to be one of the issues in the cross hairs. In the case of salmon farming, it's all about US interests, read the Alaskan salmon fishery, versus the growing imports of less expensive, consistently fresher, higher quality, available year-round, high in omega-3 fat content, farmed salmon from Chile and British Columbia. It really has nothing to do with the environment and everything to do with raw competition, a good thing when the consumer has the right information. Activist groups, advertising themselves as environmentalists, make sure the public doesn't have the right information and then raise money on the misinformation they spread.

It is no coincidence that most of the money flowing into British Columbia and Chile to combat salmon farming is from the US. For example, the David and Lucille Packard Foundation of California (based on the Hewlett-Packard fortune), is funding the anti-salmon farming activities of the David Suzuki Foundation in Vancouver. Thus local Canadian activist groups are taking money from US based charities and acting as fronts for US commercial interests. It's a winning formula for all concerned. Unfortunately the result is a perversion of the market-based competitive economic system; it is pure propaganda.

Let's look for a moment at the "wild" Alaska salmon fishery, so proud to be wild rather than farmed. The fact is much of the Alaskan salmon fishery is based on what is called "salmon ranching". Every year eggs are stripped from returning adult females, fertilized with milt (sperm) from returning males, and placed in hatcheries just like the ones salmon farmers use. When the eggs hatch they are 'ponded" into large tanks where they are fed the same fish feed that farmed salmon get, complete with synthetic canthaxanthin as a nutrient/colorant. When the smolts are ready to go to sea they are transferred to netpens in the ocean, just like farmed salmon, and are fed on a diet containing the same fishmeal and oil that farmed salmon enjoy. If they get sick they are fed the same antibiotics that farmed salmon have the privilege of receiving. Some months later they are released to the open ocean to forage for themselves.

About 1.5 billion salmon are released into the wild each year from these aquaculture facilities in Alaska. After they are released they must compete with the truly wild salmon that have not been artificially spawned, hatched, reared, fed, and medicated. While promoters of Alaskan salmon go on about the amount of wild fish used to feed farmed salmon their own industry is churning out "ranch" salmon that consume about 20 times the wild feed than the entire Canadian salmon farming industry. The Alaskan ranched salmon are competing directly with the wild salmon for their feed in the ocean while the farmed salmon are confined to their pens, feeding on anchovies, soybeans, and wheat germ.

This is the reason I put "wild" in parentheses" earlier on. The practice of salmon ranching is about as wild as the practice of cattle ranching. Who would contend that cattle, reared on the farm and then released to the range, should be classified as "wild" when they are rounded up for slaughter? Yet the activists who decry the salmon farming industry endorse salmon ranching. This is another clue that it has little to do with the environment and everything to do with an unholy alliance between the primary killers of wild salmon and "environmentalists" who are acting as their agents.

I wouldn't have spent so much ink on this subject if I didn't think it was vital to our future health and the health of the world's oceans. Allow me to spend a little more time providing the positive vision for aquaculture as the negative side already has way too much airtime.

First and foremost, aquaculture is the only feasible way to increase seafood production while at the same time managing the wild fisheries on a sustainable basis. More seafood is good for us; the health benefits of the Mediterranean diet and the longevity of Japanese people attest to this. And if it is done in an intelligent manner, aquaculture can even help increase the productivity of many wild fisheries.

The Japanese abalone and scallop fisheries are good examples of combining high-tech aquaculture with traditional fishing methods. All around the coast of Japan there are modern solar-powered hatcheries where abalone and scallop are bred and reared, fed on algae grown in large vats, and grown until they are the size of a penny. They are then seeded by the millions into the ocean at appropriate spots where they grow to market size. In the south of Japan where the sea is warm they are harvested by women who dive for them in a traditional costume. In the north where it is too cold for free diving they must be harvested with long poles from small boats, in the same way they have been for centuries.

Another fine example is the abalone aquaculture practised in Monterey, California. Juvenile abalone are purchased from a commercial hatchery and placed in cages suspended by ropes beneath the fisherman's pier. The cages are hauled up regularly for cleaning, sorting, and harvesting and then filled with California giant kelp (*Macrocystis*) harvested from nearby reefs. The kelp provides the staple diet for the abalones, along with algae and other marine species that grow inside the cages. California giant kelp grows very quickly, up to three feet a day, so is easily sustainable in quantities capable of feeding a lot of abalone.

There are now over 100 species of finfish and over 50 species of shellfish being grown in commercial or experimental aquaculture operations around the world. Tilapia, now available in Costco and other large chains along with farmed salmon and prawns, makes a firm white fillet and is growing in production rapidly in tropical and sub-tropical countries. Farmed Atlantic cod is already on the market and other species such as Alaska black cod (sablefish), sturgeon, halibut, and tuna are not far behind.

While fish farm production can still increase considerably in sheltered inshore waters with the available feed supply there are three ways in which production could become much larger.

First, aquaculture operations can move offshore where the pens will be suspended below the surface to avoid the destructive power of storms. A float at the surface will be tethered to a submerged feeding tube that is pulled to the surface by a ship that could service tens of such cages along the continental shelves. The activists are so anti-fish farming that they have set themselves preemptively against open ocean fish farms, where all of the above claimed environmental harms have even less validity. In the US, the National Oceanic and Atmospheric Administration has proposed greatly expanding fish farming in the internationally recognized Exclusive Economic Zones that extend 200 miles from each nation's shoreline. The US wants to create privatized zones and sell multi-year leases to aquaculturists on a percentage of their sales. In these open waters, wastes from the fish are greatly diluted and wash away with the currents. Off-shore fish farms miles from shore have raised halibut, cod, red snapper, and tuna. The response from the environmentalist community has been predictable wailing over the "industrializing" of the seas by greedy big business. Anne Mosness with the anti-biotech, anti-development Institute for Agriculture and Trade Policy told the Seattle Post-Intelligencer that the US's open ocean proposal is "the equivalent of having a hog farm in a city park flushing its wastes into the street." Pure nonsense.

Second, if geneticists can enhance land crops like soybeans and corn to contain omega-3 oils and other essential nutrients this will vastly increase the feed supply. It will then make more economic sense to feed these crops to fish rather than to less efficient land animals. Don't worry; there will still be steaks for the barbecue and bacon for breakfast, but it would be very good for all of us who eat meat if fish consumption went up and red meat went down.

Third, we will learn how to use the waste from fish farms as feed for shellfish grown nearby. The beauty of many shellfish such as oysters, mussels, and clams is they obtain their food directly from plankton in the ocean. Plankton thrive on the nutrients from fish waste. Designed properly, the combination of finfish and shellfish farming could dramatically increase seafood production while simultaneously removing any excess nutrients from the ocean.

There is every reason to believe that we could increase seafood production by five to ten times over the next century while at the same time improving the environment for wild fisheries. We are quite capable of managing wild fisheries sustainably; the real problem is the inability to manage fish stocks that spend their time in international waters or migrating from one country's territory into another's. The collapse of the Atlantic cod and Atlantic salmon were both the result of 15 or more nations' fishing fleets competing for the same fish with no coordinated management plan. In the North Pacific, where only four countries: Canada, the US, Japan, and Russia had fleets, they were able to create formal agreements that have resulted in considerable success in managing halibut and salmon sustainably.

The greatest obstacle to the sustainable management of many fisheries is the classic "tragedy of the commons" situation. It is virtually automatic that a species will be over fished if it is a public property resource with no effective management system in place. As each fisherman or fishing fleet tries to maximize their catch so do all the others, adding up to declining stocks and declining catches in a downward spiral that ends in collapse. One of the most effective ways to overcome this tragedy is to establish a system of allocations known as individual tradable quotas (ITQs). Each fisherman buys or is granted a quota that allows them to catch a certain amount of a given species with a particular type of gear. The sum of the individual quotas adds up to the allowable catch, which can be raised or lowered, affecting everyone's quota proportionally. The quotas can be bought and sold on the open market so the healthier the stock the more value they have. Therefore it is in every fisherman's interest to ensure the stocks are healthy and because of this they will support reductions in catch when necessary. Through private interest a self-policing system emerges that results if the opposite of the tragedy of the commons.

The only problem with the ITQ system is that many "environmental groups", entrenched fishing interests, and activists of a leftist bent are totally opposed to it. Even though there are well-established successful examples such as the Alaskan salmon fishery and the Dungeness crab fishery they object to the "privatization" of a public resource. They argue that because it is a public resource that all members of the public should have access to it and that ITQs amount to turning public property into a private monopoly. No doubt there are some good examples of socialism, like universally available health care, but free fishing isn't one of them. Under the ITQ system the public, through government, get their rent from the fishermen through a royalty, some of which can be used to enhance the fishery. In the end it is the seafood-consuming public that is the real beneficiary, certainly more so than if the species were wiped out through lack of effective management.

Prediction of Phosphorous Concentration in Effluent of Recirculating Aquaculture Systems

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An unsteady-state model for predicting dissolved phosphorous (DP) concentration in the effluent of a single RAS was developed. The input parameters are daily feed rate, make-up water flowrate, and volume of the system. The phosphorous wasted by the fish is calculated using the feed phosphorous content (1.2 wt%), feed conversion ratio (0.9), and phosphorous retention of the fish (4.32 g/kg fish). The dissolved portion of the total phosphorous rejected by the fish is the digestible portion (55%) less that retained by the fish, and amounts to 30% of the rejected phosphorous. The residual 70% remains with the solids. The model assumes that the water is well-mixed, there is no leaching of the phosphorous contained in the fish faeces, there is no excess feed, and the make-up water flowrate is constant. The concentration of DP in the effluent is determined from the weighted cumulative daily feed rates. Model predictions are compared with experimental data collected over several months at a recirculating salmon-smolt hatchery and indicate that dissolution of phosphorous may be occurring in the septic tank used to store the waste solids.

Introduction

Environmental regulations with respect to phosphorous emissions from aquaculture facilities have become increasingly stringent. Our work focuses on developing cost-effective strategies for reducing phosphorous emissions from recirculating aquaculture systems (RAS). The objective of this study is to use a mass balance approach to track dissolved phosphorous across a salmon-smolt recirculating aquaculture system, and in so doing, predict dissolved phosphorous concentration at the outlet of the facility.

Materials and Methods

Treatment system

The land-based salmon-smolt farm under study is located in New Brunswick. Fish were fed pellets adapted to fish size and having a phosphorous content of 1.2 wt%.

Incoming well water was divided between independent recirculating sections of the facility. Each section housed fish of a different age. Most of the water was recycled (90% overall) and the remainder proceeded to an underground septic holding tank. Solids were removed from the recirculated water using rotary drum filters and swirl separators. The waste collected by this equipment was also sent to the septic tank. Solids were removed from this septic tank once it was full. Septic tank overflow was discharged to receiving waters.

Experimental procedure

Weekly samples were taken at various accessible points within a section of the hatchery and at the plant effluent. The samples were analyzed using phosphate acid reagent vials (Hach, model #27429) to determine dissolved phosphorous content. Daily feed rates and feed conversion ratio (FCR) were obtained from the hatchery. Water flowrate was measured at the entrance, outlet, and within the facility to determine inflow, outflow and recirculation rate. The mass flowrate of dissolved phosphorous leaving the section or the plant was calculated as follows:

$$DP_{out} = Q \times C \quad \textbf{(1)}$$

where:
DP_{out} = Mass flowrate of dissolved phosphorous, kg/day
Q = Measured effluent flowrate, m^3/day
C = Measured concentration of dissolved phosphorous, kg/m^3

Model for fish output

The phosphorous wasted by the fish was calculated using the phosphorous content of the feed, the feed conversion ratio and the phosphorous retention of the fish. Phosphorous content was obtained from the manufacturer and phosphorous retention was measured by analysing several fish. The total phosphorous rejected by the fish (TP) is the difference between the phosphorous fed and that retained by the fish:

$$TP = \left[PF - PR / FCR\right] \times F \quad \textbf{(2)}$$

where:
TP = Total phosphorous wasted by the fish, kg/day
PF = Phosphorous content of the feed, kg P/kg feed
PR = Phosphorous retention of the fish, kg P/kg fish
FCR = Feed conversion ratio, kg feed/kg of weight gained
F = Actual feed used, kg/day

Part of the total phosphorous rejected by the fish is in dissolved form. The dissolved phosphorous is the digestible phosphorous less the phosphorous retained by the fish:

$$DP = \left[PF \times f_{digest} - PR / FCR \right] \times F \quad (3)$$

where:
DP = dissolved phosphorous rejected by the fish, kg/day
f_{digest} = fraction of phosphorous in feed which is digestible

Model for dissolved phosphorous in effluent of single RAS

The dissolved phosphorous in the effluent of a single section was predicted using an unsteady state model based on the following assumptions: the section behaves as a well-mixed system, phosphorous in fish faeces does not dissolve, the concentration of dissolved phosphorous in the make-up water is constant and flowrates of the make-up and effluent water are constant and equal. Under transient conditions,

accumulation of dissolved phosphorous in system	=	dissolved phosphorous entering system	–	dissolved phosphorous leaving system

or

$$V \frac{dC}{dt} = QC_o + DP - QC \quad (4)$$

If DP is constant throughout the day but varies from day to day, integration of Equation (4) gives:

$$C(t) = C_i e^{\frac{-t}{\tau}} + \frac{1}{Q} \sum_{j=0}^{t-1} DP_{t-j} \left(e^{\frac{-j}{\tau}} - e^{\frac{-(j+1)}{\tau}} \right) + C_o \quad (5)$$

where:
Q = flowrate of make-up water, and effluent water, m^3/day
$C(t)$ = concentration of dissolved phosphorous at any time in the loop, kg/m^3
C_i = concentration of dissolved phosphorous at the beginning of the testing period, kg/m^3
C_0 = concentration of dissolved phosphorous in the make-up water, kg/m^3
t = time, day
V = volume of the water in the section, m^3
$\tau = V/Q$ = average residence time of the water in the section, day
$DP_j = DP$ on day j, kg/day (Equation 3)

Equation (5) states that the concentration of dissolved phosphorous in the effluent at the end of the day t is determined not only by the dissolved phosphorous rejected by the fish on day t but also by the phosphorous rejected on previous days. The terms in brackets can be viewed as weighting factors for the daily inputs of dissolved phosphorous. The weighting factor is greatest for DP_t and gets smaller as time elapses. As a result, the impact of DP_{t-j} on $C(t)$ is negligible when $j > 6\tau$. Furthermore, according to Equation (5), the concentration of dissolved phosphorous is also inversely proportional to the flowrate of effluent water. An increase in the level of recirculation will thus lead to an increase in the effluent concentration of dissolved phosphorous.

Model for dissolved phosphorous in combined effluent

The concentration of dissolved phosphorous in the effluent of the plant, C_{out}, was predicted by applying Equation (5) to each section of the plant and adding the predicted output of each section.

$$C_{out}(t) = \sum_{j=1}^{N} Q_j C_j(t) \Big/ \sum_{j=1}^{N} Q_j \quad (6)$$

where:
$C_j(t)$ = concentration of dissolved phosphorous in section j as predicted by Equation (5)
Q_j = flowrate of water leaving section j, m^3/day
N = total number of recirculation systems within the facility

Results and Discussion

The values used in this study for the parameters of the fish output model are presented in Table 1.

Table 1. Fish output model parameters

Parameter	Value
PF	0.012 kg P/kg Feed
PR	0.0432 kg P/kg fish
FCR	0.9
f_{digest}	0.55[1]

After substituting these values in Equations (2) and (3) we obtain:

$$DP / TP = 0.3 \quad (7)$$

In other words, 70% of the wasted phosphorous is in the solid form, in agreement with reported values[2]. This phosphorous can be removed from the wastewater by simply separating the waste solids from the water before phosphorous dissolution can occur.

The concentrations of dissolved phosphorous measured at several locations within one RAS of the hatchery are plotted versus time in Figure 1. The temporal variations are largely due to fluctuations in the daily amount of feed given to the fish in this section. However, on any given day, the concentration is essentially independent of position, confirming the model's assumption that the water in the system is well-mixed. This is not surprising because the flowrate of recirculated water within the section is about twelve times that of the effluent water. By moving the water around the system, the recirculation pump acts as a mixer which keeps the concentration of dissolved phosphorous uniform throughout the RAS.

The dissolved phosphorous concentration predicted by Equation (5) using the actual daily feed rates and a calculated mean residence time of 2.6 days is also shown in Figure 1. The agreement between the model prediction and the experimental data is generally good; the small deviations are probably due to the fact that the effluent flowrate was not always constant as assumed by the model. Since the model neglects any leaching of phosphorous from the fish faeces, these results suggest that there is negligible dissolution of phosphorous occurring within this section of the hatchery.

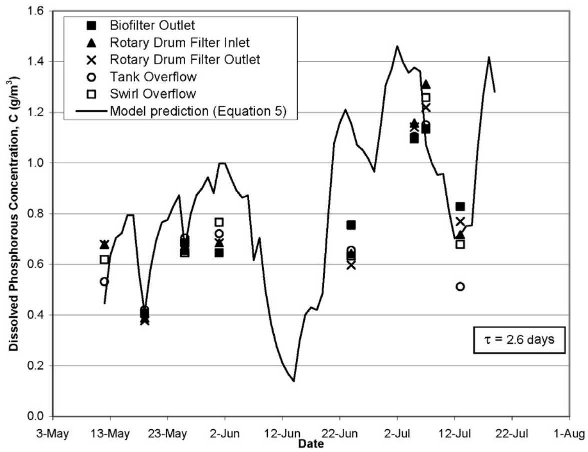

Fig. 1. Measured and predicted dissolved phosphorous concentrations in a section of the hatchery.

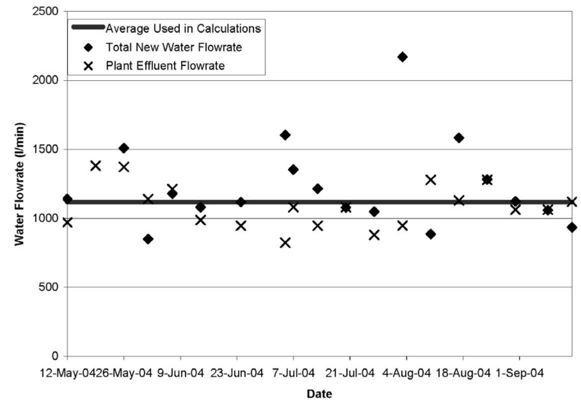

Fig. 2. Measured hatchery water flow rates.

One of the main assumptions of the model is that the water flowrate is constant during the testing period. As indicated by the fluctuations in Figure 2, this assumption, although not entirely correct, is nearly valid.

The concentrations of dissolved phosphorous measured at the exit of the facility are plotted versus time in Figure 3. The fraction of dissolved phosphorous leaving the facility was generally close to that predicted by the model, with the exception of the period between mid-July and August.

The high concentrations of dissolved phosphorous in late July and August could have been caused by a drop in water flowrate, but since this is not the case (see Fig. 2), it must exist because dissolution is occurring within the overall system. Since all sections are similarly structured and there is negligible dissolution occurring within the individual RAS sections, it must follow that any dissolution occurs in the final septic tank, before overflow is discharged to receiving waters.

Large retention times of the waste solids in the septic tank may contribute to the increased percentage of phosphorous in dissolved form in the effluent water. It is therefore essential to avoid leaving the separated solids in contact with the wastewater to minimize this dissolution and in turn reduce phosphorous emissions to the environment.

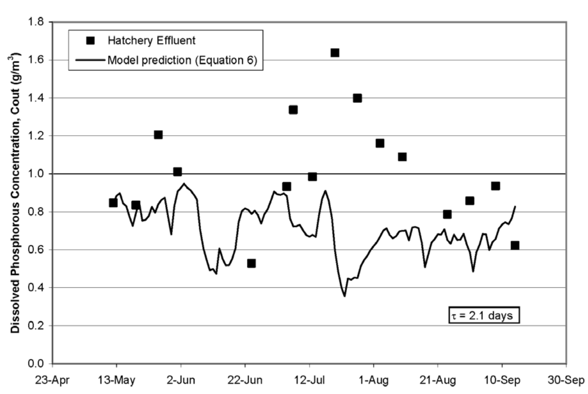

Fig. 3. Measured and predicted dissolved phosphorous concentration at the outlet of the hatchery.

Conclusion

Of the total phosphorous rejected by the fish, 30% is in dissolved form and the residual 70% remains with the solids. The concentration of dissolved phosphorous leaving the facility was higher than predicted by the model, indicating that dissolution of phosphorous is occurring within the system. Since there is negligible dissolution occurring within the individual sections of the facility, leaching of phosphorous must be occurring within the final septic tank used to store the waste solids.

Future Work

This is the preliminary phase of an ongoing project. The focus is on removing dissolved phosphorous from the wastewater of RAS and preventing further dissolution by removing the suspended solids from the wastewater. Converting those solids into a viable by-product is the final objective.

Acknowledgements

This work was funded by the Atlantic Innovation Fund and was performed in partnership with Atlantech Engineering & Associates, and Cooke Aquaculture Inc.

Notes and References

1. Lall SP. 1990. Digestibility, Metabolism and Excretion of Dietary Phosphorous in Fish. 1991. pp. 21-36. *In*, *Nutritional Strategies and Aquaculture Waste.* (CB Cowey, CY Cho, eds). Proceedings of the First International Symposium on Nutritional Strategies in Management of Aquaculture Waste. University of Guelph, Guelph, Ontario, Canada. 275p.
2. Timmons MB, Ebeling JM, Wheaton FW, Summerfelt ST, Vinci BJ. 2001. *Recirculating Aquaculture Systems*. Ithaca, NY.

Effects of Atlantic Salmon (*Salmo salar*) Aquaculture on the Reproductive Cycle of the Blue Mussel (*Mytilus edulis*) in the Bay of Fundy, New Brunswick

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The blue mussel (*Mytilus edulis*) can exhibit flexible reproductive strategies where gametogenesis is not only linked to seasonal cycles, but also to changes in available food supply. This allows the species to opportunistically capitalize on periods when feeding conditions are favourable. Mussels cultured in proximity to Atlantic salmon aquaculture may utilize the edible and bio-available pulses of suspended organic particulates generated via daily fish feeding cycles to increase their yearly reproductive output. The reproductive cycle of *M. edulis* grown at salmon sites and paired reference sites (not influenced by salmon farms) was examined over a 12-month period via histological preparations of gonadal tissues. Using computer-based image analysis, several reproductive indices (total reproductive area, egg number, and egg size) were quantified. Mussels grown adjacent to the salmon cages experienced an increase in overall reproductive area and subsequent loss in late fall, suggesting a second, opportunistic spawning period, which was not seen in the reference mussels. The increase was due to egg number and not egg size. The overall reproductive output is higher in salmon site mussels during the summer spawning. The trends in reproductive output seen in this experiment suggest that *M. edulis* grown directly adjacent to the salmon site appear to have adopted a more opportunistic reproductive strategy than reference mussels, channelling extra available energy from salmon farms into increased reproductive output.

Introduction

The blue mussel, *Mytilus edulis*, can inhabit a wide range of estuarine and marine environments and is one of the dominant organisms on rocky shores in most temperate areas. However, *M. edulis* populations can also be found sub-tidally, to depths of 50 m(1). These sub-tidal populations exhibit continuous growth as a function of greater food availability, allowing individuals to attain large sizes in relatively short periods of time(2), which has led to the successful development of fixed suspended cultivation of the blue mussel throughout the world. Like many temperate water bivalves, most *M. edulis* populations exhibit a seasonal pattern of reproduction(3). In this species most gametes are generated in the gonad located within the mantle folds, with some occurring in the visceral mass and mesosoma(3). The reproductive period is characterized by spawning cycles (release of gametes) in the spring or summer, after which the reproductive follicles partially or completely empty. Accumulation of summer nutrient reserves then fuels subsequent re-development of the gonad during the late fall and gametogenesis (the production of gametes) then proceeds throughout the winter, so that by early spring the gonads of most mussels are morphologically ripe and ready for summer spawning(3).

M. edulis has the ability to adjust its reproductive strategy according to prevailing environmental conditions. It can conserve its nutrient stores, utilizing them solely for gametogenesis during the winter and subsequent summer spawning(3). Alternatively, an opportunistic strategy may be employed where gametogenesis and spawning is closely linked to available food supply, enabling the species to capitalize on periods when feeding conditions are favourable(4). Such a strategy may produce secondary opportunistic spawning outside of regular spawning, but may come at considerable risk if food supplies fall below maintenance levels. Late spawnings are anticipated only when energy reserves surplus to those required for basal metabolism and gamete production over the winter occur(3).

Recently, a study in the southwest area of the Bay of Fundy examined the potential of the blue mussel as an organic extractive species within an integrated multi-trophic aquaculture situation with Atlantic salmon. In a salmon aquaculture environment there is a potential for mussels to be exposed to higher organic particulate loads as a result of exogenous feed input due to salmon feeding. Studies have shown that the blue mussel can actively incorporate such aquaculture generated food particles into their diet(5,6). Although many factors have been suggested as controls to gametogenesis and spawning in *M. edulis*, food supply appears to be particularly important. If elevated levels of particulate organic matter are present on a daily basis at aquaculture sites, the seasonal fluctuations of food available to the mussels may be decreased compared to the natural system. The availability of aquaculture-generated particles may help maintain localized, stable food concentrations throughout the year, particularly during periods when ambient food concentrations are typically low. Such a decrease in seasonal food availability may in turn influence the reproductive strategy of mussels grown near the salmon sites (i.e., duration of spawning, reproductive output, gamete size, and number of spawnings).

Several methods have been used to assess the course of the reproductive cycle in *M. edulis*. The most reliable and detailed type of information regarding the annual reproductive cycle is

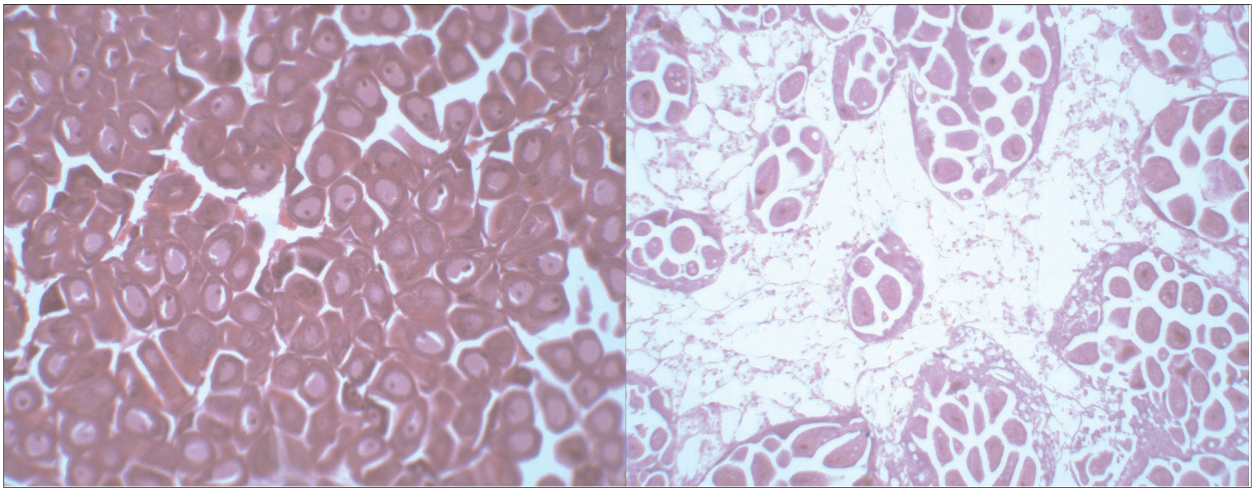

Figure 1
Histological sections illustrating changes in quantifiable reproductive area (darkened area) of female mussels collected in June (left) and October (right), 2003.

that obtained from histological preparations of mussels sampled at regular intervals throughout the year. The objective of this study was to quantitatively compare the reproductive cycles of mussels cultured adjacent to and away from operational Atlantic salmon aquaculture sites using histological preparations of reproductive tissue to examine possible effects of salmon aquaculture on reproduction in this species.

Materials and Methods

Adult *M. edulis* (> 50 mm, shell length) were socked into 1m lengths of commercial nylon socking, hung inside predator proof cages and deployed at three commercial salmon sites and at a reference sites 200 m away from each site. At the salmon sites, one sock/cage unit was tied directly to three randomly chosen salmon cages, with three units being bottom-moored at the reference site. All units were maintained at a depth of 5 m below the surface. Mussels were sampled at monthly intervals from August to October 2003 (post summer spawning) and April to July, 2004 (before and during subsequent summer spawning), with one winter sampling in February 2004. On each sampling day 20 mussels were randomly chosen from each sock and transported to the lab where a 100-mm^2 section of reproductive tissue was cut from each mussel and fixed in a 10% formalin solution. The segments were then embedded in paraffin using a Tissue-Tek™ vacuum infiltration processor after dehydration and clearance through ethanol:xylene series. Sections 6-µm thick were cut, mounted and stained with Harris' haematoxylin and eosin. After microscopic sex determination, five female and five male mussel samples were analyzed for reproductive features. Quantitative analysis of gonadal tissue preparations was carried out using a compound microscope with an attached camera to capture images at 100× magnification. Five fields per specimen were analyzed to ensure detection of within-specimen variations in gametogenic development. Images were uploaded to PC and analyzed using Image Pro Plus™ (Media Cybernetics Inc.). Males were analyzed for percent reproductive area, while females were analyzed for percent reproductive area (Fig. 1), egg number, and egg size. Mean monthly values for each site were calculated and plotted.

Results and Discussion

Image analysis of reproductive tissues has currently been completed for mussels from one salmon site and its paired reference site. Female mussels at the salmon site and the reference site showed no differences in reproductive area at the commencement of the experiment (August 2003), with overall reproductive area (RA) covering 19-20% (Fig. 2) of the microscopic fields. This RA coincides with the post-summer spawning interval when reproductive follicles are typically partially or fully empty. Mussels at the salmon cages increased their reproductive area in September (from 19-50 %) with a subsequent reduction in RA in October to 22%. This suggests the occurrence of a second, late fall spawning in mussels at the salmon sites, with no corresponding pattern in the reference mussels. This trend was also in synchrony with male mussels collected at the salmon site (data not included) with an increase in their reproductive area from 22-58% in September followed by a decrease to 30% in October. Mussels at the salmon site may be utilizing the increase in available food at this site[(7)], to fuel a further opportunistic spawning in the fall, whereas reference mussels may be using a more conservative strategy, storing energy for the winter period when food supply is typically lower[(8)].

Reproductive area increased at a higher rate from October to February in the salmon site mussels, with reference mussels losing RA over the same period. These mussels did not begin to add RA until after the February sampling period. This again might correspond to changes in food supply with an increase in RA occurring during the spring when phytoplankton blooms typically occur in this area. Salmon site mussels, on the other hand, appear to add RA throughout the winter and spring periods, with the maximum RA reaching 68% by May, surpassing the reference mussels RA maximum by 18%. Post summer spawning RA fell to 29% in all mussels, independent of site. Therefore, overall RA loss was higher in salmon site mussels, suggesting a higher overall reproductive output. Increased RA in the salmon site mussels was a result of an increase in egg number (Fig. 2, right), as there was no difference in egg size in reference and salmon site mussels seen.

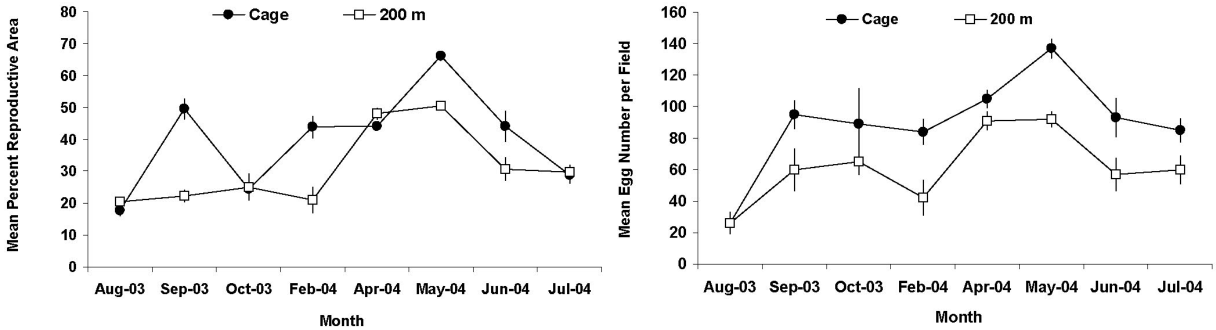

Figure 2
Mean percent reproductive area (left) and mean egg number (right) for female mussels grown adjacent to and 200 m away from an operational salmon farm determined. Error bars represent one standard error.

Conclusions and Future Work

The trends in reproductive output seen in this experiment suggest that *M. edulis* grown directly adjacent to the salmon site appear to have adopted a more opportunistic reproductive strategy, channelling some of the extra available energy from salmon farms into increased reproductive output. However, data from only one salmon site does not provide a definitive conclusion on the overall effects of salmon farming on reproductive output of *M. edulis* in this area of the Bay of Fundy. Subsequent analysis of seasonal reproductive trends at the remaining two sites sampled will be necessary before overall conclusions can be made. Once complete, this study will provide valuable insight into the yearly reproductive cycle in this species and whether an effect of coastal aquaculture can be identified.

Acknowledgements

We wish to thank the following for help in gathering the field information and data presented in this paper: Jamie Emberly for histological preparations; the crew of the Coast Guard Vessel Pandalus III; the site managers at Heritage Salmon Ltd.; and Bill Martin and Dawn Sephton for sample collection and preparation. This research has been supported in part by funds from AquaNet, the Network Center of Excellence in Aquaculture, and carried out at the Department of Fisheries and Oceans – St Andrew's Biological Station.

References

1. McDonald JH, Seed R, Koehn RK. 1991. Allozyme and the morphometric characteristics of three species of *Mytilus edulis* in the Northern and Southern Hemispheres. *Mar. Biol.* 111: 323-335.
2. Page HM, Hubbard DM. 1987. Temporal and spatial patterns of growth in mussels *Mytilus edulis* on an offshore platform: relationships to water temperature and food availability. *J. Exp. Mar. Biol. Ecol.* 111: 159-179.
3. Seed R, Suchanek TH. 1992. Population and community ecology of *Mytilus*. *In*, The Mussel *Mytilus*, ecology, physiology, genetics and culture (EM Gosling, ed), p 87-169. Developments in aquaculture and fisheries science, No. 25. Elsevier, Amsterdam.
4. Rodhouse PG, Roden CM, Hensey MP, McMahon T, Ottway B, Ryan TH. 1984. Food resource, gametogenesis and growth of *Mytilus edulis* on the shore and in suspended culture in Killary Harbour, Ireland. *J. Mar. Biol. Assoc. UK* 64: 513-529.
5. Barrington KA. 2005. Use of exhalent siphon area to determine the feeding rates of mussels (*Mytilus edulis*) integrated with salmon (*Salmo salar*) aquaculture. M.Sc. Thesis, University of New Brunswick, Saint John.
6. Mazzola A, Sará G. 2001. The effect of fish farming organic waste on food availability for bivalve mollusks (Gaeta Gulf, Central Tyrrhenian, MED), stable carbon isotope analysis. *Aquaculture* 192: 361-379.
7. Lander TR, Robinson SMC, MacDonald BA, Martin JD. 2005. Potential of the blue mussel (*Mytilus edulis*) as an extractive organic species in integrated aquaculture systems in the Bay of Fundy, NB. I. Quantification of Seston. *Aquaculture*. Submitted.
8. Widdows J, Fieth P, Worrall CM. 1979. Relationship between seston, available food and feeding activity in the common mussel *Mytilus edulis. Mar. Biol.* 50: 195-207.

Semi-Submersible Offshore Cages

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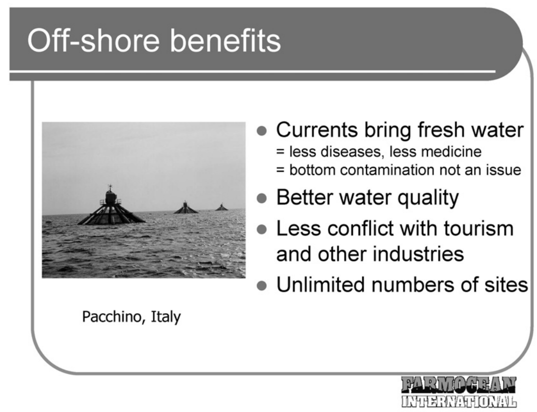
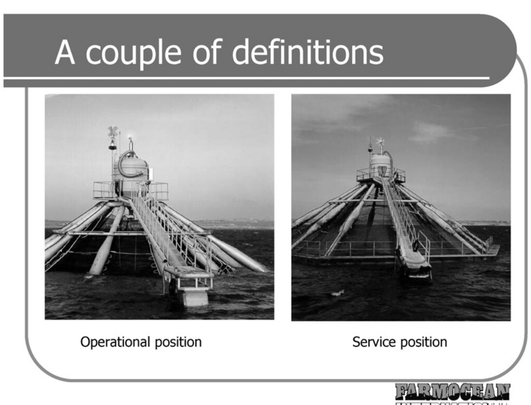


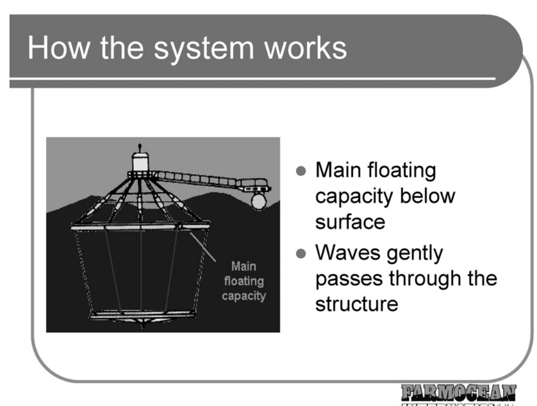
Good afternoon. Many thanks for the introduction.

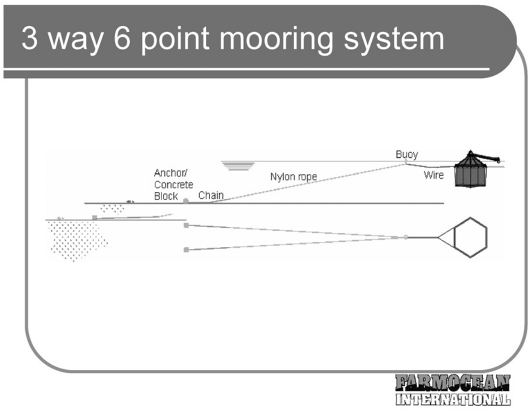
I am delighted to be here at the Aquaculture Canada[OM] 2005 conference to present Farmocean and their semi-submersible offshore cages. It is wonderful to once again visit this beautiful and exciting part of Canada. A few years back, I had the pleasure of visiting Newfoundland on an almost monthly basis.

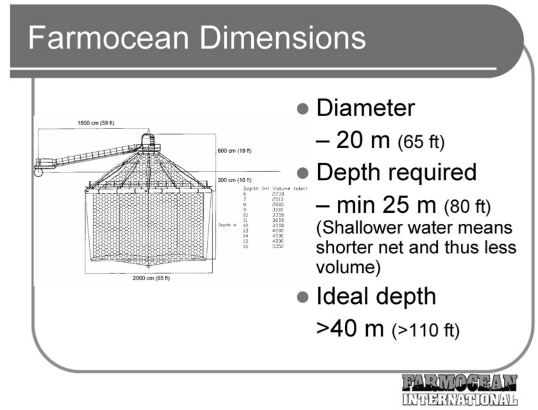
First, I want to acknowledge Mr. Johan Olbing at Farmocean's head office in Göteborg, Sweden. As Product Manager, Johan is our expert and partly responsible for this presentation. Farmocean's offshore cages have been around for 20 years. It is a product that has left the R&D stage. It has been in successful commercial operation in Europe almost as long.

A weekend as a tourist, visiting places such as Twillingate, Durrell, Moreton's Harbour and Valley Pond, convinced me that there are plentiful of sites around Newfoundland that are very well suited for Farmocean's cages. Investments in these cages could expand life in these communities, combining the fishing industry with tourism.









A couple of definitions. *Operational position* means the normal position for the cage. *Servicing position* is the raised position, roughly 3 metres, to make it easier for the crew to work on the cage, for instance at harvest and maintenance or removing on-growth on the net.

Offshore aquaculture has some distinct advantages. By locating the cages further out from the shoreline, we get access to cleaner water; water of higher quality. Currents will bring an on-going supply of fresh water. As a result, we can expect less disease among the fish, less need for medicine. We will get a healthier, a better product.

The currents will also spread out the waste from the biomass in concentrations that will not damage the environment.

In some parts of the world, traditional, or inshore, aquaculture has come into conflict with the tourism industry or people who want to live close to the water. Being further out minimizes, or completely eliminates, such conflicts. We even have installations in Sicily, Italy, used for excursions. Tourists can catch their own fish and bring it ashore to a restaurant, where the chef will cook it for them. An example of profitable interaction between aquaculture and tourism.

There are basically an unlimited number of potential offshore sites. In some areas, there are no longer any in-shore sites available. Offshore aquaculture opens up many new sites. It can also bring new life to coastal areas.

This is how Farmocean's cages work. The main floating capacity is below the surface. The waves pass gently through the structure. While the waves may be five-ten metres high, the structure and the net with the biomass won't move much.

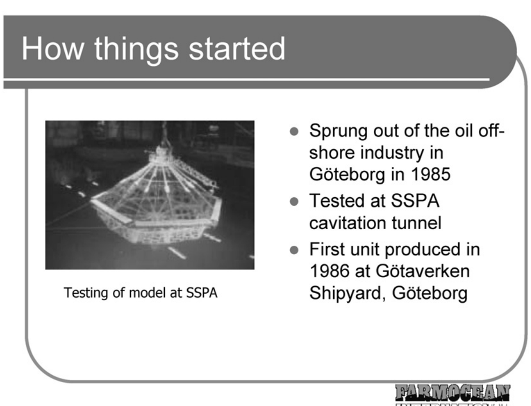
The cage has three-leg mooring system. Wires connect the cage to a buoy. The wire is connected to the cage at the main structure level, 3 m under the surface during operational position. Hence, there is no problem with wires getting in the way for supply vessels approaching the cage. The buoys are then each connected to anchors or concrete blocks.

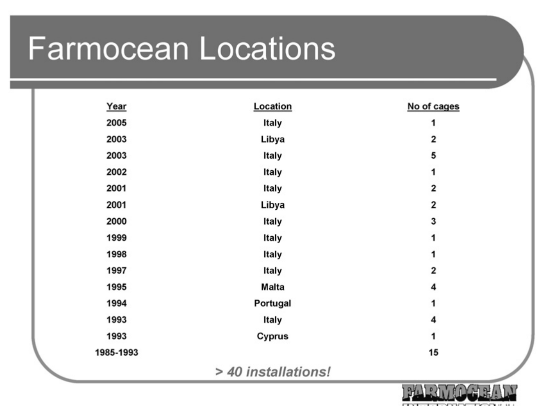
Let me come back to the fact that Farmocean has a long track record in offshore aquaculture. It all started in the mid-80's. The company was founded based on research by the University of Halmstad, south of Göteborg and the Swedish Maritime Research Institute, SSPA.

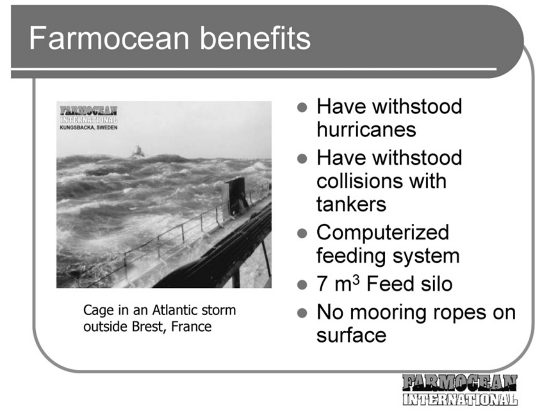
They were looking at designing offshore fish-farming equipment. By moving offshore, waves, currents and wind forces increase dramatically. It was decided that the cages should meet the following criteria:

- Maximum wave height of 5-10 metres (15-30 ft)
- Current speed of 2-3 knots
- Wind speed of 35 m/s
- All happening at the same time and in the same direction

Inspired by the semi-submersible oil rigs built in Göteborg at the time, the objective was to develop a cage that would provide







the best environment for the fish, as well as a safe, practical and profitable operation for the fish farmer.

The first cages were produced by Götaverken in Göteborg, famous for its ship and oilrig building.

Tests were carried out with a 1:10 scale model at SSPA's wave tanks. The picture is from those tests.

The diameter of the cage is 20 metres. Depth varies from 10 to 17 m. The total weight is around 20 tons.

In the operational position, the pontoon gangway is circa 3 metres below the surface. The minimum depth of water required is approximately 25 m for a 4500-m^3 system, but another 10-15 metres for a total of 40 metres or more is desirable. Mooring systems for deeper water is also available. A 4500-m^3 system will yield roughly 100 tonnes fish.

The structure is made from galvanized steel. There is a pontoon ring going around the structure and a ballasting system to be used for raising or lowering the cage. The cage comes in three different sizes; the only difference being the size (depth) of the net. There is a second upper walkway, which is used when the cage is in its operational position.

On top of the structure is a feed silo with computer controlled feeding. There is a wind generator (or a solar panel), a navigation light on top of the feeding unit. The computer can be remotely controlled by a land based PC. The connection is either by radio or a GSM telephone.

The boarding gangway is rotating around the cage, always being in a downwind position, which makes it easier for the crew to enter the cage. There is a feed transport pipe along the gangway.

As I mentioned earlier, Farmocean's cages have been in commercial operation for a number of years. Here is a list of cages sold since 1993, broken down per country. 2003 was particularly good for us. 5 units were sold that year; repeat orders in a couple of instances.

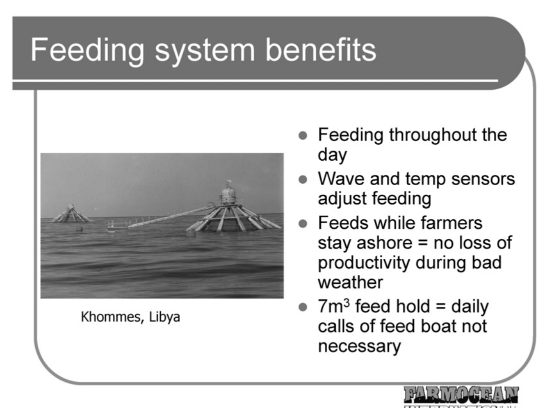
Since 1993 almost all orders have come from clients in the Mediterranean. The units sold between 1985-93 have also been located in the Baltic's, and around Iceland and Scotland.

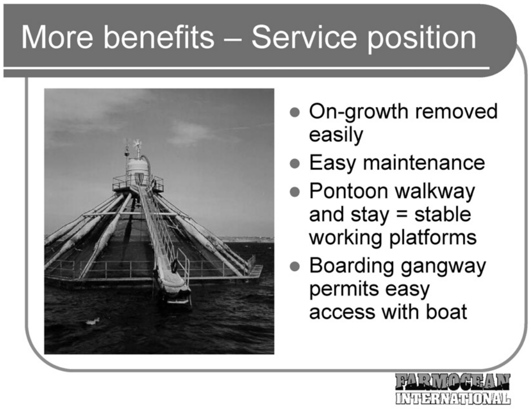
Over the years, a number of species have been farmed in the cages. Salmon, trout, sea bass, and sea bream are four kinds that have been commercially raised in Farmocean cages. However, our cages should also be of interest for many other species that the aquaculture industry is looking at, including cod, which is of particular interest in Newfoundland.

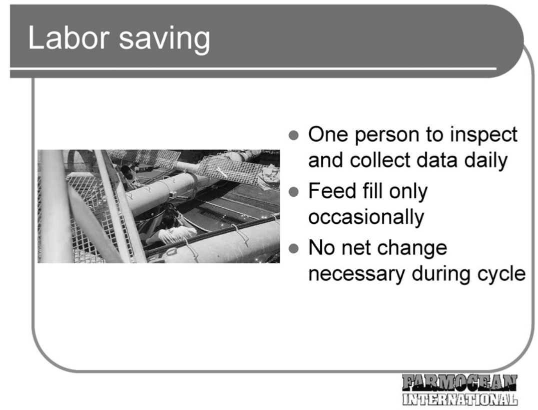
This slide shows the assembly of a cage. Everything comes in three 40-ft open top containers and is assembled locally. Assembly takes four-five days.

Here, we see the structure being almost complete. You can judge the size of the unit by looking at the man standing close to the feeding unit on top of the structure. He is roughly 7 metres above the ground.

Going offshore has many advantages, as we said earlier. Cleaner water, etc.







But, it also means that the cages must be able to withstand tougher conditions. Farmocean's cages were approved by DNV – Det Norske Veritas – in the days they approved cages.

In 'real life', Farmocean's units have successfully managed hurricanes with 10-metre waves without losing any fish. They have also been run into by 17 000 dwt coast liners, again without losing any fish. We don't recommend that kind of treatment, but it shows the strength.

Other advantages with the system are the result of some of the features, such as the remotely controlled computerized feeding system.

The size of the silo, 7 m^3, means that there isn't a need to visit the site every day. How long 7 m^3 feed lasts will, of course, depend on many factors, e.g. type of fish, weather, temperature, current, and the stage of the cycle.

It is also worth mentioning that the cage can be moved with stock in it, should that be required. One reason may be that you want to move the cage to another location during the winter season. Moving the cage is done in Service position

A few more points about the feeding system. The farmer can program it to his or her liking. Sensors record waves and temperature and adjust the feeding accordingly. The size of the silo on top of the cage will make the feed last for at least a few days, limiting the need for daily visits. This, of course, is very advantageous in bad weather. It can be connected to a land based PC by radio or GSM. This means that data collection and recording can be done ashore. If there is need for reprogramming this can also be done from the PC.

The Service position simplifies maintenance. It makes it easier to remove on-growth on a large portion of the net thus making net change during the cycle unnecessary.

The platform and gangway also make it easier and safer to work at the unit.

Another picture showing how the pontoon walkway makes it easy to work the cage when harvesting.

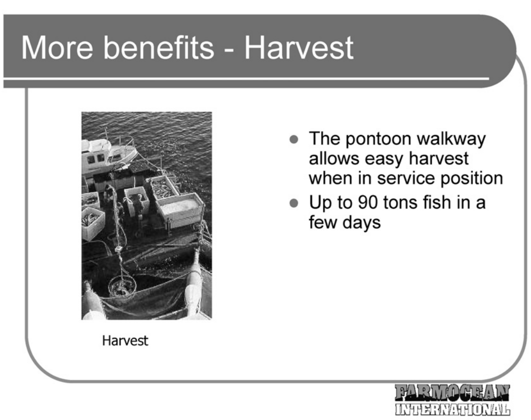
The Farmocean system doesn't require a lot of workers. One person is sufficient most of the time. Filling of feed, as we have already mentioned, is not required on a daily basis.

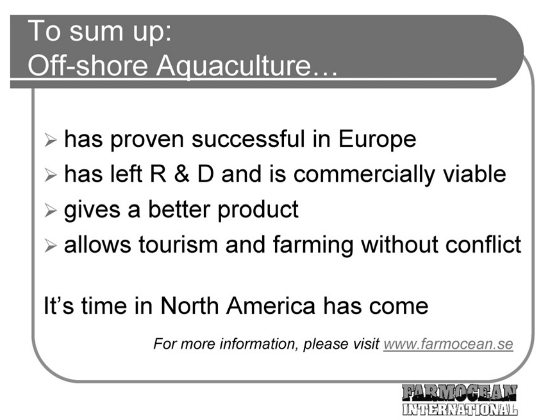
So to sum it up, offshore aquaculture has proven to be quite successful in Europe. It has long left the R&D stage and proven to be commercially viable. Farmocean's cages have a 20 year track record.

Offshore aquaculture has shown that it gives a better product. In addition, offshore aquaculture has allowed aquaculture to coincide with tourism and real estate development in coastal areas.

So we suggest that the same development could, and will, take place in North America. Again, this province – Newfoundland and Labrador – is particularly well suited to take the lead.

Thank you for your attention!





Growth of Sea Scallops (*Placopecten magellanicus*) in the Magdalen Islands (Quebec, Canada): A Field Experiment

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Seeding activities of sea scallops (*Placopecten magellanicus*) are carried out in the Magdalen Islands (Quebec) since the early 1990s. A better understanding of natural processes such as post-seeding dispersal, predation and growth rates are needed in order to improve harvesting results. In this regard, experiments coupled with numerical modelling are presently in progress. This paper reports on a field experiment focusing on scallop growth rates at different periods of the year. Groups of scallops belonging to three age cohorts were placed in cages hanging from longlines at 1 m from the sea bottom. Cages were suspended in order to prevent predation on scallops. Initial shell height of cohort 1 represented the commercial seeding size class (25-35 mm), corresponding to approximately 20-month aged individuals. Cohort 2 (40-50 mm) and 3 (65-75 mm) corresponded to 32 and 44-month aged individuals, respectively. Monthly samplings were taken to monitor growth rates from June through November 2004. Four anatomical components were monitored, namely shell height, wet weight of the adductor muscle, the gonads, and the rest of the soft tissues. Data generated from this study will be used with environmental variables to model the population dynamics of scallops seeded in the Magdalen Islands.

Introduction

In the early 1970s, landings of sea scallops (*Placopecten magellanicus*) in the Magdalen Islands significantly decreased from 350 t of muscles (1970) to about 50 t (1973), with no sign of recovery thereafter[(1)]. In 1990, a long-term program (REPERE) aimed at resource restoration was put in place. This included seeding operations, particularly in the area called Chaîne de la Passe, south of the archipelago, which was identified as the most appropriate. The seeding approach includes (i) off-shore spat capture, (ii) juvenile growth on suspended structures for approximately one year, and (iii) subsequent seeding in the Chaîne de la Passe. A period of four to five years elapses before harvesting adult scallops of commercial size. In order to be economically profitable, the seeding/harvesting cycle should achieve recovery rates ranging between 20-30%[(2)]. However, according to estimates made between 1993 and 1995, the average recovery rate was smaller than 6%[(2,3)]. Subsequent estimates were fairly consistent with this first estimate (Nadeau M., unpublished).

Recent studies were undertaken to help improve the recovery rate by understanding the processes affecting it, namely natural mortality, predation, growth and dispersal[(4,5)]. As well, another study is developing a model for the population dynamics of seeded scallops in the Magdalen Islands. This model is based on the approaches of Barbeau and Caswell[(6)] and Gangnery et al.[(7)], and is composed of three modules focusing on growth, predation and dispersal. The objective of the present study was to provide field data to calibrate the growth module. For this purpose, a field experiment was performed, where growth rates of three scallop cohorts were monitored.

Materials and Methods

Three 60-m longlines supporting experimental cages (40 cm L × 40 cm W × 16.5 cm H; mesh size = 1.5 cm) were placed within the scallop seeding area located approximately 8 km south of the Magdalen Islands. The longlines were deployed within a circular area with a radius of approximately 800 m centred on 47°08’85" N and 61°46’67" W. Sea bottom was characterised by coarse gravel.

Groups of scallops belonging to three cohorts were placed into the cages on June 18, 2004. A cage contained individuals of one cohort, and each longline supported an equal number of cages of each cohort. Initial scallop shell heights of the three cohorts were 25-35 mm (C1), 40-50 mm (C2), and 65-75 mm (C3). Size classes corresponded to one, two and three years old individuals. The number of scallops per cage varied between cohorts: 50 for C1, 30 for C2, and 15 for C3. Numbers of scallops per cage were determined in order to prevent density effects, and were based on previous small-scale experiments (Georges Cliche, MAPAQ, unpublished). The cohorts were monitored on a monthly base until November 23, 2004.

Sampling consisted of randomly collecting a cage per cohort per longline every month. Scallops of each sampled cage were dissected into four anatomical components, i.e. adductor muscle, gonad, soma (i.e., rest of soft tissues), and shell. Gonads were measured only in C3, as they were not yet developed in C1 and C2 cohorts. Wet weights of the four anatomical components were measured. Average morphometric values were obtained from scallops belonging to a single cage, and monthly means and standard deviations (SD) calculated for each cohort (n = 3 cages). Growth rate was

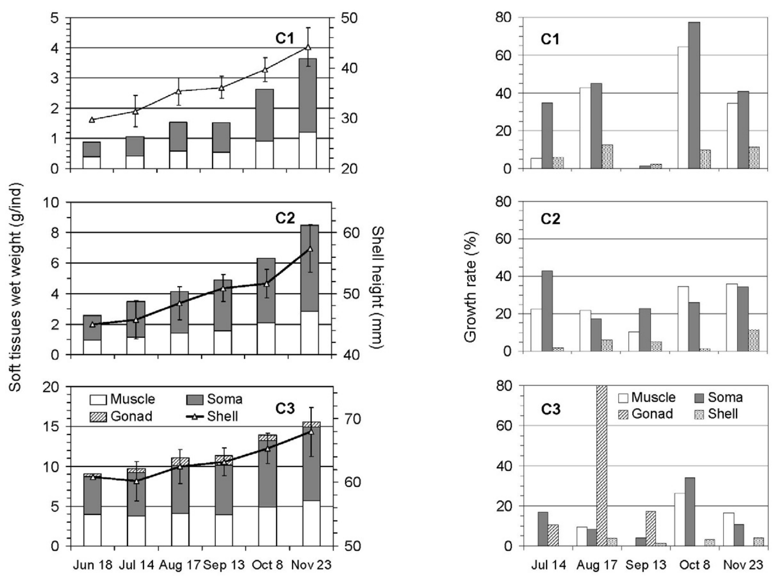

Figure 1
Left: Mean (± SD) wet weight of soft tissues (bars) and shell height (line) for the three scallop cohorts on six monitored dates. Right: Growth rate of the different anatomical components in the three cohorts.

calculated as a percentage: $(value_t - value_{t-1})/value_{t-1} \times 100$, where the subscript *t* represents sampling time.

Chlorophyll-*a*, particulate organic matter (POM), and water temperature were measured twice per month. An S4 current meter was moored for monitoring water currents between August 12 and November 10, 2004.

Results and Discussion

Chlorophyll-*a* concentration was 0.85 ± 0.19 µg/l (mean ± SD, $n = 12$ dates), with minimums (< 0.7 µg/l) in summer and a distinct peak at the end of September (1.12 ± 0.09 µg/l, $n = 3$) and another one at the end of October (1.21 ± 0.25 µg/l, $n = 3$). POM ranged between 0.3 and 0.6 mg/l in summer, and between 0.6 and 1.2 mg/l in autumn. Water temperature progressively increased from June 1 (~2°C) to the beginning of September (~ 12°C), and started decreasing at the beginning of October. Water current velocity averaged 13.1 ± 8.7 cm/s ($n = 11$ 562 uninterrupted readings at a 10-minute pace), with maximums averaging ~25 cm/s, and exceptional peaks up to 70 cm/s.

Over the entire monitoring period, scallop shell height of C1, C2 and C3 cohorts increased on average by 48 % (14.4 ± 0.9 mm), 28% (12.4 ± 3.9 mm) and 12% (7.1 ± 3.0 mm), respectively (figure 1, left). As well, over this period, muscle wet weight increased by 216% (0.83 ± 0.03 g/ind), 200% (1.9 ± 0.43 g/ind) and 43% (1.7 ± 0.98 g/ind), and soma wet weight increased by 393% (1.9 ± 0.14 g/ind), 247% (4.0 ± 1.21 g/ind), and 96 % (4.5 ± 1.2 g/ind) for each size class, respectively. Gonad wet weight of C3 increased until mid-September by 217%, and subsequently decreased by 44% following spawning. Growth rate for all organs was generally lower in mid-September (Fig. 1, right). This was likely due to a decrease in food availability (i.e., chlorophyll-*a* and POM) observed in the first half of the same month. Growth rate of all organs tended to decrease in the late autumn as well, which was likely due to the cooling water temperature.

The present study was meant to monitor scallop growth over two summer seasons; i.e., 2004 and 2005. However, the 2005 monitoring had to be cancelled following severe damages occurred to cages and longlines during the 2004-2005 winter season. Nonetheless, the authors consider that the results obtained from the 2004 monitoring can be used to model population dynamics of sea scallops as originally planned.

Acknowledgements

This study was funded by the Ministry of Agriculture, Fisheries and Food of Québec (MAPAQ), the Network of Centres of Excellence for Mathematics of Information Technology and Complex Systems (MITACS), and the Société de développement de l'industrie maricole (SODIM). The authors wish to thank all the staff from the Station technologique maricole des Îles-de-la-Madeleine for their logistical support, as well as SCUBA diver Mario Desraspe for his availability.

References

1. Cliche G, Giguère M. 1998. Bilan du programme de recherche sur le pétoncle à des fins d'élevage et de repeuplement (REPERE) de 1990 à 1997. *Rapp. can. ind. sci. halieut. aquat.* 247: x + 74 p.
2. Nadeau M, Cliche G. 1998a. Evaluation of the recapture rate of seeded scallops (*Placopecten magellanicus*) during commercial fishing activity in Îles-de-la-Madeleine, Quebec. *Bull. Aquacul. Ass. Canada* 98 (2): 79-81.
3. Cliche G, Giguère M, Joncas P-A, Thomas B, Vigneau S. 1999. Programme de Recherche sur le Petoncle à de fins d'Élevage et de Repeuplement – Phase II. Compte Rendu. Direction de l'innovation de des technologies, Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec, p. 17.
4. Nadeau M, Cliche G. 1998b. Predation of juvenile sea scallop (*Placopecten magellanicus*) by crabs (*Cancer irroratus* and *Hyas* sp.) and starfish (*Asterias vulgaris, Leptasterias polaris*, and *Crossaster papposus*). *J. Shellfish Res.* 17(4): 905-910.
5. Bourgeois M, Brêthes J-C, Nadeau M. (in press). Survival, growth and dispersal of juvenile sea scallop, *Placopecten magellanicus*, (Gmelin 1791). *J. Shellfish Res.*
6. Barbeau MA, Caswell H. 1999. A matrix model for short-term dynamics of seeded populations of sea scallops. *Ecological Applications* 9(1): 266-287.
7. Gangnery A, Bacher C, Buestel D. 1999. Application of a population dynamic model to the Mediterranean mussel, *Mytilus galloprovincialis*, reared in the Thau Lagoon (France). *Aquaculture* 229: 289-313

The Most Recent Nomenclature of Tilapia Species in Canada and the Sudan

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Tilapias, the "Miracle Fish," are the world's most important fresh/marine, warm-water cultured food fishes of the past, the present, and the future. They have originated from Africa and Palestine and evolved in the River Nile. They have been introduced in 150 countries and are being cultured by more than 75 nations because of their excellent characteristics for aquaculture. They are now known as Saint Peter's Fish, Golden Perch, Cherry Snapper, Aquatic Chicken, etc. In Canada, Ontario was the first Province to culture tilapia since 1995 as an exotic species introduced from Egypt. In the Sudan, where the River Nile and its tributaries extend for 6500 km, three species of tilapias are indigenous. This paper reports on the justifications for the new nomenclature of tilapias, to acquaint fisheries and aquaculture personnel in Canada and The Sudan with the most recent nomenclature of the Family Cichlidae of the Tribe Tilapiine and their use in fish culture.

Introduction

Tilapias, the "Miracle Fish," are a group of 77 species described by Thys in 1968; they belong to the Family Cichlidae of the Tribe Tilapiine[1,2]. They have originated exclusively from the African continent and Palestine (Jordan Valley and coastal rivers) and evolved in the River Nile. In Africa, they are absent in north and southwest[3,4]. However, several popular species for use in aquaculture and the aquarium fish trade were introduced in more than 150 countries in tropical, subtropical, and even temperate regions[1,5]. Their use in aquaculture spread through Africa after the 1920s and became established in North America in the 1950s[4,6]. Now they are the world's most important fresh/marine, warmwater cultured food fishes, farmed from extensive to super-intensive water recirculating (more than 100 kg/m^3) and integrated hydroponic systems by more than 75 nations[3,7], due to their hardiness and tolerance of varying degrees of temperatures (8-42°C), brackish (10-14 ppm), salinity (42 ppt), pH (5-9), DO levels as low as 1 mg/l, and high levels of carbon dioxide and ammonia. They are now known as Saint Peter's fish, Golden Perch, Cherry Snapper, Hawaiian Sunfish, "Aquatic Chicken," "New White Fish," and the "Miracle Fish"[3,8].

In Canada, Ontario was the first province to culture tilapia in intensive water recirculating and integrated hydroponic systems as an exotic species introduced from Egypt after the ban on its culture was lifted in 1995[3,9]. In the Sudan, where the River Nile and its tributaries extend for about 6500 km, three species of tilapias are indigenous, identified by Sandon[10] as *Tilapia zillii* (Gervais), *T. galilaeus* (Artide), and *T. nilotica* (Linnaeus).

All tilapias exhibit a high degree of parental care and it is on the basis of their reproductive habits and behaviour that Dr. Ethelwynn Trewavas (British Museum) had placed in 1973 the macrophagus substrate-spawners and the microphagus mouth-brooders into two genera: *Tilapia* and *Sarotherodon*[11]. Later on, in 1982, she had grouped the mouth-brooders into a further two genera: *Sarotherodon* and *Oreochromis*. Thus, all the species of tilapia had been placed in four genera: *Tilapia* (Bushman word for fish), *Sarotherodon* (brush-toothed), *Oreochromis* (mountain cichlid), and *Danakilia*[12]. Accordingly, those species indigenous in The Sudan became *T. zillii*, *S. galilaeus*, and *O. niloticus* (Fig. 1); that in Canada is *O. niloticus*.

These major changes on the classification of tilapias and the fact that these changes confused many fisheries and aquaculture personnel, necessitated this report on the justifications for the new nomenclature and provide remarks and relevant aquaculture information so as to acquaint those in Canada and The Sudan with the most recent nomenclature of the Family Chilidae of the Tribe Tilapiine and their use in aquaculture.

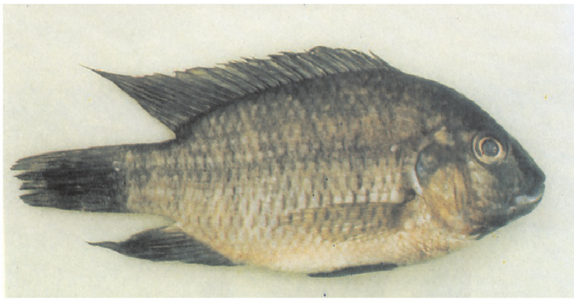
Justifications for the New Tilapia Nomenclature

According to the rules of nomenclature, the name used for a generic rank must be the first generic name given to a species within that group, i.e., the rule of priority, which lays down that the first generic name to be proposed for a group is the one to be used. In defining the genera *Sarotherodon* and *Oreochromis*, the main evidence is behavioural backed by geographical. Many observers contributed to the behavioural evidence; the geographical evidence is well set out by Thys[2,12].

1. Tilapia zillii *(Gervais)*

The first species was *T. sparrmanii*, a substrate-brooder, and that is why the name Tilapia is retained for the group of substrate-brooders. In this 'soudanian' form, the female adheres the eggs to the substrate and they are guarded by the parents in the eggs, hatchling, and larval stages[12].

Firm pair-bonding over relatively prolonged association periods and strict monogamy during the breeding cycle is the rule. Also, both sexes develop a breeding dress, a red-pink breast which is more intensified in the male during the breeding period. The region chosen for spawning is usually in shallow water, where the bottom is covered with sand or gravel; a hole is prepared by both parents. Here, the female spawns and the eggs re-



Tilapia zillii **(Gerv.)**

Sarotherodon galilaeus **(Art.)**

Oreochromis niloticus **(L.)**

Figure 1
The three indigenous Tilapia species in the River Nile and its tributaries, Sudan (Photos by H. Bishai).

main untouched by either parent until all have been shed. The eggs are small, dark olive green and during oviposition attach themselves to where they are deposited by means of adhesive fibres. After oviposition is over, the male and female do not separate like the mouthbrooders, rather both sexes defend their territory which they establish together and ventilate the eggs with their fins. After hatching, they move the alevins frequently from one hole to another until they know how to swim and live independently[4,13].

2. Sarotherodon galilaeus *(Artedi)*

The first mouth-brooding tilapia to receive a separate generic name was first given by Ruppel (1852) to *S. melanotheron*, the black-chinned tilapia of West African brackish waters. In this species, it is the father that mouth-broods the eggs (paternal); the males do not congregate in breeding areas and do not have a distinctive breeding colouration or dress as in *Oreochromis*. Related to it is *S. galilaeus*, a biparental mouth-brooder (both father and mother), also, lacking differential colouration and habits of the sexes at breeding time. Thus, the genus *Sarotherodon* is restricted to the group of tilapias whose brooding is paternal or biparental[12,13].

3. Oreochromis niloticus *(Linnaeus)*

The first maternal mouth-brooder to receive a separate generic name was given by Gunther (1889) to *O. hunteri*, an inhabitant of a small, rocky crater-lake on the slopes of Mount Kilimanjaro. Moreover, brooding is strictly maternal and members of this group have the "lek" type of breeding behaviour. The males develop a distinctive body colouration and congregate in special arenas where each defends a territory – a circular, bowl-like nest made by sweeping movements of the tail and deepened by pectoral fanning. Here, they are visited by gravid females that lay golden eggs in the centre of the nest of the chosen male after a brief courtship. The female, unlike that of the substratum-breeders, immediately takes the eggs into her mouth with great haste; sperm emitted by the male fertilizes them either on the ground or when they are already in the mouth (Fig. 2a-c). The female may then visit another male before she moves away with her eggs to a special nursery area; the male may mate with other females[12].

In this group, the female does not concern herself with territorial matters. Breeding females undergo physiological change before spawning begins – a ventral bulging of the hyoid region to increase the mouth capacity to accommodate the fertilized eggs. The contents of the mouth are well-aerated by the normal respiratory current of the parent; the eggs are also moved around within the mouth by 'churning' movements which help to keep their surfaces clean and prevent fungal infections. Besides, if these yolky eggs are allowed to remain in one position, the heavy lipids sink to the lower pole within a few hours, disrupt their internal organization and, consequently, they fail to develop[13].

Other relatives of this group are "*T.*" *mossambica*, "*T.*" *nilotica* (Nile tilapia), "*T.*" *oureus* (blue tilapia), and "*T.*" *macrochir* (tassled tilapia). These now become *O. mossambicus*, *O. niloticus*, *O. oureus*, and *O. macrochir*. Based on reproductive habits, *Oreochromis* includes four subgenera: *Oreochromis* (which is both genus and sub-genus), *Nyasalapia* Thys, 1968 (for the species with a genital tassel), *Alcolapia* Thys, 1968, (for the little species of the alkaline lakes Natron and Magadi), and *Neotilapia* Regan, 1920 (for *O. Ne.*) *tanganicae* of lake Tankanyika[12] (Table 1).

Remarks and Relevant Aquaculture Information

All the genera and the subgenera as well as *Tilapia* itself are included in the Family Cichlidae of the Tribe Tilapiine and may be referred to colloquially as "tilapiine cichlids" or simply as "tilapias" (single, tilapia), with small "t" and no italics. A name in brackets after the generic name denotes a sub-genus. In writing them in a context other than systematic, it is not necessary to use the sub-generic name. When it is desired to indicate that a species of *Oreochromis* was formerly included in *Tilapia*, one may write *O.* (formerly *Tilapia*) *mossambicus* but not *O.* (*Tilapia*) *mossambicus*[12].

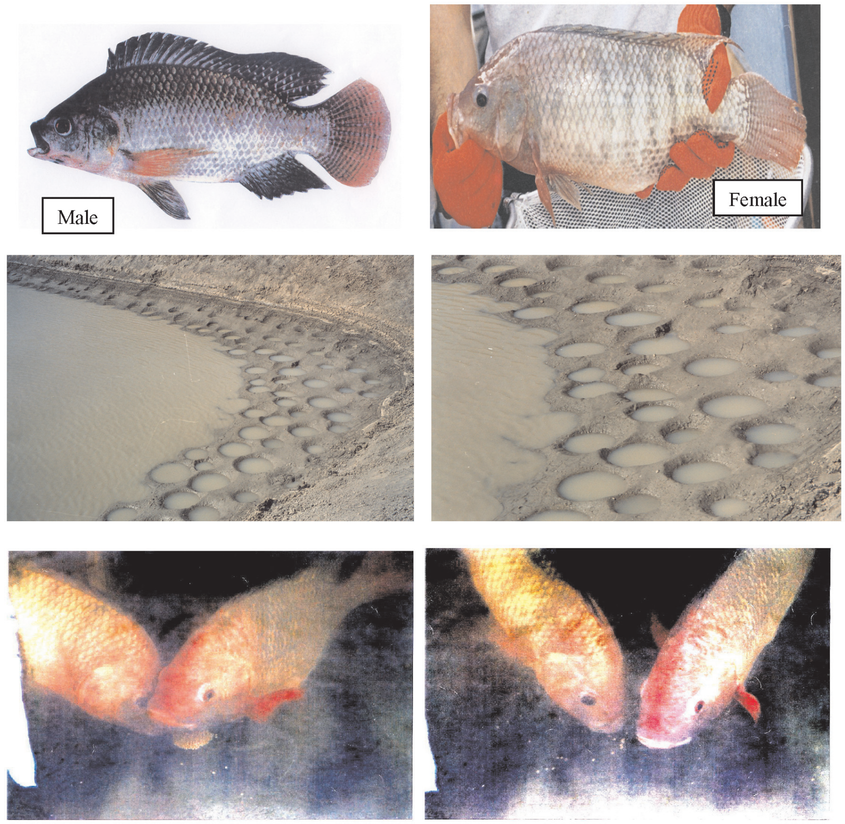


Figure 2
(Top L-R) *Oreochromis niloticus* (L.) – a colourful male and a gravid female before mating (Photos by Gary Chapman). (Middle L-R) Mating nests built by the males of *Oreochromis niloticus* in the shallow part of a pond in Jebel Aulia Fish Farm, Khartoum, Sudan (Photos by TT George). (Bottom L-R) Female *O. niloticus* taking the fertilized eggs into her mouth with great haste (Photos by Gary Chapman).

T. zillii, S. galelaeus, and *O. niloticus* are 'soudanian' species and have a common wide range (Senegal, Niger, Chad, Sudan, Jordan, Lake Turkana, Lake Nyasa) resulting from formal interconnections of the Chad and Nile basins[4]. *T. zillii* is native to a large swath of north-central, sub-Saharan Africa from Senegal in West Africa through Northern Zaire and The Sudan, and north into the Nile River basin and Asia Minor[8]. *S. galilaeus* is distributed in the Jordan Valley, the Nile, and West Africa fresh waters while the maternal mouth-brooders (*Oreochromis*) are natives of the Jordan Valley, the Nile, and Central African waters, and two of them are found in Lake Chad, the Niger, and Rivers Senegal to Gambia.

Of the seventy-odd Tilapiine species, those used in aquaculture are mostly the maternal brooders, *Oreochromis*, and about 30 species are the substratum-spawners, *Tilapia.* For

Table 1. The most recent nomenclature of tilapias in the Family Cichlidae of the tribe tilapiine (after Trewavas 1982).

Genus	Subgenus	Type species	Other examples
Tilapia A. Smith	(three to six)	*T. sparrmanii* A. Smith	*T. rendalii* Boulenger
			T. zillii Gervais
Sartherodon Rüppell		*S. melanotheron* Rüppell	*S. galilaeus* (Linn.)
			S. linnellii (Lönnberg)
Oreochromis Günther		*O. hunteri* Günther	
	Oreochromis Günther	*O. hunteri* Günther	*O.* (*O.*) *niloticus* (Linn.)
			O. (*O.*) *mossambicus* (Peters)
			O. (*O.*) *aureus* (Steindachner)
			O. (*O.*) *spilurus* (Günther)
	Nyasalapia Thys	*O.* (*N.*) *squamipinnis* (Günther)	*O.* (*N.*) *macrochir* (Boulenger)
			O. (*N.*) *variabilis* (Boulenger)
			O. (*N.*) *angolensis* (Trewavas)
	Alcolapia Thys	*O.* (*A.*) *grahami* (Boulenger) = *O. alcalicus grahami*	*O.* (*A.*) *alcalicus alcalicus* (Hilgendorf)
	Neotilapia Regan	*O.* (*N.*) *tanganicae* (Boulenger)	None
Danakilia		*O.* (*D.*) *franchetti* (Vinciguerra)	None

aquaculture purposes, *T. zillii* is a poor candidate because of its high fecundity, high spawning periodicity, slow overall growth rate, and narrow optimum temperature for good growth. Fecundity is 10-20 times higher than mouth-brooding tilapias[8]. Feeding rates on macrophytes and growth rates approach zero at temperatures less than 20°C[14]. The mouth-brooders, on the other hand, are omnivores/herbivores feeding on benthic algae, phytoplankton, macrophytes, zooplankton, fish eggs/larvae, and detritus. They are able to grow rapidly on lower protein levels and tolerate higher levels of dietary carbohydrate. Another major advantage over various other fish species for aquaculture is that their fry accept prepared feeds at first-feeding. This simplifies tilapia culture significantly in that it is not necessary to culture algae, rotifers, or *Artemia* at any time during the culture cycle; therefore, reduced costs of feeding and very low investment to begin a hatchery. Furthermore, these species can be easily interbred and hybridized and, therefore, provide a benefit from heterosis (hybrid vigour); also, the genetic basis for domestication is greater than that of most aquaculture species. In addition, commercial farms and polyculture of these tilapias with shrimps are developing very rapidly in Central and South America to meet the market demand in the United States, where imports have skyrocketed. In Brazil and Mexico, skin of tilapias is processed into leather goods: belts, purses, brief cases, jackets, and dresses. Other value-added products in the marketplace are the excellent smoked tilapia, sashimi, and high-quality fresh fillets. More important, they are virtually disease-free when compared to most aquaculture species and their mild, firm-textured meat suits all kinds of cooking and cuisines. Thus, these tilapia species are poised to be the single biggest aquaculture crop in the world, surpassing the carps, shrimps, and salmonids in the coming decades[7,15].

Discussion

The major taxonomic revisions of tilapias in 1973 and 1982 by Trewavas created confusion because of the name changes within a short period of time from *Tilapia* to *Sarotherodon*, and then *Oreochromis*. Unfortunately, due to this confusion which started after 1973, plus the classic scientific arguments made by taxonomic “lumpers” versus “splitters," the taxonomy of Trewavas in 1982 had not been accepted by the American Fisheries Society[8]. Lo-Chai Chen, in his 1990 book *Aquaculture in Taiwan*[16] took the same stand as Robins and others of the American Fisheries Society, retaining the usage of the generic name *Tilapia* for all the tilapias. He believes that the elevation of intrageneric groups into genera serves little systematic purpose because it does not involve new phylogenetic interpretation and, therefore, it is against the principles of nomenclature stability and only confuses the names of this group of important fishes in aquaculture literature[16,17]. However, these new taxonomic standards are now widely recognized in international literature due to the publication of a large, comprehensive monograph on tilapias by Trewavas in 1983[18]. As a career aquaculture field scientist, I urge all fisheries and aquaculture personnel in Canada and The Sudan to use this most recent nomenclature of tilapias.

Due to increased market acceptance by domestic consumers and lucrative export markets, aquaculture of tilapias is growing quickly in more than 75 nations of the world. It has recently become important in Canada as a cultured food species and also as a tool for diabetes research at Dalhousie University[9]. This is because tilapias have large, anatomically discrete pancreatic islets – Brockmann bodies (BBS) – that can easily be harvested without expensive, fickle islet isolation procedures and that provide mammalian-like glucose tolerance profiles when transplanted into diabetic recipients [19]. Besides. the largest US niche markets are the live markets in Asian ethnic areas of California, New York, and Toronto. In US seafood circles, tilapias are named as the “new white fish” because they are viewed as a replacement for cod and hake which are in short supply; they have white flesh, are relatively odourless, and have a mild flavour[8]. Personally, I call them the “Miracle Fish” of the past, the present, and the future; the past because the biblical parable of the loaf and fish; the present, because global production has grown astronomically; and the future, because the unique mix tilapias’ physiology, reproduction, biology, genetic plasticity, development of domesticated strains, improved culture techniques, new farms, low cost diets, ecological efficiency, and emerging markets will boost tilapias, in particular *Oreochromis*, to be the world’s largest aquaculture crop; a tool for sustainable development[1].

Conclusion

In recognition of the outstanding contribution of Dr. Trewaves to fisheries science, it is strongly recommended that fisheries and aquaculture personnel use her new taxonomic nomenclature of tilapias. She deserves a great debt of gratitude for putting together a definitive monograph on tilapias in 1983. For commercial aquaculture purposes, it is recommended to use the species of the genus *Oreochromis*, the mouth-brooders. Leather goods from tilapia skin, smoked tilapia, fresh fillet, and sashimi will become a significant contributor to profitability.

Acknowledgements

I am deeply indebted to the late Dr. Ethelwynn Trewavas, British Museum (Natural History) for her letter of April 6, 1982 and reprints on the new nomenclature of tilapias. Also, I am grateful to the conference organizers for accepting this paper to be presented at Aquaculture Canada[OM] 2005.

References

1. George TT. 1997. Saltwater culture of tilapias and possible commercial application in Canada. *Bull. Aquacult. Assoc. Canada* 97-2:42-44.
2. Thys van den Audenaerde DFE. 1968. *An annotated bibliography of Tilapia* (Pisces: Cichlidae) Mus. R. Afr. Cent. Doc. Zool. No. 14, 406 p.
3. George TT. 1996. Tilapia - a potential culture species in Canada. *Bull. Aquacult. Assoc. Canada* 96-3:44-46.
4. Philippart J-CL. and J-CL Ruwet 1982. Ecology and distribution of tilapias. pp. 15-29, *In R.S.V. Pullin and R.H. Lowe-McConnel (eds.) The Biology and Culture of Tilapias*, ICLARM Conf. Proc. 7, 432 p., Manila, Philippines.
5. Courtenay WR Jr. 1997. Tilapias as non-indigenous species in the Americas: environmental, regulatory and legal issues. pp. 18-33, *In*, *Tilapia Aquaculture in the Americas*, (BA Costa-Pierce, JE Rakocy, eds) Vol. 1, World Aquaculture Society, Baton Rouge, Louisiana, USA.
6. Iversen ES. 1976. *Farming the edge of the sea*. Fishing News Books Ltd, London, 436 p.
7. Fitzsimmons K. 2000. The most important aquaculture species of the 21st Century. pp. 3-8, *In*, *Tilapia in the 21st Century*, (K

Fitzsimmons, ed.) Proc. Fifth Int. Symp. on Tilapia Aquaculture, Vol. 1, Rio de Janeiro, Brazil.

8. Costa-Pierce BA, Doyle RW. 1997. Genetic identification and status of tilapia regional strains in southern California. pp. 1-17, *In, Tilapia Aquaculture in the Americas* (BA Costa-Pierce, JE Rakocy, eds.), Vol. 1, World Aquaculture Society, Baton Rouge, Louisiana, United States.

9. George TT. 1998. Status of commercial culture of tilapia in Canada. *Bull. Aquacult. Assoc. Canada* 98-2:53-55.

10. Sandon H. 1950. An illustrated guide to the freshwater fishes of the Sudan. *Sudan Notes and Records* 31:1-61.

11. Trewavas E. 1973. On the cichlid fishes of the genus *Pelmatochromis* with proposal of a new genus for *P. congicus*; on the relationship between *Pelmatochromis* and *Tilapia* and the recognition of *Sarotherodon* as a distinct genus. *Bull. Brit. Mus. Nat. Hist. Zool.* 25:1-26.

12. Trewavas E. 1982. Tilapias: taxonomy and speciation. pp. 3-13, *In*, *The Biology and Culture of Tilapias* (RSV Pullin, RH Lowe-McConnel, eds.) ICLARM Conf. Proc. 7, 432 p., Manila, Philippines.

13. Geoffery F, Iles TD. 1972. eds. *The Cichlid Fishes of the Great Lakes of Africa, their Biology and Evolution*, Oliver and Boyd, Edinburgh, 64 p.

14. Platt S, Hauser W. 1978. Optimum temperature for feeding and growth of Tilapia zili. *Progr. Fish Cult.* 40:105-107.

15. Stickney RR. 1997. Tilapia nutrition, fees and feeding. pp. 34-54, *In*, *Tilapia Aquaculture in the Americas* (BA Costa-Pierce, JE Rakocy, eds). Vol. 1, World Aquaculture Society, Baton Rouge, Louisiana, USA.

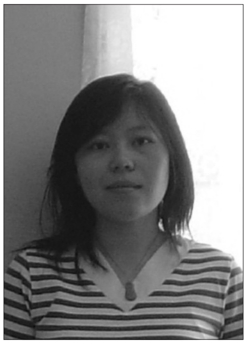
16. Chen. L-C. 1990. *Aquaculture in Taiwan*. Fishing News Books, Oxford. 273 p.

17. Robins CR, Bailey RM, Bond CE, Brooker JR, Lachner EA, Lea RN, Scott WB. 1980. A list of common and scientific names of fishes from the United States and Canada. 4th edition. *Am. Fish. Soc. Spec. Publ.* No. 12: 1-174.

18. Trewavas 1983. Tilapiine fishes of the genera *Sarotherodon*, *Oreochromis* and *Danakilia*. British Museum (Natural History), London. 563 p.

19. Wright JR, Yang H, Dooley KC. 1998. Tilapia - A source of hypoxia-resistant islet cells for encapsulation - a biological insulin pump to facilitate surgery in diabetic rats. *Cell Transplantation* 7(3):209-307.

Effect of Oxidized Dietary Lipid on Growth, Muscle, and Liver Quality of Atlantic Cod, and the Protective Role of Vitamin E



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The effects of oxidized dietary lipid and the role of vitamin E on growth, muscle and liver quality of juvenile Atlantic cod (average weight of 54.9g) was evaluated over a 9-week feeding trial period. Four isonitrogenous experimental diets containing fresh or oxidized fish oil, with or without added vitamin E (α-tocopherol or mixed tocopherols), were fed to juvenile cod in duplicate tanks. The highly oxidized lipid used had a peroxide value of 94 meq/kg oil. No significant change (P>0.05) on growth performance or feed utilization was observed when oxidized dietary lipid was used. Viscerosomatic index (VSI) and hepatosomatic index (HSI) as well as hematocrit did not show any significant difference (P>0.05) among the four treatments. However, the erythrocyte osmotic fragility (EOF), referred to as susceptibility to hemolysis, of fish fed oxidized oil without added vitamin E was high in comparison with those fed unoxidized oil. Supplementation of α-tocopherol appeared to decrease the hemolysis, but mixed tocopherols had no significant effect (P>0.05) on EOF. With regard to the body composition, oxidized oil reduced the ash content of fish whole body. Fatty acid composition of liver total lipid reflected that of dietary lipid. Fish fed fresh oil had higher proportion of polyunsaturated fatty acids (PUFA) in both muscle and liver lipid than those fed oxidized oil.

Introduction

Atlantic cod, *Gadus morhua*, is one of the most widely utilized fish in the western world. This fish has a mild flavour and is a well recognized food fish. In addition, cod liver oil is one of the best sources for essential n-3 fatty acids as well as vitamin A. However, Atlantic cod is now considered an endangered species due to overfishing. With wild cod stocks in decline, farming of Atlantic cod is an emerging commercial activity. Successful farming of cod depends on several factors, including physical farming conditions, feeding methods, and dietary variables. Diet plays an important role in survival and growth as well as muscle and liver quality of the cultured cod. For marine fish, n-3 polyunsaturated fatty acids (PUFA) are required for the supply of essential fatty acids. Nevertheless, these highly unsaturated fatty acids are very susceptible to oxidation with detrimental effects on sensory and nutritive value of the diet, and thus may potentially lead to the suppressed growth and tissue oxidation of the cultured fish receiving the diet[(1)]. Endogenous antioxidant systems such as free radical scavenging enzymes and exogenous antioxidants such as vitamin E protect the fish from oxidative damage. The present investigation aimed to study the effect of oxidized dietary lipids and vitamin E on growth as well as muscle and liver quality of Atlantic cod.

Materials and Methods

Feeding trial

Juvenile Atlantic cod were allocated among 8 tanks at 10°C (water temperature) after acclimation for 3 weeks to experimental conditions. Filtered and UV-treated seawater was supplied to each tank at a rate of 10 l/min. A 12h light/12h dark photoperiod was employed with a light intensity of 60 lux. Four experimental diets, containing unoxidized oil, oxidized oil, oxidized oil with α-tocopherol, and oxidized oil with mixed tocopherols (COVI-OX T70, from ADM), respectively, were assigned to duplicate tanks; basal diet used in all treatments was identical. The fresh oil used had a low peroxide value and thiobarbituric acid reactive substances (TBARS) value, while the peroxide value and TBARS value of the oxidized oil is 94 meq/kg, and 11 μmol malondialdehyde(MDA) eq./g, respectively. Fish were fed twice daily to satiation for 9 weeks. Fish weight, feed intake and mortality were recorded at 3-week intervals.

Sampling and analytical methods

Fish from the same diet treatment were minced together for whole body proximate composition tests. For muscle and liver analyses, fish were dissected, and muscle and livers collected. Blood samples were collected from caudal vein. Hematocrit was determined by centrifugation of the whole blood. Erythrocyte osmotic fragility was measured as hemolysis in saline solution with varying concentrations[(2)]. Proximate composition of diets and fish whole body was also measured. Moisture content was determined by oven-drying method, ash by incineration in a muffle furnace at 550°C for 24 h, crude protein by Kjeldahl, and lipid by gravimetric determination of lipids extracted according to Bligh and Dyer[(3)] method. Fatty acid composition of diets and fish tissues was determined by gas chromatographic (GC) analysis following production of fatty acid methyl esters (FAMEs) using a sulfuric acid/methanol reagent, as described by Hamam and Shahidi[(4)].

Statistical analysis

One way ANOVA (analysis of variance) with pairwise comparisons (Tukeys HSD) was performed at a P<0.05 level to determine the significant differences.

Results and Discussion

The growth performance parameters in terms of survival, weight gain, specific growth rate, hepatosomatic index (HSI), viscerosomatic index (VSI), and feed utilization in terms of feed conversion efficiency, net protein utilization and protein efficiency ratio were calculated (data not shown) and compared among diet treatments. Neither oxidized oil nor vitamin E supplementation had any significant (P>0.05) effect on growth performance of juvenile cod. No significant difference (P>0.05) on feed conversion efficiency (FCE) was observed among the treatments.

Erythrocyte osmotic fragility (EOF) of fish fed different diets was measured as hemolysis in saline solution. Hemolysis of fish in all treatments decreased as the saline concentration increased. No significant difference (P>0.05) was found among the four treatments when saline concentration was in the range of 0.1-0.55%. At higher saline concentrations (0.6-0.85%), fish fed oxidized oil had a higher hemolysis compared to those fed fresh oil. Supplementation of α-tocopherol reduced the hemolysis, while mixed tocopherols had no effect on hemolysis. It is indicated that oxidized dietary oil increased EOF by increasing the oxidative stress on red blood cells, and that α-tocopherol enhanced the resistibility of erythrocyte membranes to hemolysis; this lends further suggest to earlier reports in the literature[5,6]. Hematocrit did not show any significant difference (P>0.05) among all treatments.

The proximate composition of fish whole body was determined (data not shown). Fish fed oxidized oil had a lower ash content than those fed on fresh oil. Both α-tocopherol and mixed tocopherols reduced the moisture content. Crude protein and lipid contents were not affected by either oxidized oil or vitamin E supplementation. With respect to the lipid levels in fish tissues, oxidized oil had no significant effect on either liver or muscle lipid content. Supplementation of α-tocopherol decreased the lipid content of liver and muscle. Mixed tocopherols reduced only liver lipid content with no influence on muscle lipid.

The muscle lipid contained a higher proportion of polyunsaturated fatty acids (PUFA) than liver lipid. The trend among the treatments of both muscle and liver fatty acid composition reflected that of dietary fatty acids.

Acknowledgements

We would like to thank AquaNet for providing funding for this work. We are also grateful to all the staff in the Ocean Sciences Centre (OSC), St. John’s, NL, for their kind and generous help.

References

1. Baker RTM, Davis SJ. 1996. Oxidative nutritional stress associated with feeding rancid oils to African catfish, *Clarias gariepinus* (Burchell) and the protective role of alpha-tocopherol. *Aquacult. Res.* 27: 795-803.
2. Miale J. 1982. Method of Dacie. *In*, *Laboratory Medicine Hemotology*, 6th edition., p.883. CV Mosby Co., St. Louis, MO.
3. Bligh EG, Dyer WJ. 1959. A rapid method of total lipid extraction and purification. *Can. J. Biochem. Physiol.* 37: 911 -927.
4. Hamam F, Shahidi F. 2005. Enzymatic incorporation of capric acid into a single cell oil rich in docosahexaenoic acid and docosapentaenoic acid and oxidative stability of the resultant structured lipid. *Food Chem.* 91: 583-591.
5. Kaewsrithong J, Oshima T, Ushio H, Nagasaka R, Maita M, Sawada M. 2001. Effects of an excess dose of dietary alpha-tocopherol on hydroperoxide accumulation and erythrocyte osmotic fragility of sweet smelt Plecoglossus altivelis (Temminck et Schlegel). *Aquacult. Res.* 32 (Suppl. 1): 191-198.
6. Kiron V, Puangkaew J, Ishizaka K, Satoh S, Watanabe T. 2004. Antioxidant status and nonspecific immune responses in rainbow trout (Oncorhynchus mykiss) fed two levels of vitamin E along wit three lipid sources. *Aquacultur*e 234: 361-379.

Optimizing Cultured Mussel Yields: Second-Set Dynamics and Avoidance Strategies

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A major production constraint for some mussel farms is an accumulation of unwanted mussel seed, known as second-set, on growout socks. Second-set reduces harvest yields and increases processing costs. The objectives of this study were 1) to examine mussel seed behaviour under varying environmental conditions, 2) to identify the biotic and abiotic factors involved in second-set dynamics, and 3) to determine the influence of socking depth (4 m, 9 m), deployment time (spring, autumn) and initial socking density (~100, 200, 250, 300+ mussels per 30 cm) on mussel sock performance. The results indicate that mussel seed mobility is greatly influenced by seed size but to a lesser extent by food availability or temperature. Mussel settlement was heaviest during August. There was evidence of byssal drifting in the spring which may be a source of second-set. Reduced second set occurred at 9 m compared to 4 m, for all deployments times (ANOVA, $P<0.001$). High initial sock density (>300 mussels / 30 cm) resulted in less accumulation of second-set, regardless of depth. Husbandry practices were shown to influence second-set accumulation to a large extent. We conclude that second-set can be significantly reduced or avoided by a thorough understanding of site environmental and biological conditions with appropriate adjustments to husbandry practices.

Introduction

A major production constraint for some mussel farms in Canada and elsewhere is related to 'second set' – an accumulation of unwanted mussel seed on culture gear (Fig. 1). Accumulated seed may originate from primary settlement -annual settlement of mussel larvae[1], or to a lesser extent, secondary settlement – resettled spat (3-5 mm) from byssal drifting[2,3]. Accumulated seed may be severe enough to decrease growth of production mussels, reduce harvest yields (less than 30% of optimal), and increase costs of production such as extra floatation, transportation, and processing costs.

There are several key factors to consider in developing a strategy for avoiding unwanted mussel seed: (1) a thorough understanding of local site conditions and their effects on mussel settlement patterns, (2) how environmental conditions (food, temperature) affect crawling behaviour of seed mussels, and (3) the influence of husbandry practices on sock quality. Sock quality is a critical factor in amount of second-set mussel accumulation on growout gear.

The objectives of this study were to examine biotic and abiotic conditions involved in second-set appearance to formulate avoidance / mitigation strategies for industry.

Materials and Methods

Environmental data were collected approximately once per month. Data recorded included temperature (°C), food levels (as µg/L total Chl-a) and salinity (ppt) for the 2000 and 2001 seasons. Mussel meat yields (%) and plankton tow monitoring (larval numbers per ml and size in mm) were carried out at least every two weeks to identify key spawning periods.

Laboratory experiments at the Ocean Sciences Centre investigated mussel seed crawling behaviour at water temperatures of 0°C, 5°C, and 10°C, with and without food, at two seed sizes (small: 5.4 mm, large: 19.4 mm, mean shell lengths). Mussels were placed on small grids in tanks, and individual mussel positions quantified at 15-minute intervals over a 120-minute period.

Mussel collector ropes were deployed monthly at the surface, 3 m, 6 m and 9 m depths. A multifactorial socking trial consisting of four initial sock densities (4M socking =100, 5M socking = 200, 6M socking = 250, 7M or TMM socking = 300+ mussels per 30 cm of socking), two deployment depths (4 m and 9 m) and two sock times (spring and autumn) was undertaken at two mussel farm sites on the South Coast of Newfoundland starting spring 2000.

The amount of second-set was assessed for each treatment combination and the resulting numbers expressed as individuals per 30 cm of socking. Sock yields were estimated and standardized to kg of mussels greater than 50 mm in shell length per 30 cm of socking.

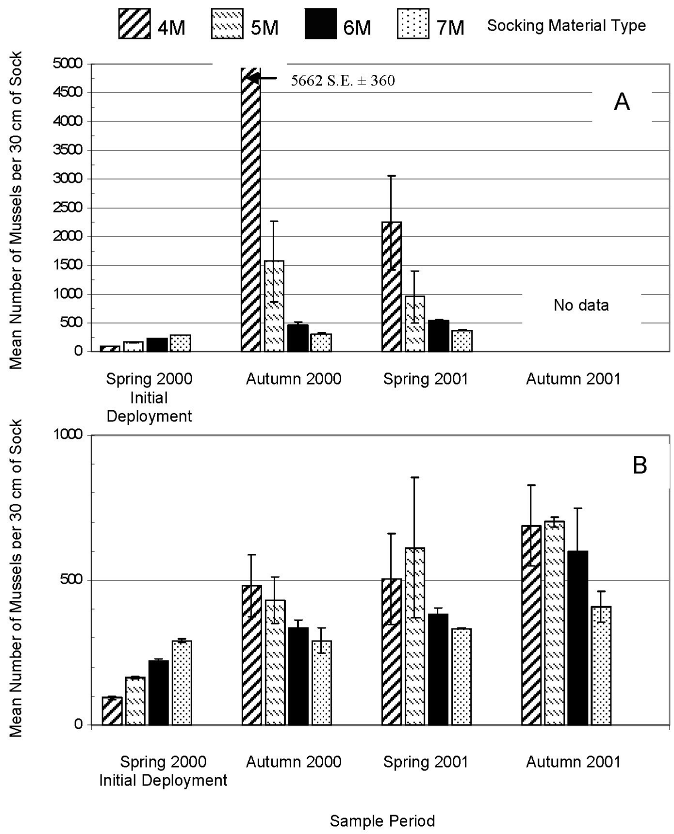
Husbandry observations were taken note of throughout the culture process in hopes of identifying key activities that may help contribute to second-set accumulation on production socks.

Results

Environmental data

Food abundance was highest in April of each season, then tapered off throughout the summer. A small phytoplankton bloom appeared in the autumn at both sites. Temperatures peaked at 19°C, but showed wide daily fluctuations in late summer of more than 12°C in a 24-hour period. A seasonal thermocline appeared on each site at about 8-12 m depth in early July, before disappearing in October. Salinity was influenced by surface run-off, but remained high (>30 ppt) throughout the year.

Figure 1
Mean number of mussels per 30 cm of socking at Salmonier Cove, (A) 4 meters (B) 9 m – spring 2000 deployment, sampled autumn 2000 and spring 2001. All socks were lost at 4 m during storm by the autumn 2001 sampling period. Bars represent means ± SE, n = 3.



Mussel crawling behaviour

Laboratory results showed that small spat were significantly more active than large spat, typically 3-4 times faster (12 to 25 body lengths per hour) on average (ANOVA, $P<0.001$), even at 0°C. Crawling rate increased with ambient water temperature for both small and large spat, but rate was not significantly influenced by food levels.

Mussel settlement

Mussel settlement was most intense during August. There was no significant difference in the amount of seed collected with depth of collector deployment. Spat growth varied significantly with depth and month of collection (ANOVA, $P<0.001$).

Initial socking density, deployment depth, time of deployment, and sock yields

Depth of deployment was a significant factor in the amount of second-set accumulated on socks, with socks at 9 m accumulating less seed than socks deployed at 4 m ($P<0.001$), for both spring and autumn deployment times (Figs. 1, 2).

There was a significant reduction in the amount of second set with increased initial sock density at 4 m but not 9 m, for a spring 2000 deployment. Initial sock density had little effect on reducing second-set for the autumn 2000 socking (Figs. 1, 2). Mussel yields per 30 cm of socking after 1 year of deployment were significantly less for socks deployed at 9 m than 4 m (ANOVA, $P<0.001$), but there was no significant difference in harvest yields with initial sock density (ANOVA, $P=0.08$). Yields for socks deployed in the autumn of 2000 were poor after 1 year deployment, compared to the spring deployment (70% vs. 2%, respectively).

Husbandry observations

Mussel seed was harvested quickly and graded for size within a few hours of harvest. There were a variety of sock materials available for use and the choice of the one used often corresponded to tray order beneath the grading machine. Crushed and broken mussels sometimes found their way to the socking table. Socks with second-set present were often of low density, fouled or had mussels trapped inside the mesh.

Discussion and Conclusion

Mussel spawning, seed collection and crawling behaviour were all influenced by environmental conditions. Fluctuating temperature due to wind, tidal change, physical disturbances from storms, separately or in some combination, may play a role in the spawning of mussels[3]. The seasonal thermocline that appeared on each site may affect where the majority of mussel larvae are located in the water column, as shown with scallop larvae in previous studies[4,5]. In both 2000 and 2001, heaviest settlement was during August and as such, deploying mussel socks at these sites just before or during this time should be avoided.

In areas where second-set regularly occurs, knowledge of the crawling behaviour of different size seed and under varying environmental conditions is important when considering a second-set avoidance strategy, as it is crucial that sock uniformity be created and maintained to limit future settlement opportunity. Good sock quality depends to a large extent upon choosing the proper mesh size for the various size grades so that they have ample room and time to migrate to the outside of the sock. Knowing that larger seed are generally slower moving than small seed and environmental conditions can affect movement behaviour overall (i.e., more crawling at increased temperature and with food present), better sock material choices and sock times can be made that do not compromise proper sock formation. It is recommended that a thorough knowledge of a site's environmental conditions and mussel stock be obtained through careful monitoring and record keeping.

The results showing that deploying socks in deeper water and at increased initial seed densities resulted in less second-set should be very encouraging to operators in areas where second-set has been a problem. Low density socks were often fouled and had poor mussel arrangement.

A properly formed sock has high enough density to force mussels to compete for position on the outside, forming a solid col-

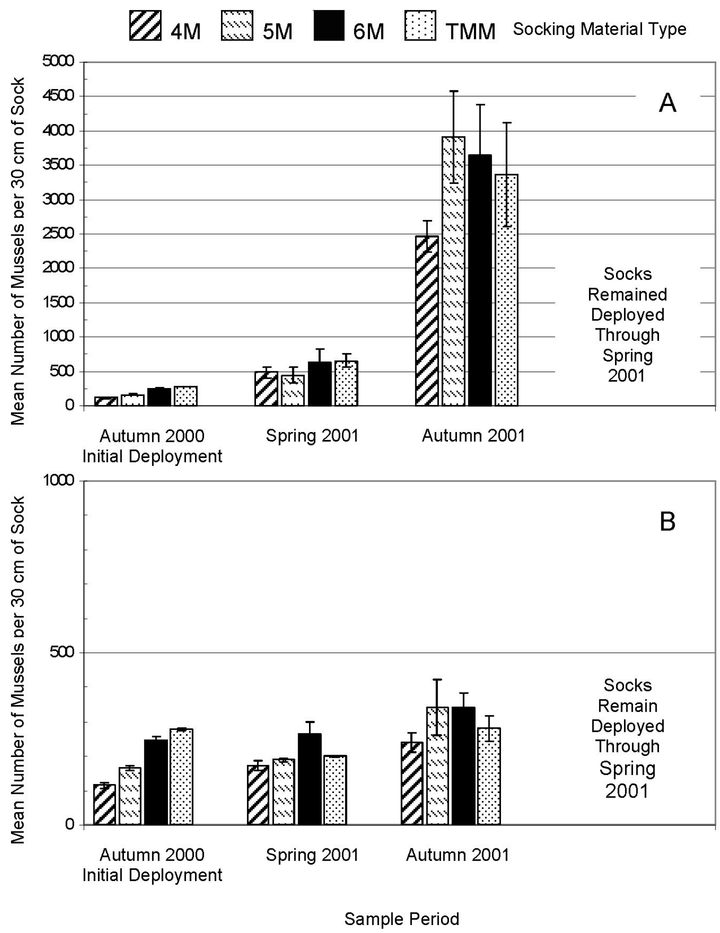


Figure 2
Mean number of mussels per 30 cm of socking at Salmonier Cove, (A) 4 m (B) 9 m – autumn 2000 deployment, sampled spring 2001 and autumn 2001. Bars represent means ± SE, *n* = 3.

umn, mussels positioned side by side, with siphons exposed to the passing food supply. Socks formed like this remain clean and free from heavy fouling and second-set due to the filtering out of zooplankton[6] which includes bivalve larvae. Lehane and Davenport[7] reported in laboratory experiments that about 90% of bivalve larvae made available to mussels were ingested and apparently fully digested. In essence, a properly formed sock becomes a good filtering system, enough to discourage fouling organisms and settling mussel larvae. It is suggested that deploying socks in deep water or below the seasonal thermocline with increased initial seed density can reduce the amount of second set and improve sock commercial yield.

In terms of time required to produce high yields of marketable product, deploying socks in deeper water increased the time required to reach marketable size. However, the benefits of a cleaner product outweighed the extra time required. To maximize growth, it is recommended that socks be deployed in the spring, as mussels are able to take advantage of the spring bloom.

Acknowledgements

We would like to thank the following for financial and technical support: Atlantic Canada Opportunities Agency, Canadian Centre for Fisheries Innovation, Connaigre Fish Farms, Newfoundland Aquaculture Industry Association, Newfoundland and Labrador Department of Fisheries and Aquaculture, Fisheries and Marine Institute of Memorial University, Ocean Sciences Centre.

References

1. Bayne BL. 1965. Growth and delay of metamorphosis of the larvae of *Mytilus edulis* (L.). *Ophelia* 2(1):1-47.
2. De Block JW, Tan-Maas M. 1977. Function of byssal threads in young post larval *Mytilus edulis*. *Nature* 267:558.
3. Newell C, Hidu H, McAlice BJ, Podniesinski G, Short F, Kindblom L. 1991. Recruitment and commercial seed procurement of the blue mussel *Mytilus edulis* in Maine. *J. World Aquacult. Soc.* 22(2):134-152.
4. Mann R, Campos BM, Luckenbach MW. 1991. Swimming rate and responses of larvae of three mactrid bivalves to salinity discontinuities. *Mar. Ecol. Prog. Ser.* 68: 257-269.
5. Manuel JL, Burbridge S, Kenchington EL, Ball M, O'Dor RK. 1996. Veligers from two populations of scallop, *Placopecten magellanicus* exhibit different vertical distributions in the same mesocosm. *J. Shellfish Res.* 15(2): 251-257.
6. Davenport J, Smith RJJW, Packer M. 2000. Mussels *Mytilus edulis*: significant consumers and destroyers of mesozooplankton. *Mar. Ecol. Prog. Ser.* 198: 131-137.
7. Lehane C, Davenport J. 2004. Ingestion of bivalve larvae by *Mytilus edulis*: experimental and field demonstrations of larviphagy in farmed blue mussels. *Mar. Biol.* 145(1): 101-107.

The Effect of Acute Increase in Water Temperature on the Physiology of Juvenile Atlantic Cod (*Gadus morhua* L.)

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Cultured and wild Atlantic cod are subjected to environmental fluctuations in temperature. Such fluctuations can cause considerable stress on the homeostatic mechanisms of fish rendering them susceptible to a wide variety of pathogens. We conducted an experiment to evaluate the physiological changes associated with a sudden increase in water temperature on juvenile Atlantic cod. An experimental group of 21 fish was exposed to 6°C increase over a period of 1h. Both control and experimental fish were sampled before and at 1h, 3h, 6h, 24h, and 72h after. Plasma cortisol, osmolality, blood glucose, total plasma proteins were measured for both groups. Skin samples were taken to evaluate the histological changes associated with acute temperature stress. Results showed increased cortisol levels one hour after temperature increase and changes in the epidermal mucus and mucus cells during the first few hours thereafter. Changes in husbandry practices in cod farms are suggested.

Introduction

Stress is an inevitable component in modern intensive aquaculture; but minimizing it in farmed fish is the key for success[(1)]. The fluctuating water temperature with seasonality is one of the crucial factors that seldom have control in sea cages[(2)]. Such environmental changes together with day to day husbandry practices could predispose the cultured fish to pathogens by compromising their immunity[(3,4)]. There are several studies that determine the effect of temperature on different aspects of larval and juvenile cod rearing; e.g., growth[(5)], ontogenetic changes[(6)], and energy metabolism[(7)].

In Bay d'Espoir, Newfoundland, temperature along the water column fluctuates and changes considerably. It has been reported that temperature could vary from around 0°C at 30m deep to 3-4°C at the surface during spring[(2)]. This thermal gradient markedly increases during the summer with increased surface water temperature, necessitating farmers to alter the net depth for salmon to attain optimal growing conditions[(2)]. Bay d'Espoir fish farmers observed that fish go deeper in the water column in times other than feeding during spring and summer. Such behaviour has also been reported by Fernoe et al.[(8)]. As food is usually offered on the surface, fish has to swim up the water column to feed. This practice will expose them to a sudden change in temperature that amount to several degrees especially during summer and may alter their physiology. This study is intended to measure the physiological and histological changes associated with sudden increase in water temperature at a laboratory setting.

Materials and Methods

Hatchery reared Atlantic cod juveniles were obtained from the Ocean Sciences Centre, Memorial University of Newfoundland. They were kept at the Department of Fisheries and Oceans for 8 months at ambient temperature. Two months before the experiment, fish were anaesthetized using MS222, individually tagged and randomly assigned as experimental and control (21 fish in each group) in two 500-litre tanks. Fish were kept under ambient temperature (0.81±0.34ºC) at a flow rate of 6-7 L/min. Daily temperature, salinity, dissolved oxygen and mortalities were recorded. Both tanks were fed ad libitum every other day with commercial pelleted feed. The experimental tank was equipped with a submerged titanium coil to be used for heating-cooling purposes with an external water line.

Before temperature manipulation, three fish were sampled from each tank. Then the temperature was increased by 6°C over 15 min (from 3.5°C to 9.5°C) in the experimental tank and kept high for one hour, then dropped to ambient. The temperature, dissolved oxygen and behaviour of the fish were constantly monitored through out the heating period. Cooling process took nearly an hour, and then three fish was sampled from each tank then at 3 h, 6 h, 24 h, and 72 h after. Sampled fish were anaesthetized with a lethal dose of MS222. Fish were then immediately bled. Approximately 0.5 ml of the blood was centrifuged and serum stored at -80°C. The rest of the blood was transferred to a heparinized tube, centrifuged and plasma was store at -80°C. Fish weight and length were recorded. The mean wet weight and fork length were 205.2±97 g, 192.6±84 g and 28.3±3.7 cm, 27.9±3.1 cm in experimental and control groups, respectively. Skin samples were collected from the right side rostral to the dorsal fin in Bouin's solution. Blood glucose was measured using Trinder colorimetric assay (Catalogue # 220-32, Diagnostic Chemicals Limited, Charlottetown, PEI, Canada). Plasma cortisol levels were measured using an ELISA test (Kit # 402710, Neogen Corporation, Lexington, KY). Total plasma protein concentration was measured with Bio-Rad protein assay using bovine gamma globulin as standard (Catalogue #: 500-0001, Bio-Rad Laboratories, Hercules, CA). Plasma osmolality was measured using Fiske Micro-Osmometer. Blood Na^+ ion concentration, pH, haematocrit, and haemoglobin concentration were measured using i-Stat portable clinical analyzer

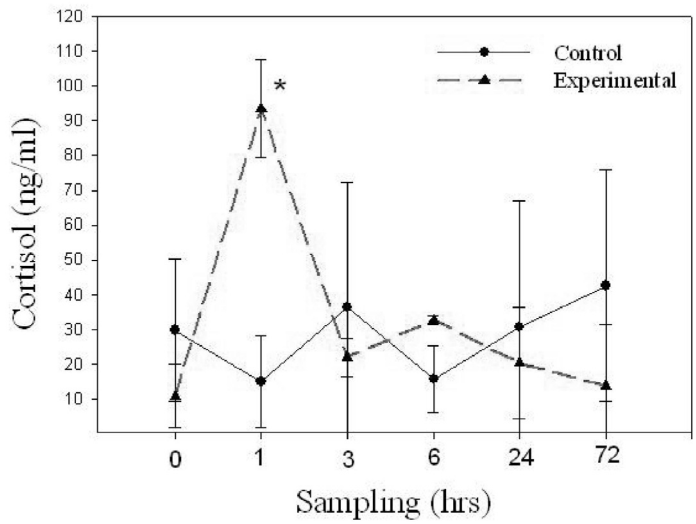


Figure 1
Mean blood cortisol levels (ng/ml) in control and experimental cod juveniles.

(Heska Corporation, Fort Collins, CO). Skin samples were stained with Alcian blue and Haematoxilin and Eosin.

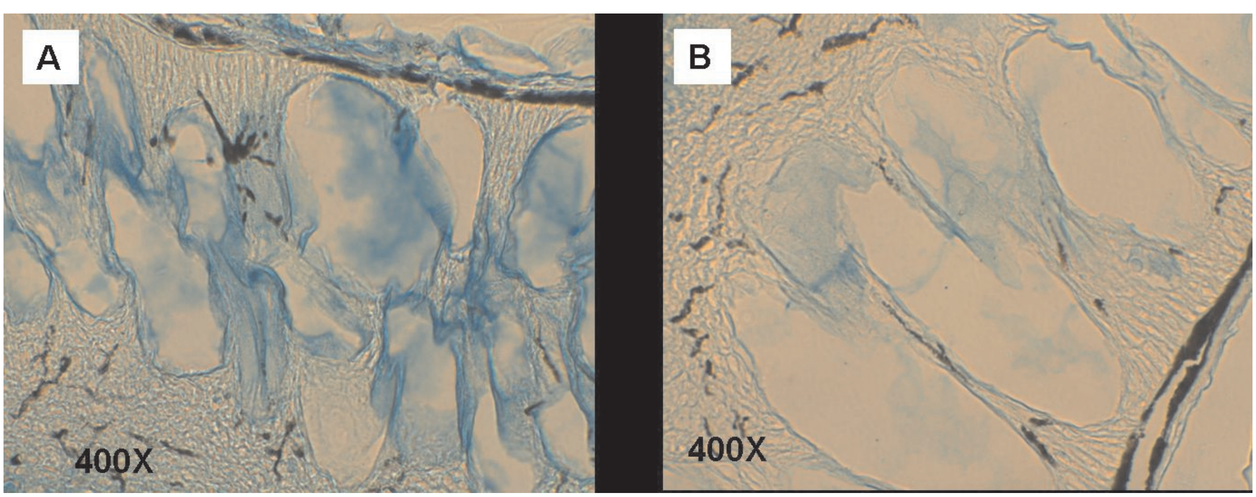
Differences in blood parameters between control and experimental groups were compared using the general linear model in SPSS (SPSS 10.0 for windows). The means of the variables were compared using Bonferroni correction. Residuals were found to be homogeneous and normally distributed[9].

Results

The plasma cortisol concentration of experimental fish was significantly higher at 1hr after the acute temperature increase (Fig. 1) ($P<0.005$), however, it was not significantly different during the rest of sampling times. Plasma protein concentration in the experimental tank showed a significant interaction between the tank and the sampling time ($P = 0.046$). However, it was not significant when examined at each sampling time ($P = 0.051$). Blood glucose levels ($P = 0.527$), plasma osmolality ($P = 0.397$), Plasma Na^+ ion ($P = 0.122$), haematocrit ($P = 0.330$), haemoglobin concentration ($P = 0.482$) and oxygen partial pressure ($P = 0.209$) were not significantly different between experimental and control groups at any sampling time.

Histological examination of the epidermis showed that the mucus present in mucus cells changed over time post exposure in the experimental group. The amount of mucus was visibly low in 1, 3, and 6-h samples compared to control (Fig. 2). The mucus cells were more prominent in those samples with the cells being more oval and enlarged. Samples with multiple layers of mucus cells were common. However, the abundance of mucus cells present was less in the 24-h sample and no changes were noticed at 72h.

Figure 2
Mucus cells stained with Alcian blue, in the skin epidermis of control (A) and experimental (B) cod juveniles under high power (400×), one hour after the acute temperature increase.



Discussion

Change in environmental temperature is known to induce physiological and behavioural changes in cod[10]. Rapid elevation of plasma cortisol levels is one of the primary responses following exposure to an acute stressor[1]. The results showed that the increase in temperature caused the cortisol levels to increase significantly in experimental fish during the first hour post exposure. It was raised six folds over the control group (93 ng/ml vs.15 ng/ml). However, there were no significant differences in cortisol levels at 3 h and beyond. Similar results have been shown in other studies[11,12]. Post stressor cortisol levels could rise up to 100-200 ng/ml in an hour after the stimuli and it drops back to basal level if the stress is not sustained[13].

There was no significant difference in blood glucose, plasma protein, blood osmolality, haematocrit and haemoglobin concentrations between groups. The activation of neuroendocrine system and release of cortisol due to stress, usually stimulate the production of glucose via gluconeogenesis[14,15]. However, the nature and the degree of physiological response to a stressor could depend upon its severity and the biological significance of the stress. The increase in temperature in this study did trigger a primary response with increased cortisol levels; but, it may have been inadequate to affect other physiological responses measured.

The changes seen in skin may be due to elevated cortisol levels. An increased level of cortisol is known to induce structural changes in skin of rainbow trout (*Oncorhynchus mykiss*)[16]. The low level of mucus during the first few hours post exposure may be due to stimulated release. Increase in cortisol levels in fish exposed to environmental stressors has reported apoptosis and an initial mucocytopenia following post exposure[17]. The multiple layers of mucus cells in the latter samples suggest an increase turnover of mucus cells. Iger[18] reported a similar increase in mucus containing cells following a cortisol treatment in Rainbow trout. However, further investigation is required to confirm these preliminary findings.

Bay d'Espoir farmers commonly encounter fluctuating temperatures in the upper water column and cod has to swim up the column for feeding that may cause stress response. With the findings of blood and skin changes, fish immunity may be lowered making the fish more prone to infection. Tube feeding lower in the water column is suggested as a husbandry practice that may prevent such changes.

References

1. Reddy PK, Leatherland JF. 1998. Stress Physiology. pp. 293-294, *In*, *Fish Diseases and Disorders, Non Infectious Disorders* (JF Letherland, PTK. Woo, eds). Vol. (2), Wallingford, UK.
2. Pepper VA, Mansour AAH, Nichols T, Whelan D. 2002. Optimal net depth for over wintering Bay d'Espoir aquaculture salmonids. *Can. Tech. Rep. Fish. Aquat. Sci.* 2452: vii + 55 p.
3. Maule AG, Schreck CB, Kaattari SL. 1987. Changes in the Immune system of coho salmon (*Oncorhynchus kisutch*) during the parr-to-smolt transformation and after implantation of cortisol. *Can. J. Fish. Aquat. Sci*. 44:161-166.
4. Maule AG, Tripp RA, Kaattari, S. L, Schreck CB. 1989. Stress alters Immune function and disease resistance in Chinook salmon (*Oncorhynchus tshawytscha*). *J. Endocrinol*. 120:135-142.
5. Hunt von Herbing I, Boutilier RG, Miyake T, Hall, BK. 1996. Effects on temperature on morphological land marks critical to growth and survival in larval Atlantic cod (*Gadus morhua*). *Mar. Biol.* 124:593-606.
6. Lafrance P, Castonguay M, Chabot D, Audet C. 2005. Ontogenetic changes in temperature preference of Atlantic cod. *J. Fish. Biol*. 66(2): 553-567.
7. Sartoris FJ, Bock C, Serendero I, Lannig G, Poertner HO. 2003. Temperature dependent changes in energy metabolism, intracellular blood oxygen tension in the Atlantic cod. *J. Fish. Biol*. 62 (6):1239-1253.
8. Fernoe A, Huse I, Juell J-E, Bjordal A. 1995. Vertical distribution of Atlantic salmon (*Salmo salar*) in net pens: Trade off between surface light avoidance and food attraction. *Aquaculture* 132: 285-296.
9. Sokal RR, Rohlf JJ. 1995. Biometry: the principles and practice of statistics in biological research. 3rd Edition, Freeman, New York.
10. Claireaux DM, Webber DM, Kerr, SR Boutilier RG. 1995. Physiology and behaviour of free swimming Atlantic cod (*Gadus morhua*) facing fluctuating temperature conditions. *J. Exp. Biol.* 198:49-60.
11. Gollock MJ, Kennedy CR, Brown JA. 2005. Physiological responses to acute temperature increase in European eels *Anguilla anguilla* infected with *Anguillicola crassus*. *Dis. Aquat. Org.* 64(3):223-8.
12. Das MK, Dutta T, Acharya S, Bhowmick S. 2002. Sublethal temperature stress in juvenile *Labeo rohita* (Ham-Buch.) and *Rita rita* (Ham.): some physiological changes. *Indian J. Exp. Biol.* 40(5):589-93.
13. Sumpter JP. 1997. The endocrinology of stress. pp. 95-118, *In*, *Fish Stress and Health in Aquaculture* (GK Iwama, AD Pickering, JP Sumpter, CB Shreck, eds). Cambridge University Press, Cambridge. UK.
14. Wedemeyer GA, Barton BA, McLeay DJ. 1990. Stress and acclimation. pp. 451-489, *In*, *Methods for Fish Biology* (CB Schreck, PB Moyle eds.). Am. Fish. Societ. Bethesda, Maryland.
15. Suarez RK, Mommsen T P. 1988. Gluconeogenesis in teleost fishes. *Can. J. Zool*. 65:1869-1882.
16. Iger Y, Balm PHM, Jenner HA, Wendelaar Bonga SE. 1995. Cortisol –inducesed stress related changes in the skin of Rainbow Trout (*Oncorhynchus mykiss*). *Gen. Comp. Endocrinol*. 97:188-198
17. Iger Y, Abraham M, Dotan A, Fattal B. Rahamim E. 1988. Cellular response in the skin of carp in the maintained in organically fertilized water. *J. Fish Biol*. 33:711-720.
18. Iger Y, Hilge V, Abraham M. 1992. The ultrastructure of fish skin during stress, in aquaculture. pp. 205-214, *In*, *Progress in Aquaculture Research* (B Moav, V Hilge, H Rosenthal, eds), EAS, Oostende, Belgium.

Growth of *Arthrospira platensis* (*Spirulina* sp.) in Varied Salinity Conditions

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Growth of the blue-green algae *Arthrospira platensis*, (*Spirulina* sp.), was challenged under various levels of salinity (0, 10, 20, 28, 32, 36, 45, and 50‰). Initial inoculation into each salinity, was from a 32‰ culture. The experiment was repeated after the cultures were acclimated for a duration of 10 days. Growth, cell size, and absorbency was measured. *A. platensis* possess the ability to survive in a wide range of salinities and growth is not influenced (P>0.05) through an acclimation period. A significant difference (P<0.05) between salinities was found on days 6 and 9, where growth (number of counted cells) of 0 and 50‰ was greater than all other tested salinities. The amount of chlorophyll (absorbency read at 605 nm) present at 32‰ (0.527) or 50‰ (0.238) is greater (P<0.05) compared to 0‰ (0.021). Mean cell size also decreased as salinity was challenged from 32‰. The mean cell size at 32‰ was 9.574 µm, 0‰ was 3.358 µm, and 50‰ was 6.974 µm.

Introduction

Arthrospira platensis (*Spirulina*) is commonly recognized as a freshwater blue-green phytoplankton found in alkaline lakes(1), as opposed to a marine inhabitant. Often organisms that are capable of moving will distribute according to their optimal salinity(2). Many phytoplankton species possess the ability to adapt to grow in higher salinities(3), and unless the salinity happens to be optimal, the species will either thrive or die off(2).

There is a lack of blue-green algae in marine environments because large quantities of sodium is believed to be inhibitory(4). *Spirulina* has the ability to survive in a marine or freshwater environment, which is dependant on several physiological mechanisms(5,6). The nutritional value of *Spirulina* alters as the salinity is increased(7,8). Determining optimum salinity is essential in order to maximize both production as well as nutritional value.

A. platensis is appealing to the production industry because of its nutritional value(9,10) as well as its tolerance to a wide range of environmental conditions which makes it ideal for industrial production(11,12). Cyanobacteria contains sodium-proton antiporters that allow the cells to tolerate hypersalinity(13,14). This species, like other blue-greens, is extremely self-sufficient in its nutritional requirements.

Materials and Methods

Salinities of 0, 10, 20, 28, 32, 36, 45, and 50‰ (in accordance to YSI EC 300 salinity meter) were adjusted using distilled water and the addition of commercial sea salts (Instant Ocean®). 75 ml of each salinity in F/2 (Guillard) medium was added to Erlenmeyer flasks and sterilized through autoclaving at 121° C and a pressure of 6.82 Kg for 15 minutes.

Ten millilitres of *A. platensis* CH-9 (Cyanophyceae), acclimated at 32‰, were aseptically inoculated into each flask. The trial was repeated after a 10-day acclimation period in each salinity. Flasks were randomized in the culture chamber and swirled on a daily basis. External parameters in the culture chamber (SANYO MLR 350) were kept constant at a temperature of 22°C and 18h light :6 h dark with white fluorescent lighting at a illuminance of 80µmol photon flux densities $m^{-2}{\cdot}s^{-1}$.

The cultures were grown in triplicate for each treatment. Cell counts were performed in duplicate every third day for a 12-day period. Growth was determined using a Multisizer3 Coulter Counter, with 0.3-µm filtered seawater as the dilutant. Absorbency was measured on day 10, using a multi-wavelength filter colorimeter (HACH-DR/2010) set at 605 nm. Instantaneous growth rate (K) was calculated for each salinity through the following expression:

$$K = \frac{\ln N_f - \ln N_i}{t} \qquad (1)$$

where t = number of tested days, N_f = final cell count, and N_i = initial cell count(15). Statistical analysis was performed for all data using a one way analysis of variance (ANOVA), at a significance level of 0.05.

Results

Growth (the number of cells detected), was not influenced by acclimation period, as cells given a 10 day acclimation period in each salinity was not significantly different (P>0.05) from those acclimated at 32‰ (Fig. 1). The number of cells on days 6 and 9 was greater (P<0.05) for 0 and 50‰ than all other tested cultures.

Mean cell size was influenced by salinity – at 32‰ mean cell size was greatest (12.574 µm), and decreased as salinity was challenged from 32‰ (Table 1). Cell size was not influenced by time, after day 3, cells had adjusted to their maximum size. The level of absorbency was significantly different (P<0.025) for the salinities 0, 10, and 20‰, (absorbency readings between 0.021-0.0238) compared to 28, 32, 36, 45, and 50‰ (0.348-0.527).

Discussion and Conclusion

Species that are well adapted to the sea thrive in brackish water but do not persist in freshwater(16). Contrary, *A. platensis* sur-

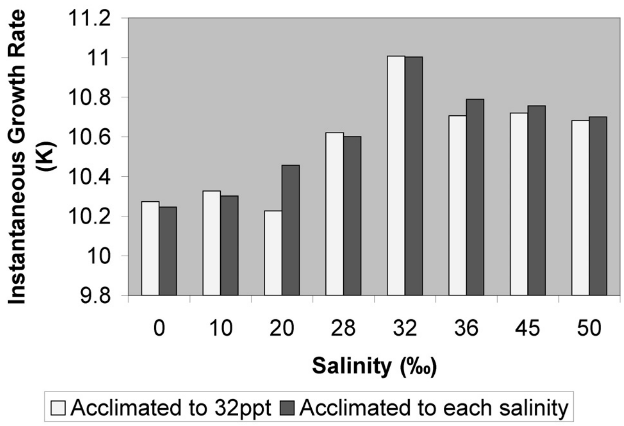

Figure 1
Instantaneous growth rate (K) of *A. platensis* grown under different salinities.

vived equally well in freshwater as in saltwater. The only significant difference in growth was on days 6 and 9, where 0‰ and 50‰ were greater than other tested salinities. As salinity changed from 32‰, the number of cells increased, however cell size decreased. Cell size of *A. platensis* is known to measure between 6-8 µm in length, and 3-6µm in diameter[17]. Mean cells were as long as 12.5 µm at 32‰, exceeding the maximum suggested length. Cell size tends to decrease when exposed to stressed conditions[18].

Although the majority of blue-green algae can grow equally well in both freshwater and saltwater[16], the chlorophyll level tends to alter. Similar results were found in salt-stressed environments[19]. This is not an immediate change, under a 12h examination, the chlorophyll level in *A. platensis* does not change when under salt-stressed conditions[20].

A. platensis was able to adapt to interchanging salinity levels, under lighting levels of 80µmol photon flux densities $m^{-2}{\cdot}s^{-1}$, when grown under higher lighting levels (200 µmol $m^{-2}{\cdot}s^{-1}$ photon flux densities), cells are less tolerant to salinity-stress[21]. Lighting intensities combined with hypersaline conditions causes damage in proteins[22]. Many other parameters influence the ability of *A. platensis* to survive in marine conditions. When nitrate and ammonium are present, hypersalinity tolerance of cyanobacteria increases[23]. Altering conditions will result in a change in nutritional content. Hypersalinity causes several adaptive responses such as alteration in potassium levels[23]. This should be considered when growing *A. platensis* under alternate saline conditions.

Growth, cell size, and absorbency showed no difference after being acclimated for a 10-day period, indicating that an acclimation period does not influence results. This makes *A. platensis* a desirable species as it has the ability to grow in both freshwater as well as saltwater.

References

1. Berry S, Bolychevtseva YV, Rogner M, Karapetyan NV. 2003. Photosynthetic and Respiratory electron transport in the alkaliphilic cyanobacterium *Arthrospira (Spirulina) platensis. Photosynth. Res.* 78:67-76.
2. Carpelan LH. 1964. Effects of salinity on algal distribution. *Ecology* 45(1):70-77.
3. Blindow I, Dietrich J, Mollmann N, Schubert H. 2003. Growth, photosynthesis and fertility of *Chara aspera* under different light and salinity conditions. *Aquat. Bot.* 76:213-234.
4. Round FE. 1965. Arnold E. (Ed.) The Biology of the Algae. Pitman Press, Bath. pp.153-156.
5. Mackay MA, Norton RS, Borowitzka LJ. 1984. Organic osmoregulatory solutes in cyanobacteria. *J. Gen. Microbiol.* 130:2177-2191.
6. Rafiqul IM, Hassan A, Sulebele G, Orosco CA, Roustaian P, Jalal KCA. 2003. Salt stress culture of blue-green algae *Spirulina fusiformis*. *Pak. J. Biol. Sci.* 6(7):648-650.
7. Vonshank A, Guy R, Guy M. 1988. The response of filamentous cyanobacterium *Spriulina platensis* to salt stress. *Arch. Microbiol.* 150:417-420.
8. Warr SRC, Reed RH, Chudek JA, Foster R, Stewart WDP. 1985. Osmotic adjustment in *Spirulina platensis*. *Planta* 163:424-429.

Table 1
Absorbency read at 605 nm and mean cell size (µm) of *A. platensis* grown under different salinities.

Salinity (‰)	Absorbency at 605 nm	Mean Cell Size (µm)
0	0.021 ± 0.002	3.358 ± 0.280
10	0.022 ± 0.003	6.179 ± 1.32
20	0.025 ± 0.019	7.500 ± 0.69
28	0.309 ± 0.022	9.785 ± 0.29
32	0.527 ± 0.036	12.574 ± 0.33
36	0.417 ± 0.009	9.184 ± 0.98
45	0.364 ± 0.012	8.510 ± 1.10
50	0.348 ± 0.006	6.974 ± 2.01

9. Sánchez M, Bernal-Castillo J, Camilo R, Rodriguez S. 2003. *Spirulina (Arthrospira)*: an edible microorganism. A review. *Univ. Scient.* 8(1):2-17.

10. Ciferri O. 1983. *Spirulina*, the edible microorganism. Microbiol. Rev 47:551-578.

11. Dillion JC, Phan Phuc A, Dubacq JP. 1995. Nutritional value of the alga *Spirulina*. *In*, (AP Simpopoulos, ed). Plants in Human Nutrition. *World. Rev. Nutr. Diet.* 77:32-46.

12. Richmond A. 1988. Spriulina. *In*, (MA Borowitzka, LJ Borowitzka, eds). Microalgal Biotechnology. Cambridge University Press, Inc. UK.

13. Apte SK, Bhagwat AA. 1989. Salinity-stress-induced proteins in two nitrogen-fixing *Anabaena* strains differentially tolerant to salt. *J. Bacteriol.* 141:909-915.

14. Buck D, Smith G. 1995. Evidence for a Na^+ /H^+ elelctrogenic antiporter in an alkaliphilic cyanobacterium *Synechocystis* FEMS *Microbiol Lett.* 128:315-320.

15. Abu-Rezw TS, Al-Musallam L, Al-Shimmari J, Dias P. 1999. Optimum production conditions for different high-quality marine algae. *Hydrobiologia* 403:97-107.

16. Humm HJ, Wick SR. 1980. Introduction and guide to the marine bluegreen algae. John Wiley and Sons, Canada. pp.37-40.

17. Kay RA. 1991. Microalgae as food and supplement. *Crit. Rev. Food Sci. Nutr.* 30(6):555-573.

18. Prescott GW. 1968. The Algae: a review. Houghton Mifflin Co., Boston. p.307.

19. Sudhir P-R, Pogoryelov D, Kovács , Garab G, Murthy DS. 2005. The effects of salt stress on photosynthetic electron transport and thylakoid membrane proteins in the cyanobacterium *Spirulina platensis*. *J. Biochem. Mol. Biol.* 38(4):481-485.

20. Lu C, Vonshank A. 2002. Effects of salinity stress on photosystem II function in syanobacterial *Spirulina platensis* cells. *Physiol. Planta.* 114(3):405-413.

21. Zeng M-T, Vonshak A. 1998. Adaption of *Spirulina platensis* to salinity-stress. *Comp. Biochem. Physiol.* 120A(1):113-118.

22. Vonshank A. 1997. Appendicies. In: *Spirulina platensis* (*Arthrospira*) (A Vonshank, ed) Physiol. Cell biol. Biotechnol. London: Taylor and Francis, pp.213-216.

23. Sekar S, Subramanian G. 1999. Influence of low levels of salinity on the primary metabolism of the freshwater cyanobacterium *Phormidium* and *Nostoc*. *Rev. Brasil. Fisiol. Veg.* 11(2):83-89.

Comparing Preservatives to Increase Viability of Marine Diatoms Stored as an Algal Paste

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The marine diatoms *Chaetoceros muelleri* (*gracilis*), *Thalassiosira pseudonana*, and *C. calcitrans* were each centrifuged (1500 rpm) to form an algal paste. The preservatives consisting of a brine solution (38 $g \cdot l^{-1}$ salinity) 5.0%, a weak iodine solution 5.5% (v/v), propylene glycol (10%), and a control with the addition of no preservative were added to the paste and compared. The resuspension of pastes in 15-l carboys after 7, 15, 30, 60, 90, and 120 days of storage at 4°C were tested in triplicate. Results showed that a preservative is required for storage after 7 days, and a brine solution is effective (33%) for storage for a duration up to 90 days. Success rates of resuspension favoured the addition of a brine solution over propylene glycol and a weak iodine solution.

Introduction

The aquaculture industry relies heavily on marine algae as feedstuff for both finfish and shellfish production[1]. In algae culture operations, both stock and production lines must be maintained and require considerable resources. Conventional methods need to be established to increase efficiency in production[2]. The demand for preserved microalgae for the use of starter cultures and as a reserve is increasing[3], along with the aquaculture industry[4].

The preservation of an algal paste with the intentions of resuspension are beneficial in the commercial industry for various reasons; 1) cultures can easily be transported; 2) a variety of cultures can be stored, avoiding high maintenance costs of up-keep; 3) pastes take up little space, which is beneficial when storage is limited; and 4) the confidence that pastes are available when required on demand. Additional advantages of cryopreservation is the fact that cells do not alter through genetic drift, and there is a reduced chance of microbial contamination[5].

Frozen algae is usually mixed with glycerol or a similar substance to prevent changes in cell shape, and success appears to be species-dependant[6]. Despite the addition of glycerol, misshaping does occur and viability has been known to decrease[7]. Other commonly used preservatives include methanol (MeOH), dimethylsulphoxide (DMSO; Me_2SO)[8], brine, and iodine solutions[9].

Cryopreservation of flagellates is a more common practice as opposed to the use of diatoms; even though the combination of diatoms and flagellates is an excellent diet for marine species[10]. *Chaetoceros muelleri* can easily be spun down into an algal paste, however because of its delicate outer shell, *C. muelleri* is not commonly used as a paste[11]. This may be influenced by cell size: *Thalassiosira weissflogii* (6-20 × 8-15µm) which is commonly used by Reed Mariculture, and as is much larger than *T. pseudonana* (4-8 × 5-6 µm), *C. muelleri* (4-10 × 4-9 µm), and *C. calcitrans* (3-7µm × 4-8 µm)[12].

Materials and Methods

An axenic culture of the marine diatoms *C. muelleri*, *T. pseudonana*, and *C. calcitrans* (Coscinodiscophyceae) were individually inoculated in 150-L kalwall tubes until late-exponential phase. The cultures were then centrifuged (1500 rpm) to form the tested algal pastes. 2.0 ± 0.3 g of the paste was then aseptically added to 2-ml glass vials. A brine solution (38 $g \cdot l^{-1}$ salinity) 5.0%, a weak iodine solution 5.5% (v/v), and an analytical grade of propylene glycol (10%) were selected as preservatives. The preserved vials, along with controls (no preservative) were nitrogen-capped and stored in a refrigerator at 4°C in the dark.

After 7, 15, 30, 60, 90, and 120 days of storage, the cultures were incubated in a freshwater bath, increasing temperature from 4°C to 15°C over an 8h period before inoculation. Three replications of each preservative were resuspended in 15-l carboys with 12 l of sterilized natural seawater (31.8 $g \cdot l^{-1}$ salinity). After initial resuspension the cultures were grown under fluorescent lamps providing 40 µmol photon $m^{-2}s^{-1}$ at 16:8h light:dark photoperiod which was increased after a 48-hour time period to 120 µmol photon $m^{-2} \cdot s^{-1}$ at 24:0h. Adequate parameters were provided with a consistent temperature of 23°C, 7.8 ± 0.3 pH and F/2 (Guillard) medium. Every other day, 8.5 ml of sodium silicate (15%) was added to the cultures.

The experiment was repeated to ensure accuracy. Replications were qualitatively measured, being rated as a success with an algal bloom over a 21-day growth period. The cultures were plated on marine agar (Difco 2216) to determine whether bacteria contributed to the inability of viability. Hemocytometer readings were performed as growth occurred.

Results

Viability of *C. muelleri*, *T. pseudonana*, and *C. calcitrans* from an algal paste proved to be successful up to 60 days of storage using both iodine and brine preservatives. Propylene glycol hindered resuspension after 7 days of storage, and is therefore not a beneficial preservative for the tested diatoms. Success rates were greater in the brine solution for all three diatoms, where 100% viability was found up to 30 days of storage, and 67% of the tested replications were viable after a duration of 60 days, and 33% successful (*C. muelleri* and *C. calcitrans* only) after 90 days of storage (Fig. 1). *T. pseudonana* was not viable after 90 days.

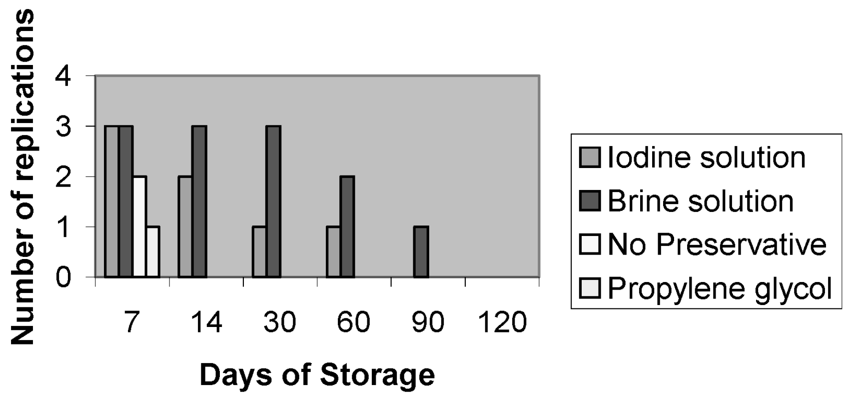

Figure 1
Average viability of the marine diatoms *C.muelleri*, *T. pseudonana*, and *C. calcitrans* comparing the additives iodine, brine, propylene glycol after being stored as an algal paste.

Repeated experimentation showed isotropous results, indicating that preservatives are required. Bacterial plating was positive for the cultures which did not have the addition of a preservative, indicating that survival was influenced by bacteria. The addition of either iodine or brine solution as a preservative is required after a 7-day storage period in order for successful resuspension in *C. muelleri*, *T. pseudonana*, and *C. calcitrans*.

Discussion and Conclusion

In order to promote viability, the addition of a preservative is required, which is similar to previous research where the addition of a cryoprotectant at 4°C for *C. minutissima* is necessary after 5 days of storage(3). Although centrifuging is supposed to reduce contamination(13), a preservative was found to completely eliminate tested bacteria. The addition of an iodine solution, is claimed to allow storage for several months(9) and is non-toxic(14); iodine preservative for the tested diatoms was only 33% successful up to 60 days. The use of a brine solution (38 $g \cdot l^{-1}$ salinity) at 5.0% (v/v), showed greatest success of viability for up to a 90 day duration. While the tested diatoms were not viable with the addition of propylene glycol, *Tetraselmis* can successfully be preserved under similar conditions(15).

Storage during this procedure was not under typical cryopreservation temperatures of -130°C(5), but kept under 4°C, which alternatively, is commonly used(12). Viability under alternate storage conditions varies within species(3), resulting in a selection of a set desirable temperature for all microalgae species is indefinite. Methods of cryopreservation have not yet been fully defined, as cell survival during thawing and freezing is not completely understood(16), alternative thawing processes may cause results to vary.

Although a brine solution (38 $g \cdot l^{-1}$) at 5.0% (v/v) showed successful viability for the diatoms *C. muelleri*, *T. pseudonana*, and *C. calcitrans*, alternative preservative concentrations may prove to be beneficial for resuspension. Variables impacting resuspension of marine algal cells do not just include preservative selection and concentration, storage duration and temperature, and cooling and thawing processes, but also initial cell phase. During cell division, in exponential phase, cells are more sensitive to freezing injury than during stationary phase(17).

Viabilities greater than 60% is a recommended protocol(17), a brine solution (38 $g \cdot l^{-1}$ salinity) 5.0% for the diatoms *C. muelleri*, *T. pseudonana*, and *C. calcitrans* stored at 4°C for 60 days is recommended for (67%) viability. A brine solution can easily be accessed and is the most economical selection for use in the commercial industry; making it a favourable substitute for diatoms over commonly used preservatives such as propylene glycol (10%).

References

1. De Pauw N, Persoone G. 1988. Micro-algae for aquaculture. In: Borowitzka MA, Borowitzka LJ (eds), *Micro-Algal Biotechnology*. Cambridge Univ. Press, Cambridge, pp.197-221.
2. Borowitzka MA 1999. Economic evaluation of microalgal proccesses and products. In: Cohen, Z. (ed), *Chemicals from Microalgae*. Taylor Francis, London, pp.387-409.
3. Tzovenis I, Triantaphyllidis G, Naihong X, Chatzinikolaiou E, Papadopoulou K, Xouri G, Tafas T. 2004. Cyropreservation of marine microalgae and potential toxicity of cyroprotectants to the primary steps of the aquacultural food chain. *Aquaculture* 230: 457-473.
4. Food and Agriculture Organization [FAO], 2000. Aquaculture Production. www.fao.orgAccessed August 2, 2005.
5. Anderson RA. 2005. *Algal Culturing Techniques*. Elsevier Academic Press. MA. pp.166-178.
6. Molina Grima E, Sánchez Pérez, JA, García Camacho F, Acién Fernández FG, Lopez Alonzo D, Segura del Castillo CI. 1994. Preservation of the marine microalga, *Isochrysis galbana*: influence on the fatty acid profile. *Aquaculture* 123: 377-385.
7. Babarro JM, Fernández Reiriz MJ, Labarta U. 2001. Influence of preservation techniques and freezing storage time on biochemical composition and spectrum of fatty acids of *Isochrysis galbana* clone T-ISO. *Aquacult. Res.* 32(7): 565-569.
8. Taylor R, Fletcher RL. 1998. Cryopreservation and of eukaryotic algae- a review of methodologies. *J. Appl. Phycol.* 10:481-501.
9. Castagna M, Gibbons MC, Kurkowski K. 1996. p. 680, *In*, *The Eastern Oyster Crassostrea virginica* (VS Kennedy, RIE Newell, AF Eble, eds) Maryland Sea Grant College, Maryland.
10. Lavens P, Sorgeloos P. 1996. *Manual on the Production and use of Live Food for Aquaculture*. Food and Agriculture Organization (FAO) of the United Nations.
11. Reed R. 2005. Reed Mariculture. Pers. Comm., June 3, 2005.
12. Reed Mariculture. n.d.. Home page. *www.reed-mariculture.com* Accessed April 28, 2005.
13. Jones GG, Sanford CL, Jones BL. 1993. Manila Clams: Hatchery and Nursery Methods. p. 25. Innovative Aquaculture Products Ltd.
14. Sanford C. 2005. Innovative Aquaculture Products. Pers. Comm., July 15, 2005.
15. Day JG, Fenwick C. 1993. Cryopreservation of members of the genus *Tetraselmis* used in aquaculture *Aquaculture* 118:151-60.
16. Baust JM. 2002. Molecular mechanisms of cellular demise associated with cyropreservation failure. *Cell Preserv. Technol*. 1:17-31.
17. Morris GJ. 1981. Cryopreservation: An Introduction to Cryopreservation in Culture Collections. p. 27 Institute of Terrestrial Ecology, Cambridge.

The Potential for Public Participation GIS as a 'Push' Technology for Disseminating Aquaculture Information to Stakeholders

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One of the major barriers to community acceptance of the aquaculture industry is a transparent decision-making process, which includes an effective methodology for stakeholder consultation. Currently much of the relevant, publicly accessible information is available only on request. This assumes that the public is knowledgeable in the type of information available, and where to obtain it. Transparency in the regulatory processes can be increased through 'push' technologies, whereby the public is provided with information without a specific request. One such technology may be Geographic Information Systems (GIS). The use of GIS for the dissemination of aquaculture information is still being developed in Canada, with both British Columbia and Nova Scotia implementing such technology to varying extents. Both systems can be improved by including additional information and incorporating a public consultation aspect through an emerging technology known as Public Participation GIS. This technology not only permits information dissemination, but also provides a forum for individuals to express their concerns and contribute information and observations to the decision-making process. There are limitations to this technology, however, including an inherent distrust some stakeholders may have in the system. Other limitations include errors in the information provided by stakeholders, privacy protection, and data ownership.

Introduction

Despite the potential economic and social benefits of aquaculture, the practice of fish farming is of great concern to some stakeholders. This concern is founded upon a perception that aquaculture has the potential to detrimentally impact the marine environment and other coastal users. Insufficient transparency in government-industry relations contributes to the stigma surrounding aquaculture, with a lack of information and appropriate public participation in decision-making garnering distrust towards the industry. This paper highlights the importance of public participation, and identifies some of the major areas of federal and provincial policy where transparency and public participation is lacking. The concept of 'push' technologies is introduced as a solution to the transparency issue, with Public Participation Geographic Information Systems (PPGIS) being one method of utilising this proactive approach. The limitations of further information provision and PPGIS are then explored. This paper is part of a larger research project focussing on improving perceptions of the aquaculture industry through better information management and planning processes.

The Importance of Public Participation

It has been proven time and again that public consultation is crucial to preventing stakeholder conflict. Such disputes may impede development and increase the cost of projects through lost construction/operation time and legal proceedings. There are varying levels of public consultation ranging from evasion, the least participatory, to full empowerment at the top. This is illustrated through the ladder of public participation[1], as shown in Figure 1.

Transparency in Government Policy and Consultation Processes

Fisheries and Oceans Canada (DFO) states that it is committed to ensuring transparency within the aquaculture industry and promoting two-way communication between all stakeholders, as identified by Principles 2 and 3 of its Aquaculture Policy Framework[2].

Principle 2: "DFO will address issues of public concern in a fair and transparent manner, based on science and risk-management approaches endorsed by the Government of Canada".

Principle 3: "DFO will communicate with Canadians and be informed by their views on issues pertaining to aquaculture development".

Despite these commitments, public participation in the industry remains a confusing process to many stakeholders both during site assessment and operation. Under CEAA (Canadian Environmental Assessment Agency) public consultation is mandatory for all site assessments, however this requirement is limited to the placement of two advertisements in two local newspapers and notification of upland neighbours within 100 metres of a site. Provincial requirements are generally similarly limited in scope and while the responsible authorities may request more public input and many proponents choose to engage stakeholders in further consultation, it remains a confusing and inconsistent process from the perspective of the general public. Ultimately the process falls on the fourth rung of the Public Participation Ladder (Fig. 1), allowing the public to object, but in most cases not permitting further participation in finding solutions.

Figure 1
Ladder of public participation[(1)].

The availability and accuracy of information is one of the main transparency issues. Annual environmental monitoring is required by Provincial Government regulations, however industry is reluctant to release this information to the public due to fears that it will be misinterpreted. In the 2003/2004 DELG (Department of Environment and Local Government, New Brunswick) Annual Report, and it was detailed that annual monitoring revealed 33 hypoxic sites and 2 anoxic sites[(3)]. However, confidentiality requirements prevent the individual sites from being identified[(4)] leaving concerned individuals to question the health of all aquaculture sites. In contrast, all annual monitoring information in British Columbia is publicly disclosed through the Ministry of Agriculture and Lands website[(5)].

Improving Transparency through Proactive Information Provision

'Push' technology is a term used most prevalently to indicate information that is made available without a specific request. This proactive information dissemination technique is being seen more prevalently in today's increasingly transparent stakeholder consultation environment as it encourages the perception that the information provider is being transparent. The current climate of aquaculture information provision is largely based on 'pull' technology, where interested members of the public must first understand what data is available, and then seek out the information. British Columbia, on the other hand, is far more proactive in their information provision, as demonstrated by their Coastal Resource Information System[(6)], an online web-based Geographic Information System (GIS). While GIS is an excellent tool for disseminating information it remains a one-way communication device, as the public has no means to comment on or question the presented data. An emerging technology known as Public Participation GIS (PPGIS) is working to change this by permitting a two-way exchange of information.

Public Participation Geographic Information Systems

Public Participation GIS cannot be defined by one application, but should be viewed as a system or concept involving stakeholders in a decision making process through the use of GIS. It is a tool that communicates information to participants, as well as incorporating user feedback and information, thus ensuring two-way communication between the GIS provider and participants. This capability ensures the consultation process is higher on the public participation ladder (Fig. 1). While remote access is not required, this capability is likely to raise involvement and increase the flexibility of the tool.

British Columbia and Nova Scotia already have geographic information tools that allow queries related to aquaculture to be addressed, while New Brunswick is currently designing its own. The present GIS application in British Columbia is the most extensive aquaculture information dissemination tool in Canada, and already encompasses some public participation characteristics, as illustrated in Figure 2.

It is recommended that this system be used as a model for other provinces in the development of similar information dissemination tools. This product should still be improved, however, to incorporate two-way communication between stakeholders. This may be achieved through an online discussion forum, which would allow real-time discussion between stakeholders. This would permit concerned stakeholders to voice their concerns in real-time rather than waiting until an appropriate public forum. It would also allow regulators and industry to be aware of stakeholder concerns so that these may be addressed quickly, which is particularly important if the concerns are based on misinformation.

Limitations of PPGIS and Further Information Provision

1. Information relevance, privacy, and liability

One of the key problems with providing information is the danger of misinterpretation or extrapolation. This is particularly problematic where scientific information is concerned, as many members of the general public are not well versed in scientific methodologies and may not understand the provided information, to the detriment of the industry. There is another school of thought that states that the public should appreciate that the aquaculture industry is well regulated and place their trust in the Government to ensure that the appropriate measures are taken under the precautionary principle. The lack of transparency in this approach is likely to be of concern to some members of the public, and garner distrust. Of course, not all information should be publicly available. Aquaculture is a business, and should not be held to unreasonable standards that could compromise their operations[(7)]. Aquaculture must be compared to similar commercial ventures to evaluate the present privacy protections. Privacy protection in New Brunswick, where industry financial records are kept confidential even from the provincial govern-

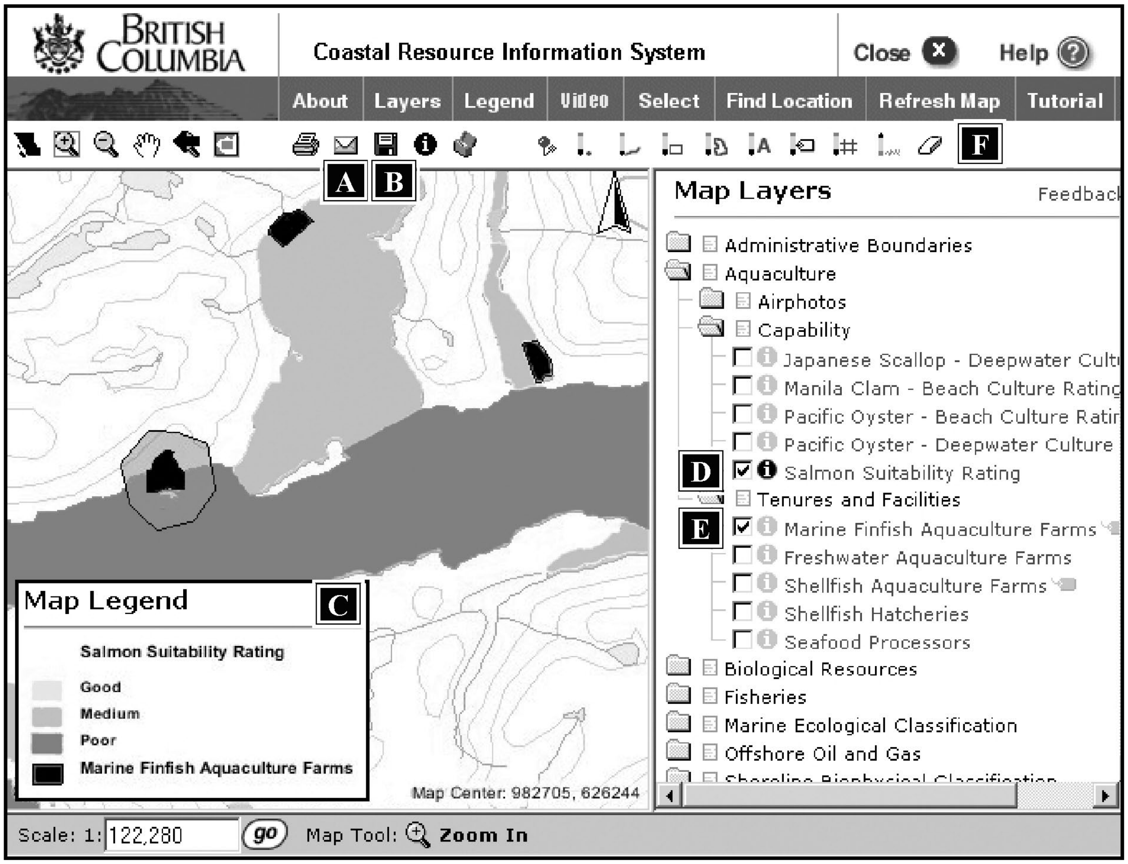

Figure 2
British Columbia's Coastal Resource Information System[5]. Features include:

A: The map may be emailed as an PDF document with attached comments. This capability allows specific scientific and geographic information to be communicated remotely with little technical knowledge. For example a concerned lobster fisher may contact DFO in regard to an aquaculture site they believe is in an unsuitable location, as shown here (see the circled finfish farm), and incorporate all the identifying details for a faster response by the government official.
B: The current map view, settings and annotations may be saved as a link and emailed.
C: A legend is provided for all displayed layers.
D: A 'Salmon Suitability Rating' is assigned to most of the larger water bodies in this region of BC. This rating, previously determined by DFO, is one example of a layer of geographic information that may be utilized in conjunction with another layer, such as salmon farms. The circled finfish farm in this diagram is situated in a region deemed poor for salmon farming.
E: This option provides information about selected aquaculture sites including company name, legal description, geographic coordinates, area, tenure status and relevant file numbers (details not shown).
F: A range of annotation tools is available to add text and shapes to the map so as to communicate issues or concerns.

ment[8], is certainly greater than in British Columbia. This extreme privacy protection may be of some concern given the Auditor General's assessment that the protections prevent communication of important site information even between government departments[4].

2. Data ownership

Data ownership is a consideration in any information provision. Information and data provided by sources external to the information provider may be subject to copyright or may be in proprietary formats. Examples include government data collected by other agencies, such as the Canadian Hydrographic Service, or information collected by the proponent for annual environmental monitoring. Information collection is expensive, and providing such information free of charge with the potential for misuse by third parties may not be appropriate.

3. Errors in community information

The recommended online forum for discussion of aquaculture sites raises the potential for errors to be made by the public. Such errors may be misinterpretation, exaggeration, or fabrication, and may occur in an attempt to sway the decision makers' opinions, or simply to subvert the process. Information may also be erroneous due to a lack of education or understanding about a situation. Errors of this nature are more easily detected, however they slow down the decision making process.

Conclusions and Recommendations

The issue of transparency in Canada's aquaculture industry is very important and must be addressed. This paper recommends that 'push' technology be used to proactively convey relevant information to stakeholders, and that PPGIS would be a beneficial tool, particularly as basic GIS products are already being developed in three of the provinces with large aquaculture industries. It is recommended that the GIS product currently being developed in British Columbia be used as a model and improved to incorporate an online discussion forum to attract further stakeholder input. Further investigation must be undertaken to ascertain the information needs of all stakeholders. However, a balance must be struck between the public desire for information and the privacy needs of industry.

This paper forms part of a larger research project to investigate ways in which the public perception of aquaculture can be improved through better information management, planning and public consultation.

References

1. Weiner D, Harris TM, Craig WJ. 2002. Community participation and geographic information systems. pp.3-16, *In*, *Community Participation and Geographic Information Systems* (WJ Craig, TM Harris, D Weaver, eds), Taylor and Francis, NY.

2. Fisheries and Oceans Canada [DFO]. 2002. *DFO's Aquaculture Policy Framework*, Communications Branch, Ottawa, ON.

3. New Brunswick, Department of Environment and Local Government [NB DELG]. 2004. 2003-2004 Annual Report - Department of the Environment and Local Government. *www.gnb.ca/009/0374/0008/0001.pdf*. Accessed June 15, 2005.

4. Fraser S, Gélinas J, Strelioff W, Wilson D. 2004. *Salmon Stocks, Habitat, and Aquaculture*. Report of the Auditor General, Office of the Auditor General of Canada, Ottawa, ON. *www.gnb.ca/oag-bvg/2004v1/agrepe.pdf*. Accessed December 16, 2004.

5. British Columbia, Ministry of Agriculture and Lands [BC MAL]. 2005. *4th Annual Inspection Report on Marine Finfish Aquaculture Sites (2003)*. Government of British Columbia, Victoria. *www.agf.gov.bc.ca/fisheries/aqua_report/index.htm*. Accessed June 20, 2005.

6. British Columbia, Land Information B.C. 2005. *Coastal Resource Information Management System*, Ministry of Environment, Government of British Columbia, Victoria. *srmwww.gov.bc.ca/dss/coastal/crimsindex.htm*. Accessed June 19, 2005.

7. Smith J., New Brunswick Salmon Growers Association, personal communication.

8. *Aquaculture Act*, S.N.B. [1988]

Mitigating Fisheries and Aquaculture Interactions: A Case Study Involving Salmon and Mussel Farms in New Brunswick and Newfoundland and their Impact on Lobster Fishing

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The majority of present day multi-use conflicts result from concerns of lobster fishers on the potential loss of habitat from new farm sites, although there is little empirical evidence in support of this notion. The objectives of the present study were 1) to examine the relationship between aquaculture and lobster landings in Atlantic Canada, 2) to determine if salmon feed affects lobster feeding behaviour, and 3) to determine if there are long term effects on lobster habitat from aquaculture. The results show that, in spite of 25 years of commercial fish farming, lobster landings are at historical high levels, particularly in areas with active fish and shellfish farm sites. Lobsters avoided commercial feed pellets in feeding trials suggesting salmon farms do not contribute to "baiting" of fishing grounds. New Brunswick fishermen were negative towards aquaculture and were concerned with crowding of fishing areas, yet they have not seen declines in their catch rates in the farming areas. In contrast, Newfoundland harvesters generally supported aquaculture, stating that it has helped conserve lobster habitat and prevented poaching. In conclusion, there is little evidence of long-term deleterious impacts of aquaculture farms on lobster habitat. Moreover, stakeholder consultations in advance of development will greatly reduce the potential for fisheries and aquaculture interactions.

Introduction

Aquaculture is practiced worldwide and utilizes a variety of technologies. Potential sites for aquaculture can range from the open sea to coastal impoundments to privately owned ponds or enclosed tanks[1]. Conflicts over space may arise between the more established activities, such as traditional fisheries, and aquaculture. There are five basic categories of potential conflicts: land/water property rights, traditional uses (fishing), recreation and navigation, compatibility with natural resource systems (wetlands), and species conflicts (exotic or genetically engineered species)[1].

Conflicts between modern aquaculture industries and existing users of the marine environment are not unusual[2,3]. The major problem for aquaculture is that it must compete with many other groups for resources, and these are considered social risks to aquaculture production[3,4].

The inconsistencies and differences in regulations and management have been problematic[3]. Benefits have also been noted between aquaculture and fisheries co-existing in the marine environment. One example is the herring fisheries that co-exist with aquaculture, as herring is a major ingredient in prepared foods for the salmonid culture. The aquaculture industry offers potential employment diversification for members of the traditional fisheries and together they provide stronger justification for improved facilities and services[3].

The majority of potential multi-use conflicts in Atlantic Canada at present result from concerns of lobster fishers regarding the potential of loss of habitat from new culture sites[5]. One of the underlying assumptions made by fishers is that lobster habitat will be reduced and that catch rates will decline, but there is little empirical evidence to support either these opinions.

The problem raised by some of the lobster fisheries is that most of the conflict statements are based on anecdotal and preliminary findings. These conflict statements are in relation to environmental impacts of aquaculture on lobster habitat (destruction) below the sites from the excess feed and faeces produced leading to organic pollution[6]. In contrast, there have been statements by some fishermen in Atlantic Canada that there is an increase in lobster populations since aquaculture has developed, and vice-versa. The complaints include the lobsters feeding on the leftover salmon pellets thereby decreasing their catchability; lobsters eating the pellet feed and no longer attracted to the bait. However, in mussel farming areas, fishermen report increased lobster catches near and beneath sites (unpublished observations). Therefore, there seems to be no general consensus on the impact of aquaculture sites on lobster fisheries habitat and impacts.

The importance of the present study towards aquaculture is that it may help better determine where farms should be sited, as well as answer questions lobster fishermen may have about the site affecting their lobster fishing areas. This may lead to better understanding of aquaculture interactions including any mitigation steps or beneficial factors aquaculture may have towards the fishery.

Objectives of the Study

1) Examine the relationship between aquaculture, both finfish and shellfish, and lobster landings in Atlantic Canada.

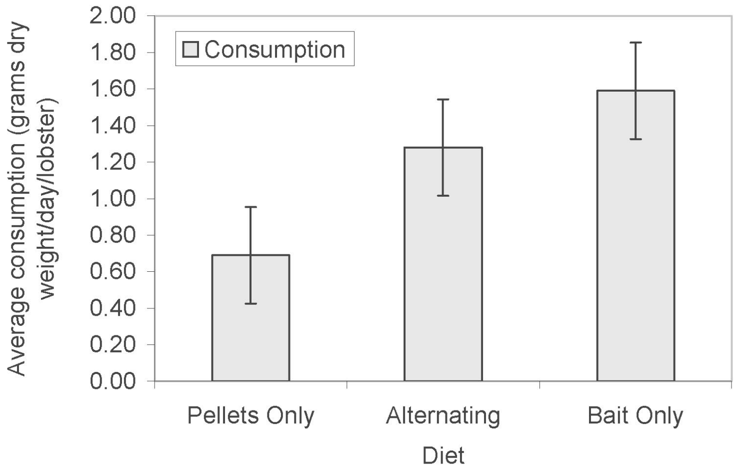

Figure 1
Average daily consumption per lobster for each treatment over six weeks. Bar represents x ± SD, *n*=216.

2) Examine if aquaculture sites have affected the catch rates of lobsters, and if lobsters consume salmon pellets and turn away from natural feed.
3) Determine if there are long term effects on lobster habitats from aquaculture.

Materials and Methods

Study 1 – Examination of historical fisheries and aquaculture production

Capture data and aquaculture production figures were obtained from Department of Fisheries and Oceans (DFO) stock status reports, Statistics Canada, and DFO lobster biologists[7-11].

Study 2 – Interviews with fishermen in New Brunswick and Newfoundland

Personal interviews with lobster fishers in various locations in New Brunswick (NB) and Newfoundland and Labrador (NL) were undertaken in person. An objective questionnaire was prepared for the interviews.

Study 3 – Lobster feeding trials

Bay of Fundy lobsters (~500 g each; Dipper Harbour, NB) were obtained fresh and kept at 6°C and 29-32 ppt salinity at the Marine Institute in recirculating holding facilities.

Diets consisted of either 8-mm commercial salmon pellet or bait (combination of cod, smelt, and squid) and were fed in the following treatment combinations: (1) ~ 6 weeks lobster fed salmon pellets only, (2) ~ lobster fed 2 weeks bait, 2 weeks pellet, 2 weeks bait, (3) ~ 6 weeks lobsters fed bait only.

Lobster feed consumption (g dry weight) and behaviour were monitored daily (*n*=12 individuals per treatment)

Results and Discussion

Lobster landings increased in parallel with salmon and mussel production in both NB and NL aquaculture zones. Lobster landings are at all time record high levels in both salmon and mussel aquaculture zones.

Feeding trials indicated lobsters do not like the salmon pellets. They prefer a varied diet of seafood. Salmon pellets were consumed initially during week one, but at a low rate, followed by a drastic decline in consumption rates thereafter (Fig. 1).

Major variations in harvester opinions on aquaculture were observed between NB and NL (Table 1). The NB aquaculture industry has been around for years and the opinions from lobster fishermen were negative. Newfoundland harvesters have the opposite opinion and they think aquaculture is good, as long as they are consulted in advance. In general NL harvesters cited aquaculture as providing employment, rural support, and habitat protection.

The views on what impacts lobster habitat were different. New Brunswick opinion was that aquaculture destroyed lobster habitat, though landings had gone up in the farm areas. In NL, draggers were the main concern for the destruction of lobster habitat, and farms were seen as "protecting" lobster habitat and preventing poaching. In both provinces there were concerns about long term effects from aquaculture on habitat, especially if not done in a sustainable and environmentally friendly manner, including sufficient time for fallowing.

Conclusions

In conclusion, lobster landings are higher than ever, in both provinces in areas with active aquaculture farm site development. Aquaculture production is also increasing illustrating that aquaculture does not appear to have a negative effect on lobster catch rates. No effects are seen on catch rates but some displacement of fishing grounds may occur with the placement of aquaculture sites, but the overall abundance of lobster's masks any potential effects at present. Impacts are relatively minimal, if practices of good husbandry, site selection and fallowing occur and industry continues to operate best practices.

Site impact data should be more readily available to locals in New Brunswick because what occurred in the past and what occurs in aquaculture today are drastically different. Unfortunately, opinions are formed for whatever purpose and happen to persist more than 10+ years and those images and perceptions stay within small communities. Aquaculture companies need to be open with what goes on how they select sites, in consultation with local communities, and if unsure about such things as lob-

Table 1
General comments obtained during surveys of lobster fishers in salmon and mussel farming zones.

General Comments on aquaculture effects	NB (n=5)	NL (n=7)
Displacement of lobster fishing area	5	1
Distribution of lobsters affected	5	1
Initial abundance of lobsters affected	5	0
Decrease in vicinity after a year of farming	5	0
Observed no change or an increase in lobsters	0	6
Wooden traps smell and “mud” covered	5	1
Lobsters smell around site	2	0
Do not like aquaculture	5	1
Like aquaculture	0	6
More poaching near sites	5	0
Reduced poaching near sites	0	6
Managed differently would have different opinion	3	1
Site selection poor (without consultation)	5	1
Site selection good (with consultation)	0	6
Too many cages in one area	5	0
Crowding fishing areas	5	0
Harder to catch lobsters in aquaculture areas	5	1
Concern for sufficient habitat for lobsters	5	6
Concerns related to scallop draggers destroying lobster habitat	0	5
Effluent worries if site not fallowed	5	1
Encouraged aquaculture development	0	6
Good for employment	5	7
Worried about younger generation fishing lobsters	5	0
Concerns for future as feeding increases	5	2

ster breeding grounds, some of the best people to ask are the local fishers who know the area the best.

It is obvious that lobsters do not like feed pellets; therefore, they may move away from a farm site to find a variety of food. They don’t like to eat the pellets and from the trials they do not want to be around them as they kept pushing them to the other side of the basket. Improved management to reduce accumulation including site fallowing are important practices the industry is undertaking to minimize and mitigate possible impacts. Certainly it is unlikely that farm feed pellets result in “baited” grounds, as speculated by some fishers.

In spite of nearly three decades of farm production in New Brunswick, there is little substantial evidence of long-term deleterious impacts on lobster habitat. Careful siting and good management practices likely minimize any potential impacts and lingering negative opinions on aquaculture are probably from unrestricted development nearly 20 years ago. Today’s environment is much more stringently regulated with careful considerations are given to habitat effects at all times by fish farms.

With more communication between industry and locals, especially those who fish, both can be sustainable in an area and both can co-exist quite readily. Impacts are relatively benign from a fish farm if good husbandry, site selection, and fallowing are practiced.

Acknowledgements

We thank Alistair Struthers for help in aquaculture facility. Thank you to Ron Mawhinney for supplying the lobsters to run the trials and for setting up the meetings with fishermen in New Brunswick. To all the fishermen who agreed to be interviewed, thank you for your time. Thank you to Terry Fleet, Department of Fisheries and Oceans Habitat for partial financial support. Thanks to DFO Scientists Geoff Perry, Peter Lawton, David Robichaud, and Susan Waddy for the discussions on lobster feeding and habitat. Thank you also to Audrey Butt, Tasha Hynes, and Ryan Legge who assisted with trials.

References

1. DeVoe MR, Pomeroy R. 1992.Use conflicts in aquaculture: a worldwide perspective on issues and solutions. *World Aquaculture* 23(2):13.
2. Millar C, Aiken DE. 1995. Conflict resolution. pp.617-647, *In, Cold-water Aquaculture in Atlantic Canada* (AD Boghen, ed), Print Atlantic, Moncton, NB.
3. Stephenson RL. 1990. Multiuse conflicts. *World Aquacult.* 21(2):34-45.
4. Walters BB. 2005. Interactions between salmon farming and lobster fishing in the Bay of Fundy, New Brunswick. Mount Allison University (Unpublished manuscript).
5. Perry G, Department of Fisheries and Oceans, pers. comm.
6. Pohle G, Frost B, Findlay R. 2001. Assessment of regional benthic impact of salmon mariculture within the Letang Inlet, Bay of Fundy. *J. Mar. Sci.* 58:417-426.
7. Lawton P, St. Andrews Biological Station, pers. comm.
8. Robichaud D, Department of Fisheries and Oceans, pers. comm.
9. Lawton P, Robichaud DA, Strong MB, Pezzack DS, Frail CF. 2001. Spatial and temporal trends in the American lobster, *Homarus americanus*, fishery in the Bay of Fundy (Lobster Fishing Areas 35, 36, and 38). Canadian Science Advisory Secretariat, Research Document 2001/094. Available online at *www.dfo-mpo.gc.ca/csas*.
10. Ennis GP, Collins PW, Badcock GD, Collins RK. 2003. An update on the Newfoundland lobster fishery and its recent management. Canadian Science Advisory Secretariat, Research Document 2003/036. Available online at *www.dfo-mpo.gc.ca/csas*.
11. Smith JS, Tremblay MJ. 2003. Fishery-independent trap surveys of lobsters (*Homarus americanus*): design considerations. *Fish. Res.* 62:65-75.

Applying GIS and the Analytic Hierarchy Process on Seafarming Spatial Assessments in the Magdalen Islands (Quebec, Canada)

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The aquaculture industry continues to grow worldwide. In the Magdalen Islands seafarming started in the 1980s and experienced significant growth in the last decade in terms of production and added value. According to integrated environmental management and planning, sustainable development in aquaculture can be ensured through a rigorous evaluation of the seafarming potential in the available areas. Appropriate farming site choices is a key factor that may substantially affect the ecological and economical viability of an aquaculture project. Therefore, it is of great importance to develop an adequate space evaluation/allocation system. In the present study, we looked at suspended blue mussel and giant scallop farming, as well as giant scallop and softshell clam seeding activities in the Magdalen Islands. Site assessment was based on a geographical information system (GIS) coupled to an analytic hierarchy process (AHP). The GIS allowed precise site positioning, while AHP enabled qualitative and quantitative aspects to be included in the evaluation process. The combination of these two approaches appears to be an interesting aid in determining likely seafarming potential of available areas.

Introduction

The aquaculture industry has been steadily growing on a global scale for about thirty years. In the Magdalen Islands first attempts of shellfish farming were carried out in the early 1980s, although only in the last decade a sustained growth occurred in terms of biomass and added value(1). Local shellfish farming focuses on blue mussels (*Mytilus edulis*), sea scallops (*Placopecten magellanicus*) and soft-shell clams (*Mya arenaria*). Exception made for offshore scallop seeding activities, seafarming had been taken place mainly within the lagoons of the archipelago. However, lagoons represent a spatial limit for aquaculture further development that may occur in future years. Offshore seafarming may represent an alternative to such a spatial limitation. In this regard, some small-scale experimental mussel farming activities are carried out since three years in an offshore area to east of the Magdalen Islands(2).

Although offshore seafarming may represent an interesting avenue for the local economy, future seafarming expansion should rely on sustainable development principles in order to preserve the natural resources engaged as well as other potentially conflicting human activities (e.g., fisheries, recreational tourism, navigation). For this purpose, it is of great importance to develop and apply a rigorous methodological approach for seafarming potential assessments in the areas under scrutiny. In this regard, Kapetsky et al.(3) successfully combined two different techniques applied to a large spatial scale study: (i) a geographical information system (GIS) as a support for spatial positioning and (ii) the analytic hierarchy process (AHP) developed by Saaty(4,5) for sectorial assessments.

The main objective of our study was to provide decision-support information for shellfish farming development in the Magdalen Islands, including suspended farming techniques (blue mussels and sea scallops) and seeding activities (sea scallops and soft-shell clams). This was achieved by coupling GIS and AHP techniques in order to (1) identify sectors with seafarming potential, and (2) provide a qualitative characterisation for each of them. Our study aimed lagoon and offshore areas. However, for space constraints we present here results concerning only the suspended shellfish farming potential assessment in the offshore areas.

Materials and Methods

Study area

The Magdalen Islands are situated in the southwestern area of the St. Lawrence gulf between meridians 61°09'18" and 61°11'18" W, and parallels 47°12'36" and 47°51'00" N. Seven islands linked to each other by sand dunes enclosing lagoons represent the main core of the archipelago. This paper focuses on the offshore marine areas surrounding the archipelago and extending from the coastline to the 50-m isobaths (total surface = 8300 km^2).

Analytical approach

The ArcView software was used as a GIS support for the analytic hierarchy process (AHP) developed by Saaty(4,5). The AHP was employed for assessing the level of appropriateness for shellfish farming of a given spatial sector. The global analytical approach included a five-step process summarized here below:

1. Identifying and mapping the exclusion areas by defining constraints for seafarming.

2. Selecting the evaluation criteria through interviews to experts and literature review.
3. Weighing the evaluation criteria through further interviews to experts.
4. Scaling the evaluation criteria in order to reflect a verbal judgement according to their numerical values.
5. Building a map showing the levels of appropriateness for the different sectors.

Three main types of constraints were applied for defining exclusion areas, i.e. biophysical (e.g., ice cover and water depth), statutory-related (e.g., navigation routes and sea-bottom cable lines), and use conflicts (e.g., fishing areas and recreational tourism). Eight evaluation criteria were selected for sector assessments: water temperature range, salinity, food availability (i.e., chlorophyll and seston concentrations), current velocity, bathymetry, substrate type, distance from homeport, and ice cover-free period (months/year). Importance of each criterion was weighed through interviews to experts (sea-farmers and researchers) that were asked to choose among multiple pairwise comparisons (i.e., multiple Boolean choices). Respondents had to assess the importance of one criterion over another on a scale of 9, enabling authors to determine weighing coefficients ranging between 0 (least important) and 1 (most important). The latter were subsequently combined with evaluation criteria into an appropriateness scale of four levels: (1) inappropriate, (2) moderately appropriate, (3) appropriate, and (4) very appropriate. Weighing coefficient and appropriateness levels were then combined in order to obtain an assessment index (with a same scale of four levels as for the appropriateness scale) for each evaluation criterion applied to assess the different sectors. Finally, assessment indices were used for building a map identifying the different sectors by their level of appropriateness for mussel and scallop suspended farming.

It is important to mention that this study was based on existing environmental variables data selected as evaluation criteria. However, for some areas such data were incomplete or deficient for a precise environmental assessment. Empirical knowledge gathered from local fishermen and other marine operators was then applied. This allowed authors to assess those areas within a range of two levels of appropriateness. According to this problem, the authors recommend that additional field investigations should be carried out prior to any seafarming development in such areas.

Results

Evaluation criteria

Weighing coefficients rankings were similar for the two studied species, blue mussels and sea scallops, although their numerical values were somehow different (Table 1). Top ranking criteria were food availability, temperature and ice cover-free periods. It is worth noting that “distance from homeport” was ranked among the least important criteria. This is explained by the interviewed sea-farmers who affirmed that distance is not a main concern if economically profitable farming is proved to be possible at a relatively significant distance from the coast.

Seafarming potential evaluation

Exclusion areas accounted for 56% of the study area (Fig. 1). In the northwestern side of the archipelago exclusion was mainly due to the occurrence of a thick and drifting ice cover over an extended wintertime period, as well as to the presence of lobster fishing areas. In the southern areas, exclusion was mostly due to strong water currents and to navigation routes. Few exclusion areas, mostly corresponding to lobster fishing areas, were present in the eastern part of the archipelago.

The GIS-AHP combined approach showed that 2.9% (23 971 ha) of the total study area would be appropriate for suspended shellfish farming activities, while 7.4% (61 586 ha) and 4.9 % (48 679 ha) would be moderately appropriate and inappropriate, respectively. For the southeastern sector (SE in Fig. 1) (28%; 234 175 ha) there was limited information on some environmental variables underlying the evaluation criteria. This introduced a certain level of uncertainty in the analytical procedure leading to an assessment index lying between moderately appropriate and inappropriate levels.

Discussion

The present paper reports on the scallop and mussel suspended farming potential in the offshore areas of the Magdalen Islands. This study is part of a broader one focusing also on local lagoon habitats as well as on other shellfish species and farming techniques, namely scallop and clam seeding.

Exception made for offshore scallop seeding activities, seafarming in the Magdalen Islands is presently restricted to lagoons and occupies a total surface of approximately 450 ha. This study showed that suspended shellfish farming surface might theoretically be increased to at least 23 971 ha (i.e., sectors defined as appropriate) if offshore areas were used. Moreover, the experimental mussel farming production that had been taken place since three years in the eastern offshore area[(2)] provided mussels of superior quality compared to the lagoon habitats.

Water temperature represents another advantage in extending shellfish farming to offshore areas. Since the mid 1990s, summertime water temperature maximums in the lagoons tended to

Table 1
Weighing coefficients (WC) estimated for the selected environmental evaluation criteria for blue mussel and sea scallop suspended seafarming.

Blue mussel	WC	Sea scallop	WC
Food availability	0.175	Food availability	0.271
Temperature	0.175	Temperature	0.175
Ice cover-free period (months /year)	0.146	Ice cover-free period (months /year)	0.147
Bathymetry	0.115	Salinity	0.135
Currents velocity	0.106	Bathymetry	0.131
Distance from homeport	0.104	Currents velocity	0.066
Substrate type	0.097	Distance from homeport	0.050
Salinity	0.083	Substrate type	0.025

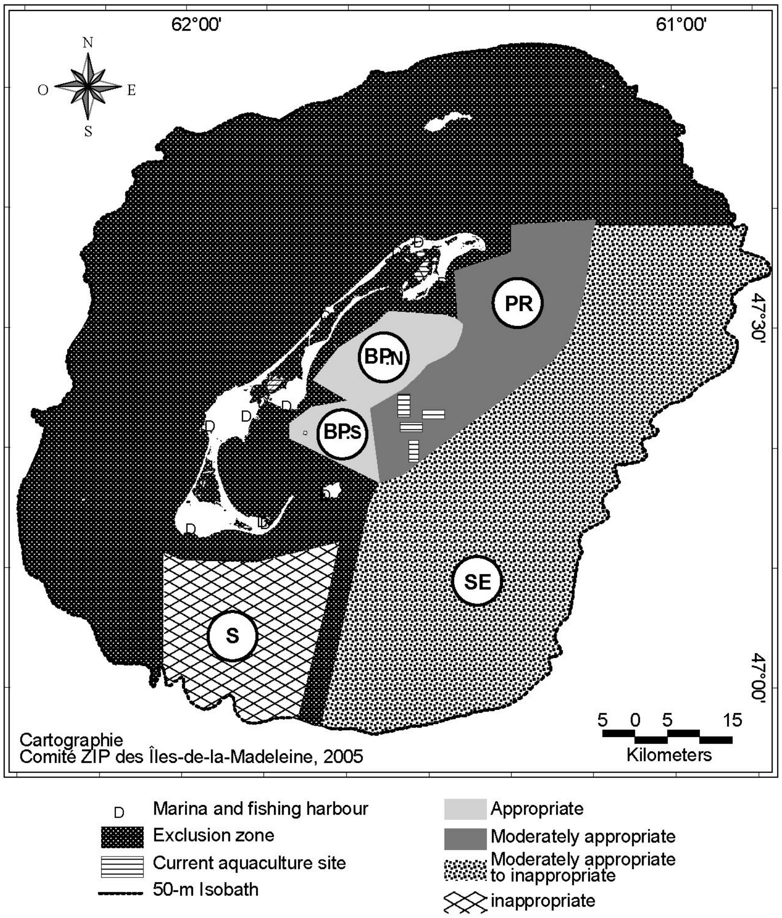

Figure 1
Offshore sectors surrounding the Magdalen Islands and defined by their corresponding assessment index for suspended shellfish farming potential. Exception made for exclusion zones (dark), sectors are identified by symbols referring to current toponomy, i.e.: PR (Pearl Reaf), BP_S (Baie de Plaisance – South), BP_N (Baie de Plaisance – North), SE (Southeast), S (South).

increase from 18-20°C to 20-23°C (Tita, unpublished), thereby increasingly approaching tolerance levels for both bivalve species (~24°C). Approaching physiologically critical temperatures may reduce shellfish productivity and increase summer massive mortalities(6). By contrast, open seawater temperature rarely goes above 18°C, which represents an optimal thermic environment for blue mussel and sea scallop.

Of course, such considerations suggest that offshore shellfish farming may represent a very interesting avenue for the local economy. However, in order to ensure a sustainable development of such an industry, the planning of this land use should include environmental carrying capacity aspects and studies. This is particularly important if one considers the size of the concerned sectors as well as the main local industry; i.e., coastal fisheries.

As a conclusion, we wish emphasizing that the combined GIS-AHP techniques revealed to be an effective approach to assess seafarming potential at a local scale. The main advantage of this approach is that all available information, although dispersed, may be cost-effectively integrated into maps and assessment indices that may be useful aids for coastal zones environmental management. This approach is also sufficiently flexible to allow empirical knowledge to be successfully integrated into the analytical process.

Acknowledgements

The authors wish to thank the numerous people who were consulted for the present study, particularly the staff of the Station technologique maricole des Îles-de-la-Madeleine (MAPAQ), as well as the sea-farmers in the Magdalen Islands. A special thank goes to the collaborators from the Comité ZIP des Îles-de-la-Madeleine for their help with GIS techniques, and to the several collaborators from the Department of Fisheries and Oceans Canada. Funding was provided by Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ), Société de développement de l'industrie maricole (SODIM), Fondation communautaire Gaspésie-Les Îles, Centre local de développement (CLD-IDM), and Société d'aide au développement des collectivités (SADC).

References

1. Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec [MAPAQ]. 2005. *www.mapaq.gouv.qc.ca/Fr/Peche/md/statistiques*. Accessed August 18, 2005.
2. Bourque F, Myrand B, Tita G. 2005. Open-sea culture of mussels (*Mytilus edulis*) in Îles-de-la-Madeleine: a promising avenue. *AAC Spec. Publ*. 9:56-59.
3. Kapetsky JM, McGregor L, Herbert NE. 1987. A geographical information system and satellite remote sensing to plan for aquaculture development: a FAO-UNEP/GRID cooperative study in Costa Rica. *FAO Fish. Tech. Pap.* No.287, FAO, Rome, p.51.
4. Saaty TL. 1977. A scaling method for priorities in hierarchical structure. *J. Math. Physiol.* 15:234-81.
5. Saaty TL. 1980. The Analytic hierarchy process. McGraw-Hill, New York, p. 287.
6. Myrand B, Guderley H, Himmelman JH. 2000. Reproduction and summer mortality of blue mussels *Mytilus edulis* in the Magdalen Islands, southern Gulf of St. Lawrence. *Mar. Ecol. Prog. Ser.* 197:193-207.

Economical Scenarios Applied to Soft-Shell Clam (*Mya arenaria*) Culture in Îles-de-la-Madeleine: Requirements for Profitability

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The R&D program MIM has generated data on the soft-shell clam culture in Îles-de-la-Madeleine, which were used to run economical scenarios. According to these scenarios, 6 000 000 spat/year are obtained through benthic collection with AstroTurf™ mats or pelagic collection employing suspended cages. Small clams are subsequently over-wintered in pearl-nets and seeded in springtime at a density of 550 clams/m^2. The estimated total production costs are increased by 10% to correct for possible under-estimated expenses. Profitability is influenced by two main factors: retrieval rate of cultured clams at harvest and price. At a price of \$2.65/kg, break-even point is reached when 30-35% of the seeded clams are harvested as commercial-sized clams according to the source of seed supply. This retrieval rate has not been attained yet. Furthermore, a 30% retrieval at harvest means a yield of about 165 commercial-sized clam/m^2. The following question arises: Is it realistic to expect such a production level with clam culture in lagoon habitat of the Îles-de-la-Madeleine? The use of these economical scenarios will help to orient future R&D.

Introduction

Soft-shell clam is a candidate as an alternate species for shellfish aquaculture in North-Eastern America. However, few research efforts had been done to help triggering a substantial commercial production, which results in a knowledge deficiency in this field. Transfers and seedings of undersized clams on aquaculture leases had been performed for a while in Prince Edward Island before natural and cultured clam populations were decimated by neoplasia(1). Small-scale seeding experiments were performed with hatchery clams in New-Brunswick in the late 1990s(2). Several stock enhancement activities using transfers and seedings of undersized clams on public beds have been done in New England but they are not well-documented and no profit-driven(3). As a result, there are presently no well-established soft-shell clam farms.

An integrated R&D program called "MIM" (French acronym for soft-shell clam culture in Îles-de-la-Madeleine) was put in place in 2000. Over the past five years, a lot of information have been obtained through this program(4,5), which aims the biological and technical feasibility, as well as the economical profitability.

As for any other cultured species, soft-shell clam culture must be profitable to have a future. Therefore, it is important to periodically assess the actual and the potential profitability of this alternate species. That helps to look at the progress made over time. Also, it may help to set R&D priorities in order to direct and accelerate the pace towards profitability. Moreover, funding agencies and investors are increasingly requiring solid reasons for investing on such an industry.

A simple and friendly-user economical analysis procedure was developed on Excel sheets in 1998 by M. Louis Fournier, economist at the "Direction régionale des Îles-de-la-Madeleine" (MAPAQ) to provide a rough idea about the potential for local clam culture. Most data were just estimates due to the lack of adequate information to feed the economic scenarios. Since then, several data were generated under field conditions from the local clam grower and/or under experimental conditions by program "MIM". Some data have been validated repeatedly over several years. In this context, it was time to re-examine the potential profitability of soft-shell clam culture and, of course, its perspective of development.

Materials and Methods

As seeding and harvest operations are pretty much the same whatever the seed source, two basic scenarios were examined according to the source of natural seed supply : benthic and pelagic spat collection. Over the past years, both techniques, benthic collection with mats (individual collection area = 0.46 × 0.62 m or 0.28 m^2) laid down in the intertidal zone(5) and pelagic collection with cages (collection area : 0.31 × 0.31 × 0.81 m or 1.18 m^2 each) covered with mosquito screen, proved to be efficient and reliable in Îles-de-la-Madeleine. Transfers and hatchery production as seed sources were not examined, as they are not considered realistic options in the local context. Each of the two scenarios based on seed supply were then examined under three possible operational conditions (pessimistic, realistic, and optimistic).

The basic data provided to the six economical scenarios were :

- Seed supply of 6 000 000 clams with shell length > 2.5 mm in fall

	Pessimistic		Realistic		Optimistic	
	Benthic	Pelagic	Benthic	Pelagic	Benthic	Pelagic
Seed success	300/mat	10 000/cage	350/mat	12 500/cage	400/mat	15 000/cage
Over-wintering losses	10%		5%		5%	
Retrieval at harvest	20%		30%		40%	
Price at farm gate	$1.65/kg ($0.75/lb.)		$2.65/kg ($1.20/lb.)		$3.31/kg ($1.50/lb.)	

Table 1
Basic data provided to the model according to different scenarios based on two sources of spat supply (benthic collection with mats and pelagic collection with cages) both under three operational scenarios (pessimistic, realistic, and optimistic).

- Seed over-wintered in suspended pearl-nets placed in the lagoons of Îles-de-la-Madeleine
- No grow-out operation prior to seeding
- Seeding density at $550/m^2$
- At harvest, clams are mechanically retrieved with a small hydraulic rake(4)
- At harvest, 10 wild clams of legal size/m^2 are harvested along with seeded clams
- Labor costs are set at $12 per hour (including benefits)
- Manager hired for 10 months per year
- Extra 10% is added to the total production costs for unexpected and underestimated expenses.

It was assumed that seed clam sorting could be faster and more efficient in separating undesired material (e.g., debris, mussel juveniles, algae) than what had been previously done at an experimental scale. The various scenarios differed from each other according to four variables: (1) seed collection success, (2) over-wintering losses, (3) retrieval success at harvest, and (4) price at farm gate (Table 1).

Operation costs were estimated for each activity, such as: seed supply, over-wintering, seeding and harvesting. These costs include the depreciation costs for the material specifically used for each corresponding activity as well as the associated labour costs. Fixed costs were also calculated and included (1) the manager's salary, (2) the annual costs for services (e.g. electricity, insurances, telephone, land lease) and equipment operation/maintenance, and (3) the depreciation costs of equipments (e.g., boat, truck, trailer, shed, hydraulic rake, high-pressure water jet, pans).

Results

The total costs (operation + fixed + 10 % unexpected costs) are quite comparable between the three operational scenarios (i.e., pessimistic, realistic, optimistic) given that they differ mostly according to the retrieval rate at harvest and the price for clams, i.e., when most production costs already occurred. Fixed costs are similar for all scenarios accounting for $52 760. Operation costs differ between the seed collection techniques: $40 876-41 772 employing mats and $25 573-29 288 employing cages. The total costs are estimated between $103 000 and $103 986 when seed supply is obtained from mats, and are about 15% lower when it is obtained from cages ($86 167-90 253). The major operation costs are for seed supply followed by harvesting. Over-wintering and seeding do not contribute substantially to the operation costs.

Using mats as source of seed supply, soft-shell calm culture would presently be profitable only under the optimistic scenario with a $43 242 profit. The balance would be negative under the realistic (-$13 668) and the pessimistic (-$67 086) scenarios. The financial outcome would be better while using the pelagic collection as seed supply. Profitability could be reached under the optimistic ($55 989 profit) but also under the realistic ($1215 profit) scenario. However, balance would still be negative under the pessimistic scenario (-$49 267).

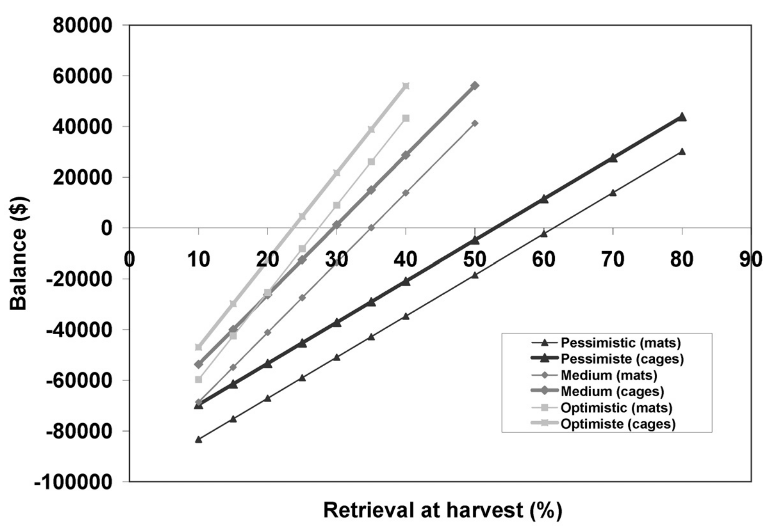

Figure 1
Retrieval rates needed to reach the break-even point according to different economic scenarios.

Since the grower has a limited influence on the price given to his product, the retrieval rate at harvest would be a major concern for attaining profitability. Fortunately, a grower may have some influence on this parameter through his husbandry practices. The retrieval rate needed to reach the break-even point of all six scenarios was identified (Fig. 1). As expected, the break-even point could be reached at lower retrieval rates when employing pelagic techniques (i.e., cages). High retrieval rates would be needed (53% for cages - 62% for mats) when the price for clams is low (pessimistic scenario: $1.65 per kg). Much lower retrieval rates would be needed (24% for cages-27.5% for mats) when clams are paid at a high price (optimistic scenario: $3.30/kg). Retrieval rates of 30-35% would be needed to reach the break-even point when clams are paid $2.65/kg ($1.20/lb.), which is a current price in many areas including the Îles-de-la-Madeleine.

Discussion

According to our present knowledge, it seems that the soft-shell clam culture could be profitable in Îles-de-la-Madeleine but under certain conditions : (1) seed supply should come from pelagic collection employing cages, (2) retrieval rate of commercial-sized clams at harvest should be 30% at least, and (3) clams price should be close to $2.65 per kilo. Harvest retrieval rates in Îles-de-la-Madeleine are still below the required levels for profitability.

Furthermore, a 30% retrieval from the 550 seeded clams/m^2 means a harvest of about 165 commercial-sized (>50 mm) clams/m^{-2} or 17 clams /ft^2, which is a very high density. No such densities had been observed in the commercial clam beds in Îles-de-la-Madeleine. However, it should be a realistic target as higher retrieval rates have been obtained in New England[6], where 75-80% retrieval rates of commercial-sized clams were obtained after seeding at a density of 660 individuals/m^2.

Growers have little control on price. Therefore, profitability could be reached decreasing the operation costs and/or increasing the retrieval at harvest. As well, the optimization of cages for seed supply as well as a better mechanization of some operations like sorting and harvesting should help lower these costs. A better retrieval at harvest should be obtained by seeding 15-20-mm clams after a grow-out phase prior to seeding and by keeping the protective nets over the seeded plots during the whole first season. More research should also be done to minimize predation and/or dispersion and to reduce the high variability in growth performance of clams placed in identical conditions.

References

1. McGladdery S, Reinisch CL, MacCallum GS, Stephens RE, Walker CL, Davidson JT. 2001 Haemic neoplasia in soft-shell clams (*Mya arenaria*): Recent outbreaks in Atlantic Canada and discovery of a p53 gene homologue associated with the condition. *Bull. Aquacult. Assoc. Canada* 100-3:19-26.
2. Gionet C, Ministère des Pêches et de l'Aquaculture du Nouveau Brunswick, Shippagan, pers. comm..
3. Calderon I, Chevarie L, Myrand B, Nadeau ME, Roussy M. 2005. Contexte technologique et réglementaire de l'élevage de la mye et de la quahaug commune en Nouvelle-Angleterre, rapport de mission 25 août au 1er septembre 2002., ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec, 42 p. Compte rendu no. 15.
4. Chevarie L, Myrand B. 2003. Programme de recherche/développement en myiculture aux Îles-de-la-Madeleine (Programme MIM)- Compte rendu 2000-2002. Rapport déposé à la SODIM dans le cadre des activités du programme MIM. Juillet 2003. 117 p. Available from *www.sodim.org/publ_doc.htm.*
5. Chevarie L, Myrand B. 2005. Programme de recherche/développement en myiculture aux Îles-de-la-Madeleine (Programme MIM)- Compte rendu 2003. Rapport déposé à la SODIM dans le cadre des activités du programme MIM. Février 2005. 104 p.
6. Beal B, University of Maine at Machias, pers. comm.

Sinking of Mussel (*Mytilus edulis*) Longlines as a Strategy to Control Secondary Set in Îles-de-la-Madeleine

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A study was carried out to examine the impacts of longline sinking as a strategy for secondary set control on commercial sleeves in Îles-de-la-Madeleine lagoons. In fall 2003, 1-year-old mussel sleeves were sunk on the bottom of Grande-Entrée and Havre-aux-Maisons lagoons for 1, 3, and 7 weeks. Other sleeves were kept suspended in the water column and used as controls. Rock crab (*Cancer irroratus*) densities on the sunken sleeves peaked in week 1 and decreased thereafter while starfish (*Asterias* sp.) densities peaked in week 3. More than 50% of secondary set biomass was eliminated within the first week while the commercial yield (mussels $\geq$50 mm) had decreased by 59% in week 3. It is concluded that longline sinking for a period shorter than one week may be a profitable strategy for secondary set control on commercial sleeves. Longer sinking periods are undesirable because of the important losses in commercial yield.

Introduction

Sleeving of 12-25 mm mussels in Iles-de-la Madeleine is usually done in fall and most sleeves are harvested 12-18 mo later (November to May). A smaller part of the production is harvested up to 2 yrs after sleeving (June to September) to supply the local summer market. Adult mussels spawn in early summer in Iles-de-la Madeleine lagoons and huge numbers of larvae are produced. After a couple of weeks in the water column, the larvae are looking for suitable substrates to settle on and metamorphose into small mussels (post-larvae). Sleeves kept suspended in the water column provide attractive substrates (like collectors, buoys, longlines, piers,…) for settlement. As a result, the small mussels (called secondary set) attach themselves on and among the larger mussels on the sleeves. Once settled, they will grow rapidly. When abundant they compete with the sleeved mussels for food and space. This competition will increase with time due to the growth of these small mussels. As a result, the growth of the sleeved mussels may slow down and higher losses through fall-offs may occur. Furthermore, the extra weight added on the culture gear (sleeves, longlines, buoys) may exceed the longline buoyancy and thus leading the sleeves down to the bottom, involuntarily.

Secondary set on commercial sleeves is inevitable in shallow waters like in Îles-de-la-Madeleine lagoons (max. depth: ~6-7 m) with all its potential impacts on production. Controlled longline sinking is a common practice in Prince Edouard Island mussel industry as a strategy to control secondary set. This approach relies on the selective action of the benthic predators in the culture area to decrease the abundance of the secondary set while ignoring the larger mussels.

The mussel growers from Îles-de-la-Madeleine wanted to look at the potential of this approach in the Îles-de-la-Madeleine lagoons which are used for mussel culture : Havre-aux-Maisons and Grande-Entrée lagoons. The main objective of this study was to look at the positive and negative impacts of longline sinking on the secondary set and commercial production. Longline sinking was studied according to the general information provided by mussel growers from Prince Edward Island; i.e., for periods of 1 and 3 weeks[(1)]. Further, a longer sinking period (7 weeks) was examined to look at the effects of an involuntarily longline sinking due to a lack of buoyancy.

Materials and Methods

Sixteen metal frames were built to suspend the experimental sleeves at the desired depth and eight were placed on the bottom of each the two lagoons (Havre-aux-Maisons et Grande-Entrée) in late September 2003. One-yr-old mussel sleeves (filled in October 2002) were provided by mussel growers and cut to a standardized length of 1.35 m. Four sleeves were attached to each frame by scuba divers. Their lower part was left 1 m above the bottom. On week later, 3 out of the 4 sleeves on each frame were gently pulled down by scuba divers so that their lower 30-cm portion was laying down directly on the bottom. The fourth sleeve on each frame was kept suspended in the water column and used as a control.

Three sinking periods were examined : 1, 3, and 7 weeks. At each period, one sleeve per frame was retrieved by divers, brought back to the surface and sampled to characterize the biomass and of the secondary set and the commercial yield (1^+). The mean shell length of 1^+ mussels was also measured. Samples (30-cm sections) were taken at two different locations on each sleeve : the lower portion laying down directly on the bottom and the upper portion kept off the bottom. Controls were sampled only at the end of the experiment (week 7). All common crabs and starfishes found on the sleeves were counted and measured.

The commercial (1^+ mussels) biomass of a given sleeve was extrapolated by balancing the results from each portion according to its relative importance : lower portion laying down on the bottom (30 cm or 22.2 % or the experimental sleeve) and the upper portion kept off the bottom (105 cm or 77.8% of the experimental sleeve). The lower and upper portions on the sleeves were compared with paired t-tests.

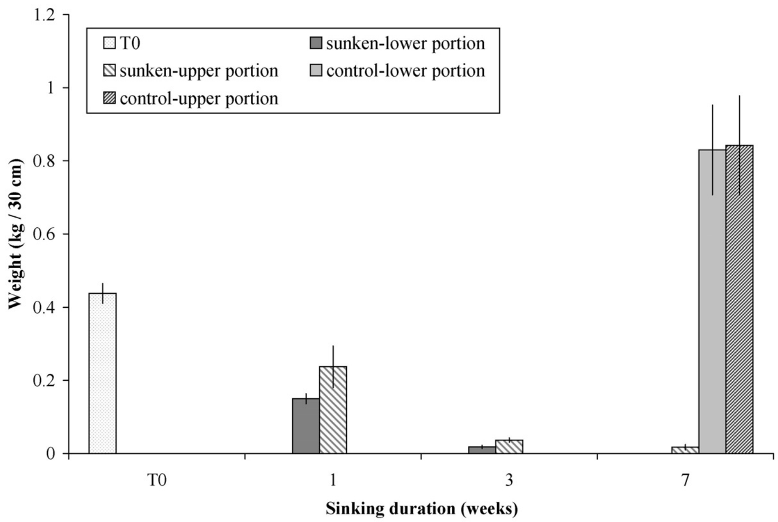

Figure 1
Evolution of secondary set abundance (mean ± SE) in Havre-aux-Maisons lagoon.

Results and Discussion

To shorten the length of the paper, attention will be focussed on the results from the Havre-aux-Maisons lagoon. However, some results from Grande-Entrée lagoon will also be presented.

Crabs (*Cancer irroratus*) rapidly reached and climbed on the sunken sleeves to began the cleanup of the secondary set. One week after sinking, there were 8.1 (±1.4) common crabs and 16.5 (±1.9) starfishes by sleeve. At that time, there was an important decrease in biomass of the secondary set on the lower portions (66%) as well as on the upper portions (46%) of the sleeves when compared to values at T_0 (Fig. 1). The crab abundance decreased after the first week (2.9±0.3 at week 3 and 0.6±0.3 at week 7). The peak in starfish (*Asterias* sp.) abundance was rather observed in week 3 with 36.4±7.7 individuals per sleeve. Very few crabs and starfishes were found on the sleeves at week 7.

The action of both predators resulted in a near complete elimination of the secondary set over time with an overall decrease of about 50% at week 1, 90% at week 3, and 95% at week 7 compared to T_0. In contrast, the biomass of the second set doubled during the experiment on the sleeves kept away from the benthic predators: 0.44 kg/30 cm on the sleeves at T_0 vs. 0.84 kg/30 cm on the control sleeves at week 7 (Fig. 1).

The evolution in predator abundance and biomass of the secondary set showed a similar trend in Grande-Entrée lagoon but at a lesser scale. In contrast to the Havre-aux-Maisons lagoon, several lobsters were seen close to the sunken sleeves in this lagoon.

The commercial production (1^+ mussels) on the sunken sleeves also decreased substantially over time (Fig. 2). This decrease was observed on the portions laying down on the bottom (lower portions) but also on the those kept off the bottom (upper portions). However, the losses were significantly (paired t-tests) less important on the upper than on the lower portions at week 3 (t=-6.18; df=7; P=0.0005) and week 7 (t=-2.74; df=7; P=0.03). Compared to T_0 (2.11 kg/30 cm), the estimated biomass of 1^+ mussels per sleeve had decreased by 27% at week 1 (1.54 kg/30 cm), 59% (0.87 kg/30 cm) at week 3, and 76% (0.50 kg/30 cm) at week 7. Losses of 1^+ mussels were probably caused by the high abundance of starfishes as most dead mussels were found with their shell unbroken. Crabs must usually break the shell of the

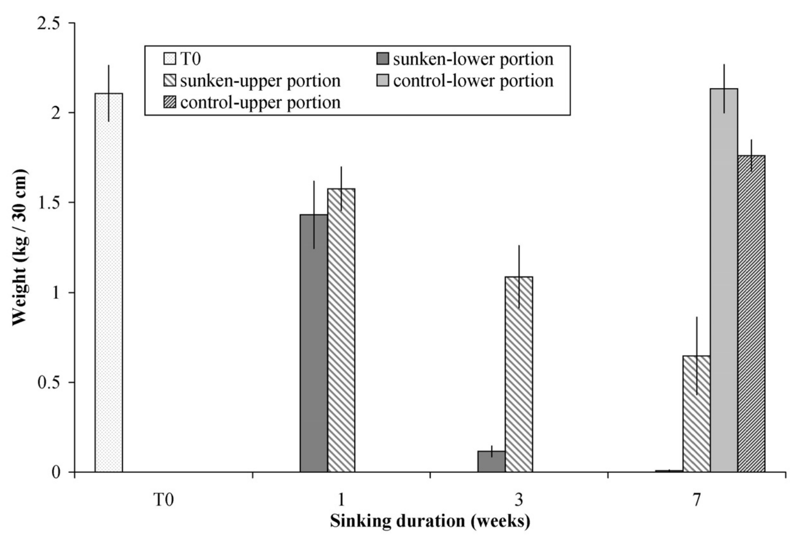

Figure 2
Evolution of the 1^+ mussel biomass (mean ± SE) in Havre-aux-Maisons lagoon.

mussel before eating its flesh[2]. It seems that sleeves kept in suspension (out of predators reach) had not lost much 1^+ mussels during the experimental period through fall-offs, "normal" action of predators or natural mortality as their biomass on the control sleeves at week 7 was about 2 kg/30 cm compared to 2.11 kg/30 cm at the sleeves at T_0 (Fig. 2).

It seems that the growth of the 1^+ mussels on the sunken sleeves in Havre-aux-Maisons lagoon slowed down during the experimental period as a result of the presence and the activity of numerous predators. The mean shell length of 1^+ mussels was 55.8±0.4 mm at T_0 and 59.4±0.4 mm on the control sleeves at the end of the experiment for an estimated growth of about 4 mm in 7 weeks. In contrast, the mean shell length of 1^+ mussels on the sunken sleeves was only 56.7±0.4 mm at week 7 for an estimated growth of about only 1 mm during the same period. Furthermore, as almost all 1^+ mussels had disappeared from the lower portions of the sunken sleeves after 7 weeks (Fig. 2) the mean shell length was measured only on mussels from the upper portion (kept off the bottom) of the sleeves.

In Grande-Entrée lagoon, the 1^+ mussel biomass on the sunken sleeves also decreased with time but to a lesser extent than in Havre-aux-Maisons lagoon largely because the decrease was restricted to the lower portion of the sleeves. The biomass of the 1^+ mussels on the upper portions of the sunken sleeves was similar to that measured at T_0 throughout the experiment in Grande-Entrée lagoon. This difference between the lower and upper portions of the sunken sleeves is due to the action of the lobster which is the main benthic predator in this lagoon. In contrast to the crabs and the starfishes, lobsters cannot climb on the sleeves so that their action is restricted to the portion laying down directly on the bottom.

Conclusion

It is possible to reduce sharply the abundance of the secondary set on the commercial sleeves using the selective action of the benthic predators. To do so, the sleeves could be sunk so that their lower part is laying down on the bottom. However, sinking period should be limited to a short period because of the associated losses of commercial (1^+) mussels which increased with sinking duration. Even a 1-week sinking period resulted in a 27 % decrease in 1^+ mussels biomass in Havre-aux-Maisons lagoon. Thus, sinking period should last < 1 week to offer some interest at a commercial scale but it has not been examined in the present study. Further, mussel growers would have to look at the technical feasibility of sinking and re-floating tens of longlines in a few days before adopting such an approach on a commercial scale.

Based on these results, mussel growers from Îles-de-la-Madeleine decided not to use longline sinking to reduce the abundance of secondary set on their commercial sleeves.

Acknowledgements

The authors would like to thank the "Société de développement de l'industrie maricole du Québec" for its financial support as well as "Grande-Entrée Aquaculture" and "Moules de culture des Îles" for their collaboration. Also, special thanks to the technical staff at the "Station technologique maricole des Îles-de-la-Madeleine" and the divers from "Le repère du plongeur" for their dedication and help.

References

1. Rogers G., PEI mussel grower, pers. comm.
2. Myrand B, Bourque F. 2005. The size refuge against rock crab (*Cancer irroratus*) predation is not totally reach by commercial-sized mussels (*Mytilus edulis*). AAC Spec. Publ. No 9: 60-63.

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Aquaculture Canada^{OM} 2006 Silent Auction

This year, to continue the tradition, there will be a silent auction at the Student BBQ, all the proceeds of which will benefit the AAC Student Endowment Fund (SEF), an account used to fund AAC student travel awards as well as prizes for presentation awards. In addition to supporting AAC students, this is also an opportunity for increased exposure for a company or service. Last year's auction raised over $900 for the SEF, and this year, we hope to pass this milestone!

Items that have been donated to previous auctions have included books, articles of clothing, artwork, gift certificates, etc., although any item would be much appreciated. All donors are acknowledged on the conference website, at the silent auction, and in the published conference proceedings.

I sincerely thank you for your consideration of this worthy cause, and hope to see you in Halifax in November. Please check out the AC06 website (*www.aquacultureassociation.ca/ac06*) for more conference information.

Chris Hendry
President, AAC

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Calendar

- **Aqua 2006**, Fortezza da Basso Convention Centre, Firenze (Florence) Italy, 9-13 May 2006. After the very successful AQUA 2000 in Nice, France, EAS and WAS agreed to meet in 2006 in Firenze, Italy. Combining the very popular Aquaculture Europe with the successful international World Aquaculture makes for a tremendous meeting of aquaculture participants from around the world. This is a fantastic opportunity for aquaculturists to come together and find common ground and solutions for situations facing all segments of the industry. There will be many aquaculture groups and agencies involved in AQUA 2006. AQUA 2006 will draw on Europe, Canada, USA, the Asia-Pacific region, Latin America and the rest of the world to create one of the largest aquaculture trade shows in the world. The trade show definitely will have one of the widest variety of products of any trade show ever. This is your opportunity to inspect the latest in products and services for the aquaculture industry. For more information, contact the Conference Manager, Tel: +1-760-432-4270; Fax: +1-760-432-4275; e-mail: *worldaqua@aol.com*; website: *www.was.org*.

- **XII International Symposium on Fish Nutrition & Feeding**, Casino Bellevue, Biarritz, France, 28 May - 1 June 2006. For more information, contact the Conference Secretariat, XII ISFNF, Station d'Hydrobiologie I.N.R.A., 64310 Saint Pée sur Nivelle, France, Tel. : +33 5 59 51 59 51; Fax : +33 5 59 54 51 52, e-mail: *12isfnf06@st-pee.inra.fr*; website: *www.st-pee.inra.fr/btz06*.

- **FSBI 2006**, The Fisheries Society of the British Isles Annual Fisheries Symposium, University of Aberdeen, Aberdeen, Scotland, 10-14 July 2006. Advice on fish dynamics and the sustainability of fishing practices is often based on a spatial scale that is different to that of the exploited populations. Failure to recognize the nature of structuring has been associated with the loss of genetic diversity and population instability. This symposium will address individual and population level approaches to the analysis of population structure in fish and the implications this has to their conservation and management. By bringing together researchers working in all types of marine and freshwater ecosystems the symposium will provide a timely overview of this rapidly developing field of fish ecology. For more information, contact *fsbi2006@marlab.ac.uk*, website: *www.fsbi2006.org.uk*.

- **Australasian Aquaculture Conference 2006**, Adelaide Convention Centre, Adelaide, South Australia, 27-30 August 2006. Australasian Aquaculture 2006 will be the second in a series of international conferences, meetings, events and trade shows held biennially near the major aquaculture producing regions of Australia. Not only does South Australia provide the perfect venue and location for Australasian Aquaculture 2006, it leads the nation in aquaculture production. The diverse and active industry produces around 38 per cent of Australia's aquaculture product. The theme for Australasian Aquaculture 2006 is "Innovation in Aquaculture". Maintaining or increasing profit, entering new markets, obtaining skilled labour, in fact, all aspects of aquaculture require a level of innovation. Australasian Aquaculture 2006 will provide a forum for aquaculture farmers, processors, business operators, equipments suppliers, scientists, educators, students, consultants, and government representatives to meet and discuss the latest advances and innovations in the industry.

- **Aquaculture Pacific Exchange 2006**, Strathcona Gardens, Campbell River, BC, Canada, 14-15 September 2006. The Aquaculture Pacific Exchange is regarded as the top aquaculture event on the West Coast. The 2006 APE conference will be organized by Linda Hiemstra. We are always looking for excellent speakers to deliver relevant topics. If you have any suggestions or have a particular speaker who you would like to sponsor/bring to the conference, please contact Linda at: Mel Mor Science 6036 Breonna Drive Nanaimo, BC V9V 1G1, e-mail: *hiemstras@shaw.ca*; Tel: 250-756-4862. If you are interested in exhibiting at the 2006 Aquaculture Pacific Exchange, please contact Show Manager, Jeff Lacey at Master Promotions Ltd. Toll-free: 1-888-454-7469; e-mail: *jlacey@masterpromotions.ca*; website: *www.masterpromotions.ca*.

- **Aquaculture Canada 2006**, Westin Nova Scotian, Halifax, Nova Scotia, Canada, 19-22 November 2006. Themed "Culturing Quality and Confidence", a comprehensive technical, industry-oriented program is being prepared and developed. Special symposia and workshops will highlight achievements by various sectors of the Canadian aquaculture industry. In addition, the trade show and an extensive social program will provide opportunity for valuable networking and knowledge exchange. For more information, contact Chrissy McGregor, Conference Secretariat, Tel: 506-529-4766; Fax: 506-529-4609; e-mail: *aac@mar.dfo-mpo.gc.ca*; website: *www.aquacultureassociation.ca/ac06*.