Aquaculture Canada^{OM} 2006

Proceedings of Contributed Papers

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Culturing Quality and Confidence

Halifax, Nova Scotia
November 19-22, 2006

Linda D. Hiemstra
Editor

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Aquaculture Canada^{OM} 2006

November 19-22, 2006
Westin Nova Scotian Hotel
Proceedings of Contributed Papers

Table of Contents

Proceedings of Contributed Papers Aquaculture Canada^{OM} 2006

Errata of the Proceedings of Contributed Papers of the Canadian Freshwater Aquaculture Symposium AAC Special Publication No. 11

President's Report

After many months of planning and collaboration, Aquaculture Canada^{OM} 2006 was a great success! Co-hosted by the AAC, the Aquaculture Association of Nova Scotia (AANS) and Nova Scotia Fisheries and Aquaculture (NSFA), AC06 was attended by over 400 delegates representing all aspects of Canadian aquaculture including government, academia, students, suppliers, and industry. I must acknowledge the efforts of both of our co-hosts for helping ensure a successful meeting, as well as our Steering and Local Organizing Committees. I would like to specifically thank Linda Hiemstra for the tremendous work she did throughout the planning and implementation stages of the conference, as her professionalism and organizational skills were remarkable assets to the Association and its 23rd annual meeting; and Jason Mullen and his Program Committee, who developed a current and informative technical program which benefited all in attendance. I am also indebted to Master Promotions for their great work in managing our conference registration and organizing a successful tradeshow, the latter of which allowed many exhibitors to display their products and services to the attendees. Finally, the conference (and the Association itself) could not exist as successfully without the tremendous efforts of Susan Waddy and the AAC Home Office in St. Andrews.

The opening session was a great opportunity to welcome everyone to the conference on behalf of the co-hosts – myself, Brian Muise (Executive Director of AANS), and the Honourable Ronald Chisholm (Nova Scotia Minister of Fisheries and Aquaculture) – as well as David Rideout (Executive Director, Canadian Aquaculture Industry Alliance) and Patrick Murphy (Councillor, Halifax Regional Municipality). I thank those mentioned for being able to address the conference delegates, understanding their busy schedules.

The conference theme – "*Culturing Quality and Confidence*" – alluded to many aspects of aquaculture, from on-farm activity all the way through to the consumer.

Ensuring quality and confidence in aquaculture is a shared responsibility among us all as regulators, researchers, producers, and suppliers. This interconnectivity was illustrated by our keynote, plenary, invited, and contributing speakers throughout our comprehensive program.

Our conference keynote speaker, Dr. Gary Smith, an expert in the US beef industry and based at Colorado State University, drew many parallels between criticisms directed toward both the beef and aquaculture industries. In his charismatic style, Dr. Smith was able to use examples of the manner in which the US beef industry reacts to such criticism to be helpful to those in the aquaculture industry. Aquaculture, as a relatively newcomer to the North American food industry, has an advantage to learn from experiences of other similar industry sectors.

The two conference plenary speakers also touched on different aspects of the conference theme. John Sackton, President of Seafood.com, reviewed the various marketing strategies for seafood and how aquaculture products fit therein. He began by reviewing the overall markets for major aquaculture products such as salmon, mussels, cod, tilapia (among others) and continued his presentation with an examination of various marketing statements being made and how these influence consumer perception and their ultimate impact. Adolfo Alvial from INTESAL (Chile) spoke of the various means his organization has employed to build trust in aquaculture, while at the same time building the Chilean salmon farming industry to a level that rivals that of Norway's. This is accomplished, in part, by actively promoting R&D and innovation initiatives, emphasizing the cooperation between producer and suppliers, developing highly qualified human resources, and by opening new strategic avenues for the industry.

Aquaculture Canada^{OM} 2006 also allowed the AAC to recognize significant contributions to Canadian aquaculture through its Lifetime Achievement Award and the Research Award of Excellence. The former award was presented to M. Lucien Poirier for his significant contributions to the development of the aquaculture industry in Quebec, while the latter honoured Dr. David Higgs for his research into (1) improving the cost effectiveness of hatchery and mariculture operations, (2) minimizing organic matter, nitrogen, and phosphorus discharge from salmon farms into the environment, and (3) enhancing the flesh quality and consumer acceptance of market-size salmon and sablefish. Both awardees gave excellent presentations illustrating their achievements.

AC06 was also an opportunity for AAC to start a process to increase its relevance to the industry itself. AAC was able to start this process by ensuring industry-relevant sessions covered current topics of interest. This was strengthened by having the AANS as a co-host and leading the conference program development. Such sessions included: invasive species, genomics in aquaculture, animal health and welfare, industry marketing and communications, a national code system, environmental management, research and development tax credits, orchestrating aquaculture research and development, integrated multi-trophic aquaculture, cold-water aquaculture, and open-ocean aquaculture. These sessions were supplemented by numerous contributed papers ranging from alternate species to shellfish and finfish culture. AC06 was also an opportunity for members of the AAC Board of Directors to meet with leaders of regional and national industry associations to discuss potential roles AAC could play to directly benefit industry, a meeting that was mutually beneficial and will aid the AAC in assessing future goals and objectives.

Not only was the conference program valuable, AC06 (with traditional AAC flair) also provided many opportunities to interact with national and international colleagues during its many social events. The President's Reception on the eve of the conference allowed attendees to sample many different aquaculture products, primarily from local producers. The conference banquet – Lets Salsa!! – was a delicious seafood dinner featuring cultured salmon and Nova Scotia products that was followed by Salsa dance lessons and an internationally famous 10-piece band (Los Primos with Latin Groove). I must thank all the food product contributors for these fantastic seafood feasts, as well as the incredible talent exhibited by the entertainment at Let's Salsa!

Student development in aquaculture has always been a high priority for the AAC, and AC06 was no different. The third social event was the Joe Brown BBQ in Support of AAC Students, renamed permanently this year in honour of a dear friend, colleague, and mentor who is remembered not only for his professional accomplishments, but also his dedication to students. The BBQ is held to raise money for the AAC Student Endowment Fund, which provides funding for AAC's student-oriented efforts. A highlight of this annual event is the silent auction, which raised over $2000 this year. I must thank Darrell Harris and Carla Walbourne for organizing the BBQ, Greg MacCallum for a tremendous job with the auction, Select Pearls for donating the pearl necklace to the oyster prize table, and all the silent auction item donors. This year the Student Endowment fund provided travel awards to nine students to attend the conference. In addition, all student presentations were judged for either the best oral presentation or poster presentation award and the winners were Bernard Antonin Dupont-Cyr (Université Laval) and Erika Uribe (Dalhousie University), respectively. Honourable mentions for oral and poster presentations were given to Robyn O'Keefe (University of New Brunswick) and Laurent Seychelles (Université de Rimouski), respectively. Promoting and recognizing student research and development are two of the main goals of the AAC, and I commend all of the student presenters and attendees in the amazing progress they have attained in their careers thus far.

A novel approach was taken this year in the design of the conference logo. Previous years have seen professional artists contracted to design logos, however this year the goal was to tap into the extensive, but sometimes unknown, artistic talents among the AAC membership. A logo contest was held with submissions from numerous AAC members. The logo chosen, illustrating the many species currently cultured as well as a nod to the Halifax venue, was designed by Darrell Green of the Ocean Sciences Centre in Newfoundland. Thanks to Darrell and everyone who submitted contest entries.

The conference also highlighted local aquaculture companies through two organized tours. The first traveled to the south shore of Nova Scotia to tour an Atlantic halibut hatchery (Scotian Halibut Ltd.) and an innovative and exciting red abalone quarantine land-based facility (Mariponics N.S. Limited) while the second traveled to the rugged and scenic Parrsboro shore to visit a facility using fresh and saltwater wells to culture Atlantic halibut, Arctic charr, and salmonids (Atlantic Ova Pro Limited) as well as a modern recirculation facility where Arctic charr and rainbow trout are grown (Millbrook First Nation Fish Culture and Hydroponic Facility). Thanks to Darrell Harris for his great work in organizing these post-conference tours, as well as the participating companies.

As is clearly evident, Aquaculture Canada^{OM} was a tremendous group effort, and as conference chair, I am totally grateful to all those who contributed their time and energy to another successful AAC annual meeting! Now the AAC gavel has been passed on to Chris Pearce, whose abilities and experiences will be a great asset to seeing our Association grow. Chris was proud to announce the details for the next AAC conference – AC07 – which will be held in Edmonton, AB from September 23-26, 2007 at the Shaw Conference Centre and the Westin Edmonton will be the official hotel. The theme of AC07 will be Securing Sustainable Economic Prosperity.

I sincerely thank the AAC membership and the Board of Directors for a great 17 months (whew!) as President, and I enthusiastically look forward to continuing as Past President on the AAC Board under the leadership of Chris Pearce. I hope to see you all at an even more successful AC07 in Edmonton in September!

Chris Hendry
AAC President 2005-2006

Northern Aquaculture Ad

Honorary Lifetime Achievement Award

Lucien Poirier

Director, Innovation et Technologies, Direction générale des pêches et de l'aquaculture commerciales, MAPAQ

Lucien Poirier a débuté sa carrière dans le secteur administratif québécois des pêches après ses études en biologie à l'Université de Montréal et à l'Université McGill. Il fut le premier biologiste québécois à s'intéresser à la mytiliculture et à la pectiniculture. Depuis 1982, il occupe des fonctions de direction. À ce titre, il a contribué à la conception et à la mise en application d'une offre de service aux pêches et à l'aquaculture favorisant l'établissement de liens entre la recherche et le développement. En aquaculture, son nom est associé au développement de plusieurs services à l'industrie et à la recherche dont, notamment, la Société de recherche et de développement en aquaculture continentale (SORDAC), la Société de développement de l'industrie maricole (SODIM). Au cours de sa carrière, il a 23rd Annual Meeting – Aquaculture Association of Canada / 23è réunion annuelle – Association Aquacole du Canada 9 Aquaculture Canada^{OM} 2006 su appliquer avec succès une stratégie reposant sur le partage des priorités d'intervention sectorielle en innovation, la recherche d'effets multiplicateurs des investissements et la réalisation de travaux en partenariat.

Lucien Poirier began his career in the administrative sector of fisheries in Quebec after completing his studies in biology at the University of Montreal and McGill University. Mr. Poirier became the first biologist of Quebec to develop an interest in the culture of mussels and scallops. Since 1982, he has held various administrative roles which have contributed to the conception and the application of fishing and aquaculture services. Subsequently, these services have facilitated the merging of the fields of research and development. Within the area of aquaculture, his name is associated with the development of several services and research initiatives within the industry. More notably, some of these research initiatives have included, the Society of Research and Development in Continental Aquaculture (SORDAC), and the Society for the Development of the Mariculture Industry (SODIM). Over the course of his career, he has adopted with great success a strategy based on the following foundations: the amalgamation of the operations and innovation sectors, the research of the multiplier effect of investments towards the agreed priorities and the importance of working together in partnerships.

Lucien Poirier (MAPAQ) receives the 2006 AAC Lifetime Achievement Award from Chris Hendry, AAC President.

Research Award of Excellence

David A. Higgs, Ph.D.

Head of Fish Nutrition Program, Department of Fisheries and Oceans, Pacific Region

Since August 1975, Dr. Higgs, as head of the DFO Fish Nutrition Program based at the West Vancouver Laboratory (presently the DFO/UBC Centre for Aquaculture and Environmental Research), has conducted collaborative projects within DFO and with universities (professors and graduate students) and/or industry that have been directed primarily to (1) improving the cost effectiveness of hatchery and mariculture operations, (2) minimizing organic matter, nitrogen and phosphorus discharge from salmon farms into the environment, and (3) enhancing the flesh quality or consumer acceptance of market-size salmon and sablefish. Major study areas modifying the foregoing goals have included: nutrient and energy requirements; feedstuff digestibility; improvement of fish meal quality; alternate protein, lipid and carotenoid pigment sources to expensive premium quality fish meal and oil and synthetic astaxanthin, respectively; comparisons of the nutrient profiles of farmed and wild BC sources of salmon; development of nutritional strategies to reduce flesh organohalogen concentrations and enhance (n-3) highly unsaturated fatty acid levels for potential human health benefits; nutrition-disease interactions; exercise-nutritional status interactions; nutrition-endocrine interactions; nutrition of non-transgenic versus transgenic salmon; and assessment of the potential nutritive values of salmon prey species and of the energy expenditures of wild Pacific salmon undergoing their spawning migration.

Dr. David Higgs (DFO) receives the 2006 AAC Research Award of Excellence from Chris Hendry, AAC President.

Aquaculture Canada^{OM} 2006 Student Affairs Report

Student Presentations

This year 27 students provided 20 oral and 7 poster presentations at Aquaculture Canada^{OM} 2006. The student presentations were of high quality and provided cutting edge research information as well as insights into new methods for culture of many species both shellfish and finfish.

Best oral paper was awarded to **Bernard Antonin Dupont-Cyr**, Université Laval, QC, for his presentation "Compression of the reproduction cycle of Wolffish (*Anarhichas minor* and *A. lupus*)". Special mention was given to **Robyn O'Keefe**, University of New Brunswick for "Temperature preference of diploid and triploid brook trout (*Salvelinus fontinalis*)". The best oral paper is in this issue.

Best poster presentation was awarded to **Erika Uribe**, Dalhousie University, for her poster presentation entitled "Expression of recombinant Atlantic salmon (*Salmo salar*) serum C-type lectin in E. coli and Drosophila cells". Special mention was given to **Laurent Seychelles**, UQAR, for her poster "Lipid profile transfer from frozen-concentrated marine microalgae to rotifers (*Brachionus plicatilis*)".

Thank you to all student presenters for their excellent contributions and a special thank you to the judges who participated in evaluation of the student presentations. Your time and efforts are invaluable to the student evaluation process.

Joe Brown BBQ in Support of AAC Students

One of the main contributors to the Student Endowment Fund and a fun filled activity at the Joe Brown BBQ is the Silent Auction. For 2006 over $2,000 worth of items were donated including a beautiful pearl necklace provided by Select Pearls, Halifax NS. Much gratitude is extended to Greg MacCallum for doing such a great job organizing the Silent Auction and many thanks to the Silent Auction Sponsors (listed on page 13).

Student Travel Awards

The Aquaculture Association of Canada encourages student participation in the annual meetings by providing travel awards from the Student Endowment Fund. For 2006, nine students were provided a total of $4100. Benefiting from this program in 2006 were Matthew Liutkus, MUN; Laurent Seychelles, UQAR; Erwann Fraboulet, UQAR; Marcia Chiasson, UNG; Robyn O'Keefe, UNB; Bernard-Antonin Dupont-Cyr, ULaval; Catherine Gaudreau, UQAR; Joanne Power, MUN; Fernando Salazar, UGuelph.

Erika Uribe, Dalhousie University, receiving Best Poster Award from Rich Moccia, University of Guelph and Nathalie LeFrançois, AAC Student Affairs Committee.

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Aquaculture Association of Canada Board of Directors 2005/2006

Chilean Cluster Evolution: Culturing Quality and Confidence

Adolfo Alvial and Felipe Bañados

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Abstract

The Chilean salmon farming industry has shown an impressive evolution as consequence of its strategic and competitive advantages which allowed it to overcome with noticeable success the distance to foreign markets and lead salmon farming production along with Norway. Very early in its development the industry tried to promote associative approaches in order to face upstream and downstream challenges. This paper reviews the industry evolution and cluster consolidation process, in order to assess the critical factors of development and current challenges to strengthen the supply chain for the Chilean salmon industry. This has been done considering the Porter (1998) cluster perspective through a qualitative analysis of secondary sources. To understand the Chilean salmon cluster structure and its economic impact, the contribution of several authors was analysed. This paper reveals that in the current consolidation phase of the industry, some differences in perception between producers and suppliers arise regarding cluster priorities. While producers prioritise innovation in fish health, selected suppliers consider an update in the correspondent legislation as the most important issue. The CORFO Integrated Territorial Program (PTI) Cluster Salmon has contributed to advance in the solution of these challenges through the implementation of an innovation program, which shows as its most relevant outcome, having pushed R&D public investment to a historically highest level, in relation with total sales of the salmon industry.

Introduction

In the early 1970's Chile decided to initiate salmon culture, understanding that this was a great product with a great market which could be reared in the Southern Fjords where environmental conditions were favourable and also considering the availability of fish meal and fish oil, basic for feed, in the north and central coasts of the country. In addition there was availability of qualified human resources, an efficient and rapid technology transfer and adaptation was put in place, and pioneer spirit and associative efforts predominated. All these factors generated the conditions for the new industry, internally concentrated and coordinated but the goal to compete in foreign and distant markets.

The rapid growth and dimensions reached by Chilean Salmon farming –competing with the leadership of Norway- as well as the dynamics of the world agro-alimentary industry have revealed some pending issues in different links of the value chain from the Chilean Salmon cluster.

The paper herein refers to Porter's (1998) concept of cluster and its contribution to competitiveness and regional and national development. Likewise, different authors like Hirschman (1977), North (1995), Krugman (1995), Enright and Roberts (2001), and Borges (1997) explore the influence of geographic agglomeration and its consequent impact on economic development, however, Porter's (1998) "Competitive Advantages of Nations" has been the most used. The latter states that the geographical concentration of companies, institutions, specialized suppliers, services suppliers, interconnected and associated reduce the cost of transaction[1], therefore, improving competitiveness as a whole. All in all, Porter states the need to create multiple strategic links in the value chain of that territory, generating within social capital through associative networks that create and establish cooperation between public and private parties, basing its growth and survival on a constant process of learning and technological innovation.

It is possible to observe different examples of successful clusters around the world based on Porter's theory, for example in the paper "The demography of cluster-findings from the meta cluster study" by Van der Linde (2003). Other examples of cluster*s*, competitiveness and economic development are found in the paper "Competitiveness upgrading in cluster*s* and productive chains in Latin America" by Pietrobelli and Rabelloti (2004), comparing cluster*s* based on natural resources exploitation.

The document herein also reviews the contribution of different authors, who analysed the structure and the economic impact of the Chilean Salmon cluster in Porter's definition, and investigated evolution data which led it to become the natural resources based cluster with the most competitive progress in Latin America (Pietrobelli and Rabellotti, 2004). Special attention was given to the diagnostic work "Strengthening of the Salmon Cluster in the South of Chile" entrusted to Agraria Consultores by CORFO Xth Region. This work was the baseline for the design and implementation of the Integrated Territorial Program (PTI) for the Salmon Cluster.

The objective of the survey herein is to determine the main challenges the Salmon industry is facing in its current consolidation process and the contribution of PTI in searching for solutions to reinforce the Salmon cluster.

[1] The term transaction was defined by Coase in 1937. Afterwards, Williamson in 1979 would define it as the "cost to do business".

The Salmon Cluster

Authors like Achurra (1995); Maggi (2002); Montero (2004); Iiuzka (2004), Ulloa (2006); Pietrobelli and Rabelloti (2004); Torres (2006), have investigated the origin of the Chilean Salmon cluster, its structure, competitiveness and its contribution to the development of the Chilean aquaculture industry. Authors agree there is enough evidence to sustain the Chilean Salmon farming industry greatly meets cluster requirements, vis-à-vis Porter's definition.

In a little more than two decades, Salmon industry has reached a position of leadership in the national economy, contributing with 80% of exports from the Xth region and with 20.2% of food exports from the country. In 2005, Chilean exports of salmon and trout reached US$ 1.721 million with a total of 383.700 net tons (SalmonChile, 2006).

In 2005, 87% of national Salmon farming activities were concentrated in the Xth Region. However, as a result of excellent comparative advantages, today the industry is naturally extending towards the XI region where the highest growth is projected (SalmonChile, 2006).

One of the most significant factors of this cluster is the emergence of important associative networks after collective efforts in the standardization of processing quality and phytoplankton monitoring. As a result of the aforesaid, the Chilean Salmon Farming Association (SalmonChile A.G) was born, made up of 27 producing companies and 36 supplying companies, and its technological institute (INTESAL). In this guild, there are more specialised associations like the association of ship owners (ARASEMAR)[2], the association of net Producers and services (ATARED), the association of diving companies (ADEB), and the association of veterinarian labs (ALAVET).

It is most likely that one of the triggering factors for association and innovation in the industry is the integrated character of pioneer companies where professionals and technicians emigrated from to develop service companies. The latter along with the physical proximity with the different

[2] Some shipowners of higher tonnage vessels are represented in a second association (ARMASUR).

stakeholders eased the interaction and construction of associative efforts[3].

On the other hand, according to INE[4] Xth Region, the Salmon cluster has the participation of almost 500 key companies devoted to the sale of goods and services throughout the value chain of the Salmon industry. As a whole, these companies have generated more than 7.631[5] indirect jobs (SalmonChile, 2006). From this universe of companies, around 350 are service suppliers and 150 are input suppliers. According to Torres (2006), one of the most significant factors in the existence of the Salmon cluster is that due to the permanent demand for new productive solutions most suppliers are moving towards the intensive use of technologies.

According to Agraria (2004), from total annual sales around 23% -approximately US$400 million- corresponds to the purchase of goods and services.

Certainly, for suppliers, feed plants play an important role. According to Agraria, as percentage of the total annual sales, these represent 50% (approximately US$ 850 million) of production costs in the fattening stage. Nowadays, Salmon cluster has seven feed producing plants and a new one under construction. Five of these are associated to Salmon producing companies (SalmonChile, 2005).

Regarding the link and coordination between the Salmon industry and the public sector Maggi (2003), Iizuka (2004), and Montero (2004) document multiple networks of mutual collaboration throughout the industry evolution. These show a higher level of influence during the early stages of Salmon farming through demonstrative units and later in the promotion of technological development initiatives.

Evolution of the Salmon Cluster

Maggi (2002), Iizuka (2004), Montero (2004), Pietrobelli and Rabelloti (2004), and Ulloa (2005) collected data on the Salmon industry evolution process. From this analysis, it is possible to observe four key periods (Table 1). The first corresponds to an experimentation and learning period from 1960-1973, where the entrepreneurial ability and the implementation of demonstrative units are remarkable. The second, from 1974-1995, has been defined as an education and maturity period, observing commercial improvement, association and unification of quality standards. After this stage, the industry goes through different transformations in its financing, productive, and associative processes leading to, from 1996-2002, a stage of product and market diversification. As of 2002, the industry begins a consolidation stage through different political-guild initiatives promoted by the Salmon Industry Association (SalmonChile A.G.), and in the innovation and research and development, the Salmon Technological Institute (INTESAL), technical branch of SalmonChile.

At guild level, SalmonChile has developed actions to promote cooperation and deepen links of confidence among the different stakeholders of the cluster. Additionally, it has led initiatives oriented to the creation of social capital, and education and labour training in the X and XI Regions. For example, it is worth to mention the combined participation amongst SalmonChile, INTESAL, and the "Chile Califica" program to develop a unique standardized system of certification of labour competences for workers of the industry.

At technical level, INTESAL has developed different associative and great scale projects at industry level which are part of a Surveillance and management model. Essentially this model has surveillance programs which provide information in the fields of: environment, fish health, production, regulations and technology. This information is processed, analysed and directed to associated SalmonChile companies, at the same time this information is used to develop joint and coordinated actions through the Integrated Management System for producers and suppliers

[3] Based in Adolfo Alvial observations and experiences in the industry.
[4] National Institute of Statistics, survey on a statistics platform for the Chilean Salmon cluster.
[5] Indirect jobs.

(SIGES)[6], the Homo-Environmental Management Zones System and the Research-Development and Innovation Program. INTESAL has also coordinated the Clean Production Agreement (CPA) for the Salmon industry.

Likewise, INTESAL has technically worked with different public organisations like the Undersecretary of Fishery, the National Fisheries Service (SERNAPESCA), the Maritime Interests Department and the Livestock and Agricultural Service (SAG), and the National Commission for the Environment (CONAMA) to solve difficulties associated to the vaccines registration, the use of the coastal border, safety in farms, the application of regulations, mitigation of environmental impacts, among others. At the same time, and through the constitution of advisory committees and the development of common projects, it has deepened links with suppliers and the academic sector. Actually, it has acted as an articulator and catalyst for associative work, and to generate confidence when performing projects of common interest for the industry.

It is in this context of union and coordination that by the end of 2004, CORFO Xth, Region, entrusted Agraria Consultores with a diagnostic of needs for all Salmon value chain. This survey, performed with the support of INTESAL, intended to evaluate critical areas of development and identify the main challenges to contribute to the strengthening of the Salmon cluster in the south of Chilean.

Jointly, Agraria and INTESAL considered a representative sample to conduct 56 interviews to leaders of opinion from the Salmon cluster. This sample included representatives of Salmon producing companies, feed plants, nets and cages elaboration workshops, and diving and anchoring companies, carriers, labs, technological centres, and universities. Representatives from public institutions like the Regional Maritime Authority, National Fishery Service (SERNAPESCA), Undersecretary of Fishery, the Statistics National Institute (INE), and the Regional Labour Department were also included.

As a result, participants prioritised eight areas of intervention (diving, fish health, feed plants, maritime transport, environment, genetic and hatchery, ongrowing and plants, nets and cages) and their possible lines of action. The proposed lines of action were then analysed in discussion groups or "focus groups". To enrich the discussion, expert professionals were invited, reaching 109 people in the eight workshops.

According to this diagnostic, the most significant challenges foreseen for the Salmon cluster are related to four main elements.

The first corresponds to the displacement of Salmon farming towards the XI region, Aysén, and its impact on investment projects, the infrastructure associated, and the access to qualified manpower.

The second is related to the integration of production and associated services, and deepening cooperation at industry level as a strategy to improve confidence levels, reinforcing the cluster concept as a strategic tool to improve competitiveness.

The third includes the analysis of commercial challenges due to diversification economies in marketing, distribution, new trends in retail and the demands of international markets.

Finally, all people interviewed agreed the industry has developed a constant learning process, where innovation and technologies development played a fundamental role, especially on the maturity stage. Nevertheless, they pointed out that to overcome current weaknesses and to maintain leadership, it is necessary to improve: control of regulations; infrastructure and logistics; reinforce association levels; education and training; occupational safety and environmental management; increase promotion and distribution, and especially, foster technological innovation (Tables 2 and 3)[7].

[6] Currently, there are 19 producing companies associated to SIGES-SalmonChile. This is a voluntary system that seeks for standardization of productive and processing systems in matters of fish health, food quality, security and safety, environment and occupational safety and health.

[7] To the effect of this work the three most important areas are shown, according to the weightings of interviewees. For further detail, refer to CORFO 2004, Final Report "Fortalecimiento del Cluster del Salmón en la Zona Sur Austral de Chile, Agraria Consultores.

Table 2 includes results of weightings according to the different production stages split into hatchery and fresh water, fattening and sea water, and processing facilities.

Table 3 presents results of weightings according to different critical sub-sectors split into feed plants, nets and cages, diving, maritime transport, and clean production and quality.

Table 1. Salmon Cluster Evolution Own Elaboration, Based on Different Sources - Maggi (2002); Montero (2004); Iiuzka (2004); Pietrobelli; and Rabelloti (2004); SalmonChile (2006); Ulloa (2006).

Cluster life	**Initial learning**	**Formation and Maturity**	**Internalisation**	**Consolidation**
Period	1960 -1973	1974-1995	1996- 2002	2002 onwards
Production	900 tons.	1.350 -143.000	150.000 – 300.000	487.900 -
Landmarks	Technological transfer and adaptation. Demonstrative and experimental operations.	Increase in commercial level.	Asian crisis. Dumping accusations. Mergers and acquisitions. Forward linking Salmon cycle control New regulations.	SIGES Industry Surveillance Systems CPA Salmon Cluster PTI
Main Challenge	Initial boost and survival.	Association and specialisation Creation of technical institute. INTESAL	Product diversification and market penetration. Public private cooperation.	Add value to the value chain Create alliances with key suppliers.
Entrepreneurial Competitive Factor	Production: obtain and produce.	Quality: Unify standards. Backwards linking. R+D Reinforcement.	Efficiency: harvested salmon cost.	Technological Innovation and R+D in genetics, vaccine development, logistics.
Human Capital	Entrepreneurs. Non qualified manpower	Manufacturers, managers and semi-qualified manpower.	System engineers, operators, qualified manpower, researchers and experts.	Processing Certifiers. Labour Competence Certification
Social Capital	Public-private international cooperation.	Association among producers.	Productive System inserted in a global production and commercialisation Chain.	Public-private local cooperation. Diploma in managerial skills.

Table 2. Results of Weightings According to Production Stages. (Source: Agraria, 2004)

Areas of Intervention	**Areas of Action**
Hatchery and fresh water production	1. R+D in genetics (made in Chile) for: disease resistance, fish growth rate and protein digestibility.
	2. Creation of alliances and networks for the development of genetics in Chile.
	3. Creation of joint-ventures for genetics and fish health.
Fattening and sea water	1. Creación de laboratorio de referencia, estandarizar técnicas y validación de laboratorios. Creation of reference laboratories.
	2. Homologation of technical criteria and standards for the best evaluation of companies rendering services.
	3. Integral plan to face the sanitary issue and reduce the use of antibiotics.
Processing facilities	1. R+D post harvest and persistent organic components (POCs) mitigation.
	2. Generation of non-traditional sources of energy for Chiloe and XI region.
	3. Human resources recruiting and education. (TTC and Technical Schools).
Transversal	1. SIGES market validation and international accreditation.
	2. Official system for the processing and distribution of information at industry level.
	3. Full implementation of SIGES in producing companies.

Table 3. Results of Weightings According to Sub-sector**. (**Source: Agraria, 2004)

Areas of Intervention	**Areas of Action**
Feed Plants	1.Diet standardisation
	2. Feed digestibility.
	3. R+D Agricultural research of new species and varieties for fish meal and oil.
Nets, rafts and cages	1. Higher control of and supervision of current regulation.
	2. Implement cross-reference for net washing and authorised net workshops.
	3. Coordination and homologation for the application of criteria in public services.
Diving	1. Certified diving gear, further training and specialisation for divers.
	2. Hyperbaric chambers, working and properly located.
	3. Adapt regulations to Salmon farming demands.
Maritime transport	1. Roads and ports and infrastructure.
	2. Construction of unloading ports in Chiloe and the XI region
	3. Criteria unification
	4. Asymmetrical relationship among Salmon farming companies and carriers.

Table 4. Results of the First Year of PTI in the Salmon Cluster per Line of Action. (Expressed in CORFO instrument amounts)

Line of Action	**Activity**	**Goal or Benchmark $M**	**Results Year 1**
Innovation platform	Salmon Cluster Technological Programme	2.200	3.443
Public-private coordination commissions	Commissions for net workshops, maritime transport, diving and Aysen's commission.	60	150
Alliance and Networks	Record of suppliers. Management, Strengthening program for suppliers.	31	75
Total		**2.291**	**3.668**

Data collected show that the most interesting action areas for producers are oriented towards the generation of R+D alternatives in genetics and in post-harvest, but particularly in the establishment of alternatives to improve the sanitary status of the industry. It is also important the concern for the complete implementation of SIGES and its accreditation in international markets. Suppliers, otherwise, show a concern for adequate regulations and their control, and reinforcing commercial relationships with producers.

A different problem is observed in feed suppliers that just like producers also favour R+D. In the short term, this sector shall face strong challenges in the improvement of diets, the development of feed with higher digestibility, and the substitution of proteins and animal oils by vegetal origin inputs.

Contribution of the Integrated Territorial Program (PTI) Salmon Cluster

Due to the diagnostic performed by Agraria and to focus efforts in areas and actions prioritised by the industry itself, and address technological challenges of cluster at medium and long term, in 2005 CORFO Xth Region decides to commence a support initiative and invites INTESAL as technical coordinator. This initiative is materialized through the implementation of the Integrated Territorial Program (PTI) of the Salmon Cluster.

Even though the administration and coordination of the Salmon Cluster PTI is CORFO's and INTESAL's responsibility, the program has an advisory committee represented by the presidents of the Salmon Industry Association (SalmonChile A.G), the Association of Diving Companies (ADEB), the Association of Veterinarian Labs (ALAVET), the Association of Maritime Ship-owners (ARASEMAR), the Association of nets workshops (ATARED), and the Regional director of CORFO Xth Region.

The Salmon Cluster PTI has four strategic areas, these are: focusing public resources towards critical points of the Salmon value chain, reinforce the entrepreneurial base of suppliers, update the regulative base, and detect opportunities for conducting R+D projects and investment. The program is projected throughout four years, and they have been organised through three lines of action.

First, an ***innovation and knowledge platform***, which makes different CORFO instruments for the promotion of innovation and research available for cluster parties. This line is intended to maximise the coordination between public and private areas, focusing public investment on sectors prioritised from the vision of the industry's stakeholders.

Public-private coordination committees, as opinion instances to define priorities in matters related to the improvement and application of regulations governing companies of the cluster, particularly suppliers.

Finally, a transversal action line called ***alliances and networks*** to agree on initiatives to support the previous action lines. This line mainly intends to include problems related to suppliers' development and improvement, creation of standards for suppliers, and management certification.

In its first year of execution, the PTI program of the Salmon Cluster shows a hundred per cent compliance with goals and benchmarks related to the placement of CORFO instruments by action line (Table 4). This is equivalent to an investment of $3.668 million Chilean pesos inside the Salmon cluster, 38% higher than projected for the first year of operation.

In the innovation platform line the first Technological Program of the Salmon Cluster was started along with Innova Chile from CORFO. During the first stage of this program, 29 projects were approved in the areas of fish health (5), genetics (5), animal food and nutrition (3), environment and clean production (7), development of new technologies (4), productive management (2), and quality and processing (1), finally in management and certification of suppliers (2). In terms of quantity, these projects represent a total investment of $7.281 million Chilean pesos.

In the public-private coordination line four work committees were established in the Xth Region, in the areas of maritime transport, net workshops, diving, animal sanitation, and a commission for the XI Region of Aysén. As a result of this work, improvements in the labour situation of divers and crews on board were proposed; one proposal for a new calculation of ships fulfilling the needs of the cluster depending on their GRT or GT[8]; one proposal to implement a nets register system in coordination with SERNAPESCA; one proposal to reinforce education and training for divers in the XI Region; one plan of education and training for divers in the XI Region, Aysén; and finally one prospective survey on vaccines and pharmaceuticals accreditation process.

At the same time, and as a part of the transversal support to the public-private coordination commissions, the program, in coordination with the quality area of INTESAL, focused on the conduction of a project to make standards and a certification process for suppliers, called SIGES-suppliers. To that aim, an alliance was established with 16 companies from the sub-sectors of maritime transportation, net workshops, pharmaceutical and analysis labs, industrial sanitation, diving, packages and packaging, the certifying organisation CMI Agrivera, and public organisations as NNI, and the Ministry of Economy Regional Department. The project shall conduct for every sub-sector a complete review of regulation, manuals of best practices, and a certification process, consolidating SIGES as a cluster tool, establishing standards for all the chain as a whole.

Regarding alliances and networks, the focus was on the implementation of a suppliers register for

[8] Gross Register Tonnage (GRT) and Gross Tonnage (GT).

12 key sub-sectors. This register will include legal, financing, technical-curricular and labour aspects, as well as data on accreditations, technical files and procedures. This project has the initial support of four big producers and intends to include more than 200 suppliers after two years of operation.

Additionally, it has been established a reinforcing program for suppliers by implementing an entrepreneurial training program with a first group of 15 supplier companies linked to the Salmon cluster, and support for the management of three Supplier Development Programs (PDP) within Salmon producing companies.

Discussion and Conclusions

The economic, productive, and relational evolution of the Salmon industry meets the requirements of a cluster vis-à-vis Porter's definition. The Salmon cluster is mainly concentrated in Regions X and XI, and associative networks among different stakeholders have been created around it. It also has a wide offer of suppliers of specialised goods and services that along with producers and Universities have generated a constant learning process, and technological innovation through permanent networks of mutual collaboration.

The Salmon cluster evolution has also been marked by different initiatives of public-private collaboration. The most important has been the investment in technology transfer and development.

The abovementioned is consistent with the evolution of the innovation expenditure inside the cluster. In absolute terms, figure 1 shows -as a result of contributions from different sources of public support and their private counterparts, added to investments made by INTESAL in industry's programs- that between 1997 and the first semester of 2006, R+D investment in the cluster increased from $10.000 million to more than $42.000 million[9].

Particularly, CORFO has contributed to the sector's development supporting different programs, projects, and surveys. Areas of higher investment have supported suppliers with projects and programs oriented to the quality management, disease control, productive innovations, and mitigation of environmental impacts[10].

The evolution process shows that as of 2002, Salmon industry started a consolidation stage through different political- guild and technical initiatives promoted by SalmonChile and INTESAL, respectively.

To reinforce this consolidation process, INTESAL strongly contributed to the generation of new approaches among the different cluster stakeholders, developing projects along with suppliers, the academic sector, and public institutions. This interaction has made possible the development of a Surveillance and Management Model covering environment, fish health and production aspects in the industry.

Amongst these actions, it is possible to remark the joint effort between CORFO and the Industry in order to elaborate a diagnostic throughout the value chain, in for identifying the main challenges and to provide courses of action to deepen the consolidation process of the Salmon cluster. This diagnostic was useful as a base line for the Implementation of an Integrated Territorial Program (PTI) which shall take as challenge the integration of production and associated services, and the reinforcement of the cluster concept as a strategic tool to improve competitiveness.

From the results of this diagnostic, we may also highlight -from the producers standpoint-there is a strong orientation towards reinforcing innovation, especially in fish health. This is consistent with the sanitary issues of the industry, since the presence of infectious disease currently produces big economic losses. The reduction of this mortality shall generate,

[9] We considered up to the first semester of 2006 due to the start up of Innova Chile and the periods of application and delivery of results (project formalization). The final figure of 2006 shall depend on projects received through CORFO innovation.

[10] Official sources CONICYT, FIA, FIP, CORFO, FNDR X Region and SalmonChile.

therefore, bigger economic margins and an increase in the industry's profitability.

From the suppliers standpoint priority was on interaction between producers and suppliers, the construction of confidence within the cluster and the improvement of regulations governing suppliers of the industry. Thus, it is possible to infer that even present, innovation in the suppliers under study does not seem to be a priority in the short term.

In terms of producers and suppliers interests, the abovementioned is consistent with the evolution cycle of the commercial relationship of producers and suppliers in relatively new industries like the Salmon industry. These go from basic policies based on prices and volumes to collaborative long term policies, with evaluation processes and negotiations based on the total cost of the operation (FUNDES, 2005).

Feed suppliers, on the other hand, face strong innovation challenges in oil replacement. The latter, along with recent price increases due to national and international shortage, has enabled a positive scenario to generate strategic alliances between feed producers and suppliers. Certainly, due to productive size and concentration of companies in fattening stage, feed plants have a significant power of negotiation to establish this kind of agreements with producers. To the latter, however, represents a strategy to ensure the supply of a critical input.

The implementation of the Integrated Territorial Program (PTI) of the Salmon Cluster is an answer to underpin the current consolidation process, according to the evolution cycle of the Salmon cluster. Its action lines were focused on solving the most urgent concerns of different sub-sectors within the Salmon cluster.

From a quantitative standpoint, results show investments in each action line exceeded initial projections for the program. Specially, as shown in Figure 2, only during the first semester of 2006 CORFO increased more than 50% its incentives in innovation instruments compared to the previous year, especially incentives for public interest projects i.e. oriented to improve market conditions.

As the most relevant result, Figure 1 shows that the Technological Program of the cluster took R+D investment to its highest level in relation to the increase in the total sales of the industry.

Nevertheless, analysing the actual impact of this resources injection entails posterior surveys and analysis where benchmarks related to growth, efficiency and productivity are evaluated. In addition, it is also necessary to evaluate the level of influence amongst the different stakeholders of the industry and its incidence in the cluster competitiveness.

Finally, and since the Chilean Salmon cluster has a strong dependence on foreign trade, any analysis must consider the effects of the new trends in distribution and retail in destination markets.

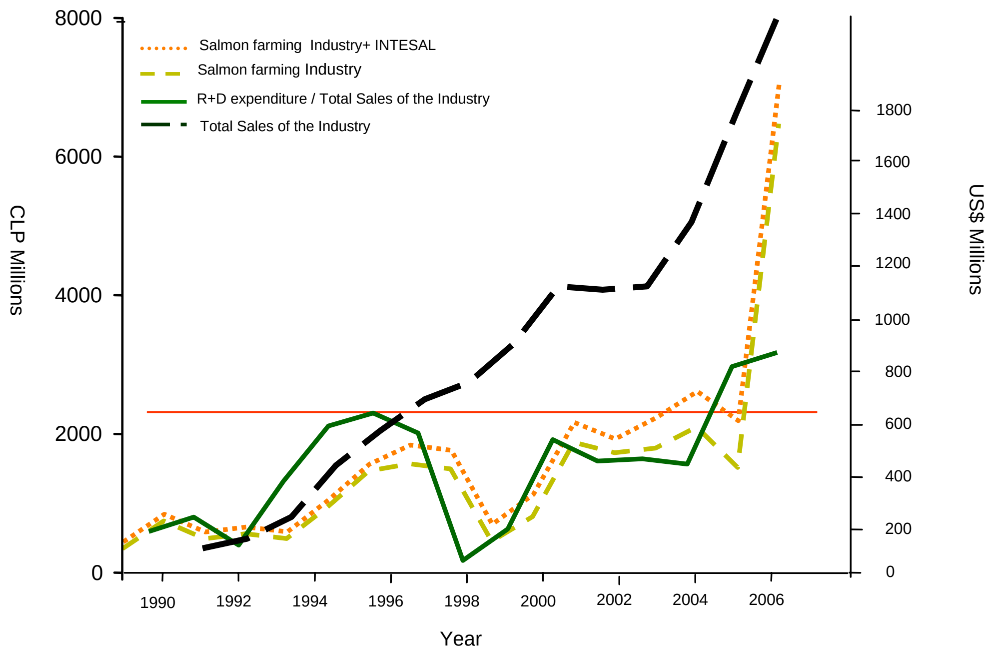

Figure 1. Evolution of public funds and INTESAL's contributions in the Salmon Cluster. (Source: Made from the national base of R+D projects (FIA) and official sources from CONICYT, FIP, CORFO, FNDR Xª Region, INTESAL.)

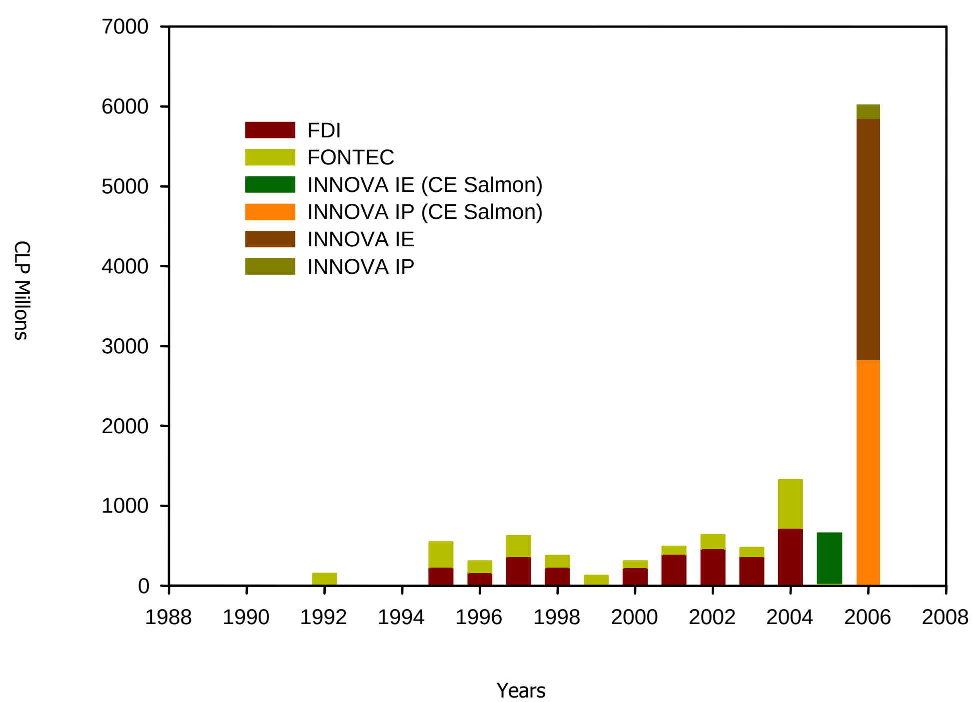

Figure 2. Evolution of CORFO innovation investment in the Salmon Cluster. (Source: Made from the national base of R+D projects (FIA) and official CORFO sources 2006.)

References

1. Achurra M. 1995. La experiencia de un nuevo producto de exportación: los salmones, in P. Meller y R.E Saez (eds.), *Auge Exportador Chileno: Lecciones y Desafíos Futuros, Santiago, Chile*. CIEPLAN/Ediciones DOLMEN.
2. Agraria Consultores. 2004. Fortalecimiento del Cluster del Salmón de la zonasur Austral de Chile, study developed for CORFO, X[a] Región, por *J. Echenique,* L.Vidal y W. Vera.
3. Borges Méndez R. 1997. The new geographical Economics, natural resources based development and some policy challenges for Latin America, *CEPAL, mimeo*, April, 1997.
4. CORFO 2006. *National Database on Projects Approved by Innova Chile*, former Fontec and FDI funds.
5. Enright M, Roberts B. 2001. Regional Clustering in Australia, *Australian Journal of Management*, vol.26, Special Issue.
6. FUNDES 2005. At *www.fundes.org*, in publications/presentation for the implementation of supplier development programs (SDP).
7. Hirschman A. 1977. A generalized linkage approach to development with special reference to staples, In *Economic Development and Cultural Change,* Chicago, University of Chicago Press.
8. Iizuka M. 2004. Organizational capability and export performance: the salmón industry in Chile. SPRU, *Science & Technology Policy Research*. January 5, 2004. 23 pages.
9. INE 2004. *Statistics platform for the Chilean Salmon cluster.* Document entrusted by CORFO Xth Region.
10. Krugman P. 1995. *Development, Geography and Economic Theory*. Cambridge, Massachussets, MIT Press.
11. Maggi C. 2002. *Cadenas productivas: lecciones de la experiencia internacional y regional: el cluster del cultivo y procesamiento del salmón en la región su-austral de Chile*. Documento basado en el proyecto de cooperación tecnica: BID-FOMIN
12. Montero C. 2004. Formación y Desarrollo de un Cluster Globalizado: el Caso de la Industria del Salmón en Chile, *ECLAC Series Productive Development*, Nº 145, Santiago de Chile: ECLAC.
13. North D. 1995. Location theory and regional economic growth. *Journal of Political Economy*, June edition.
14. Pietrobelli C, Rabellotti R. 2004. *Upgrading in Clusters and Value Chains.Washington, D.C.: Inter-American Development Bank.(*versión en castellano: Mejora de la competitividad en clusters y cadenas productivas en América Latina -El papel de las políticas*)*.
15. Porter M. 1998. *Clusters and the New Economics of Competition*. Harvard Business Review, November-December, pp. 77-90.
16. SalmonChile 2006. Informe económico de la salmonicultura 2005. Departamento de Estudios, Junio 2006. In *www.salmonchile.cl*.
17. Torres C. 2006. *Development of Technology Intensive Suppliers in Natural Resources Based Economies: the Case of Aquaculture in Chile*. Universidad de Leipzig. PhD Degree Thesis.
18. Ulloa A. 2005. Document. *Diseño de un Sistema de Información Sobre Variables eIindicadores a Interior del Cluster del Salmón*. Industrial Engineering Department. University of Chile.
19. Van der Linde C. 2003. *The Demography of Cluster- Findings from the Cluster Meta Study.* Harvard Business Review, mimeo.

Framed Salmon: How an ENGO Coalition Frames the Salmon Farming Issue in British Columbia

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Abstract

This paper describes and interprets how an environmental non-profit coalition develops and frames their communications strategies in the midst of an ongoing social controversy in the context of the modern globalized environmental movement. Focusing on the Farmed and Dangerous campaign against salmon farming in British Columbia by the Coastal Alliance for Aquaculture Reform (CAAR), this paper describes how framing processes are used as a tool to further CAAR's political and organizational goals by using technology and the media to make claims. This paper takes existing literature on framing approaches in social movements and explores how CAAR members frame the salmon farming issue in order to preserve messaging alignment within their coalition using diagnostic framing and frame communications using emotional language, celebrities, technology and linkages to other powerful organizations to influence government, retailers, consumers and ultimately public policy. This paper is an excerpt from a Master's Degree Manuscript by Walling 2006.

Introduction

The concept of framing as a communicative strategy was introduced by Gregory Bateson who described it as a meta-communicative device that set parameters for "what is going on" (Bateson, 1973). Framing can provide the context in which information is presented and processed and has widely been used as a tool for interpreting and analyzing public debate on issues (Hallahan 1999). By developing this interpretive framework, participants can define how others actions and words should be understood (Bateson 1973).

Framing provides the context in which information is presented and processed and has also widely been used as a tool for interpreting and analyzing public debate on issues. It has evolved into a form of deliberate and strategic structuring and aligning of information used by social movements to shape a shared understanding of the world in order to legitimatize and motivate collective action.

Collective action frames can emerge through affiliation with preexisting groups and networks, especially important in a globalized environment (Swaminathan 1995). These networks are transnational in nature and seek alliances with movements in other countries to support their efforts (Lee & Tjernshaugen 2004). Frames draw on already developed or existing cultural codes (Gamson & Modigliani 1989) and "masterframes" are then linked to protest cycles functioning to "turn the heads" of movement participants and movement entrepreneurs in a certain direction (Snow & Benford 1992).

Throughout history, social movements have acted as agents for change. Starting with a prolonged period of grassroots mobilization for environmental movements in the 1960's, environmental non-profit organizations (ENGOs) began to take on what they perceived as environmental crimes and neglect of governments and industry to address these concerns. These "movement entrepreneurs" have evolved into highly sophisticated international organizations, demonstrating strength, reach and political savvy (Edelman 2001). In many Western countries, membership in environmental organizations has grown rapidly, sometimes surpassing membership in traditional political parties (Edelman 2001). Part of the reason for this growth is that ENGOs have successfully framed their organizations to be credible advocates to protect the environment and the public interest.

Environmental non-governmental organizations (NGOs) use a variety of strategies to implement their goals, which include lobbing, litigation and campaigning, as well as more expressive tactics like protests and boycotts. Since 1980s there has been a growing trend for ENGOs to engage in negotiation with government and industry to further their objectives. Individual organizations have aligned themselves into coordinated and multifaceted coalitions which have achieved greater success in fund raising and gathering power with the media than the individual organization. The ENGO movement has had success in building a direct communication link with the media by framing the issue for the journalist and in some cases, becoming a part of the story.

British Columbia Situation

Through the completion of a multi-year, multi-million dollar review of the industry, the extensive Salmon Aquaculture Review concluded that "farming in British Columbia, as presently practiced and at current production levels presents a low overall risk to the environment." As a result, there was an expectation that the moratorium on salmon farm licenses would be lifted in 2002.

The outcome of this review had other results.

- Several ENGO groups immediately framed the government review as inadequate to defend the public interest.
- The report became a galvanizing point for the establishment of a formal collation of ENGO groups, Coastal Alliance for Aquaculture Reform (CAAR), to "oppose sustainable practices and to protect wild salmon, coastal ecosystems, cultural traditions and humans from destructive salmon farming practices."

Since then the British Columbia salmon farming industry has seen a systematic manipulation of information about the industry by various groups that has contributed to a lack of forward movement in new salmon farming site approvals vital to the continued success of the industry. This has occurred in spite of the industry efforts to provide a balance of information in the media and to consumers. This study was undertaken to determine why the ENGO attacks on the salmon farming industry and other industries have been so successful and the implications this has for our society in terms of their influence on future public policy.

Methodology

The CAAR website www.farmedanddangerous.org and 10 CAAR coalition member websites were reviewed during a two-week time period, from December 15, 2005 to January 1, 2006. All web documents from these 11 sites referencing salmon farming, fish farming and salmon aquaculture were retrieved. Each piece of information was sorted and coded to identify key themes and unique patterns within the data collected from each site. Framing themes were identified and prioritized and several themes were selected. The text was sorted into manageable pieces through identification of frequency of key words using a visual outcome called "key word density clouds". Analysis was conducted using a key word density tool. The keyword density tool crawls each URL and extracts the text as a search engine would, removing common stop words, or words that are passed over by search engines such as: the, for and because, as an example, and analyzes the density of the keywords. The words that are used more frequently or have a higher density are depicted in larger fonts, blending word and image. Table 1 is an example of this research.

Table 1. Density Cloud Example from the David Suzuki Foundation Salmon Farming Page.

david suzuki foundation oceans fishing aquaculture open netcage salmon farm british columbia coast fish farming practiced humans centuries canada farms operational coasts 's sustainably viable alternative harvesting wild stocks bc polluting environment threatening integrity primarily studies shellfish effects marine environments history culture plants animals long tradition human main historical incentives cultured food production increase amount reduce energy costs involved searching gathering transporting improve stability predictability reliability supply cultivating storing excess stabilize quality earliest records date thousands years china carp freshwater

Table 2. Comparison CAAR and David Suzuki Foundation Objectives.

David Suzuki Foundation policy recommendations from Net Loss report	CAAR Farmed and Dangerous Campaign goals
Replace open cages with closed containment systems	Develop technology that eliminates the risk of disease transfer to wild fish and escapes of farmed salmon into the wild
Eliminate discharge of fish sewage (zero discharge)	Guarantee fish farm waste is not released into the ocean
Develop and use a process for gaining the agreement of coastal communities regarding the siting of all existing or proposed aquaculture operations	Respect the views of coastal residents by not locating farms where First Nations or other local communities object
Prohibit the use of firearms and acoustic deterrent devices that harass marine mammals and require the use of technologies that safely separate local wildlife from salmon farming operations	Ensure that wildlife is not harmed as a result of fish farming
Eliminate the use of fish that could be used as human food as the primary feed for farmed salmon	Develop fish feed that does not deplete global fish stocks

Back link analysis was used to determine linkages between organizations. Further analysis by sorting by key words, listing of negative or emotional language and references to food safety was completed to gain a better understanding of the use of language and discursive and action tactics.

Results

Diagnostic Framing

Diagnostic framing consists of outlining the issues, proposing solutions and identifying the antagonist. CAAR developed their shared understanding of the nature of the problem and views of possible solutions for the members of the coalition by using several of the policy recommendations developed previously by the David Suzuki Foundation in their report "Net Loss" posted on the CAAR member websites, see Table 2.

CAAR's additional goals referenced their emerging market campaign direction and, as such they focused on food safety with the following consumer oriented objectives 1) prohibit the use of genetically modified fish; 2) eliminate the use of antibiotics, biocides and harmful chemicals in fish farming; 3) ensure contaminants in farmed fish do not exceed safe levels and 4) label all farmed fish so consumers can make informed choices.

The anti-salmon farming campaign was built on previous forest industry campaigns. CAAR's decision to direct a portion of the campaign goals toward the market has its roots in the success of the forest boycotts products. British Columbia has a history of conflict in resource industries most notably the conflicts in the forest sector. Several of the individuals and organizations now involved in CAAR, joined by US environmental groups, were also involved in the successful consumer boycott of forest products made from British Columbia's old-growth wood.

In the case of the BC salmon farming industry, industry and government were interpreted by CAAR as powerful and highly organized actors that imposed their interests on others. CAAR characterized the salmon farming industry in BC as a group of uncaring and powerful multinational corporations and government as a willing allay.

Bridging with the Media

Because CAAR is attempting to gain legitimacy to achieve desired results, non-member groups play an important role in testing the issue in the media using confrontational tactics that are edgier and less acceptable to the mainstream audience. These activities were successful in gaining media attention and positioned the salmon farming issue with the media without endangering the CAAR position.

The coordinated anti-salmon farming campaign was launched with several direct action confrontations initiated by the Forest Action Network (FAN), which appeared to operate at arms length from the CAAR organization (www.fanweb.org). FAN is not listed as a CAAR member or referenced by CAAR but the backlink analysis indicates several links from FAN to the CAAR website and FAN was joined by CAAR members at some events. FAN's tactics are focused on securing media attention for the issue of interest. FAN used their expertise in direct action campaigns to initiate several media focused direct actions against salmon farming. These public demonstrations were successful in gaining media attention and positioned salmon farming as a hot issue in the mainstream media.

This confrontational approach provided the opportunity for CAAR to frame their coalition goals as reasonable and solution oriented and because they must preserve messaging alignment between member organizations, they can create a distance from more radical organizations such as FAN.

Technology and Linkages with Powerful Organizations

Technology is used to enhance the traditional advocacy techniques of ENGO organizations, providing information, expertise and intervention strategies, which broadly raises awareness and coordinates action more efficiently. Professionally designed websites are an important part of the ENGO campaign. Effective grassroots engagement is a key factor to campaign success.

Originally CAAR relied on linkages to technology that maximized on line advocacy efforts though Wild Canada.Net, an online conservation organization (www.actionworks.ca). According to their website, Wild Canada.net received funding mainly through foundations and partner groups and with a mailing list of 25,000 people in Canada they had ambitious goals to recruit 10,000 new network participants in 2005 (www.wildcanada.net).

Wild Canada ceased providing services and as a result CAAR transferred to ONE/Northwest (www.onenw.org) a Seattle based nonprofit that provides technology resources and expertise to groups in the Pacific Northwest (subscriber email Feb 2005). One/Northwest is part of a larger organization called Democracy in Action, a US based organization that develops online advocacy tools and campaigns to create social change assisting over 200 organizations with their advocacy efforts with over 7 million supporters, sending over two million messages a week to subscribed individuals, with the service quadrupling in size since the beginning of 2005 (www.democracyinaction.org).

These partners develop technology tools for their clients use to distribute maps, reports, photos, information, news releases, articles, media materials, frequently asked questions, (FAQs), activist toolkits, stickers, flyers, labels and e-postcards. Lobbying actions driven with the aid of the online technology tools from the CAAR website include: participating in the boycott market campaign, writing and customizing pre-written letters and sending faxes to industry officials, industry shareholders, provincial and federal government representatives, letters to the editors of selected news publications, retailer education programs, posting testimonials, donating money, purchasing products and direct action protests.

Use of Emotional Language

The use of negative language is consistent with motivational theories that people act to protect themselves more readily if the action is framed negatively (Hallahan 1999, p. 208). The CAAR farmed and dangerous anti-salmon farming campaign uses multiple messaging series that include: disruptive oppositional arguments, emotional and negative language, use of celebrity, bearing witness and market driven rhetorical invention, as key elements of their campaign. Examples of disruptive oppositional arguments are shown in Table 3.

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Table 3. Examples of Disruptive Oppositional Arguments.

Social Positive	Social Negative	Inference for Consumer/ Public
Healthy, nutritious and tasty product • reducing coronary heart disease by 30% • good taste and quality • year round supply and good quality product	Poison and toxic product • inferior to wild salmon contaminated with PCBs and other chemicals • reputable restaurants and chefs won't serve the product	Risky food choice especially for children and pregnant women
Protects wild stocks from over fishing by providing a source of fish to meet growing world population	Destroy wild stocks through disease, escapes leading to genetic dilution through inbreeding, genetically modified and sea lice	Fear of losing cultural heritage
Opportunities for coastal communities providing employment, and benefits for having a stable year round industry, BC's largest agricultural export	Multinational companies taking advantage of workers while threatening other industries such as commercial fishing and tourism because of collapse of stocks	Urban market and voters not affected day to day and want a pristine place to visit or retire in

The choice of words used on the CAAR and its coalition member websites also present information in a variety of ways, described as "valence framing" (Hallahan 1999). CAAR must preserve messaging alignment between member organizations, gain legitimacy in the dominant culture to achieve desired results and at the same time, ensure that tactics are acceptable to their supporters. The key word analysis reveals strong emphasis on emotional and negative language yet the CAAR goals are framed in positive solution oriented language.

The solution oriented language may be aimed at mainstream audiences such as government, industry and policy makers to build CAAR's attributes to be seen a reputable organization.

Use of Celebrities

A key strength of ENGOs is their ability to recruit support from celebrities and high profile public figures to take up their causes (Olson & Goodnight 1994). CAAR has also capitalized on a growing interest in food and some chefs' interest in increasing their profile by aligning themselves with high profile campaigns and have recruited several chefs as advocates for the farmed and dangerous campaign. These celebrities receive media attention in BC with no questions asked about scientific accuracy of their statements.

Communicating about science-based issues in salmon farming is complex. One of the challenges in communicating complex concepts is the need to be clear and simple while leading people to migrate from the black and white issues into more complex areas (SustainAbility 2005).

Because of this complexity, journalists rely on one or two scientists and position them as important authority figures to interpret scientific findings (Nisbet et al 2002, p. 590). As an example, CAAR's highest profile celebrity scientist, Dr. David Suzuki, is framed as one of their leading authority on science and the environment.

Conclusion

CAAR has been highly successful in using framing techniques to emerge as a science based lobbying coalition, framing themselves as the primary source of information on salmon farming to the media, government and the public. Successful framing techniques practiced include the following.

- Preserving message alignment with CAAR member organizations.
- Building strong linkages to other powerful organizations that provide valuable support services.
- Using technology to build membership and provide information.
- Developing direct and sustained contact with the media.
- Using emotional language to enhance the message and to motivate action.
- Using celebrities framed as leading authorities.

References

1. Walling ME. 2006. *Framed Salmon: How an ENGO Coalition Frames the Salmon Farming Issue in British Columbia*. M. Sci. Thesis , Royal Roads University, Victoria, BC
2. SustainAbility, The 21st Century NGO: In the Market for Change Accessed October 25, 2006 *http://www.sustainability.com/downloads_public/insight_reports/21st_ngo.pdf*
3. Bateson G. 1973. *Steps to an Ecology of Mind*. London: Paladin B.C. Seafood Year in review (2004).
4. Edelman M. 2001. Social Movements: Changing Paradigms and Forms of Politics. *Annual Review of Anthropology* 30:285-317.
5. Gamson WA, Modigliani A. 1989. Media Discourse and Public Opinion on Nuclear Power: A Constructionist Approach. *American Journal* of *Sociology* 95(1):1-37.
6. Hallahan, K. 1999. Seven Models of Framing: Implication for Public Relations. *Journal of Public Relations Research* 1(3): 205-42.
7. Lee H, Tjernshaugen A. 2004. Shaming and Framing: Norwegian Nongovernmental Organizations in the Climate Change Negotiations. Accessed May 2006 from *http://www.cicero.uio.no/publications/detail.asp?publication_id=3014&lang=en*
8. Nisbet MC, Scheuffele DA, Shanahan J, Moy P, Brossard D, Lewenstein BV. 2002. Knowledge, reservations, or promise? A media effects model for public perceptions of science and technology, *Communication Research* 229(5):584-608.
9. Olson KM, Goodnight GT. 1994. Entanglements of Consumption, Cruelty, Privacy and Fashion: The Social Controversy over Fur. *The Quarterly Journal of Speech* 80(3): 249-276.
10. Snow DA, Benford RD. 1988. Ideology, Frame Resonance and Participant Mobilization, *International Social Movement Research* 1:197-219.
11. Swaminathan A. 1995. The proliferation of specialist organizations in the American wine industry: 1941-1990. *Administrative Science Quarterly* 40:653-680.

Growth, Feeding and Motile Behaviour in Blue Mussels (*Mytilus* sp.) in the Presence of the Starfish, *Asterias vulgaris*

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Abstract

Predation of mussels, *Mytilus sp.*, by the common starfish *Asterias vulgaris* can be a serious problem on mussel farms. In addition to direct predatory losses, starfish can affect growth and behaviour in wild mussels, so it is important to understand these possible influences on farmed mussels. The objectives of this study were to determine the relationship between the presence of starfish waterborne chemical cues ('scent') and the growth, feeding rate, and mobility of farmed blue mussels at both low and high temperatures. Our findings show that mussels exposed to starfish 'scent' grew slower, had a reduced clearance rate for food and showed reduced mobility over those not exposed to starfish chemical cues. Visual observations suggest mussels produced more byssal threads when exposed to higher concentrations of starfish scent. Temperature influenced the relationship between starfish scents and mussel performance but the pattern was unclear. We conclude that high standing biomass of starfish below or near culture gear can contribute to reduced mussel performance, and hence losses to farmers.

Introduction

Starfish predation on mussel farms can be a major production constraint. Starfish, such as *Asterias vulgaris*, may reach very high concentrations in the natural environment (up to 809/square meter) (Dare 1982) and mussels are a major food source for numerous species of seastar (Feder 1959, 1970; Paine 1966, 1976; Landenberger 1968; Menge 1972; Menge and Menge 1974). For this reason, starfish tend to collect in high concentrations on mussel aquaculture sites in areas where drop off is common from suspended gear. Existing studies have shown that blue mussels have evolved predator-inducible plastic defences to deal with the presence of starfish in their habitat (Reimer and Tedengren 1996). Bivalves possess chemosensory mechanisms allowing detection of predator presence and modification of their behaviour. In the presence of waterborne effluents from crabs and starfish, mussels can develop firmer byssal attachments, thicker shells and larger adductor muscles, and likely also increase reproductive effort (Cote 1995; Reimer and Tedengren 1996; Leonard et al. 1999; Reimer 1999). Recent trials on cultivated mussels by Copp (2000) showed impaired growth of tissue and shell by water-borne chemical scents from starfish at temperatures below 10ºC. Starfish may not only cause losses in mussel culture production through predation on the mussels, but by inducing defense mechanisms in mussels which would decrease their growth, thereby decreasing farm production. Although this knowledge does exist, it is limited and only small amounts of research have focused upon cultured mussels.

The rationale behind this study was to examine the effect of starfish presence upon farmed mussels and to determine the influence on feeding behaviour, growth performance, and survival, with a view to extend current knowledge on starfish-induced mussel behaviour from wild to cultured mussels. The overall objectives of this study were to determine the relationship between the presence of starfish (*Asterias vulgaris*) water-borne chemical cues and the growth rate, feeding rate, and motility of mussels (*Mytilus sp*.), as well as to determine if mussel response to the presence of starfish water-borne chemical cues is temperature dependent.

Materials and Methods

This study was carried out at the Marine Institute's Aquaculture Facility over a total trial period of 28 days, subdivided into two trials, each two weeks in length, allowing for observations of mussel behaviour at 'low' temperatures (3 - 5°C) and at 'high' temperatures (increasing from 7.5°C - 14.5°C). Mussel growth, filtration rate and mobility were tested at four concentrations of 'starfish scent' with these treatments being designated as a 'control', 'low', 'medium', and 'high' concentrations of 'scent'. Twenty individually numbered mussels (between 25 and 45mm in length) were randomly assigned to each treatment. Mussels were fed a mixture of three algae, every second day. 'Starfish scent' was induced by holding starfish at three different densities (***Low Temperatures***: Low -0.2kg starfish/30L seawater, Medium – 1.0kg starfish/30L seawater, and High – 5.0kg starfish/30L seawater. ***High Temperatures***: Low – 0.04kg starfish/30L seawater, Medium- 0.2kg starfish/30L seawater, High - 1.0kg starfish/30L seawater), in three separate aquaria, and adding water (2 litres) from each aquarium to the designated mussel treatment container during feeding time.

Mussel growth was determined by measuring mussel length, height and width (nearest 0.01 mm), prior to starfish scent exposure and after the two week exposure period. Mussel filtration rates were measured by taking algal density samples pre- and post-feeding for a 24 hour period (N=2 measurements per treatment). Cell densities were measured with a haemocytometer and filtration rates calcultated per mussel. Mussel mobility rates (cm/hr) were measured for 10 mussels exposed to each tested starfish concentration. This was accomplished for both temperature trials by using a 1x1cm grid and monitoring mussel movement over an hour (four 15 minute intervals) and recording initial and final positions of each mussel's umbone during the interval.

Results

Mussel Growth Rate

Figure 1 shows the average growth rate (microns/day) in width, height and length of mussels exposed to the three trial concentrations of starfish 'scent' and in the control group, at 'low' and 'high' temperatures, respectively. Mussel heights and widths were significantly different among starfish scent concentration treatments, in the low temperature trial (ANOVA, $P<0.05$).

Mussel Filtration Rates

No statistically significant trends were noted in filtration rates between starfish concentration exposures. However, there was a slight decrease in the filtration rate in mussels exposed to starfish scent at high temperatures compared to controls. Mussels at lower temperatures filtered faster than those at high temperatures. Figure 2 shows the visual evidence of mussels not exposed to 'starfish scent' filtering faster than those exposed to 0.04kg/L starfish effluent.

Mussel Mobility

Mussel crawling rates were significantly different among the starfish scent concentration treatments in the high temperature trial at a significance level of 0.10. It was also noted that most movement occurred in the first 30 minutes of the movement trials.

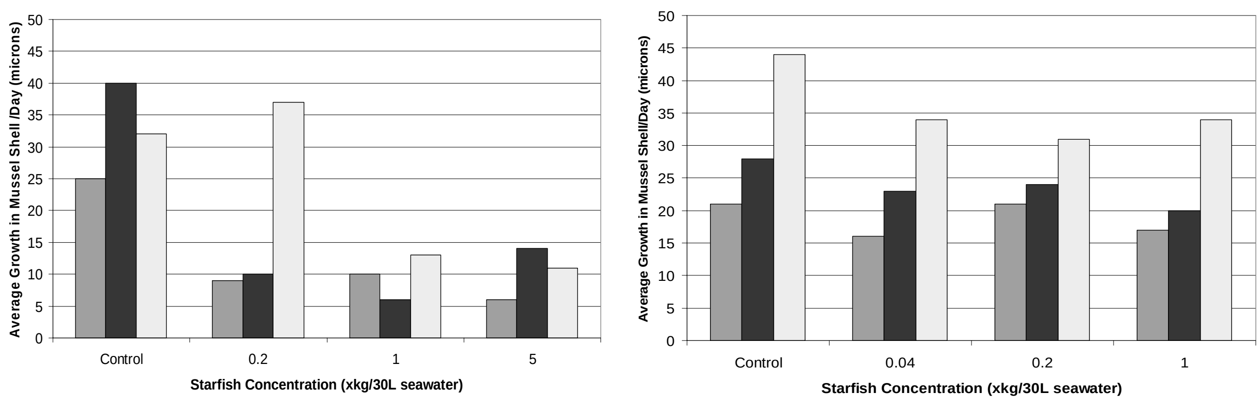

Figure 1. Growth rates of mussel shell width, height and length (n=18-20) in a control (no starfish scent concentration) and exposed to low, medium and high starfish scent concentrations, at low temperatures (3-5˚C, left panel) and high temperatures (7.5-14.5˚C, right panel) over two week periods. ***Legend:*** *Gray = Width; Black = Height; White = Length.*

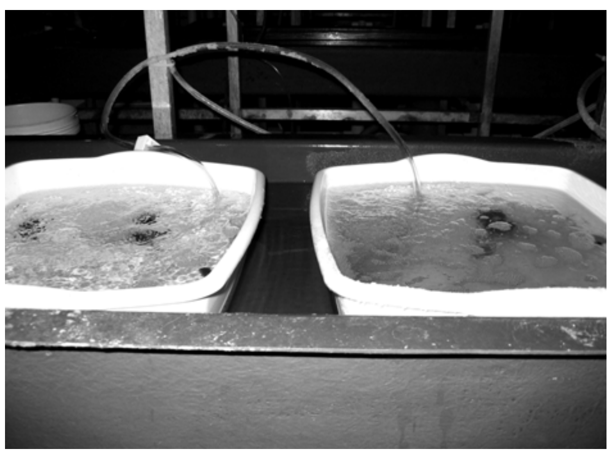

Figure 2. Left - Control treatment without starfish exposure showing no food remaining after 24 hours exposure. Right – Treatment exposed to scent of 0.04kg starfish/30L seawater concentration showing food remaining at 24 hours post-feeding.

Discussion

Mussel Growth

Higher mussel growth rates were observed at higher temperatures as anticipated.

Decreased shell growth rates were observed in mussels with increasing exposure to starfish at both temperatures, but only significant at lowest temperature (2-3X less than control). The findings support previous studies on farmed (Copp 2000) and wild mussels (Reimer and Tedengren 1996) in which presence of small levels of starfish scent will affect growth of mussels in the vicinity of predators.

Mussel Feeding Rates

A slight decrease in filtration was observed from ‘control’ to mussels exposed to starfish odours, suggesting an effect of starfish presence upon mussel feeding rate. However, from visual observations mussels not exposed to starfish fed more rapidly than exposed mussels. Mussels at lower temperatures fed faster than those at high temperatures, suggesting the mussels at higher temperatures had not acclimated to lab conditions fully.

Mussel Mobility
Contrary to expectations, mussels at higher temperatures increased crawling speed with an increase in starfish scent, suggesting an escape response. The escape response was not observed at lower temperatures, where mussels had a tendency to produce more byssus with exposure.

Conclusions

Our study confirms previous studies on wild mussels where starfish exposure increases energy expenditures in terms of byssus production, escape (crawling) responses and shell thickening, all resulting in reduced growth of mussels. The presence of starfish predators appears to reduce food intake and modify feeding behaviour in mussels, likely resulting in reduced energy intake. We conclude that farm areas with large predator abundances near culture lines, may experience reduced production on the farm if mitigative measures to reduce predator abundance are not taken.

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References

1. Dare PJ. 1982. Notes on the swarming behaviour and population density of *Asterias rubens* L. (Echinodermata, Asteroidea) feeding on the mussel *Mytilus edulis. J. Cons .Int. Explor. Mer* 40:112-118.
2. Feder HM. 1959. The food of the starfish, *Pisaster ochraceu*s, along the California coast. *Ecology* 40:721– 724.
3. Feder HM. 1970. Growth and predation by the ochre seastar, *Pisaster ochraceus* (Brandt), in Monterrey Bay, California. *Ophelia* 8:161–185.
4. Paine RT. 1966. Food web complexity and species diversity. *Am. Nat.* 100:65– 75.
5. Paine RT. 1976. Size-limited predation: an observational and experimental approach with the *Mytilus* – *Pisaster* interaction. *Ecology* 57:858– 873.
6. Landenberger DE. 1968. Studies on selective feeding in the Pacific starfish *Pisaster* in southern California. *Ecology* 49:1062– 1075.
7. Menge BA. 1972. Foraging strategy of a starfish in relation to actual prey availability and environmental predictability. *Ecol. Monogr*. 42:25–50.
8. Menge JL, Menge BA. 1974. Role of resource allocation, aggression and spatial heterogeneity in coexistence of two competing intertidal starfish. *Ecol. Monogr*. 44:189– 209.
9. Cote IM. 1995. Effects of predatory crab effluent on byssus production in mussels. *J. Exp. Mar. Biol. Ecol*. 188:233-241.
10. Reimer O, Tedengren M. 1996. Phenotypical improvement of morphological defences in the mussel *Mytilus edulis* induced by exposure to the predator *Asterias rubens*. *Oikos* 75:3.
11. Leonard GH, Bertness MD, Yund PO. 1999. Crab predation, waterborne cues, and inducible defenses in the blue mussel, *M. edulis*. *Ecology* 80:1-14.
12. Reimer O.1999. Increased gonad ratio in the blue mussel, *Mytilus edulis*, exposed to starfish predators. *Aquatic Ecology* 33**:**185–192.
13. Copp J. 2000. Growth and behaviour of mussels (*Mytilus sp.*) exposed to water-borne chemical cues of the sea star *Asterias rubens*. Independent Research Option Report, Marine Institute of Memorial University, St. John’s, NL.

Grow-out of Soft-shell Clams, *Mya arenaria*, Before Seeding

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Abstract

Young soft-shell clams obtained through either benthic or pelagic collection reach an average shell length of ~7-9 mm (range of 2.5-20 mm) in the fall in Iles-de-la-Madeleine. Clams are overwintered under the ice cover in suspended structures like pearl-nets, oyster bags, etc. Growth is minimal during this period and, in early summer, the young clams are still smaller than the targeted size for successful seeding (20 mm SL). As a result, they need a grow-out period before being seeded. A growth rate of ~ 1 mm/wk would be required for a seeding operation before mid-August. Different grow-out systems (i.e. FLUPSY, floating oyster bags and sand-filled trays) were examined for clams growth and survival. Growth rate was about 0.45 mm/wk in floating bags and 0.50 mm/wk in the FLUPSY. In both methods losses accounted for 6 % of the cultured population. Growth rate in sand-filled trays was 0.92 mm/wk and clams reached 20 mm by early August. However, this system needs further investigation and improvement as losses amounted to 53 %. All considered, sand-filled trays seemed to be a very promising technique for growing-out clams before seeding.

Introduction

Seed supply for soft-shell clam culture in Iles-de-la-Madeleine relies on spat collection. In the fall, the size of the spat retrieved from the collectors ranges between ~3-20 mm with a mean of 7-9 mm. Young clams are then overwintered in suspension structures until the next summer (early June). During this period growth is very limited due to the low water temperature (-1.5 C during the winter months). According to previous experiments, it seems that seeded clams should reach 20 mm to avoid the heavy losses observed with smaller individuals. That means the 7-9 mm clams should grow about 10 mm before mid-August (~1 mm/wk), otherwise seeding should be delayed to the next summer.

To our knowledge, only two grow-out systems have been used for soft-shell clams: floating trays and FLUPSY. Floating trays are used in Maine[1] to grow small hatchery clams between May and November. Clams are then overwintered for a second winter before being seeded in the next summer. Commercial FLUPSYs are used in Massachusetts for hatchery clams[2]. However, as the latter technique is still too recent, very little information is available on how to apply it to *Mya arenaria*. Both these systems are used to grow 2- to 3-mm clams to a size of ~ 12 mm. Further, these systems are used in environmental conditions different from those encountered in Iles-de-la-Madeleine (Gulf of St. Lawrence).

The objective of this study was to document three grow-out techniques in the environmental conditions of the Iles-de-la-Madeleine for clams with an initial mean size > 7-9 mm.

Material and Methods

Spat collectors were deployed during the summer 2005. Juvenile clams were retrieved from the collectors in the fall and then overwintered in suspension under the ice cover. In early summer 2006, these clams were sorted in two size classes (mean SL = 8 and 10 mm) and used to compare the grow-out systems.

FLUPSY

The commercial FLUPSY is a 2.4 x 6.1 m raft from which eight silos (0.61 x 0.61 x 0.61 m each) are suspended[3]. The silos bottom is made of 2-mm mesh netting and each silos is connected to a central trough (4 silos on each side) provided with a pipe allowing water circulation between the silos and the trough. A 1/2 HP submerged pump (1 025 L / min) located at one end of the trough creates an upward water circulation in the silos. According to the manufacturer company (Fukui North America) up to 12,000 12-mm bivalves can be grown in each silo.

The four central silos were used for the commercial operation from May 16 to August 9. Two silos were each filled with 80,000 clams with a mean SL = 8 mm and two others with 72,000 10-mm clams each.

The silos located at both extremities of the trough (the two near the pump and the two at the opposite side) were used for our experimental purposes between July 14 and September 8. Growth and survival were compared between clams grown near the pump and those grown at the opposite side. Furthermore, these unmoved clams were compared to clams whose position in the four silos was changed through rotation every two weeks and each time following a 1-h emersion to simulate handling time. The experimental clams (10-15 mm with a mean size = 12.7 mm SL) were placed in cylinders kept vertical in the silos. Both extremities of the cylinders were covered with mesh netting. There were 25 clams/cylinder and 8 to 10 cylinders per treatment per silo.

Floating Bags

A series of eight Vexar™ bags were arranged as for oyster culture in floating bags[4]. Each bag was filled with a 2-mm mesh bag. Three densities were compared, i.e. 3,000, 6,000 and 8,300 clams / bag. The smallest density is equivalent to 9,000 clams / m^2 as in floating trays in Maine[1]. The experiment lasted from June 1 to September 11 with 8-mm clams only. There were 2-3 bags per treatment.

Sand-filled Trays

This new approach was employed by the local clam grower, M. Gérald Noël. Trays (0.49 m^2) were lined with plastic sheets over the bottom and on the sides before being filled with sand (Photo 1). 5,000 clams (10,000 ind./m^2) were added to each tray and left burying by themselves. Three trays were seeded with 8-mm clams and three others with 11-mm clams. Each tray was covered with another tray and then placed in suspension in the water column between May 16 and July 27 / August 3.

Results

In the silos used for commercial production, the 8-mm clams had a mean growth rate of 0.55 mm/week compared to 0.46 mm/week for the 10-mm clams in the FLUPSY. Thus the overall mean growth rate was 0.51 mm/week. This was comparable to that obtained in a preliminary trial in July and August 2005 for clams of similar sizes and comparable densities (8-mm clams at a density of 75,000 per silo and 11-mm clams at a density of 60,000 per silo): 0.53 mm/week. Growth slowed down in August, possibly because of a higher competition for food and/or space as a result of their increase in size over the previous two months. Clams had reached a mean size of 15-16 mm in mid-August 2006. In 2006, the silos walls were colonized by the golden star tunicate (*Botryllus schlosseri*) and that substantially increased the maintenance needs (cleaning with vinegar). Furthermore, mussel spat were found among the clams in the silos in mid summer, which also increased the maintenance needs (sorting) since each mussel spat attaches itself to 25-30 clams.

There was a significant difference in growth for the experimental clams kept in the FLUPSY cylinders ($F_{(2,36)}$ = 5.66 ; P = 0.007). The clams that were moved every two weeks after a 1-h immersion were significantly larger than those kept in silos at the opposite end of the pump while the clams kept in silos near the pump were not significantly different from the two other groups (Figure 1). However, clams kept near the pump tended to grow faster than those kept at the opposite side. This is not surprising since water circulation (repeated measurements in the silos before filling them with clams) is higher in the two silos near the pump (1.4-1.5 cm/sec) than in the silos at the opposite end (0.9-1.0 cm/sec). Overall, 6% mortality was observed throughout the experiment. These results also suggest that handling (1-h emersion at every 2 weeks) is not detrimental to growth and survival.

Shell length of clams grown at different densities in floating bags did not differ significantly at the end of the growing period. However, a higher density tended to result in a lower growth rate: 0.32 mm/week at 8 300 clams/bag, 0.38 mm/week at 5,000 clams/bag, and 0.43 mm/week in bags with 3,000 clams/bag. In 2005, clams kept at 3,000 per bag showed a similar growth rate in July-August with 0.46 mm/week. The experimental clams reached 14-16 mm in early September. Only 6 % of the experimental clams were lost throughout the experiment. Mussel spat settled in abundance on the bags but very few were found inside the bags and among the clams. Furthermore, mussel spat were weakly attached on the bags. As a result, it was easy to control mussel abundance on bags and among clams although they were visited only once a month.

Clams grown in the sand-filled trays provided the best growth rates with 0.92 mm/week for the 8-mm clams and 0.94 for the 10-mm clams. These rates were similar to what was observed in early summer 2005: 0.92 mm/week for 11-mm clams. Clams reached an overall mean of 19 mm by late July-early August. However, 53% of the experimental clams were lost during the experiment. Furthermore, results suggested a density-dependent growth. For example, losses were highly variable (40.6-62%) in trays with 8-mm clams and these clams reached a mean size of 15.6 mm at a final density of 5,950/m^2 compared to 16.9 mm at 4,650 /m^2 and 20.8 mm at 3,800/m^2. Therefore, an initial density of 10,000 clams/m^2 is probably too high for achieving maximal growth. Mussels were not a problem with this system.

Photo 1. Sand-filled tray.

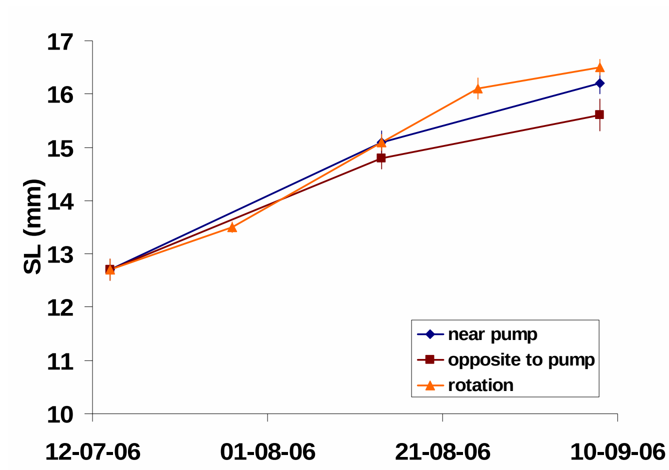

Figure 1. Growth of experimental clams in the FLUPSY according to their position relative to the pump and to their rotation in silos every two weeks.

Discussion

All grow-out systems are operating away from the bottom so that predation of young clams by benthic predators like crabs is avoided. Furthermore, clams are always immersed and thus can feed all day long. As a result, their growth should be faster than on intertidal flats. Clams in the FLUPSY and the floating bags are kept at high densities and out of substratum. In contrast, clams in the sand-filled trays are kept into the sediment. As a result they take advantage of ideal conditions for infaunal bivalves. Another advantage of the sand-filled trays technique is that it does not require any power supply as in the FLUPSY technique, thereby reducing technology-related needs and costs. Growth rates measured for a given grow-out system was similar in 2005 and 2006.

The slowest growth was observed in the floating bags so that 15-mm clams were not available before early September. Thus, these clams should be overwintered for a second time and seeding should be delayed until the next summer. This is the current procedure with floating trays in Maine.

Growth was slightly better in the FLUPSY and 15-mm clams could be seeded in mid-August, if needed. However, these clams are still relatively small for a successful seeding. Furthermore, it is a little late in the season for seeding. Beal[1] suggests to seed early in the summer to take advantage of the entire growing season. When operating the FLUPSY it would be better to rotate the clams regularly between the different silos to get the best growth and to compensate for the slower growth in the silos located at the opposite side of the pump.
Only the sand-filled trays were able to provide 20-mm clams early in the season so that seeding could be performed in late July-early August. However, this is a new approach and this system needs further improvement. The optimal density is still unknown and losses should be reduced markedly. Furthermore, this concept must be adapted for commercial-scale operations. Nevertheless, it seems a promising way to grow-out small clams before seeding. A similar approach is currently under investigation in Massachusetts[5].

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References

1. Beal BF. 2005. Soft-shell clam, Mya arenaria, mariculture in Maine, USA: Opportunities and challenges. AAC Spec. Publ. 9: 41-44.
2. Buttner JF, Salem State College, MA, personal communication.
3. Fukui North America, http://www.fukuina.com/shellfish/flupsy_sm.htm. Accessed December 14, 2006.
4. Doiron S. 2006. Manuel de référence de l’ostréiculteur. Ministère de l'Agriculture, des Pêches et de l'Aquaculture du Nouveau-Brunswick. 75 p.
5. Grunden DW, Ewart D. 2006. Early steamer clam (Mya arenaria) restoration efforts in two coastal ponds in Oak Bluffs, MA (Martha’s Vineyard Island). J. Shellfish Res. 25: 663.

Development of Open-sea Mussel Culture in Iles-de-la-Madeleine: Four Years Later

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Abstract

Mussel culture in Iles-de-la-Madeleine is concentrated in sheltered lagoons where there is limited room for additional leases. In 2002, we began investigating the potential for mussel farming in open waters. An experimental site was selected 7 km away from the harbour of Cap-aux-Meules at a depth of 19 m. This site is usually free from ice cover during the winter, although there may be some occasional ice drifting. Three longlines were deployed at 8 m from the surface. None of them have moved from its anchors after 4 years. Over the years, spat collection success was examined as well as growth, production and meat yield. In 2005, a continuous sleeve (400-m long) was suspended to one longline. Mussels reached the commercial size as fast as in the lagoons, i.e. 12 mo after sleeving. Indeed, commercial yields of 6.7 kg/m were obtained within this period. During the summer, meat yield is higher for mussels in open sea than in the lagoons. This is partly due to their thinner shells: ~ 35% lighter for a similar size. Preliminary observations suggest that these shells are robust enough to go through processing with no additional shell breakage. An environmental assessment showed no detectable effects of the experimental mussel longlines on the sedimentary habitat between 2002 and 2005. In 2005 we observed a slight biodiversity increase in the benthic communities, which may be related to interannual variations. Commercial culture in open waters will possibly begin in 2007.

Introduction

In Iles-de-la-Madeleine blue mussels are cultivated in shallow and protected lagoons. However, there is no room for further development because virtually all sites deeper than 6 m in the lagoons have already been leased. Therefore, open-sea culture is the only option for further development of the local mussel culture industry. Although located in the middle of the Gulf of St. Lawrence, the Iles-de-la-Madeleine are surrounded by a relatively wide and shallow plateau. As a result, longlines for mussel culture must be located at some distance from the shore while preventing their movement or losses, particularly from ice drifting.

In 2002 a study was started to document the potential for open-sea culture of blue mussels in Iles-de-la-Madeleine[1]. At that time, there was little information about open-sea culture of mussels. Mussel culture had been introduced for some years in the Baie des Chaleurs, south of the Gaspesia peninsula, where longlines were installed relatively close to the shore, which is a different environment compared to the coastal zone in Iles-de-la-Madeleine. There had also been a large-scale project to develop open sea culture off the coast of Maine initiated in 1999, only a couple of years earlier than our project[2].

Methods and Results

Site Selection and Longline Design

The first step was to select an appropriate site, which would prevent any users conflict, mainly with local fisheries and navigation, while providing appropriate conditions for mussel growth. The selected site was located in the Baie de Plaisance at about 7 km away from the main commercial harbour (Cap-aux-Meules). Water depth (19 m) was ideal for installing longlines at a sufficient depth to prevent any damaging from ice drifting. Its sandy substratum is ideal for anchoring longlines. Water temperature in the water column can reach 18 °C in summer and water currents are 6.9 cm/sec in average in this season[3].

Three experimental longlines (each 100-m long) were installed at 8-m from the surface. They were anchored at both extremities while 55-kg concrete blocks were attached every 20 m along the line. Anchors consisted in 15-kg metal rods with lateral spikes buried deep into the sediment. A 30-cm plastic buoy was associated to each block to keep the longlines at the desired depth. When needed buoys were added during the growing cycle of the mussels to compensate the resulting additional load on the lines. In 2006, no longlines were displaced nor lost since their installation, four years ago.

Mussel Production with Spat from the Lagoons

The open sea site was used according to three scenarios. In the first, mussels were collected in the Bassin du Havre-Aubert lagoon and grown in open sea. This is the usual seed source for mussel culture in Iles-de-la-Madeleine. The spat from this site is more resistant to stressful conditions and reaches a larger size than the other local stocks[4,5]. Indeed, the mode size of this spat can reach 25 mm in October and it is sleeved in the fall. One constraint with this scenario is that sleeving in the fall would be more difficult in open sea than in the lagoons because of the wind conditions in that period.

Spat from the Bassin du Havre-Aubert (mode = 23 mm SL) was sleeved in November 2003. In October 2004 (10 1/2 months later), the mussels had already reached a mode of 53 mm. In November 2004, 98 % of the mussels were of commercial-size (> 50 mm) and the mode size was 58 mm. The commercial production was estimated at ~6.7 kg/m. Thus growth in open sea is similar to that in the lagoons. Therefore these mussels could be harvested as soon as 1 yr after sleeving which possibly means winter harvest.

There are very few days with a solid ice cover at this open sea site because of the dominant NW winds pushing the ice farther offshore. Therefore, harvest would be possible almost all-year round. There would be no interruption of harvest during the freezing and the ice melting periods as in the lagoons, exception made for significantly windy days. That would help to guarantee an almost uninterrupted supply of mussels to customers. Another advantage is that no special equipment is needed for winter harvest in open sea.

In May 2005, i.e. 18 months after sleeving, the size mode was 61 mm and the commercial production had reached ~7.8 kg/m.

During three summer seasons, the meat yield of mussels collected in Bassin du Havre-Aubert was followed in parallel in a lagoon and in the open sea. The meat yield pattern varied from year to year but most of the time the meat yield of mussels kept in open sea for a second summer is higher than in the lagoon. For example, in mid-July 2003, the meat yield in open sea was 59 % compared to 31 % in the lagoon[1]. That means high-quality mussels for the consumers even during the summer months when mussels have already spawned in the lagoons and therefore have lower meat yield. However, these ready-to-spawn mussels will have to be handled carefully when harvested to avoid spawning during handling and processing.

The higher meat yield in open sea is due to a higher meat weight but also to a lower shell weight. Mussels of similar age and size and from the same origin (spat from Bassin du Havre-Aubert) have significantly different shell weight during their second summer in culture. The shell of mussels kept in open sea was always about 35 % lighter than in the lagoon (Fig. 1). That means the shells of mussels in open sea are thinner. But are they more fragile for processing?

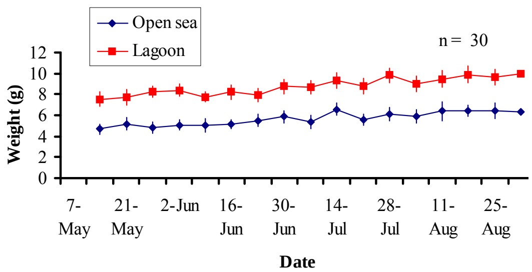

Figure 1. Shell weight of ~ 65-mm mussels (mean ± s.e.) grown in open sea and in the lagoon in 2004.

Twice in 2006, 2-year-old mussels from open sea were harvested and processed at a commercial plant. Samples of mussels were examined all along the processing line: after harvest, declumping-grading, and debyssing. After debyssing, 95% of the shells were undamaged and 2-3 % had their edge slightly eroded by the declumping process. Vacuum-packing did not cause any significant additional breakage. Therefore, it is concluded that thinner shell of the open-sea mussels does not represent a constraint for the industrial processing as it is presently performed.

Mussel Production with Local Spat

In another scenario the spat was collected directly on site for cultivation in open sea. Polyrope collectors were suspended to the longlines. In 2002 spat collection was abundant at a water depth between 4 and 18 m and the greatest numbers (~15 000 spat/m of collector) were recorded between 12 and 17 m. In contrast to the lagoons, there is a continuous settlement leading to the presence of several cohorts on collectors. Several associated species are found on collectors in open sea, mainly caprellas, hydrozoans and seastars. In the fall, the spat is generally too small for continuous (mechanized) sleeving because of the difficulties to adjust the system for the desired density with such small individuals.

Photo 1. Summer harvest 2006 with a mussel grower.

Mussel growers in Iles-de-la-Madeleine are not equipped with an efficient spat grading machine because they usually sleeve with larger juveniles from Bassin du Havre-Aubert. Therefore, it was not possible to efficiently grade the spat from the open sea before sleeving. Spat collected in open sea (mode = 14 mm SL) was used to fill 400 m of continuous sleeve in July 2005, when field operations are easier. In June 2006, 11 months later, the mussels' size mode was 57 mm and 93 % had reached the commercial size. The commercial production was 5.3 kg/m. Harvest was carried out in July with the local mussel growers (Photo 1).

Seed Supply for Culture in the Lagoons

In a third scenario the open sea site was used to supply spat for mussel culture in the lagoons. This seed supply could be used as a supplementary seed source and/or as a back-up in case of poor collection in the usual spat collection site in the Bassin du Havre-Aubert. Because of the small size of this spat in the fall, that means summer sleeving in contrast to the usual fall sleeving in the lagoons.

The little spat (mode = 12 mm) was used to fill continuous sleeves in late June 2005. One year later (early July 2006) the mussels reached a mode of 58 mm with 88 % of individuals displaying the commercial-size.

Environmental Assessment

An environmental study was carried out in 2005 in order to assess the effects of the experimental longlines on the benthic community (i.e. density and biodiversity) as well as on the sediment characteristics (i.e. granulometry, organic matter, organic carbon, and total nitrogen). Samples were collected from the same stations as in 2002, when an environmental characterization of the site was performed before installing the experimental longlines[3]. In 2005 samples were collected in the same period as in 2002, i.e. June.

Analyses did not reveal any significant difference in sediment features between the 2002 and the 2005 samples, and between control and longline stations. The absence of effects on the sediment characteristics may have two possible explanations. Firstly, the scale of the experimental mussel farming was too small to cause any significant modification. Secondly, the local hydrology favoured the rapid dispersion of sedimenting mussel feces and pseudofeces that may have cause an increase in organic matter and nitrogen sediment contents.

As for the benthic communities, no significant difference was found for densities between 2002 and 2005, and between control and longline stations. However, in 2005 species diversity tended to be higher. On one hand, the interannual variability of the benthic communities may explain this difference of biodiversity between 2002 and 2005. On the other hand, the dynamic equilibrium model[6] may explain this difference. According to this model biodiversity tend to increase following small-scale environmental disturbances, which in our case may have been caused by the three experimental longlines. However, as the biodiversity difference was observed only between years and not between control and longline stations, this second hypothesis appears to be unlikely.

Conclusion

Since 2002 encouraging results were obtained for the development of mussel culture in open sea near the Iles-de-la-Madeleine. No real constraints have been identified yet. Furthermore, approximately 24,000 ha with potential for suspension culture in the south of the Baie de Plaisance had been identified[7]. In this regard, blue mussel commercial culture in open sea would probably begin in 2007 in Iles-de-la-Madeleine.

Acknowledgements

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References

1. Bourque F, Myrand B, Tita G. 2005. Open-sea culture of mussels (*Mytilus edulis*) in Iles-de-la-Madeleine: A promising avenue. *AAC Spec. Publ*. 9:56-59.
2. University of New Hampshire, Open Ocean Aquaculture *http://ooa.unh.edu/* Accessed December 15, 2006.
3. Tita G, Crémer JF, Long B, Desrosiers G. 2004. Caractérisation environnementale d'un site mytilicole expérimental dans la baie de Plaisance, Îles-de-la-Madeleine (Québec). *Rapport technique canadien des sciences halieutiques et aquatiques* 2559: v + 17 p.
4. Myrand B, Tremblay R., Sévigny JM. 2002. Selection against blue mussels (*Mytilus edulis* L.) homozygotes under various stressful conditions. *J. Hered*. 93: 238-248.
5. Myrand B, Gaudreault J. 1995. Summer mortality of blue mussels (*Mytilus edulis* Linneaus, 1758) in the Magdalen Islands (Southern Gulf of St Lawrence, Canada). *J. Shellfish Res.*, 14: 395-404.
6. Huston MA. 1979. A general hypothesis of species diversity. *Am. Nat*. 113: 81-101.
7. Werstink G, Tita G, Wilson J. 2006. Applying GIS and the analytic hierarchy process on seafarming spatial assessments in the Magdalen Islands Quebec Canada) *AAC Spec. Publ*. 10:58-60.

Harpacticoid Copepods in a Cold Marine Mesocosm: Production in Sand Filters and Diel Migrations in the Water Column

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Abstract

Previous research showed that harpacticoid copepods were abundant (up to 40 g/m²) in the rapid sand filters of the Marine St. Lawrence mesocosm at the Montreal Biodome, and that they were found at all times in the mesocosm water column. The current study's objective was to estimate their production in the filters and their diel migrations in the water column. Samples (800 L) of the water supplies entering and leaving the filters were filtered over tiered sieves, and copepodites and adults were counted. Four copepod species were found: *Amonardia normani* (79%), *Pseudonychocamptus proximus* (20%), *Tisbe furcata* and *Mesochra pygmeae* (1%). The 300 um, 150 um and 63 um sieves retained 77%, 21.5% and 1.5% of the specimens, respectively. Daily production of copepods was 220,000 ind./m² in summer and 133,000 ind./m² in winter. These values are 100 to 917 times greater than reported rates in nature. Copepod density in the water column reached 401 ind./m³. Copepods are put in suspension by fishkeepers' diving activities. They then remain suspended in the water column for several days due to the water circulation system. Diel vertical migrations were observed within five days after feeding and cleaning dives were suspended.

Introduction

Harpacticoid copepods are common inhabitants of closed or semi-closed marine systems filled either with natural or artificial seawater (1, 2, 3). They appear to be passively introduced in these systems along with fish and invertebrates collected from the wild. They colonize all available substrates in a system: gravel beds, rocks, periphyton, piping and filter sand colums (4).

Recent research has shown that harpacticoid copepods were particularly abundant in a large marine mesocosm at the Montreal Biodome (3, 5). Densities of up to 9.5×10^6 ind/m² and dry weight biomasses of up to 40 g/m² were observed in the sand filters. These values are 20-40 times higher than those reported for copepod-rich marine shallow waters (6). It was also found that harpacticoid copepods were living and breeding in these sand filters (4) and that they were found at all times in the water column of the main pool. Parent and Morin (3, 5) also found that harpacticoid copepods were affecting the mineralization rate of organic matter as well as the conversion rate of nitrite to nitrate.

The current study's objective was to estimate the production of harpacticoid copepods in the sand filters and their diel vertical migrations in the water column of this mesocosm. Operation conditions of the filters are defined, and abundance, size spectrum, seasonal production and hyperbenthic behavior of the copepods are reported.

The Marine St. Lawrence Mesocosm

The Marine St. Lawrence (MSL) mesocosm is an indoor closed system that holds about 3 x 10^6 L of cold (10°C) artificial seawater (28-30‰). It exhibits over 100 seabirds, 600 fish, and 2,000 invertebrates in two display pools, the main pool (2.5 x 10^6 L; 5.5 m deep) and the tidepool (25,000 L). Their bottom is either bare (35%) or covered with artificial rocks (32%), gravel (27%) and sand (6%). The life support system consists of six rapid sand filters, a 200 m^3 trickle filter filled with 9 cm Lanpac® plastic bioballs, a denitrification unit and an ozonation system. The sand filters are cylindrical pressure filters (220-230 kPa) 3.6 m in diameter and 3 m high. Each contains 65 cm of fine sand, 250-300 µm effective particle size with a maximum uniformity coefficient of 1.55. The sand is supported by 30 cm of coarse sand and 30-45 cm of pea gravel. Flow rate is 58 L/s, filtration rate 5.6 mm/s and the hydraulic retention time (HRT) is 5 min. Filters are backwashed with filtered seawater every 4 days or so. Backwash flow is about 9 mm/s and lasts for 6 to 8 min. Backwash water is sent to a 150,000 L reservoir where it is filtered again by two filters 1.8 m in diameter, and reused later. Periphyton covers all hard surfaces, including concrete walls and bottom, and rockwork. Its structuring elements are the green alga *Cladophora glomerata*, the red alga *Pterothamnion plumula* and the yellow-green alga *Vaucheria* sp. (4). Instant Ocean™ salt mix is used to prepare seawater. Nitrate and phosphate have accumulated since start-up in 1992 and reached values of 140 mg N/L and 17 mg P/L in 2001 (7, 8). Dissolved oxygen level is always near saturation in the filter influent (9.4 mg/L) and effluent (9.2 mg/L) waters.

Material and Methods

Measurement of copepod production in the sand filters was done over four consecutive seasons. On each occasion, five samples (800 L) of the water supplies exiting the drains, the skimmers and the filters were taken at noon and midnight, after a dive session (feeding and cleaning) or on a calm day, for a grand total of 45 samples per season. Samples were filtered over 300 µm, 150 µm and 63 µm sieves. Copepodites and adults – but not nauplii – were then sorted and counted. Mean size was estimated at each season by taking a random sample of 150 copepods from the backwash water of a filter. Total length was measured directly from rostrum to caudal rami (9). Seasonal production estimates were expressed in number of copepods produced per m² of filter surface per day. In order to compare with published estimates, seasonal production estimates and mean lengths were converted into yearly biomass production (g/m²/yr) using mean animal lengths, a size-weight conversion factor of 485, and the calculation method described by Feller and Warwick (10). The following spring, diving activities were interrupted for 10 days to detect diel migrations, during which period samples were taken and treated as described above.

Results

Four copepod species were found living in the rapid sand filters: *Amonardia normani* (dominant, 79.5%), *Pseudonychocamptus proximus* (19.5%), *Tisbe furcata* and *Mesochra pygmeae* (1%, n=500). Mean total length of the copepods varied seasonnally from 407 to 468 µm. Tukey grouping ($p<0.05$) showed that copepods were significantly larger in the fall than in any other season. The 300 µm, 150 µm and 63 µm sieves retained 77%, 21.5% and 1.5% of the specimens, respectively (n=107,000). Daily production of harpacticoid copepods was 220,000 ind./m² in summer and 133,000 ind./m² in winter (Table 1). These values are equivalent to annual production rates of 100 to 167 g/m². The copepods were flushed from the filters mainly during backwashing (>70%).

During the regular operation of the mesocosm, i.e. when diving was done for feeding the animals and cleaning the pools, copepod density in the water column was most of the time over 100 ind./m³. It reached a maximum of 401 ind./m³ on a diving day in the fall. Diel vertical migrations could not be detected. In all seasons, copepod density was higher after a diving session than on a calm day or (except in spring) at night. Diel migrations were observed within five days after the dives were interrupted the following spring (Fig. 1). On Day 10, the copepod density during the day was three times lower than at night. Diel migrations were no longer detectable after the fishkeepers resumed their diving activities.

Table 1. Seasonal Production of Harpacticoid Copepods (Copepodites plus Adults) in the MSL Sand Filters (mean ± SD, n ≥ 4)

(x 10^5 ind./m²/day)	Winter	Spring	Summer	Fall
Filter Influent (I)	0.68 ± 0.13	0.82 ± 0.19	1.04 ± 0.40	1.20 ± 0.15
Filter Effluent (E)	0.50 ± 0.10	0.76 ± 0.20	1.51 ± 0.40	1.74 ± 0.69
Net return to pools (E-I)	-0.18 ± 0.17	-0.06 ± 0.27	0.47 ± 0.56	0.54 ± 0.71
Backwash water (B)	1.51 ± 0.62	1.96 ± 0.40	1.75 ± 0.55	1.26 ± 0.41
Production (P = E-I+B)	1.33 ± 0.79	1.90 ± 0.68	2.22 ± 0.79	1.80 ± 1.12
Production in g/m²/y	99.6	138.1	144.0	167.4

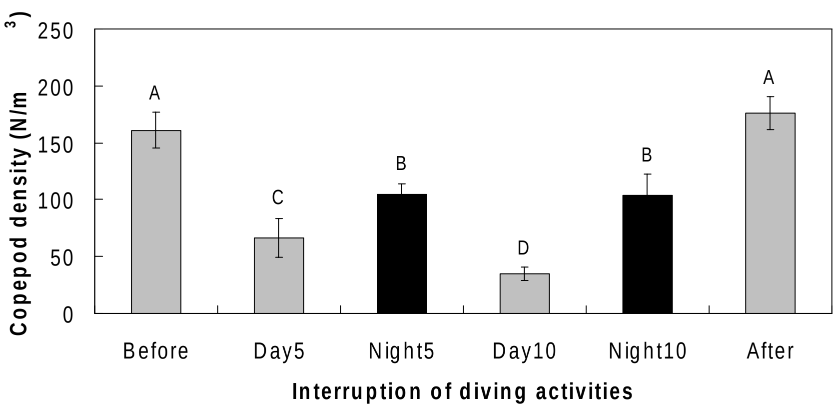

Figure 1. Copepod density in the MSL water column before interruption of diving activities, during interruption and after resumption (mean ± SD, n = 5). Letters indicate differences from a Tukey grouping (p<0.05)

Discussion

Harpacticoid copepods are not only extremely abundant, but they are also massively produced in the rapid sand filters of a cold marine mesocosm. Their annual production rate is 20 times higher than that of all subtidal meiobenthos in the North Sea (11), and 100 times higher than harpacticoid production in the Baltic Sea (12). Moreover, this estimate represents 78 to 917 times the production rates empirically derived for two harpacticoid species on the Atlantic US coast (13, 14). It must be remembered that our production estimate does not include the production lost to natural mortality, nor does it include nauplius production, which Feller (14) and Fleeger and Palmer (13) estimated to account for 35% to 39% of the total production of two harpacticoid copepod species. The total production of harpacticoid copepods in the MSL sand filters is therefore much higher than the partial estimate reported here.

Reasons for such a high productivity per surface unit probably lie in the deep sand column (large copepod densities were found at all depths (5)), the large amount of dissolved oxygen, the abundance of food all year round (organic detritus, bacterioplankton, phytoplankton and feces), and the lack of predators. Copepods – especially nauplii – seem to easily withstand the strong downward current during filtration and the turbulence during filter backwashing. Nauplii are dorso-ventrally flattened animals that attach themselves tightly to the sand grains and therefore can resist to the water current and the mixing of the sand column. The copepodites are also reputed to grab into their substrate – periphyton or otherwise – in their natural habitat (15). *Amonardia* is a typical genus of the coarse shell-gravels, whereas Laophontids, such as *Pseudonychocamptus*, are epibenthic forms often associated to fine to medium sands (15).

Large numbers of harpacticoid copepods are put in suspension by fishkeepers' diving activities. They then remain suspended in the water column for several days due to the water circulation system. When diving activities are interrupted, one observes that harpacticoid copepods make diel vertical migrations in a closed system, just as they do in their natural habitats (16).

Harpacticoid copepods are highly adaptable and resistant animals. They can adjust to harsh conditions, such as those prevailing in a sand filter, and live deeply within a sand column as long as their primary needs – oxygen, food, and lack of predation – are satisfied. Moreover, in such conditions, harpacticoid copepods remain abundant and productive throughout the year.

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References

1. Boucher G, Chamroux S. 1976. Bacteria and meiofauna in an experimental sand ecosystem. 1. Material and preliminary results. *J. Exp. Mar. Biol. Ecol*. 24: 237-249.
2. Adey WH, Loveland K. 1991. *Dynamic Aquaria*. Academic Press, Toronto, 498 p.
3. Parent S, Morin A. 1999a. Role of copepod-dominated meiofauna in the nitrification process of a cold marine mesocosm. *Can. J. Fish. Aquat. Sci.* 56: 1639-1648.
4. Parent S, Morin A, Gagnon D. 2001. Are meiofauna transient or resident in sand filters of marine aquariums? *Wat. Res.* 35: 3625-3634.
5. Parent S, Morin A. 1999b. The role of copepod-dominated meiofauna in the mineralization of organic matter in a cold marine mesocosm. *Can. J. Fish. Aquat. Sci.* 56: 1938-1948.
6. Coull BC. 1988. Ecology of marine meiofauna. In, *Introduction to the Study of Meiofauna* (RP Higgins, H Thiel eds.) pp. 18-38, Smithsonian Institution, Washington.
7. Parent S, Morin A. 2000. N budget as water quality management tool in closed aquatic mesocosms. *Wat. Res.* 34: 1846-1856.
8. Trépanier C, Parent S, Comeau Y, Bouvrette J. 2002. Phosphorus budget as a water quality management tool for closed aquatic mesocosms. *Wat. Res.* 36: 1007-1017.
9. Volkmann-Rocco B. 1972. Species of *Tisbe* (Copepoda Harpacticoida) from Beauport, North Carolina. *Arch. Oceanogr. Limnol.* 17: 223-258.
10. Feller RJ, Warwick RM. 1988. Energetics. In, *Introduction to the Study of Meiofauna* (RP Higgins, H Thiel eds.) pp. 181-196, Smithsonian Institution, Washington.
11. McIntyre AD. 1964. Meiobenthos of sub-littoral muds. *J. Mar. Biol. Ass. U.K.* 44:665-674.
12. Ankar, S, Elmgren, R. 1976. The benthic macro- and meiofauna of the Askö-Landsort area (Northern Baltic proper). A stratified sampling survey. *Contr. Askö Lab. Univ. Stockholm* 11:1-115.
13. Fleeger JW, Palmer MA. 1982. Secondary production of the estuarine meiobenthic copepod *Microarthridion littorale*. *Mar. Ecol. Prog. Ser.* 7: 157-162.
14. Feller RJ. 1982. Empirical estimates of carbon production for a meiobenthic harpacticoid copepod. *Can. J. Fish. Aquat. Sci.* 39: 1435-1443.

15. Hicks GRF. 1983. The ecology of marine meiobenthic harpacticoid copepods. *Oceanogr. Mar. Biol. Ann. Rev.* 21: 67-175.

16. Palmer MA, Gust G. 1985. Dispersal of meiofauna in a turbulent tidal creek. *J. Mar. Res.* 43: 179-210.

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Seeding Soft-Shell Clam (*Mya arenaria* L.) Spat along the Eastern Shore, Nova Scotia

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Abstract

Harvesting soft-shell clams (*Mya arenaria* L.) from Nova Scotia's vast mud flats has been an essential source of income for many inhabitants of these coastal areas. Over the past decade there has been a steady decline in the population of soft-shell clams. It is essential to determine attributing factors to amplify populations for future years. Regional population assessments were conducted in Eastern Chezzetcook and Clam Harbour, Nova Scotia in order to determine current clam status. Spat growth and percent viability was examined when placed under two different sediment types; a soft substrate (0.6% by wt) and a hard substrate (1.3% by wt). The influence of a predator net on these substrates was also examined. Viability was greater when seeded in a soft substrate 86.7 ± 1.3% versus a hard substrate 70.0 ± 2.2%. The impact of a predator net resulted in a low ($p < 0.05$) percent viability for both substrates. The use of a predator net on a hard substrate was 16.6± 1.22% and 23.3± 0.89% on a soft substrate. Growth was not significantly ($p > 0.05$) influenced by soil substrate. Growth in a hard substrate was 0.4 ± 0.11cm and 0.3 ± 0.07 with a predator net; 0.378 ± 0.15 in a soft substrate and 0.3± 0.10 with a predator net.

Introduction

Along the coast of Nova Scotia many livelihoods are dependant on the harvesting of soft-shell clams (*Mya arenaria* L.). There has been a steady decline in the abundance of soft-shell clams over the past decade [1]. An efficient and economically feasible enhancement method needs to be established for local communities who are dependant on harvesting soft-shell clams. There are several factors that influence recruitment of soft-shell clams such as pollution, predation, water currents, and food availability[2]. Recruitment mats have been successful for collection of spat[3], but are an inadequate environment for grow-out, as commercial sized clams burrow to a typical depth of ≥15cm[4]. Selection of a post-recruitment site should contain minimal bedload movement to ensure the clams are maintained within the region[5]; be supplied with adequate nutrients to provide optimal growth[2]; and contain a suitable substrate for increased viability. Regional substrates will vary[7], therefore it is essential to determine optimal sites where re-seeding will be effective.

Methods

Utilizing 0.25m^2 quadrats population assessments were conducted within the Marine Protected Areas (MPAs) along Eastern Chezzetcook, Nova Scotia. Quadrats were excavated to a depth of 20cm[8,9] in a cross-sectioning diagonal pattern. Inactive sites where abundance <1 soft-shell clam / m^2 were selected. Study sites were confined to 100m^2 consisting of 10x10 - 1m^2 plots, with a gradual slope of (ca.1°). During the duration of the experiment, maximal affix water depth reached 1.4m; average air exposure was 7hd^{-1}, and soil temperature ranged from 22.5- 24.0 °C. Water temperature ranged from 21.5°C 23.0°C. Nitrite water quality was 0.019mg/L, ammonia remained under range, dissolved oxygen ranged between 8-

10mg/L and salinity ranged from 10.2 - 27.1 ‰, depending on tidal flow.

Hydrodynamic force, as well as grain size distribution differed for each site. Area 1 (44°43.605-43.698/062°52.359- 52.331), referred to as 'hard substrate' consisted of a median grain size of 56% 200 µm particles; silt-clay content (1.3% by wt). Presence of seagrass (*Zostrea* sp.) was abundant surrounding the confined site. Area 2 (44°43.726-43.831/062°52.146- 51.998), the 'soft substrate' consisted of a median grain size of 74% 150µm and 21% 70 µm; silt-clay content (0.6% by wt).

The experimental spat was collected utilizing 1m^2 astro-turf recruitment mats placed within that region. Graded spat 5.0 ± 0.2mm shell length (SL= greatest anterior-posterior distance) were seeded at a depth of 1.5cm at a density of 5 clams/m^2 into the two locations of soft and hard substrates. A predator net (aperture size = 6.4mm) was affixed over half of the plots in each substrate. After a 55d period, the sites were evaluated through excavation.

Percent viability and SL were measured. General linear models (ANOVA) with a fixed significance level at 0.05, was used to analyze the data utilizing Minitab software.

Results

Growth was not significantly ($p>0.05$) influenced by soil substrate. Growth in a hard substrate was 0.4 ± 0.11cm and 0.3 ± 0.07 with a predator net; 0.378 ± 0.15 in a soft substrate; and 0.3± 0.10 with a predator net (Figure 1).

Although viability was greater when seeded in a soft substrate 86.7 ± 1.3% (Figure 2) versus a hard substrate 70.0 ± 2.2%, a comparison of the two substrates they were not significantly different ($p>0.05$). The impact of a predator net resulted in a lower ($p = 0.028$) percent viability. The use of a predator net on a hard substrate was 16.6± 1.2% and 23.3± 0.89% on a soft substrate.

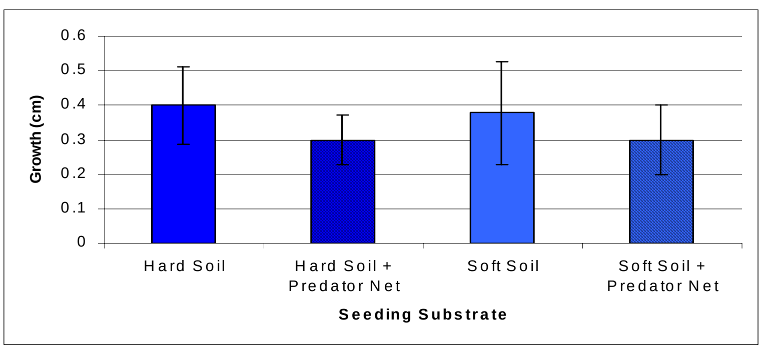

Figure 1. Growth (SL) of spat over a 55d period when seeded in a hard or soft substrate and the influence of a predator net.

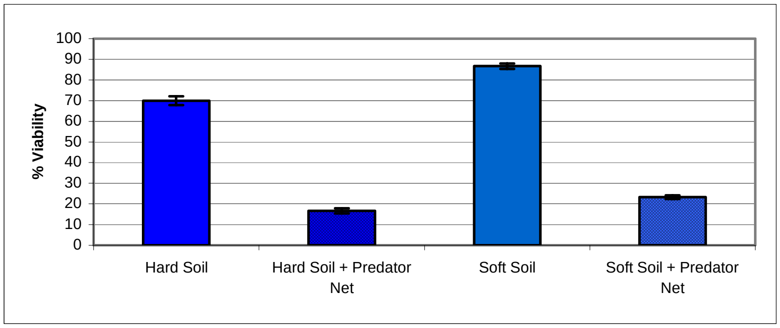

Figure 2. Viability of spat over a 55d period when seeded in a hard or soft substrate and the influence of a predator net.

Discussion and Conclusion

The soft substrate location provided a more suitable environment for the seeding of juvenile clams when compared to the hard substrate location. Although there was no significant difference ($p>0.05$) between the two locations, the survival of clams seeded in the soft substrate was 16.7% greater than the clams seeded in the hard substrate. Soft-bottom environments allow clams to quickly escape flow forces by burrowing[10,11,12]. Sediment (<0.5mm) yields a greater percent of burrowing activity[13]. The soft sediment area was located close to shore, sheltered from high velocity currents which reduced erosion transport of the juvenile clams. The hard sediment area was located close to the mouth of the bay, which experienced higher velocity current. Lower survival in the hard substrate location can be, in part, attributed to sediment erosion, resulting in the dispersion of the seeded clams.

Predator nets hindered both the growth and percent viability of the seeded juvenile clams in both soft and hard substrate locations. This may be due to the large amount of sediment deposition on the predator nets. Controversy, soft-shell clams have the ability to withstand anoxic environments when located at 14°C for several weeks[14]. A higher percent of mortality occurs when juvenile clams are exposed to predators as opposed to being located in an anoxic environment[15]. Previous experiments used wooden frames to create a fence over the seeded clams which reduced predation and increased percent viability[6]. It is recommended that in future applications, buoys be used under the predator nets to prevent asphyxiation of clams.

Acknowledgments

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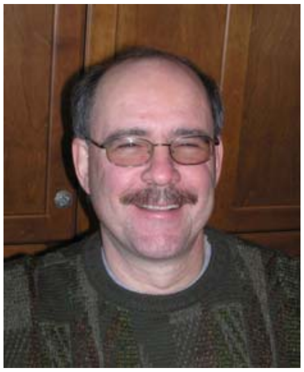
References

1. Sullivan D. 2006. Gulf of Maine Clam Management Study *http://www.saltwaternetwork.org/images/MaineStudyTourReport%20(2).pdf* Accessed 11/01/06.
2. Wilbur HM. 1980. Complex life cycles. *Annu. Rev. Ecol. Syst*. 11: 67-93.
3. Greening L, Clancey L. 2001. Clam enhancement on the Eastern shore: NSDAF innovation in fisheries program in action. *Hook, Line and Thinker*. 2006-1: 17-18.

4. Beal BF, Vencile KW. 2001. Short-term effects of commercial clam (*Mya arenaria* L.) and worm (*Glycera dibranchiata* Ehlers) harvesting on survival and growth of juveniles of the softshell clam. *J. Shellfish Res.* 20: 1145-1157.
5. Palmer MA. 1988. Dispersal of marine meiofauna: A review and conceptual model explaining passive transport and active emergence with implications for recruitment. *Marine Ecology. Prog. Ser.* 48: 81-91.
6. Beal BF, Kraus MG. 2002. Interactive effects of initial size, stocking density, and type of predator deterrent netting on survival and growth of cultured juveniles of soft-shell clam, *Mya arenaria* L., in *Eastern Maine Aquaculture* 208: 81-111.
7. Emerson CW, Grant J. 1991. The control of soft-shell clam (Mya arenaria) recruitment on intertidal sandflats by bedload sediment transport. *Limnol. Oceanogr.* 36(7): 1288-1300.
8. Maltais P. 1994. Inventaire et analyse des populations de la mye commune, *Mya arenaria,* au Parc national Kouchibouguac. *Parks Can.* No. KOU92006.
9. LeBlanc and Miron. 2006. Bentho-pelagic distribution of early stages of softshell clams (*Mya arenaria*) in tidally contrasted regimes. *Can. J. Zool*. 84: 459-472.
10. Levinton JS, Martinex DE, McCartney MM, Judge ML. 1995. The effect of water flow on movement, burrowing, and distributions of the gastropod *Iiyanassa obsoleta* in a tidal creek. *Mar. Biol.* 122: 417-424.
11. Stock KI. 2002. Flume experiments on post-settlement movement in polychaetes. *J. Mar. Res.* 60: 743-762.
12. Lundquist CJ, Pilditch CA, Cummings VJ. 2004. Behaviour controls post-settlement dispersal by the juvenile bivalves *Austrovenus stuchburyi* and *Macomona liliana*. *J. Exp. Mar. Biol. Ecol*. 306: 51-74.
13. Pfitcenmyer HT, Drobeck KG. 1967. Some factors influencing reburrowing activity of soft-shell clam (*Mya arenaria*). *Chesapeake Science*. 8(3): 193-199.
14. Collip JB. 1921. A further study of the respiration processes in Mya arenaria and other marine molluscs. *J.Biol. Chem.* 49: 297-310.
15. Lindsay JA, Savage NB. 1978. Northern New England's threatened soft-shell clam populations. *Env. Manag.* 2(5): 443-452.

Follow-up of Sea Scallop (*Placopecten magellanicus*) Spat Loss in the Gaspe Bay, Quebec



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Abstract

In the Gaspesie and the Magdalene Islands, 70 to 90 % of sea scallop (*Placopecten magellanicus*) spat are generally lost before the removal of the collectors at the end of summer. A producer willing to optimize spat collection needs information on the behaviour of spat collectors, as well as the temporal evolution of spat growth. A study was carried out over 2 years to determine the optimum period of scallop collectors harvest. Spat size, spat abundance and biofouling abundance were assessed on 3 different lines of collectors, immersed in September and October 2004, by divers at bi-weekly intervals in 2005 (5 collectors per line and sampling date). Between mid June and the beginning of November 2005, 14 surveys were carried out, followed by 3 samplings in June and August 2006. During the first year of the study, a progressive loss of spat was observed between mid-June and the end of July 2005. Subsequently, the mean quantity of sea scallop spat per collector bag remained stable until their retrieval in November 2005. There was a slight decrease in 2006, following > 20 months of immersion. Data from our survey suggests that the two scallop species (*P. magellanicus* and *Chlamys islandica*) have different growth rates and growth periods in our area. Spat shell height increases after 12 months, but there is an important decrease in quantity. In addition, the results of spat collection were lower than those of previous surveys in the area. The effect of late immersion of spat collectors as well as the feasibility of using neighbouring sites still needs to be explored. Sea scallop spat loss of in early summer could not be related to adverse recorded environmental conditions; except for temperatures below 10 °C. The developmental behaviour and physiological conditions of small spat have to be investigated in order to explain this decrease in spat collecting success observed at the end of summer when collectors are commercially recovered.

Introduction

A 2005 study of sea scallop collectors in the Magdalene Islands showed that between 70 and 90 % of spat are lost prior to collector retrieval at the end of summer [(1)]. The highest loss was found to be in mid-August, following 11 months of immersion. A pre-grow-out strategy is being tested in the Magdalene Islands in order to prevent this loss. Other studies carried out in the Gaspe Bay [(2,3)] also demonstrated important losses (from 70 to 75%) in this region as well. To date, we know that the period of highest loss is somewhere between June and August. Therefore, in the Gaspe Bay, early harvest of spat collectors followed by a pre-grow-out strategy would help a producer to optimize his spat supply. In order to do this, the temporal evolution of giant scallop spat loss and size needs to be determined. A study was therefore carried out over 2 years to determine the optima harvest time of the collectors. The results of the first year study [4] are confirmed by data gathered on collectors following 21 and 24 months of immersion.

Method

In the Gaspe Bay (48° 47.162' N; 064° 20.838' W), three long lines of 1000 collectors were immersed on a scallop farm in autumn 2004. One line on September 21st (F3), one on October 6th (F1) and a third was partially filled at these two dates (F2). Collectors sampled were located 4 m above bottom at a 20 m deep site. All lines were maintained at a stable depth of between 15-17 m and they had been submitted to the same temperature profile as recorded on a pressure data recorder (VEMCO, TDR, Halifax, NS). Meteorological conditions were obtained from the Gaspe airport station (Environment Canada) and wave height with current speed at various depths via a current meter (Aanderaa Data Instruments, Doppler DCM12, Norway) immersed on site. Every two weeks from June to November 2005, five collectors from each line were enveloped with a 500 µm NITEX® bag and harvested by a diver. Due to the mixed origins of the collectors, follow-up of line F2 was not maintained after mid-season 2005. In 2006, there were three sampling, two in June and a final one in August, when the company started commercial exploitation of the long lines. Neither no divers nor bag were used during this last sampling. All collectors were washed using pressurized water jets and the contents frozen in plastic bags until sorted in the laboratory, where scallops were identified, counted, sized and the associated organisms separated.

Results

Losses of *P. magellanicus* spat were highest from mid-June to end of July 2005. On June 15th, counts of 288 ± 168 sea scallops/bag were obtained and they kept decreasing until the fourth survey at the end of July (Figure 1a). From then onwards, the amount of spat remained stable through the 12th survey in mid November at 35 ± 24 sea scallops/bag. Losses occurred mostly when sea bottom temperatures were below 10 °C (Figure 1e). The results of spat collection (288 sea scallops/bag) were lower than those of previous survey for this site from 1999 through 2004 (>1100 sea scallops/bag). This could be the result of the late immersion of the collectors in the autumn of 2004.

In the collectors, spat of *C. islandica* was more abundant after June 2005 (Figure 1a). They amounted to > 85 % of the total scallop count. This may be due to their larger size which permitted them to stay in the bags during sampling and specific identification. This is higher than the historic proportion of 45 % known for this site. Spat numbers of *P. magellanicus* were only slightly higher on F3, immersed on the 21st September 2004, than on F1, immersed on October 6th 2004. Results from all lines display the same seasonal pattern in the 2005 and 2006 surveys (Figure 2a).

When examining seasonal growth changes, shell length of P. *magellanicus* and *C. islandica* remained similar until the end of July. However, from the end of August 2005, *P. magellanicus* spat growth increased and appeared to be faster. Since August 2005 (Figure 2b), *P. magellanicus* spat shell height was higher on F3 (immersed 21st Sept.) than F1 (6th Oct.). Following more than 12 months of immersion (20 Sept. 2005), spat on F3 (8.9 ± 8.3 mm) was bigger than on F1 (2.9 ± 2.7 mm). From November onwards, shell height remained stable until the following June, which indicates that no winter growth occurred on either line. *C. islandica* spat shell height increased lightly after the winter months, showing that very limited winter growth occurred. It is also noted that in the last samples, (Figure 2b, August 20th 2006), the higher mean shell height was caused by the sampling technique, since no protective bag was used when the collectors were recovered commercially. This may have caused small spat loss through the collector mesh, thus increasing the mean obtained.

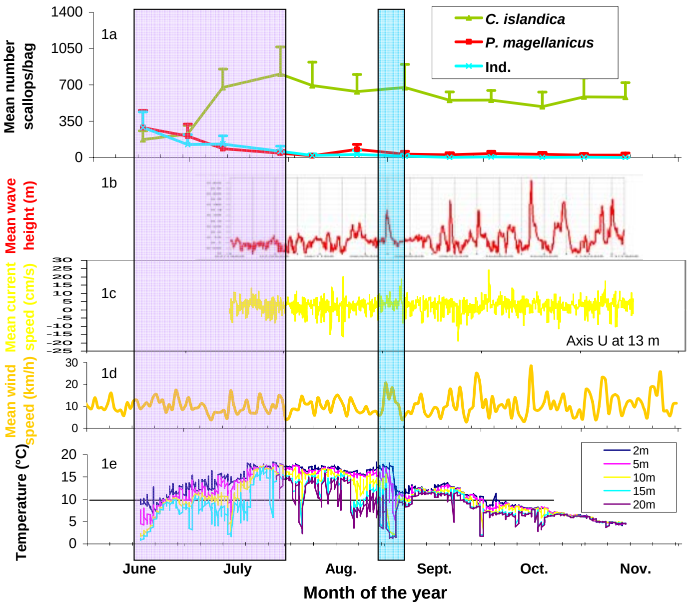

Figure 1. Comparison of seasonal variation means of a) number of each scallop species, b) wave height, c) current speed, d) wind speed and e) temperature at five different depths (violet zone: sea scallop spat losses; blue zone: occurrence of hurricane Katrina; ± SD).

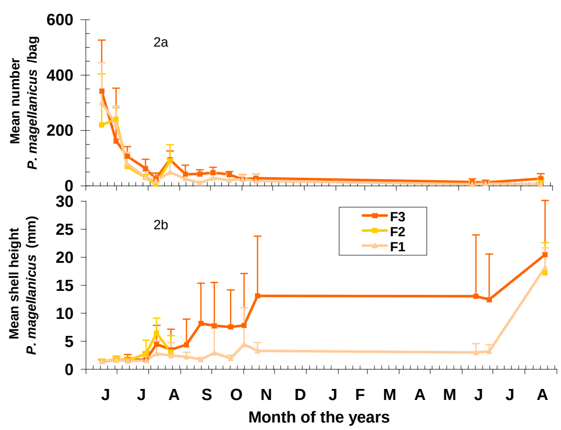

Figure 2. Monthly fluctuations of the mean a) number and b) shell height of *Placopecten magellanicus* spat in 2005 and 2006 from collectors immersed in Gaspe Bay in 2004 (± SD).

Discussion and Conclusion

Sea scallop spat loss occurs primarily early in the season; before the end of July (Figure 1a). Comparison with recorded environmental conditions did not explain those losses (violet zone on Figure 1). Even a hurricane or strong autumn storms did not have much effect on the loss rate (blue zone on Figure 1). Such storms, causing bigger wave height, high wind speeds and rapid temperature drops, occurred from the end of August onwards, but they didn't have a major effect on the quantity of spat counted in the following surveys. Our advice to scallops growers is to retrieve collectors early and to adapt their pre-growth equipment! Environmental conditions do not appear to affect spat loss. Other factors contributing to spat loss may be behaviour (mobility and byssus production) or physiological factors (temperature and size related conditions).

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References

1. Cliche G, Giguère M, Cyr C. 2005. Captage du naissain de pétoncles en milieu naturel aux Îles-de-la-Madeleine. In: 4e réunion annuelle de transfert de technologie – REPERE II. Cliche G and F. Coulombe (ed.), Îles-de-la-Madeleine, 26-27 March 2003. MAPAQ, *Compte rendu* 22: 3-9.
2. Thomas B, Giguère M, Brulotte S. 2003. Bilan des essais de captage du pétoncle géant, *Placopecten magellanicus*, en Gaspésie entre 1999-2002. Poster presented at 133rd Annual meeting of American Fisheries Society 10-14 August 2003, Québec.
3. Thomas B, Giguère M, Brulotte S. 2005. Bilan des activités de captage du pétoncle géant (*Placopecten magellanicus*) réalisées entre 1999 et 2004 en Gaspésie, Québec. *Public. Spec. Assoc. Aquac. Canada* 9: 81-83.
4. Thomas B, Giguère M, Brulotte S. 2006. Évaluation des pertes de naissain de pétoncles en baie de Gaspé. Oral presentation at Rendez-vous de l'industrie maricole, édition 2006, Regroupement des mariculteurs du Québec, 21-23 March 2006, Gaspé.

Modeling and Design of a Submersible Longline System for Near and Offshore Blue Mussel (*Mytilus edulis*) Culture

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Abstract

There is currently a need in the mussel aquaculture industry for the use of innovative technologies to keep competition among farm sites and to keep production levels high. The implementation of a submersible longline system would bring about a number of benefits to an operation, including minimizing the cost of production, taking advantage of 'food layers' within the water column, as well as avoiding settlement of fouling organisms. The ability to manage a commercial bivalve operation with respect to the biological and physical parameters of a culture site (e.g., thermocline, halocline, chlorophyll depths) represents a competitive advantage over traditional static farms. The use of airlift technology through this study has been shown to be one method of varying the depth of a culture backline. Various aspects and benefits of designing and implementing a submersible longline system for use in nearshore and offshore culture were examined in this report.

Introduction

Profitability of an operation is associated with a good business plan, including appropriate production technologies. However, this assumes the operation maintains a certain level of efficiency, which allows for optimal growth and profitability from the cultured product.

The amount of husbandry effort for an expanding operation to be efficient requires increasing amounts of maintenance cost. When plans for expansion reach a certain threshold, there is a need to implement automation and new technologies to decrease the cost of maintenance, while maintaining a reasonable return.

Managing a commercial bivalve operation with respect to the biological and physical parameters of a site (e.g., thermocline, halocline and chlorophyll layers) is essential for the success of the operation (Fig. 1).

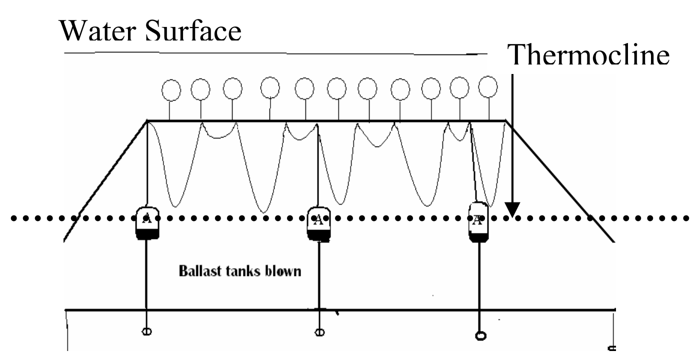

Figure 1. Longline set-up in the upper water column.

Rationale
The reasons for developing a cost effective submersible longline are: to take advantage of the maximum food layer (Ogilvie et al. 2004), to avoid secondary settlement, to reduce maintenance costs and to easily sink below ice and turbulent surface environments (Bonardelli & Morissette 2001). Taking advantage of the above parameters could increase the production and profitability of the Atlantic Canada industry, and allow expansion into new areas of production, including deeper, more open ocean areas (Langdon & Horton 2002).

Objectives
The general objectives of the proposed work were to better understand the physics of submerged longlines and to determine the suitability of submerged longline systems for bivalve culture. More specifically:

1. Quantify biomass and density (cultured and fouled) of a 30 cm length of market-sized mussel rope to determine buoyancy of total systems,
2. Determine the tension and deflection of a bivalve longline system in a laminar flow flume tank.
3. Design and model a ballast system for submerging a longline.

Methods

Biomass and Density Estimates
Commercial mussel socks (age 2+) were obtained from a farm site in Notre Dame Bay, transported to the lab and kept live in flowing seawater. Mussels were also purchased from various grocery stores for five consecutive weeks to determine density of a larger market size product. Sock weights were measured in water, the mussels were then removed from the tanks, drained for 25 minutes, and the "dry weight" determined. Meat Yields were determined on triplicate samples each week according to Ibarra et al. (2000).

Tension and Line Deflection
The Marine Institute's flume tank was used for the tension and deflection trials. The tension and deflection on the backline were measured by a 50 kg load cell, attached to a scale model longline submerged diagonally in the flume tank (Fig. 2). The mussel drops were constructed of tarpaulin strips, and weighed down with lead weights and aluminum bars.

Figure 2. Longline set-up in MI flume tank. Floats are approximately 1 meter apart in the model.

Two types of longline treatments were evaluated: fouled and unfouled. Four current speeds were evaluated for each treatment: no flow (0cm/s), low flow (10cm/s), medium flow (20 cm/s), and high flow (30cm/s). Tension and deflection measurements were obtained at each current speed.

Submersible Ballast System
The main concept of the design was to employ water and airtight sealed plastic containers with cement as ballast, allowing for sufficient lift capacity for moving lines up and down in the water column (up to 1 atmosphere pressure). The design also permitted the use of low volume and low pressure airlift systems for ease of use. The system

was tested in the flume tank and in the acoustic tank (4 meters depth).

Results and Discussion

Biomass and Density Estimates

Based on 6 independent measures of mussels varying from 25-40% meat yield, the maximum submerged weight would be 1.37 kg of marketable product per 30 cm. Using a safety factor of 1.5 on advice from the engineering consultant increased the maximum wet weight from 1.37 kg per 30 cm to 2.05 kg per 30 cm section. This calculation of a 30 cm section of culture line allows for the extrapolation of the mussel and fouling weight of any given length of mussel longline.

Tension and Line Deflection

Line tension was 3.10 kg at 10 cm/s current speed, and increased to 4.47 kg with fouling. At 20 cm/s the tension on the unfouled lines was 8.50 kg and this increased to 9.31 kg in fouled lines. At 30 cm/s, tension was 11.32 kg in unfouled lines and line deflection increased significantly (Fig. 4), however the fouled lines were pulled from the substrate at this current speed resulting in line movement.

We will use the results of the flume tank study to model line deflections and movement behavior in real life scenarios. The analyses are ongoing, but the results will permit an assessment of maximum load conditions in submerged lines before failures occur in the systems.

Submersible Ballast System

The ballast system design is shown in Fig. 3. The container was bottom heavy when lowered, and nearly impossible to flip. The vertical legs re-bounded the container to the upright position when lowered on an angle, thus serving as a self-righting mechanism.

If the system was deployed in muddy areas, the system could sink and possibly be stuck in mud. However, the water currents exiting from the tank should displace any fine muds from the sides and allow the ballast container to be freed.

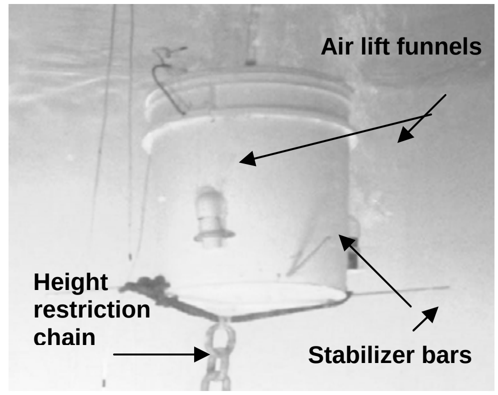

Figure 3. Components of a ballast system.

The anchor chain restricts vertical and horizontal movement of the container. The system can be lowered to higher food concentrations simply by blowing the ballast tank and allowing the system to sink to the bottom. The rope attached to the positively buoyant container is lengthened or shortened to fix the mussel drops at an appropriate height so to be able to deploy mussels in high food zones or in more suitable environmental conditions.

References

1. Ibarra D, Couturier C, Mills, T. 2000. Calculation of meat yields by mussel growers in Newfoundland. Seafoods in Health and Nutrition, Transformation in Fisheries and Aquaculture: Global Perspective. *Science Tech 2000*, 261-269.
2. Ogilvie S, Fox S, Ross A, James M, Schiel D. 2004. Growth of cultured mussels (*Perna canaliculus* Gmelin 1791) at a deep water chlorophyll maximum layer. *Aquaculture Research* 35, 1253-1260.
3. Langdon R, Horton C. 2002. Submerged longline culture of blue mussels in exposed oceanic environments. *Bulletin of the Aquaculture Association Canada* 102-3, 96.
4. Bonardelli J, Morissette S. 2001. Offshore mariculture: Logistical considerations for socking mussels and operating submerged longline structures. *Bulletin of the Aquaculture Association Canada* 101-2, 4-10.

Egg Enumeration, Incubation, Hatching and Development of the "Miracle Fish", *Oreochromis niloticus*, in the Sudan

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Abstract

The "Miracle Fish", *Oreochromis niloticus*, is a mouth brooder that exhibits a high degree of parental care. Brooding is strictly maternal and breeding females undergo physiological change before spawning begins – a ventral bulging of the hyoid region to increase the mouth capacity in order to accommodate the eggs after being fertilized by the male in a circular bowl-like nest built at the shallow part of the river bank or the pond. There are no records on the number of eggs accommodated in the female's mouth nor the egg development after hatching until the fry stage. In this paper, therefore, egg enumeration, artificial incubation, hatching and development are recorded for the first time in the Sudan to promote sound hatchery operation and provision of quality fish seed.

Introduction

The "Miracle Fish", *Oreochromis niloticus*, is one of 77 tilapia species described by Thys in 1968 and belongs to the Family Cichlidae of the Tribe *Tilapiine*.(1,2) It is indigenous to Sudan among other tilapia species namely, *Tilapia zillii* and *Sarotherodon galilaeus*. (2,3) As a matter of fact, *O. niloticus* is believed to have originated exclusively from the African continent and evolved in the River Nile.(4,5) Also, it is assumed to have evolved from a marine ancestor and its penetration to freshwater is secondary.(5,6) However, now it is one of the world's most important fresh/marine, warm water cultured food fish, farmed from extensive to super-intensive water recirculating (> 100 kg/m3) and integrated hydroponic systems.(2,7) This is due to its hardiness, tolerance to varying degrees of physical and chemical environmental factors and other characteristics for aquaculture: better food conversion efficiency, faster growth rates on low protein diets, higher resistance to diseases and better palatability with superb flavor and firm, moist nutritious meat. Every 100 grams (3.5 oz) of raw meat contains 19.2 g protein, 2 g fat, 100 calories calcium and 400 g omega-3 fatty acids.(4,5)

In 1982, Ethelwyn Trewavas (British Museum) had placed *O. niloticus* in the genus *Oreochromis* mainly because it is a microphagous mouth brooder tilapia species that exhibits a high degree of parental care and brooding is strictly maternal. Before spawning begins, breeding females undergo a physiological change – a ventral bulging of the hyoid region to increase the mouth capacity for the accommodation of the eggs after being fertilized by the male in a circular bowl-like nest built at the shallow part of the river bank or the pond.(2,8,9) The number of fertilized eggs brooded in the female's mouth increases with the fish body weight.(10) While there are a number of scientific publications available on the different culture aspects of *O. niloticus*, there is no one publication in Sudan which could serve as a reference to the embryonic development of the fertilized eggs up to the post-yolk sac fry stage during natural brooding or in artificial incubators. An investigation,

therefore, was undertaken for the first time in Sudan at Jebel Aulia Fish Farm on the White Nile for enumeration of fertilized eggs, artificial incubation, hatching and development of *O. niloticus* in order to promote sound hatchery operation and provision of quality fish seed.
record any relevant information for sound

Objectives

The objectives of the investigation are:

- collect and enumerate the fertilized eggs incubated in the mouth of *O. niloticus* females of different sizes and weights;
- hatch the collected fertilized eggs artificially in different types of incubators and find which type is more efficient under recorded environmental factors;
- find if the clutch-removal method of fertilized eggs from the mouth of incubating females is better than the natural brooding or not and why?
- follow up and record the embryonic development of the fertilized eggs up to the post-yolk sac fry stage;
- record any revelant information for sound hatchery operation and provision of quality fish seed.

Materials and Methods

The investigation was conducted at Jebel Aulia Fish Farm (Golden Arrow Co.) which is 73 ha in area and located on the White Nile, west of Jebel Aulia Dam, about 40 km south of Khartoum, the capital of Sudan. Broodstock of 75 females and 25 males, ranging in total lengths and weights from 15 – 35 cm and 50 – 250 g respectively, were collected from the White Nile and growing ponds and used in the investigation. They were put before the breeding time in hapas, each measuring 8 x 1.5 x 2 m. These hapas were erected in half a hectare earthen pond above the water level and above the pond bottom by a quarter of a meter respectively.

Applying the clutch-removal method, the fertilized eggs were collected directly from the mouth of incubating females. The number of fertilized eggs and length/weight of each female were recorded. Number of eggs produced per gram body weight was estimated by dividing the total number of eggs collected from each female spawn by the weight of the fish. The eggs were then transferred indoor for hatching in three types of incubators: porcelain Zoug jars, round plastic containers and perspex Zoug jars. Each incubator was stocked with up to 2011 eggs per liter and shielded from sunlight to avoid any damage to the eggs by ultra-violet radiation. A steady current of plankton-free water was allowed to pass through each incubator after being mixed with oxygen as soon as it was out of the bio-filter. Temperature, dissolved oxygen and pH were monitored daily at 10 am, 1 pm and 5 pm. Ammonia, total hardness, Chlorine, salinity, iron and copper were also monitored biweekly at 8 am.

Results

The investigation achieved its goals. The clutch-removal method of fertilized eggs from the brooding females, hatching and rearing them artificially in incubators, provided the necessary quantity at the required time. Tables 1 and 2 show the average data record for the enumerated fertilized eggs with respect to the females' sizes/weights (cm/kg) and the water analysis with respect to the physical and chemical parameters respectively.

The results and observations are summarized hereinafter:

- the eggs are pear-shaped, very yolky, yellowish brown with average weight of 0.005 g;
- the data in Table 1 indicate that the number of fertilized eggs incubated in the mouth of each female increased as the total length and weight of the fish increased; it was also observed that the number in several females was less within the same parameters of length and weight;
- the number of eggs per gram body weight increased in the smaller females, i.e. 5 eggs per gram in the female that weighed 50 grams as compared to 2 and 1 in those that weighed 150 and 250 grams respectively;

- the data in Table 2 indicate that the eggs when put in three types of incubators needed a constant flow of plankton-free water mixed with dissolved oxygen in a concentration of 6.3 ppm, an appropriate temperature of 25 C, a pH of 8.7 and incubation in a well shaded place to avoid ultra-violet rays especially during early cell cleavage of the eggs;
- hatching of fertilized eggs in the three artificial incubators was highest in the Perspex Zoug jars followed by the porcelain Zoug jars and the round plastic containers;
- after the eggs were transferred in the incubators, they started to develop through a sequence of events which can be briefly defined into three phases from the start of incubation till after the yolk sac was completely absorbed (Plate 1):
  - phase 1: from fertilization until the appearance of the eyes ('eyed eggs');
  - phase 2: from the appearance of the eyes until hatching (yolk sac fry);
  - phase 3:from hatching until the absorption of the yolk sac (post-yolk sac fry).

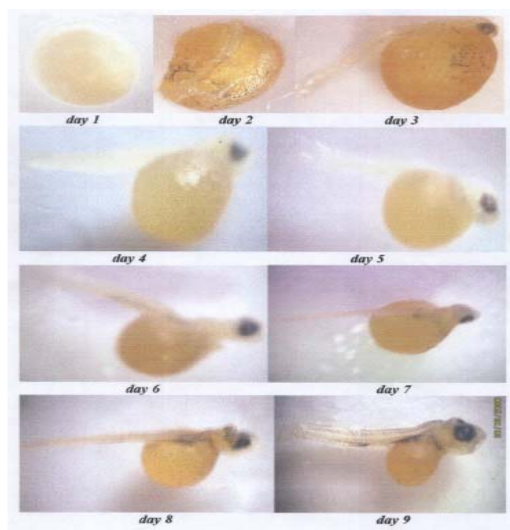
Table 1. Average Data Record of Enumerated Fertilized Eggs of *O. niloticus* with Respect to the Female Parent Size (cm) and Weight (kg).

Total length (cm)	Weight (kg)	Number of fertilized eggs Actual - Per g body weight
16.6	50	230 - 4.6 = 5
20.0	140	242 - 1.7 = 2
20.9	150	313 - 2.0 = 2
22.3	225	320 - 1.4 = 1
23.6	250	354 - 1.4 = 1

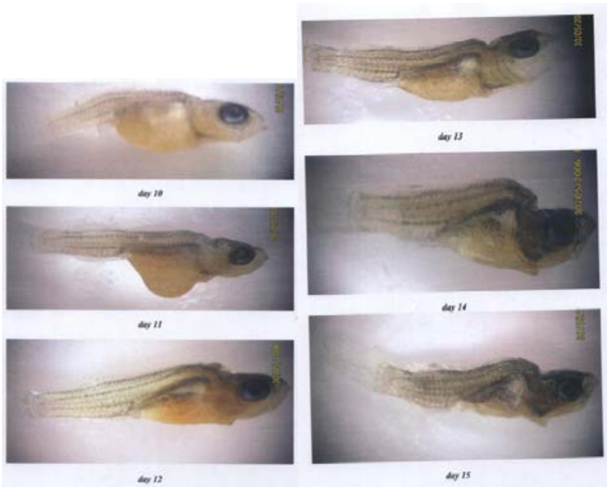
Table 2. Average Data Record for Water Analysis.

Parameter	Average data
Temperature (C)	25.1
Dissolved Oxygen (ppm)	6.3
pH	8.7
Total Hardness (ppm)	350.0
Ammonia (ppm)	2.0
Chlorine (ppm)	0.0
Salinity (ppm)	0.0
Copper (ppm)	0.0
Iron (ppm)	0.0

Plate 1. Sequence of the Egg Embryonic Development of *O. niloticus* During the First 15 Days (Afra).



Day 1: yellow brown and yolky fertilized egg;
Day 2: small dark spots collected on the egg surface;
Day 3: eyes and hair-like tail appeared;
Day 4: head appeared;
Day 5: head and tail more developed, the yolk sac decreased and the embryo started slight movement;
Day 8: yolk sac fry started to swim out of the incubators with the water flow;



Day 12: skeleton and fins more developed and yolk sac decreased in size;
Day 13: fry transferred from water trough to small fiberglass tanks with slow water flow and left until day 15;
Day 15: post-yolk sac stage whereby yolk sac was fully absorbed and fry started to feed on supplementary food at the rate of 10% while average body weight reached 0.0168 grams.

Discussion

Development of any aquaculture species requires research into several areas such as broodstock management, egg incubation, larval rearing, juvenile-on growing and marketing. The present investigation dealt only with egg enumeration and incubation. It supports an earlier finding that the number of eggs per clutch increases with the length and weight of the spawner (10, 11) However, it was observed that within the same parameters of weight and length, the number of eggs could be less. This may be attributed to the fact that the broodstock used in the investigation was a mix of females from the White Nile and the growing ponds. It is a known fact that in ponds, tilapias mature much sooner (earlier age) than under natural conditions and produce smaller and more numerous eggs for a given body weight because of the unfavorable pond conditions, a homeostatic device in response to the environment.(10, 11) The number of eggs per gram body weight increased as the weight of the brooding female decreased. Therefore, it is advisable to use females of smaller size (50 g) for breeding.

O. niloticus spawns easily and frequently but one of the major constraints to large-scale commercial farming is the scarcity of quality seed in large numbers required at any time. That is why, the clutch-removal method was used in the present investigation. Also, because previous studies ascertained that it is superior to natural mouth brooding which produces poor seed due to cannibalism of eggs and fry by the adults and besides, it increases the spawning frequency of the females and consequently, the overall production of fry or seed.(11) It is very important to shield the eggs from direct sunlight especially during early development to avoid damage by ultra-violet radiation. A previous study recommended that hatcheries should be equipped with subdued lighting. (13) Furthermore, the concentration of dissolved oxygen in the plankton-free water for artificial egg incubation was found to be extremely important and more effective than the ‘churning’ action of the female during maternal incubation. The temperature maintained during the egg incubation period served the purpose. However, there is need for more studies on this aspect because it was ascertained in other species that small temperature changes can cause considerable variation in the development and physiology of the developing fish. The water flow into the incubators in liters per minute was not carried out in the investigation. This is another important factor because it is reported to remove harmful metabolites (CO2, NH3) excreted by the developing eggs and prevent the lipids in the heavy yolk of the eggs from settling and disrupting development.(10, 11) Finally, the embryonic (brooding) period begins with the fertilization of the egg and terminates with the transition from endogenous to exogenous feeding i.e. up to the post-yolk sac fry. In *O. niloticus*, egg development is a fast process whereby the main distinguishable stages are swelling, germ development and embryonic development stages. These stages are clearly illustrated in Plate 1 and demonstrate for the first time in Sudan, a detailed sequence of development in the fertilized egg of *O. niloticus*. However, it is interesting to know that only Morrison et.al.(14) of Dalhousie University, Faculty of Medicine, Halifax, N.S, Canada published a detailed histological study of the development of the embryo and early larva of *Orechromis niloticus*.

Recommendations

The following recommendations are suggested:

1) Initiate finfish reproduction and broodstock development program in the Faculty of Agricultural Technology and Fisheries Sciences, Al Neelain University, Sudan.

2) Develop a genetic-based broodstock management approach for *O. niloticus* to optimize egg and fry quality through artificial diets, selective breeding, photoperiod and temperature manipulation.

3) Hatchery operators are advised to breed smaller spawners, follow the clutch-removal method of eggs from the incubating *O. niloticus* females and hatch/rear them artificially in efficient incubators to increase the spawning frequency of the females and avoid the problem of cannibalism of eggs and fry.

4) Study the selection effects of *O. niloticus* females in ponds for spawning frequency, number and diameter size of eggs per clutch as compared to natural brooding females.

5) Study the influence of egg size on the progeny with respect to natural and pond broodstock.

6) Study the effects of water flow (liters/min), dissolved oxygen concentration, temperature, pH and photoperiod on the incubation /hatching time and embryonic development of the fertilized eggs of *O. niloticus*.

Acknowledgments

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References

1. Thys van den Audenaerde DFE.1968. An annotated bibliography of Tilapia (Pisces: Cichlidae) *Mus. A. Afr. Cent. Doc. Zool.* No. 14, 406 p.
2. George TT. 1995. The most recent nomenclature of Tilapia species in Canada and the Sudan. *Bull. Aquacult. Assoc. Canada, Sp. Pub*. No 10: 33 – 37.
3. Sandon H.1950. An illustrated guide to the freshwater fishes of the Sudan. *Sudan Notes and Records* 31: 1-61.
4. George TT.1996. Tilapia – a potential culture species in Canada. *Bull. Aquacult. Assoc. Canada* 96-3: 44 – 46.
5. Pullin RSV, Lowe-McConnell RH.1982. *The Biology and Culture of Tilapias*. ICLARM, Manila, Philippines, 432 p.
6. George TT.1997. Saltwater culture of tilapias and possible commercial application in Canada. *Bull. Aquacult. Assoc. Canada* 97-2:42-44.
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. 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.
9. Trewavas E. 1983. *Tilapiine Fishes of the Genera Sarotherodon, Oreochromis and Danakalia*. British Museum (National History) London. 563 p.
10. Fryer G, Iles TD. 1972. *The Cichlid fishes of the Great Lakes of Africa – Their Biology and Evolution*. Oliver and Boyd. Edinburgh, 641 p.
11. Balarin JD, Hatton JP. 1979. Tilapia. *A Guide to their Geology and Culture in Africa*. Unit of Pathobiology. University of Sterling. Scotland. 174 p.
12. Sheppeard CJ, Bomage NR. 1989. *Intensive Fish Farming*. Blackwell Scientific Publication, 436p.
13. Morrison CM, Miyake T, Wright Jr. JR. 2001. Histological study of the development of the embryo and early larva of Orechromis niloticus (Pisces: Cichlidae). *Journal of Morphology* 247: 172 – 195.

An Integrated Bio-Treatment System for the Management of Land-Based Aquaculture Solids

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Abstract

A respirometric technique was used to assess the feasibility of using anaerobic digestion technology and/or an aerobic composting process to treat aquaculture biosolids. A batch study on digestibility of aquaculture biosolids was conducted using a respirometer system. Based on the batch results a digester with an active volume of 4 L was started and operated at room temperature (23°C±2). The digester was fed continuously with VS loading of 0.6 kg VS/m^3.d. Loading rates were gradually increased until no inhibition was observed. Performance of the digester was studied during start up and continuous operation. To evaluate the biodegradation of aquaculture biosolids using a composting process, a respirometer study was conducted. Aquaculture solids were blended with paper sludge to maintain various moisture contents and C/N ratios. Different blends of paper sludge and aquaculture solids resulted in C/N ratios that ranged between 19:1 and 58:1. In the same manner, digested solids were added to the paper sludge to obtain C/N ratios of 26:1 to 71:1. In both the cases, paper sludge alone, with a C/N ratio of 109:1, was taken as a control. Results indicated that digested aquaculture solids were suitable for composting compared to raw aquaculture solids.

Introduction

Land-based fish farming operations are increasing world wide due to demand for fish products. This increasing industrial activity has taken its toll on the environment. The discharge of unstabilized waste from land-based fish farming operations pollutes land, air and water bodies. The wastes generated from these industries are a mixture of unutilized fish feed and fish excretes that settles at the bottom of fish tank (Ramachandran et al, 2006). These wastes are heterogeneous, with a TS of 11-16%, have a high organic content, and are rich in nutrients such as nitrogen and phosphorous. At many land-based facilities, the sludge is collected from a settling tank and stored under anaerobic conditions in holding tanks for later disposal. The storage of solids promotes dissolution of nutrients and produces strong odours. These solids are normally disposed by spreading on fields. Current disposable methods will lead to a gradual degradation of these solids and produce a significant amount of lechate.

There are a number of natural biosolids treatment and management systems currently in use; some are anaerobic (anaerobic digestion, lagoons and wetlands) and others are aerobic (composting and land application) processing systems. Anaerobic digestion and aerobic composting are preferred technologies because of the possibility of energy recovery from the digestion process and the production of a beneficial soil conditioner from the composting process. The success of these bio-treatment technologies depends on the type of waste managed. Certain types of waste may not be suitable for digestion, for composting, or for both. Aquaculture wastes can be handled by either anaerobic and composting treatment technologies, or both.

Anaerobic digestion is a proven technology for stabilizing various biosolids wastes including industrial waste, agricultural waste and municipal solid waste (Lanari and Franci, 1998; Gebauer, 2004; Sung and Liu, 2003). In anaerobic digestion organic matter is converted into methane (CH_4), carbon dioxide (CO_2), hydrogen and traces of hydrogen sulfide (H_2S) via a series of interrelated microbial metabolisms by two groups of organisms: acidogens and methanogens (McCarty, 1964; Quasim, 1985; van Handel and Lettinga, 1994). Methane has a high calorific value which can be recovered and used for heating purpose as well for generation of electricity.

Composting is a widely accepted method for stabilizing organic wastes and converting them to a usable, value added compost product (Ashbolt and Line, 1982; Deschamps et al., 1979). Aerobic composting is an autothermal aerobic process which has the potential to convert the waste biologically into a stable, less heterogeneous material. The resulting compost should be free of pathogens, can be beneficially applied to land, and will have a lower impact on air, land and water environments (Haug, 1980). Paletski and Young, (1995) evaluated microbial activity and composting efficiency in composting research using respirometry experiments (or oxygen uptake rate). Respiration is a global measure of total microbial activity that can provide a reliable, repeatable and scientifically sound assessment of microbial activity. Oxygen uptake provides an improved measure of the compost stability because it represents a fundamental biological characteristic of the compost process and directly reflects the activity of the aerobic microbial reaction.

In the present study the feasibility of using anaerobic digestion technology and/or aerobic composting to manage aquaculture solids was assessed by a respirometer system. The anaerobic degradation of aquaculture solids (AS) was investigated in a digester at room temperature (23±2°C) and digester performance was studied during the continuous operation at various loading rates. A respirometeric study was also conducted to study the compostability of anaerobically digested aquaculture solids.

Materials and Methods

An aerobic/anaerobic Respirometer System (Challenge AER-208, Challenge Environmental Systems Inc., USA) was used to study the methane production potential of the aquaculture solids. The same setup was also used to find the degradability of raw aquaculture solids and digested aquaculture solids using a composting process.

Digestion of the aquaculture solids in continuous mode was carried out at room temperature (23±2°C) in a bench-scale digester made of glass with an active volume of 4 L. Aquaculture solids were mixed with anaerobic seed sludge and allowed to acclimatize for two months. After the acclimation period, the digester was fed with a volatile solids loading rate of 0.6 kg VS/m^3.d, then the loading rates was gradually increased to 1.2 kg VS/m^3.d and increased again to 1.8 kg VS/m^3.d. Degradation of the organic matter and production of VFAs were studied at various loading rates and retention times to optimize the solids destruction efficiency of the digester. The corresponding biogas production was recorded to evaluate the performance of the digester.

Composting experiments (Figure 1) were carried out at a temperature of 35°C and oxygen was supplied to the system continuously at a rate of two bubbles per minute. Oxygen uptake was measured until samples were stable, as indicated by a lack of further oxygen uptake. Due to a very high nitrogen content, the aquaculture solids lacked adequate C/N ratio for composting. Bulking agents were added to provide structural support during composting, to maintain air spaces within the composting system, to reduce the moisture content of the mixture, and to provide adequate C/N ratio. A locally available paper sludge was selected as the bulking agent for this study since it had a very high C/N ratio and very good moisture absorption capacity. Samples were prepared by blending known weight of paper sludge with different weights of raw aquaculture solids or digested aquaculture solids. The paper sludge and raw aquaculture solids were blended to provide a C/N ratio in the range of 19.1 to 58:1. In the same manner, digested aquaculture solids were added to the paper sludge to obtain a C/N ration of 26:1 to 71:1. In both the cases paper sludge alone, with a C/N ratio of 109:1, was taken as a control. A 1mm nylon mesh is placed inside the sample insert to hold the compost samples. Each sample insert was filled with 100 gm of sample. The sample inserts were placed inside the compost columns which were capped air tight to prevent the escape of oxygen from the system.

The raw AS were tested for water content, TS, VS, pH, total Kjeldahl nitrogen (TKN), inorganic nitrogen, phosphorous, carbon and nitrogen content. Parameters such as water content, TS, VS, pH, ORP, COD, total alkalinity, VFA, and ammonia-nitrogen were tested for digested solids. For analysis, procedures given in Standard Methods (APHA, AWWA and WEF, 1998) and Hach Colorimetric Method (1999) were adopted. The carbon content and nitrogen content was obtained using a LECO 2000 CNS analyzer. For the composting study the prepared samples and final samples were tested for total solids, moisture content, volatile solids, carbon and nitrogen content.

Results and Discussion

Anaerobic Digestion

At the end of startup period anaerobic biomass adapted to the aquaculture solids and this presumably increased the tolerance of microbes for ammonia and VFA concentrations in the digester. An increase in VFA concentration of approximately 56% was noticed during the first week of start-up which led to a decrease in pH of the system. However, because of the sufficient alkalinity (2090 mg/L as $CaCO_3$) in the digester, the high concentration of VFA due to acidification of the digester contents did not cause process disturbance. Biogas production increased at the beginning and declined after five weeks of operation. Methane composition increased from 53% to 69% during this time.

Continuous feeding at successive increase in loadings began at the end of second month. The pH in the system kept increasing during the third loading due to an increase in ammonia-nitrogen concentration. Maximum reduction in TS of 83.6% and VS of 88.0% was achieved for the first loading rate. Removal efficiency of the digester decreased as the loading rates were increased. Decreases in TS removal of 14.8% and 11.3% were noted during the successive loading. A similar trend in VS removal efficiency was observed in the system. VS removal decreased by 13.2% and 9.4% during the second and third loadings, respectively. During the third loading rate, a steady increase in VFA was noticed and an accumulation of acids started to build at this stage of the process. This indicated that the methanogens may have been inhibited. The increase in ammonia concentrations from 358 mg/L to 820 mg/L might have caused the inhibition to methanogens and led to the decrease in specific gas production during the operation at third loading rate. Feeding was discontinued at this stage.

Figure 1. Laboratory setup showing respirometer system with compost columns.

Composting

Seven samples of raw aquaculture solids mixed with paper sludge and one control were placed in the respirometer, which was operated until oxygen uptake ceased. Oxygen uptake with raw aquaculture solids occurred in less than 100 hours which clearly shows the rapid oxygen uptake by the compost samples. All the samples were very active within the first 24 to 48 hours of active aeration. High oxygen uptake rates within the first few days of composting could lead to rapid temperature increase in the system because of the excessive microbial activity. In the field, this would mean that the compost mass would quickly use up any available oxygen, leading to the possibility that the pile would turn anaerobic. This highlights the difficulty in composting the raw aquaculture wastes. In the second phase, the experiments were repeated using aquaculture solids which had been first subjected to an anaerobic digestion process. With this digested solids blend, the uptake of oxygen occurred in 430 hours compared to 100 hours for the earlier study. A constant oxygen uptake rate was observed through the aeration period. The active aeration period for the digested solids sample was 18 days, which suggests that the digested solids would remain in aerobic condition long enough for composting to proceed in the field without condition turning anaerobic. This demonstrates that the digested solids are suitable for composting, while the raw aquaculture solids are not a suitable compost feedstock.

Conclusions

This study concluded that anaerobic digestion of aquaculture solids is a technically feasible process. Furthermore, anaerobic digestion of aquaculture solids can be considered as a viable alternative for recovering energy in the form of biogas with 65-70% methane content, while at the same time reducing environmental pollution. Inhibition of methanogens was observed and was most probably caused by ammonia concentrations which increased with the increase in volatile solids loading rate. To achieve stability of the digestion process it is suggested to operate the digester at VS loading of 1.2 kg VS/m^3.d and at a TS of 11-16%, which may keep the ammonia concentration below the inhibition range.

Rapid oxygen uptake, less reduction of VS and moisture, more loss of nitrogen indicates the unsuitability of raw aquaculture solids for composting. Nitrogen conservation and better removal of VS and moisture shows the suitability of composting digested aquaculture solids. This study suggests that an integrated waste management system for land-based aquaculture solids could be achieved using anaerobic digestion technology followed by aerobic composting process.

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References

1. Ramachandran M, Singh, KS, Wilson BG. 2006. Anaerobic digestion of land-based aquaculture solids. In: *Research Advances. Proceedings of the 21st International Conference on Solid Waste Technology and Management*, March 26-29, 2006. Philadelphia, PA, USA 307-316.
2. Lanari D, Franci C. 1998. Biogas production from solid wastes removed from fish farm effluents. *Aquatic Living Resource* 11(4), 289-295.
3. Gebauer R. 2004. Mesophilic anaerobic treatment of sludge from saline fish farm effluents with biogas production. *Biosource Technology* 93, 155-167.
4. Sung S, Liu T. 2003. Ammonia inhibition on thermophilic anaerobic digestion. *Chemosphere* 53, 43-52.
5. McCarty PL. 1964. Anaerobic waste treatment fundamentals III. *Public Works* 95, 91-94.
6. Quasim SR. 1985. *Wastewater Treatment Plants: Planning, Design, and Operation.* Holt

Rinehart and Winston, CBS College Publishing, New York, NY, 1985, 451p.
7. van Handel AC, Lettinga G. 1994. *Anaerobic Sewage Treatment: A Practical Guide for Regions with a Hot Climate*. Chichester: John Wiley & Sons Ltd, 147p.
8. Ashbolt NJ, Line MA. 1982. A bench-scale system to study the composting of organic wastes. *Journal of Environmental Quality* 11(3) 405-408.
9. Deschamps AM, Henno P, Pernelle CL. Caignault C, Lebeault M.1979. Bench-scale reactors for composting research. *Biotechnology Letters* 1:239-244.
10. Haug RT. 1980. *Compost Engineering: Principles and Practice*. Ann Arbor Science, Ann Arbor.
11. Paletski WT, Young JC. 1995. Stability measurement of biosolids compost by aerobic respirometry. *Compost Science and Utilization* 3(2), 16-24.
12. *Challenge Environmental Systems, Inc. 2004. Challenge AER-200 Aerobic/Anaerobic Respirometer System – Instruction Manual.* CES, Inc. USA.
13. *Standard Methods for the Examination of Water and Wastewater. 1998.* 20^{th} *ed.* American Public Health Association/ American Water Works Association/ Water Environment Federation, Washington, DC, USA.
14. Hach 1999. *Colorimeter Procedures Manual*. Hach Company USA.

Performance Characteristics of the Horizontal Moving-Bed Biofilter

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Abstract

The hydrodynamic, nitrification, degassing and oxygenation characteristics of the horizontal moving-bed biofilter were investigated in this study. Spatial ammonia concentration measurements confirmed that each half of the biofilter is hydrodynamically well mixed. The rate of nitrification is first order with respect to the ammonia concentration and the apparent nitrification rate constant is $0.005 s^{-1}$ at a particle filling fraction of 0.6. The air bubbles keep the water saturated in oxygen and provide significant removal of carbon dioxide. By combining nitrification, degassing and oxygenation in one low-head unit, the horizontal moving-bed biofilter eliminates the need for a degassing column and offers new design opportunities for reducing the pumping costs of recirculating aquaculture farms.

Introduction

The predominant technologies currently being used by the salmon-smolt aquaculture industry for ammonia and carbon dioxide control are fluidized-sand biofilters and packed columns. A major drawback of these technologies is their high pumping costs. The most effective strategy for reducing pumping costs is to reduce the overall elevation and head losses of the biofilters and degassing columns(1). It is possible to achieve this objective by combining these two unit operations into one horizontal reactor based on the design of the moving-bed biofilm reactor. This approach has the added benefit of reducing the complexity of recirculation systems by reducing the number of water treatment steps.

The horizontal moving-bed biofilm reactor is a new low-head reactor which has been operated successfully as an ammonia biofilter(2). However, limited results on the nitrification capabilities of this new reactor have been published and no performance data is available on its ability to remove carbon dioxide. This study presents results on the nitrification, degassing, oxygenation and mixing characteristics of the horizontal moving-bed biofilter.

Materials and Methods

The measurements were taken on a horizontal moving-bed biofilter in operation at a commercial salmon-smolt hatchery. The reactor (Figure 1) was in the shape of a shallow rectangular box split into two cells by a dividing wall. Each cell was 3 m long, 3 m wide and 1.3 m deep. Water was fed at one end of the reactor at a rate ranging between 0.05 and 0.11 m^3/s and overflowed at the opposite end. Kaldnes type K1 rings were used as biofilm carriers. These rings are made of polyethylene (PEHD) and float in water. The bulk volume of the rings occupied approximately 60% of the volume of the biofilter. Air was injected at a rate of about 0.04 m^3/s at the base of each cell using a network of perforated pipes. The rising air bubbles mixed the buoyant particles vigorously and provided a large interfacial area for gas-liquid transfer. A sieve placed horizontally across the exit of each cell prevented the carrier particles from escaping the biofilter.

Water samples were periodically taken at different positions along the biofilter over a 10 month period. The pH, dissolved oxygen concentration (DO) and temperature of the water were measured with calibrated probes immediately after taking the samples. The samples were then stored on ice until further analysis in the lab the next day. The ammonia, nitrite and nitrate concentrations of the samples were measured using a Hach colorimeter whereas the free carbon dioxide concentration was measured by direct titration(3).

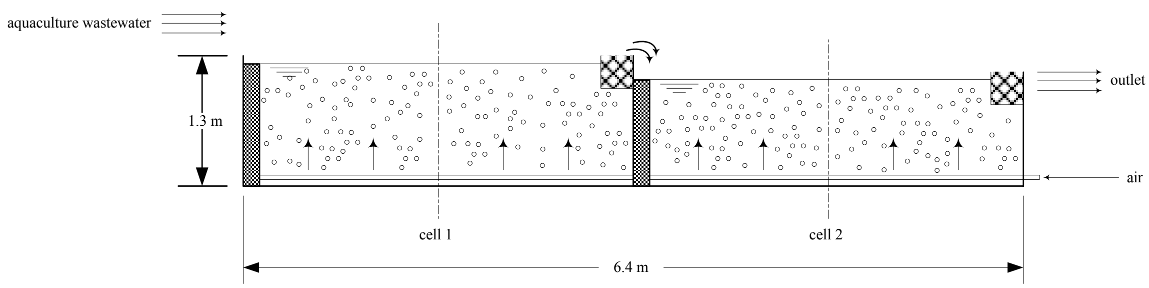

Figure 1. Schematic diagram of the full-size horizontal moving bed biofiter.

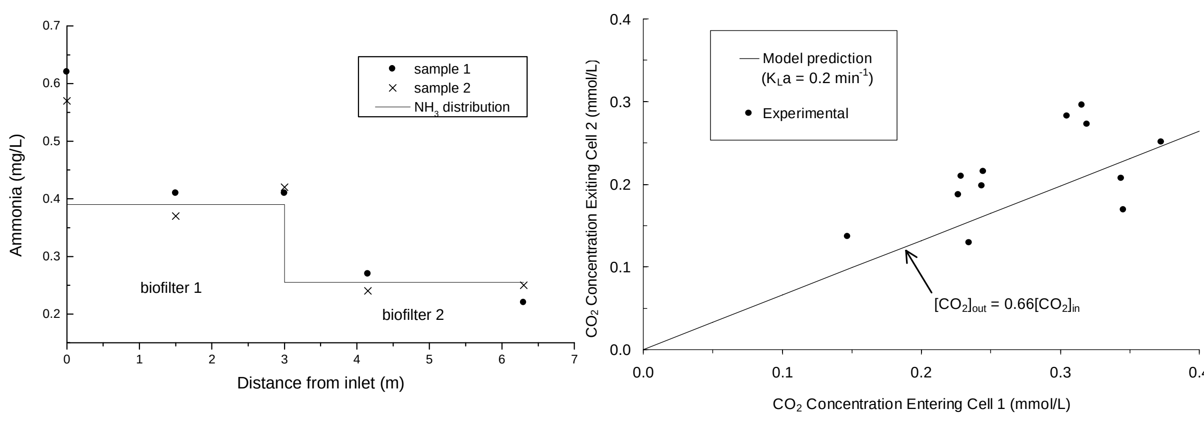

Figure 2. (a) Typical ammonia concentration profile (b) Carbon dioxide removal from horizontal moving bed biofilter.

Results and Discussion

Ammonia measurements taken at different positions along the biofilter (Figure 2(a)) show that the ammonia concentration is spatially uniform within each cell, further confirming that the cells are well-mixed. Consequently, the average concentration C_a in each cell is numerically equal to the outlet concentration.Ammonia profiles across the biofilter were obtained at different times during a period when the ammonia loading to the biofilter changed significantly because of fish growth. For each set of measurements, the average nitrification rate *R* in each cell was calculated from the drop in ammonia concentration across the cell and the results were plotted versus the average cell concentration C_a. The nitrification rate *R* increases linearly with C_a confirming that the apparent reaction rate is first order. The slope of the straight line regressed through the data is 0.0050 ± 0.0003 s^{-1} and is the reaction rate constant *k*.

The concentration of carbon dioxide at the outlet of the full-scale biofilter was calculated using a mass balance and a measured overall mass transfer coefficient, K_La, of 0.2 min^{-1}. The predictions were compared to the measured values and it was found that approximately 34% of the inlet carbon dioxide is removed within the biofilter (Figure 2(b)). Dissolved oxygen measurements taken from the biofilter also show that the water leaving the biofilter remained saturated with oxygen.

Conclusion

Ammonia concentration profiles confirm that each cell of the horizontal moving-bed biofilm reactor is a well-mixed system. The air bubbles used to mix the buoyant plastic rings also keep the water saturated in oxygen and provide significant removal of carbon dioxide. The rate of nitrification is first order with respect to the ammonia concentration and the apparent nitrification rate constant is $0.005 s^{-1}$ at a particle filling fraction of 0.6. By combining nitrification, degassing and oxygenation in one low-head unit, the horizontal moving-bed biofilter offers new design opportunities for reducing the pumping cost and complexity of recirculating aquaculture farms.

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References

1. Renaud NJ, Couturier MF. 2004. Energy Management at Aquaculture Facilities Operating under Northern Climates. 5th International Conf. on Recirculating Aquaculture Systems, Roanoke, VA.
2. Rusten B, Eikebrokk B, Ulgenes Y, Lygren E. 2006. Design and Operations of the Kaldnes Moving Bed Biofilm Reactors. *Aquac. Eng.* 34:322-331.
3. American Public Health Association. 1981. Standard methods for the examination of water and wastewater, 15th Ed. American Public Health Association, Washington, D.C.

Velocity Profiles in Multi-drain Circular Tanks

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Abstract

Circular fish-rearing tanks can be designed as self-cleaning primary solids separators. The rotational velocity in circular tanks generates a secondary radial flow along the floor that carries settled particles to the central drain. The shape of the tangential velocity profile determines the strength of the secondary flow and therefore whether the tank is self-cleaning. The objectives of this project were to study the hydrodynamic characteristics of multi-drain tanks and to develop a model for predicting the tangential velocity profile within the tanks. Work was done on 1.5m and 5m double-drain and triple-drain tanks. In agreement with model predictions, the tangential velocities near the center of the tank increase as the inward radial bulk flow increases. It is also shown that the triple-drain tank design provides greater flexibility than the conventional double-drain designs for controlling tank hydrodynamics.

Introduction

The removal of solid wastes such as fish faeces and uneaten feed is an important water treatment step in recirculating aquaculture systems. Inadequate removal leads to poor water quality in the fish rearing tanks and favours the proliferation of pathogens.

Fish-rearing tanks can be designed to act as primary solids separators. Circular tanks are commonly used for this purpose because they are self-cleaning. The high rotational velocity in circular tanks generates a secondary radial flow along the floor that carries solids to the central drain[1]. This is known as the "tea-cup effect" [2]. However if this flow is not completely evacuated through the underflow outlet, it rises in the middle of the tank and leads to re-suspension of particles. Circular tanks used for solids separation have at least two drains. The double-drain tanks reduce the size of the downstream solids removal equipment by concentrating settleable solids in the bottom center drain[3]. The top drain can either be located on the side wall (Cornell design) or at the center of the tank (Waterline design). The performance of both double-drain designs is affected by the flow split (i.e. fraction of water leaving via the underflow outlet). Both designs are inefficient at low splits: Cornell tanks are not self-cleaning and Waterline tanks do not achieve good solid separation because of re-suspension. The triple-drain tank with one outlet at the side, one at the top center and one at the bottom center was proposed to avoid the disadvantages of the Cornell and Waterline designs[4].

The objectives of this project are to study the hydrodynamic characteristics of multi-drain tanks, to develop a model for predicting the tangential velocity profile within the tanks and to predict their self-cleaning ability. Work was done on double-drain and triple-drain tanks.

Materials and Methods

Steady-state experiments were performed on a 5m tank at a salmon smolt hatchery and on a 1.5m tank at the University of New Brunswick in Fredericton, NB, Canada. These circular tanks did not contain fish. Water was injected into the tank through the inlet pipes and could leave via the bottom center drain, the side drain or the top center drain. By plugging some outlets, the tanks could be used in the Cornell, Waterline or triple-drain configurations.

In both tanks, the inlets were located such that the volumes of water between the center and the inlets and between the inlets and the wall were the same (i.e. $r_j = R/\sqrt{2}$, where R is the radius of the tank (m) and r_j is the radial position of the inlets (m)). The radial position of the inlets was fixed but the direction of the incoming water could be changed by rotating the pipes by an angle θ. The inlets consisted of vertical pipes with water injection holes distributed over their full length. The inlet flow rate was adjusted between 100 and 500 L/min in the 5m tank and between 30 and 150 L/min in the 1.5m tank.

The tangential water velocity V_θ (m/s) was measured with a SonTek™ Acoustic Doppler Velocimeter. The measurements were taken at several radial positions and depths within the tank using a traverse system to hold the probe. Each velocity measurement lasted 30 seconds during which readings were taken every 0.1 second. The 300 values were then averaged to provide a time-averaged value for the fluctuating tangential velocity.

The model for the tangential velocity profile was derived on the premise that the tangential velocity is independent of depth and angular position. Under those conditions, the tangential component of the equation of motion[5] reduces to:

$$\rho V_r \left(r \frac{d\omega}{dr} + 2\omega \right) = -\frac{1}{r^2} \frac{d}{dr} (r^2 \tau_{r\theta}) \quad (1)$$

where ω is the angular velocity of the water (s^{-1}, $=V_\theta/r$), V_r is the radial velocity (m/s), r is the radial position (m) and ρ is the water density (kg/m^3). The turbulent shear stress τ was evaluated using Prandtl's mixing length model[2]:

$$\tau_{r\theta} = -r^2 \rho l^2 \left| \frac{d\omega}{dr} \right| \frac{d\omega}{dr} - \mu r \frac{d\omega}{dr} \quad (2)$$

where μ is the dynamic viscosity of water (kg/m.s) and l is the mixing length[6]. The model was integrated numerically after specifying the tangential velocity $V_{\theta j}$ at the position of the inlets (i.e. at $r=r_j$) and the proportion α of water leaving via the side drain.

Results and Discussion

The tangential velocity profiles in the Cornell and Waterline tanks can be modified only by changing the flow out of the bottom center drain or the total inflow. The triple-drain design on the other hand offers the possibility of modifying the radial profile of the tangential velocity by changing the split between the side and top-center drains. This is possible because the radial profile of the tangential velocity is a function only of the total flow leaving via the two central drains and not of the flow split between these two drains (Figure 1).

The model predicts that the velocity at the center increases as the flow of water leaving via the central drains increases (Figure 2). As the strength of the secondary radial flow along the floor is proportional to the local tangential velocity, it is important that the tangential velocity remains everywhere above a certain critical value for the tank to be self-cleaning. However the tangential velocity in the core must not be too high in order to avoid re-entrainment of the solids.

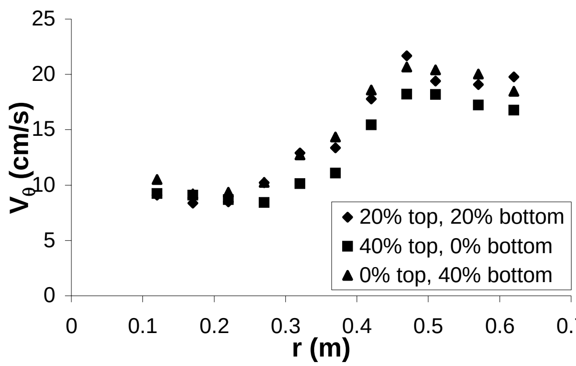

Figure 1: Effect of flow split between two central drains. 1.5m tank, r_j=51cm, $\theta = 0°$, $Q \approx$90L/min

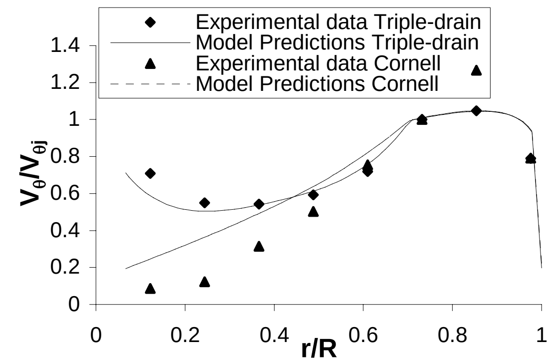

Figure 2: Model predictions. Triple-drain, 5m tank, Q=242L/min, α=58%Cornell, 5m tank, Q=225L/min, α=91%

Conclusion

A model for predicting tangential velocities within circular tanks was developed. In agreement with experimental data, the model predicts that the radial profile of the tangential velocity is a function only of the total flow of water leaving via the central drains and not of the flow split between these two drains. Consequently, the tangential velocity profile in triple-drain tanks can be modified by adjusting the flow split between the side and top-center drains while keeping the flow out of the bottom center drain small. This is an advantage over double-drain tanks because the size of the equipment required to remove the solids from the underflow is proportional to flowrate.

Acknowledgements

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References

1. Timmons MB, Ebeling JM, Wheaton FM, Summerfelt ST, Vinci BJ. 2001. *Recirculating Aquaculture Systems*. Cayuga Aqua Ventures, Ithaca, NY, USA.
2. Schlichting H. 1979. *Boundary-Layer Theory*. McGraw-Hill Book Company, NY, USA.
3. Timmons MB, Summerfelt ST, Vinci BJ. 1998. Review of Circular Tank Technology and Management. *Aquacultural Engineering.* Vol.18: 51-69.
4. Veerapen JP, Lowry BJ, Couturier MF. 2004. Solids Separation in Double-Drain Fish Tanks. *5th International Conference on Recirculating Aquaculture Systems*, Roanoke, VA.
5. Bird RB, Stewart WE, Lightfoot EN. 2002. *Transport Phenomena*, 2nd Ed., John Wiley, NY.
6. Despres B. 2006. *Hydrodynamic Characteristics of Multi-drain Circular Tanks*. M.Sc. Thesis, University of New Brunswick, Fredericton, NB, Canada.

Méthodes D'hivernage des Filières D'élevage des Bivalves

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Abstract

In New Brunswick, aquaculture has significant economic value. There is interest in the rearing of two species of shellfish on the province's East Coast: the blue mussel (*Mytilus edulis*) and the eastern oyster (*Crassostrea virginica,* Gmelin). Although the rearing techniques are well known, overwintering still poses a considerable challenge. There are two major steps in mussel rearing: spat collection and growout. Collection is done on the surface of the water and growout is done on long lines suspended a few metres below the surface. That way, the socked mussels are not subject to the action of the waves and are protected from the thick layer of ice. The overwintering of the structures has been resolved, facilitating the harvest of the stock. Oysters are reared in floating structures on the surface of the water in most of the bays on New Brunswick's East Coast. The rearing sites are located in shallow waters (less than 3 meters deep). Two problems relating to the overwintering of the structures must be resolved: protection of the structures and winter harvest.

Introduction

Au Nouveau-Brunswick, l'aquaculture a une valeur économique importante. Deux espèces de mollusque bivalves suscitent de l'intérêt pour l'élevage le long de la côte-est de la province; soit la moule bleue (*Mytilus edulis)* et l'huître américaine (*Crassostrea virginica* Gmelin). Bien que les techniques d'élevage soient bien connues, les techniques d'hivernage présentent encore des défis importants. La résolution des problèmes relatifs à l'hivernage des structures doit répondre à deux stratégies : la protection des structures et la récolte hivernale.

Description

La moule bleue

Il y a deux étapes importantes dans l'élevage des moules : le captage du naissain et le grossissement. Le captage du naissain se fait à la surface de l'eau à l'aide de collecteurs (corde de polypropylène de 2 mètres de longueur) suspendus sur des longues lignes. Le captage débute généralement entre la fin juin et le début juillet. À l'automne, les petites moules sont suffisamment grosses pour être triées et mises en bas. C'est le début de l'étape de grossissement.

Au Nouveau-Brunswick, les sites d'élevage de moules sont situés dans des zones exposées aux vents où la profondeur ne dépasse pas 10 mètres. Les bas sont suspendus sur des longues lignes disposées à quelques mètres sous la surface de l'eau. Ainsi, les moules dans les bas ne sont pas soumises à l'action des vagues et sont protégées de l'épaisse couche de glace. La figure 1 illustre schématiquement une longue ligne d'élevage de moules. Des essais d'élevage ont également été tentés dans la baie des Chaleurs où la profondeur atteint plus de 25 mètres.

Afin d'éviter les effets des énormes vaques et des banquises dérivantes, de longues lignes sont suspendues à plus de 8 mètres de la surface de l'eau. À l'heure actuelle, la récolte n'est possible que lorsqu'il n'y a pas de glace. Dans la baie des Chaleurs, la glace est trop épaisse et la banquise trop instable pour entreprendre des activités de récolte pendant l'hiver.

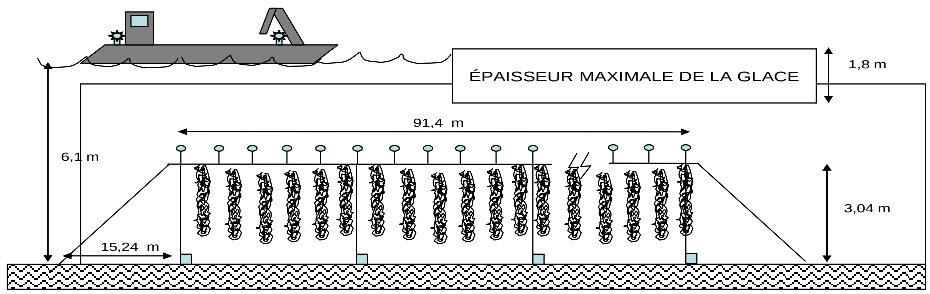

Figure 1. Schéma d'une filière d'élevage de moules.

L'huître américaine
Les huîtres sont mises en élevages dans des structures flottantes à la surface de l'eau dans la plupart des baies de la côte-est du Nouveau-Brunswick. L'utilisation des structures flottantes est récente (moins de 10 ans) et toutes les étapes de production ne sont pas encore bien définies. Il existe plusieurs types de casiers et chacun présente ses avantages et ses désavantages. La figure 2 montre une filière de poches flottantes, un des casiers le plus utilisé pour l'élevage. Ce casier de 80 cm x 40 cm x 10 cm de dimension est construit en polyéthylène. Les mailles sont carrées ou en forme de losange. Le casier flotte grâce à des bouées fixées à ses côtés. L'hivernage de ce type de filière est simple. Il suffit d'enlever les bouées de chaque côté des poches et la filière se dépose sur le fond marin.

L'hivernage des structures flottantes se fait en fonction de la dimension du casier et de la méthode de récolte envisagée. Au cours des années, deux stratégies d'hivernage ont été développées soit, le dépôt des structures directement sur le fond marin ou l'entreposage sur des longues lignes flottantes dans la colonne d'eau. Chacune des stratégies offre ses avantages et ses désavantages.

Figure 2. Filière d'élevage d'huîtres (2 rangées de 50 poches flottantes).

L'hivernage sur le fond
Il y a plusieurs avantages à hiverner directement sur le fond. C'est rapide et facile. Les flotteurs sont enlevés et les casiers coulent au fond. Le cheptel reste dans les casiers en respectant les densités d'élevage. Généralement, cette stratégie est pratiquée sur le site du producteur. La position des filières à récolter est notée à l'aide d'un GPS. Pendant l'hiver, un trou creusé dans la glace à l'aide d'une scie à chaîne permet l'extraction des casiers.

Cette méthode pose certains problèmes. Plusieurs sites d'élevage sont situés dans des endroits peu profonds (moins de 3 mètres). Pendant les marées basses extrêmes, la glace peut se déposer sur les structures est les endommager. Au début de l'hiver et au printemps, des banquises dérivantes déplacent parfois les filières. Les casiers déposés sur le fond vaseux mous subissent parfois un envasement important lors des tempêtes d'automne. À l'automne, la zostère (*Zostera marina*), très abondante dans les baies de la côte-est du Nouveau-Brunswick, se détache du fond et forme des îlots qui se déplacent avec les courants. Éventuellement, ces îlots se déposent sur le fond et peuvent recouvrir une grande quantité de casiers causant ainsi des pertes de cheptel aux ostréiculteurs. Au printemps, dès que les conditions le permettent, il est impératif de remettre rapidement les structures d'élevage en flottaison afin d'éviter des stress inutiles au cheptel.

L'hivernage en filière flottante

La technique utilisée ressemble à celle de l'élevage des moules. Les casiers sont suspendus à des longues lignes flottantes dans la colonne d'eau. Ils ne touchent pas au fond et la glace ne peut les atteindre. Cette technique permet l'utilisation de casiers de plus grande dimension. Les densités de stockage varient en fonction des stratégies préconisées par l'ostréiculteur. Au printemps, la remise en flottaison est moins urgente car les huîtres ont accès à une bonne circulation d'eau. Les casiers sont rarement envasés et la zostère ne s'accumule pas dessus.

L'hivernage en filières flottantes est très exigent en main d'œuvre. Il faut transférer de grande quantité d'huîtres du site de grossissement au site d'hivernage. La mise à l'eau de structures plus volumineuses nécessite des bateaux et de l'équipement plus robuste. La densité d'huître à mettre en casier reste à déterminer en fonction des structures utilisées.

La récolte des poches se fait à partir d'un trou dans la glace. Les filières sont tirées hors de l'eau par un treuil hydraulique. Cette méthode est efficace pour récolter une grande quantité de casiers mais demande trop d'effort pour de petites quantités. La récolte des huîtres mises dans des structures plus volumineuses, reste à être développée.

Conclusion

L'hivernage des structures d'élevage de moules a été résolu. Le cheptel ainsi que les équipements sont sécurisés et la récolte se fait aisément sur la glace. L'hivernage des structures d'élevage d'huîtres est encore en développement. La taille des casiers et les caractéristiques physique des sites sont les principaux facteurs limitants.

Characterization of Wolffish Hybrids (*Anarhichas minor* X *A. lupus*)

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Abstract

Wolffish hybridization could enable the combination of the higher growth performance of the spotted wolffish with the robustness and antifreeze protein synthesis capacities of the Atlantic wolffish. However, the survival of wolffish hybrids might be challengrd by a disruption of mitochondrial function through intergenomic coadaptation. Furthermore, if wolffish hybridization is possible and hybrids are viable, what will they look like and how will they perform? Our research concentrates on the characterization of hybrid juveniles of spotted and Atlantic wolffish on three important aspects: 1) growth performance, 2) aerobic capacities development and viability and 3) geometric morphometrics. Growth trials under two temperatures (8°, 10°C) were conducted in spring 2006 in a recirculation water system. Microsatellites assay were used to confirm hybrid status. Different physiological determinants such as lipid peroxidation and enzymes involved in the mitochondrial electron transport system and aerobic energy metabolism will be used to assess what could possibly limit hybridization success. According to their respective optimal growth temperature (7-8°C for *A. minor* and 10-11°C for *A. lupus*), our preliminary results indicate that the hybrids displayed their highest growth performance at 10ºC compared to 8°C for the pure spotted wolffish juveniles. Analyses of metabolic and oxidative stresses, as well as morphology measurements are currently underway. This research is the first to document wolffish hybridization.

Introduction

Hybridization in aquaculture has been shown to produce considerable gains in production, by improving performance and productivity, that in turn lead increased profits for the industry[(1)]. It has been the object of studies in the salmonids industry since the seventies and now more than one thousand varieties of hybrid, mostly freshwater fishes, are produced[(2,3)]. Our project concentrates on the hybridization of two species: the spotted and Atlantic wolffish (*Anarhichas minor*, *A. lupus*). These non-metamorphic marine fish species display a range of attractive characteristics for aquaculture, that include high specific growth rates in captivity at low temperature, low complexity of the rearing technology, tolerance to high densities and resistance to disease[(4,5)]. These species also show interesting potential for the extraction of by-products or biomolecules of economic interest [(6)].

However, both species differ in many aquaculture traits. The spotted wolffish has a higher growth rate and a more farming-friendly behaviour than the Atlantic wolffish[(4)]. However, the Atlantic wolffish has a higher tolerance to environmental fluctuations such as temperature and salinity than the spotted wolffish[7]. Furthermore, *A. lupus* has a higher antifreeze protein synthesis (AFP) that presents an interesting economic value[8]. The principal objective of hybridization is to combine desirable traits of distinct species with the aim to produce offspring that will perform better than both parental species[1]. Thus, by moving genes between both species, wolffishes hybridization could enable us to have the better of the two worlds: the higher growth performance of the spotted wolffish combined with the higher robustness and biomolecule potential of the Atlantic wolffish.

However, survival of wolffish hybrids might be challenging. Nuclear and mitochondrial genes, that encode subunits in some electron transport system (ETS) enzyme complexes, has co-adapted to each other in synchrony throughout evolution to able an efficient mitochondrial respiration[9]. The function of the mitochondria critically depends on this interaction. In a hybrid organism, the contribution of the other species to the nuclear genome may expose functional incompatibilities among both kinds of encoded proteins. These may cause metabolic limitations at the level of mitochondrial catalytic capacities and an oxidative stress that could lead to an hybrid breakdown[10,11].

Furthermore, few studies document morphological differences between wolffishes. In 1954, Luhmann[12] described, on a coloration basis, interspecific forms between *A. minor* and *A. lupus*. Templeman (1986)[13] called into question his conclusions after describing spotted forms of Northern wolffish (*A. denticulatus*). Thus, additional morphological variability introduced by hybridization complicates species identification especially if inappropriate techniques are used[14]. Geometric morphometric techniques allow a complete reconstruction of the shape to understand the form directly rather than indirectly via fragmentary measurements as in traditional morphometry[15]. Appearance and shape differences can thus be quantified between the two species and their hybrids.

The objective of this research is to characterize hybridization of the spotted and the Atlantic wolffish by two highly important attributes in aquaculture, viability and growth performance, and by morphometry through geometric morphometric techniques.

Materials and Methods

The experiments were performed at the Centre Aquacole Marin de Grande-Rivière (CAMGR) (Qc, Canada). Brood fish from both species were crossed during the summer of 2005 and four families were produced: one pure spotted wolffish family (A), two spotted wolffish hybrid families (B and C) (spotted wolffish ♀ x Atlantic wolffish ♂) and one Atlantic wolffish hybrid family (D) (Atlantic wolfish ♀ x spotted wolffish ♂). Eggs were incubated at 6ºC and hatching occurred in January 2006. Growth trial followed a factorial plan where families were raised separately in triplicate (150 fishes per tank) in a recirculation water system under 2 temperatures (8, 10°C) until they reached 140 days post-hatch (dph). Family D, due to low fecundity and egg quality of our F1 domestic Broodstock (1st reproductive season), was raised with no replicate at 8°C only.

Six fishes per tank were sampled at regular interval (0, 30, 60, 90 dph), weighed, measured and preserved at -80ºC until analysis. Enzymatic activity of lactate dehydrogenase (LDH), citrate synthase (CS), cytochrome *c* oxidase (COX) and the overall electron transport system (ETS) were measured in whole fish. These activities were measured spectrophotometrically in our laboratories. Thiobarbituric acid reactive substances (TBARS) were measured in fluorescence to estimate lipid peroxidation. Genetic variability was estimated at eight microsatellites loci in the wolffishes broodstock and on sampled fishes using PCR techniques. Moreover, five fishes at 0, 30, 60 and 90 dph and 20 at 140 dph were randomly taken in each family, weighed, measured and preserved in a neutral buffered formalin solution (NBF). Standardized picture of these fishes will be taken in order to conduct software morphological analysis (TPS-DIGIT) using the procrustean superimposition approach.

Preliminary Results and Discussion

First of all, the factorial correspondence plot (Figure 1) indicates that Atlantic and spotted wolffish are genetically distinct species. It also confirmed the hybrid status of our experimental fish.

Growth Performance

Fish growth is a highly complex process influenced by numerous biotic and abiotic factors where temperature is the single most dominant[16]. Wolffishes follow a pattern typical of most fish species: a rapid increase of growth rate with a peak at optimal and a sharp decline as temperature gets higher[16]. According to this, when we consider temperature as a factor, significant differences for each group are found (ANCOVA, $p<0.05$) (Figure 2).

Furthermore, growth performance has a genetic basis and thus varies within species[17]. In wolffishes, spotted wolffish usually gain 5 kg in two years compared to only 2.5 kg for the Atlantic wolffish[16]. For hybrid fishes, studies demonstrate that performances are generally 1) intermediate 2) superior (heterosis) or 3) similar to one of the parental species[18]. When we consider family as a factor, growth rate is significantly different under each temperature (ANCOVA, $p<0.05$) (Figure 2) (Family D excluded). More precisely, spotted wolffish hybrid juveniles gave the highest growth performance at 10°C, whereas it's at 8°C for the pure spotted wolffish juveniles. This is quite interesting, because each species has its own temperature optima. The optimal growth temperature of the Atlantic and the spotted wolffish is respectively 10-11°C and 7-8°C [4,19]. So through hybridization, Atlantic wolffish genes seem to be moved to the spotted wolffish and confer to the hybrid a better potential of growth at higher temperatures.

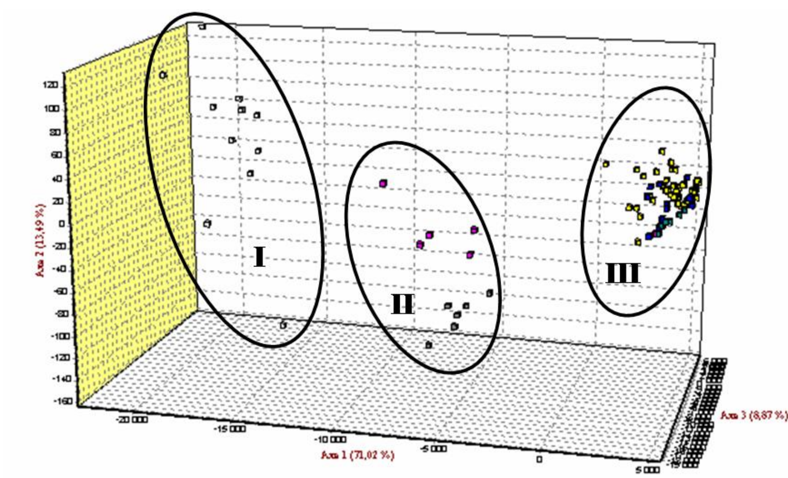

Figure 1. Factorial correspondence plot of wolffishes (Atlantic, spotted and hybrids) based on eight microsatellites loci. Circles I, II and III are in order: pure *A. lupus*, hybrids and pure *A. minor*.

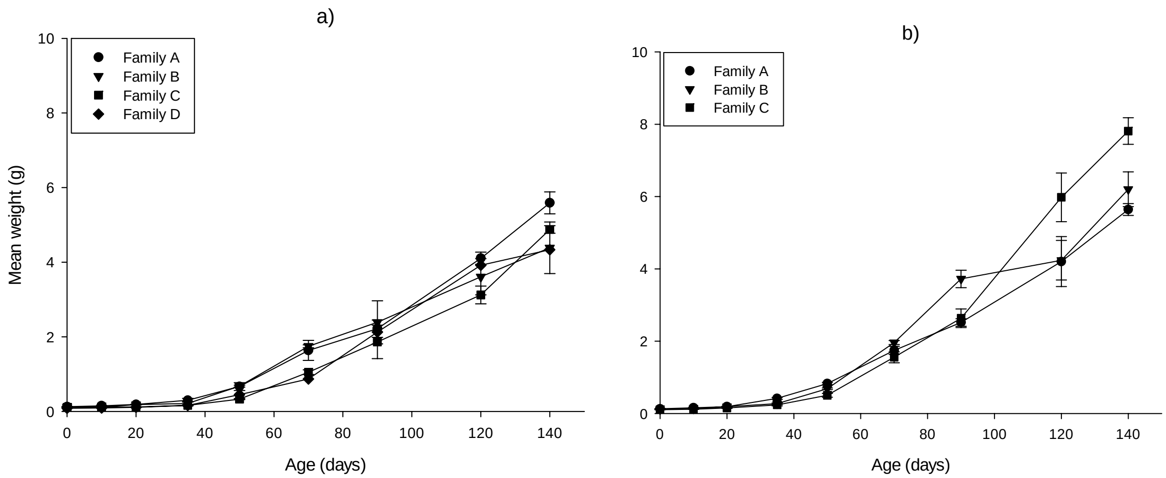

Figure 2. Growth of pure spotted wolffish juveniles (Family A), spotted wolffish hybrid juveniles (Families B and C) and Atlantic wolffish hybrid juveniles (Family D) at 8°C (a) and 10°C (b).

Conclusion

This research is the first to document hybridization of the spotted and Atlantic wolffish. It shows that wolffishes hybridization is feasible. By moving genes between both species, hybridization seems to have an impact on the optimal growth temperature of wolffish hybrids. Analysis of metabolic and oxidative stresses and their impact on viability as well as morphology measurements are currently underway. In 2007, wolffish hybridization research continues at CAMGR to further assess hybrid aquaculture characteristics.

This study gives an insight into the functional conservatism in mitochondrial evolution and into the biology of these endangered species. For the aquaculture industry, this project is a step toward the optimization of growth performance and the commercialization stage of these promising species.

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References

1. Bartley DM, Rana K, Immink AJ. 2000. The use of inter-specific hybrids in aquaculture and fisheries. *Reviews in Fish Biology and Fisheries.* 10:325-337.
2. Refstie T, Gjedrem T. 1975. Hybrids between salmonidae species: Hatchability and growth rate in the freshwater period. *Aquaculture*. 6:333-342.
3. Wang J, Xia D. 2002. Studies on fish heterosis with DNA fingerprinting. *Aquaculture Research*. 33 :941-947.
4. Foss A, Imsland AK, Falk-Petersen IB, Oiestad V. 2004. A review of the culture potential of spotted wolffish *Anarhichas minor* Olafsen. *Reviews in Fish Biology and Fisheries*. 14:277-294.
5. Le Francois NR, Lemieux H, Blier PU. 2002. Biological and technical evaluation of the potential of marine and anadromous fish species for cold-water mariculture. *Aquaculture Research.* 33:95-108.
6. Le François NR, Lamarre S, Blier PU. 2004. Tolerance, growth and haloplasticity of the Atlantic wolffish (*Anarhichas lupus*) exposed to various salinities. *Aquaculture*. 236(1-4):659-675.

7. Moksness E, Pavlov DA. 1996. Management by life cycle of wolffish, *Anarhichas lupus* L., a new species for cold-water aquaculture: a technical paper. *Aquaculture Research.* 27:865-883.
8. Desjardins ME, Le François NR, Fletcher GL, Blier PU. 2006. Seasonal modulation of plasma antifreeze protein levels in Atlantic (*Anarhicas lupus*) and spotted wolfish (*A. minor*). *Journal of Experimental Marine Biology and Ecology*. 335:142-150.
9. Blier PU, Breton S, Desrosiers V, Lemieux H. 2006. Functional conservatism in mitochondrial evolution: insight from hybridization of arctic and brook charrs. *Journal of Experimental Zoology.* 306B.
10. Ballard JWO. 2004. The incomplete natural history of mitochondria. *Molecular Ecology.* 13: 729-744.
11. Ellison CK, Burton RS, 2006. Disruption of mitochondrial function in interpopulation hybrids of *Tigriopus californicu. Evolution*. 60(7):1382-1391.
12. Luhmann M. 1954. Uber intermediare Formen zwischen *Anarhichas minor* Olafs. Und *A. lupus* L. (Teleostei). *Fish. Res. Board Can. Transl. Ser.* 13:310-326.
13. Templeman W. 1986. Spotted forms of the Northern wolffish (*Anarhichas denticulatus*). *J. Northw. Atl. Fish. Si*. 7:77-80.
14. Loy A, Bronzi P, Molteni S. 1999. Geometric morphometrics in the characterization of the cranial growth pattern of Adriatic sturgeon *Acipenser naccarii*. *Journal of Applied Ichthyology*. 15:50-53.
15. Richtsmeier JT, Burke-Deleon V, Lele SR. 2002. The promise of geometric morphometrics. *Yearbook of Physical Anthropology.* 45:63-91.
16. Moksness E. 1994. Growth rate of the common wolfish, *Anarhichas lupus* L., and spotted wolfish, *A. minor* Olafsen, in captivity. *Aquaculture and Fisheries Management.* 25:363-371.
17. Gjedrem T. 1983. Genetic variation in quantitative traits and selective breeding in fish and shellfish. *Aquaculture.* 33:51-72.
18. Paspatis M, Markakis G, Koumoundouros G, Kentouri M. 1999. Preliminary Results on Rearing of *Sparus Aurata* - *Pagrus Pagrus* Hybrids: Performance comparison with the parental species. *Aquaculture International.* 7:295-306.
19. McCarthy I, Moksness E, Pavlov DA. 1998. The effects of temperature on growth rate and growth efficiency of juvenile common wolffish. *Aquaculture International.* 6(3):207-218.

Compression of the Reproduction Cycle of Spotted Wolffish (*Anarhichas minor*)

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Abstract

Wolffish have been selected as promising species for cold-water aquaculture in eastern Canada. However, a major constraint to the emergence of a new aquaculture species is a year-round supply of high-quality juveniles, a limitation that may be partly resolved by increasing the production of larvae and juveniles. Photoperiod plays an important role in the timing of gonadal maturation in several fish species, including wolffish. The objectives of this study are to compress the reproduction cycle of wolffish by manipulation of the photoperiod and to quantify the effects of photoperiod manipulation on gamete quality, fish growth and appetite. Each month, sexual maturation of female wolffish is monthly monitored through oocyte diameter by ultrasound. After 8 months, the preliminary results of this 2-yr study show a shift of one month in maturation of males under the accelerated photoperiod compared to males under natural photoperiod. Maturation of females, as measured by egg diameter, did not different under the two regimes. However, Norwegian females showed a proportion of atresia. We expect a compressed 8-month reproduction cycle within 2 years.

Introduction

Spotted (*Anarhichas minor*) and Atlantic wolffish (*Anarhichas lupus)* are currently cultured in northern Norway[1] and these species have been selected as promising candidates for cold-water aquaculture in Canada[2]. A principal advantage for aquaculture in north temperate regions is their high growth rates at low temperatures[3, 4]. Fertilization in wolffish is internal; artificial insemination is used under culture conditions.

A major hindrance to research and development of a new aquaculture species is the limited availability of juveniles[5, 6]. At present, the supply of juvenile wolffish is limited to the annual reproduction cycle, with spawning taking place in August to November depending on the stock[7]. In contrast, salmonid aquaculture facilities can count on a year-round supply of eggs and fry, since hatcheries produce sufficient numbers during the entire year. An increased supply of juveniles would be an important step in the development of a profitable wolffish aquaculture industry.

Reproduction in teleosts is cyclical, in synchrony with seasonal changes[8]. Gonadal maturation is an endogenous process that is cued by several environmental factors, yet photoperiod appears to be the dominant agent in the majority of north temperate fish species[9, 10]. The influence of photoperiod involves the pineal gland and the hormone melatonin; the daily sequence of melatonin secretion is modulated by day-length[9]. Gonadal maturation involves the hypothalamus - pituitary- gonad axis and a cascade of hormones[9, 10]. The hypothalamus releases gonadotropin releasing hormone, inducing the release of gonadotropin by the pituitary, which in turn stimulates the production of the principal sex steroids (estrogen, E2 and testosterone, T) by the gonads[10]. In females, E2 induces the production of the female egg protein vitellogenin in the liver that is subsequently secreted in the blood and sequestered in oocytes[10].

Manipulation of the photoperiod is a well-established method to decrease the reproductive cycle or delay maturation of salmonids[11], and other cultured species[9, 12]. An accelerated photoperiod was used to alter spawning time of spotted wolffish in Norway[13]. The objectives of this work are 1) to accelerate the reproductive cycle of two wolffish stocks (Canadian and Norwegian) by manipulation of the photoperiod, and 2) to quantify the effects of photoperiod manipulation on growth, appetite and sexual maturation of adults and on the quality of the gametes produced. Here we present initial results of sexual maturation during the first reproductive cycle under the two photoperiod regimes.

Materials & Methods

These experiments were conducted at the Centre Aquacole Marin de Grande-Rivière (CAMGR; Grande-Rivière, QC, Canada). This study involved two stocks of three year-old spotted wolffish. The Canadian stock is the first generation (F1) of a breeding stock maintained at CAMGR since 2001. We also obtained fertilised eggs of Norwegian fish from Tommamarinfisk A/S a commercial operation that were then hatched at CAMGR.

Fish for these experiments were divided into four 0.5m^3 troughs, with 25 Norwegian and 15 Canadian fish per trough. Fishes are individuals tagged with a microchip (AVID Identification Systems Inc. Folson, LA, United State). The troughs are provided with flowing seawater (flow: 8L/min, temperature: 7.5 - 8°C,) and divided into two photoperiod regimes – a natural (12 month) cycle and a compressed (8 month) photoperiod. Seasonal changes and daily cycles with simulated dawn and dusk are controlled with an Aquabiotech Sunmatch photoperiod controller (Aquabiotech inc. Coaticook, QC, Canada). Light intensity is maintained at 50 lux. Fishes are fed to satiation three times per week with Corey Aqua Clear 10 mm pellets (Corey Feed Mills Ltd, Fredericton, NB, Canada).

Growth (wet weight, length) is measured every month. The reproductive status of the individual is evaluated at the same time, using the parameters of spermiation and sperm motility in males and mean oocyte diameters in females. Oocyte diameters are visualized using a Sonosite 180 plus ultrasound equipped with a L38/10-5 transducer (SonoSite Canada Inc., Markham, ON, Canada).

The effect of photoperiod on maturation of females from Norwegian and Canadian stocks was investigated using a analysis of variance (ANOVA). The statistical analyses are done using Systat 11 software (Systat Software, Inc., San Jose, CA USA).

Results and Discussion

The monthly measurements of oocyte diameters during the first reproductive cycle are presented in Fig. 1 Maturation of females of both stocks was similar under the two photoperiod regimes (Fig. 1; ANOVA, $P > 0.05$). However, there is a significant difference in mean oocyte diameters between Canadian and Norwegian wolffish prior to spawning (Fig. 1; ANOVA, $P < 0.05$). A large proportion of oocytes from Norwegian females were atretic - 53.7%, much higher than the rate of 8.7 % observed with oocytes from the Canadian stock.

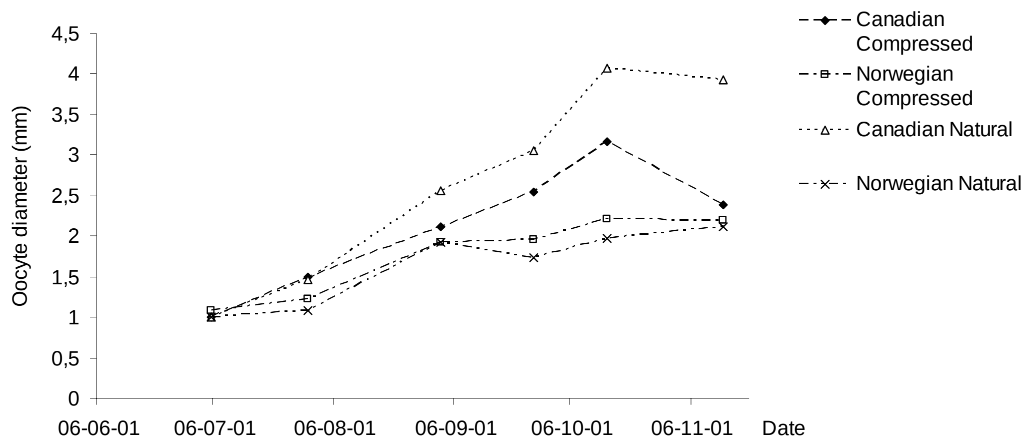

Figure 1. Mean oocyte diameters in Norwegian and Canadian female wolffish during the first spawning cycle under natural and accelerated photoperiod regimes.

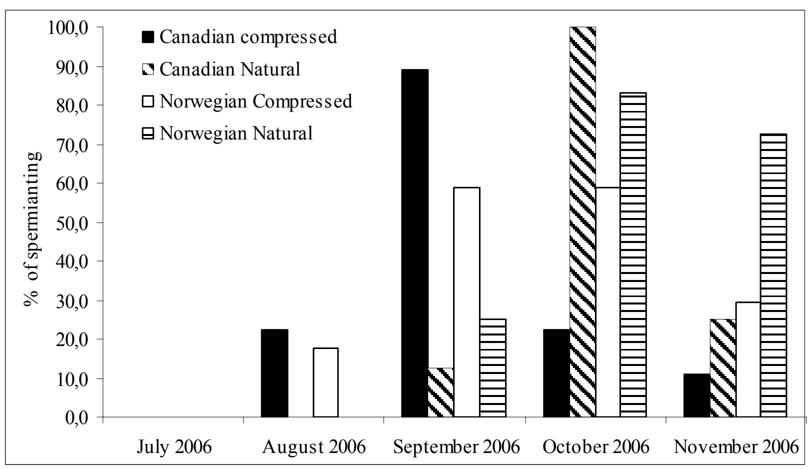

Figure 2. Proportions (%) of spermiating Norwegian and Canadian male wolffish during the first spawning cycle under natural and accelerated photoperiod regimes.

Other studies have indicated that constant or compressed photoperiod regimes can induce oocyte degeneration or atresia, at least during the first reproductive cycle (trout *Oncorhynchus mykiss*[14]; sea bass *Dicentrachus labrax*[8]). A high proportion of atresia can also be traced to degenerative follicles from a previous sexual cycle[15]. However, these fish were virgin females (F1 generation) and had shown no apparent indications of precocious maturation in previous years. Atresia in fish is also generally attributed to sub-optimal conditions, such as temperatures, nutritional deprivation[15], stress, genetic. Food is not a contributing factor as these fish were fed to satiation with a proven marine feed. Norwegian studies suggest an optimal breeding temperature of 4 - 6°C for spotted wolffish[13, 16] while the breeding temperature in this study is 7.5 - 8.0°C because we were not expecting them to reproduce in the fall of 2006. The fishes derive from a stock maintained at this temperature since June 2005. The superior performance of the Canadian females (less atresia) may be due to some genetic effect (for example: different level of inbreeding, better adaptation to higher temperature, etc.).

The proportions of males spermiating in each month of the study are presented in Fig. 2. At this point of the study, the accelerated photoperiod appears to affect the maturation of males to a greater degree than females (Fig 1 compared to Fig 2). Males of both Norwegian and Canadian stocks under the accelerated photoperiod regime produce sperm approximately one month before the corresponding natural photoperiod group. The greatest percentage of spermiating males in the accelerated photoperiod occurs in September, compared to October in the natural photoperiod group.

In contrast, the maturation of females was not influenced by the accelerated photoperiod at this first spawning (Fig 1 compared to Fig 2). It is possible that the females under the accelerated regime will mature earlier for the second spawning. Norberg et al. (2004) studied the effects of natural and accelerated photoperiodism on the sexual maturation of cod (*Gadus morhua*). They found that females kept in the accelerated photoperiod matured earlier, yet this was only evident during the second spawning cycle.

In conclusion, these preliminary results indicate a shift in the maturation of male wolffish under the accelerated photoperiod, while females appear less affected (delayed response?). This study is ongoing and these results may be confirmed in succeeding reproductive cycles. In addition, data on somatic growth and plasma samples for measurements of sex steroids and vitellogenin continues to be collected every month. The complete study will provide a profile of the maturation of spotted wolffish under accelerated and natural photoperiod regimes, as well as effects of these conditions on growth and reproductive success.

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References

1. Grontvedt RN, Lund V, Espelid S. 2004.A typical furunculosis in spotted wolffish (*Anarhichas minor* O.) juveniles: bath vaccination and challenge. *Aquaculture* 232: 69-80.
2. Le François NR, Lemieux H, Blier PU. 2002. Biological and technical evaluation of the potential of marine and anadromous fish species for cold-water mariculture. *Aquaculture Research* 33: 95-108.
3. Imsland AK, Foss A, Sparboe LO, Sigurdsson S. 2006. The effect of temperature and fish size on growth and feed efficiency ratio of juvenile spotted wolffish *Anarhichas minor. Journal of Fish Biology* 68: 1107-1122.
4. Hansen T, Falk-Petersen I-B. 2002. Growth and survival of first-feeding spotted wolffish (*Anarhichas mino*r Olafsen) at various temperature regimes. *Aquaculture Research* 33:1119-1127.
5. Moksness E, Kjørsvik E, Olsen K. 2004. *Culture of Cold-water Marine Fish*. Blackwell Scientific Publications Ltd, UK.
6. Bromage NR 1995. Broodstock management and seed quality-general considerations. In: *Broodstock Management and Egg and Larval Quality (*NR Bromage, RJ Roberts eds.) Oxford: Blackwell Science 1-24.
7. Bjornsson BT, Halldorsson O, Haux C, Norberg B, Brown CL. 1998. Photoperiod controlof sexual maturation of the Atlantic halibut (*Hippoglossus hippoglossus*): plasma thyroid hormone and calcium levels. *Aquaculture* 166: 117-140.
8. Prat F, Zanuy S, Bromage N, Carrillo M. 1999. Effects of constant short and long photoperiod regimes on the spawning performance and sex

steroid levels of female and male sea bass. *Journal of Fish Biology* 54: 125-137.

9. Bromage N, Porter M, Randall C. 2001. The environmental regulation of maturation in farmed finfish with special reference to the role of photoperiod and melatonin. *Aquaculture* 197:63-98.
10. Idler DR, Ng TB. 1983. Teleost gonadotropins: isolation, biochemistry and function. In: *Fish Physiology* (WS Hoar, DJ Randall, EM Donaldson eds.). Academic Press, New York, 187-221.
11. Bromage N, Randall C, Duston J, Thrush M, Jones J. 1993. Environmental control of reproduction in salmonids. In *Recent Advancesin Aquaculture IV* (JF Muir, RJ Roberts Eds). Oxford: Blackwell. 55-66.
12. Norberg B, Brown CL, Halldorsson A, Stensland K, Bjornsson BT. 2004. Photoperiod regulates the timing of sexual maturation, spawning, sex steroid and thyroid hormone profiles in the Atlantic cod (*Gadus morhua*). *Aquaculture* 229: 451-467.
13. Foss A, Imsland AK, Falk-Petersen IB, Oiestad V. 2004. A review of the culture potential of spotted wolffish *Anarhichas minor* Olafsen. *Reviews in Fish Biology and Fisheries* 14: 277-294.
14. Blythe WG, Helfrich LA, Sullivan GV. 1994. Sex steroid Hormone and Vitellogenin Level in Striped Bass (*Morone saxatilis*) Maturing under 6-, 9- and 12-Month photothermal Cycles. *General and Comparative Endocrinology* 94: 122-134.
15. Tyler CR, Sumpter JP. 1996. Oocyte growth and development in teleosts. *Reviews in Fish Biology and Fisheries,* 6:287-318.
16. Falk-Petersen I-B, Hansen TK. 2003. Early ontogeny of the spotted wolffish (*Anarhichas minor* Olafsen). *Aquaculture Research* 34:1059-1067.

Pathological Health Survey of Bivalves from Experimental and Farming Sites

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Abstract

Shellfish culture is in effervescence in the Province of Quebec. Technological innovations enable the increase of production volumes and help to sustain the constantly growing demand. Some techniques like spat transfers also permit to improve the performance of culture farms. These transfers must be safely executed in order to avoid disease propagation that could strongly affect the production. Thus, a histological health survey has been conducted in 2004 and 2005 on different culture and experimental marine shellfish sites in order to establish a data base essential to accurately differentiate primary pathogens from opportunistic ones taking advantage of sub-optimal culture conditions. This data base also includes all the results of health reports realized since 1999. The targeted species were blue mussels, *Mytilus edulis*, softshell clams, *Mya arenaria*, giant scallops, *Placopecten magellanicus* and Iceland scallops, *Chlamys islandicus*. Histological examination revealed the presence of largely observed organisms such as gills, digestive gland and intestine ciliates, digenean metacercarian cysts, *Rickettsia*-like organisms and copepods. Pathology or pathogen observed such as *Prosorhynchus squamatus* and haemic neoplasia are disease concern in Atlantic Canada and require a stronger monitoring.

Introduction

In the past several years, we have seen a diversification in the shellfish species cultivated in the province of Quebec from which we now find mussels, scallops and soon softshell clams farming. Techniques such as transfers from one site to another assure a continual supply of seed quality. It has been established that there is a direct relationship between the performance and the survival rate of a stock and their genetic characteristics (Dickie et al. 1984; Mallet and Carver 1989; Tremblay et al. 1998). Thus the transfers will increase the productivity of the farms by providing a good stock supply while benefiting of ideal environmental conditions. DFO (Department of Fisheries and Ocean) now requires a health diagnostic before each stock transfer to limit the risk of disease propagation. Histopathological analyses are also performed to clarify certain reproductive difficulties, abnormal growth and mortalities. Summer mortalities of blue mussels have been observed in Magdalene Islands.

The health analysis have established that these mortalities were not associated with the presence of a pathogen, but were due to ecophysiological problems during breading season (Myrand et al. 2002). The need of stock transfer explains partially the increase in the demand of health diagnosis observed within the past 3 years.

Fortunately to this day, there has been no mass mortality associated with diseases or pathogens in the marine regions of the province of Quebec, but vigilance is the key word in safe and low risk transfers and farming. In 2002, a disease called MSX (Multinucleated Sphere X) appeared in the American oyster populations (*C. virginica*) of Cap Breton, Nova-Scotia. The disease was first observed in Delaware Bay in 1957 (Ford and Tripp 1996), and spread to oyster populations in Chesapeake Bay in 1959. Since that time, outbreaks have occurred in Long Island Sound and along the coast of Maine (Sunila, Karolus et al. 1999). The 2002 Bras d'Or Lakes Region outbreak was the first incidence of MSX in Canadian waters (ICES 2004). Furthermore, our southern neighbours from PEI are confronted with a disease affecting softshell clams called heamic neoplasia. Heamic neoplasia, also known as shellfish leukemia, is responsible for severe losses since 1999 in this region (McGladdery and Davidson 2003).

It is essential to have a good knowledge of the diseases and pathogens that are present in the shellfish populations of the maritime regions of Quebec and limit the risk of an infectious outbreak. That is why the main objective of this study is to evaluate the prevalence and intensity of pathological agents present in the shellfish populations at commercial and experimental sites and also evaluate their seasonal and spatial variations. Since mussels are the most abundant species and the most exploited ones in our province, we also do health evaluations on the wild mussel populations of many sites in the maritime regions of Quebec. A survey will be realized at the end of the project on the further needs of the industries concerning juvenile supplying and exportation, in order to help in targeting the needs of health reports.

Methodology

The sampling regrouped all the commercial bivalve farming sites of the province of Quebec as well as the experimental sites. We also collected wild mussels from 10 sites. We sampled in four regions, Magdalene Islands, Gaspésie, North Shore of the Gulf of St-Lawrence and Bas St-Laurent. In Magdalene Islands we collected mussels and softshell clams from an commercial site in the lagoon of Havre-aux-Maisons. We also sampled wild mussels from the same site and scallops from an industry. In the Gaspésie we collected farmed mussels from Carleton and Gaspé, as well as wild populations in the surrounding area. Wild mussels were collected from sites in New-Richmond, Port-Daniel, Penouille and Barachois de Malbaie. Softshell clams were sampled at two experimental site, in Barachois de Malbaie and Métis. Samples of giant scallops were collected in the Baie de Jacques-Cartier and Iceland scallops in Mingan. We also collected softshell clams from experimental 2004 and 2005 to evaluate the potential temporal development of pathogens and seasonal cycles. At each site, 60 organisms bigger than 25 mm length were collected, which is the minimum number required to detect diseases that are present at a 5% prevalence (Oie 2003). Samples were delivered within 24h after being collected to the CAMGR laboratory in Grande-Rivière. Prior to the fixation, the organisms were measured and the shell and the soft tissues were grossly observed to detect any apparent abnormalities. The tissues were treated following the method suggested by McGladdery (1991). A 5 mm thick transversal tissue section was fixed for 24 to 48 hours in a 10% formaldehyde solution. The tissues were than dehydrated in successive alcohol baths with a tissue processor and embedded in wax. Slides were built from 5µm wax-tissue sections and automatically stained according to a hematoxylin and eosin regressive coloration.

For each specimen, we noted the sex, the sexual maturity level, the digestive gland content, non specific responses such as metaplasia, neoplasia, heamocyte cells infiltration, concretions, tissue necrosis which were all evaluated according to qualitative scales. We also noted the presence of all parasites and pathogens. Prevalence and intensity were calculated and integrated in a data base that also included the results from health reports realized since 1999.

Results

Mussels

Many parasites were observed in wild and cultured mussel populations. The gill ciliate *Ancistrum mytily* was observed in all sites almost every year since 1999 with prevalences reaching until 73,3% in wild mussels from Gaspé. The abundance was variable between sites but higher in the wild populations than cultured ones. For the *Sphenophrya* species (gill ciliates) the tendency was the same but in lower prevalence. Ciliates were also seen in the intestine and the digestive gland (MPX). Mussels *Protozoean* X ciliates were sometimes present in intensity higher than 1000/tissue section without causing any damage. *Rickettsia*-like organisms were omnipresent in all the sites without showing any specific occurrence pattern. Other parasites like trematodes, copepods and turbellarian were observed in very low prevalence causing local heamocyte infiltration. We noted the presence (less than 5,2% of the population affected) of heamic neoplasia in wild mussel populations from Gaspé every year since 2003. The disease was also observed in cultivated mussels from the same site in 2003. *Prosorhynchus squamatus* infected cultivated mussels from Carleton (8,4% of prevalence) and Blanc-Sablon (1,7% prevalence) in spring 2004.

Softshell Clams

Gill ciliates were the most abundant parasite observed in softshell clams of all sites. In Magdalene Islands, the prevalences were higher in autumn than spring. Trematods, intestine ciliates, turbellarians and copepods were present in low prevalence (usually less than 10%) and intensity (1 or 2 per tissue section). RLO's occurred more often in gill cells and digestive gland tubules, with prevalences higher than 25% without causing any host response. Heamic neoplasia was observed in low prevalence (1,7%) in softshell clam populations from St-Georges de Malbaie, sampled in spring and autumn 2005.

Scallops

Only few parasites were observed in the scallop samples. The most abundant was *Rickettsia*-like organisms infecting gill, digestive gland and kidney cells. We observed high intensity of infection with average reaching 50,7 (spring 2002) and 48,8 (autumn 2003) colonies per tissue section. The gill ciliates *Trichodinids* were present in low prevalence (<3%) and only in spring.

Discussion

Prior to this study, there was no data base existing that gave an overview of the health condition of shellfish populations in the maritime regions of the Quebec province. The development of the shellfish industry and the coinciding growing demands for introductions and transfers increase the risk of disease and pathogen propagation when transfers are uncontrolled. Accessibility to this information provides an essential tool to avoid the introduction of undesirable pathogens.

Most of the infectious agents observed in this study are classified in the category 4 of the scale defined by Bower and McGladdery (2003). This category regroups all the agents of infectious diseases which have negligible or questionable significance in Canada because they cause no significant pathology or the pathological condition is related to husbandry. Gill ciliates were observed in each species of shellfish (mussel, softshell clam, scallop) and are considerate as non pathogenic. These gill protozoan are found around the world in wild and cultured shellfish populations with prevalence can often reach 100% in mussel population (Figueras 1991; McGladdery and Stephenson 1991; Bower et al. 1994). Gill ciliates are usually lightly attached to the epithelial cells of the gills and cause no host response (Laruelle et al. 1999).

Rickettsia-like organisms (RLO) are also common parasites present in many shellfish populations. These gram negative bacteria colonies (Gulka 1983; Elston 1984) can be pathogenic for some species and totally inoffensive for others. In Canada, these "blue bodies" are classified category 4 (Bower and McGladerry 2003) and cause no damage to the host even in high prevalence.

However, heavy infection observed in cultured clams *Hippopus hippopus* has lead to gill cells inflammation in the Philippine (Norton et al. 1993). Gulka (1984) also noted mass mortalities associated with RLO in scallop populations in Maine.

The other parasites observed such as metacercariens, copepods and turbellarians are classified categogy 4 in Canada (Bower and McGladerry 2003). They usually have a low pathogenicity and stimulate focal haemocytic infiltration but are rarely associated with extensive tissue damage. However, the sporocyst larval stage of digeneans can induce more significant pathology. For example, *Prosorhynchus squamatus* causes the castration of the mussel by undamaging severely the reproductive tissues.

The bucephalid trematode is classified in category 2 which regroups the infectious agents that have a limited geographic distribution within Canada and because these diseases can have serious impact on shellfish health, we must prevent them from spreading to regions or provinces where they are not known to occur (Bower and McGladerry 2003). The pathogen is responsible for notable losses in Nova Scotia mussel farms. Besides the fact that the mussels have almost no developed gonads, they are weakened and consequently the product losses value at the time of transportation and commercialisation (Bower and Figueras 1989; McGladdery et al. 1999).

P. squamatus was not present in high prevalence but we observed it in mussels aquaculture facilities. We also observed haemic neoplasia in wild mussel and softshell clam populations which is also a category 2 disease (Bower and McGladerry 2003). The symptoms are mostly the same for mussels and softshell clams. The disease leads to distortion and disfunction of haemic cells (Elston et al. 1988; St-Jean et al. 2005). Mortalities have been associated with this disease in many softshell clam populations in PEI (McGladdery et al. 2001). To this date, the causes remain unidentified. Many hypothesis take in consideration the chemical pollution as a possible causal agent (Elston et al. 1992; O'Connor 2002). Transfer and importation can be restricted by the presence of such disease (category 2).

Conclusion

Most of the diseases observed in this study are not harmful for the shellfish populations but we have to take in consideration that diseases such as haemic neoplasia and *P. squamatus* are present in the water of the marine regions of the Quebec province. Their impact under high density farming conditions could cause the proliferation of the diseases and have disastrous consequences. Regulated and certified transfers and the monitoring of exploited zones are necessary to reduce the risk of accidental introductions of undesirable pathogenic agents.

References

1. Bower SM, Figueras AJ. 1989. Infectious diseases of mussels, especially pertaining to mussel transplantation. *World Aquaculture* 20(4): 89-93.
2. Bower SM, McGladdery SE et al. 1994. Synopsis of infectious diseases and parasites of commercially exploited shellfish. *Annual Review of Fish Diseases* 4: 1-199.
3. Bower SM, McGladdery SE. 2003. Synopsis of infectious diseases and parasites of commercially exploited shellfish.
4. Dickie LM, Boudreau PR et al. 1984. Influences of stock and site on growth and mortality in the blue mussel (*Mytilus edulis*). *Can. J. Fish. Aquat. Sci.* 41: 134-140.
5. Elston RA. 1984. Prevention and management of infectious diseases in entensive mollusc husbandry. *J. World. Maricul. Soc.* 15: 284-300.
6. Elston RA et al. 1988. Progression, lethality and remission of hemic neoplasia in the bay mussel, Mytilus edulis. *Dis Aquat Org* 4: 135-142.
7. Elston RA, Moore JD et al. 1992. "Disseminated neoplasia of bivalve molluscs." *Reviews in Aquatic Sciences* 6: 405-466.
8. Figueras AJ, Jardon CF, Caldas JR. 1991. Diseases and parasite of rafted mussels (*Mytilus galloprovincialis* Lmk:) preliminary results. *Aquaculture* 99: 17-33.
9. Ford SE, Tripp MR. 1996. Diseases and defense mechanisms. In *The Eastern Oyster Crassostrea virginica*. V. S. K. Ed. by R.I.E.

Newell, and A.F. Eble. Maryland Sea Grant College, College Park, MD.
10. Gulka G, Chang PW. 1984. Host response to rickettsial infection in blue mussel, *Mytilus edulis* L. *Journal of Fish Diseases* 8: 319-323.
11. Gulka G., Chang PW, Marti KA. 1983. Prokaryotic infection associated with a mass mortlity of the sea scallop, *Placopecten magellanicus*. *J. Fish Diseases* 6: 355-364.
12. ICES 2004. *Trends in important affecting fish and molluscs in the ICES area 1998-2002*. E. b. t. W. G. o. P. a. D. o. M. Organisms. Copenhagen, Denmark**:** 26 pp.
13. Laruelle F, Molloy DP et al. 1999. Histological analysis of mantle-cavity ciliates in Dreissena polymorpha: their location, symbiotic relationship, and distinguishing morphological characteristics. *J. Shellfish Res.* 18(1): 251-257.
14. Mallet AL, Carver CEA. 1989. Growth, mortality, and secondary production in natural populations of the blue mussel, Mytilus edulis. *Can. J. Fish. Aquat. Sci.* 46: 1154-1159.
15. McGladdery SE, Davidson TJ. 2003. Factors, Risks and Significance of Emergent Neoplasia in Cultured and Wild Soft-Shell Clams (Mya arenaria) in Atlantic Canada. *AQUANET Report AP*-18**:** 40.
16. McGladdery SE, SMF et al. 1999. Prosorhynchus squamatus (Digenea: Platyhelminthes) infection of blue mussels, Mytilus edulis, in Atlantic Canada. *J. Shellfish Res.* 18: 297.
17. McGladdery SE, Reinisch CL, et al. 2001. Haemic neoplasia in Soft-Shell Clam (*Mya arenaria*): Recent outbreaks in Atlantic Canada and Discovery of p53 Gene Homologue Associated with the condition. *Bull. Aquacul. Assoc. Canada* 101(3): 19-26.
18. McGladdery SE, Stephenson MF. 1991. Parasites and Diseases of suspension- and bottom-growth shellfish from Eastern Canada. *Bull. Aquacul. Assoc. Canada* 91(3): 64-66.
19. Myrand B, Tremblay R, Sévigny JM. 2002. Selection against blue mussels (*Mytilus edulis* L.) homozygotes under various stressful conditions. *J. Hered.* 93, 238-248.
20. Norton JH, Shepherd MA, et al. 1993. Mortalities in the Giant Clam Hippopus hippopus associated with Rickettsiales-like organisms. *J. Invert. Path.* 62: 207-209.
21. O'Connor TP. 2002. National distribution of chemical concentrations in mussels and oysters in USA." *Marine Environmental Research* 53: 117-143.
22. Oie 2003. *Manual of Diagnostic Tests for Aquatic Animals.* http://www.oie.int/eng/normes/fmanual/A_summry.htm.
23. St-Jean SD, Stephens RE et al. 2005. Detecting p53 family proteins in haemocytic leukemia cells of Mytilus edulis from Pictou Harbour, Nova Scotia, Canada. *Can. J. Fish. Aqua. Sci.* 62: 2055-2066.
24. Sunila I, Karolus J et al. 1999. A new epizootic of *Haplosporidium nelsoni* (MSX), a haplosporidian oyster parasite, in Long Island,Connecticut." *J. Shellfish Res.* 18(1): 169-174.
25. Tremblay R, Myrand B et al. 1998. Bioenergetic and genetic parameters in relation to susceptibility of blue mussels, Mytilus edulis (L.) to summer mortality. *J. Exp. Mar. Biol. Ecol.* 221(1): 27-58.

Prospective Analysis of Aquaculture Development: A Delphi Approach

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Abstract

Recognizing the increasing contribution of aquaculture to food security, livelihoods and economies worldwide, as well as the potential challenges to further development of the sector, the FAO of the UN undertook a prospective analysis, the objectives of which were to: (1) determine and analyse important policies which could affect aquaculture development regionally and globally and; (2) determine priority areas for action in aquaculture (regionally and globally). It was decided to adopt the "Delphi method" because of its advantages; amongst which: anonymity – thus avoiding the limitations of group decision-making, expert inputs; and iteration with controlled feedback. Initially 305 questionnaires were sent out via mail to experts in different regions. This paper presents some of the Delphi results, with particular attention to North America.

Introduction

The expansion of aquaculture output is forecast to continue because while demand for food fish is increasing due to population growth, consumer preferences, higher incomes and urbanisation; the supply of fish food from the capture fisheries is expected to grow slowly, if at all (Delgado, et. al, 2003). The result will be higher relative prices for fish which while dampening demand for fish will also stimulate investment into aquaculture. Forecasts suggest that output of farmed food fish by 2030 could triple the 2004 global total of 45.5 million tonnes (Brugere and Ridler, 2005).

This forecast expansion of aquaculture raises a number of concerns, in particular whether government policies can overcome constraints and challenges. Experts within regions may offer the best insights and even mitigating policies. The FAO therefore undertook a Delphi survey asking experts to explore aquaculture constraints and opportunities in six regions. This paper briefly presents some results for the North American region.

Materials and Methods

The Delphi technique is an adaptive iterative survey method. It offers a number of advantages; during later rounds of the process questions can be formulated based on replies; this enables all experts to explore issues they may never have considered before. Secondly it is anonymous which avoids the limitations of group-decision making such as deference to seniors or a dominating expert. Thirdly it is relatively cheap and efficient saving expense and time on face-to face meetings.
In 2005 305 experts were identified by FAO staff in seven regions of the world; however because of the low number of replies coming from the Near East this region was omitted from further rounds. From experts in the remaining six regions (Africa, Asia/Pacific, Latin America, North America, East Europe and Western Europe), the initial round asked whether aquaculture should be encouraged in their region and if so, why. Experts from all regions but Africa were also asked what factors had contributed to the positive development of aquaculture in their region in the past, what were the negative constraints and which were expected

to worsen over the next fifteen years (until 2020). The first round for Africa was different because of the slow and erratic development of aquaculture there. Hence experts were initially asked what factors had negatively affected aquaculture in Africa and whether these factors would become more acute over time. The question was posed to expose challenges in the region that should be addressed by policy-makers as a priority. Table 1 summarizes what North American experts think are the major challenges within their region.

In the second round experts were asked to comment on the first-round results from within the region, to rank the factors that had been suggested as positive factors and also the constraints. They were also asked to suggest mitigating policies to constraints and potential unexplored opportunities.

In the third round these were again ranked according to their perceived importance by the experts. Mitigating policies were also ranked for their practicality, as were the opportunities identified in the second round. Table 2 summarizes the most important.

Table 1. Delphi Results of Major Constraints in North America.

CHALLENGES	**Africa**	**Asia/Pac**	**Latin America**	**North America**	**Eastern Europe**	**Western Europe**
Few supporting policies	1	1	1	1	1	1
Lack of capital	1	1	1	1		1
Technology	1	1	1	1		1
Access to sites	1	1		1	1	1
Negative perceptions	1	1	1	1		1
Environmental management		1	1	1	1	1
Cost/price volatility		1		1	1	1

Table 2. Summary of Major Corrective Measures Suggested for North America.

Challenge	**Corrective Measures**	**Other Regions**
Capital	Assist producers with good business plans	Africa/ Asia
	Promote producers' co-operatives	Africa/ Asia
	Improve image with lenders	Africa
Site Access	Zoning	Asia
	Updates on availability of sites	East. Europe
Negative Perceptions	Positive media campaign	Asia, Western Europe
	Promote science-based debates	Asia
	Better communication with media	Asia
	Develop proper regulations for sustainable aquaculture	Latin America
	Regulations/ sanctions to reduce environmental impact	Western Europe

Results

As Table 1 indicates the experts thought that aquaculture globally lacked government policy support. This was ranked the primary problem in Africa but in North America the most important constraint to aquaculture development in the past was judged to be access to financing. The mitigating policies which would have a "very large positive impact" were providing aquaculture the same insurance guarantees as agriculture, and improving the image of the industry particularly in the financial sector. Other positive impacts would come from extending lease periods and reducing the regulatory burden, and providing fiscal incentives.

A constraint which was expected to have a "very detrimental impact" on aquaculture development in the region over the next fifteen years is public opposition to aquaculture. This opposition might appear as negative media reports or a general negative perception by the public. The opposition could be focused in certain interest groups such as the fishing industry, or cottagers. Linked to this was the second major impediment; an increasing residential population near (potential) aquaculture sites. Increasing spatial constraints "are almost certain to happen". There was concern that politicians would react to vocal opposition. Experts in Asia and Western Europe also saw negative media publicity and public perceptions as a growing threat to the industry.

Experts were asked for their ideas on aquaculture development in North America. The experts saw "very large positive" impacts from land-based aquaculture, diversification into new species, value-added processing and polyculture. There was no consensus on off-shore aquaculture. For some there were concerns about environmental and social implications, whereas for others offshore aquaculture was seen as a means of negating aesthetic opposition from cottagers, and of providing more space. From the policy perspective very large benefits would flow from simplifying regulations, giving aquaculture a higher priority in government bureaucracies, providing farmers access to financing and investing in innovations.

Conclusion

Experts in North America thought that aquaculture should be encouraged primarily because it increased food supply but also because it enhanced ecosystem sustainability. Other reasons, although less important, included economic development and supporting the viability of rural communities. In the past financing was the principal challenge but more important in the future is likely to be the public's attitude towards aquaculture. The experts suggested some opportunities such as land-based aquaculture, multi-trophic aquaculture and species diversification. Off-shore aquaculture was advocated by some.

References

1. Brugere C, Ridler N. 2004. Global aquaculture outlook in the next decades: An analysis of national aquaculture production F\forecasts to 2030. *Fisheries Circular* No 1001 FAO Rome
2. Delagaldo C, Wada N, Rosegrant M, Meijer S, Ahmed M. 2003. *Fish to 2020: Supply and Demand in Changing Markets.* International Food Policy Research Institute, Washington, DC and WorldFish Center, Penang.
3. FAO 2005. Regional review on aquaculture development 7. North America-2005. *Fisheries Circular* No 1017/7. FAO: Rome.

Enhancing Sustainability of Salmon Culture in Canada: A Socio-economic Analysis of Multi-trophic Aquaculture (IMTA)

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Abstract

Integrated multi-trophic aquaculture (IMTA) is one approach to mitigate ecological effects of finfish monoculture, and its benefits are prompting increased interest among researchers and commercial growers worldwide. This paper examines the socio-economics of one IMTA enterprise that integrates salmon, mussel and seaweed on the same site in the Bay of Fundy in eastern Canada. By using the waste of one crop as feed for another, results suggest that IMTA increases revenues from sales of additional species, and also reduces risk through diversification. Linked to this ecological remediation is the positive perception towards IMTA by the public, which should assist applicants for site licences and reduce litigation and lobbying by aquaculture opponents.

Introduction

Expansion of farmed Atlantic salmon (*Salmo salar*) has been rapid with output exceeding 1.2 million tonnes, worth more than four billion US dollars in 2004, and with expansion forecast to continue (Brugere and Ridler, 2005). For independent farmers in a market that has become global and concentrated, and in locations where there is public participation in policy-making, survival requires acquiring some competitive advantage while maintaining public support. Social acceptability is a pre-requisite for sustainability: positive perceptions towards the industry are critical. Therefore independent farms are under pressure to improve their economic performance, while also enhancing the image of their industry.

This paper examines one option available to farmers; that of growing different species on the same site, a practice known as integrated multi-trophic aquaculture (IMTA). A pilot project in the Bay of Fundy, Atlantic Canada, is growing seaweed (*Laminaria saccharina* and *Alaria esculenta*), mussels (*Mytilus edulis*) and Atlantic salmon together. Results have been positive. The project has demonstrated the biological and technical feasibility of combining mussels and seaweeds on salmon sites (Chopin et al., 2004).

Using data from the project this paper indicates why IMTA might be an attractive strategic choice for salmon farmers, not only in Canada, but world-wide. Three reasons are suggested: 1) IMTA can increase profitability; 2) risk is reduced because of diversification; and 3) IMTA appears to reduce public opposition to finfish mariculture.

Materials and Methods

To determine the potential profitability of IMTA a capital budgeting model was designed using technical data for the Bay of Fundy to determine economic returns of a salmon farm that was practicing monoculture. The model assumed that a start-up salmon farmer buys half a million smolt, as well as incur fixed costs. It then estimated costs and revenues generated from operating mussel and seaweed farming, in conjunction with salmon farming. Net Present Values were estimated with all three species for a 10 year period at discount rates of 5% and 10%.

Since there is the risk of disease and wind chill, it was imperative that a risk factor be added. Three IMTA scenarios were run, and each scenario was given a probability of occurrence. The best scenario, Scenario 1, has salmon coming to harvest every second year, with a mortality rate of 11%. This would give a total of five successful harvests in the ten year span with a probability of occurrence of 20%. The worst scenario was Scenario 2. It followed the same rules as the first, except it had only four successful harvests, because in one harvest all fish were assumed destroyed. This scenario was assigned a 40% probability. Finally, Scenario 3 was intermediate between the first and second. It had four successful harvests and one harvest in which only 30% of the fish survived. This final scenario was also given a weighting of 40%.

Not only must IMTA be profitable and not too risky but there must also be social acceptance. Two attitudinal studies towards salmon farming in general, and IMTA in particular, were conducted in New Brunswick. The first was in 2003 when a random survey of 165 participants was conducted in Charlotte County (total 2001 population of 27,366) (Robinson, et. al., 2004). The response rate for the general public group (*N*=110) was 11.4 percent, and 53 respondents were from the 15 professional organizations and companies. Two respondents from environmental organizations were also invited to participate. A second attitudinal study towards IMTA was conducted in 2005 using focus groups (Barrington et al., 2005). The individuals who participated in this study were of mixed gender, ranging in age from 20 to 70 years old. Five focus groups were conducted in 2005, with a total of 23 participants.

Results

As Table 1 indicates, additional revenues from mussels and seaweeds more than compensate for additional costs with a resulting higher NPV for IMTA than salmon monoculture. The increase in NPV is significant at 9.3%. As one would expect with diversification, IMTA results in higher NPV in all three scenarios of risk. Mussel and seaweed provide alternative uncorrelated sources of income, thereby softening the damaging effect of salmon losses. Just one bad harvest, in which all the fish must be destroyed, or have been killed by uncontrollable events, causes the NPV to approach zero on the entire 10 year run of a monoculture salmon farm , whereas with IMTA the NPV remains positive.

Table 1. Salmon Monoculture and IMTA Scenarios - 10 Year Run
NPV Discounted at 5%. (in Canadian Dollars).

Operation	**Items**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Salmon Monoculture	NPV at 5%	8,961,125	55,933	2,930,523
IMTA	NPV at 5%	9,797,078	742,038	3,625,641

In general perceptions towards IMTA are more favourable than towards salmon monoculture. This was indicated in both the survey and by the focus groups. Participants all linked success with sustainability The groups emphasized that making a profit, raising quality products and not harming the environment were key to making the aquaculture industry successful.. Participants, after watching the video, appeared sceptical or unsure if IMTA could improve disease outbreaks, replenish natural stocks, and improve food quality. However, people felt that IMTA had the potential to reduce environmental impact of salmon farming (65%), while improving waste management in aquaculture (100%), employment opportunities (91%), community economies (95%), industry competitiveness (95%), food production (100%) and sustainability of aquaculture overall (73%). They also felt that it would improve the public perception of the industry as well as a way of lowering costs.

Conclusion

To enhance sustainability that is widely defined to incorporate socioeconomic as well as ecological variables, a project in New Brunswick is assessing the potential for IMTA. The biological results are good, and while insufficient data preclude a definitive assessment of its economic impact, financial feasibility and societal attitudes also are encouraging: IMTA increases profitability and reduces risks and perceptions of the public towards salmon farming are improved. Generally, stakeholders felt that IMTA appears to be an improvement over current monoculture practices and would be cautiously welcomed in the marketplace.

Acknowledgments

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References

1. Barrington K, Ridler N, Chopin T, Robinson S, Page F, MacDonald B, Haya K. 2005. Social perceptions of integrated multi-trophic aquaculture. OMRN Conference, Ottawa.
2. Brugere C, Ridler N. 2004. Global Aquaculture Outlook in the Next Decades: an Analysis of National Aquaculture Production Forecasts to 2030. *FAO Fisheries Circular* No 1001. FAO, Rome. 47p.
3. Chopin T, Bastarache S. 2004. Mariculture in Canada: finfish, shellfish and seaweed. *World Aquaculture* 35: 37-41.
4. Robinson B, Ridler N, Chopin T, Bastarache S, Belyea E, Haya K, Sephton D, Martin JL, MacDonald B, Barrington K, Robinson S, Lander T, Martin JD, Page F, Eddy S, MacDougall J, Stewart I., Fitzgerald P, Evans F., Ugarte R, Barrow C. (In press) - The socio-economics of integrated aquaculture: a case study of the Bay of Fundy. *In: Ocean Management*. N. Catto (Ed.) OMNR.

DEPOMOD in Relation to Salmon Farming in the Southwest New Brunswick Area of the Bay of Fundy

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Abstract

This project focuses on gaining experience with the application of the DEPOMOD particle tracking and deposition model to salmon farming in the southwestern New Brunswick area of the Bay of Fundy. This Aquaculture Collaborative Research and Development Program (ACRDP) project is a collaboration with Cooke Aquaculture and is mid-way through its three-year duration. This report presents field data concerning water velocities and sediment sulphide concentrations that were collected from one fish farm. The current meter data indicated considerable spatial and temporal variation in the velocity at this site. The sediment sulphide data indicated that sulphide concentrations were elevated under the farm cage array and adjacent to the array for a distance of approximately 100 m.

Introduction

DEPOMOD is a time dependant two dimensional particle tracking and deposition model that was developed in Scotland to help estimate the spatial extent of the benthic footprint generated from wastes (excess feed pellets and fish feces) released from finfish farms (Cromey et al. 2002). The model assumes a time dependent, horizontally homogeneous water velocity, a specified sinking velocity for farm wastes and information on the spatially dependent water depth underneath and in the vicinity of a farm. Information on the temporal distribution of fish feeding and the spatial location of fish cages is used to define the initial time and location of waste release. The particle tracking algorithm estimates the location of the particles relative to the farm and notes when the particles reach the bottom. The spatial distribution of the concentration of particles on the bottom is estimated by gridding the bottom and accumulating the number of particles within each grid cell. This concentration grid can then be displayed as a contour, or some other type of map.

The DEPOMOD model is being used in British Columbia (BC), Canada to estimate the zone of potential benthic impact for fish farms as part of the regulatory approach being applied to fish farming (J. Chamberlain, pers. comm.). On the east coast of Canada the Habitat Protection and Sustainable Development Division within the Maritimes Region of Fisheries and Oceans Canada and the Aquaculture Environmental Coordinating Committee (AECC) for fish farming in the southwestern New Brunswick (SWNB) area of the Bay of Fundy are interested in evaluating DEPOMOD for its usefulness in the SWNB area.

As a result of this interest an Aquaculture Collaborative Research and Development Program (ACRDP) project was developed. One aspect of this project is aimed at examining the assumption of spatial homogeneity of the current by collecting time series of water velocities over several time periods and several locations in the vicinity of fish farms in the SWNB area. Another aspect is aimed at mapping the spatial distribution of sediment sulphide concentration in the vicinity of the farm so model outputs could be compared to the observed distribution of benthic impact as indicated by sediment sulphide.

The purpose of this communication is to describe some of the preliminary results concerning the spatial variation in water velocities and sediment sulphide concentrations around a single fish farm site in SWNB.

Materials and Methods

The study site was located in the near-shore area of the SWNB portion of the Bay of Fundy. The farm site consisted of fourteen polar circle salmon cages arranged in two rows of seven cages (Fig. 1). The circumference of each cage was approximately 100 m (diameter ~32 m).

Water Velocities

Current meters were deployed at the farm site at six locations (Fig. 1). Five of these were located around the outside of the farm at various distances from the cages. One was located inside a fish cage. At three of the moorings upward looking RDI Acoustic Doppler Current Profilers (ADCP) were deployed a few meters off the bottom. At two of the locations, InterOcean S4s (S4) were deployed and an Anderra RCM9 (RCM) was deployed at the remaining location. The latter three instruments were suspended at approximately 5 m below the sea surface and measured the currents only at the mooring depth. The ADCP-324 was deployed from 12 January to 19 April 2005; ADCP-329, ADCP-330 and RCM-23 were deployed from 13 September to 25 October 2005; and S4-156 and S4-157 were deployed from 12-24 October 2005.

Sediment Sulphide

Fifty-seven benthic grab samples were taken with a Hunter-Simpson grab at a series of locations (Fig. 2) distributed around the salmon farm. The grab samples were taken within the cage grid, at the edge of some cages and outside the cage grid at distances of approximately 25 m, 50 m and 100 m from the cages (Fig. 2). The latitude and longitude of each grab was recorded using a GPS referenced to the North American Datum (NAD) 1983. The same locations were sampled in the fall (23 September) of 2005 and the spring (24 May) of 2006 except locations 49, 50, 52 and 56 were not sampled in 2006. The 2005 samples were taken using a 0.096 m^2 grab deployed from the 12.8 m long CCGS Pandalus III and the 2006 samples were taken using a 0.024 m^2 grab deployed from the 7.3 m long Vector.

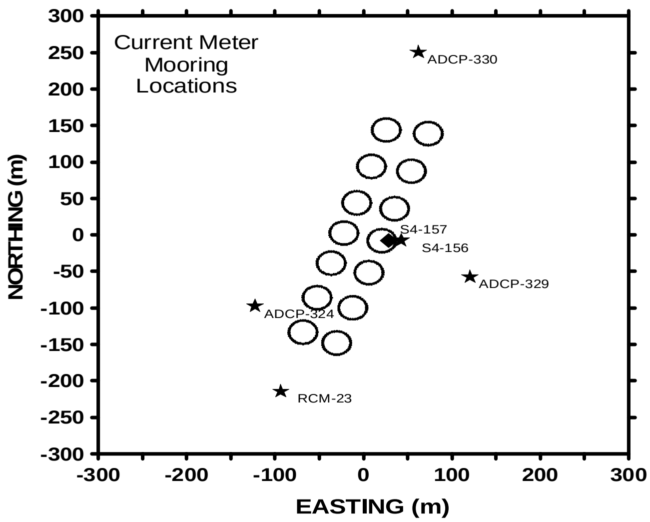

Figure 1. Schematic of the relative location of fish cages (open circles) and current meter deployments (symbols) at the farm study site referred to in the text. The labels beside each symbol indicate the type of instrument moored and the deployment code.

The sediment surface of each grab sample was sub-sampled by taking three spatially scattered 5 ml syringe samples of sediment from the top 2 cm of the sediment surface. This resulted in a total of 171 samples being collected. Sample syringes were stored on ice for transport to the laboratory where they were transferred to a refrigerator for storage until they were analyzed for sulphide content. The concentration of sediment sulphide within each 5 ml syringe sample was measured within 2 days of collection using the method described by Wildish et al. (2004). An Orion 9616B sulphide probe was connected to an Accumet meter and 4.0 M KCl was used to fill the sulphide probe. For the fall 2005 survey, eighty-seven samples were processed the day (day 1) immediately following the date of sampling (day 0) and eighty-four samples were processed on the second day after sampling (day 2). The samples were processed in non-sequential order with the caveat that at least one sample from each grab was processed on each day.

The sulphide probes were calibrated, just before use, on each day with freshly prepared $Na_2{\cdot}9S{\cdot}H_2O$ solutions at three concentrations (10, 100, 1000 µM). A comparison of results between the two days indicated no systematic difference between the days. For the spring 2006 survey, all samples were processed the day after sampling.

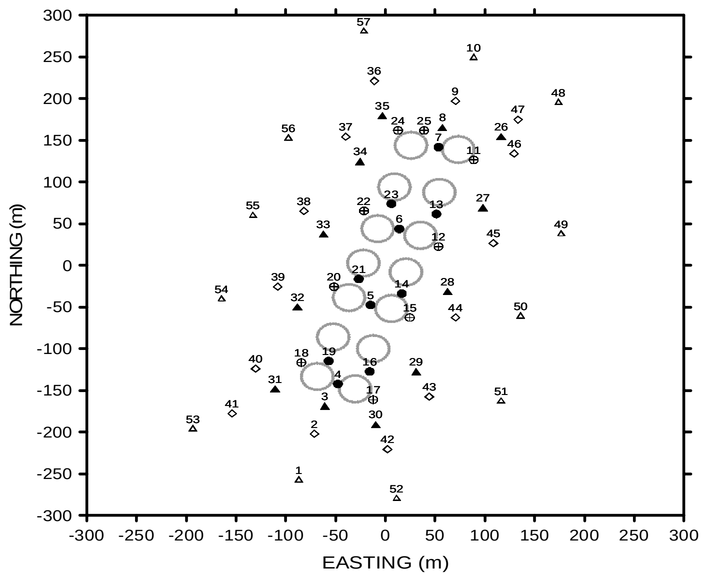

Figure 2. The relative location of grab samples taken from the study farm site referred to in the text. The open circles represent the location of the fish cages. The labels above each symbol indicate the sample station number. The symbol shape indicates the relative distance of the sample from the site (solid circle – within the cage array; open circle with internal cross – cage edge; solid triangle – approximately 25 m from a cage edge; open diamond – approximately 50 m from cage edge; open triangle – approximately 100 m from cage edge).

Data Analyses

The latitudes and longitudes of sample stations, cages and equipment moorings were transformed to Northings and Eastings in units of meters relative to the center of the sample grid. This transformation was made by assuming a spherical earth with a radius of 6,378,137 m (NAD83 equatorial radius). The sediment sulphide concentrations were normalized by subtracting the site mean concentration from each measurement and dividing each difference by the standard deviation of sulphide concentration estimated from all of the measurements.

Contouring of the log transformed normalized sulphide concentrations was done by gridding the irregularly spaced sample data onto a 10 m by 10 m grid using triangulation with linear interpolation. All gridding and contouring was done using SURFER version 8.02 (Golden Software Inc.).

Results

Water Currents

Preliminary analyses of the current meter data indicates that the radial frequency distribution of water velocity for each of the current meter deployments differs between moorings. Figure 3 shows the radial frequency distributions for the mid-water column currents at the three ADCP moorings. Although the prevailing direction of flow is toward the west in all cases, the ADCP-324 record shows a predominantly W-SW flow, the ADCP-329 record shows a predominantly W-NW flow and the ADCP-330 record shows a dominant NW flow.

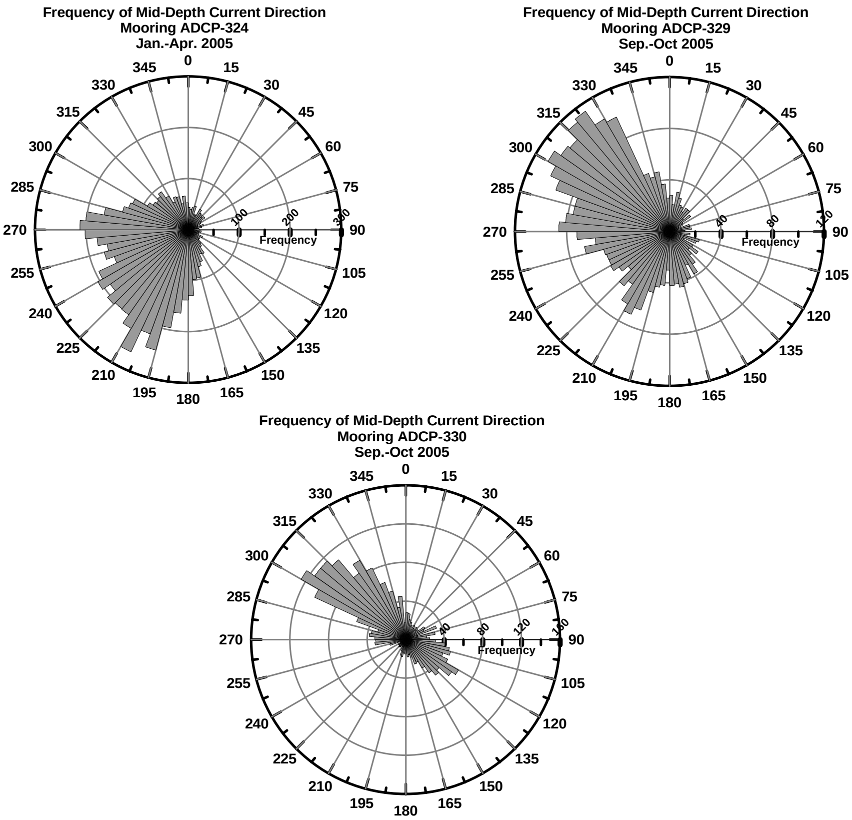

Figure 3. Radial frequency distributions of mid-depth currents at the study site as recorded by ADCP instruments.

Sediment Sulphide

The contour plots of the concentration of sediment sulphide indicate that sediment sulphides near and under the cage array were elevated relative to those distant from the cages and that the area of elevated sulphides was essentially one continuous patch (referred to below as the sulphide patch) with a few smaller and isolated patches of relatively high sulphide concentrations superimposed on it (Fig. 4). The patches of highest sulphide concentration had linear dimensions of order 10-100 m. The general sulphide patch was not symmetrically located about the center of the site; it was shifted westward by a few tens of meters relative to the location of the cage array. The shape and location of the relatively high sulphide patches changed somewhat between the fall and spring sampling periods. In the fall of 2005 a relatively large (spatially) patch of high sulphide concentration was located near and under the northwest corner of the site and a relatively small patch was located under the southern edge of the site. In the spring of 2006 two patches of relatively high sulphide were again indicated but the locations of the patches were somewhat different from the fall. In the spring a relatively large patch was located near the northwest corner of the site and a relatively small patch was located under the middle cages on the eastern side of the cage array. There was no evidence of a southern patch, as observed in the previous fall.

Discussion

As indicated in the Introduction, one purpose of our study was to examine the assumption of spatial and temporal homogeneity in the water current at a farm site. The results from the current meter deployments clearly indicate that the directional frequency of the current varies with time and space at this site. Hence, it is expected that the spatial deposition pattern generated by application of the DEPOMOD or a DEPOMOD-like model to this site will be sensitive to the velocity time series used as input to the model. Therefore, decisions based on DEPOMOD results should take into consideration this source of variability.

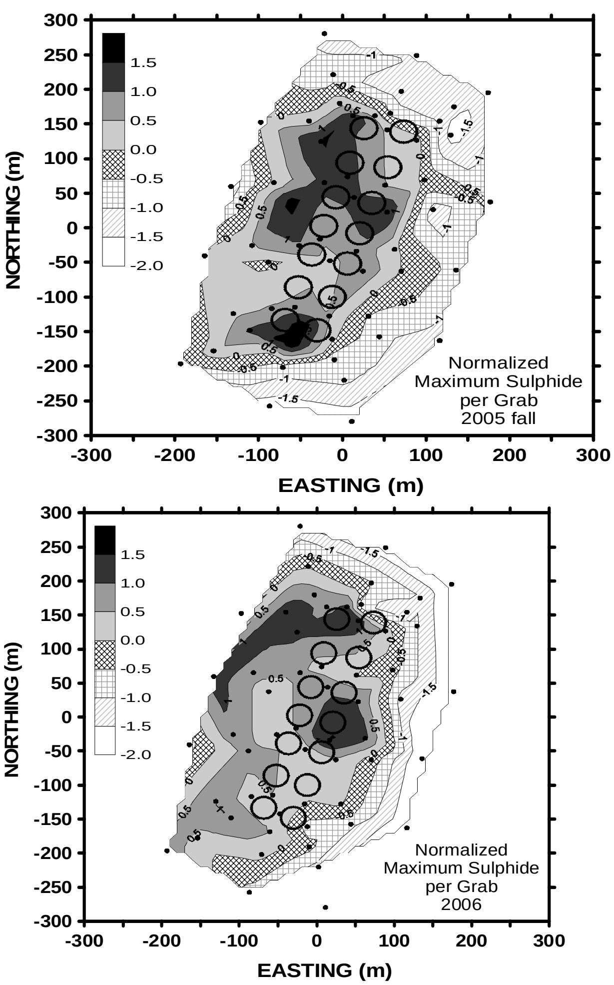

Figure 4. The spatial distribution of normalized maximum sediment sulphide concentrations for the fall 2005 and spring 2006 sampling conducted at the study site The scale bar indicates the relative concentration of sediment sulphide with the lowest concentration being at the bottom of the scale (no shading) and the highest concentration being at the top (black shading). The black dots indicate the location of the sediment sulphide samples.

Although there is variation in the details of the current meter records a simple calculation of the spatial extent of the benthic zone of influence is consistent with the findings of the sediment sulphide sampling. The simple calculation assumes the sinking rate of feed pellets is 10-15 $cm \cdot s^{-1}$ and the water depth at the farm site is 20 m. The time for fish pellets to sink to the bottom, is therefore 2 to 4 minutes. At the current velocities observed at this site (not reported here) the horizontal distance (independent of direction) feed pellets would be transported during this sinking time would be 0.01 - 89 m where the minimum (maximum) distance was estimated by multiplying the sinking time by the minimum (maximum) observed velocity at the site. This is consistent with the spatial distribution of the elevated concentrations in sediment sulphide observed within and near the farm site.

Another aspect of the study was the mapping of the spatial distribution of sediment sulphide concentration in the vicinity of the farm. We were successful in doing this using the grab sample survey approach and to our knowledge the sampling conducted at this site is one of the few times, if not the first time, a spatially intensive survey has been conducted at a farm site in SWNB. The mapping of sediment sulphide concentration suggests that the near-field zone of elevated sulphide extends approximately 100 m from the edge of the farm cage array and that within this zone there are only a few spatially limited areas or patches of relatively high sulphide concentrations.

Finally, it should be recognized that the results reported above are from one farm site only, and that similar sampling conducted at other sites is required to determine whether the general insights gained from this site can be extrapolated to other farm sites.

Acknowledgements

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References

1. Cromey CJ, Nickell TD, Black KD. 2002. DEPOMOD - modelling the deposition and biological effects of waste solids from marine cage farms. *Aquaculture* 214: 211-239.

2. Wildish DJ, Akagi HM, Hargrave BT, Strain PM (*Editors*). 2004. Inter-laboratory Calibration of Redox Potential and Total Sulphide Measurements in Interfacial Marine Sediments and the Implications for Organic Enrichment Assessment. *Can. Tech. Rep. Fish. Aquat. Sci*. 2546: iii + 25p.

Aquaculture Sustainability: Developing Concepts of a Decision Support Tool for Licensing Freshwater Cage Aquaculture in Ontario

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Abstract

Approaches to managing aquaculture's sustainability have traditionally focused on a relatively few, but important, environmental impact parameters. A broader and more contemporary concept of aquaculture sustainability has now evolved to include various other parameters considered relevant to those multiple stakeholder groups who may be affected by the industry and its practices.

Consequently, the lead licensing agency for aquaculture in Ontario initiated a project to establish new 'Harmonized Guidelines' for reviewing a cage-farm site application, in an attempt to develop a 'one-stop' application approach, and improved licensing procedures that can accommodate the needs of multi-stakeholder assessment. A formalized, Decision Support Tool (DST) was developed to incorporate these new guidelines into an objective and transparent decision-making matrix that could be used to aid in the more efficient assessment of an application for either the establishment of a new farm site, or the expansion of an existing farm. The primary objectives for the DST development included: the provision of an 'approved', 'cautionary' or 'refusal' rating system for each section criteria; an overall licensing application analysis; a clear explanation of the decision and rating criteria used; clear indications on how data provided by the applicants is to be assessed; ability to address obvious licence refusal criteria early in the application process; provide documents for each section which have been developed by a multi-agency writing team to support the decision-making rationale; enable easy changes to formulae constants and compliance values as science improves; and finally, to develop the DST tool in an easy to use software application package. Subsequently, a DST was developed that provides 'ratings' for multiple areas such as water quality, operational practices, ecosystem impacts (including species at risk, fish health/habitat/communities), sediment impacts and other user conflict criteria. Specifics for each information section and potential outcomes of the decision analysis approach developed here are detailed in this paper.

Introduction

Until recently, sustainability of the aquaculture industry was a somewhat illusory concept that traditionally was poorly defined and narrowly interpreted to encompass mainly environmental objectives. An 'ecological footprint' methodology that assessed the capacity of a natural system to supply environmental goods and services (Folke, Kautsky and Trell 1997, Tyedmers 1999, Bunting 2001) was typically central to the evaluation of aquaculture sustainability. However, sustainability, after all, implies that a profitable industry must evolve in some sort of delicate harmony within the social, environmental and economic milieu of the community in which it exists (Moccia and Hynes, 1998). This recognition has resulted in significantly more complex decision-making and strategic planning objectives that must be employed to determine the growth rate and geographical distribution of farms in any given ecosystem. Such increased complexity has lead in part, to the use of enhanced decision support systems (or expert systems) to reconcile a variety of facets involved in aquaculture management and regulation. In Ontario, Canada, licensing decisions for cage-aquaculture occur as part of a complex, laborious and time-consuming process; a process reviewed and commented upon by several government agencies and regional interest groups who often have very disparate views about what is, or is not acceptable. This has resulted in a form of 'quiet' moratorium on the issuing of new licences in the Province, and has created a somewhat disabling environment in which the aquaculture industry can manage its development.

In the last half-decade, there have been several attempts to incorporate a broader scope of social and economic measures within models of aquaculture sustainability (Burbridge, Hendrick, Roth and Rosenthal 2001, Caffey, Kazmierczak and Avault 2001, Costa-Pierce 2003, Frankic and Hershner 2003). This is an essential step to ensuring orderly growth of the aquaculture sector through a synergy of ecological sustainability objectives coupled with economic viability goals.

An expanded definition of aquaculture sustainability necessarily results in increased complexity in the decision analysis process. In most instances, it is unreasonable to expect regulators to have the expertise in all facets of multi-criteria decision making related to this relatively new agrifood industry. This complexity is compounded by the recent, rapid growth of aquaculture that has affected additional stakeholders in addition to the owner /operators themselves. These are individuals or groups that also need to be part of the decision making process (ICES 2003). These issues have, in part, been justification for the increased use of more formal decision support systems for aquaculture management and development.

A number of decision support systems have been proposed, or are presently used by the aquaculture industry for a variety of purposes. The specific objectives of each decision support system may vary, focusing on areas such as; facility design/management (Ernst, Bolte and Nath 2000), site selection (Stagnitti and Austin 1998, Hargrave 2002) or evaluation of environmental impact potential (Silvert 1994, Brister and Kapuscinski 2002). A decision support system that encompasses all aspects of sustainability for all types of operations would be extremely large, overly complex itself, and potentially unwieldy. However, the nature of a particular operation will by default, partition relevant sustainability criteria. Any logical approach then taken in decision analysis, must address overall sustainability issues at a conceptual level first, in order to identify relevant criteria and the overall value of the proposed project. This can be followed by the selection of a more detailed and appropriate decision support system which will embody applicable expertise related to, say, environmental siting criteria for example, within the larger framework of sustainability.

Development of a Decision Support Tool for Freshwater Cage-Aquaculture Licensing

This formal, decision matrix approach is being proposed for the licensing of finfish cage aquaculture in Ontario, Canada. A decision support tool (DST) has been developed by us, and is presently being tested and reviewed in conjunction with Provincial, Federal, industry and other community stakeholders. The licensing of cage-based aquaculture in Ontario is complex and dynamic, especially in the Great Lakes where the majority of the province's food fish production occurs. This is due largely to overlapping jurisdictions and interests of federal Departments (e.g. Fisheries and Oceans, Transport Canada, Environment Canada), provincial ministries (e.g. Natural Resources, Environment, Northern Affairs and Mines, and the Ministry of Agriculture, Food and Rural Affairs), and a variety of other industry, First Nations and non-governmental organizations

(NGOs). As a result, licence applications are required to pass through several agencies for approval; a painstakingly long and laborious procedure. To address this issue, the lead aquaculture licensing agency, the Ontario Ministry of Natural Resources, initiated the development of a Harmonized Guidelines approach, intended as a 'one stop' application procedure to streamline and improve the licensing process. The DST presented here is consequently embodied as part of the new Harmonized Guidelines and they are intended to be used together.

Within this design framework, the DST developed here was developed to accommodate the following objectives:

- Display decision criteria and their ranking in each section, so users can understand how compliance decisions and rating criteria are determined.
- Clearly demonstrate how data provided by the applicant is used. This ensures that agencies requesting the data provide rationale as to how and why the information is required.
- DST data inputs and criteria that could trigger a licence refusal are requested early in the application process. This is intended to avoid unnecessary costs associated with 'late discovery' of some basic information that otherwise would have resulted in obvious licence refusal (i.e. the proposed location is not compliant with Navigable Waters Protection Act) had it been provided at the onset of the application process.
- Each section (e.g. water quality, operations) is accompanied by a support document produced by a multi-agency writing team, which assesses the state of knowledge of their respective section, and recommends rating or decision criteria based on existing compliance and research findings.
- Individual sections and the overall licence rating criteria will return a red (licence refused), amber (cautionary) or green (section approved) rating; a similar conceptual rating approach proposed by Hargrave (2002).
- Constants and compliance values assessed by mathematical formulae are stored separately so these values can be easy updated as the science improves or compliance values change.
- Develop the DST in a commonly used and easily understood software platform. Given the relatively small size of the industry in Ontario, and the small number of people who would be using the DST, and allowing for the potential for continual updates, we felt that the DST would be most practically developed in an Excel ® (Microsoft Corp.) based, spreadsheet application. In this way, computer programmers are not required; sections or cells can be password protected if required (to prevent tampering); and the general familiarity and availability of this spreadsheet software in most organizations reduces the need to train staff on new application software.

The DST developed here, effectively 'rates' such areas as water quality, operations, ecosystem impacts (such as species at risk and fish, communities/ habitat/ health), user conflict, physical site aspects, sediment impacts etc., and provides a variety of functions to assist in overall application assessment. These sections require a series of questions to be answered or have data entered depending on the licence stream ('New Licence' or 'Re-issue'), or type of water body proposed for the farm (e.g. either 'closed' or 'open' site locations). Specific details, organizational requirements, structure and various decision criteria that we employed are detailed in Table 1. Interface examples from the spreadsheet application are shown in Figure 1.

Discussion and Conclusions

Existing legislative requirements for Ontario aquaculture often result in very specific, 'go' or 'no go' criteria, negating the need to proceed with more complex decision support systems. However, once the obvious 'no go criteria' have been addressed in an application, a decision support system will be a very useful tool for the assessment of more subjective criteria for which there may be less clearly defined compliance criteria. One of the challenges with the development of the Ontario DST occurred when writing teams were presented with the task of addressing the subjective criteria in their discipline area, and defend how they should be rated. Most teams returned specific trigger limits or, 'no' or 'go' decisions for the licence, resulting in relatively few subjective responses that led to a ***cautionary*** rating. In some cases, compliance values were already in existence, although in other cases, the absence of scientific support data appeared to discourage attempts to justify a range of 'appropriateness' within subjective ratings.

Dealing with subjectivity of analysis can be a potential strength or weakness of any given decision support system. Where there is an absence of scientific justification for a particular decision outcome, or where legitimate differences in the value-based judgements of various stakeholders exist, a default to a somewhat 'arbitrary' threshold may occur, and inevitable – and controversial- debate will arise. For example, some stakeholders may see an adverse impact where others see a benefit in the exact same parameter! How then, should such criteria be ranked? Differences in opinion are unavoidable, and their resolution will no doubt be situation and site specific. However, formal decision support systems can help to quickly identify those specific issues where stakeholders may disagree, and do it early in the decision-making process. This will ultimately assist in the negotiation processes that are often required to reconcile these differences, and lead to a more expedient decision outcome.

Future developments in world aquaculture systems, such as open ocean technologies (Marra 2005) and integrated, multi-trophic systems (Troell et al, 2002, 2004; Neori et al. 2004) are intended to improve aquaculture sustainability through either reductions in stakeholder conflicts, mitigation of ecosystem effects, or in combinations of both. Such developments will introduce ever-greater complexity into aquaculture decision making, and will create an increased demand for the development of decision support tools like the one described here.

As the aquaculture industry evolves, it is important to appreciate that a decision support system that facilitates sustainability is not an end unto itself, and the 'support' aspect of the tool needs to be emphasized. Decision support systems do not, and should not, exclusively make the decision to establish a new farm, or expand an existing farm operation. Rather, they should foster accountability and efficiency of the process employed to assess farm applications and arrive at decision outcomes. For example, if decisions are made in contradiction to a DST recommendation, the regulators and other decision makers should be required to provide a legitimate and defensible justification for this apparently conflicting decision outcome.

Ultimately, a valid decision support system will ensure that the appropriate criteria for environmental, social and economic sustainability criteria have been considered, while accommodating a transparent rating system that is available to, and accepted by, all stakeholders.

Table 1. Section Descriptions and Organization of the DST.

Info Sections in DST	Description
DST Contents and Site Map	
Project Description	Describes project goals and rationale
Application Schematic	Analogous to a site map
Administration	Applicant information, dates, names of reviewers etc.
Licence type	Type will dictate application stream and activate appropriate questions for the stream
Proposed production	Displays proposed production output and links to 'Production and husbandry section'
Escape risk and security	Reports results from 'Risk analysis and security' section
Site location	Reports site location details entered in the 'Operations' section
Operations	
Operational Layout	Reports operational layout
Stage 1 application process	Initial application and review details
Stage 2 application process	Applicable legislation, process requirements, site markings, consultations and stage 3 requirements
Stage 3 application process	Data collection, draft application submission, continued consultation, concern mitigation
Stage 4 application process	Submission of final application, decision making and notification
Site Details	
Site location	Latitude, longitude and regional location (e.g. water body)
Production and husbandry	Proposed species and annual production targets
Infrastructure	Cage type, moorings, layout, depth, distance from shore, site dimensions, support structures
Standard operating protocol (SOP)	Is there an SOP for Environmental monitoring, escape prevention/reporting, Fish Health Management Strategy, Feed Management Strategies
Site Decommissioning	Determines if an acceptable site closure plan has been submitted
Physical Parameters	
Lake type classification (Decision stream)	Lake type is entered here (I, II, or III). The type will dictate question and data requirement steams for the DST
Flushing and currents	Approximates flushing rate of site based on mean current velocitie
Bottom contour map	Imports maps. Used to asses sediment footprint

Info Sections in DST	Description
Water Quality	
Total phosphorus	Entry and assessment of total phosphorus data. Determines if median concentrations are below regulatory guidelines
Dissolved oxygen	Entry and assessment of dissolved oxygen data. Determines if concentrations and percent saturation are below regulatory guidelines
Sediment Effects	
Organic matter	Entry and assessment of total organic mater (TOC) data at the site boundary and reference location
Phosphorus	Entry and assessment of sediment Tot-P organic mater data at the site boundary and reference location
Nitrogen	Entry and assessment of total Kjeldhal (TKN) data at the site boundary and reference location
Ecosystem Impacts	
Risk of Escape	Returns facility requirement based on presence of species in receiving waters and rudimentary Genetic risk assignment (as per Provincial licensing requirements)
Fish habitat	Questions answered about distance of site from feral fish nurseries, spawning beds and up-welling areas
Fish communities	Status of existing of fish community assessment data in the area, ‘special value populations’ and predator stocking rate)
Fish health	Distance form other fish cage operations
Species at risk	Assess species at risk data, and if range overlap, are there mitigating measures to correct
Section consensus	Describes questions and data still required or section outcome
User Conflicts	
Navigation	Approval status under the Navigable Waters Protection Act
First Nations concerns	Aboriginal consultation, land claim issues, dispute resolution process if needed
Section consensus	Describes questions and data still required or section outcome
Numerical Constants	
Sediment Severe Effects Levels	Total phosphorus (%), total organic carbon (mg/g) , total Kjeldahl Nitrogen (mg/g)
Water Quality Compliance	Total phosphorus (μg/l), dissolved oxygen (mg/l), % oxygen saturation

Info Sections in DST	Description
Nutrition and Waste	% phosphorus digestion, % feed waste, % non-settleable solids, % phosphorus retention in carcass and mean fecal settling rate
Selected conversions	Conversion values listed for some common units
t-test formula	Details t-test formulae used to assess significant difference between reference site (e.g. sediment)
Farm Maps and Diagrams	Essentially a storage area for e-versions of maps required as part of the application process
Map of site location	Stores imported map
Map of 'Site footprint'	Stores imported map
Functions and Supporting Information	Information and functions to assist usage for DST
Analytical Quantification Calculator	Details relationships between, lower level of detection, instrument detection level, method detection limit and limit of quantification
Classification of Genetic Risk	Genetic risk assessment calculator. An initial rudimentary assessment of risk on proposed culture species (based on existing Provincial classifications)
Lake Type Assessment	Details characteristics of lake type determination (lake type will affect the application stream and consequently data requirements)
Cage and Farm Volume	Farm and cage volume calculator
Species Eligible for Culture	A list of species legal for culture in the province
Acts and Regulations	Hyperlinks to applicable legal Acts and Regulations
Class EA categories	Details environmental assessment classes that could be invoked for major works
Phosphorus modelling	Estimates potential change in localized or water body phosphorus concentrations
Theoretical footprint	Rudimentary depositional model from single point source
User Instructions	Provides operating instructions for user
Final DST Recommendation	
Data Assessment	Displays the section rating criteria of Operations, Physical, Water quality, Ecosystems and User Conflict
Overall Rating Criterion	Reports final outcome of licence assessment

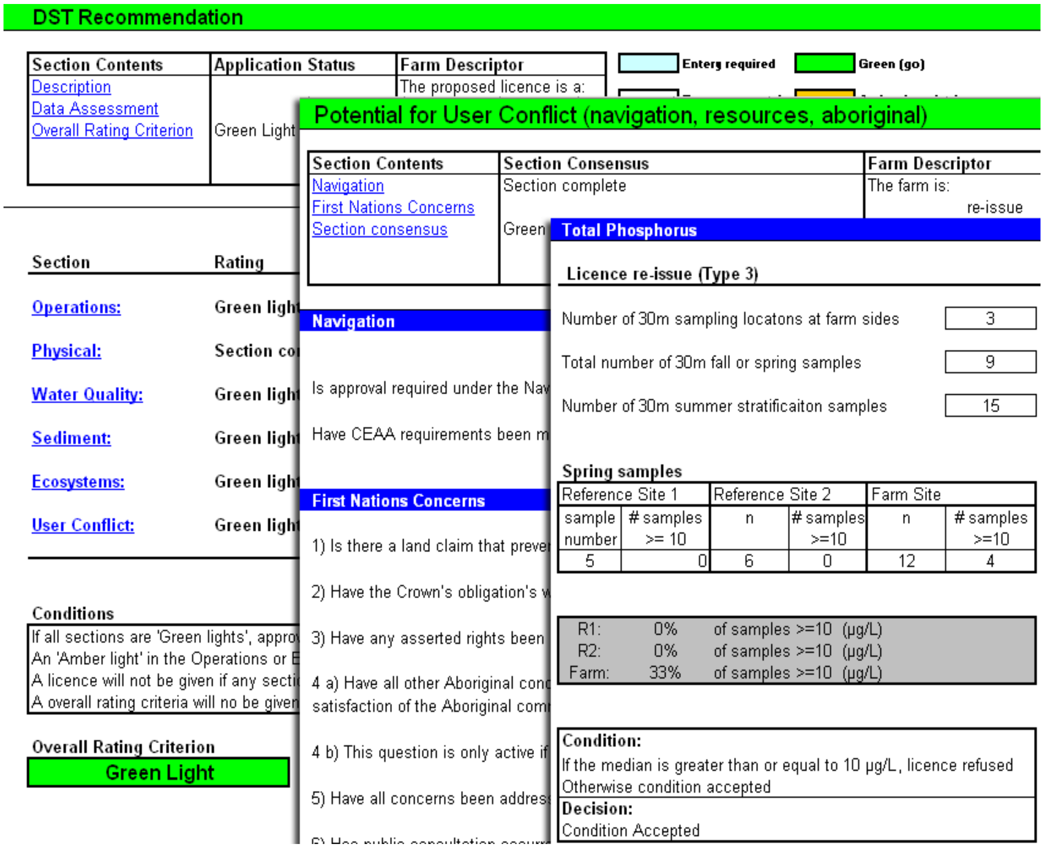

Figure 1. Selected DST interface examples.

References

1. Brister DJ, Kapuscinski AR. 2002. Environmental assessment tool for aquaculture in the Great Lakes Basin. Great Lakes Fishery Commission Misc. Rep. *http://www.glfc.org/boardcomm/clc/EATq/index.htm* Accessed 2005, 20 June.
2. Bunting SW. 2001. Appropriation of environmental goods and services by aquaculture: a reassessment employing the ecological footprint methodology and implications for horizontal integration. *Aquaculture Research* 32: 605-609.
3. Burbridge P, Hendrick V, Roth E, Rosenthal H. 2001. Social and economic policy issues relevant to marine aquaculture. *J. Appl. Ichthyol.* 17: 194-206.
4. Caffey RH, Kazmierczak RF Avault JW. 2001. Developing consensus indicators of sustainability for Southeastern United Sates aquaculture. *Louisiana State University Ag Center Bulletin* 879, 40pp.
5. Costa-Pierce B. 2003. Use of ecosystems science in ecological aquaculture. *Bull. Aquacul. Assoc. Canada* 103(2): 32-40.
6. Ernst DH, Bolte JP, Nash SS. 2000. AquaFarm: simulation and decision support for aquaculture faculty design and management planning. *Aquacultural Engineering* 23:121-179.
7. Frankic A, Hershner C. 2003. Sustainable aquaculture: developing the promise of aquaculture. *Aquaculture International* 11: 517-530.
8. Folke C, Kautsky N, Troell M. 1997. Salmon farming in context: response to Black et al. Journal of *Environmental Management* 50:95-103.
9. Hargrave B. 2002. A traffic light decision system for marine finfish aquaculture siting. *Ocean & Coastal Management* 45: 215-235

International Council for Exploration of the Sea (ICES). 2003. Report of the Working
10. Group on the Environmental Interactions of Mariculture. *ICES CM* 2003/F:04, Ref. ACME. Vigo, Spain, March 31-April 4.
11. Marra J. 2005. When will we tame the oceans? *Nature* 436, July 14.
12. Moccia, RD, Hynes J. 1998. *Sustainability of Ontario's Aquaculture Industry: 1998 and Beyond*. AEC Publication #98-001, University of Guelph, Aquaculture Centre.
13. Neori A, Chopin T, Troell M, Buschmann AH, Kraemer GP, Halling C, Shpigel M, Yarish C. 2004. Integrated aquaculture: rationale, evolution and state of the art emphasizing seaweed biofiltration in modern mariculture. *Aquaculture* 231: 361-391.
14. Schrank WE. 2003. *Introducing Fisheries Subsidies.* FAO fisheries technical paper 437 (ISSN 0429-9345). 58 pp.
15. Silvert W. 1994. Decision support systems for aquaculture licensing. *J. Appl. Ichthyol.* 10: 307-311.
16. Stagnittie F, Austin C. 1998. DESTA: A software tool for selecting sites for new aquaculture facilities. *Aquacultural Engineering* 18:79-93.
17. Troell M, Halling C, Neori A, Chopin T, Buschmann AH, Kautsky N, Yarish C. 2002. Integrated mariculture: asking the right questions. *Aquaculture* 226:69-90.
18. Tyedmers 1999. *Salmon and Sustainability: the Biophysical Cost of Producing Salmon through the Commercial Salmon Fishery and the Intensive Salmon Culture Industry.* Ph.D. Thesis, University of Waterloo.

Results from Sediment Surveys in the Vicinity of Freshwater Net-pen Aquaculture Operations in the North Channel

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Abstract

In 2001 provisional sediment sampling was proposed by Ontario Ministry of the Environment (MOE) predicated on the assumption that any site which is causing measurable degradation in sediment quality outside the limits of its tenure instrument is exceeding the carrying capacity of the licensed operational zone. According to the provisional recommendations, an aquaculture site will be deemed to have exceeded the capacity of the licensed operational zone when concentrations of total phosphorus (TP), or total organic carbon (TOC), or total Kjeldahl nitrogen (TKN) in sediment at the boundary of the site tenure agreement significantly exceed (at $p = 0.05$) those from appropriate reference sites. Additional concern would be raised if site boundary nutrient concentrations were above the MOE Severe Effects Levels (SELs) Sediment Quality Guidelines since these indicate concentrations that would be considered to be detrimental to a majority of benthic species. The SELs for TP, TOC, and TKN are 2.0 mg/g, 100 mg/g, and 4.8 mg/g respectively. Results from two surveys conducted in 2001 led to collaborative effort in 2004 between provincial and federal agencies to: define the extent and composition of sediment footprints, estimate accumulation rates, track recovery rates, and assess benthic communities.

Introduction

Preliminary sediment sampling was undertaken by the Ministry of the Environment and Energy (MOEE) EMRB at the LaCloche Channel (Manitoulin Island/North Channel) aquaculture site during 1999, following a literature review of experiences in other jurisdictions. The results listed in Table 1 suggested the potential need to include a sediment monitoring component in the water quality monitoring recommendations as a means of detecting possible cumulative effects on sediment, and hence benthic habitat, before these effects become observable in the water column.

Table 1. Sediment Results from the July 14, 1999 LaCloche Channel Sediment Survey.

Station	Particle Size in Percent			LOI	TOC	TKN	TP
	1000 - 62 um	62 - 2.63 um	2.63 - 0.10 um	mg/g dry	mg/g dry	mg/g dry	mg/g dry
326	0.0	8.0	92.3	220	100	12	2.0
452	0.0	73.0	27.3	16	6	1	0.4
453	0.0	8.0	91.8	210	94	12	1.9
454	0.0	29.0	71.7	270	130	15	4.3
456	0.0	4.0	96.3	170	80	9	0.8

A sediment sampling method was proposed in the Recommendations for Operational Water Quality Monitoring at Cage Culture Aquaculture Operations (MOE, 2001). This sediment sampling strategy was predicated on the assumption that any site which is causing measurable differences in either water or sediment quality outside the limits of its land use permit or other tenure instrument, is exceeding the carrying capacity of the licensed operational zone. As documented in the previously cited monitoring recommendations, an aquaculture site will be deemed to have exceeded the capacity of the licensed operational zone when concentrations of total phosphorus (TP), or total organic carbon (TOC), or total Kjeldahl nitrogen (TKN) in sediment at the boundary of site tenure agreement significantly exceed (at $p = 0.05$) those from appropriate reference sites. Additional concern would be raised if site boundary nutrient concentrations were above the MOEE Severe Effects Levels (SELs) Sediment Quality Guidelines since these indicate concentrations that would be considered to be detrimental to a majority of benthic species (MOEE, 1993). The SELs for TP, TOC, and TKN are 2.0 mg/g, 100 mg/g, and 4.8 mg/g respectively.

The monitoring recommendations require that aquaculture operators undertake sediment sampling in *"...the year prior to any renewal of, or revision to, an existing aquaculture licence or site tenure agreement"*. Additional concerns regarding metals enrichment, particularly for zinc, as the result of fish feed enrichment have also been raised. The current MOE monitoring recommendations do not yet require that these be included in the analysis by aquaculture operators since the nutrient analysis was deemed to be a sufficient tracer of aquaculture operations and since the primary goal was to determine the extent of the aquaculture sediment footprint relative to the boundaries stipulated in its site tenure agreement.

Objectives

The 2001 sediment survey was designed to test Recommendation #6 concerning sediment sample collection and data analysis from the report entitled Recommendations for Operational Water Quality Monitoring at Cage Culture Aquaculture Operations (MOE 2001) which states:

Sediment sampling should be undertaken at the "upstream" and "downstream" boundaries specified in the site tenure agreement and at the two local reference sites. At a minimum, this sampling should be undertaken the year prior to any renewal of, or revision to, an existing aquaculture licence, or site tenure agreement. The precise sampling location(s) will be determined independently for each aquaculture operation based on examination of local bathymetry and prevailing current patterns; the goal will be to assess sediment quality at the boundary of the area occupied by the operator while making allowance for local sediment depositional factors. Sampling will occur once in duplicate during the May sampling period and once in duplicate during October with samples being analysed for particle size (% > 63 μm) and nutrient status including total phosphorus (TP), total Kjeldahl nitrogen (TKN), total organic carbon (TOC) at a CAEL accredited laboratory. Results should be compiled and reported according to the schedule established for water quality TP data.

If the data satisfy assumptions of normality, the mean nutrient (C, N and P) data at the boundary of the site tenure agreement (four samples at two stations) will be compared against the local reference station data (also having $n = 8$) using an appropriate t-statistic (e.g. $\alpha \leq 0.05$). If assumptions of normality are not satisfied then a non-parametric (distribution-free) comparison will be made. If nutrient concentrations in sediment at the boundary of the site tenure agreement significantly exceed those at the local reference stations then the operator will be required to undertake an operational audit and submit an abatement plan leading to a reduction in the site's operational scale (or feed quota) for the subsequent operational season. Pending discussion with MNR regarding the loss of cold water fish habitat, it may also require the development of a benthic sampling program sufficient to estimate the extent of any impairment to the benthic habitat.

As part of the preamble to the 2001 Monitoring

Recommendations, three general types of aquaculture sites were defined to classify the potential for water quality impacts:

Type 1. *enclosed (lake like) basins with limited assimilative capacity;*

Type 2. *partially exposed sites having good epilimnion/metalimnion mixing but no hypolimnion mixing;*

Type 3. *exposed locations where the hypolimnion is also well mixed*

The sediment monitoring recommendation was tested at two active aquaculture sites. Eastern Island considered a Type 2 site, and Fisher Harbour, considered to be a Type 3 site were chosen as active aquaculture operation test sites. The "historical" LaCloche Channel site was decommissioned in the spring of 1999 to determine if the effects of historical aquaculture operations were still measurable in the sediment two years later. Figure 1 illustrates the sampling locations for the 2001 sediment survey and the 1999 LaCloche Channel sediment survey.

Methods

Sampling was undertaken at the "upstream" and "downstream" boundaries specified in the site tenure agreement and at the two local reference sites. Precise identification of boundary locations was not possible with currently available geo-referencing and sketch-map information contained in the Land Use Permit documentation. However, stations were located so as to be conservative in this respect by applying a generous interpretation of the apparent boundaries and placing them further from cage boundaries when there was any doubt as to the position of the boundary. Reference sites were located in similar depths, exposure, orientation, and circulation as the cage site and were at least 1 km away from the cage sites. In order to make allowance for local sediment depositional factors precise sampling location(s) were determined independently for each aquaculture operation based on examination of local bathymetry and prevailing current patterns. Samples were collected in triplicate in May and September and were analyzed for particle size, nutrients, metals, organic carbon and loss on ignition according to MOE Laboratory Services Branch standard methods.

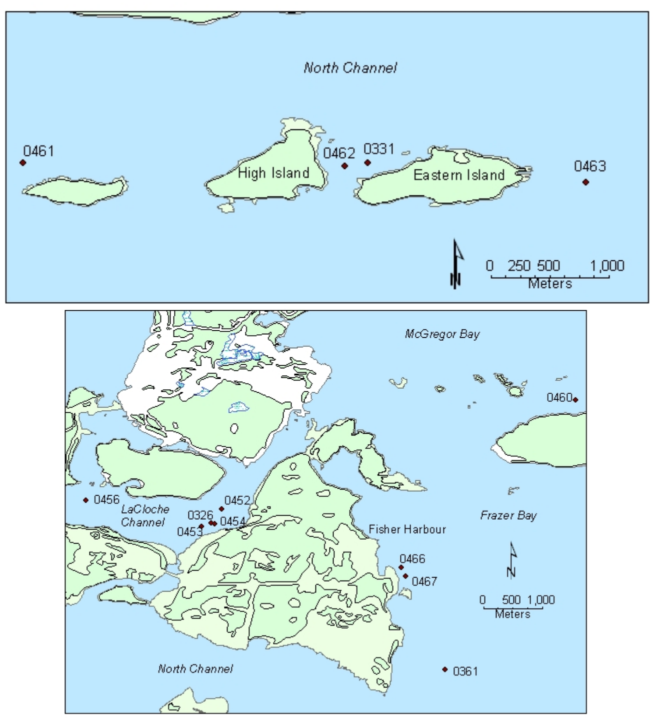

Figure 1. Location of 2001 sediment collection sites.

At the decommissioned LaCloche Channel site sediment samples were collected in duplicate at five historical stations during the spring and fall survey. These samples were analyzed for the same parameters as those samples collected from the active sites.

All sediment samples were obtained using a Mini Box Core, Shipek, or Ponar sampler. At Eastern Island, Fisher Harbour and LaCloche Channel two homogenized subsamples from the top ~3 cm were collected and submitted for analysis. In addition to sediment sample collection at each collection site, a qualitative field evaluation of benthic invertebrates was made by sieving a subsample of the top ~10 cm from the sampler. Samples were labelled and photographed, and a description of benthos was made using EMRB "sediment description" sheets.

All statistical analyses were performed using SigmaStat version 2.0. As specified in the 2001 MOE monitoring recommendation, data were analyzed to determine the significance of differences between site tenure boundary sites and reference sites using either a t – test ($\alpha \leq 0.05$) or a Mann-Whitney Rank Sum Test, depending upon the normality of the data distribution. Normality was assessed using the Kolmogorov-Smirnov test with Lilliefors' correction.

Although not part of the monitoring recommendation, the data were also analyzed using a two-way Analysis of Variance (ANOVA), or two–way ANOVA on ranks, to examine the significance of both sampling location and sampling season effects, and to observe any interaction between them (i.e. whether location effects differed according to sampling season or *vice versa*). The Tukey Test was used on all pairwise multiple comparisons to assess differences among stations.

Results

Reference data from both stations at both active sites have been pooled and summarized in Table 2 to establish the range of natural background conditions for this area.

Table 2. Descriptive Statistics for Pooled Reference Data (n = 24).

Variable	Mean	Std. Dev.	95% C.I.	Max.	Min.	Median	Normal Distribution (p<0.05)?
% fines	81	11.3	4.8	100	63	78	Yes
TOC (mg/g dry)	24	8.4	3.5	39	12	22	No
TKN (mg/g dry)	2.6	0.90	0.38	4.4	1.4	2.6	No
TP (mg/g dry)	0.68	0.169	0.071	0.96	0.40	0.64	Yes
Zn (ug/g dry)	100	15.8	6.7	120	58	105	No
Mn (ug/g dry)	2120	2264.5	956.2	6900	240	1050	No
Fe (ug/g dry)	26708	7153.5	3020.6	38000	13000	28000	No
Cu (ug/g dry)	36	7.7	3.2	50	17	37	Yes

It is evident that all nutrients and those metals potentially associated with aquaculture operations were found at reference sites with median concentrations well above Provincial Sediment Quality Guidelines (PSQG) Lowest Effect Levels (LELs), although none exceeded Severe Effect Levels (SELs). For Fe and Mn, in particular, median reference concentrations demonstrated such naturally elevated background concentrations that they appear to represent poor tracers of aquaculture operations even if present as additives in feed.

Results from Fisher Harbour reference stations and site tenure boundary stations are summarized in Tables 3 and 4. Mean TP concentrations at the site tenure boundary stations were significantly greater than reference stations, whereas for TOC and TKN concentrations at site tenure boundary stations were significantly less than reference stations. Nutrients other than TP were not associated with any apparent sediment enrichment from aquaculture operations. For TP, however, the enrichment was significant, especially since the association between particle size and TP which was evident at reference sites would have tended to diminish the apparent difference between boundary and reference locations.

Table 3. Fisher Harbour Reference Data Summary (n = 12).

Variable	Mean	Std. Dev.	95% C.I.	Max.	Min.	Median	Normal Distribution (p<0.05)?
% fines	78	6.3	4.0	85	63	78	Yes
TOC (mg/g dry)	28	10.0	6.3	39	12	30	No
TKN (mg/g dry)	3.2	0.89	0.56	4.4	1.4	3.4	Yes
TP (mg/g dry)	0.61	0.179	0.114	0.96	0.4	0.56	Yes
Zn (ug/g dry)	89	14.7	9.4	110	58	89	Yes
Mn (ug/g dry)	873	619.6	393.7	1800	240	720	No
Fe (ug/g dry)	22667	7088.2	4503.6	30000	13000	23000	No
Cu (ug/g dry)	35	10.7	6.8	50	17	34	Yes

Table 4. Fisher Harbour Site Tenure Boundary Data Summary (n = 12).

Variable	Mean	Std. Dev.	95% C.I.	Max.	Min.	Median	Normal Distribution (p<0.05)?
% fines	69	20.4	12.9	90	33	76	No
TOC (mg/g dry)	21	7.4	4.7	32	12	20	Yes
TKN (mg/g dry)	2.1	0.78	0.49	3.6	1.2	2.1	Yes
TP (mg/g dry)	0.96	0.252	0.160	1.6	0.6	0.88	Yes
Zn (ug/g dry)	89	25.7	16.3	150	65	76	No
Mn (ug/g dry)	252	76.5	48.6	370	170	225	No
Fe (ug/g dry)	15167	4365.8	2773.9	21000	10000	14000	No
Cu (ug/g dry)	22	7.9	5.0	33	13	20	No

The two-way ANOVA illustrates significant seasonal effects along with the station effects previously illustrated with the *t*-test. There was no significant interaction between stations and seasons so the relative difference between boundary and reference stations was not dependent upon sampling season. Site tenure boundary sites 0467 and 0466 were not significantly different but reference site 0361 was significantly different from all other sites. Boundary site 0467 was significantly different from both reference sites, whereas boundary site 0466 was only significantly different from reference site 0361.

This analysis demonstrates the potential significance of reference site selection, and the potential influence of the selected sampling season on the TP concentration data. It does not, however, diminish the general applicability of the boundary and reference site comparison contained in the MOE 2001 monitoring recommendations. This is because the recommended comparison is conservative in that it effectively incorporates any seasonal and interaction effects, along with any differences among boundary stations or among reference stations, into the sampling error associated with boundary versus reference station effects.

Results from Eastern Island reference stations and site tenure boundary stations are summarized in Tables 5 and 6. Median concentrations of TP, TOC, and TKN at the site tenure boundary stations were significantly greater than for the reference stations and hence, in this case, all nutrients clearly demonstrated apparent sediment enrichment associated with the aquaculture operation. Sediment samples collected from Eastern Island site tenure boundary stations had a sulphurous and/or rotting organic odour and were either devoid of invertebrates or were populated with only pollutant tolerant oligochaetes and chironomids. This was in marked contrast to sediment samples collected from Eastern Island reference stations which had no odour, and exhibited a larger variety of sensitive infauna such as mayflies, chironomids, amphipods, oligochaetes, and clams.

Table 5. Eastern Island Reference Data Summary (n = 12).

Variable	Mean	Std. Dev.	95% C.I.	Max.	Min.	Median	Normal Distribution (p<0.05)?
% fines	85	14.1	9.0	100	67	86	No
TOC (mg/g dry)	20	3.2	2.0	25	15	22	Yes
TKN (mg/g dry)	2.1	0.45	0.29	2.8	1.4	2.1	Yes
TP (mg/g dry)	0.74	0.135	0.086	0.96	0.56	0.76	Yes
Zn (ug/g dry)	111	6.7	4.2	120	100	110	No
Mn (ug/g dry)	3366	2636.3	1675.0	6900	790	3150	No
Fe (ug/g dry)	30750	4595.0	2919.5	38000	26000	30000	Yes
Cu (ug/g dry)	37	2.3	1.5	41	32	38	Yes

Table 6. Eastern Island Site Tenure Boundary Summary (n = 12).

Variable	Mean	Std. Dev.	95% C.I.	Max.	Min.	Median	Normal Distribution (p<0.05)?
% fines	80	13.6	8.7	100	61	77	Yes
TOC (mg/g dry)	59	37.6	23.9	150	29	45	No
TKN (mg/g dry)	6.2	3.37	2.14	13.0	3.0	5.6	No
TP (mg/g dry)	3.85	3.385	2.151	9.90	0.72	2.9	No
Zn (ug/g dry)	321	185.0	117.5	640	150	265	No
Mn (ug/g dry)	617	270.3	171.7	1200	410	490	No
Fe (ug/g dry)	26917	4481.4	2847.4	33000	18000	28000	Yes
Cu (ug/g dry)	56	9.3	5.9	79	47	54	No

The two-way ANOVA for ranked TP data yielded significant seasonal effects along with the station effects demonstrated by the *t*-test. In this case, however, there was significant interaction between stations and seasons. Specifically there was a significant difference between seasons at stations 0461, 0463 and 0462 and no significant difference between seasons at station 0331. In the spring and fall there was no significant difference between reference station 0461and reference station 0463. In the spring, boundary station 0331 was not significantly different from boundary station 0462 but in the fall, station 0331 was significantly greater than station 0462. Boundary station 0331 was significantly greater than both reference stations 0461 and 0463 whereas boundary station

0462 was only significantly greater than reference station 0461 in both the spring and the fall.

The two-way ANOVA on ranked TOC and TKN indicated significant differences between station locations after allowing for effects of survey time, no significant difference between survey times after allowing for effects of station locations, and no significant interactions between station locations and survey time. TOC concentrations were not significantly different during the spring and fall surveys except at boundary station 0462. Similarly, TKN concentrations were not significantly different during the spring and fall survey among all stations except at station 0461. For both TOC and TKN, concentrations were significantly different from one another at all stations in the spring and fall survey except site tenure station 0462 which was not significantly different from reference station 0461 in the spring survey.

This analysis once again demonstrates the potential significance of reference site selection, and the potential influence of the selected sampling season on the TP concentration data. As with the Fisher Harbour data, however, it does not diminish the general applicability of the boundary and reference site comparison contained in the MOE 2001 monitoring recommendations. In this case the use of a non-parametric test and the observation of significant seasonal effects, interaction effects, and among-station effects for boundary and reference stations combine to diminish the statistical power of the pooled boundary-reference station comparison, and yet a significant difference was still observed. This finding has important implications for the interpretation of sediment quality data since the recommended simple method of comparison was extremely conservative and was still able to discriminate significant differences.

It is also noteworthy that all samples collected from station 0331at the site tenure boundary exceeded the provincial sediment quality guidelines (PSQG) severe effect level (SEL) of 2 mg/g for TP and 4.8 mg/g for TKN. According to these guidelines, sediment at station 0331 can be considered heavily polluted and likely to affect the health of the majority of sediment-dwelling organisms.

Although a quantitative comparison between 1999 and 2001 LaCloche Channel data is not possible, comparison of maximum observed nutrient concentrations for the two survey years show a reduction in TP from 4.3 mg/g to 1.6 mg/g; in TKN from 15 mg/g to 8.4 mg/g; and in TOC from 130 mg/g to 74 mg/g. Although the significance of these reductions cannot be quantified, they indicate an approximate 50% reduction over the period from July 1999 to May 2001. The spring and fall sampling undertaken in 2001 permits a quantitative comparison of seasonal effects and these data are summarized in Tables 7 and 8.

Table 7. LaCloche Channel May 2001 Data Summary (n = 10).

Variable	**Mean**	**Std. Dev.**	**95% C.I.**	**Max.**	**Min.**	**Median**	**Normal Distribution ($p<0.05$)?**
% fines	85	23.8	17.0	98	36	96	No
TOC (mg/g dry)	55	23.1	16.5	74	12	63	No
TKN (mg/g dry)	6.1	2.58	1.85	8.4	1.4	6.7	No
TP (mg/g dry)	0.93	0.398	0.285	1.60	0.44	0.89	Yes
Zn (ug/g dry)	159	65.3	46.7	220	41	185	No
Mn (ug/g dry)	331	112.1	80.2	450	140	350	Yes
Fe (ug/g dry)	26400	8167.1	5842.8	32000	11000	30000	No
Cu (ug/g dry)	67	30.6	21.9	92	12	81	No

Table 8. LaCloche Channel September 2001 Data Summary (n = 10).

Variable	Mean	Std. Dev.	95% C.I.	Max.	Min.	Median	Normal Distribution (p<0.05)?
% fines	79	13	9.3	98	66	71	No
TOC (mg/g dry)	47	19.2	13.7	64	12	56	No
TKN (mg/g dry)	4.9	2.02	1.45	6.9	1.2	5.6	Yes
TP (mg/g dry)	0.57	0.217	0.155	1.10	0.32	0.54	Yes
Zn (ug/g dry)	129	49.0	35.0	170	40	150	Yes
Mn (ug/g dry)	296	91.7	65.6	390	130	315	Yes
Fe (ug/g dry)	26700	7846.4	5613.0	32000	12000	30000	No
Cu (ug/g dry)	54	24.0	17.2	86	12	63	Yes

Spring concentrations were significantly greater than in the fall for TP, but not for TOC and TKN. TKN concentrations remained above the PSQG SEL of 4.8 mg/g at stations 0326, 0453, 0454, and 0456 during both the spring and fall surveys.

Discussion

The observation of a slight but significant difference in sediment concentrations of TP between boundary and reference locations at Fisher Harbour, but not TOC or TKN, contrasts with the situation at Eastern Island where large clear-cut differences were found for all three nutrients. Although the recommendation does not actually stipulate whether an observed difference between a boundary and reference station applies to **any** rather than **all** of the three nutrient tests, the supporting discussion in the monitoring recommendations document suggests that observation of significant differences in TOC **or** TP **or** TKN would trigger the recommended action. As written, therefore, this recommendation makes no allowance for the differences in relative severity between these two locations. Given the obvious differences between conditions at Fisher Harbour and Eastern Island, there may be a need to re-examine the recommendations and consider various degrees of alteration. In essence, we need to decide whether these data provide sufficient evidence that Fisher Harbour has reached, or exceeded, the operational capacity associated with the boundaries established in its current Land Use Permit. However, given the already conservative approach to sediment sampling proposed in recommendation # 6, a significant difference between the boundary of the site tenure agreement and the reference station should always result in further action regardless of the more extreme situation observed at Eastern Island.

One item for discussion could include a requirement to apply the federal EEM protocol for benthic invertebrate monitoring as a means of demonstrating a significant biological impact in situations where the chemistry data and field observations do not provide the overwhelming evidence of biological impairment observed at Eastern Island.

Another obvious issue associated with determining the significance of boundary station versus reference station differences arises from the difficulty we experienced in establishing the precise location of the site tenure agreement boundaries. As we currently understand the situation, this is to be improved as part of future licensing agreements between operators and MNR. The question of interest here is how these boundaries are to be established. A general rule which bases the size of the zone on the water depth and anchoring requirements of the cages provides an independent basis for this determination. It has not escaped our notice however, that the industry may lobby for the allocation of larger zones on the basis of a desired operational scale; consequently, increasing the size of the operational zone defined in the site tenure agreement would diminish the likelihood of observing a difference between boundary and reference conditions.

Sediment at Eastern Island station 0331 exceeds the SELs for TP and TKN (and the federal PEL for Zn) and according to the Provincial sediment quality guidelines (MOEE 1993), can be considered heavily polluted and likely to affect the health of sediment-dwelling organisms. There is also evidence of benthic habitat impairment. Unless the site tenure agreement boundary has been inappropriately defined, the operation in question is significantly exceeding the carrying capacity of its currently defined operational zone. The question remains whether this obvious inferred and observed impact on the benthic invertebrate community outside the boundary of the site tenure agreement constitutes sufficient grounds to apply the trigger actions described in the MOE 2001 monitoring recommendations and to reduce the feed quota (hence scale) of the operation. If further evidence is deemed necessary, then sediment toxicity testing in the vicinity of station 0331 could be completed to determine whether or not the sediment is acutely toxic, however the inclusion of sediment toxicity testing would represent a significant addition to the weight-of-evidence currently implied by the monitoring recommendations. If the sediment were to be characterized as acutely toxic (most probably as the result of ammonia or hydrogen sulphide in pore water) outside the Land Use Permit boundary, then MOE will need to determine an appropriate management response.

There have been recent attempts to portray the LaCloche situation more favourably by highlighting its recovery. Nevertheless, it is important to establish that the legacy of the decommissioned operation is still very much in evidence. The LaCloche Channel sediment data clearly demonstrate the effect of the historical aquaculture operation(s) in the area with TKN concentrations remaining above SEL. There is also clear evidence of late summer hypolimnetic DO depletion. That being said, however, TP, TKN and TOC concentrations in sediment appear to have decreased by approximately 50% since 1999 and DO profiles also show considerable improvement since the extreme situation observed in 1998. This raises the issue of fallowing, and the potential for future re-establishment of an operation at this location. Ongoing monitoring is needed to establish whether the predicted natural late-summer DO depletion is a genuine feature of this location and represents a reason to prohibit any future use for aquaculture.

Any alteration of the sediment quality is inherently destructive and should be cautioned against. However, we must recognize and consider the need to find a level of allowable "alteration" that is not considered "destructive" to the point of being harmful, nor detrimental to the water and sediment quality of the Great Lakes. This level should consider that sites affected by such an alteration should readily return to initial conditions if operations are discontinued. Although evidence from the LaCloche Channel suggests that fallowing may result in improvements to sediment quality, these improvements should occur within a finite time frame. Further consideration is needed to establish whether fallowing should be allowed, and what acceptable time-frames should be considered. Further consideration should also deal with possible cumulative effects in the environment, particularly dealing with the accumulation and potential effects of increased nutrients in sediment.

References

1. Boyd D, Wilson, M. Howell T. 2001: Recommendations for Operational Water Quality Monitoring at Cage Culture Aquaculture Operations. *Technical Memorandum to Northern Region* April 2001.
2. Boyd D, Hobson G., Neary B, McBride J, Gale P. 1998: Conditions at the LaCloche Channel During June and July 1998 — Provisional Data Summary and Interpretation for Discussion. *Technical Memorandum to Northern Region* September 1998.
3. Canadian Council of Ministers of the Environment. 1999. *Canadian Environmental Quality Guidelines*. Canadian Council of Ministers of the Environment, Winnipeg.
4. Persaud D, Jaagumagi R, Hayton A 1993: *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario.*
5. Thorburn M, Boyd D, Benoit, N. 2004. *2001 Sediment Survey in the Vicinity of Active and Historical Freshwater Net Pen Aquaculture Sites in the North Channel.* Ontario Ministry of the Environment. In Prep.

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b) *To promote, support, and encourage educational, scientific, and technological development and advancement of aquaculture in Canada;*

c) *To gather and disseminate technical and scientific information on aquaculture development in Canada and throughout the world;*

d) *To conduct seminars for the presentation, exchange, and discussion of information, findings, and experiences on all subject and techniques related to aquaculture;*

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