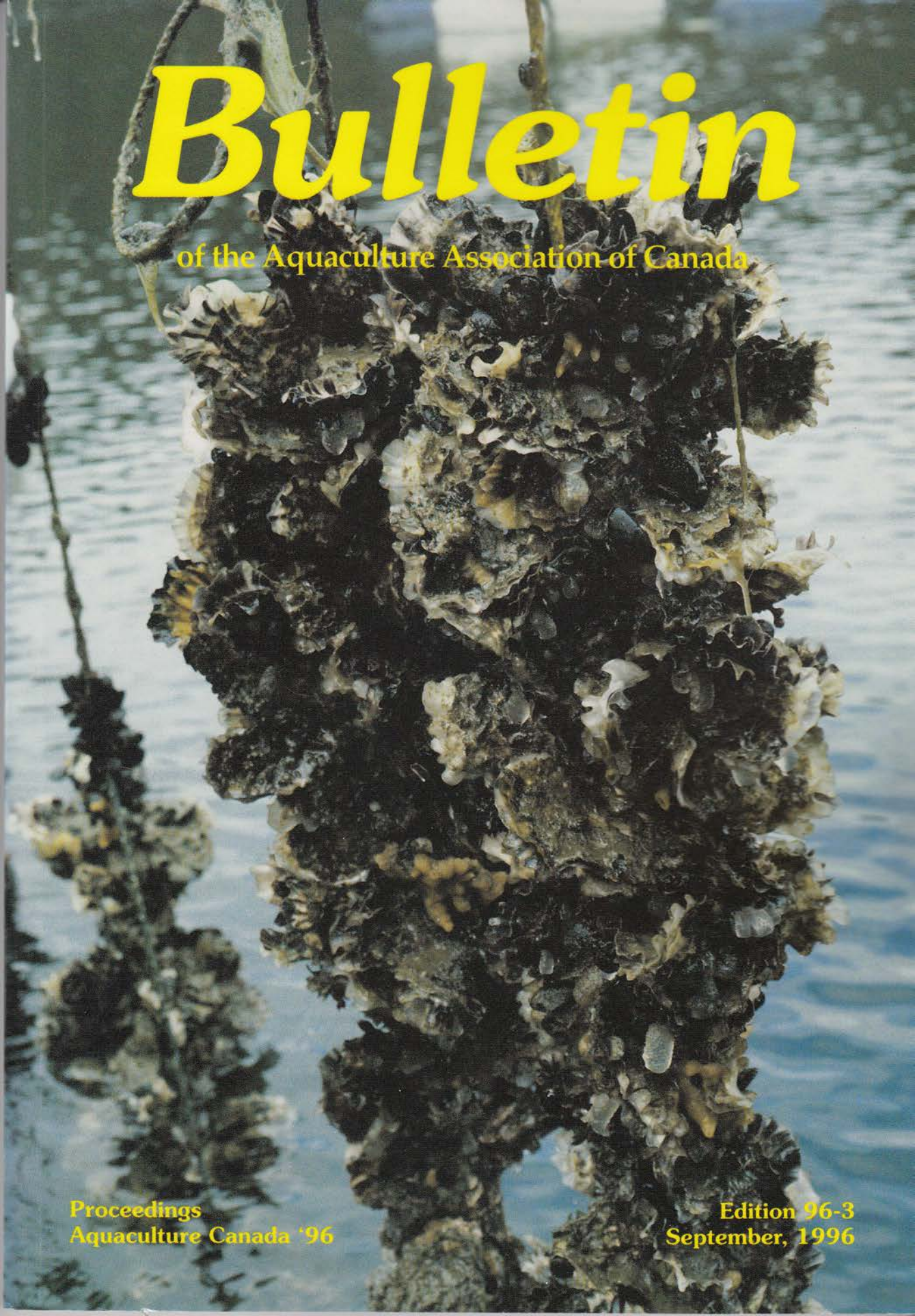

Bulletin

of the Aquaculture Association of Canada

Proceedings
Aquaculture Canada '96

Edition 96-3
September, 1996

Aquaculture Canada '96

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Bulletin of the Aquaculture Association of Canada

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1997 Publications

Proceedings of the AquaTech '96 conference held in St. John's, Newfoundland, May 5-7, 1996 — December 1996 issue of the *AAC Bulletin*

Proceedings of the Sea Urchin Gonad Enhancement Workshop held in conunction with Aquaculture Canada '96 — March 1997 issue of the *AAC Bulletin*

Proceedings of the Huntsman Marine Science Center Symposium *Cold Water Aquaculture to the Year 2000* held in St. Andrews, N.B., 6-8 September 1995 — *AAC Special Publication No. 2* (available in March 1997)

Education and Training Directory, — *AAC Special Publication No. 3* being produced in collaboration with the Canadian Aquaculture Industry Alliance (available in early 1997)

Cover: Biofouling is a serious problem in shellfish aquaculture. William Pennell photo.

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Salmonid Culture

Freshwater Fish Culture

Fish Health and Water Management

Shellfish Culture

Human Resources

Funding for this proceedings was provided by the Department of Fisheries and Oceans, Ottawa

President's Report

The past year has been both hectic and rewarding for the Association. In response to requests from our membership and an express wish to offer members more in the way of benefits, a number of ongoing initiatives have been completed and several new initiatives are underway.

In general terms, the Association is healthier than ever, with a total membership now approaching a record 1000 members from all segments of the aquaculture community (producers, suppliers, educators, researchers, government, etc.). This represents an increase of 20% over the previous year, resulting primarily from membership recruitment at the annual meetings. This trend will hopefully continue in the next few years as aquaculture production increases both in Canada and globally. While our membership lies predominantly in Canada (80%), members from more than 18 other countries also enjoy the benefits of AAC membership.

On the financial side, the AAC is holding its own and we have been able to accumulate a modest "contingency" fund over the past five years as a precautionary measure in the event of an operating deficit or unexpected shortfalls.

On the publication side of things, the Association is now up-to-date in the publication and distribution of all the periodicals received by our members *(AAC Bulletin, Northern Aquaculture*, and *World Aquaculture)*. Most of the credit for this is due to the dedicated and tireless efforts of our editorial team and the Publications Committee. Future issues of the AAC Bulletin are now planned a year or more in advance.

A special initiative commenced this past year and nearing completion is the proceedings of a conference organized by and held at the Hunstmen Marine Science Centre—*Cold-Water Aquaculture to the Year 2000* . This 100 page proceedings *(AAC Special Publication No. 2)* will be distributed to AAC members in early 1997.

Another initiative undertaken in the past year is the production of an updated *Directory of Education and Training Opportunities in Aquaculture and Related Fields* (the first education directory was published in 1990 by AAC

Cyr Couturier (left), President of the Aquaculture Association of Canada, with The Honourable Fred Mifflin, Minister of Fisheries and Oceans, at Aquaculture Canada '96 in Ottawa.

Top: The student-sponsored BBQ held on Parliament Hill was catered by Nate's Delicatessen.

Bottom (l to r): Irwin Judson, Christine Hodgson, Al Castledine, Maureen McInerney-Northcott, Tillmann Benfey, Jay Parsons, Cyr Couturier, Joseph Brown, Ted White, Brenda Bradford and Becky Field at the closing banquet.

Cyr Couturier (left) accepting a $1000 donation to the Student Endowment Fund from the Canadian Aquaculture Industry Alliance (CAIA). Presenting the cheque on behalf of CAIA are Julian Hynes (centre) and Glen Haddon. The AAC Student Endowment Fund provides travel grants to students presenting papers at the annual conference.

Brian Glebe (left), Production Manager, Aquaculture Division, Connors Bros., Ltd., and Christine Hodgson (centre), Chairman of the AAC Awards Committee, presenting a cheque for $250 to Chris Oikawa, Department of Animal Science, University of British Columbia, for the best student paper. The prize was donated by Connors Bros. Ltd.

as Special Publication No. 1). The new directorty is being done in collaboration with the Canadian Aquaculture Industry Alliance (CAIA). What is exciting about the project is that the directory will be widely available in various electronic media (diskette, web site, internet) — a first for aquaculture! The formats will permit user-friendly access, sorting, and formatting of the information. This should also permit easier updating of the directory as Canadian education programs continue to grow. The directory will, of course, be available on hard-copy as well. The directory is slated as *AAC Special Publication Number 3* and will soon be available at nominal cost.

AAC members already tuned into the e-world will probably have noticed the fruits of two special projects undertaken in the past year in the context of electronic communications. The AAC is now the proud owner and manager of the AQUA-L internet discussion list, the largest of its kind in aquaculture with approximately 1000 subscribers at present. The list was begun a decade ago by Ted White at the University of Guelph as a service to the aquaculture community. More recently the list was co-owned and managed by Ted and Nigel Robbins and was housed at the University of Prince Edward Island. Both Ted and Nigel have gone on to bigger and better things and have graciously offered the list to a "caring" supporter, the AAC. The AAC was pleased to accept responsibility for the list and to offer this service free to our members, though at present anyone with an interest in aquaculture may join. To subscribe to AQUA-L simply send a message to: majordomo@LISTSERV.ifmt. nf.ca. In the body of the text include the following: subscribe aqua-l. More information on the benefits of the list will be provided to members in the very near future.

Greg D'Avignon, Executive Director of the B.C. Salmon Farmers Association and Cheryl Fraser, Assistant Deputy Minister (Policy), Department of Fisheries and Oceans.

The AAC has also created its own web site with information on the Association's objectives and constitution. Additional information will be added as available, including the contents of the AAC Bulletin. To access the web site use: http://www.ifmt. nf.ca/mi/aac.

This year has also seen the AAC become a full voting member of the Board of Directors of the Canadian Aquaculture Industry Alliance and its Sector Council. CAIA supersedes the Canadian Aquaculture Producers Council and has a broader mandate related to industry development and competitiveness. The CAIA has representatives from various producer and service organizations. There was some concern expressed at our the annual business meeting in Ottawa (June 1996) that this undertaking might

undermine AAC's position or somehow "dilute" our effectiveness in providing service to our members. However, the motion to join CAIA was endorsed unanimously by the largest gathering of AAC members at an AGM in recent memory. It was felt that the benefits far outweigh any negative perceptions. Moreover, the AAC's primary mandate as listed in our Letters Patent (i.e., our Constitution — see AAC Bulletin 96-1), is to foster the development of Canadian aquaculture through education, training, and technology transfer. Thus, providing assistance and support on the Board of the CAIA, and particularly the CAIA Sector Council with an education and training mandate, was seen as a positive step in keeping with our stated objectives. AAC members will receive the CAIA newsletter as well as receive regular updates of joint activities.

The annual meeting was held in Ottawa, Ontario, this year at the invitation of Gary Chapman and the Ontario Aquaculture Association. A full decade had passed since the previous meeting in Ontario held at Guelph. The theme for Aquaculture Canada '96 was "Diversification", reflecting a need to diversify our approaches in Canadian aquaculture, viz. R&D on alternate species culture (e.g., tilapia, marine fish, sea urchins), industry–government liaison, human resource development, applied research, and so on.

The keynote speeches by Peter Ladner and Kim Pullen were particularly enlightening. Peter Ladner, a Vancouver-based columnist, provided an inspiring talk on the need for greater effort by the media, scientists, producers, and aquaculturists in general to "get the aquaculture message out" to governments and the general public. Mr. Pullen, President of the Pacific National Group spoke of the impediments to industry development in Canada, including fiscal restraints on R&D efforts and government regulatory issues. The Plenary Session was concluded when the recently appointed Minister of Fisheries and Oceans Canada (DFO), the Honourable Fred Mifflin, made an impromptu appearance and spoke briefly on recent DFO initiatives directed at assisting all aquaculture participants in Canada. Mr. Mifflin reiterated his government's commitment to aquaculture and asked participants to continue to "encourage" him in this direction.

Four special workshops were held during Aquaculture Canada '96 and all garnered considerable interest: 1) Sea Urchin Roe Enhancement, sponsored by the Canadian Centre for Fisheries Innovation; 2) Human Resources Develpment Issues, sponsored by the CAIA Sector Council; 3) Fish Health Management, sponsored by Salmon Health of CAIA; and 4) Industry-Government Liaison, sponsored by the CAIA. Useful recommendations were made at all sessions. The proceedings of the sea urchin workshop is being published in the March 1997 issue of the *AAC Bulletin.*

Student presence at the meeting was tremendous, with a record of over 20 student papers being presented. As well, the AAC was able to assist a record number of students (14) requesting travel funds to attend the meeting. Additional funding for student travel was provided by the Aquaculture Committee of the Atlantic Provinces Council on the Sciences and is greatly appreciated. Students actively participated in the smooth running of the sessions by operating the audio-visual equipment and assisting with general logistics. Finally, the first-ever AAC breakfast for students, sponsored by an industry member, Connors Bros., was a great success, and hopefully will become an annual event.

To finish on the 1996 annual meeting, I would personally like to extend my gratitude to the various meeting sponsors, supporters, donators, and organizers who provided, as always, much needed assistance for various aspects of the meeting. Organizing an event such as Aquaculture Canada '96 requires dedication and commitment from all, including many volunteers, and the AAC is indeed very fortunate to have excellent talent to draw upon.The contributions of these people are acknowledged on the inside covers of this proceedings.

In closing, I would like to thank the outgoing Board of the AAC for its tremendous assistance and support during the past year. I would also like to welcome and extend best wishes to the incoming Board of Directors under President Joseph Brown. As we approach the next millenium, I believe the AAC membership will continue to be well served. Your elected, volunteer Board of Directors will continue to aspire to the Association's objectives to foster and facilitate the development of Canadian aquaculture through education and information, as outlined in our Letters Patent.

—Cyr Couturier, President 1995-96

Aquaculture Canada '96 — A Great Meeting for Students

This year's annual meeting was particularly well attended by students from all across Canada, as well as from the United States and the United Kingdom. Thirteen students made oral presentations and another ten presented posters; many of their papers appear in this issue of the Bulletin. The AAC provided travel awards for 14 students to attend this year's meeting.

Students attending the conference commented on the high caliber of presentations, the number of contacts they were able to make with scientists, industry representatives and other students, and the warm reception they received. Connors Bros. Ltd. hosted a student breakfast providing students with an opportunity to meet and interact with each other, members of the AAC Board of Directors, and Dr. Harald Rosenthal from the University of Kiel, who made a surprise appearance. At the Student Endowment Fund BBQ, held on Parliament Hill, all those attending the conference were able to sample a wide variety of Canadian aquaculture products.

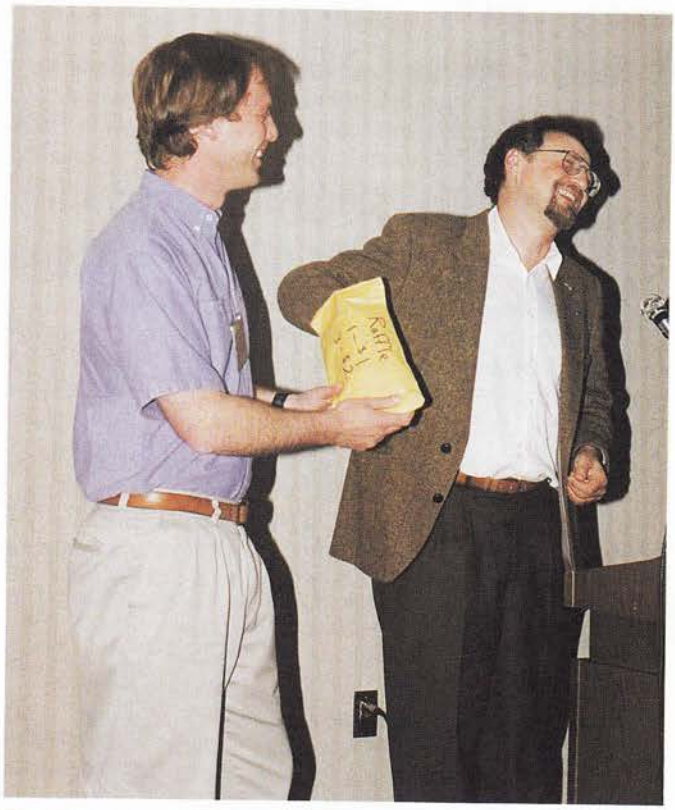
Through the generosity of Moore-Clark Co. (Canada) Ltd. and Connors Bros. Ltd., two student awards were presented at the Banquet: to Chris Oikawa of the University of British Co-

The Student Endowment Breakfast at Aquaculture Canada '96 was sponsored by Connors Bros. Ltd. Representing Connors Bros. was Bill Robertson, Director of East Coast Operations, Aquaculture Division (standing at the back on the right).

lumbia (best oral presentation) and Evelyn Stillwell of the University of New Brunswick (best poster presentation). The judges commented on the uniform excellence of all the student presentations and the difficulty in determining whose were the best.

The next annual meeting in Quebec (June 1997) promises to be even more exciting for students. The Canadian Aquaculture Industry Alliance has made a generous donation to the Student Endowment Fund to help support student attendance. We hope you will take advantage of this occasion to get involved in a great organization that offers many opportunities to students pursuing a career in aquaculture. We hope to see you there!

— Student Affairs Committee: Tillmann Benfey (Chair), Robyn O'Keefe, Melissa Rommens and Evelyn Stillwell. We can be reached via the AAC Office.



Top: Tillmann Benfey (left), Chairman of the Student Affairs Committee, with Andrew Boghen at the Aquaculture Canada '96 raffle held to raise money for the student endowment fund.

Bottom: Christine Hodgson (left), Chairman of the Student Awards Committee, presenting a certificate and cheque for $250 to Evelyn Stillwell, Department of Biology, University of New Brunswick, winner of the Best Student Poster Award. The prize was donated by Moore-Clark Co. (Canada) Ltd.

Plenary Address

The Canadian aquaculture industry: opportunities and challenges

Kim Pullen

An overview of the Canadian aquaculture industry is provided, highlighting the economic activity and employment generated by Pacific National Group as a particular example. The Canadian industry is then compared to its global competitors and the opportunities and challenges facing the Canadian industry are discussed.

Introduction

The objective of this presentation at the Opening Session of Aquaculture Canada '96 is a simple one — decision-makers need to recognize the benefits that the aquaculture industry brings to Canadians. They also need to listen to the facts about government-imposed barriers that the Canadian industry faces. Hopefully, thinking about these issues will lead someone to do something positive to help this industry reach its potential.

Canadian Industry

In 1994, total Canadian production of cultured finfish and shellfish of 54,000 tonnes was valued at close to $300 million. The majority of the production was farmed salmon from British Columbia and New Brunswick.

The Canadian aquaculture industry is tiny by world standards, representing less than 1% of world production. Canadian aquaculture products compete with other food protein sources. In North America, per capita consumption of beef and poultry far exceed per capita consumption of fish.

According to recent reports prepared for the Food and Agriculture Organization of the United Nations, growth in per capita fish consumption in North America is expected to increase gradually over the next 15 years, largely at the expense of red meat consumption. Most of the increased consumption in seafood will come from population growth. How much of this increased demand will be met by Canadian aquaculture products depends on many factors. Many of the strengths, weaknesses, opportunities and threats in the British Columbia salmon farming apply to other sectors of the Canadian industry as well.

The BC salmon farming industry

Fifteen years ago, the salmon farming industry in British Columbia produced only 100 tonnes of product. The industry has since become the largest salmon producer in North America and the fourth largest in the world, with a wholesale value in 1995 of $165 million. Over 86% of the products are exported, the major market being the United States.

For the second straight year, farmed salmon represents British Columbia's largest agricultural export and the 1995 value of BC farmed salmon was more than double the total value of the BC commercial salmon fishery.

The industry has had significant economic impact from limited land use. The total area covered by net pens from 100 active salmon

farm sites in British Columbia is smaller than the average farm in the Ottawa Valley.

The industry generated $62.7 million in wages and benefits in 1995 with over 1,100 direct jobs and almost an equal number of indirect jobs. Almost all of the direct employment has been in rural areas, with 92% of the jobs located outside greater Vancouver and Victoria. This job creation has benefited smaller coastal communities in the south coast that have experienced declines in resource industry employment.

Salmon farming in British Columbia is a very different business today than it was five years ago. The number of companies has declined from 50 to 18 and most are vertically integrated, owning their own hatcheries and farm sites. Some have their own processing facilities, transportation, marketing and distribution networks.

From this rationalization has emerged a group of professional, efficient farmers. Both Atlantic and Pacific salmon are farmed on the West Coast. Introducing an exotic species farmed successfully elsewhere and learning to domesticate a wild species has presented many challenges that the industry has been largely able to overcome.

However, the continued growth of the industry is constrained by both market and institutional factors. Markets have been exceptionally dynamic, changing from a seller's to a buyer's market. Prices are on a downward trend due to large increases in production in Norway and Chile, and increased supplies of wild salmon from Alaska.

The world's farmed salmon production is now approaching 600,000 tonnes. In 1995, the BC farmed salmon industry accounted for less than 5% of the total. Unfortunately, even this share is declining.

Pacific National Group

Pacific National Group (PNG) is a Canadian-owned salmon farming company headquartered in Victoria. It is British Columbia's largest salmon producer with 10 farm sites in Clayoquot Sound on the west coast of Vancouver Island.

PNG produces both Pacific and Atlantic salmon and is the world's largest producer of

Table 1. World production and value for farmed salmon, 1992-98

Production (dressed weight in tonnes) of Atlantic, Chinook and Coho Salmon

	1992	1993	1994	1995	*1996	*1997	*1998
Canada (actual)	28	34	33	36	39	41	44
Norwegian (growth)	25	30	37	44	53	57	61
Chilean (growth)	32	34	43	69	90	102	110
World (growth)	27	32	37	44	52	56	60

Production Value (Cdn$ Millions)

	1992	1993	1994	1995	*1996	*1997	*1998
Actual Canadian Growth	$181	$252	$229	$269	$273	$297	$314
Based on Norwegian Growth	$165	$225	$253	$324	$376	$412	$436
Based on Chilean Growth	$207	$254	$295	$508	$633	$731	$782
Based on World Growth	$176	$238	$257	$326	$368	$405	$428

* Forecast

chinook. In 1995 PNG produced about 6,000 tonnes of farmed salmon, one quarter of the Canadian industry's combined production of Atlantic and Pacific salmon. The business is highly integrated — PNG operates a large hatchery and processes and markets its own fish. PNG also has a fleet of transport trucks.

PNG employs approximately 220 people and is the largest employer in the town of Tofino, where over 100 people are employed in different aspects of the operation. Most farm managers have post-secondary degrees and have had specialized training. Output per farm employee has increased from less than 30 tonnes in 1990 to a projected 120 tonnes in 1996. Fewer and fewer processes are labour-based, and capital intensity is increasing.

Pacific National Group has a commitment to quality and has developed an intensive quality control program. Internal standards are typically higher than government regulations require. PNG has been developing its own brand image and is also supporting the generic marketing efforts of the BC Salmon Farmers' Association. Marketing is becoming increasingly important. Indeed, PNG has had to adopt more of a marketing focus as a matter of survival. An important direction for the company has been towards more value-added production. Improvements in processing and packaging technology have further developed niche markets.

Comparison of Canadian Industry to the World

The following provides an overview of how Canadian salmon aquaculture production compares to the other major salmon producing countries.

1996 Production

Norway currently produces 48% of the world's farmed salmon, while Chile has a 20% share and Canada has only 6%. Canada's proportion of world production has declined steadily the past few years.

Current levels of production are 270,000 tonnes for Norway, 111,000 tonnes for Chile and 39,000 tonnes for Canada. Norwegian and Chilean production has grown much more than Canadian production.

Value of farmed production

Norway's salmon industry is currently worth approximately $2 billion and is estimated to directly and indirectly support 40,000 people. Chile's production is about $780 million, while Canada's production is approximately $273 million

Growth in value from 1992 to 1996

Over the period of 1992-96, the Norwegian industry had increased in value and production from $835 million to $1.9 billion, while Chile's production increased from $256 million to $780 million. Growth in value of Canada's salmon has only been from $181 million to $273 million. For the three years 1993 to 1996, growth was a mere $21 million.

Value of lost growth

What would have been the value of Canadian production in 1996 had it grown at the same rate as other countries? If it had grown at the same rate as Norway, the value and production would have been $376 million and 53,000 tonnes. Growth at the same rate as Chile would have produced $633 million and 90,000 tonnes. And based on the increase in world average production, Canadian production would have been $368 million and 52,000 metric tonnes. For a comparison of what the value would be in 1998 if growth had continued, see Table 1.

The BC salmon farming industry currently operates on just 70 hectares of water tenure, an area about one-sixth the size of Stanley Park. Compared to the present area of crown land under tenure, salmon farms represent only 1.7%. If the industry could expand its operating tenure area to the size of Stanley Park (i.e., 425 hectares), it could generate over $1 billion in revenue and over 15,000 new jobs on Vancouver Island. With these new jobs, wages and benefits paid by industry would be $450 million compared to the current $62 million. Exports could generate over $800 million of foreign exchange annually.

Available coastlines

Canada has a coastline of 66,000 km, three times that of Norway (22,000 km) and ten times that of Chile (6,400 km).

Barriers to Growth

Market forces

Salmon prices have been falling and profits have been squeezed. Industry has to take action to expand demand. This will be achieved by moving to consumer-friendly, value-added products, and to more cooperative generic marketing campaigns.

Access to capital

The climate in British Columbia is not conducive for investors, banks or the public.

Fish stocks

The salmon industry must have access to the best stocks available. Unfortunately, access to these stocks has been a problem. For Atlantic salmon, the *Fish Health Protection Regulations* and the *Manual of Compliance* are so complicated that they are impossible to work with.

There has been had reasonable success with chinooks, however this now appears to be over. PNG is currently attempting to develop a new chinook stock. Thirty-four females and 20 males were captured from a northern tributary of the Fraser River. These fish have a commercial fishery value of approximately $70,000. PNG will spend approximately $400,000 on the development of stock generated by those fish and is now being told not to expect those fish in the future.

Tenure

The attitude of the current provincial government has been to severely restrict crown land under tenure for salmon farming. There are two problems with tenure:

- *No security of tenure.* A business cannot expand when it does not know if it will even be there tomorrow,
- *No new tenures being given out.* There will be no expansion through new sites, no production gains, and no ability to fallow sites. Hence, there will be greater losses to disease, more therapeutants, and bad publicity.

People

As a country, Canada has a highly educated workforce. Good people are needed to develop this industry in the best possible way. Good people will not be attracted if the industry appears to have no future.

Research and development

The industry has not been able to achieve a critical mass so there is little incentive for suppliers to research and develop new products or systems. As there are fewer government dollars available than in the past, there needs to be a coordinated approach to research and development whereby funds from both government and industry are pooled and strategically invested.

Conclusion

Government must devote greater energy towards working with industry. There must be more open dialogue with the purpose of effecting change. Dealing with government is often difficult. Dealing with two levels of government is often impossible. Many times issues fail to be resolved because of positioning — parties refuse to move even if they see the merits of the other side's position. Dealing with government is like dealing with an iceberg; it is the 90% you can't see that causes you problems.

A new strategy of working together must be developed. Perhaps the automotive industry provides the example. Designing a car used to cost billions and took many years, often ending with an inferior product. The root of the problem was positioning by the various groups involved. The industry moved to a team approach, whereby representatives from the engineers, the stylists, and the marketers were forced to work together from the beginning. The team had a leader with the ability to make decisions and effect change.

That is what is needed for the salmon aquaculture industry: a team approach and a team leader.

Kim Pullen is President of Pacific National Group, 350 Glanford Ave., Victoria, BC, Canada V8Z 4B9.

Keynote Address

It's time to get this story out

Peter Ladner

The aquaculture industry is currently faced with many negative perceptions that need to be actively addressed. The truth of aquaculture's importance will come out, for the benefit of the industry is too big to ignore.

Introduction

My presentation at this opening session of Aquaculture Canada '96 will address how I see this industry has been undersold and unfairly attacked. I will also be passing on some generic advice from Peter Sandman on mending fences and some suggestions for getting the real story out. I will use the salmon industry in British Columbia for examples because it is what I know best, but the comments are relevant across Canada.

Positives and Negatives

In its favour, the aquaculture industry has many positive features. Eighty-five percent of production is exported. Aquaculture has proven world-wide, seasoned investors waiting. It provides jobs in beleaguered coastal communities and has economic clout. It is a high technology, low polluting, and sustainable industry. Compared to the wild salmon fishery, it's virtually self-supporting.

In aquaculture's disfavour are negative perceptions. There is fear and uncertainty about contamination of wild stock through disease or cross-breeding. It tampers with Nature, sinning in the Garden of Eden. It threatens the wild fishery because it competes in the market, lowers prices, weakens political pressure for constant subsidies, and provides an alternative. Its self-sufficiency and new areas of knowledge threaten public service jobs. It is such a new industry that there is lots of ignorance and there is little base-line data to make research conclusions.

The industry is also a victim of skewed public priorities. This is not unique to aquaculture. For example, AIDS research gets far more research money per person afflicted than any other disease because its supporters are active. The pulp industry is forced to spend billions to eliminate dioxins while governments build more highways for cars that cause immense pollution.

Perception is a function of the rural-urban split — nobody gets excited about a forest that's cleared for a field or a factory, but if it's cleared for another harvest, it's somehow tarred as a despicable clear-cut. Farmers understand these issues.

However, there is a real danger for government to continue to be part of the problem constraining aquaculture growth. When the scales come off the public's eyes and they realize that they have lost jobs and dollars for no good reason, they will be blaming with a vengeance. A point to remember — all the diplomatic firepower spent in the Alaska fish dispute of last summer concerned the same volume of fish produced in one decent salmon farm.

Risk and Perception

So why does perception get so out of line with risk? Peter Sandman gives the following model:

RISK = HAZARD + OUTRAGE

The public responds to outrage, not hazard. Outrage against aquaculture is fueled by detractors in the wild salmon industry, by environmentalists, and by public servants with a vested

interest in traditional commercial fishing. Outrage is created by a lot of general factors related to activities. Unfortunately most of these do not work in aquaculture's favour.

Voluntary vs. coerced activities — people voluntarily get in a car despite the real risk of accidents, but what happens to salmon stocks is out of their control.

Natural vs. industrial — a flood or earthquake is disastrous, but industry is seen as tampering with nature.

Familiar vs. exotic — few people understand how the aquaculture industry works because it is remote.

Not dreaded vs. dreaded — people dread the disappearance of the wild salmon.

Chronic vs. catastrophic — incremental pollution from toilets and storm drains adds up gradually while disappearance of the wild salmon stock occurred suddenly.

Morally irrelevant vs. morally relevant — you're sinning by tampering with Nature.

Trustworthy sources vs. untrustworthy sources — it is the private operator's word against government or environmentalists.

Reducing outrage

To reduce outrage, the aquaculture industry can take a variety of actions. Stake out the middle ground. Acknowledge prior mistakes repeatedly. Acknowledge current problems dramatically, including uncertainties as this will give your denials credibility — what is the real story about antibiotics? spoiled views? Discuss achievements with humility, attribute your achievements to pressure from others. Keep giving government regulators credit for keeping fish farms safe. Put the control elsewhere — let regulators, neighbors, community advisory panels and activists certify your good performance. Don't be afraid to bring concerns to the surface. Keep expansion scale reasonable and pay costs of monitoring. Think of ways to negotiate compensation.

Do research on public spending per pound of farmed salmon compared to wild salmon. Sell the savings to taxpayers. Remember that the prime medium for political discourse these days is the TV ad. If your message won't fit on a bumper sticker, it won't sell. Play up the industry's role as job-creator. Get in the political game. Sell industry as a solution to the dislocation tragedies in the wild fishery and to unemployment insurance cutbacks. Push hard for at least a mention in the preamble to the new Fisheries Act. Get candidates for public office on the record about their support for your industry. Guarantee vocal public support for government decisions in your favour.

Build alliances with your detractors around common enemies. With environmentalists focusing on pure water, position yourselves as environmentalists, just as the forest industry is trying to position itself as preserver of fish stocks by studying over-fishing. Team up with environmental groups to promote cleaner water, especially for shellfish farms. Form joint ventures with Natives, creating jobs for them. Help promote river-mouth trapping. The common bond is saving the public the cost of the chase. With the sport fishery both you and they have an economic argument about your higher value/lower public cost compared to the capture fishery. Shoreworker unions need jobs to replace UI. Government scientists want positive results and much-maligned public servants need a good news story for their political masters to spread.

Think of a way to showcase departing investment capital — the mining industry named former BC premier Mike Harcourt as Chilean mining man of the year. Attracting job-creating investment is as holy as creating jobs. Get new data — how many people really mind looking at a salmon farm in a scenic corridor? Play the media gimmick game — mail a little package of composted waste to news media and MLAs on Earth Day. Put legitimate third-party scientific spokespeople to work for you. Get on the internet, play all the modem games.

Conclusion

The benefits of aquaculture are easily big enough to roll over these temporary setbacks. I believe that the truth will come out.

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Comparison of routine oxygen consumption rates of three species of pleuronectids conducted at three temperatures

Paul F. MacIsaac,[1,2] *Gregory P. Goff,*[1] *and David J. Speare*[2]

The oxygen consumption of three species of pleuronectids, the yellowtail flounder, *Pleuronectes ferruginea*, the winter flounder, *P. americanus*, and the American plaice, *Hippoglossoides platessoides,* were studied under simulated, land-based aquaculture conditions. Routine oxygen consumption (ROC) rates for groups of each species were measured simultaneously using single pass flow-through respirometry. The initial comparison of these species indicated significant differences in routine oxygen consumption among species. The measurements were repeated at three temperatures: 2°C, 11°C and 14°C. The ROC rates of both yellowtail and winter flounders differed significantly at each temperature. ROC rates of American plaice were significantly different at 14°C compared with the other two temperatures.

Introduction

All except the smallest of the numerous flatfish species around the world are used as food, and many are exploited commercially and marketed internationally. Some species are already used in aquaculture.[3] Among the pleuronectid species of the northwest Atlantic, yellowtail flounder, winter flounder and American plaice are being studied for their aquaculture potential. Knowledge of the aerobic demands of these flatfish is prerequisite to development of successful culture technologies.

Respirometry, which measures oxygen consumption, is an indirect method of determining aerobic metabolism.[4] Oxygen is a major requirement in intensive rearing operations,[5,6] but the aerobic demands of many species under culture, including flounder, are not fully known. Such information will help determine the feasibility for aquaculture of these species.

The state of activity must be clearly defined when determining oxygen consumption of fish.[4] There are three general metabolic states — standard, routine, and active. Standard activity reflects a non-reproductive, post-absorptive, resting fish. Fish reach the active state when stimulated to sustained swimming, reflecting [a] maximum rate of oxygen consumption. Routine activity reflects the basic daily requirements of an animal to survive through a 24 hour cycle, and hence routine oxygen consumption (ROC) is the most appropriate scale of activity for the purposes of aquaculture.

Our objective for this research was to collect basic measurements of oxygen consumption in groups of flounder under simulated land-based aquaculture conditions. We wanted to compare the oxygen requirements of three different pleuronectid species over a range of culture temperatures.

Methods

The three species of flatfish used in this study, yellowtail flounder *(Pleuronectes ferruginea)*, American plaice *(Hippoglossoides platessoides)*, and winter flounder *(Pleuronectes americanus),* were collected by otter trawl aboard the research vessel *W.B. Scott* in Passamaquooddy Bay, New Brunswick. Collected fish were habituated in 3 m diameter tanks at the

Huntsman Marine Science Center, St. Andrews, N.B., for a period of one month. Feeding began following the first two weeks of habituation.

Fish were moved to 1 m diameter staging tanks, identical in size to the respirometer tanks, 48 hours before the initiation of an experiment. Fish were subsequently transferred to the respirometer tanks where they remained overnight prior to collecting oxygen consumption data during a 24-hour period.

The respirometers were constructed using a single-pass, flow-through design. Dissolved oxygen concentrations were measured continuously in both the inlet water supply line and the outlet drain pipe of each respirometer. Flow rates were measured. The difference in oxygen concentrations, flow rate, and biomass of fish in the tank were used to calculate the rate of routine oxygen consumption.

The sizes of the experimental fish are in Table 1. A stocking density of 3 kg/m^3 (1 kg/m^2) was selected. A 3 by 3 Latin Square experimental design ensured that each group of fish was tested in each respirometer, thereby accounting for any inherent tank effects. A 3-way ANOVA was used to analyze the factors: species, temperature, and replicate, with a tank factor nested in replicate.

Results

ROC values for the trials ranged from 40 to 292 mg O_2/kg/hr (Table 2). The interaction between temperature and species had a significant effect on routine oxygen consumption ($p < 0.05$). As a result, one way ANOVAs were performed for individual temperature experiments.

At 2°C, species had a significant effect on routine oxygen consumption. A Student Newman Kuels (SNK) non-parametric test of the means indicated the three species were significantly different ($p < 0.05$) from each other.

At 11°C, rates varied significantly ($p<0.05$) among species. A SNK test also indicated significant differences ($p< 0.05$) among all species.

At 14°C, rates again varied significantly (p<

Table 1. Sizes of fish used at all three temperatures in the respirometry study.

Species	Average fish mass (g)	Weight range (g)	Average density (kg/m^3)
American plaice	166	50-370	3
Winter flounder	150	60-240	3
Yellowtail flounder	176	52-410	3

Table 2. Mean routine oxygen consumption rate (± s.d.) in mg O_2/kg/hr for the American plaice, winter flounder and yellowtail flounder measured at three temperatures in respirometers simulating an aquaculture tank environment.

Species	Temperature		
	2°C	11°C	14°C
American plaice	73 ± 25	67 ± 45	129 ± 62
Winter flounder	63 ± 30	220 ± 70	118 ± 41
Yellowtail flounder	40 ± 19	292 ± 85	91 ± 19
Sample size (N)	479	546	444

0.05) with species; all species were significantly different ($p < 0.05$) according to a SNK test of the means.

A separate series of 1-way ANOVAs tested the effect of temperature within species. The ROC rates of both the yellowtail flounder and the winter flounder were significantly different ($p < 0.05$) at all three temperatures. The ROC rates of the American plaice was significantly different at the high temperature (14°C) as compared to the other two temperatures.

Discussion

The objectives of this study and the general behaviour of these flatfish in tanks dictate that we select routine metabolism to assess normal oxygen requirements during culture conditions. Routine metabolism was the most interpretable mode of activity and using routine metabolic rates with groups of fish is a realistic method to estimate production requirements of fish in land-based aquaculture.

The rates determined in this study are similar to those determined for another species of pleuronectid, the Atlantic halibut.[7] Our data contained more variance because our study was conducted over a larger temperature range. The ROC rates we measured for flounder were far less than those determined for salmon measured under land-based conditions and over similar temperature ranges.[5] The maximum value for any of the flatfish species reported in this study are similar to the minimum values reported on salmon.

Both the yellowtail flounder and winter flounder displayed increasing routine oxygen consumption rates up to 11°C. Increasing respiration has been previously related to increased growth rate over optimal temperatures in flatfish.[8] Growth rate was greater in winter flounder at 15°C than 5°C.[9] It has also been related to the oxygen saturation level in the water supply.[10] The optimal temperature range of these northwest Atlantic pleuronectid species ranges from approximately 1.5°C to 12.2°C[11] which overlaps the 11°C temperature where we measured the highest oxygen consumption rates. The reduced oxygen consumption rate observed at 14°C suggests sub-optimal metabolism at elevated temperatures.

The optimal temperature range of American plaice ranges from below zero to 1.5°C,[11] which may explain why the low routine oxygen consumption rate never rose to the same level as the other two species. Their increased consumption rate at 14°C is more difficult to explain and requires further evaluation.

Observations of both American plaice and the yellowtail flounder in separate tanks throughout these experiments indicated that they had distended stomachs associated with feeding activity during low temperature periods. The winter flounder displayed minimal activity and had concave shaped stomachs at the cold water temperatures. Winter flounder have been reported to decrease feeding activity seasonally at temperatures below 5°C.[9]

The single pass, flow-through respirometry technique developed here is a valuable tool which can answer many questions on the requirements of these species in land-based aquaculture. Objective comparisons among species are facilitated under standard conditions. Estimates of the requirements of fish in groups are obtained. These results provide an appropriate estimate of the oxygen requirements of these fish in an aquaculture setting. The generation of this kind of data is a critical prerequisite both to determining a suitable species to culture and to evaluating other aspects of culture including the oxygen consumption of flounders during feeding and at increased stocking densities.

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A preliminary investigation of food and feeding requirements of striped wolffish, *Anarhichas lupus*

Sherra Tulloch,[1] *Stephen Goddard* [1]
and John Watkins [2]

Dietary energy balance and practical feeding regimes were examined for juvenile striped wolffish. Six extruded, isocaloric feeds were prepared with protein energy to total energy ratios (PE:TE) ranging from 0.33 to 0.58. Highest specific growth rates (SGR) and lowest food conversion ratios (FCR) were recorded for groups of fish fed diets with PE:TE between 0.4 and 0.5. A range of stocking densities and feeding schedules were also examined. Within the range of stocking densities tested (up to 80 g/L) no significant differences were observed in growth. In relation to the range of feeding frequencies tested, no significant differences were observed in either SGR or FCR. These results reveal tolerance to high stocking density, and show that food can be offered every other day without any significant reduction of either growth or food conversion.

Introduction

The striped wolffish is a cold-adapted marine species being investigated for its culture potential in Norway and Newfoundland.[3] Optimum temperature for culture is reported to be between 7°C and 9°C.[4] Wolffish display additional traits advantageous to aquaculture. They produce large eggs that hatch at an advanced stage of development, and are more fecund than Atlantic salmon, producing in excess of 2000 eggs per kilogram of fish. Results from rearing experiments have shown high growth rates at low temperatures and tolerance of high stocking densities.[4]

Most feeding studies on wolffish have been conducted on newly-hatched larvae.[5] The dietary requirements have yet to be examined, but commercial salmon diets have been widely used for feeding both juveniles and adults.[6] Our own observations of wolffish, fed exclusively on salmon diets, have revealed abnormally fatty livers.

This study was undertaken to examine the growth and liver indices of juvenile wolffish fed isocaloric diets with a range of protein energy: total energy (PE:TE). As an additional component of the study, observations were also made on the effects of stocking density on feeding, and feeding frequency on growth and food conversion. These are critical factors affecting production costs.

Materials and Methods

Juvenile wolffish (7.5 to 9.0 g), reared from egg masses collected in Conception Bay, Newfoundland, were used in the experiments. The feeding and growth trials were conducted in 4-L and 7-L tanks supplied with recirculated seawater at constant temperature (9°C ± 0.5). The dry extruded diets used were based on a commercial salmon feed modified to give six PE:TE values: 0.33, 0.36, 0.41, 0.42, 0.49 and 0.58. Fish were fed to apparent satiation twice a day, and records kept of food amounts ingested. For the purposes of these experiments, apparent satiation was taken as the point when fish ceased to orient towards or approach pellets when presented. In the feeding frequency trial, groups of fish were

fed twice per day, once per day and once every two days. Three initial stocking densities were tested, 20, 50 and 80 g/L. All treatments were in triplicate and fish were sampled for weight and length at 28-day intervals.

Mean consumption rates, specific growth rates, food conversion ratios, protein efficiency ratios, condition indices and hepato-somatic indices were tested for significant differences using a 3-way ANOVA. Tukey's B Test was then used to determine significance. All percentage data was arcsine transformed prior to analysis.

Results and Discussion

The food ingestion levels for diets with PE:TE of 0.33 and 0.36 were significantly higher than the ingestion levels of fish fed diets with PE:TE of 0.49 and 0.58.This may have been due to the attractant effects of the higher lipid content. When a comparison was made among daily protein consumption rates, fish fed the PE:TE of 0.33 diet ingested significantly less protein than the fish fed the diet with PE:TE of 0.58. The specific growth rates for the fish fed PE:TE of 0.33 was significantly lower than that of fish fed PE:TE greater than 0.40, while the SGR for fish fed PE:TE of 0.36 was significantly lower than for fish fed PE:TE of either 0.42 or 0.49. Fish fed low-protein diets (PE:TE less than 0.36) do not appear to consume sufficient protein to match the growth rates of those fed diets with PE:TE greater than 0.40. Feed conversion ratios among all treatments were consistent throughout the trial, showing neither significant difference nor obvious trend. Measurements of the hepatosomatic index (HSI) revealed no significant trend as the lipid content of the diets increased. HSI values ranged from 3.2% body weight to 4.6% body weight in fish fed diets of PE:TE 0.36 and 0.41, respectively. This range is smaller, yet comparable with the range of 2.11 to 7.2% body weight recorded from cod fed on artificial diets.[7] Dietary lipid levels used in the test diets ranged from 11.9 to 17.0% dry matter. This may have accounted for the observed range of HSI values.

Statistically significant differences in mean consumption levels between feeding regimes were found at each stocking density (Fig. 2). The amount of food consumed at each meal was highest in fish stocked at 50 g/L. Highest consumption levels in fish fed twice daily, however, were observed at a stocking density of 20 g/L. More frequently fed fish, as expected, consumed smaller meals than those fed less often. Comparisons over time indicate that fish fed twice daily consume significantly more feed than fish fed once every second day. No significant differences in specific growth rates were

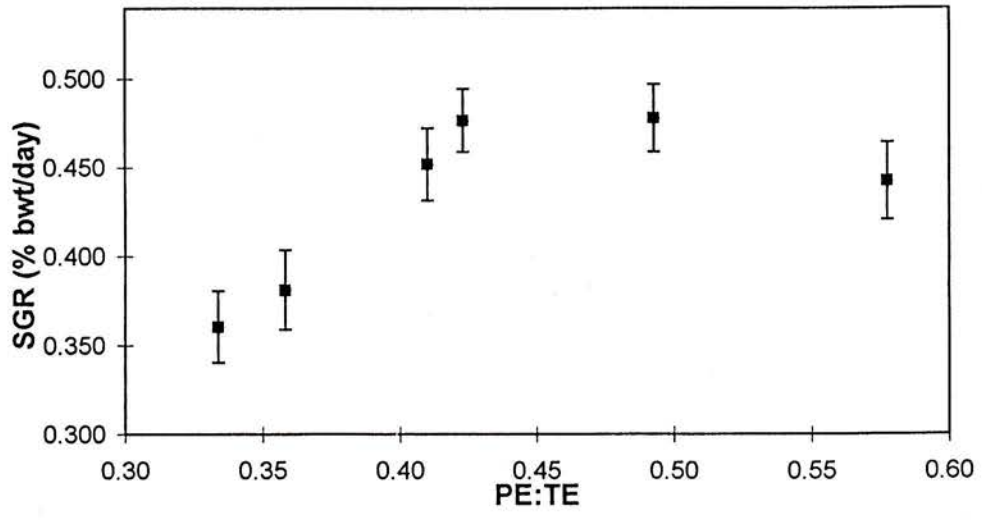

Figure 1. Mean specific growth rates (SGR) for juvenile wolffish fed diets with different protein:total energy ratios (PE:TE). Mean SGR ± standard error.

attributable to differences in either feeding schedule or stocking density. Feed conversion ratios were analyzed to account for the lack of variation in the specific growth rate. Feeding schedules did not have a significant effect on the feed conversion ratio, but the FCR decreased significantly as the stocking density increased. Fish fed once every two days swam to the water surface whenever technicians approached the tank, whether or not feed was offered. Fish at the lowest stocking density rarely approached the surface. Swimming was only observed when fish approached feed pellets or displayed aggressive behaviours. This aggressive behaviour was most evident in fish held at the lowest stocking density. Juvenile wolffish displayed good growth at 80 g/L which continued to the maximum observed stocking density of 105.8 g/L. This observed tolerance of high stocking densities indicates the potential of the species for highly intensive culture methods. Considerable cost savings can be realized by feeding the fish every second day. Fish consume less feed without compromising growth while the labour costs associated with feeding are reduced.

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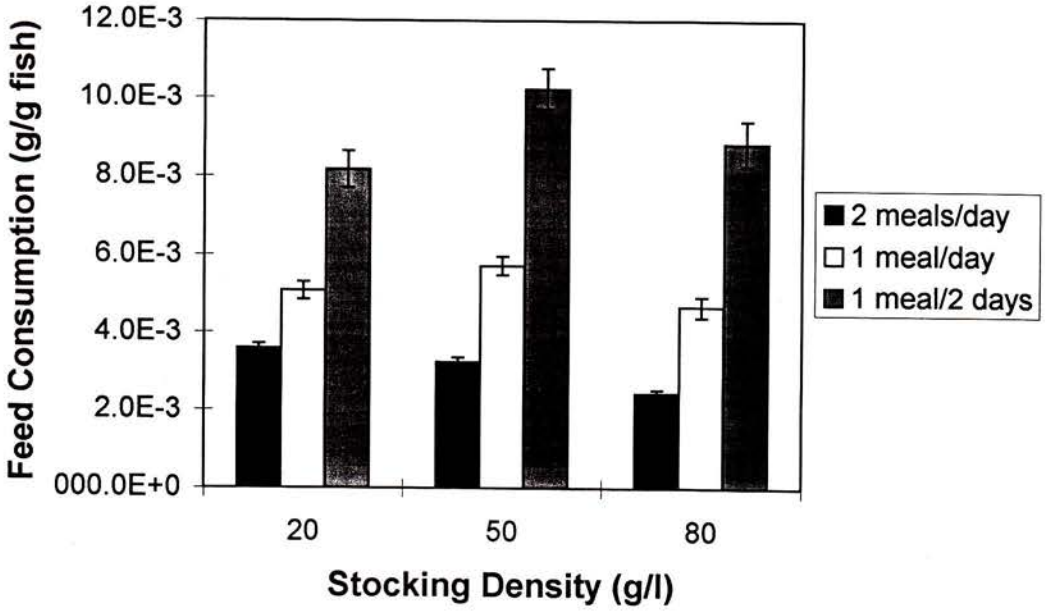

Figure 2. Comparison of mean amounts of food consumed per meal by juvenile wolffish held at three different stocking densities and fed at three frequencies. Mean value ± standard error.

Development of winter flounder *(Pleuronectes americanus)* for aquaculture: State of the art

Matthew Litvak [1]

Recently, the Canadian salmon industry has seen an increase in international competition that has lowered the price of Atlantic salmon (*Salmo salar*). Compounding this situation are losses of fish due to epizootic outbreaks and winter-kill. To ensure continued growth and health of the aquaculture industry in Atlantic Canada, aquaculturists need to diversify their product lines and develop additional species for culture. Specifically, there is a need to find other valuable species that adapt well to culture conditions, grow fast, and are tolerant of the low seawater temperatures in the region. Fish ecologists/aquaculturists are provided with the task of identifying and developing appropriate candidates for the industry. Here, I discuss recent advances and challenges that lie ahead in the development of winter flounder for aquaculture. In particular, I will focus on the development of techniques and technology for larval rearing and juvenile on-growing.

Introduction

The Canadian Atlantic aquaculture industry has seen impressive growth over the past 10 years. In order to ensure its continued growth there is interest in increasing the number of finfish species cultured in the region. Winter flounder is one of the species that has been identified as a candidate for aquaculture in Atlantic Canada. It is a highly valued species along the eastern seaboard of North America.[2] Winter flounder is a hardy fish, possessing antifreeze proteins that allow it to withstand seawater temperature below –1.0°C.[3,4] This hardiness and resistance to cold temperatures may allow for an expansion of the number of sites suitable for culture along the Canadian coast. Here, I report on the development, current hurdles and the potential of winter flounder as a fish for culture in the region.

Markets

Of the small flounders, winter flounder has the thickest fillet.[5] Winter flounder are sold as the smaller blackback or the larger and more valuable lemon sole. There is a common misconception that lemon sole are caught only on Georges Bank, possibly due to the fact that a high proportion of winter flounder caught on the Bank are large. In reality, the price distinction is not made on the basis of place of capture, but on the size of the fish.[5] In addition to these historical fillet/fish markets there is also potential for development of the high-value live-fish market, particularly in light of winter flounder's durability.

Research Strategy

Development of a new species for aquaculture, particularly r-selected marine species (many small eggs), can be a challenge. In order to identify these challenges it is best to identify key moments in the life history of the fish (Fig. 1). In most marine fish species that have small eggs, the major bottleneck has been survival to the juvenile stage. However, as I will outline, we have negotiated many of the hurdles for early rearing of winter flounder and only a few biological problems remain.

Basic biology

Winter flounder is one of the most researched marine species in North America. They are fecund, with a female producing up to 3.5 million eggs.[6] They are different from most flounders in that they produce eggs that are demersal and adhesive. Smigielski and Arnold [7] developed a dry fertilization protocol that prevents eggs from clumping. Eggs take approximately 7-14 days to hatch depending on temperature (12°C to 8°C). After hatching, larvae can be placed directly into larval rearing tanks.

Early rearing

My laboratory uses a system based on an upwelling cylindroconical tank. I chose to develop this upwelling design to help larvae and food maintain position in the water column. There are two advantages:1) negatively buoyant food will be suspended for a longer time in the water column; and 2) larvae can allocate more energy to growth because they receive a lift from the upwelling flow. Larvae reared in this system tend to reach metamorphosis at about 30 days of age at 10°C.

Recently, I ran an experiment to determine the photoperiod that promotes the highest survival and growth. I found that a continual light regime led to a 5-fold increase in survival over the natural photoperiod (50% survival versus 10% survival). Not only did constant light lead to a greater number of larvae reaching metamorphosis, but the larvae also grew faster. Significant

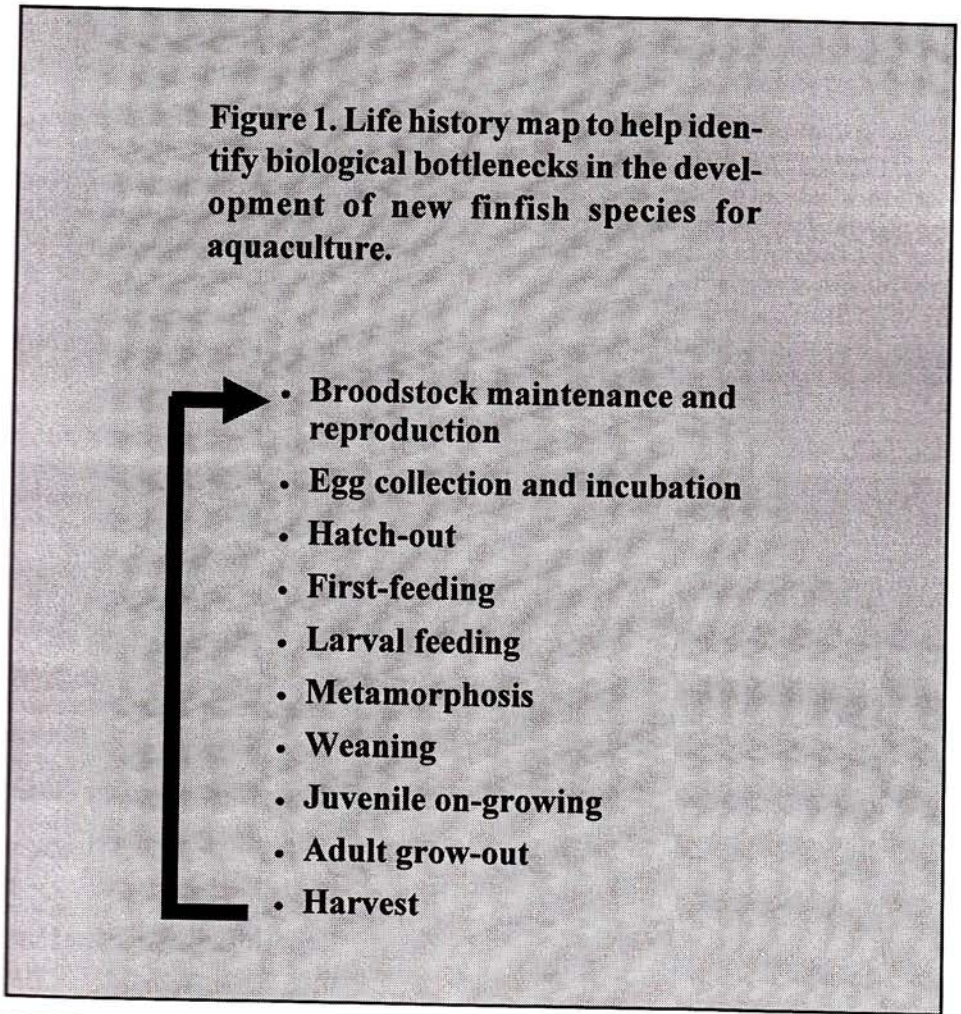

Figure 1. Life history map to help identify biological bottlenecks in the development of new finfish species for aquaculture.

differences in larval size between the two treatments were noted after only five days. Larvae grown in continuous light metamorphosed four days sooner than larvae grown under ambient photoperiod (10% faster). The use of constant light also allows for more effective use of production units.

Food and feeding

It is extremely important to determine the best food type and feeding regime, not just in terms of fish growth, but also in terms of economics. Previously, we fed larval winter flounder TISO (Tahitian strain of *Isochrysis galbana*), trochophores, rotifers and *Artemia*. With this regime, 40-60% of larvae reach metamorphosis. However, live food production is time consuming, occupies available space, and increases the amount of labor required for production. We ran a series of experiments to assess the importance of different food combinations on growth and survival of larval winter flounder. Results analyzed to date suggest that survival is not influenced by the presence of trochophores. The highest larval survival was with diet combinations that included rotifers. These data suggest that we can eliminate trochophores from the feeding regime of winter flounder larvae.

Larvae and recently metamorphosed fish are removed from larval rearing tanks after approximately 30-35 days (depending on seawater temperature). Recently metamorphosed winter flounder can be weaned to prepared diets in one week.[8] Lee and Litvak[8] found there was no difference in growth between recently metamorphosed juveniles fed Nippai (Catvis, The Netherlands) and Corey Hi Pro commercial feed (Corey Feed Mills, Fredericton, N.B.). This suggests that winter flounder juveniles may be grown on inexpensive, locally available feed.

Grow-out

There are many possible avenues for grow-out of these fish. Mr. John Mallock, Harbour De-Loutre, Campobello, adapted a Malloch collar for winter flounder. He made a solid bottom out of wood and plastic-coated weld-mesh. Winter flounder grew well in his cage. However, the chosen strategy for grow-out will be conditioned by the economics of each grower's situation. Winter flounder are sufficiently adaptable that they may be cultured under a wide variety of conditions. Extensive, pond-style systems and high intensity land-based tanks are among the many possible grow-out strategies. Submersible cages may also be a viable option. They have the advantage of putting the fish close to the environment in which they normally live and are also safer when seas become rough. In addition, in terms of shared resources, submersing a cage is not as obtrusive as a floating cage.

Future Work

Development of on-growing tanks and establishment of optimum stocking density, temperatures and diets for juvenile winter flounder are key to the further development of winter flounder. It is also important that we examine the characteristics of the different stocks of winter flounder. Are differences seen in growth rates among flounder from different regions environmental or genetic? If genetic, can we develop strains of faster growing winter flounder from known stocks?

The development of protocols for growing winter flounder in a culture situation has reached the stage that it can and has been transferred to industry. Currently, there is enough known about winter flounder that we are ready for a pilot-scale attempt at hatchery, on-growing and grow-out phases. This pilot information is key to the further development of this species for aquaculture.

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Weaning of Atlantic cod *(Gadua morhua)* larvae onto a commercial microparticulate diet

B. Baskerville-Bridges and L. J. Kling

Successful culture of many marine species has been impeded by high mortality during the early life stages. Live feeds have consistently resulted in superior growth and survival in larval feeding trials when compared to microparticulate diets (MPD). The purpose of this study was to introduce a commercially available MPD to Atlantic cod (*Gadus morhua*) larvae at different weaning times to determine how early it could effectively replace live feed organisms.

Fertilized cod eggs were received from the National Marine Fisheries Service at the Narragansett lab in Rhode Island. They were disinfected upon arrival and incubated between 6-8°C. Continuous aeration was applied to provide motion of the eggs within the experimental tanks. One day prior to hatch the eggs were again disinfected, measured volumetrically and moved to individual 22–L rearing tanks. Two days post-hatch, unhatched eggs were enumerated to calculate hatchability which was greater than 94%.

Each tank was stocked with approximately 3454 larvae (157 larvae/liter). At first feeding (3 days post-hatch), the temperature was increased by 1°C/day until 10-11°C was achieved. The lighting was also increased from 0.3 lum/ft^2 to 0.6 lum/ft^2 at this time. The cod larvae were kept on a 24 hr light/0 hr dark photoperiod throughout the study. Flow rates were initially 70 mL/min, but were increased to 200 mL/min to maintain good water quality.

The microparticulate diet was given to the cod larvae at four different weaning times. In treatment 1, rotifers, *Artemia*, and the MPD were introduced at day 3, 22, and 36 respectively. The diets were co-fed for 8 days. In treatment 2, rotifers were added at day 3, *Artemia* at day 22 and the MPD at day 29. In treatment 3, rotifers were added at day 3 and the MPD was introduced on day 22. In treatment 4, larvae received rotifers at day 3 and the MPD was introduced on day 11.

Twenty larvae from each of the 16 tanks (n=4) tanks were sampled on 0, 3, 11, 22, 29, 36, 43, 50, 57, 64, 71, and 78 days post-hatch. Images of the larvae were saved for length measurements. Larvae were then frozen for dry weight and fatty acid analysis. Histological samples were also taken from each treatment after introduction of the MPD to determine digestibility of the diet. At the end of the experiment larvae in each tank were counted and survival was calculated.

In all treatments, the larvae accepted the MPD shortly after introduction and the MPD was able to support growth up to metamorphosis. Atlantic cod can be successfully weaned on to a MPD as early as 11 days post-hatch, however survival was greatest when introduced on day 36.

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Rearing of cod larvae up to metamorphosis at high stocking densities in a closed recirculating system using artificial seawater

B. Baskerville-Bridges and L. J. Kling

Atlantic cod (*Gadus morhua*) can be successfully reared with small tanks in a recirculating system using artificial seawater. In addition, good survival was achieved using two high larval densities which may be desirable for commercial culture. Fertilized cod eggs were received from the National Marine Fisheries Service at the Narragansett lab in Rhode Island. They were disinfected upon arrival and incubated between 6-8° C. Continuous aeration was applied to provide motion of the eggs within the experimental tanks.

One day prior to hatch the eggs were again disinfected, measured volumetrically and moved to individual 22–L rearing tanks. The tanks were part of a 7500–L closed recirculating system containing artificial seawater. Two days post-hatch unhatched eggs were enumerated to calculate hatchability which was greater than 94%. Treatment 1 tanks (n=4) were stocked with approximately 3454 larvae (157 larvae/liter). Treatment 2 tanks (n=4) were stocked with approximately 6909 larvae (314 larvae/liter).

Water flow was adjusted during the experi-

ment to ensure low ammonia levels (varied between 70-200 mL/min). Water temperature was increased at a rate of 1° C/day until 10-11°C was reached. Lighting was increased at first feeding from 0.3 lum/ft^2 to 0.6 lum/ft^2 with a 24 hr light: 0 hr dark photoperiod. Larvae were offered enriched (DHA-Selco) rotifers three days post-hatch and *Artemia* were introduced on day 22. On day 36 they were gradually weaned onto a commercial microparticulate diet (BioKyowa). Twenty larvae from each tank were sampled on days 0, 3, 22, 36, and 44 for length and weight determination. At the end of the experiment larvae in each tank were counted and survival was calculated.

Good survival was observed at both density levels. Survival of cod larvae was higher in treatment 2 tanks (43.3%) as compared to treatment 1 tanks (29.8%). This study verifies that cod can be reared at high stocking densities up to metamorphosis in a closed recirculating system using artificial seawater.

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Importance of motion during incubation and early rearing for cultivation of Atlantic cod (*Gadus morhua*) larvae in a closed recirculating system

B. Baskerville-Bridges and L. J. Kling

Continuous motion within the tank influences viability of Atlantic cod (*Gadus morhua*) eggs and survival of the larvae. Fertilized cod eggs were received from the National Marine Fisheries Service at the Narragansett lab in Rhode Island. They were disinfected upon arrival and incubated between 6-8° C. Continuous aeration was applied to provide motion of the eggs within the experimental tanks. The control tanks initially received no aeration, but aeration was adjusted as needed to maintain equivalent dissolved oxygen levels; motion was negligible in these tanks throughout the experiment. Eggs incubated with low aeration tended to aggregate and acquired an opaque shell membrane that appeared pitted, resulting in poorer hatch rates. Eggs incubated with high aeration maintained a clearer translucent shell membrane and were free floating throughout incubation,resulting in more viable eggs.

One day prior to hatch the eggs were again disinfected, measured volumetrically and moved to individual 22 L rearing tanks. Two days post-hatch unhatched eggs were enumerated to calculate hatchability which was greater than 94%. Each tank was stocked with approximately 3454 larvae (157 larvae/liter). In control tanks (n=4) low aeration (75 mL air/min) was employed, which did not inhibit movement of the cod larvae. In treatment 2 tanks (n=4) however, aeration was sufficiently high (350 mL air/min) to continuously move them throughout the tanks; larvae were unable to swim against the current. Oxygen levels within both treatments were equivalent and were maintained above 8 ppt.

Flow rates were initially 70 mL/min, but were increased to 200 mL/min to maintain good water quality. Water temperature was increased at first feeding by a rate of 1° C/day until 10-11°C was achieved. At this time lighting was also increased from 0.3 lum/ft^2 to 0.6 lum/ft^2. They were kept on a 24 hr light: 0 hr dark photoperiod throughout the study. Larvae were offered enriched (DHA-Selco) rotifers three days post-hatch and *Artemia* were introduced on day 22. On day 36 they were gradually weaned onto a commercial microparticulate diet (BioKyowa). Twenty larvae were sampled from each tank on days 0, 3, 22, 36, and 44 for length and weight determination. At the end of the experiment larvae in each tank were counted and survival was calculated.

Survival of cod larvae was lower in the tanks receiving low aeration (8.62%) as compared to tanks receiving high aeration (29.8%). This study suggests that vigorous movement within the tank is important during early rearing for survival and should be continuous throughout egg incubation and larval rearing.

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A method for assessment of the effectiveness of feeding stimulants for salmonid fish

C.K. Oikawa and B.E. March [1]

A procedure is described that tests the effectiveness of feeding attractants for rainbow trout (*Oncorhynchus mykiss*). The test stimulants, liquid krill (*Euphausia pacifica*) hydrolysate or acid-preserved krill were either added to the diet before pelleting, or coated on the pellets. Fish were fed to satiation once daily. Feed consumption and wastage were recorded over a period of 4 min at successive 1 min intervals. Fish fed the stimulants showed increased feed intake, more rapid feeding, and decreased feed wastage. These responses were enhanced when the stimulant was coated on the pellet. The method is sensitive, and yields consistent and repeatable results.

Introduction

Smell and taste are key senses in feeding behaviour,[2] and are used for the long range detection of food by fish.[3] Fish can be induced to bite or swallow normally unpalatable objects such as cotton pellets or agar gel that are scented with appropriate feeding attractants.[4,5] Taste is important in the decision to either swallow or reject a grasped object.[6] Feeding stimulants, therefore, have a potentially important role to play in the aquaculture industry. They could improve the palatability of 1) starter diets for early life stages of fish, 2) medicated feeds, and 3) diets containing alternate (plant) sources of protein. To maximize these benefits, techniques should be developed for measuring the effectiveness of palatability enhancers. The following three experiments (Exps 1, 2, 3) were conducted to devise a procedure for assessing potential feeding stimulants.

Materials and Methods

A control diet was formulated to contain 20% of fish meal as a protein source with the remainder of the protein supplied by ground wheat (20%), soybean concentrate (10%), corn gluten meal (10%), and canola meal (22%). The diet also contained fish oil (13%), sodium lignosulfonate as binder (2%) and a vitamin-mineral premix (3%). Of the fish oil, 54 % was added to the diet prior to pelleting and 46% was sprayed onto the pellets.

The potential stimulant was either a hydrolysate of krill (*Euphausia pacifica*) or acid-preserved krill (Exp 3 only). The respective stimulants were added to the diets in substitution for, on a dry weight basis, 2% of the fishmeal in the control diet. The stimulant was either mixed into the diet before pelleting or blended with the oil reserved for coating the pellets to yield 3 diets for each experiment: 1) control, 2) control + stimulant (either krill hydrolysate (Exps 1 & 2) or acid-preserved krill (Exp 3) mixed into the diet, and 3) control + stimulant coat (krill hydrolysate applied as a coat).

Rainbow trout (*Oncorhynchus mykiss*) were randomly distributed to nine treatment tanks (150 L) with an individual flow through (2 L/min) of freshwater. Each diet was randomly assigned to three replicate tanks.

In Exp 1 each tank held 95 fish averaging 10.5 g. Water temperature ranged from 5.5-7.5°C. The experiment ran 30 d after the fish accepted the diets.

In Exp 2 each tank contained 58 fish averaging 19.5 g. Water temperature ranged from 8.5 - 10.5°C. The fish were fed for 30 d.

In Exp 3 each tank held 81 fish averaging 18.9 g. Water temperature ranged from 13.0-14.0°C. Fish were fed for 19 d. Group weights of fish from each tank were taken before and after each experiment. Fish were fed once daily, to satia-

tion (4 min in Exps 1 & 2; 4-11 min in Exp 3) following a scotoperiod of 12 h. The water was turned off during feeding. Feed was dispensed with a plastic spoon to prevent skin contact/contamination of flavour[7] Diets were coded to conceal their identity. Tanks were fed in the same order as the random allotment of dietary treatments so that replicates of a given treatment were not fed successively.

Feed was dispensed as rapidly as the fish would eat; rates were adjusted as feeding slowed to minimize feed wastage. Feed consumption and wastage were determined for each successive minute of the feeding period by feeding from a separate container in each minute and counting the number of uneaten pellets at the bottom of the tank at the end of each minute.

Wastage weight was estimated by multiplying pellet numbers by their average weight. Wastage was subtracted from the weight of feed dispensed to estimate consumption.

Data were analyzed with Analysis of Variance and Tukeys HSD tests, both at the 0.05 significance level using Systat software v. 5.02. Before analysis, feed wastage data were transformed using a modified arcsine (Freeman-Tukey) transformation.[8]

Results

In all experiments the stimulant increased feed intake and decreased wastage (Table 1). Coating the pellet with the stimulant enhanced these effects in Exps 1 and 2. The latter statement cannot be applied to Exp 3 because different stimulants were used in the coated and mixed applications. The data are not given here, but the differences in feed consumption apparent during the first 5 days of feeding were maintained throughout the experimental period and growth corresponded to feed intake.

None of the fish in Exp 1 ate during the first 5 days of the trial, when they eagerly mouthed the pellets but spat them out. Feed consumption rates and the timing of feed wastage for Exp 1 are shown in Fig 1. Patterns are similar for Exps 2 and 3 (not shown).

Differences in feed intake were observed after the first minute of feeding. The feeding rate declined for all treatments as feeding progressed and most wastage occurred towards the end of the 4 min feeding period, near satiation. The control diet was rejected earlier in the feeding period than the other diets. Relative differences in consumption rates were qualitatively consistent throughout the feeding period.

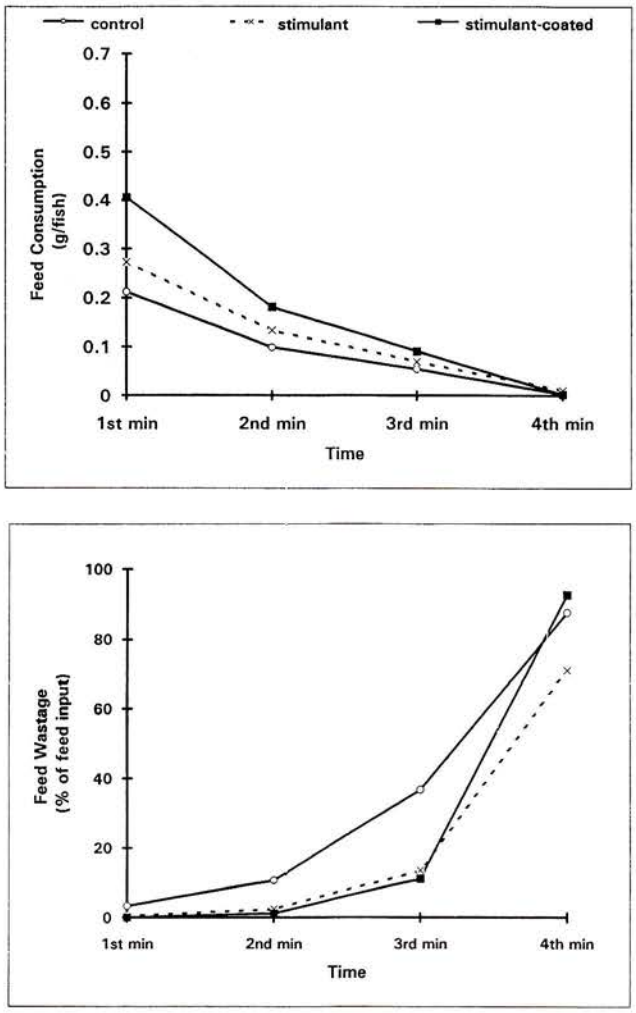

Figure 1. Feed consumption rates (corrected for uneaten feed) and the timing of feed wastage in experiment 1, days 6-10.

Discussion

The method uses a variety of

assessment criteria such as the magnitude, timing, and intensity of feeding responses. Measurement of feeding rate incorporates visually apparent features of feeding "enthusiasm" (rapid swimming, splashing) that are difficult to quantify. The variety of criteria provide a more sensitive technique than measuring only food intake and growth.

In Exp 3 there were no significant differences in feed intake but there were in wastage. Higher water temperatures increased the metabolic rate and, therefore, appetite of the fish, which may have obscured effects of diet palatability on feed consumption.

Because differences in feed intake occurred in the first minute of feeding we can conclude that the response was due to the palatability, rather than nutritional value, of the stimulant. The timing of wastage (Fig. 1) indicates that the fish had suitable access to feed and were fed to satiation; conditions essential for comparing voluntary feed intakes. Fig. 1 also shows that as a result of eating more quickly, fish fed the stimulant diets reached satiation more abruptly.

The degree to which fish mouth or reject feeds has been used by others as criteria for measuring palatability.[9, 10] With this technique, low feed wastage indicates high acceptability, which may be important when assessing feeding stimulants for start-feeding fish. The ability to decrease costly feed wastage is an important quality of a stimulant.

Wastage was generally lower for tanks with the highest feed intake, indicating that the observed differences in wastage were not an artifact of feed input rate. However, because wastage is influenced by the judgment of the person feeding the fish, this data is best considered in relative terms rather than as a quantitative parameter of a stimulant.

Therefore, the amount and rate of feed consumption are the principal criteria for assesment of feeding stimulants.

In this study, the feeding responses were consistent over time and qualitatively the same among three experiments indicating that the method yields repeatable results for assessing the effectiveness of feeding stimulants.

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Table 1. Effect of stimulant on feed consumption and feed wastage.

	Control	Stimulant Incorporated	Stimulant Coated
Feed Consumption (g/fish)			
Experiment 1	2.9^{a}	3.9^{ab}	4.9^{b}
Experiment 2	10.1^{a}	11.7^{ab}	14.6^{b}
Experiment 3*	13.5^{a}	15.1^{a}	15.6^{a}
Feed Wastage (% of total feed input)			
Experiment 1	18.0^{a}	8.1^{b}	8.2^{b}
Experiment 2	5.5^{a}	4.1^{a}	2.0^{b}
Experiment 3 *	4.4^{a}	2.4^{ab}	1.9^{b}

[ab] Values with rows bearing similar superscripts are not significantly different, $p<0.05$.

* In experiment 3 the stimulant incorporated into the pellet was acid-preserved krill whereas the stimulant in the coated treatment was krill hydrolysate.

Economic feasibility of *Oncorhynchus mykiss* culture in inland waters of Chile, South America

G. Lobos,[1] G. Cea,[2] P. Quero [1] and A. Ponce[3]

One of the most successful economic enterprises in the last few years in Chile has been salmon and trout culture. This booming aquaculture development had exports of US$500 million in 1995, 30% of the total exports of the fishing industry. The main objective of this research was to determine the economic feasibility of rainbow trout culture in the inland waters of the Elqui Valley. The size of the project was limited by the amount of water available. Production was estimated at a maximum 30.3 tons per year, taking into consideration environmental regulations. To calculate the economic feasibility, the traditional indicators of net present value (NPV) and internal rate of return (IRR) were used. The results showed that the project would not be profitable — the NPV was negative and the IRR smaller than the discount rate. A larger project would be profitable because of economies of scale. However, the shortage of water in this valley limits the size of culture operations. Also the highly variable international price of trout contributes to the negative NPV because of the high sensitivity of this project to price variations.

Introduction

One of the most successful economic enterprises in Chile in recent years has been salmonid and trout culture in marine and freshwater environments in southern Chile. This booming development is reflected in exports that reached US$ 500 million in 1995. Chile is established as the world's second largest producer of salmonids, after Norway, and most of the fish is exported to Japan and the United States.[4]

Multiple competitive advantages make Chile one of the best places for salmonid culture. It has suitable environmental conditions including favorable temperatures and clean water. In addition, the time of year when the product reaches foreign markets coincides with a time of low local production.[5] Another important aspect is the advantage of Chile's lower salary level relative to Europe or the United States.[6]

However, trout production is limited by environmental conditions like pollution and the availability of water. Intensive trout culture involves hatchery activities, with strict management of biological and technical details, permitting maximum yields. Food is provided from an external source, while a continous water supply provides oxygen and carries residues away. Within this context, the purpose of this research was to determine the economic feasibility of commercial rainbow trout culture in the inland waters of the Elqui Valley, Chile.

Methodology

Technical considerations

Site selection was based on easy accessability, topography and water quality. The size of the project was calculated based on water availability, accessible surface for installation of tanks and environmental impact of the operation. Only limited water was available as this region is characterized by a water shortage due to its semi-arid climate.

Based on observed water flow, production was planned for a continous year- round flow of 258 L/s. Thus, the project was planned for an annual production of approximately 30 tons of frozen trout of 250 grams/unit. Average temperature for culture was 11°C with extremes of 8° and 17°C.

Production volume was calculated in an iterative process, considering monthly water requirements for the various developmental stages, the availability of eggs in the marketplace and the duration of the production cycle. These estimations were based on mortality and survival at each stage, oxygen concentration in the water, feeding level according to development stage, culture density and average growth rate expressed as growth per temperature unit (GTU). Length of one production cycle was estimated to be 420 days, equivalent to 4,620 degree-days, considering a growth per unit of temperature of 0.0056 cm/°C/day and a conditioning factor of 1.2E-2 g/cm^3 (Fig.1).

Because local spring temperatures are different from the incubation optimum of 10°C [7-9] a 20% mortality rate was estimated during the early rearing period (October to December) and 0% (normal rate) during July. The early rearing period, that starts when 3/4 of the vitelline sack is absorbed, begins with the initiation of active feeding until the weight of 1 gram. The duration of the latter was estimated to be 20 days at an average daily temperature of 14-15°C.

A pre-fattening period of 4 months was estimated, equivalent to 1,320 degree-days. A projected mortality of 5% was calculated for this period. The fattening period was estimated to be 234 days. Once the commercial size is reached, trout are processed. This period was divided into harvest, blood-letting, transfer to the processing plant, evisceration and cleaning, cooling, freezing and packing.

Economic evaluation

The investments in this project were grouped as fixed and nominal assets and investments in working capital. Values were estimated according to present costs, taxes not included. The costs of operation were estimated as fixed and variable costs. The former includes all costs that do not depend on the level of production, the latter varies with production. Depreciation is not a real cost, and is represented by the use of equipment and infrastructure. Income received is exclusively from the sale of "frozen trout".

Due to the characteristics of the project, the economic evaluation covered a period of 10 years. A discount rate of 12% used. To calculate economic feasibility, traditional indicators were used: net present value (NPV) and internal rate of return (IRR). The NPV represents the current economic value of the project, i.e., it measures the increase in wealth in terms of the present value, that will give a known flow of income in the next number of years.[10]

As a decision tool, it will be prudent to invest in the project only if the value of the present flow of net benefits is positive, discounting this flow to the relevant interest rate.[11]

The IRR evaluates the project relative to a rate of yield per period, with which the total benefits in present value are exactly the same as the expenditure in present money.[12] Thus, the project will be feasible if the IRR is greater than the discount rate considered.

Results

Based on the information given in the technical analysis, investments, goods and services costs, and the price of the frozen product, the cash flow table was prepared (Table 1). This represents approximately the average conditions the trout culture project would be operating under.

Table 1: Cash Flow (MUS$)

Item/ Year	0	1	2	3	4	5	6	7	8	9	10
Investment	(122,180)					(2,430)					
Sales Revenue		105,323	105,323	105,323	105,323	105,323	105,323	105,323	105,323	105,323	104,916
Operation Costs		(59,940)	(115,551)	(115,551)	(115,551)	(115,551)	(115,551)	(115,551)	(115,551)	(115,551)	(84,579)
Depreciation		(7,506)	(7,506)	(7,506)	(7,506)	(7,506)	(7,506)	(7,506)	(7,506)	(7,506)	(7,506)
Gross Benefit		42,878	(17,734)	(17,734)	(17,734)	(17,734)	(17,734)	(17,734)	(17,734)	(17,734)	12,832
Tax (15%)		(6,432)									(1,925)
Net Benefit		36,446	(17,734)	(17,734)	(17,734)	(17,734)	(17,734)	(17,734)	(17,734)	(17,734)	10,907
Depreciation		7,506	7,506	7,506	7,506	7,506	7,506	7,506	7,506	7,506	7,506
Residual Value											36,853
Working Capital	(54,940)										54,940

The results of the economic evaluation show that the project has a NPV of MUS$ -149,139. The IRR is negative. The negative profit is due mainly to technical components associated with regional limitations and site characteristics. Among the regional limitations, water shortage is the most important and has been aggravated in the past four years.

The technical analysis included biological, environmental and legal restrictions and criteria, and enabled an estimation of a rate of water flow of 258 L/sec. The low availability of water is the main restriction to the size of the plant with a maximun annual production of 30 net tons of trout. As a result, the income is small due to the low level of production.

There are also considerable investment and fixed maintenance costs due to the characteristics of the location, such as factories on the river side built at levels higher than the water supply. For example, water is captured at a distance of 150 m and is carried by pipes placed at considerable height, requiring a costly investment.

Two alternatives to re-evaluate the economic factibility are suggested:

a) To look for other locations in the area with more water, access to the river, carriage of water and adequate space for building the plant.

b) To evaluate the possibility of developing only a hatchery and moving the fattening stages to one of several dams that exist in the area.

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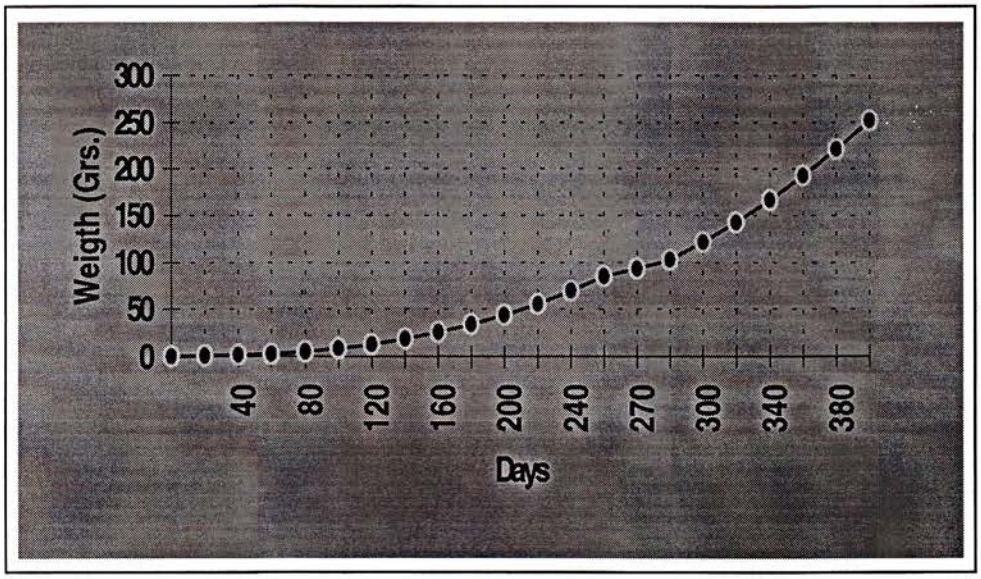

Figure 1. Growth curve of pan-size rainbow trout.

The competitive feeding success of diploid and triploid brook trout *(Salvelinus fontinalis)*

R. A. O'Keefe and T. J. Benfey[1]

The only economically feasible method for producing sterile fish for the aquaculture industry is the production of triploids. Studies have shown that the growth of triploids can be impaired when they are raised together with diploids. This difference in growth may be the result of reduced competitive feeding ability of triploids. Our objective was to determine if there is a difference in competitive feeding success between diploid and triploid brook trout. Our first experiment tested twenty-two pairs of fish (one diploid and one triploid) matched by weight or length, placed in a Plexiglas v-shaped trough, and fed an unlimited number of pellets three times a day for five days. The pellets consumed by each fish were counted and the fish consuming the most was assigned dominant status. In the second experiment, a group of three diploid and three triploid brook trout were matched by weight or length and placed in a Plexiglas v-shaped trough and fed half their normal ration three times a day for five days. Hierarchical rank among the six fish was assigned on the basis of how many pellets were eaten by each fish. This protocol was repeated for ten trials. In both the pair and group trials, there was no statistically significant difference in the competitive feeding success of diploids and triploids.

Introduction

Triploids are of interest to the aquaculture industry because they are sterile and do not undergo the normal changes associated with sexual maturation, such as decreased flesh quality.[2] They may also be utilized by aquaculturists to lessen the potential genetic impact of escaped domesticated and/or non-indigenous fish on the environment.[3]

Triploids differ from diploids in that they have three sets of chromosomes in their cells, instead of two. As a result of this extra set of chromosomes, triploids have fewer but larger cells in many of their tissues. This has been documented in the visual and central nervous systems of triploids, and may cause triploids to be less aggressive and have a reduced capacity to compete for food.[2]

A number of studies have indicated that competitive behaviour is associated with the amount of food consumed by fish, with the more aggressive fish consuming the most food pellets.[4,5] Other experiments have demonstrated that hierarchies may be formed within a tank having low stocking density and food provided in a limited manner in time and space, i.e., when food is presented to the fish from a point source for a short period of time.[6,7] Some studies have suggested that when triploids are cultured with diploids, the growth of triploids is lower.[8,9] This reduced growth may be the result of decreased competitiveness of the triploids.

The aim of these experiments was to determine if there is a difference in the competitive feeding success between diploid and triploid brook trout, by measuring the number of pellets consumed by individual fish when the two ploidies are cultured together.

Materials and Methods

Fish for both the pair and group experiments were anesthetized in 1% tertiary amyl alcohol and measured for weight and fork length. Fish were matched for size either within a 5% or less difference in weight or 3% or less difference in length.

Pair experiment

Pairs of fish (one diploid and one triploid) were placed in a v-shaped Plexiglas trough (10 cm x 29.5 cm or 21 x 55 cm), and were fed an unlimited number of pellets three times a day for five days. The number of pellets eaten by each fish was counted and dominant rank was assigned to the fish that ate the most pellets. This procedure was repeated twenty-two times with fish ranging in size from 7.2 to 46.3 g (8.6 cm –15.2 cm).

Group experiment

Three fish of each ploidy were placed in a 28.9 cm x 100 cm v-shaped Plexiglas trough. For ease of identification the fish were randomly fin clipped for each trial (adipose fin, top or bottom of caudal fin, combination of adipose fin with top or bottom of caudal fin, or no clip). The fish were fed half their normal ration three times a day for five days and the number of pellets consumed by each fish was counted. Fish were assigned a hierarchical rank based on the number of pellets eaten. This protocol was repeated for ten trials using fish ranging in size from 11.8 to 110.8 g (9.9-20.4 cm).

Results and Discussion

There was no statistically significant difference between the rank of diploids and triploids in the pair experiment based on the number of pellets consumed by each ploidy group (Fig. 1, $p>0.05$ by ANOVA). Keenleyside and Yamamoto[10] found stocking densities of less then six fish in an aquarium resulted in little aggressive interaction among the fish; our results support this finding. In addition to low stocking density, food was not limited, so there was little reason for the fish to compete for this unlimited resource.[6,7] These observations led to the group experimental protocol, where six fish were used and food was limited and presented from a point source three times a day. Despite the trend for diploids to be in first place there was no statistically significant difference in the average hierarchical rank of diploids or triploids (Fig. 2, $p>0.05$ by ANOVA). This suggests that a higher

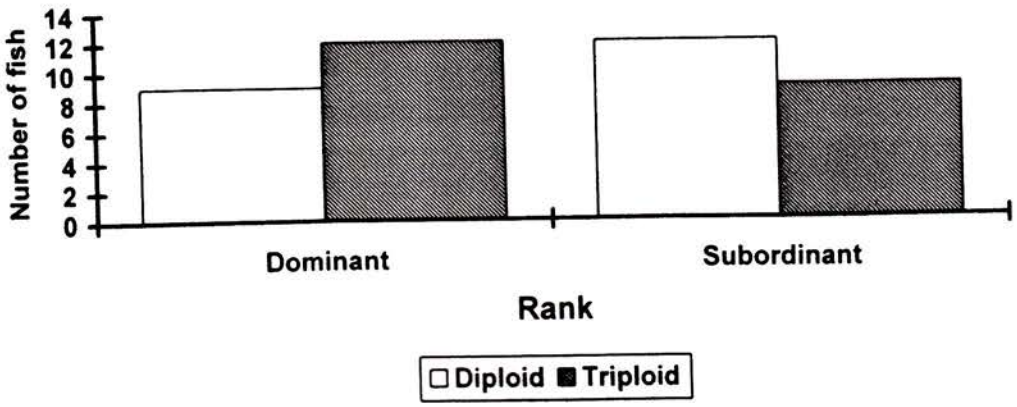

Figure 1. Number of diploid and triploid brook trout in each dominant and subordinate position in the pair competition experiments, based on the number of pellets eaten by each fish.

stocking density and limited access to food had little effect on the competition for food between diploid and triploid fish.

The fish used within trials were of similar size (less than 5% difference in weight or 3% difference in length) in both the pair and group experiments. Abbott et al.[11] found a difference of 12% adequate to ensure that the larger fish would be dominant. We therefore used fish of similar sizes within trials in our experiments to ensure that any competitive differences would be attributable to ploidy rather than size. The results reported here, as well as similar experiments conducted with another strain of brook trout and with Atlantic salmon *(Salmo salar)* showed no statistically significant difference in competitive feeding success between diploids and triploids.[12] The literature suggests that when diploids and triploids are raised together the triploids initially are delayed in growth but as time progresses their growth matches that of the diploids.[8,9] Although our experiments were not conducted long enough to assess the effects of competition on growth, our results suggest that any such differences in growth may be due to factors other than reduced competitive ability.

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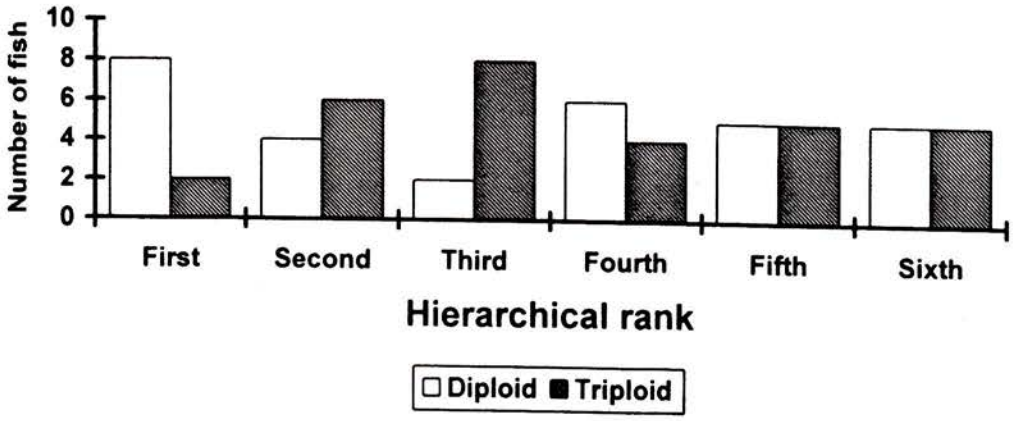

Figure 2. Number of diploid and triploid brook trout in each hierarchical position in the group experiments, based on the number of pellets eaten by each fish.

Total blood hemoglobin levels in diploid and triploid brook trout (*Salvelinus fontinalis*)

Evelyn J. Stillwell and Tillmann J.Benfey [1]

This study examined the total blood hemoglobin level (TBHL) of diploids and triploids from all-female and mixed-sex groups of brook trout over a two-year period. In the all-female group TBHLs were equivalent in both ploidies except at, and shortly after, diploid spawning when TBHLs were significantly lower in diploids than in triploids. In the mixed-sex group triploid TBHLs were significantly lower than those of diploids at 6 months post-hatch, but this difference disappeared by 9-12 months of age. After this age ploidy differences in TBHL were present only in females, appeared to be related to diploid spawning, and were such that diploids had significantly lower TBHLs than triploids. Sex differences in TBHL were noted only in diploids and only near the time of spawning, with females having significantly lower TBHLs than males.

Introduction

The presence of an extra set of chromosomes in triploids prevents normal meiosis and causes sterility. Additionally, female triploids remain sexually immature due to an endocrinological dysfunction.[2] Although these traits are attractive for culture, triploids have not been widely accepted because their performance can be inferior to that of diploids (e.g., at chronic high temperatures).[3] It has been suggested that the poor performance of triploids may be related to their hematology. Several studies have found the total blood hemoglobin level (TBHL) of triploids to be significantly lower than that of diploids.[2] Further, Graham *et al.*[4] found that in Atlantic salmon (*Salmo salar*) the oxygen loading ratio of triploid blood was 77% that of diploids; it was argued that this, combined with the lower TBHL, would reduce the oxygen carrying capacity of triploid blood by one-third relative to diploid blood. Obtaining oxygen may thus be problematic for triploids under conditions of reduced oxygen availability and increased oxygen demand, and may explain their poor performance under such circumstances.

The Graham *et al.*[4] study is the only one in which blood-oxygen loading ratio was measured. In all other studies a lower TBHL alone was used to argue that the oxygen carrying capacity of triploid blood is diminished. The validity of this argument may be suspect considering that both sex and level of sexual maturity can affect TBHL[5,6] and these factors were not controlled in the aforementioned studies. Reports of lower TBHLs in triploids may therefore be related to these factors rather than to ploidy differences per se. Certain studies in which only female or sexually immature fish were examined have indeed found equivalent TBHLs in diploids and triploids.[7,8]

Our objectives were to determine (i) whether the TBHL profiles of diploid and triploid brook trout change in relation to sexual development and spawning, and (ii) whether sex differences exist in diploid and triploid TBHL profiles.

Materials and Methods

TBHL was measured every 3-4 mo in an all-female (UNB-strain) group of diploids and triploids for 24 mo beginning at 9 mo post-hatch, and in a mixed-sex (Quebec-strain) group of diploids and triploids for 19 mo starting at 6 mo post-hatch. The number of fish sampled is indicated in Figures 1 and 2; variations in sample size over time were due to difficulties experienced with blood collection and mortalities.

Diploids and triploids came from the same egg lots; triploidy was induced by hydrostatic pres-

sure and confirmed by flow cytometric measurement of erythrocytic DNA content. Fish from the UNB-strain were hatched in 1993 and those from the Quebec-strain in 1994. Fish were tagged with passively integrated transponder (PIT) tags at 4 mo of age. After this time diploids and triploids were housed together in 1 m diameter tanks with a water current of 0.5 body lengths/sec. Fish were divided equally between tanks and stocking density was monitored and adjusted to avoid crowding (defined by Piper's Density Index[9]). Fish were maintained in dechlorinated and aerated City of Fredericton water. Water temperature varied seasonally from 6-13°C and a simulated natural photoperiod was used. Fish were fed once daily to satiation with pelleted trout feed (Corey Feed Mills, Fredericton). Diploid fish were "spawned" (manually stripped) at the times indicated in Figures 1 and 2.

TBHL was determined spectrophotometrically using a cyanomethemoglobin assay (Sigma Kit 525-A). Fish were anaesthetised in 1% tertiary amyl alcohol and a blood sample (~200 µL) was obtained via caudal vein puncture. Hemoglobin was measured in duplicate for each blood sample taken; the mean of the two values was used in statistical analyses (SAS software release 6.08) using a 2-sample *t*-test.

Results

UNB (all-female) group: Seasonal fluctuations were noted in the TBHL of diploids and triploids (Fig. 1). TBHLs were significantly lower in diploids at, and shortly after, diploid spawning (January and April 1995).

Quebec (mixed-sex) group: Seasonal fluctuations in TBHLs occurred in males and females of both ploidies (Fig. 2). At 6 mo post-hatch, TBHLs of triploids were significantly lower than those of diploids for both sexes, but this difference disappeared by 9-12 months of age. After this, TBHL differences between ploidies occurred only in females and only at, and shortly after, diploid spawning (November 1995 and April 1996), when TBHLs were significantly lower in diploids. Sex differences in TBHL were observed in diploids but not triploids; female diploids had a significantly lower TBHL than diploid males at, and shortly after, spawning.

Discussion

TBHLs fluctuated over the course of this study in all groups. These fluctuations may be related to age, seasonal environmental variations, and/or factors associated with spawning.[10] In the mixed-sex group, triploids had significantly lower TBHLs than diploids at less than 9 mo of age suggesting that ploidy differences influence TBHLs in young fish. After 1 year of age, ploidy-related differences in TBHL were no longer present except at, and shortly after, diploid spawning; at these times TBHLs were significantly lower in diploid than triploid females in both mixed-sex and all-female groups. In females, ploidy differences result in endocrinological differences: unlike diploids, triploids typically do not synthesize detectable levels of estrogen.[2] Estrogen suppresses erythrocyte production[11] and, since hemoglo-

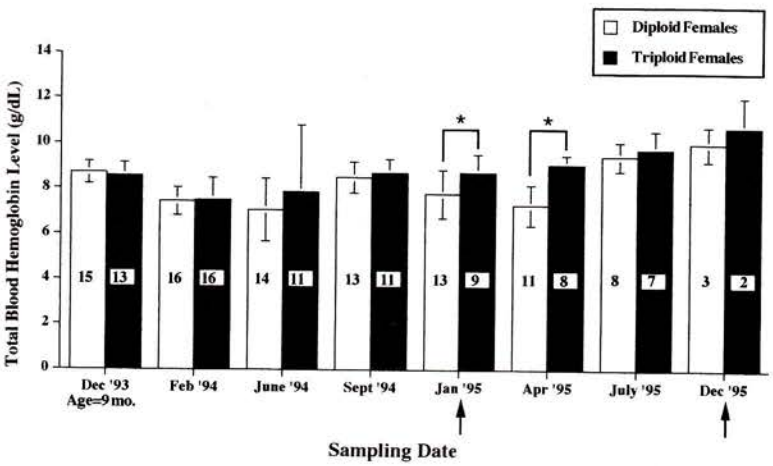

Figure 1. Mean total blood hemoglobin levels (± 1 standard deviation) in an all-female (UNB-strain) group of diploid and triploid brook trout. Dates when diploids were spawned are indicated with arrows. * indicates a significant difference ($p<0.05$). The number listed on each bar indicates the number of fish sampled.

bin synthesis occurs in maturing erythrocytes,[12] may result in a reduction in TBHL. Lower TBHLs in diploid than triploid adult females may thus be related to higher estrogen levels. Due to their altered endocrinology, female triploids, unlike diploids, do not mature sexually or spawn.[2] Since differences in the TBHL of diploid and triploid females appear to occur in relation to diploid spawning, endocrinological differences or physiological changes associated with spawning, rather than ploidy differences per se, likely account for the observed difference in TBHL.

Similar TBHLs in male and female triploids suggest that TBHLs are not affected by genetic determinants of sex. In diploids, sex-related differences in endocrinology/physiology are present and may be enhanced in relation to spawning.[5,13] The sex-related differences in diploid TBHLs associated with spawning may, therefore, be a reflection of differences in male and female endocrinology and/or physiology.

Conclusions

Our results suggest that TBHLs are generally not affected by sex or ploidy differences per se but are affected by endocrinological and/or physiological differences between sex and ploidy groups. Although TBHL profiles are similar in all groups, differences were noted when fish were young (≤ 9 mo of age) and at the time of diploid spawning. Whether the TBHL differences observed are biologically significant (i.e., affect performance under conditions of high oxygen demand/low oxygen availability) remains to be determined.

We thank Ms. R. O'Keefe for technical assistance and Mr. P. Jardine and Dr. A.J. Wiggs for critical input. We are grateful to the AAC and UNB for funding to support our attendance at Aquaculture Canada '96. This project was supported by an NSERC research grant.

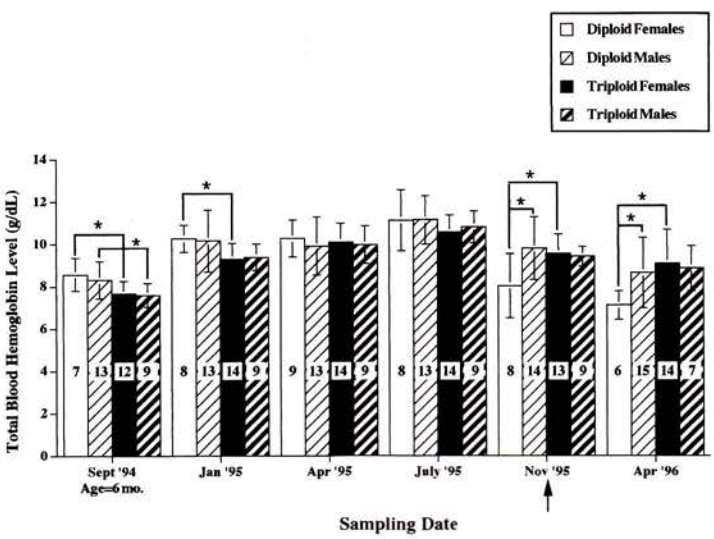

Figure 2. Mean total blood hemoglobin levels (± 1 standard deviation) in a mixed-sex (Quebec-strain) group of diploid and triploid brook trout. Dates when diploids were spawned are indicated with arrows. * indicates a significant difference (p<0.05). The number listed on each bar indicates the number of fish sampled.

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Acclimation temperature effects on baseline physiological parameters of Atlantic salmon parr

C.A. Wartman, and J.F. Burka[1]

Alteration of temperature in the freshwater phase of development has been shown to affect growth in Atlantic salmon parr. The variability of "normal" parameters of Atlantic salmon (*Salmo salar*) parr acclimatised to 7°C ("normal" well temperature) or 14°C are being examined. Preliminary results are reported in this paper. One hundred and fifty male and female Atlantic salmon parr were randomly allocated to each of the groups and tagged. The tanks were then filled to a density of 10.5 kg/m^3. No significant difference was found between the two groups initially. Atlantic salmon parr raised at different temperatures show modifications in growth parameters, with parr raised at 14°C growing at a faster rate than those maintained at 7°C. Changes in baseline physiological parameters seem evident but more study is required to determine the exact nature and validity of these alterations.

Introduction

Temperature affects the physiology of fish in many ways, including alterations in the rate of chemical reactions, and structural changes in the chemical bonds of proteins, lipids and other macromolecules.[2] Generally, low temperatures constrain flexibility whereas high temperatures promote it to the point of dissociation. Williams and Hazel[3] illustrated that the fluidity of the inner hemilayer of the intact plasma membrane is relatively insensitive to temperature, thus needing fewer modifications than the outer hemilayer during temperature acclimation. This illustrates that changes in body temperature can pose serious challenges to the maintenance of physiological function by alterations in metabolic rates.[4]

The thermal range giving optimal growth for juvenile Atlantic salmon in freshwater in a laboratory environment with feeding to satiation is 13 to 16°C.[5] Welch *et al.*[6] demonstrated that wild stocks of salmonids tend to choose the temperature for optimal growth dependant upon the food ration availability. Experimentally it has been demonstrated that temperatures selected by fish behaviourally are similar to the temperature yielding optimal growth rates.[7] Even behavioural alterations in response to temperature can be linked to changes in growth. For example, a recent study demonstrated that decreasing temperature resulted in nocturnal activity in juvenile salmon.[8] This was linked to changes in food availability, predator absence, and decreased aggression among conspecifics. All of these factors influence growth rates.

Some studies have examined the effects of altered temperatures on the blood indices in salmonids. Kieffer *et al.*[9] suggested that acclimation temperature does not significantly affect anaerobic capacity in rainbow trout. But it may explain the documented variability in the dynamics of the lactacidosis in the blood following exhaustive exercise in fish. Hochachka and Hayes[10] found that warm acclimated trout showed faster metabolism of labelled glucose.

In many aquaculture facilities, a temperature of 14°C is maintained to increase growth rates in the freshwater phase of development, in contrast to local ground water temperatures of 7 to 10°C. Thus, the purpose of these experiments was to determine the variability between fish acclimated to 7°C (i.e., local groundwater temperature) and fish acclimated to 14°C over a year. The following is a report of the results to date.

Methods

Male and female Atlantic salmon parr of the same hatch were obtained from the Cardigan Salmonid Enhancement Centre, Prince Edward Island. The study, carried out at the hatchery, used fish randomly sampled by crowding the entire population into one section of the tank and removing 300 fish. The fish were anaesthetized using benzocaine (0.41 mL/L), tagged, weighed and measured using fork length. Half of the tagged fish were placed in each of two tanks (2.32 m x 2.32 m x 0.52 m) that were filled to a density of 10.5 kg/m^3. This is the normal density at which fish are housed. Density was maintained by weighing the entire population every two months and removing the excess animals. Normal hatchery procedure was followed for feeding and maintenance of the population.

Growth

Each month individually tagged fish were weighed and measured to determine growth indices. Fork length was used to give direct evidence for growth or lack of growth. Length increases were generally maintained, but during starvation fish may shrink somewhat.[13] Also, growth of fish causes relatively greater changes in weight than in length because of the approximately cubic relationship between fish length and weight. Therefore, weight was used to give a more precise measurement. The retention of excess water on the surface or buccal cavity of the fish may be a source of error in the wet weight measurements. Individual monitoring of length and weight changes should control for this problem. Both of these measurements are used to calculate many indices of growth. Condition factor is a measurement calculated from the weight and length measurements which reflects the vitality of the individual fish.[13] Relative growth is calculated using an individual's initial measurements against the final measurements to determine the rate of growth in a percentage.[13]

Blood Chemistry

Normal feeding regimes were followed on the day of sampling in order to disrupt the population as little as possible. The water level of the tank was lowered to ensure randomness of samples. Sampling was initiated at 3:00 p.m. and terminated by 4:30 p.m., thus ensuring sampling occurred during the same diurnal framework. At this time of day cortisol levels approach baseline levels.[14,15] Stress of capture was minimized by keeping the net horizontal to the bottom of the tank and quickly lifting as the fish swam above.[16] All animals were exposed to similar handling procedures to ensure similar effects on the blood parameters of each group. Blood samples were collected to determine levels of glucose, electrolytes and cortisol.

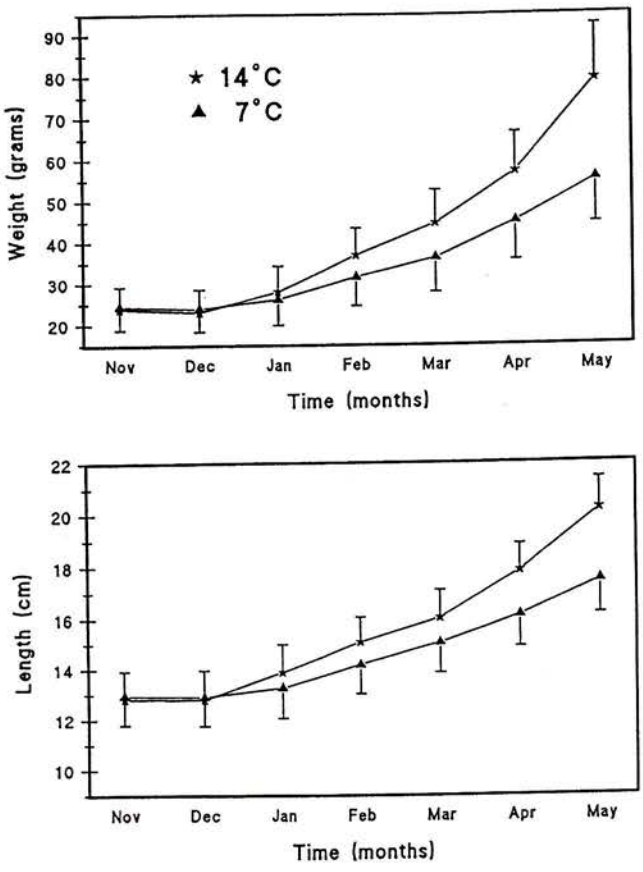

Figure 1. Growth curves for length and weight of groups acclimated to 7°C and 14°C.

Results and Conclusions

Growth studies revealed that the condition factor remained similar for both groups. The condition factor, which reflects the vitality of the individual fish,[13] was calculated using the formula : (weight/ (length)^3) x 100.This demonstrated that the overall health of the two groups remained relatively similar. The growth curves for both length and weight showed a divergence around January that increased with time (Fig. 1). Comparison of the relative growth rates (Fig. 2) revealed a difference in the percent of relative growth for the different temperature groups. Relative growth rate was calculated by:{(final weight – initial weight) / [(initial weight)(final time – initial time)]} x 100%.[13] Thus, we see that the groups are growing at different rates: with the 14°C group demonstrating a higher relative growth rate for both length (9.7% relative growth vs. 5.9% relative growth) and weight (40.8% relative growth vs. 22.2% relative growth). Blood chemistry studies and analysis of results to date are in progress. The study is continuing to determine if the trends persist and to increase the power of an analysis of this information.

Summary

Poikilothermy is very influential in the physiology of fish. Atlantic salmon parr raised at different temperatures show modifications in growth parameters, with parr raised at 14°C growing at a faster rate than those maintained at 7°C. Changes in baseline physiological parameters seem evident, but more study is required to determine the exact nature and validity of these alterations.

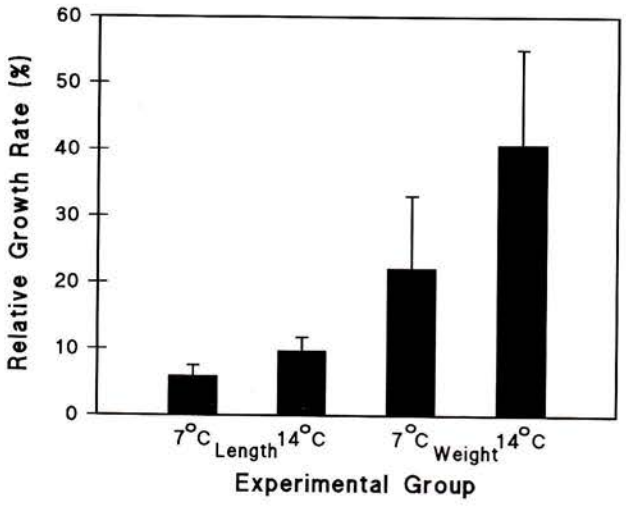

Figure 2. Relative growth rate (%) for both length and weight of the 7°C and 14°C acclimated groups.

We would like to thank the staff of the Cardigan Salmonid Enhancement Center for their technical assistance and use of the facility. Jody Mokler and Heather Briand devoted many hours to the development and techniques of this project. We are grateful to the AAC Student Travel Fund for a Travel Allowance and to NSERC and the AVC Dean's Office for funding for the project and a graduate student stipend, respectively.

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Tilapia — a potential culture species in Canada

Thomas T. George[1]

Tilapias possess an impressive range of characteristics that make them suited for widespread culture. They also display varying degrees of salt tolerance, a trait resulting in the expansion of their culture into brackish and marine systems. Most favoured is *Oreochromis niloticus,* the Nile tilapia, but *O. spilurus* is cultured in saline waters and *O. aureus,* the blue tilapia, in colder waters. The red tilapia hybrids combine favored colors with the other desirable features. This paper highlights the characteristics of tilapias that enabled them to be successfully cultured in many countries and accounts for their culture potential and prospects in the Province of Ontario.

Introduction

Tilapia orginated in Africa and evolved in the River Nile. Their use in aquaculture spread through Africa after the 1920s[2] and they became established as potential farmed species in North America in the 1950s.[3] They are now farmed in at least 75 countries, and are known as Saint Peter's Fish, Golden Perch, Cherry Snapper, Aquatic Chicken, etc.[2] The species most farmed belong to *Oreochromis* and *Sarotheradon* and their hybrids are gaining economic prominence in commercial culture.[4]

Global production is growing astronomically. Between 1984 and 1992, production of tilapias and other cichlids expanded by 150% globally, with Asia as the leading region, followed by Latin America and Africa. The following account highlights the characteristics that make tilapias well suited for widespread culture and also, their culture potential and prospects in the Province of Ontario, Canada.

Characteristics

Tilapias have provoked global interest because of the following characteristics:

- only one step from the primary producers (plant life) and all are herbivores;
- tolerant of handling, captivity, poor water quality, resistant to diseases, and readily adapt to artificial feed;[2,5]
- hardy and tolerate temperatures from 8-42°C (*O. aureus – O. niloticus*), pH from 5–11, DO as low as 1 mg/L and very high levels of carbon dioxide;[6,7]
- most species become inactive at water temperatures below 16°C;
- lethal limit is 9-13°C; growth is poor at 20°C, best at 26°C, and optimum between 25-30°C;[6-8]
- tolerant of fresh, brackish (10-14 ppt) and salt water at 42 ppt, though fecundity decreases above 18- 20 ppt *(O. spilurus, O. mosambicus)*;[2,7]
- can be reared extensively, semi-intensively and intensively under various husbandry methods (mono/polyculture, supplemental feeding and/or fertilization) and exhibit good productivity per unit volume of water; [2,5,9]
- economic, efficient food conversion and rapid growth rates on low protein diets, whether cropping natural aquatic production or receiving supplementary food;[5,9,10]
- can be reared in a recirculating system on diets in which animal protein is replaced with plant protein, provided the diet is supplemented with phosphorous,[10,11] which is also important in their pond fertilization;[12]
- have a short generation time and breed in captivity;[2]
- problem of females spawning at small sizes can be overcome in culture by producing all male populations through interspecific hybridization (80-85% males) or sex-inversion using feed laced with androgens (60 mg/k methyltestosterone) producing 100% males;[13,14] also, fry hybrid tilapia fed on a ration containing a non-steroid chemical

(100 mg tamoxifen/kg feed) produces 100% males;[15]
- palatable with a superb flavour and firm, meaty, moist flesh;[16]
- nutritious; classified as low-fat fish because 3.5-oz of flesh has 100 calories, 2 g of fat and 400 mg of omega-3 fatty acids;[16]

The hybrid red tilapias have similar habits to their mouthbrooding parent species[17] and are gaining in popularity for intensive culture because they:

- have faster growth rates, better food conversion efficiency, lower susceptibility to diseases, and better palatability;[2,5,18]
- grow better in brackish and salt waters than freshwater with lower fecundity;[5,18]
- fetch higher market prices due to their resemblance to the premium sea bream and red snapper;[17,19] however, the red color is not deeply rooted in the genetic make-up and a percentage of dark fish recur and must be eliminated through sorting.[2,19]

Culture Potential in Ontario

Tilapia culture is the fastest growing fish-farm product in the United States. In 1994, consumption reached 28 million kilograms and overtook rainbow trout in popularity as a food fish. Production output is likely to top 9070 tonnes by 1998, although some states are still prohibiting its culture. The industry is expanding rapidly; imports still exceed domestic production and the market is growing 30-40% a year.[20,21]

Two large farms in Colombia and Costa Rica supply almost 80% of the U.S. market with fresh tilapia fillets. The market for frozen fillets is supplied mostly from Indonesia and Thailand. The live tilapia market is supplied by the largest farm in the U.S., located in southern California desert, a variety of small producers, some of whom grow tilapia in heated, closed-system tanks as far north as North Dakota. New York, Toronto and Los Angeles are the largest markets where Asian buyers pay US$ 4.95/kg and up for the best quality fish.[22,23]

Canada imports mainly live and frozen whole tilapias; the market for fillets is poor. A preliminary survey of Asian buyers in Toronto indicated that either 7,000 kg[24] or 1,800 kg[25] live tilapia per week are supplied by U.S. producers to Toronto market at US$ 3.85-$4.29/kg. Retail prices are Cdn$ 8.78/kg for the grey tilapias (4.38/kg for dead fresh) and Cdn$ 10.98/kg to 17.58/kg for the red tilapias.[25]

Imports of frozen tilapias come mainly from Taiwan, Thailand, the U.S., and Trinidad and Tobago. Imports from Taiwan increased from 84,000 tonnes in 1994 to 269,000 tonnes in 1995 while those from the U.S. decreased from 38,000 tonnes in 1994 to 24,000 tonnes in 1995.[26] About 30-35 thousand kilograms of frozen tilapias are consumed monthly by the Toronto market. Retail prices of clean frozen tilapias are Cdn.$ 4.40/kg and 5.06/kg for the grey and red tilapias respectively; Cdn.$ 3.74/kg for unclean grey.[27]

Tilapia culture in Canada was prohibited until recently, with Ontario the first to proceed with tilapia culture. There are several projects attempting the production of tilapia with capital-intensive recirculation systems. One company (Northern Tilapia Inc.) plans to have fish ready for market in July 1997; initial production will be approximately 45,000 kilograms annually through aquaponic system, growing lettuce and basil above the tilapia tanks.[28]

With the existing live market in Toronto presently supplied by U.S. producers, and the market for frozen product the potential for tilapia culture is promising. These facts support what has been mentioned in *An Action Plan For Ontario's Aquaculture Industry*: "Two species, Arctic char and tilapia, are identified as having immediate, good potential for food production. The technologies of their production are reasonably well known and there are recognized markets for both species".[29]

In February 1995, the *Federal Aquaculture Development Strategy* named aquaculture development as a priority of the Federal Government.[30] In October 1995, the amendment of the regulations under the Ontario Game and Fish Act was approved whereby the legal culture of tilapia of the genera *Oreochromis, Sarotherodon* and *Tilapia* (included in a list of over 40 additional species), was made possible.[31] In December, 1995, a partnership agreement was signed with the Ministries of Agriculture, Food and Rural Affairs and Natural Resources; the contract with the federal Agriculture and Agri-Food Canada provided for developing an aquaculture strategy for the province.[32]

These federal and provincial actions, plus analysis of the markets, knowledge of culture technology, including availability of seed and feed, and favourable economics should guarantee excellent prospects for tilapia culture in Ontario.

Summary and Conclusion

Tilapias are the world's most important warm-water cultured food fishes. The current boom in production is due to increased acceptability by consumers and the successful transfer of the culture techniques. Tilapias have many characteristics that make them one of the most suitable fish for large scale commercial culture. The tilapia industry has room to grow in North America and is expanding quickly. Currently, this "Miracle Fish" is the fastest growing fish-farm product in United States; soon it will also be in Ontario and other provinces of Canada because its potential and prospects are very bright.

Given the climate in Canada, most of the tilapia production in Ontario would probably occur mainly through intensive recirculating systems. This means that developing a large-scale intensive recirculating tilapia farm would require a multi-million dollar investment. Therefore, the challenge is to produce tilapia that would compete with the existing market prices and the aggressive marketing system?

Losordo[31] concluded that the best ways to improve the economics of rearing tilapia in a recirculating system involve decreasing the costs of establishing the system and increasing production by manipulating feed formulas to reduce costs and improve feed conversion efficiency; also genetics to produce Genetically Male Tilapia, GMT ("YY" male genotypes — supermales). Production through the use of waste heat from industries and power plants, and geothermal sources also increase profitability. Besides, the technology for satisfactorily rearing tilapias in sea water is well developed; even their marketability is rated highly in terms of flavour, texture, and firmness.[32,33]

The above facts, and the necessity for a proper survey of the Ontario fish market, should be taken seriously into consideration by the Ontario tilapia producers in order to compete locally and also market the technology abroad for fresh/salt water tilapia culture. With Canadian ingenuity, determination, and scientific engineering, the threat for Canadian producers to compete for import replacement and for exports will be overcome in the near future.

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Nutritional studies in the African catfish *Clarias gariepinus* (Burchell,1882): A preliminary report

Panagiotis Pantazis[1] *and Kim Jauncey*[2]

Digestibility of various raw materials was studied in the African catfish in a specifically designed system of cylindro-conical tanks that collected faeces by sedimentation. On a diet of natural ingredients (fishmeal, soya, wheat) with a proximate composition of 38% crude protein, 10% crude lipid (on a dry matter basis) the following apparent digestibility coefficients (ADC) have been established: dry matter 96.87%, protein 89.75%, total carbohydrates 12.86%. Digestibility studies are underway to establish the coefficients for energy and total lipids. At the same time protein:energy ratios were tested based on purified diets. The aim of these trials was not only to establish the optimum dietary protein:energy ratio for maximal growth, but also to investigate the quality of the carcass obtained by the diet that gave the best performance.

Introduction

The African catfish *(Clarias gariepinus)* is a promising species for aquaculture exploitation. Its omnivorous feeding habits, sedentary life style and air-breathing faculty, coupled with good market potential, make this fish most suitable for culture.

The primary aim of this study has been to develop cost-effective feeds for *Clarias gariepinus* through an understanding of ingredient and nutrient digestibility followed by more detailed investigation of protein:energy ratios and carbohydrate utilization.

Digestibility Studies

Materials and methods

Digestibility studies were conducted on various raw materials in a specifically designed system of cylindro-conical tanks that collected faeces by sedimentation. Temperature was kept constant at 26-27°C, nitrites (NO_2) at 0-0.25 ppm, nitrates (NO_3) at 40 ppm and total ammonia at 0.5-1.00 ppm. pH ranged between 6.5 and 6.8 The flow rate in each of the individual fish chambers did not exceed 15L/h (260 mL/min). The photoperiod was kept constant at LD 12:12.

Catfish of an average weight of 50-70 g were individually stocked in the tanks. As neither feed intake levels nor the frequency of feeding affect the ADC of dry matter, crude protein, crude lipid and gross energy,[3] fish were fed "on appetite" showing a preference for a feed intake level of 0.5-1% of body weight per day (on a wet basis). Faeces were collected once daily, freeze dried, and stored at -20°C until analyses were done.

Determination of energy and protein

Rationale of the method. Determination of the energy content of different materials used in nutritional studies by bomb calorimetry requires relatively large samples (approximately 3 g for a triplicate). In addition, the Kjeldahl method for protein requires an extra quantity of approximately 0.6-0.7 g (for triplicates).

When dealing with digestibility studies, the quantity of faeces available for analyses is often restricted. By using the combustion autoana-

Table 1. Example of a low carbohydrate diet

Raw Ingredients	Incorporation % (dry matter basis)	Proximate analysis % (dry matter basis)
Casein	29	
Gelatin	33	Energy 21.31Kj/g
Destrin	9	Crude protein 60.57%
Corn oil	9.5	Crude lipid 19.48%
Fish oil	9.5	Crude fiber 5.28%
Carboxylmethylcellulose	0.5	NFE 8.63%
α-cellulose	3.5	Ash 6.031%
Vitamin premix	2	
Minerals	4	

lyzer, one can determine simultaneously the organic carbon and nitrogen content of the sample by minimizing the sample size (30-45 mg for a triplicate) with minimal compromise in the accuracy and reliability of the results.

Estimation of energy. This method is a modification of the methodology described by Salonen et al.[4] Combustion values were established using a Perkin-Elmer CHNS/O combustion analyzer and corrected by substracting 5.94 kcal/g N_2 or 24.8589Kj/g N_2[5] to exclude the non-physiological energy that is produced during combustion when NH_3 is oxidized to N_2 (and that does not happen in vivo). An average value of 42.515 Kj/g organic carbon was established which is not very far from the factor of 43Kj/g organic carbon, established by Ross[6] and based on samples of *Littorina rudis.*

Estimation of protein. Twelve different materials were selected and freeze-dried. Kjeldahl determination was done with a Tecator 1003 Distilling Unit and the combustion nitrogen values were determined using a Perkin-Elmer CHNS/O combustion analyzer. The protein content of samples was determined multiplying the nitrogen value by 6.25 for fish meal, by 6.38 and 5.55 for casein and gelatin respectively,[7,8] and by 5.71 for soya and wheat. In purified diets the nitrogen value was converted to protein by using the geometric average of the above coefficients, according to the formulation of the diets.

All the analyses were done in duplicate, unless very high standard error values were encountered. In those, cases triplicates and even quadruplicates were analysed. Based on these values, the following regression was established:
Kjeldahl value = 0.197022 + 0.996575 x CombustionValue
(correlation coefficient= 0.999162)

Determination of carbohydrates. A modification of the method as described by McCready *et al.*,[9] was used to estimate the percentage of carbohydrates in feed samples and faeces.

Digestibility coefficients

The apparent digestibility coefficients were calculated based on the determination of the marker chromic oxide, by the method of Furukawa and Tsukahara.[10]

Results

Based on a diet made from natural ingredients (fish meal, soya, wheat) and with a proximate composition of 38% crude protein,10% crude lipid (on a dry matter basis) the following Apparent digestibility coefficients have being established: protein 89.75%, available carbohydrates 12.86%. Digestibility studies are being continued in order to establish the coefficients for energy and total lipids.

Protein and energy studies

Carbohydrate utilization. A trial was initiated to assess the ability for carbohydrate utilization.

Table 2. Control diet used for the protein: energy experiment

Raw Ingredients	Incorporation (%) (dry matter basis)	Proximate analysis (%) (dry matter basis)
Fishmeal	23.5	Dry matter 96.345%
Soya	40	Crude protein 36.064%
Wheat	11	Crude lipid 13.95%
Dextrin	7	Crude fiber 6.27%
Corn Oil	5	NFE 38.14 %
Fish Oil	4.5	Ash 5.57%
Carboxylmethylcellulose	2	
α-cellulose	1	Energy 19.28Kj/g
Vitamin premix	2	
Minerals	4	

Isonitrogenous and isoenergetic diets with different carbohydrate levels (Table1) are tested on adult catfish (200 g mean weight). Blood glucose levels, liver glycogen and liver lipids were tested at regular intervals of ten days.

Protein:energy ratios. Fifty six fishes of an average weight of 104 g were allocated to 14 tanks following a Latin-square experimental design.They were fed for 30 days on six different purified diets and one control diet made with commercial-natural ingredients (Table 2).

The purified diets had the following protein and energy ratios:

Group 1	32% crude protein: 8.5% crude lipid
Group 2	32% crude protein: 13% crude lipid
Group 3	40% crude protein: 9% crude lipid
Group 4	40% crude protein: 14% crude lipid
Group 5	47% crude protein: 9% crude lipid
Group 6	47% crude protein: 15% crude lipid

Duncan's multiple-range test was used to compare the following indices and estimate the performance of the various diets: specific growth rate, thermal growth coefficient,[11] % weight gain, food conversion ratio, and protein efficiency ratio.

Discussion

On the 10% crude lipid level, the performance of the 32% crude protein diet was not statistically different from the 40% and 47% crude protein level diets. On the 14% crude lipid level, the 32% crude protein diet resulted in poor performance, whereas the diets with 40% and 47% crude protein showed better performance and were not statistically different from the performance of the control diet.

It seems that 14% crude lipid level is not enough the create a sparing effect on the 47% crude protein level.

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Lake sturgeon: A freshwater fish species with a future

Terry A. Dick,[1] M. Lu,[1] and Frederick T. Barrows [2]

The history of lake sturgeon is one of overexploitation and habitat loss with eventual extirpation from much of its former range. A resurgence of interest in lake sturgeon biology is tied to mitigation and compensation to aboriginal communities and a desire to rehabilitate traditional fisheries. This has led to an interest in culturing lake sturgeon for both stocking and meat production. Due to the limited number of spawning populations, their accessibility, and a continued decline in many populations, efforts are being made to establish brood stocks. A key aspect of culture is the cost of production of larval lake sturgeon up to the size for stocking. Foods such as live brine shrimp are used, as well as frozen brine shrimp and ocean plankton, but the cost of production per fish is high. Formulated feeds are less expensive, but reduce performance. The best results to date on formulated feed are a survival approaching 60% and growth rates of up to 6 % per day. The myth that lake sturgeon are slow growing is questioned since 3-year-old sturgeon grown at 15°C have reached a weight of up to 5 kilograms.

Introduction

The decline of lake sturgeon is a matter of historical record. Indeed, the rate of decline at the end of the 1800s and early 20th century is unparalled by any other fish species. Individual fisheries producing a million pounds annually (450 000 kilograms) vanished in less than 10 years. This occurred despite efforts about 100 years ago by some aboriginal communities and a few biologists who suggested a moratorium on commercial fisheries and the establishment of preserves to protect the species.[3] The population decline continues with most commercial fisheries in Western Canada now closed. Figure 1 illustrates the decline in the catch of lake sturgeon in Lake Winnipeg, Manitoba. However, the combined interests of aboriginal communities, provincial agencies, commercial companies, including hydroelectric companies, and numerous habitat restoration groups are being directed towards solving some of the long-standing issues.

The issues relating to maintaining or enhancing lake sturgeon populations are complex and a general strategy for rehabilitation has not emerged to date from federal and provincial agencies or co-management boards. However, any strategy will likely involve some culturing for stocking programmes. It seems likely that culturing lake sturgeon for food production will occur, as year-round employment and revenue generation will be increasingly important issues as self government progresses in aboriginal communities. Production will be initially directed at supplying meat for local consumption (historical records show that in the past some aboriginal communities supplied up to 50% of their meat needs from the lake sturgeon harvest). Other historical uses of sturgeon indicate that it will gain ready acceptance by the consumer. For example, boneless flesh with distinct flavors (prepared smoked, barbecued, broiled), caviar, leather, oils, and a non-allergenic protein (isinglass) from the swimbladder are but a few of the potential products. Indeed, 100 years ago lake sturgeon were considered to produce supe-

rior tasting caviar and meat to that of other sturgeon.[3]

Culture

Culture efforts are complicated due to the extirpation of lake sturgeon in many areas of its previous range and the continued decline of most of the accessible remaining lake sturgeon populations. The two major limitations to lake sturgeon culture are (1) locating and maintaining stable sources of brood stock as populations continue to decline, and (2) current culture methods. Sources of broodstocks are further confounded by the lack of information on genetic background of populations among watersheds, hence the conservative strategy of using only those stocks within a watershed for stocking. Under natural conditions, populations of wild sturgeon females spawn for the first time at 22-28 years of age and then every 4-6 years, while males spawn at an age of 16-18 years and then about every 2 years. As a consequence, the prospects of developing a cultured lake sturgeon broodstock are daunting. We have established multi-aged brood stocks (1- 11 years) under culture conditions and are anticipating spawning in 2-3 years. To ensure sufficient genetic variation, these stocks are from a variety of different geographic regions and each year's founding stock is from different parents (i.e., multiple crosses).

The major hurdle in lake sturgeon culture is poor survival in the early larval stages. Survival is primarily influenced by husbandry and feed. We used square tanks containing 40 L of water with a flow rate of 1 L per minute and aeration supplied through airstones. Prior to feeding the tanks were drained and excess food was removed. Larval sturgeon were fed 3-4 times daily to apparent satiation. As the tanks filled, a current was generated that circled the tank and the larvae were observed to orient head end into the current and then actively feed. If live feed such as brine shrimp or natural plankton was used, survival was 95-100% and the tank bottom and filters were much less likely to become fouled. However, if grow-out to a larger size, i.e., 15-17 cm is necessary, the use of live feed becomes prohibitive due to costs of labor as well as of brine shrimp eggs. As the fish get larger, even with feeding frozen brine shrimp and/or frozen ocean plankton , the cost per fish is about $2.00. Use of formulated larval feeds are less expensive but there are several problems: (1) lake sturgeon do not take as readily to formu-

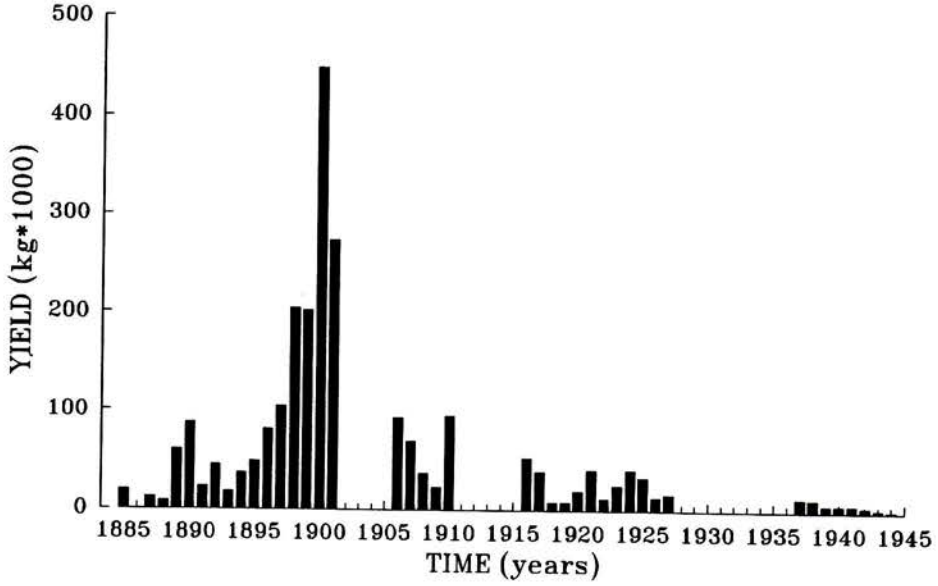

Figure 1. Lake sturgeon harvest from Lake Winnipeg.

lated feeds as most other species of sturgeon;[4,5] (2) lake sturgeon prefer to feed on the bottom rather than in the water column; and (3) sturgeon spend the majority of their time resting on the bottom of the tank so tank bottoms must be cleaned several times each day.

Commercially prepared larval diets have produced poor results with survival as low as 2%. Survival of lake sturgeon larvae fed closed formula feeds varied from 30 to 60%. Specific growth rates ranged from 3 to about 6% when lake sturgeon were raised at 15 and 20°C. Furthermore, lake sturgeon raised on formulated diets were 2-3 times larger at the end of 4-5 months than fish fed for the same period on brine shrimp and ocean plankton.

Grow-out experiments ranging from 6-36 months gave good results, with the best growth obtained at 20°C. However, lake sturgeon started on brine shrimp and then fed ocean plankton, had specific growth rates of about 1.5% per day while lake sturgeon started on formulated feeds and fed a similar diet during the growout period had growth rates as high as six percent per day. We also found that lake sturgeon under 1 year old reared at densities above 30-40 grams per liter had reduced growth rates, while older fish (1.5-3 years of age) can be grown at densities as high as 75 grams per liter. It seems that under culture conditions sturgeon are not slow growers and weights as high as 5 kg can be attained over a 3-year period for lake sturgeon fed formulated feeds and reared at 15°C (Fig. 2), well below their optimum temperature of about 20°C. While the future of cultured sturgeon looks promising there are some culture problems worth noting. A small proportion of fish have curved backs and float vertically in the tanks (eventually these fish stop feeding and die). Others problems are severely deformed pectoral fins and surface warts. The curved back appears to be genetic and may depend on the source of brood stock. Deformed fins may relate to a nutritional deficiency since only the boney portion of the fin is affected. Warts were most pronounced on fish reared at high densities (over 60 grams per liter).

Although improved conditions for rearing larval stages are still needed and a more complete knowledge of dietary requirements is necessary to optimize production and reduce costs, it is apparent from preliminary research that lake sturgeon is a fast growing culturable species. Accessibility to natural stocks, in the short term, and the development of cultured brood stocks, in the long term, will be essential to sustain enhancement programmes and to maintain a viable aquaculture industry for lake sturgeon.

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Figure 2. A three-year-old lake sturgeon reared at 15°C and weighing 5 kilograms.

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Controlling solids build-up in recirculating systems

W. James [1]

Recirculating systems reduce heating costs and effluent flow rates, but increase costs of maintaining water quality. The primary concern is that fine particles accummulate, contributing to oxygen demand, ammonia load, and disinfection requirements. A strategy to remove particles by flocculant settling and ozone-assisted froth flotation was investigated. Flocculation trials removed 85% of suspended solids and flow-through experiments using ozone-assisted froth flotation removed up to 50% of TSS in a single pass. Particles 5-10 μm were preferentially removed and volatile solids, chemical oxygen demand, and phosphate had similar removal efficiencies, but dissolved carbon and ammonia concentrations increased. To achieve water quality objectives for recirculating systems, an integrated approach must be adopted so that particle removal processes integrate with ammonia control and disinfection operations.

Introduction

Recirculating systems for culturing fish minimize raw water requirements, ensure year-round independence from climatic conditions, reduce heating costs, minimize effluent flow rates, control accidental release of cultured fish to natural waterways, and reduce the spread of pathogens. In areas of Western Canada where water supplies are limited, trout farmers have little choice but to recirculate water. Greater control over water quality is required in recirculating systems to avoid the build-up of contaminants.

Problems with Suspended Solids

Water quality issues in recirculating systems are suspended solids, ammonia and nitrite concentrations, and disinfection. The most important is controlling build-up of suspended solids (guidelines are usually stated in total suspended solids concentration (TSS)).

Fine solids accumulate, adding oxygen demand, contributing to ammonia load, and interfering with disinfection. Particle size distribution (PSD) may be as important as TSS. Particles 5-10 μm have been associated with physical toxicity in juvenile trout.[2] Fine particles can block water passage over the gills and damage the gill epithelium. Physical toxicity likely depends on the size and species of fish.

Controlling Suspended Solids

Coarse particles settle readily and well designed recirculating systems ensure that solid pellets are not pulverized, that solids are removed early in the treatment, and that fines are removed. Settling clarifiers or filters can remove suspended solids, but particles < 50 μm will not be removed by conventional clarifiers. Filters relying on mechanical straining through porous media such as screens and membranes require frequent backwashes and/or high operating pressures. Diatomaceous earth filters, depending on thin layers precoated with filter aid, can remove fine particles but they have problems common to straining processes and their operation is labor intensive.[3] Deep bed granular media filters generally do not remove particles < 30 μm.[4] Filters with 1 μm granular media exhibit the poorest removal efficiency for particless between 1-10 μm.[3] Biological filters for removing solids and nitrifying ammonia operate economically and reduce TSS effectively,[5] but are not designed for removing fine particles.

Froth flotation effectively removes fine particles and is similar to foam fractionation, but the former term is most appropriate for the removal of suspended and colloidal particles rather than soluble organics or proteins. When air is bubbled through a water column, surface active compounds concentrate on gas-liquid interfaces with the non-polar end away from the water into

the gas bubble. Surfactants can then be skimmed from the water with the bubbles. Particles with surface charges also attach to surfactants on the bubbles and are removed with the froth. If ozone is added to the air stream, oxidation reactions occur with organic constituents and additional surface active products are formed. Process variables and configurations for foam separation are discussed by Wheaton[6] and Chen.[7]

Experimental Objectives

The first study removed suspended solids by flocculative settling, to evaluate the effects of flocculation time and intensity on TSS removal during quiescent settling. The second study focused on removing TSS (especially fines) by ozone-assisted froth flotation. Controlled variables were the height of the froth collector above the water column and the ozone application rate. Several parameters including TSS, volatile suspended solids (VSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved organic carbon (DOC), total Kjeldahl nitrogen (TKN), ammonia (NH_3), and total phosphate (TP) were measured in raw, treated, and froth samples to relate percent removal to treatment variables.

Materials and Methods

Wastewater supply. A recirculating system used for rainbow trout at the Alberta Environmental Centre was the source of wastewater. Stocking density and TSS were low compared to commercial facilities, so concentrated wastewater was obtained by backwashing a sand filter in the treatment train. The TSS was 58-86 mg/L and there was a large fraction of fine particles due to the action of centrifugal pumps. Particle size characterization performed with Coulter technology (Hialeah, Florida) revealed 83% of particles by volume were < 25 μm and 51% < 10 μm. Water collected for each set of trials was kept agitated prior to use to keep solids in suspension.

Flocculation experiments. Experiments used standard jar test apparatus.[8] Controlled variables were the rotational speed of the flocculator and the time of flocculation (t_f). Quiescent settling time was 20 min. Flocculator speed was related to the velocity gradient (G).[9] Rotational speeds of 5, 10, 30, and 60 rpm corresponded to G values of 1.8, 4.5, 15, and 30/s. The flocculation times were 5, 20, and 35 min. Four trials were conducted and triplicate TSS measurements were taken on raw and treated water.[10]

Froth flotation experiments. Similar experiments were conducted on wastewater collected on November 30, 1995, and February 21, 1996. A 3.3 m high by 7.6 cm diameter bubble column was used for contacting ozone and considered only height of the froth collector above the water column and ozone application rate. The froth collection device, consisting of an inverted cone, was inserted into the top of the contacting column. Co-current contacting was used with flow rates of 3 L/min and 1.5 L/min for water and gas, respectively. Gas flow rate was maintained with a mass flow controller and the mass percentage of ozone in the gas supply was monitored continuously with a UV spectrophotometer. Ozone was applied at 1 or 3 mg/L of water flow. Froth collector heights were 2 and 4 cm. Raw and treated water and froth were analyzed[10] for TSS, VSS, BOD, COD, DOC, TKN, NH_3, and TP. Particle size distributions based on normalized volume fractions were obtained for raw and treated water from the February 21 trials.

Statistics. Regression analyses performed to assess the effects of controlled variables used data analysis tools in Excel v. 5.0 software.

Experimental Results

Flocculation trials. Highest TSS removal occurred for G values of 1.8 and 4.5/s. An optimum was apparent for trials conducted with a t_f of 1200 s: increasing G above 4.5/s resulted in decreased removal. There was a continuous positive relationship between flocculation time and TSS removed, but the removal fraction increased more as t_f went from 300 to 1200 s than for a similar increment from 1200 to 2100 s.

Froth flotation trials. Both collector height and ozone application rate (OAR) significantly ($\alpha \leq 0.05$) affected the volume of froth collected and the TSS in the froth. Increasing collector height reduced the volume of froth, but increased its TSS. Increasing OAR produced more froth by volume, but decreased TSS. In terms of reducing TSS in wastewater, OAR had a net positive effect, but collector height was not significant. Removal efficiencies of VSS, BOD, COD, TKN, and TP followed a similar pattern and only the effect of OAR was significant. Two parameters, DOC and NH_3, increased in concentration ($\alpha \leq 0.05$) as a result of ozonation. Up to 50% of TSS was removed by froth flotation

when the initial TSS was 58 mg/L and the OAR was 3 mg/L. Approximately the same fraction of VSS was removed as TSS. Particle size characterizations showed a significant decrease ($\alpha \leq 0.05$) in the normalized volume fraction in the 5-10 μm size range and an increase in the 32-64 μm sizes in response to OAR.

Discussion

Flocculation experiments. Settling clarifiers are applied early in treatment trains to remove heavier suspended particles and flocs. By increasing the efficiency of flocculative settling, much of the solids load can be removed from subsequent treatment processes.

Although the product G•t is dimensionless, it is proportional to the energy input to the system (product of the torque, rotational speed, and flocculation time). Energy input and cost would be reduced if the same degree of flocculation could be achieved using lower values of G•t. Similarly, there would be a cost saving if the hydraulic retention time for clarification could be reduced, because smaller settling tanks and less floor space would be required. There is a trade-off between flocculation energy and floc strength: higher energy promotes smaller, more stable flocs; lower energy produces larger, less stable flocs.[3] To take advantage of low-energy flocculation, a quiescent settling zone must immediately follow the flocculation chamber.

Froth flotation experiments. To minimize water loss from a recirculating system, the volume of froth collected must be small, but to remove TSS and other parameters, the froth needs to be highly concentrated. Practically, the froth collector may require a minimum flow to operate reliably. Wastewater used for this investigation showed little tendency to form froth when air was applied; no froth reached the collector until ozone was applied. Froth flotation also removes dissolved nutrients. Ozonation removes BOD and improves biodegradability of remaining organic compounds.[11] These factors reduce the amount of heterotrophic activity required in biological filters, leading to improved ammonia control by nitrification.[12]

Ozone must be carefully applied to minimize loss via off-gas and to avoid dissolved concentrations harmful to cultured fish. Ozone is a potent oxidant and disinfectant; concentrations as low as 10 μg/L can be harmful to juvenile trout.[13]

Froth flotation could be added as the second stage of a clarifier, incorporated into the disinfection process, or applied to each culture tank as a separate unit process. Adding a froth collector to an ozonation column, provides simultaneous aeration, disinfection, and froth flotation.

Conclusions

1) Fine solids (< 25 μm) constituted over 80% of the suspended particles in wastewater from a recirculating facility.
2) Bench-scale experiments demonstrated that adjusting the intensity and duration of flocculation could improve the fraction of particles removed by settling from 35% to 80%.
3) A froth collection device added to an ozone bubble column was able to remove up to 50% of total suspended solids from wastewater. Fines were preferentially removed.
4) Ozone application rate affected the volume of froth and the removal of suspended solids, biochemical and chemical oxygen demand, Kjeldahl nitrogen, and phosphate.

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Chemotactic responses by the turbellarian, *Urastoma cyprinae* to different stimuli

Nicole T. Brun, Andrew D. Boghen and Jacques Allard [1]

Urastoma cyprinae is a turbellarian found on the gills of certain bivalve molluscs, including the American oyster, *Crassostrea virginica.* Studies suggest that *U. cyprinae* can have a negative impact on the health of its host. Experiments were conducted to determine the attraction of *U. cyprinae* to oysters. Worms were isolated from infected hosts and exposed to a variety of attractants. Results indicate that *U. cyprinae* display a strong attraction to oyster tissue and to phytoplankton. Moreover, it was shown that in the absence of any stimuli, *U. cyprinae* are negatively phototactic, but that this behavior is less pronounced when attractants are available.

Introduction

With the exception of Malpeque Disease in the 1950s and 60s,[2] Atlantic Canada has been spared some of the dramatic losses attributed to infectious diseases in molluscs, such as MSX, Dermo and Bonamia.[3] Recent studies describe the occurence of a small, ubiquitous turbellarian, *Urastoma cyprinae*, in oysters found in the Gulf of St. Lawrence.[4,5] This worm has also been reported in other parts of the world from a variety of molluscan species, including clams[6] and mussels.[7-9] While some consider *U. cyprinae* to be a commensal,[10,11] and therefore not harmful to its host, others suggest that, in the mussel, *Mytilus galloprovincialis*, it is responsible for serious destruction of host tissue.[9] The aim of our study was to examine whether there is a specific attraction of *U. cyprinae* to oysters and to shed some light on what the source of the stimulus might be.

Methods

Eight samples of 30 to 40 oysters were collected from Shippagan, New Brunswick. and Ellerslie, Prince Edward Island, between July and September 1995. The animals were transported on ice to the Université de Moncton and examined within 48 hours of collection. The oysters were opened and the worms were removed from the gills with a Pasteur pipette under a dissecting microscope. They were subsequently divided into 80 groups (60 worms/group) and maintained in filtered sea water (26‰) in total darkness at 4°C for 2-3 days. Prior to experimentation, the worms were acclimated to 22-23°C for 12 hours. Eight experiments were conducted, under light and dark conditions (8 experiments x 60 worms/group x 5 replicates/experiment x 2 light/dark = 4 800 worms). The stimulants tested were: homogenized oyster tissue, concentrated phytoplankton *(Isochrysis galbana)* and a combination of the two. Filtered sea water (26‰) served as a control. Concentrates of the above products were prepared by centrifugation in the following proportions: 1:10 (v/v) oyster tissue to filtered sea water; 10 mL of phytoplankton (10^6cells/mL) and 1:10 (v/v) oyster tissue to phytoplankton (10^6 cells/mL). The concentrates were placed into one of two wells at opposite ends of specially-designed glass chambers (Fig. 1), and sufficient filtered sea water (26‰) was added to provide an aqueus medium in which the worms could displace themselves towards one stimulant or another. *U. cyprinae* were introduced into the chamber with a pipette, through a central opening (Fig. 1). After one hour, each of the wells at the ends of the chamber was drained and the worms were counted.

Because *U. cyprinae* did not display any significant positive or negative phototropism when stimulants were available, data based on experi-

ments conducted under light and dark conditions were combined. The student's *t* test was employed for all the experiments to distinguish levels of attraction of *U. cyprinae* to the stimulants.

Results and Discussion

U. cyprinae displayed a marked negative phototactic response in the absence of any stimulant. This is consistant with observations reported by others.[12,13] When *U. cyprinae* were given a choice between the following attractants: oyster vs phytoplankton; oyster-phytoplankton vs control; oyster-phytoplankton vs phytoplankton and oyster-phytoplankton vs oyster (Fig. 2a-d), no significant preference was detected.

U. cyprinae showed a significant chemotactic response to oyster tissue and phytoplankton (Fig. 2e,f) ($p<0.0005$) compared to the sea water control, suggesting that either one or the other may serve as food for *U. cyprinae* when the turbellarian is inside its host. If indeed *U. cyprinae* is feeding on oyster tissue, then the cellular deterioration that certain authors describe for other molluscs may be explained.[9] On the other hand, if *U. cyprinae* relies primarily on phytoplankton, especially if there are a high number of worms in the host, then they may be competing with the oyster for food or interfering with its feeding and respiratory mechanisms.[4,14] These aspects, along with studies on the biology of the feeding apparatus of *U. cyprinae* are presently the subject of a series of experiments being conducted in our laboratory.

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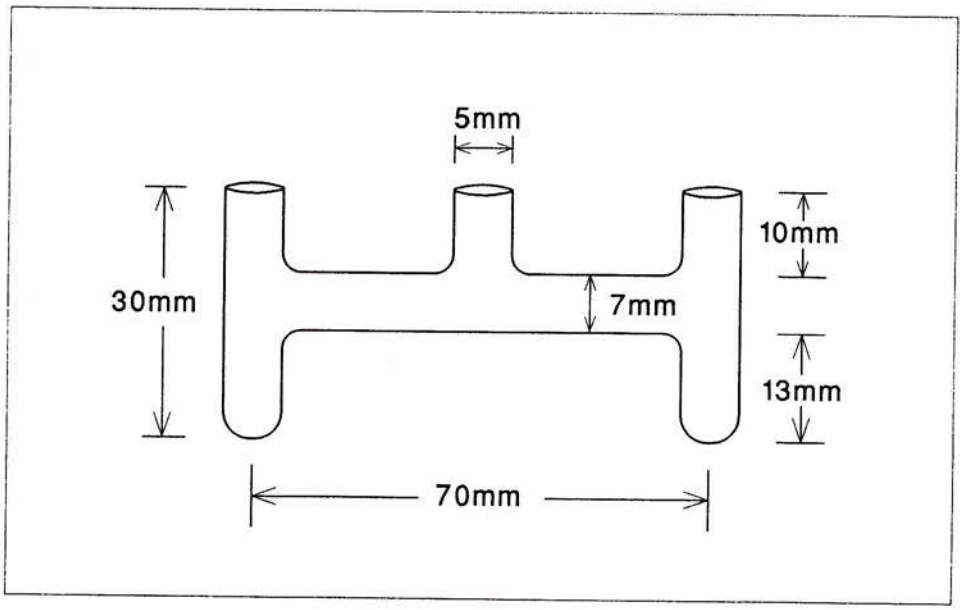

Figure 1. Glass chambers used in the chemotactic experiments with *U. cyprinae*.

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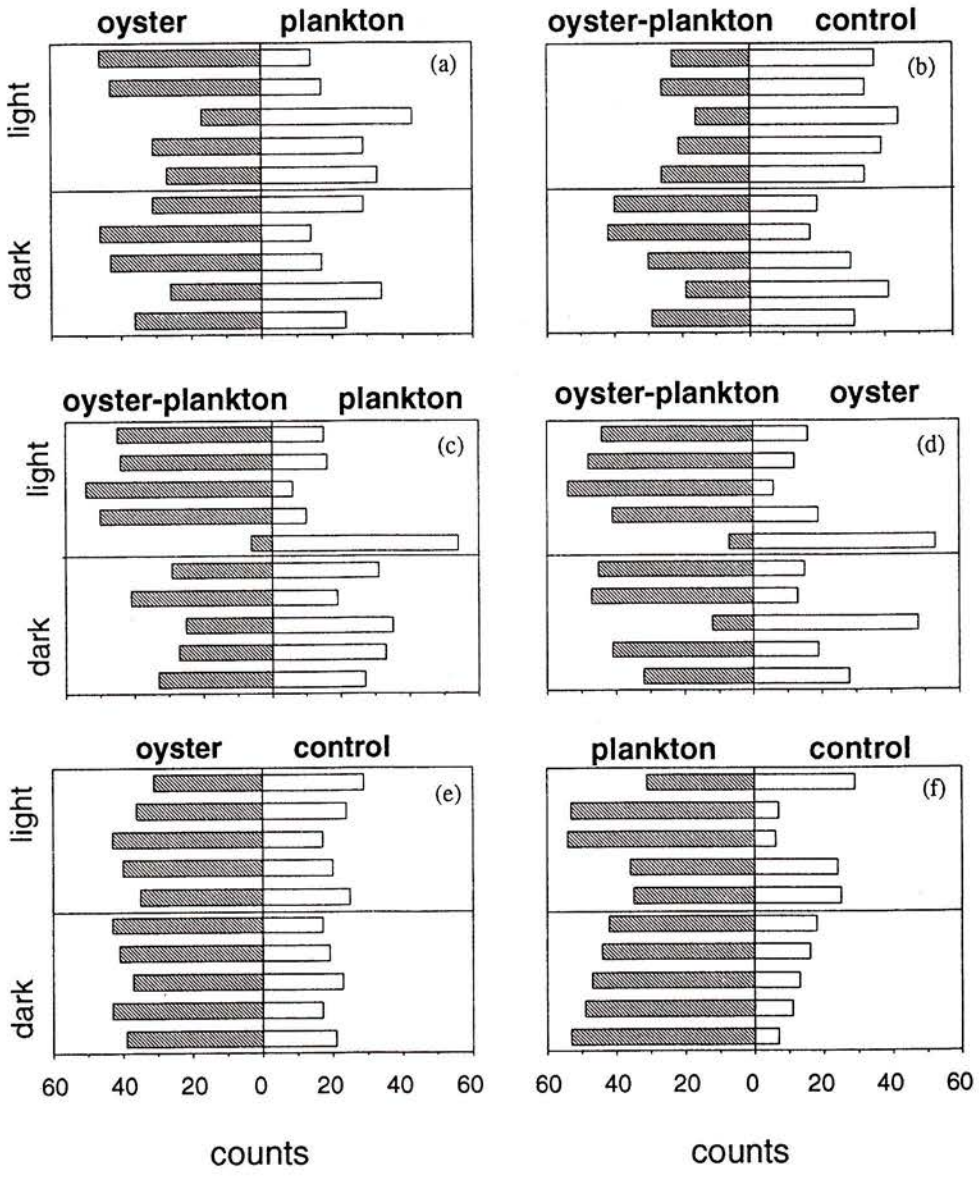

Figure 2. Total number of *U. cyprinae* counted in each of the two wells containing the respective stimulants tested. Each of the bars represents one replicate of the total number of *U. cyprinae* that were recorded under light and dark conditions.

Towards integrated management for sea lice

John D. Smith [1]

Sea lice are a major disease concern in salmon farming operations. The Alternatives Division of the Pest Management Regulatory Agency (PMRA) and the Canadian Aquaculture Industry Alliance — Salmon Health are undertaking a project on integrated management strategies for sea lice. The goal of this project is to develop national strategies in an open and inclusive manner, and in a form that can be used by all stakeholders. Participants include federal and provincial government officials from the Atlantic and Pacific regions, salmon producer groups, pesticide and pharmaceutical manufacturers and research scientists. A small working group has been formed to oversee the compilation and critical review of information on biology and management of sea lice, with an emphasis on products, practices, and devices that can contribute to integrated management, and to develop plans for communication of this information to all parties involved. This project is part of the PMRA's commitments to foster the development of sustainable pest management strategies.

The Alternatives Division of the Pest Management Regulatory Agency, in partnership with the Canadian Aquaculture Industry Alliance — Salmon Health has initiated a project on the development of integrated management strategies for controlling sea lice in salmon farming operations. This work is in its early stages and this paper serves as an introduction to the project and the process we are following.

Sea lice have been a severe and costly pest in salmon farming operations in Europe and more recently in eastern Canada. Because of outbreaks in 1994 and 1995, the Pest Management Regulatory Agency (PMRA) was called on to provide emergency registrations of products to control the pest. At the same time, as part of its new mandate, the Agency began looking at ways to promote long-term strategies for management of the disease.

A brief overview of the Agency and the Alternatives Division will set the context for this work. The PMRA was created in April 1995 within Health Canada to provide a single federal authority for the regulation of pest control products. The Agency brings together groups formerly in Agriculture and Agri-food Canada, Health Canada, Environment Canada, and Natural Resources Canada who were involved in assessment and regulation of pest control products.

In administering the Pest Control Products Act, the mandate of the new Agency is to protect human health and the environment by minimizing the risks associated with pesticides, while enabling access to pest management tools, namely, pest control products and sustainable pest management strategies. Note that the focus is broader than just pest control products.

The major objectives of the Agency are to protect health and the environment, support competitiveness, regulate cost-effectively in an open and transparent manner, and support the integration of pest management with broader goals of environmental sustainability. "Sustainable development" was defined by the Brundtland Commission as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." Consistent with this definition, the Agency describes "sustainable pest management systems" as "those that are economically viable, and meet society's needs for human health protection, food and fibre production, and resource utilization, while conserving or enhancing natural resources and the quality of the environment for future generations."

The Alternatives Division was established to find practical ways of implementing the Agency's objectives related to sustainable pest management. The key areas of activity of the Alternatives Division are development of a risk reduction policy; finding mechanisms to facilitate access to pest management strategies that present reduced risk to health and the environment; and increasing development promotion and use of sustainable pest management systems. Some of the Division's specific activities include development of a National Pesticide Use Database, development of guidelines to facilitate registration of alternative pest control products, and initiatives to develop long term strategies in areas of critical and emergency need. The sea lice project falls into this category.

In conducting this work, the Alternatives Division uses the broadest possible interpretation of alternatives and is attempting to achieve stepwise progression towards the use of alternatives in partnership with all sectors.

The project on integrated management of sea lice was developed at the same time as the Agency was dealing with the short-term but critical need for registered products to deal with sea lice outbreaks. There was a recognition of the need for long-term strategies that could lead to a more sustainable approach to management of this pest.

To this end, we convened an initial meeting in February 1996 on the development of integrated pest management (IPM) strategies for sea lice. The meeting objectives were to provide:

- an opportunity to exchange information on sea lice and sea lice management;
- a review of advances toward sea lice management; and
- a discussion of integrated pest management as a model for future sea lice management programs.

The meeting was attended by representatives of federal and provincial governments from the Atlantic and Pacific regions, grower groups, pesticide and pharmaceutical manufacturers, and distributors, as well as scientists and research agencies with interest in sea lice. The involvement of as many sectors as possible, such as attended the meeting in February, is necessary for this project to succeed.

There were two main conclusions from the meeting. First, participants emphasized that there was a critical short term need for approved sea lice control therapeutants to respond to this infection in the coming growing season.

The meeting also concluded there was a need for long-term integrated strategies for sea lice management in order to sustain the industry, protect the environment in which it operates, and to address stakeholder concerns. At its simplest, IPM means using all available and necessary techniques to suppress pests effectively, economically, and in an environmentally sound manner. It is important to note that there is not an either/or choice between use of therapeutants and IPM. Under IPM, all tools including therapeutants are used in the most effective combination possible. The meeting heard how practices that can contribute to integrated management of sea lice are known and are being used in various areas.

In order to develop an overall approach to sea lice management, the meeting decided it was necessary to compile and critically review information on the biology and management of sea lice, including information on the environment in which the industry operates, and to make this information available to all. Therefore, a working group has been set up to accomplish the following:

- oversee collection of information on sea lice biology and management, including information on the chemical, physical and biological factors in the environment of sea cages that affect sea lice and management options;
- arrange for expert review of this information by members of the working group, by members of the Sea Lice Integrated Management project group, or by other experts;
- oversee development of an overview document with recommendations for national management strategies and research needs with input, review and concurrence by members of the Sea Lice Integrated Management project group;
- develop plans for communication of this information.

To summarize, the project aims to bring together available information and develop recommendations for a national approach to integrated management that can be agreed to by all participants, and communicated to all who are involved in the industry. At this time, we are in the process of assembling information. We have solicited input from a wide range of groups. The draft "topics" list (Table 1) serves as a guide for the kind of information necessary to

Table 1: Topics to consider in an integrated management strategy for sea lice

Sea Lice Biology

Life cycle, generation time and population dynamics
Feeding activity and damage to fish
Host specificity
Variations between lice species
Methods for laboratory study of fish – lice interactions

Environmental Factors

Chemical, physical, and biological factors in the environment of sea cages that affect sea lice and choice of management option
Site selection, water quality, and impact on lice infestations
Factors leading to outbreaks
Dispersion of therapeutants from treatment sites in relation to potential for exposure of non-target species.

Sea Lice Management

Considerations for optimal use of therapeutants:
- control of different life cycle stages, including control of eggs and egg production
- techniques to minimize environmental impacts, including effects on non-target species
- coordinated treatment of sites
- scheduling treatments based on lice numbers and season
- strategies to avoid resistance

Other management methods such as:
- fallowing and rotating sites
- use of cleaner fish
- pumping of fish
- devices such as light traps
- vaccines

be included as part of an IPM strategy.

The project has a time frame of about two years. The goal will be to produce information that is useful to all participants. As a model of what we hope to accomplish, the Alternatives Division has completed a similar project in partnership with the Canadian Horticultural Council and the Research Branch of Agriculture and Agri-food Canada. This project developed an overview document and a fact sheet on integrated management of late blight, a serious fungal disease of potatoes. Participants in this project have ordered over 7000 fact sheets for distribution across the country. In addition to getting this information into the hands of growers, these documents will provide a framework for future decisions on fungicides or other controls to be made in an IPM context.

We are very hopeful that we can achieve a similarly useful result in the sea lice project.

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Tolerance of the giant sea scallop, *Placopecten magellanicus*, to low salinity

Craig Bergman, Jay Parsons and Cyr Couturier[1]

Giant sea scallop (*Placopecten magellanicus*) culture in Newfoundland has experienced several episodes of mass mortality caused by low salinity and more data is needed to accurately assess the salinity tolerance of giant scallops. Salinity tests on juvenile giant sea scallops from Nova Scotia were conducted at Memorial University of Newfoundland. The first of two experiments consisted of two short term exposures of scallops to salinities of 10, 13.5, 16.5, 20, and 31 ppt at an ambient seawater temperature of 1°C. The first experiment consisted of two parts. First, a 2-hour exposure to low salinity before recovery in ambient flow-through seawater resulted in nearly 100% survivorship in all test groups of scallops, although severe catatonic shock was exhibited by all groups except those at 31 ppt. The second part was a 6-hour exposure to low salinity that produced similar results, except that all the scallops in the 10 ppt group died. The second experiment was a long-term exposure to salinities of 10, 13, 16, 18, 21, 24, 27, and 31 ppt. Salinities of 16 ppt and below were lethal and catatonic shock was severe in the 18 ppt and 21 ppt groups. These experiments were designed to mimic extreme farm environmental conditions where a layer or lens of freshwater covers the site or the entire site's salinity drops. Scallop aquaculturalists and site selection advisors should be aware of the long term exposure limit of approximately 18 ppt and the short exposure limit of 13.5 ppt, so that scallop mortalities can be avoided and sites with tendencies to retain freshwater will not be chosen.

Introduction

Giant sea scallop meats command high market prices and because of the unreliable nature of stock recruitment, prices fluctuate depending on availability. Over exploitation of the fishing areas due to market demands and technology advances has become a recent threat and as a result the culture of giant scallops has begun at a commercial level throughout the Atlantic region.[2] Although many culture methods are employed, the most economical and successful way of farming scallops is suspended longline culture. Most sites are found in sheltered, land bound bays and inlets because of the calm water. Sites chosen for their excellent growing features will often retain freshwater during times of heavy spring and autumn run-off, and this freshwater can form a "lens" or layer on the top of the water column if flushing or adequate mixing does not occur. Depending on individual site characteristics and the amount of freshwater introduced to a site, the lens may be anywhere from 1 to 10 m deep and have salinities lower than 10 ppt in the surface water for periods exceeding several months.

Giant scallops have been found to be very sensitive to low salinity and several studies cite 16.5 - 25 ppt as the lower limit they can tolerate before stress and mortality occurs.[3-5] Scallops are unable to rapidly adjust their osmotic system and will go into osmotic "shock" at low salinities, characterized by a swelling of the tissues as water is absorbed through osmosis. Depending on the severity of the shock, scallops may eventually die.

The objective of this study was to determine salinity tolerances of giant sea scallop to long

Table 1. LC_{50} results for salinity tolerance of juvenile giant sea scallop over several time periods.

Exposure Period (hours)	LC_{50} Salinity Concentrations
24	8.2‰
48	8.1‰
72	8.1‰
96	11.4‰
144	14.4‰
240	16.9‰

and short exposures. The research was conducted in a way that both short exposure, which mimics the farm conditions of working with the scallops in the freshwater lens area, and long exposure which mimics an entire site having a lowered salinity for an extended time due to mixing, could be tested for stress and mortality.

Methods

The experiments were carried out with plastic trays (3.25 cm x 17.5 cm x 9 cm) each containing ten scallops, the appropriate salinity, and a separate air supply. These trays were set in ambient flow-through seawater on either a wet bench or in a holding tank, so that a constant temperature could be maintained. Temperature averaged about 1°C. Cultured juvenile scallops were obtained from a commercial grow-out site near Chester Basin, Nova Scotia. Shell heights ranged from 27 to 43 mm and there was no significant difference between treatments or replicates (ANOVA, $p < 0.05$).

This study was divided into two experiments, with each salinity treatment being done in triplicate. The first experiment contained two parts, one part was a 2-hour exposure and the other part was a 6-hour exposure to salinities of 10, 13.5, 16.5, and 20 ppt as well as ambient sea water (31 ppt). After exposure, these scallops were returned to ambient flow-through seawater, and were monitored for behavior and survival at the pre-determined time increments of 1, 2, 4, 8, 16, and 24 hours after exposure and every day afterwards for 2 weeks.

The other experiment was a long term salinity exposure to concentrations of 10, 13, 16, 18, 21, 24, and, 27 ppt as well as ambient (31 ppt). The water was changed every day and temperature and scallop behavior were recorded at pre-determined time periods. Catatonic stress can be identified by responses such as mantle and tentacle retraction, mucus production, soft tissue swelling, valve closure, and excessive gaping. Unfiltered seawater was used and was diluted with distilled water.

An LC_{50}, using probit analysis (SPSS), was done to analyze the acute salinity exposure data to determine at which salinity 50% of the experimental animals died.

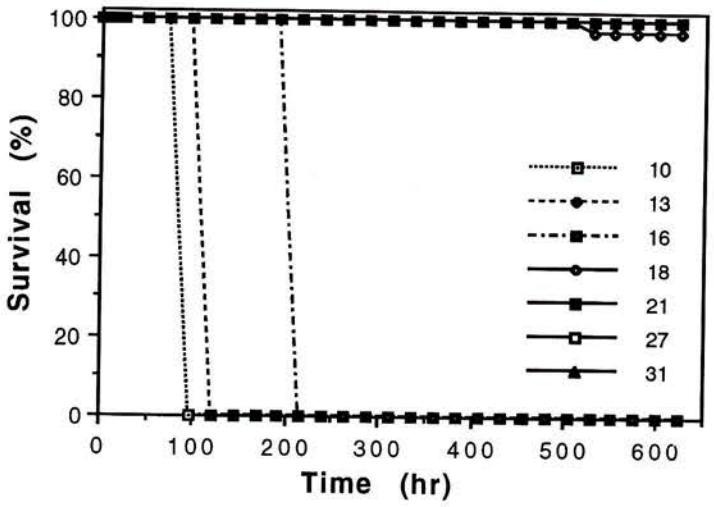

Figure 1. Long term survival of giant sea scallops exposed to a series of reduced salinities.

Results

The results of the 2-hour exposure experiment (and recovery period of 14 days) showed little mortality; all were alive after the 2-hour exposure. The 10 ppt trial had only 17% mortality after the two weeks of recovery. It was after the scallops began to recover and were exhibiting normal activity that the mortalities occurred at day 5, 9 and 11. All the other groups had 100% survivorship. All scallops in re-

duced salinities displayed catatonic shock, however, they were able to recover, except for the 10 ppt group.

The results for the 6-hour experiment were similar to the 2-hour exposure, except for greater mortalities. There were no mortalities after 6 hours but there was 0% survivorship in the 10 ppt salinity trials after the scallops were placed in ambient seawater recovery. Some of these mortalities occurred on day 4 and 8, and then the rest of the group died at day 16. All the other tests resulted in 100% survivorship. As before, the scallops experienced severe catatonic shock during exposure and for 6 days after their return to ambient flow-through seawater.

Long term low salinity exposure resulted in mass mortality of scallops at salinities of 10, 13, and 16 ppt. At 18 ppt, there was one mortality at day 22, representing a 97% survivorship for this group. Salinity tests of 21, 24, 27 ppt, and ambient (31 ppt) had 100% survivorship (Fig. 1). The results of the LC_{50} showed an increasing salinity tolerance with exposure time (Table 1). For an exposure of 240 hours, the LC_{50} was 16.9 ppt while the lethal salinity concentration for a 24 hour exposure was 8.2 ppt. LC_{50} results for 24, 48, and 72 hour exposures were only estimations as the scallops did not die during these time periods and the LC_{50}'s were outside the salinity range tested.

Stress response among the experiments was a measure of the level of catatonic shock experienced by the scallops while in low salinity. All scallops except those in ambient seawater exhibited symptoms of shock that varied in strength. The scallops recovered at different rates depending on exposure time and salinity level.

Discussion

Conclusions made in Ledwell's[5] report indicate adult giant scallops from Newfoundland suffer high mortality at short exposure (96 hours) to salinities of 25 ppt or less while juvenile scallops from this study were able to tolerate salinities as low as 18 ppt without any detriment to their long term (2 week) responsiveness or survival. Chaisson[3] found the lethal salinity concentration for adult giant scallops to be 16.5 ppt and this seems to agree with the results of the present study.

Salinity tolerance may vary according to age and stage of development. Adult scallops may be more susceptible to osmotic shock simply because of their age and may be related to changes in sexual maturity.[6] The low tolerance levels of Ledwell's[5] adult scallops compared to the juveniles in this study could be attributed to many factors; the adult scallops were from Newfoundland and they had a history of a higher and more constant salinity regime compared to the juvenile scallops used in this research, which were grown in Mahone Bay, Nova Scotia, in a wider range of salinities.

As a result of this study, salinity tolerances of juvenile giant sea scallops were found and are easily compared to extreme environmental conditions of many giant scallop culture sites in early spring or autumn during heavy freshwater run-off. Juvenile scallops have a better tolerance to low salinity than expected; however death does occur with long or constant exposure to salinities of less than 18 ppt and short exposures up to 6 hours to salinities of 13.5 ppt or less. With this information aquaculturalists can begin to establish safe conditions to work with the cultured animals without damaging or killing them. Site selection requirements will be more accurate and further studies will have a broader information base to work with. Giant scallop culture is growing in Newfoundland and as information is accumulated the industry will benefit positively.

We would like to thank Kevin Crocker and Tony Clemens of the Ocean Sciences Centre for offering information and personal experiences.

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Premiers essais de mytiliculture en baie de Gaspé. 1. Le captage

Benoit Thomas [1]

The potential for collecting mussel (*Mytilus* sp.) spat at five sites, four depths and at different dates of deployment of collectors was studied for the first time in Baie de Gaspeé in 1992 and 1993. This bay offers protected zones, rare along the coast of the Gaspé peninsula. The first results, in autumn, from the four groups of Vexar collectors (0.15 x 3 m), deployed at two-week intervals beween June 1st and July 14th, show a slight tendency for the spat in the collectors immersed in mid-July to be smaller in size, for the fresh weight to be lower and for collection to be only half as successful (kilograms of spat ready to be socked per meter of collector) as those immersed in June. Results at the Penouille, Dartmouth, Sandy-Beach, Fort Peninsule and Haldimand sites in the beginning of November 1992 show that the end-of-season spat have a mean size between 13 and 16 mm. Fall follow-ups of the five sites show that the mean collector yield (percentage of spat, by weight, greater than 10 mm) varied between a low between 3 and 14% at the end of September to a more promising 27 to 49% at the beginning of November. Depending on the immersion depth (between 2 and 10 m in 1992), the mean spat size at the end of October was respectively 13 and 9 mm and the yield decreased by 95% at the 10 m depth. The polypropylene collectors maintained at 2 m depth produced spat of comparable size to that of the Vexar collectors. However, the fresh weight of the spat from the polypropylene collectors was 40% less than that from the Vexar collector, but the yield, however, was slightly higher. The 1993 trials showed a similar tendency in the collectors maintained between 0 and 5 m depth for a period of 11 months. In order to obtain a production cycle favoring winter harvesting, collectors should be immersed before the end of June at a depth of about 2 m. The spat collected should be socked after mid-October. These first results are comparable to those obtained in the Carleton area, a more open zone in the Baie des Chaleurs. The landlocked nature of this bay, as well as stable ice cover in the winter, permits sheltered culture conditions as well as the possibility of winter harvesting.

Introduction

Afin de cerner la période de mise l'eau des collecteurs de moules (*Mytilus* sp.) au printemps, il est bon de s'avoir à quel moment la température de la masse d'eau atteint 10°C; soit la température à laquelle a généralement lieu la ponte.[2] Selon les données recueillies dans la baie de Gaspé cette température est atteinte au début juin.[3, 4] En puisque le stade larvaire subsiste de 3 à 4 semaines aprés la fertilisation[2], la période de fixation aurait lieu à la fin de juin. Ceci correspond aux observations à Carleton [5] entre 1986 et 1988. Au début juillet, les moules y atteignaient prés de 351 µm et 12 mm à la mi-octobre.

Lors du tri à la mi-octobre, les collecteurs en polypropyléne produisaient 2,5 kg/m de naissain [5], desquels étaient récupérés de 58 à 78% de naissain adéquats pour la mise en boudins

après un tamisage sur un treillis de 1/4 pouce. Prés de 3 boudins de 3 m de 1,5 kg étaient fabriqués par collecteurs de 2,8 m. Le succès de captage y est évalué [6] entre 2,5 et 3,8 kg/m de naissain de plus de 10 mm sur des collecteurs en Vexar en septembre; avec un rendement de 7,3 boudins/collecteur. Il est suggéré de procéder à la sortie des collecteurs et à fabriquer les boudins à la mi-octobre.[5-7]

Méthodologie

La majorité des collecteurs utilisés étaient fabriqués à partir de rouleaux de Vexar de 1/2 pouce coupés en bandes de 0,15 x 3 m et immergés sur des lignes maintenues à 2 m sous la surface au site de Penouille. Les poids frais des collecteurs étaient pris après un égouttement de près d'une heure. La taille moyenne du naissain était déterminée sur un sous-échantillon d'environ 100 à 150 moules à partir d'un échantillon de 15 cm de long prélevé sur chaque collecteur et tamisé, pour éliminer le naissain < 7 mm, sur un plateau en Vexar de 1/8 pouce. Le rendement des collecteurs était évalué en calculant le pourcentage en poids du naissain prêt à la mise en boudins (≥10 mm) tamisé sur un plateau en Vexar de 1/4 pouce. Une analyse plus détaillée de l'environnement[8] et des résultats de l'ensemble du projet de l'évaluation du succès de captage[9] seront disponibles dans les documents en préparation; mais voici un aperçu de la méthode employée lors de l'élaboration du suivi des principales variables étudiées.

Sites d'immersion en 1992 et 1993: Lors de la comparaison des 5 sites de captage, les collecteurs ont été mis à l'eau à la même date au printemps (15 juin en 1992 et 18 juin en 1993) et 3 collecteurs ont été prélevés par site à 3 ou 4 reprises entre juillet et novembre. Au site de Penouille s'est ajouté les sites de Dartmouth, de Sandy Beach et deux autres sites, Fort Péninsule et Haldimand, qui se retrouvent à l'extérieur de la barre de sable protégeant le Havre de Gaspé.

Profondeurs d'immersion et types de substrats en 1992 et 1993: Les collecteurs ont été immergés 4 mois en 1992 (11 juin au 26 octobre) et 11 mois en 1993-94 (22 juin 1993 au 24 mai 1994). Alors que les types de collecteurs comparés étaient le même d'une année à l'autre (Vexar et polypropylène), les profondeurs d'immersion ont varié (2, 5 et 10 m en 1992 et 0, 2 et 5 m en 1993). Le nombre de collecteurs échantillonnés était de 7 par type de collecteur et profondeur sauf en 1993 où il ne restait plus que 3 à 4 collecteurs.

Dates d'immersion en 1992: Par suivi, 4 collecteurs étaient échantillonnés; sauf lors du dernier suivi en novembre où que 1 à 3 collecteurs par date d'immersion ont été récupérés. Les dates d'immersion évaluées sont le 1 er juin, le 16 juin, le 29 juin et le 14 juillet et celles de la relevée sont le 24 septembre, le 13 octobre et le 3 novembre.

Résultats et Discussion

Sites d'immersion en 1992 et 1993: On observe une trop grande variabilité du poids moyen des collecteurs de Dartmouth et de Fort Péninsule pour assurer une production fiable. La taille moyenne des naissains varie que de 13 à 16 mm selon les sites. En novembre 1992 et 1993, les collecteurs des sites de Sandy Beach et Fort Péninsule offrent les plus faibles rendements moyens avec moins de 32%. Comparativement, les sites de Penouille et Dartmouth ont fourni en 1993 des rendements de 47 et 49%. Les deux années, le poids frais moyen des collecteurs de Sandy Beach est resté plus faible (12 à 14 kg) comparativement aux sites de Penouille et Haldimand (17 à 22 kg). En obtenant près de 9,9 kg de moules < 10 mm sur les collecteurs en Vexar de Penouille en novembre 1993 on pourrait fabriquer 6,6 boudins de 1,5 kg; ce qui est inférieur à 7,3 obtenus en septembre à Carleton[6]

Profondeurs d'immersion en 1992 et 1993: Le poids moyen, le rendement moyen des collecteurs et la taille moyenne du naissain diminuent avec l'augmentation de la profondeur d'immersion. À 10 m, les collecteurs ne sont plus efficaces car lors du boudinage, ils ne fournissent qu'en petite quantité (1,4% du poids frais du collecteur) du très petits naissains (<10 mm). À 2 m, le rendement moyen des collecteurs triple (27% vs 9%) par rapport à ceux à 5 m et cela avec un poids frais moyen que de 3 kg supérieur (13 vs 10 kg). Les meilleurs résultats sont obtenus par les collecteurs de 1993 maintenus à 0 m (à la saison estivale). Cependant ils proviennent de collecteurs gardés immerger près d'une année complète. Le poids frais moyen des collecteurs dépasse les 20 kg, le rendement moyen des collecteurs dépasse 60% et la taille moyenne du naissain atteint 20 mm. Chez les collecteurs maintenus à 2 m pendant 4 mois ou 11 mois, le poids frais moyen des collecteurs et la taille moyenne du naissain

restent semblables à près de 13 kg et 14 mm. Chez les collecteurs de 11 mois, seul le rendement moyen a augmenté passant de 27% à 36%.

Types de substrat en 1992 et 1993: Ces deux années, le poids moyen des collecteurs en Vexar, respectivement 13 et 22 Kg, était plus élevé que celui en polypropylène 7 et 13 kg. Le rendement moyen des collecteurs en polypropylène (31% en 1992 et 75% en 1993) est supérieur. Cet avantage de 4% pour les essais effectués en 1992, avec des collecteurs de 4 mois maintenus à 2 m, augmente à 12% en 1993 avec des collecteurs de près de 11 mois maintenus 0 m. On observe ici une diminution du rendement des collecteurs en polypropyléne par rapport aux résultats de Carleton. En effet, pour un poids frais de naissain comparable (2,5 kg/m à Carleton et 2,3 kg/m à Gaspé), on obtient un rendement dans la baie de Gaspé en 1992 de 31% par rapport à un rendement de 58 à 78% à Carleton.[5]

Dates d'immersion en 1992: La tendance d'une diminution du poids moyen des collecteurs avec une date d'immersion tardive au printemps s'amenuise et disparaît si l'on récolte les collecteurs au début novembre. La taille moyenne du naissain est comparable; elle ne varie que de 1,5 mm (12,0 à 13,5 mm) lors de la récolte de novembre malgré les 5 semaines séparant le début et la fin des dates d'immersion du printemps. Les meilleurs rendements moyens des collecteurs sont obtenus lors de la récolte du début novembre (29 à 34%). Une récolte en septembre (<3%) ou à la mi-octobre (<14%) ne donnerait pas des rendements acceptables.

Le poids frais moyen des collecteurs et la taille moyenne du naissain des collecteurs immergés trop tardivement à la mi-juillet ont une tendance à être inférieurs aux collecteurs immergés en juin. Mais l'écart le plus imposant est au niveau du rendement moyen des collecteurs immergés à la mi-juillet qui même au début novembre reste à 14 %. L'immersion des collecteurs serait donc préférable avant la fin de juin et la récolte après la mi-octobre; ce qui correspond au cycle proposé à Carleton.[5-7]

Conclusion

Afin de maximiser le cycle de production on devrait éviter les sites de Sandy Beach et de Fort Péninsule; immerger les collecteurs à tout au plus 2 m de la surface; utiliser des collecteurs en polypropylène peu coûteux et tout aussi productifs; mettre des collecteurs à l'eau avant la fin du mois de juin et finalement récolter les collecteurs pour la fabrication des boudins après la mi-octobre. Lors de la phase de captage, les résultats semblent se rapprocher des données recueillies dans les environs de Carleton; qui se trouve pourtant dans un milieu plus ouvert et plus au sud à l'intérieur de la baie des Chaleurs. Cependant, la présence de cette baie se prolongeant à l'intérieur des terres et le couvert de glace stable à l'hiver permettraient d'offrir des conditions d'élevage relativement abritées et adéquates à une récolte hivernale; ce qui ne se retrouvent pas ailleurs en Gaspésie. La présence d'une population de *Mytilus trossulus*, la faible qualité bactériologique actuelle de l'eau aux sites d'élevage et la présence, malgré de fortes variations annuelles, de biotoxines sont parmi les facteurs actuels qui retardent le développement de ce site de la Gaspésie.

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Toxicity of un-ionized ammonia to juvenile giant scallops, *Placopecten magellanicus*

Allison Abraham, Cyr Couturier and Jay Parsons[1]

The toxicity of ammonia is a major concern to the operators of finfish hatcheries. Although its importance to shellfish hatcheries and holding facilities is not as well documented, it could be a concern with high stocking densities. A published report indicates that un-ionized ammonia becomes toxic to the hard clam, *Mercenaria mercenaria*, at 3.3 mg/L and 6.0 mg/L for the American oyster, *Crassostrea virginica,* and it was concluded that 3.0-6.0 mg NH_3/L is the lethal limit for all marine bivalves. To test this assumption, 30-40 mm juvenile giant scallops, *Placopecten magellanicus*, were exposed to four concentrations (plus control) of un-ionized ammonia (1, 2, 3, and 4 mg NH_3/L) at two temperatures. Juvenile giant scallops were considerably more sensitive to un-ionized ammonia than other bivalves. Ammonia toxicity to scallops was temperature dependent and the 96-hour LC_{50} was 1.8 mg NH_3/L at 4°C and 1.0 mg NH_3/L at 10°C.

Introduction

There are many factors to consider when holding any aquaculture species in rearing systems at high densities. Water quality is among the most important of these, particularly in closed or semi-closed systems. Once animals are placed in a tank, the level of nitrogenous waste must be closely monitored as it becomes toxic to the animals at relatively low levels. Ammonia is the principle nitrogenous compound excreted by aquatic animals such as the giant scallop, *Placopecten magellanicus*.[3] The main site of ammonia transfer is the gill epithelium but feces and the bacterial breakdown of feed are also ammonia sources.[4,5]

Epifanio and Srna[2] tested for the acute toxicity of ammonia in the hard clam, *Mercenaria mercenaria*, and the American oyster, *Crassostrea virginica*. They defined acute toxicity as the "96-h median tolerance limit (TL_m)". They found that, at 20°C ± 2°C and 27‰ ± 2‰ salinity, pH 7.70 to 7.96, the TL_m was 3.3 mg NH_3-N/L for *M. mercenaria* and 6.0 mg NH_3-N/L for *C. virginica*. When exposed to high concentrations of ammonia, these molluscs rarely opened their valves. Gaping individuals were always dead. Therefore, death should not be difficult to determine in other bivalves, such as the scallop.

The goal of this study was to provide information on the acute toxicity of un-ionized ammonia in giant scallops for those involved in bivalve hatcheries and depuration facilities. The objectives were: 1) to determine acute toxicity levels of NH_3 in juvenile scallops, 2) to determine the effects of temperature on NH_3-N toxicity, and 3) recommend suitable ammonia levels to the industry.

Methods

Within six hours of being taken out of the water, 30-40 mm juvenile giant scallops obtained from a commercial farm in Chester, Nova Scotia, were placed in flow-through holding tanks at the laboratory in St. John's, Newfoundland. They were acclimated in the holding tank with ambient sea water for one week (3°C ±1°C, 32‰ salinity, pH 7.7 - 8.6).

A stock solution of 100 mg NH_3/L in sea water was prepared using reagent-grade ammonium chloride (NH_4Cl). Concentrations of 1, 2, 3, and 4 mg NH_3/L were prepared by dilution of the stock solution in 15 L of filtered (1 μm) sea water. Controls (0 ± 0.3 mg NH_3/L) were placed

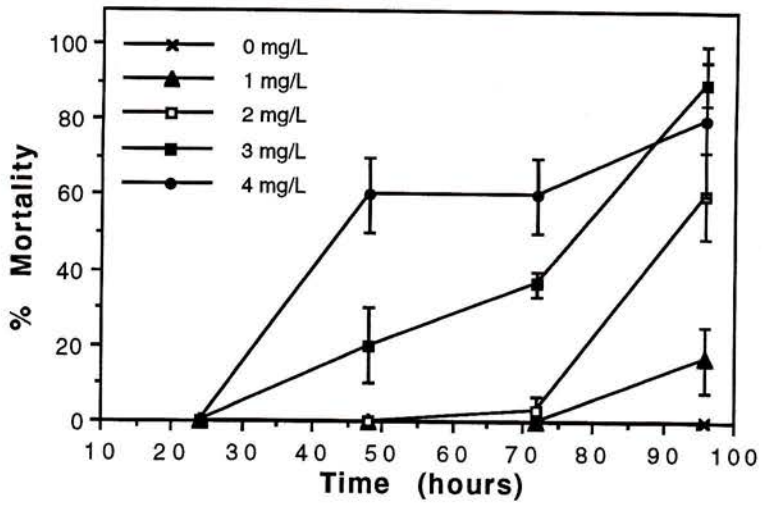

Figure 1. Mean (±SE) scallop mortalities after acute exposure to concentrations of un-ionized ammonia at 4°C.

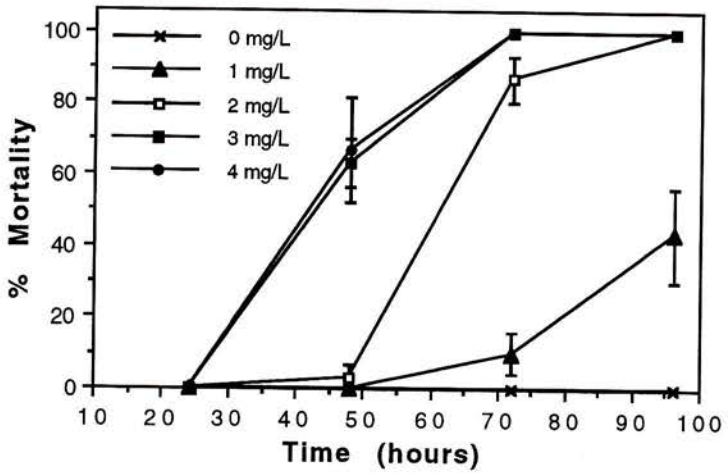

Figure 2. Mean (±SE) scallop mortalities after acute exposure to concentrations of un-ionized ammonia at 10°C.

in ambient sea water (32‰) and treated in the same manner as the test animals. Three-litre plastic containers were placed in a temperature controlled water bath during the static bioassays. Each treatment (performed in triplicate) consisted of: 1) 10 randomly selected giant scallops, and 2) each concentration at 4°C ± 1°C and 10°C ± 1°C. Scallops were not fed during the tests. Salinity, pH, and temperature were recorded throughout the trials. Test solutions were changed daily to avoid fluctuations in ammonia concentrations due to excretion, aeration, or mucous build-up.

Scallops were examined every 24 hours before and after the test solutions were changed. Behaviour was noted and dead animals were removed. The criteria for death were 1) gaping valves and 2) unresponsiveness to gentle prodding of the mantle and other soft tissue with a blunt, glass rod. The lethal concentration time (LC_{50}) was estimated by Probit analysis using SPSS statistical software package. A two-factor ANOVA, with triplicates, was performed on the arcsine transformed percent mortality data.

Results

The results indicated a difference between unionized ammonia toxicity to juvenile giant scallops at different temperatures (Figs. 1, 2). Animals subjected to 1 mg NH_3/L at 4°C did not exhibit mortalities until they were exposed for 96 hours, while those exposed to the same con-

Table 1. Acute toxicity values (LC_{50}) of un-ionized ammonia (mg/L) for juvenile giant scallops.

Exposure Time (hours)	NH_3 Concentration (mg/L) at 4°C	NH_3 Concentration (mg/L) at 10°C
24	19.3	9.3
48	4.1	3.1
72	3.8	1.4
96	1.8	1.0

centration at 10°C, began dying after 72 hours. Animals exposed to 2 mg NH_3/L at 4°C began to die after 72 hours, while those at 10°C, exhibited mortalities after 48 hours, and more scallops were dead at 10°C after 96 hours. However, animals exposed to 4 mg NH_3/L began dying after 48 hours at both temperatures (Figs. 1 and 2). A two-factor ANOVA demonstrated there was a significant difference in percent scallop mortality among ammonia concentrations and among exposure times ($p<0.05$). The interaction term (concentration x exposure time) was also significant.

Probit analysis was employed to determine the 96-hour LC_{50}, the concentration necessary to kill 50% of the population. The lethal concentration of un-ionized ammonia was 1.8 mg NH_3/L at 4°C and 1.0 mg NH_3/L at 10°C. Similar patterns were observed for the 24, 48 and 72 hr LC_{50}'s (Table 1).

Discussion

As exposure time and concentration increased, the effects of un-ionized ammonia became more noticeable: 1) the scallops were found gaping to varying degrees, 2) mantles were retracted, and 3) response to stimulus became slower. The effects on the animals subjected to concentrations at 10°C were noticed sooner than those at 4°C.

Two-factor ANOVA analysis indicated significant interactions between the variables (exposure time and concentration). Probit analysis estimated the concentration resulting in 50% mortality at 96-hours. The 96-hour LC_{50} at 4°C was 1.8 mg NH_3/L. At 10°C it was estimated as 1.0 mg NH_3/L. Therefore, as temperature increased, juvenile giant scallop tolerance to NH_3 decreased.

The juvenile giant scallop was more sensitive to un-ionized ammonia than adult hard clams or American oysters.[2] Studies completed by Young-Lai *et al.*[5] and Lin[6] have shown that both lobsters and bay scallops increase their tolerance to NH_3-N as they progress through their life cycle; this is probably also true for the giant scallop.

Although un-ionized ammonia becomes toxic to juvenile giant scallops at low concentrations, it is unlikely that scallops would be acutely exposed to 1.0–1.8 mg NH_3/L in rearing or holding facilities. Water supplied to static systems would commonly be changed frequently to avoid ammonia toxicity. Chronic bioassays may give a more accurate estimate of levels that may concern aquaculturalists, as well as the time period it would take for a system to reach these levels.

Future research should include: 1) chronic bioassays, 2) tolerance of adult giant scallops to NH_3, and 3) other bivalve species (e.g., *Mytilus edulis*).

We would like to thank Kevin Crocker, Donna Sommerton, and the staff of the Ocean Sciences Centre.

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Effects of sperm longevity and gamete concentrations on fertilization success in the blue mussel

Lorelei A. Levy and Cyr Couturier [1]

Longevity of sperm after spawning and fertilization success as a function of sperm and egg concentration of the blue mussel, *Mytilus edulis*, were studied. Four hours after spawning (at 18°C and a concentration of 10^6 sperm per mL), survival of sperm had decreased by 24%. According to the regression model, the optimal sperm concentration was 10-100 sperm per egg at optimal egg concentrations of 60 eggs/mL. The optimal sperm density may be that at which sperm remain inactive until just prior to contact with the egg. Sperm concentration contributes more to variation in fertilization success than either sperm age or egg concentration, unless these two factors are increased as a result of fertilization procedures. These factors are important considerations in artificial fertilization where high fertilization success, such as in a hatchery, is desired.

Introduction

The blue mussel, *Mytilus edulis*, uses broadcast spawning as its mode of sexual reproduction. Understanding these processes is crucial to achieving success in hatchery propagation. Reliable hatchery supply of juvenile bivalves is dependent on optimizing fertilization success to produce large numbers of viable larvae. Many of the factors associated with fertilization have not been studied *in situ* let alone in hatcheries; hence hatchery managers use procedures that are deemed to be appropriate rather than those that maximize fertilization success.

Sperm longevity and gamete concentration influence reproductive success of marine invertebrates. Sprung and Bayne[7] found that at lower temperatures bivalve sperm survive longer and that the highest fertilization rates occur at concentrations of 1000 sperm per egg. Pennington[5] concluded that echinoid sperm age does not have a major role in fertilization *in situ* due to the "respiratory dilution effect". As sperm become rapidly diluted, respiration increases and exhaustion occurs; hence concentration is a more important factor than age.

The objectives of this research were to determine longevity of sperm, and the optimum egg and sperm concentration for maximizing fertilization success in *Mytilus edulis*.

Methods

The research followed methods used by Sprung and Bayne[7] and Levitan *et al.*[3] Mussels were held for 30 days (13°C, 32 ppt salinity) at the Ocean Sciences Centre, Memorial University of Newfoundland, where they were conditioned to spawn by feeding 50 L of *Isochrysis* algae six days per week to the stock.

Sperm longevity

In the sperm longevity experiment, attempts were made to determine survival of sperm at 18°C. Using Trypan blue dye, differences between triplicate counts of dead and live sperm were determined for three mussels at 0, 30, 60, 120, 240 and 480 minutes after spawning.

Gamete dilutions

Gametes from four males and one female were diluted to give egg concentrations of 0, 10, 20, 50 and 100 eggs/mL and combined sperm concentrations of 0, 10, 10^2, 10^3 and 10^4 sperm/egg.

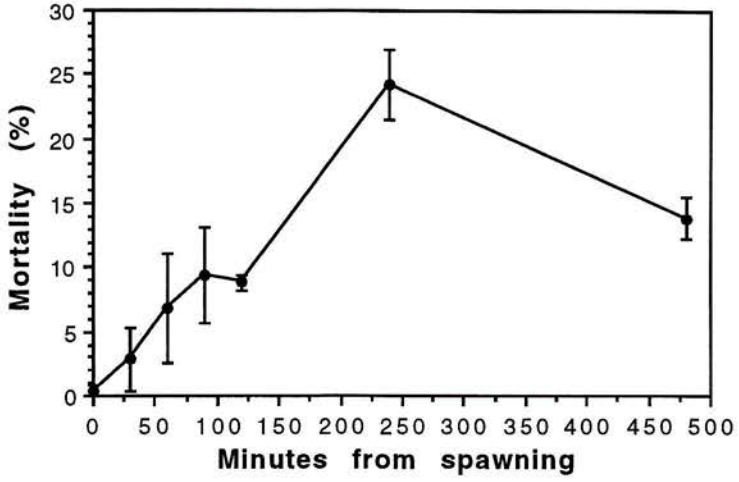

Figure 1. Mean (± SD) percent sperm mortality at specific time intervals.

Three replicates of the 25 combinations were prepared and swirled for 15 s and sperm were filtered. After 48 hours, 10% buffered formalin was added and D-veliger larvae counted.

Results

Sperm survivorship declined with time from spawning and a definite trend could be observed in the mortality of sperm (Fig. 1). After four hours, 24% of the sperm were dead.

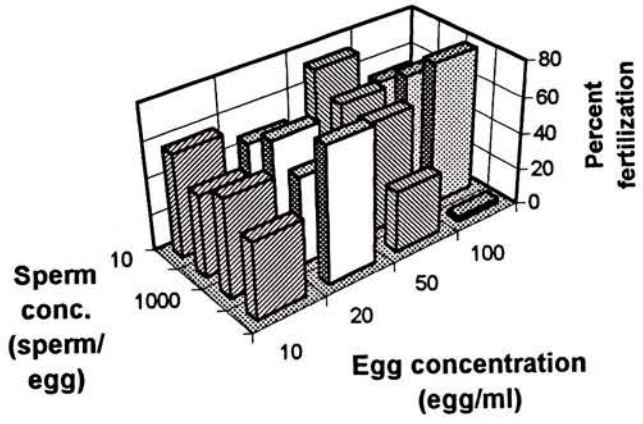

Figure 2. Fertilization success as a percentage at various sperm and egg concentrations.

Figure 2 depicts the relationship between egg and sperm concentrations. Highest fertilization rates were for sperm concentrations of 10-1000 sperm/egg at egg concentrations of 10-50 eggs/mL. In vials of 10,000 sperm per egg, few eggs were present when counts were determined. There is obviously a variation in fertilization success as a result of egg/sperm ratio.

An inverse relationship was observed ($r = -0.798$) between sperm concentration and success of fertilization; as sperm concentration increases for a given egg concentration, fertilization success decreases. The decreasing fertilization success can be supported using a model derived from the regression equation (Fig. 3). This indicated that an optimal fertilization success of 90% can be reached for concentrations of eggs between 60 and 70 eggs/mL, provided sperm concentrations are between 10-100 sperm per egg.

Discussion

Longevity of Mytilus edulis sperm after spawning

Sperm mortality at four hours after spawning was 24%; hence survival of potentially viable sperm declined. Longevity may be determined by concentration of sperm due to the "respiratory dilution effect" that reduces the possibility of fertilization of available eggs.[5] In hatcheries, more so than *in situ*, fertilization success is affected by the number of surviving sperm because sperm concentrations are higher and exposure to eggs is time-limited. Longevity has been found to play a role in

fertilization success of many marine invertebrate species. However, in sea urchins, sperm age can be overcome by higher concentrations of sperm.[2-5,8]

Concentration

Higher levels of fertilization were found at lower concentration of gametes than reported by Sprung and Bayne.[7] The difference may be due to the techniques used; for instance, gametes were mixed for only 15 s in this experiment. Low fertilization success under high sperm concentrations might be explained by low levels of dissolved oxygen, carbon dioxide and pH,[4] agglutination of sperm,[6] quiescence as in the testis,[5] or a delay in activation following spawning.[4]

Mussels avoid polyspermy by detaching excess sperm from the vitelline membrane after fertilization occurs.[7] The low concentrations of sperm necessary for high fertilization success was surprising, as low concentrations give rise to prolonged contact time, thus reducing fertilization.[4,6,8]

Generally, high concentrations of sperm are needed to ensure high fertilization success. This may be explained by the limited area on the egg surface that can induce fertilization as well as the fraction of viable sperm among those surviving.[8] Sperm may also have to overcome the quiescence of being expelled from the testis as well as avoid the respiratory dilution effect (thus need to be concentrated enough to be inactive, but able to be diluted within a short period prior to encounter with the eggs).[5]

Egg concentration was not a significant contributor to fertilization success in *M. edulis*. Egg concentration probably affects fertilization only when rather high concentrations of eggs are used. Egg concentration or sperm age changes that occur before sperm dilution may be more significant than sperm concentration in affecting fertilization success.[3]

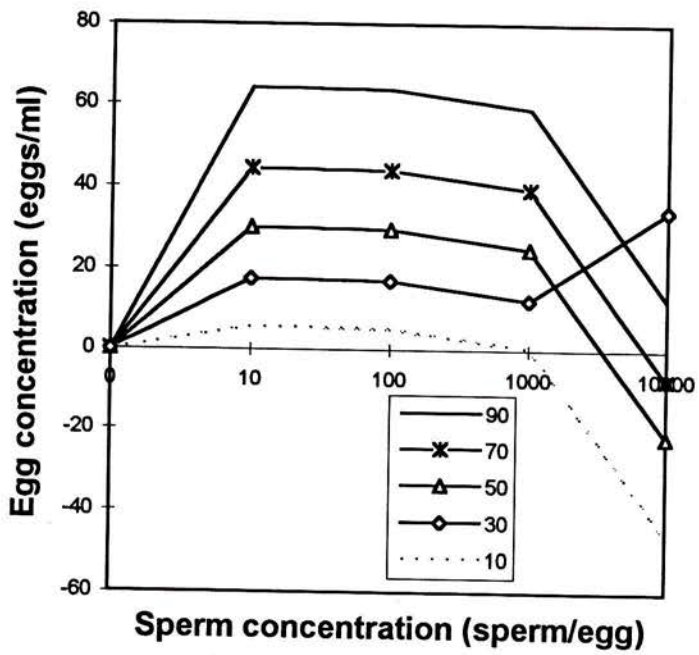

Figure 3. Fertilization success of eggs using various egg and sperm concentrations. The regression equation Y = 0.0028X + 0.5381X′, where Y=arcsin percent fertilization (in degrees), X = sperm concentration, and X′ = egg concentration, was used.

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Salinity tolerance in the blue mussel, *Mytilus edulis*

Jason Bailey, Jay Parsons and Cyr Couturier [1]

The farming of blue mussels, *Mytilus edulis*, in Newfoundland is continuing to grow. Farms located around Newfoundland are faced with varying salinity and temperature conditions. Tolerance of the blue mussels to salinities of 0, 5, 10, 15, 23, and 32 ppt, at temperatures of 1°C and 10°C, was tested in a static water experiment. Survival over the two-week exposure and recovery periods was recorded. Blue mussels were extremely tolerant of reduced salinity levels; there were few mortalities at any of the levels and the change in acclimation temperature did not influence mortality rates. Mussels exposed to distilled water (0 ppt) for a week had low mortalities. Although anecdotal evidence had indicated that blue mussels were tolerant of salinities as low as 5 ppt, no evidence on their survival following acute exposure to low salinities existed. From this research, it can be stated that periodic exposure to reduced salinities on farm sites should have little effect on survival.

Introduction

Mussels are osmoconformers. That is, they acclimatize to fluctuations in salinity by closing their valves, regulating intracellular ion and amino acid concentrations, and controlling mantle fluid concentration.[2] Salinity and temperature are very important factors in the life of bivalves. Shellfish exposed to extreme limits of these variables can experience mass mortalities. The questions we wanted to address for blue mussels were: What is the range of salinities tolerated by Newfoundland blue mussels and what effect does the interaction of salinity and temperature have on mortality?

Mussels have been shown to acclimatize to lowered salinities over a period of time, even though growth may be compromised.[3] However, with fluctuating salinity or a non-gradual change in salinity, it is believed that mussels suffer osmotic shock that can result in death.[4] It has been suggested that *Mytilus edulis* can survive salinities as low as 15 parts per thousand (ppt) or as high as 40 ppt[3] without any detrimental effect on growth rate. The mussel farming industry is established worldwide and is a valuable resource in many areas. Mussels provide a high quality, protein-rich food source and enhance local economies. Any information on mussels, especially on environmental tolerance and causes of possible mortality, is valued throughout the industry and serves as the purpose for conducting this research.

The objective of this study was to determine the salinity tolerance of mussels from northeastern Newfoundland, particularly the lower limit of salinity tolerance, when mussels are exposed to abrupt changes in salinity for a one-week duration. We also examined salinity tolerance under local temperatures in the laboratory.

Methods

The mussels used were obtained from a local retail outlet, brought in fresh that day from processors in Newfoundland. Approximately 500 mussels were purchased and then held in constant flow salinity and temperature conditions. The initial part of the experiment, conducted at 1°C, began on February 3, 1996, at the Ocean Sciences Centre, Memorial University of Newfoundland. The second part, at 10°C, began on February 20, 1996. The temperature was controlled rather efficiently by simply controlling the flow rate in a water bath.

Six 3-L trays, each holding 10 adult mussels

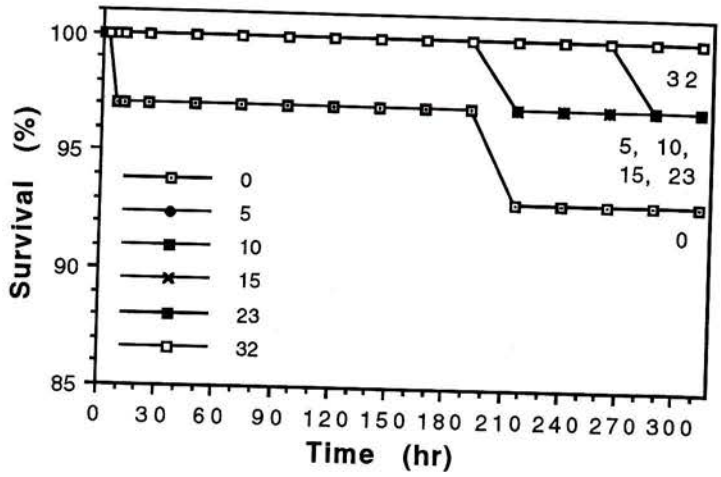

Figure 1. Percent survival of blue mussels held in 1°C water at various salinities. At 144 hours, the mussels were placed in a recovery bath at ambient (32 ppt) seawater.

about 50 to 60 mm in shell length, were placed in a temperature-controlled water bath. The protocol consisted of placing the mussels into each tray containing water of the predetermined salinity level (0, 5, 10, 15, 23, and 32 ppt) and supplying each tray with aeration. Salinities were adjusted by diluting the seawater with distilled water; water was completely changed every 48 hours. Each tray contained water at a different salinity, and mussels were measured and placed directly into the water without acclimation. Mussels tested at 10°C were acclimated to this temperature by raising the temperature slowly over 3 days from 1°C to 10°C. Mussels were left at this temperature for an additional 3 days before the experiment began. Each experiment had 3 replicates for each treatment. The schedule of observations was as follows: at 1, 2, 4, 8, 12, 24, and every 24 hours after immersion in the various salinities. After 144 hours, the surviving mussels were placed in a recovery bath of ambient (32 ppt) seawater and monitored for survival. During the experiment, behavioural observations were taken and were used to evaluate the effects of exposure to lowered salinities.

Mortalities at the various salinities and temperatures over a time period were obtained from this experiment and presented graphically. Mussel size data was analysed using the ANOVA in Microsoft Excel 5.0.

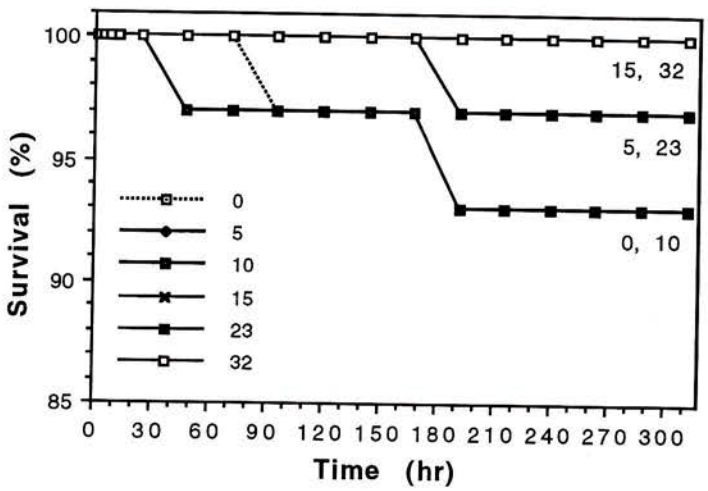

Figure 2. Percent survival of blue mussels held in 10°C water at various salinities. At 144 hours, the mussels were placed in a recovery bath of ambient (32 ppt) seawater.

Results

Mussel mortality was low at all salinities and at both temperatures (Figs. 1 and 2). At no point did salinity appear to cause severe mortalities in mussels after one week of exposure and another week of recovery. Also, size did not play a role in mortality as there was no significant difference in the sizes of mussels in the trays and no resultant trends in mortality to note (ANOVA, $p<0.05$).

Mussels were observed in the trays for incidence of open or

closed shells, foot extension, and byssal attachment. Mussels began to extend their foot and lay down byssal threads within 30 minutes of exposure to 32 and 23 ppt salinities at 1°C. Over the same time, mussels at 0 to 15 ppt remained tightly shut. After 24 hours of exposure, two of the mussels at 15 ppt began to open their valves slightly, presumably beginning to become acclimated to the salinity change. After 72 hours, all of the mussels at 10 ppt began opening their valves.

After 144 hours, all mussels were placed in recovery baths of 32 ppt seawater at 1°C. After only 15 to 30 minutes of being placed in recovery, all mussels had opened their valves, extended their foot, and were laying down byssal threads.

Mytilus edulis began to open their valves within an hour of being placed in salinities of 32, 23, and 15 ppt at 10°C. Mussels at 32 and 23 ppt extended their foot and began to lay down byssal threads. Within 48 hours, mussels at 15 ppt laid down a limited number of byssal threads, but not to the same extent as mussels at 23 and 32 ppt. After 96 hours, mussels at 10 ppt and 10°C began to acclimatize and open their valves, but no byssal thread formation occurred.

Again, after 144 hours of exposure and placement in a recovery bath of 32 ppt seawater at 10°C, mussels began to recover almost immediately. Within 15 to 30 minutes, all mussels had opened their valves, extended their foot, and begun to lay down byssal threads.

Discussion

Newfoundland blue mussels were extremely tolerant to short exposures of very low salinity. Mussels placed directly into distilled water (0 ppt) from ambient (32 ppt) seawater had very high survival after one week exposure and recovered rapidly when placed in seawater. Previous experimental work suggested that *Mytilus edulis* slowly acclimates to 13.5 ppt within 3 weeks but dies within one week upon sudden exposure to 10.5 ppt. [5] The data obtained from this experimental work, however, contradict those results. The mussels exposed to the low salinity levels simply closed their valves and the valves remained shut until the salinity increased.

During the process of recording survival in mussels, notes were made on their behaviour. Mussels protect themselves from a rapid change in salinity by closing their valves and slowly adjusting their internal ion concentration,[6] or acclimating to the external salinity. At 32 ppt (control) and 23 ppt salinities at 1°C and 10°C, mussels began to extend their foot and lay down byssal threads. These levels appeared to have no effect on survival or regular activity. Over the same time frame, mussels at 0 to 15 ppt remained tightly shut, presumably to protect themselves from a change in the ion concentration in their tissues. After 24 hours of exposure, two of the mussels at 15 ppt and 1°C began to open their valves slightly. After 72 hours the same occurred for mussels at 10 ppt.

Byssal thread formation was normal in the 32 and 23 ppt salinities, but it took about 48 hours for regular thread formation to begin in mussels at 15 ppt. Mussels at 0 to 10 ppt did not lay down byssal threads while exposed to these low salinities, but those at 10 ppt appeared to become acclimated after 72 hours.

The most interesting behavioural observations occurred when the mussels were placed into recovery after 144 hours of exposure. After only 15 to 30 minutes of being placed in recovery, all mussels opened their valves, extended their foot and were laying down byssal threads in both 1°C and 10°C seawater, seemingly unaffected by the low salinities experienced during the previous week.

This experiment was really the first time that salinity tolerance experiments have been done on Newfoundland mussels. There was anecdotal evidence that mussels can survive salinity exposure as low as 5 ppt, but no evidence on their survival upon acute exposure to such low salinities. In addition, because mussels can tolerate low salinities, does not mean that they are not detrimentally affected upon prolonged exposure. From this research, however, it can be stated that periodic salinity fluctuations on farm sites should have little effect on survival of Newfoundland blue mussels.

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Flow dynamics in and around pearl nets of various mesh sizes

Floyd Cole, Jay Parsons and Cyr Couturier [1]

In this experiment, the effect of current velocity (12.4 to 45.3 cm/s) on the internal current velocity in pearl nets of mesh sizes 1x3, 4.5, 9, and 12 mm was examined. The pearl nets significantly reduced the incoming currents and the reduction was inversely correlated with mesh size due to the nature of the mesh. With small mesh nets, more of the face of the pearl net is enclosed with the netting material, thereby limiting the amount of water passing through the net. However, as the mesh size increased, less of the net was enclosed, thus allowing more water to pass through due to increased momentum of the water forcing itself through the nets. It was also noted that the percent reduction decreased with increasing external velocity. Implications of the results with respect to grow-out methods are discussed.

Introduction

It is well established that current velocity plays a major role in the growth of certain bivalves. In some bivalves, growth ceases above certain threshold velocities. For example, bay scallop (*Argopecten irradians*) growth becomes severely inhibited at current speeds greater than 3 cm/s[2] and giant scallop (*Placopecten magellanicus*) growth becomes inhibited at currents greater than 10-20 cm/s.[3,4] This in itself would appear to not be a problem for the culture of bivalves, as sites can be chosen that have the optimum current velocity. However, the situation is not always that simple, especially for scallops where grow-out is often done in enclosures such as pearl nets. Pearl nets actually can pose a problem because, as Claereboudt *et al.*[5] have demonstrated, they reduce incoming currents by as much as 46-61%.

In scallop culture, this reduction in current velocity may be either beneficial or harmful. For example, if a farm is situated in an area with strong currents, the pearl nets could reduce the current such that the bivalve is actually in an environment of optimum velocity. In contrast, if a farm is situated in an area where the current is within the optimal range or slightly below it, then the net may reduce the current below the optimum, resulting in an insufficient rate of replenishment of nutrients, etc. Understanding how shellfish cages affect the currents may play a major role in the selection of grow-out method for a particular site.

Until now, no formal study has been undertaken to determine how pearl nets affect incoming currents over a full range of current velocities and mesh sizes. Although Claereboudt *et al.*[5] noted that pearl nets reduce incoming currents by as much as 46-61%, they did not, however, indicate the current velocity or mesh size at which the reduction occurred. The objective of our study was to examine the effect pearl nets of various mesh sizes have on the internal current velocity over a wide range of current velocities and to examine implications for scallop aquaculture.

Methods

This experiment was carried out during February 1996 in the flume tank at the Marine Institute of Memorial University. The pearl nets used were of mesh sizes 1x3, 4.5, 9, and 12 mm.

The first step was to determine external current velocities, using a current meter at the position where the pearl nets were suspended in the water. The current meter was equipped with an electromagnetic sensor that produced a digital readout. The currents used ranged from 12.4

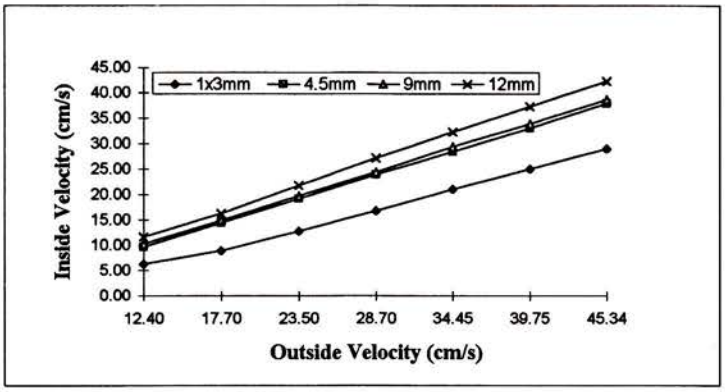

Figure 1. Average inside current velocities for the 1 x 3, 4.5, 9 and 12-mm-mesh pearl nets.

cm/s to 45.3 cm/s, in increments of about 5 cm/s.

The pearl nets were suspended from the carriage spanning the flume tank in 60 cm of water and weighted with a 500 g lead weight. Nets were fastened at the two front corners to the head of the tank to prevent excessive swaying at higher currents. The nets were suspended at the same location in each trial to compensate for differences in flow patterns within the tank. The current meter was placed inside the net in a central position to measure the current flow in the center of the net. Velocities lower than 12.4 cm/s were not used because the flume tank could not consistently reproduce accurate velocities below this level. For each mesh size, three different nets were used, representing three replicates. The outside velocity was considered the control for this experiment.

A simple dye test was performed on the 1x3-mm and 9-mm-mesh nets at a low, intermediate, and high velocity (17.7, 28.7, and 45.3 cm/s). The nets were suspended in the water and a jet of dye was released in front of them. Statistical analyses were carried out using Microsoft EXCEL.

Results

Generally, the internal velocity was lower than the external velocity and increased with increasing external velocity. Furthermore, velocity inside the net increased with mesh size. Of the four mesh sizes examined, the 1x3-mm-mesh had the lowest internal velocity while the 12-mm-mesh had the highest (Fig. 1).

A two-factor ANOVA was carried out to test for significant differences in the internal velocities among the four nets and among the seven velocities. The results showed that the inside velocities were statistically different among mesh size and external velocities ($p<0.05$).

The mean percent reduction in velocity was also determined for each of the nets (Fig. 2). Generally, percent reduction decreased with mesh size, with the 1x3-mm-mesh having the greatest percent reduction and the 12-m-mesh having the lowest percent reduction in velocity. Also, there was a decrease in percent reduction as velocity increased. This phenomenon occurred in all the nets with the exception of the 12-mm-mesh net, where the percent reduction fluctuated around the 6-7% level (Fig. 2d).

The dye tests carried out on the 1x3-mm and 9-mm-mesh nets reinforced the results obtained by the current meter. The tests visually showed that more water was passing through the nets at higher velocities as well as through the larger mesh nets. The dye tests also showed that the water being deflected by the net was more likely to be deflected over the top than around the net.

Discussion

The most notable result from this experiment was that the pearl nets reduced incoming currents and the reduction increased with decreasing mesh size. This can be explained using a very simple analogy. The face of the pearl net may be viewed as a sloping wall standing in the path of the water current. The wall contains a number of holes, with the size and quantity depending on the mesh size. As the water comes in contact with the net it either passes through or is deflected over or around the net. Due to the slope of the face most of the deflected water will go over the top. When a pearl net of small mesh size is used, much of the surface area of the face is enclosed with the netting, causing a large percentage of the water to be deflected over the net rather than to pass through it. However, as

the mesh size increases, less of the wall is enclosed and more of the net's surface area is filled with holes, allowing more water to pass through the net.

The decrease in percent reduction with increasing external velocity was possibly a result of the increased momentum of water flowing at higher speeds, allowing it to pass through the net much easier. In this experiment, only the 1x3-mm-mesh net displayed a percent reduction in the range of 46-61% noted by Claereboudt *et al.*[5] and this was only at low velocities. However, this was to be expected because Claereboudt *et al.*[5] only dealt with velocities of 16.5 cm/s and lower; 16.5 cm/s was at the low end of the range of velocities used in our study.

Claereboudt *et al.*[5] demonstrated that giant scallops grown inside pearl nets at a strong current site had better growth rates than those grown directly in the current, while scallops grown at a weak current site grew better if they were not inside the pearl nets. At the strong current site (16.5 cm/s), currents were well above the optimal levels for scallop growth. The pearl nets reduced the currents so that the filtration was no longer inhibited. The scallops growing outside the pearl nets were exposed to currents above the optimal levels resulting in reduced filtration levels. At the weak current site (8.4 cm/s), the pearl nets reduced the currents to the extent that food renewal was insufficient, leading to seston depletion and restricted growth.

Clearly there are advantages and disadvantages in the use of pearl nets. For example, if a farm operates in a high current area it may be advantageous to use pearl nets, as they may reduce the current to optimal levels. In contrast, if a farm is located in an area of low current it may not be feasible to use pearl nets. Instead, other grow-out methods such as ear-hanging or bottom culture should be used as early as possible.

We wish to thank Yvonne Flynn for her assistance in the flume and George Legge and Zygmunt Kwindzinski for their technical advice.

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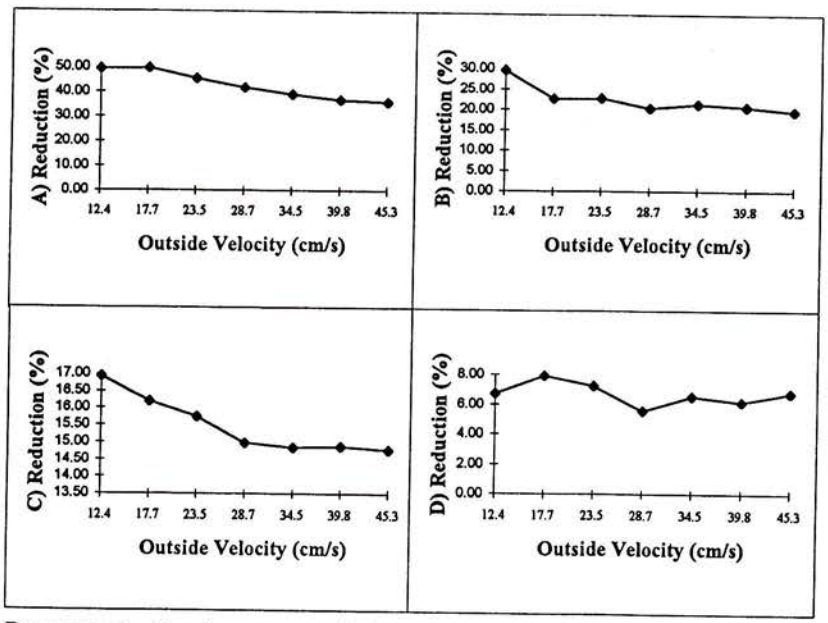

Figure 2. Percent reduction in current velocity inside pearl nets of A) 1x3, B) 4.5, C) 9, and 12-mm-mesh.

Effect of spat grading and net mesh size on the growth and survival of juvenile cultured sea scallop, *Placopecten magellanicus*, in Newfoundland

R. W. Penney[1] *and T. J. Mills*[2]

Sea scallops, *Placopecten magellanicus*, were graded on the basis of shell height and stocked into pearl nets of varying mesh size for grow-out to the 50-70 mm size required for whole "princess-style" scallops-in-the-shell. Pearl nets of larger mesh size produced scallops of greater shell height. Shell height after 2 years of culture was not related to initial spat size. Survival was not related to mesh size but was significantly related to spat size, with greater survival attained by the larger spat. Implications of these data to prospective scallop producers are discussed.

Introduction

In recent years, the sea scallop has emerged as a candidate aquaculture species with considerable potential in Atlantic Canada. Initially, scallop culture was envisaged as a means of producing meats (adductor muscle) similar to the traditional capture fisheries. While financial analyses have questioned the economic viability of commercial culture based on production of meats using existing culture methods,[3,4] the financial viability may be dramatically improved with production of products such as roe or whole scallop in the shell.[5,6] Favorable financial projections, coupled with the shorter production cycle, have led to interest in production of whole "princess" or cocktail-style scallops in the 50-70 mm shell height range. This paper examines the effect of grading scallop spat by shell height, as well as the effect of varying mesh size of the pearl nets, on the growth and survival of sea scallops.

Methods

This study was conducted in Charles Arm, Notre Dame Bay, on the northeast coast of Newfoundland, site of a commercial mussel and scallop farm owned by Thimble Bay Farm Limited. The scallops originated from wild stock collected in spat collectors at Port au Port Bay in western Newfoundland and transferred as 1-year-old spat to the site in October 1989. The spat were divided into two size ranges according to shell height: those less than or greater than 18 mm. Spat were stocked into standard Japanese 34 cm square pearl nets of varying mesh sizes (4.5, 6, and 9 mm for the large spat grade; 4.5 and 6 mm for the small grade) at the rate of 50 individuals per net. The pearl nets were hung in vertical arrays of 10-15 nets at 1-2 m intervals along a horizontal sub-surface headline suspended at approximately 3 m water depth by plastic floats. In September of both 1990 and 1991, the pearl net arrays were retrieved and scallops were measured for shell height, counted, and all mortalities were removed.

Results

Initially in October 1989, the mean shell height of the small and large size grades of scallop spat were 15.3 mm and 22.5 mm, respectively. In September 1990, after the first year in the pearl nets (Fig. 1), a significant positive relationship had developed between shell height and net mesh size (ANOVA, $p < 0.05$) for both size grades of spat. Shell height ranged from a low of 46.5 mm for small grade scallops in 4.5 mm pearl nets to a high of 53 mm for large grade scallops in the 9 mm pearl nets. Small grade scallops grew faster during the year than large grade scallops, averaging a mean monthly growth rate of 2.8 mm/mo, while the large grade

scallops averaged just 2.3 mm/mo.

In September 1991, after the second year of grow-out, the relationship between shell height and net mesh size continued (ANOVA, $p < 0.05$). However, the lowest mean shell height (62 mm) was now recorded for the large grade spat in the 4.5 mm mesh and the greatest mean shell height for large grade scallops in 9 mm pearl nets. The small scallops in pearl nets of both mesh sizes continued to achieve the fastest mean growth rates during the second year (1.43 mm/mo for small grade spat vs 1.22 mm/mo for large spat) and, after 2 years of grow-out, were now intermediate in mean shell height, at 64 mm and 67 mm for the 4.5 mm and 6 mm mesh sizes, respectively. Overall, the mean growth rates for the 2-year period were 2.1 mm/mo for the small grade scallops vs 1.8 mm/mo for large grade scallops.

After 1 year of grow-out (Fig. 2), mean survival was significantly different between the two size grades (ANOVA, $p < 0.05$), but not between the three mesh sizes (ANOVA, $p > 0.05$). The interaction term was also not significant. Mean survival for the small spat grade was 87% vs 95% for the large grade spat. During the second year of grow-out, mean survival was excellent for all mesh sizes and both spat grades (100% for small grade vs 96% for large grade). No significant relationships occurred between mean survival and net mesh size or spat grade (ANOVA, $p < 0.05$). Overall, after 2 years of grow-out, mean survival was significantly greater (91.3% vs 87%) for the large grade scallops (ANOVA, $p < 0.05$), but no significant differences developed between survival and net mesh size.

Discussion

Size grading of scallop spat collected from wild seed in spat collector bags had no significant effect on the harvest size of scallops after two years in pearl nets. Varying the mesh size of the pearl nets produced significant differences in shell height after one year of grow-out. Irrespective of initial spat size grading, the shell height of cultured juvenile sea scallops increased with increasing mesh size of the pearl nets. Increasing mesh size appears to have no significant effect on survival, at least to the 60-70 mm size range for production of "princess-style" whole scallops. However, spat grading had a significant effect on survival, with the greatest mean survival being achieved by the large size grade. The overall growth in shell height of scallops was slightly slower while survival was on par or better than that reported in other studies in Atlantic Canada.[7,8]

Initially the difference in mean shell height between the two spat size grades was 7.2 mm. However, the small spat grew faster from the outset and by the end of 2 years the small spat were approximately equal in shell height to the large grade individuals. The difference in growth rate is probably due to the effect that reduced survival among the small grade spat had on the density of scallops within the pearl nets. Increased density has been shown to exert a significant negative effect on scallop growth.[7,9,10] Reduced survival of small grade spat, coupled with their smaller size meant that stocking density (defined as the proportion of floor space utilized by scallop biomass) was reduced compared to the pearl nets stocked with large grade spat.

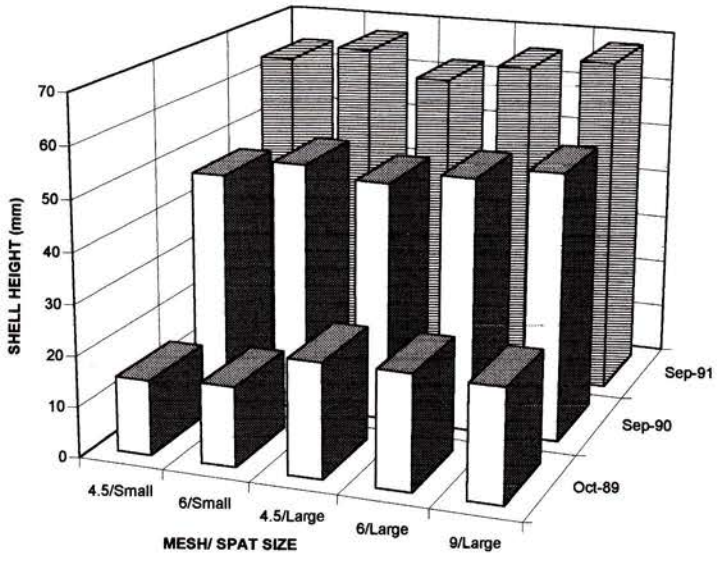

Figure 1. Mean shell height of two size grades of cultured scallop, graded as one year old spat, and held in pearl nets of varying mesh size.

From these data, it is obvious that the size of spat derived from collections of wild seed in onion bag type, monofilament mesh collector bags cannot be used as an indicator of future growth performance or "scope for growth". Rather, the size variation of spat may have more to do with micro-scale differences (non-uniformity) in monofilament packing or settlement density of seed within the onion bags. For prospective commercial scallop growers, these data do not support any justification for a price premium for larger wild spat. This may not be true of hatchery reared spat where uniformity of culture conditions during the spat production stage may be assured.

Analysis of the survival data indicates that most mortalities occurred early in the culture cycle, probably because of handling during the initial transfer of spat to pearl nets. Small size spat are apparently more susceptible to injury during handling than the larger ones. The implication to commercial growers is that spat handling generally has a hidden cost as handling is probably the largest source of mortalities in the grow-out cycle (unforeseen catastrophic events excepted). It could be argued that grading and handling during culture should be avoided since grading doesn't confer a growth advantage. However, lack of handling and culling may produce scallops of wider size range variation per net at harvest time. As a compromise, when considerations of labor costs, mortalities, etc. are considered, it may be more effective to dispense with size grading, reduce handling to a minimum, and grade at harvest time when the scallops are larger. Handling then occurs at a time when minimal mortality is likely. The under-sized scallops could be re-deployed for further ongrowing.

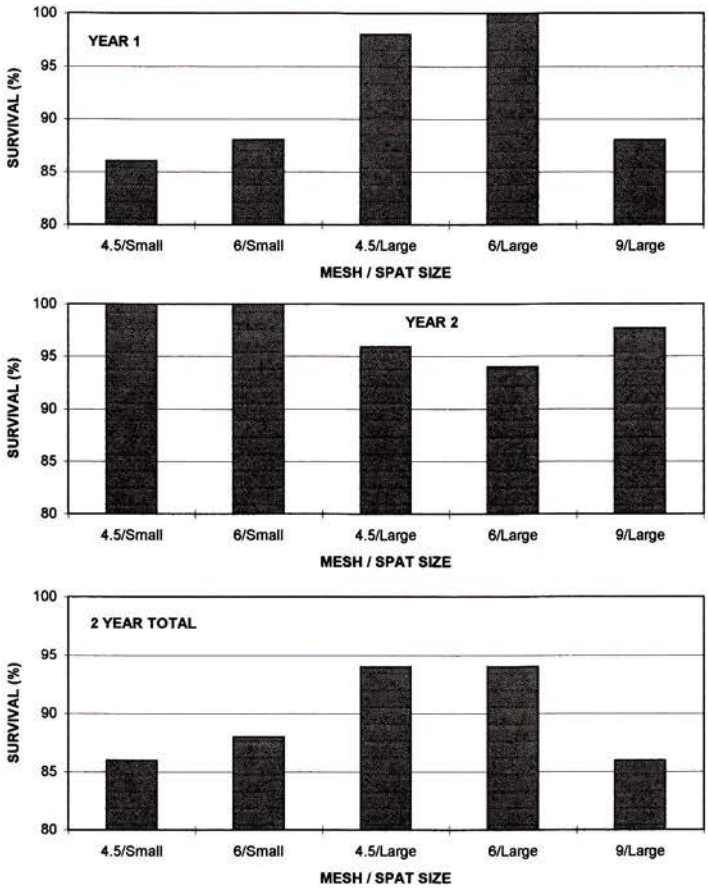

Figure 2. Mean survival of two size grades of cultured scallop, graded as one year old spat, and held in pearl nets of varying mesh size.

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Relationship between giant scallop, *Placopecten magellanicus*, spawning and temperature fluctuations during downwelling events[1]

J. C. Bonardelli,[2] John H. Himmelman[3] and Ken Drinkwater[4]

We examined the relation of spawning to biological and physical factors for the scallop, *Placopecten magellanicus* (Gmelin, 1791), over 8 years (1984-1991) in the Baie des Chaleurs, southwestern Gulf of St. Lawrence, Canada. Spawning was always abrupt and occurred between July and mid-September. It did not appear to be related to the abundance of phytoplankton or particulate organic carbon and nitrogen in the water. It further showed no relationship with lunar or tidal phases or with current velocity. Spawning consistently occurred during the summer temperature maximum but did not coincide with any critical temperature or cumulative temperature threshold. All but one of the 33 spawning events, for which temperature data were recorded, were associated with temperature changes; 25 of these were sharp temperature increases and 7 were during strong temperature fluctuations when the mean temperature was 9 to 14°C. Both types of temperature changes were caused by downwelling of warm surface water. The delay by about 2 days in time of spawning between sites coincided with the rate at which downwelling events propagated into the bay. Virtually all of the spawning events resulted in gametes being ejected into warm water masses where conditions are likely to favour larval development.

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1. Full paper published in Marine Biology 124(4): 637-649 (1996).

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Human Resources Workshop Presentation

Training and profitability: One company's experience

Jamie Bridge

A new training program at North Island College, Campbell River, British Columbia was developed with the input of the salmon farming community. The employee training program occurs on-site and emphasizes practical and economic perspectives of salmon farming with minimal disruption of the work schedule. The program is taught in modules and while the program is only partly completed, there have already been positive results. Nor Am Aquaculture Ltd. considers training to be an ongoing process and feels the unique approach of the North Island College course to involve industry directly in the training process will be very effective.

I have been asked to share some of Nor Am Aquaculture's experiences with training programs and relate them to profitability in this Human Resources Workshop entitled "Competitiveness Through Training". Nor Am Aquaculture is an Atlantic Salmon farming company based in Campbell River, British Columbia. It is comprised of seven grow-out sites, a large hatchery, and a processing facility. The company employs 165 people and has sales of 12 million dollars annually.

Nor Am has made a significant effort to prevent turn-over of staff. We implemented a profit sharing program in the early 1990s that rewards seniority and have always viewed our personnel as our most valuable asset. Nor Am often promotes its employees from within rather than going outside the company. As a result, employees see the potential for growth and development within the company, and they tend to remain with the company longer. Well-trained employees are definitely an asset considering our grow-out sites operate feed machines worth $100,000, and at times feed up to $10,000 worth of feed per day, while sites can brake as much as $3 million worth of inventory at one time.

Nor Am finds itself competing in a global marketplace with fierce international competition from Norway and Chile, as well as local competitors within British Columbia. Increasing feed costs have raised cost of production, while competition has softened markets and lowered the price per pound we receive for fish. It would seem obvious that since we cannot control these factors, we have to become more effective and more efficient at raising salmon to maintain our competitive edge. We believe that it will be our employees that allow us to do this.

A general trend I have noticed in salmon farming in British Columbia, seems to be that companies are depending more on technology and automatic feeding machinery and less on brute manpower. Farms tend to have fewer people working, but the ones they do have are responsible for more things. Thus the impact of a single employee becomes more significant to the farm's success. This is where training becomes very important.

Recently, Nor Am was invited to participate in an exciting new employee training program that emphasizes practical and economic perspectives of salmon farming in a manner that least disrupts the work schedule and occurs on-site.

In a 1994 report for the Canadian Aquaculture Producers Council, Dr. Chris Campbell identified that the training needs of the aquaculture industry were not being met by current educational offerings and that current worker training was difficult due to the lack of flexibility in workers' schedules, shift work, time required for training, and timing and location of educational facilities.

North Island College, in Campbell River, has pursued the recommendations of the Campbell report but added, that to be successful, the training program must be industry-led and facilitated by the college. The college appointed a B.C. Salmon Farming Industry Advisory Committee, made up of eight people representing six large companies, and their task was to develop course curricula, develop a training program for the trainers, and train the trainers in delivery of the production worker curricula. The point to emphasize is that the industry–college partnership led to a product that had an industry seal of approval. Industry input was requested to determine the skills they want their employees to possess.

This (1996) is the pilot year of the program and it is funded by "B.C. Skills Now". Enrollment costs charged to the companies were $750 per student. Sea-site production workers were selected by companies on the basis of their ability and willingness to learn, and their career goals. The course is very comprehensive and is composed of 27 modules. These modules are taught on-site by assigned company trainers. At the end of the course, successful graduates will receive a salmon production skills certificate signed by the college and the employer, and receive credit for Aquaculture 190. The course constantly emphasizes the impacts that the employee has on the company's bottom line. It is the goal of the program to have the Salmon Production Skills Certificate recognized throughout the industry and have it become a recruiting standard for new employees. Currently there are 23 students enrolled with 8 trainers. Many students were denied access to the course because this is only the pilot year and enrollment was limited.

The trainers are mostly site managers and are required to spend 2 days a month at the college where they are presented the next month's course modules and must practice presenting them to each other. New teaching techniques are emphasized at these training sessions. A specialized 3-day training program was given to these trainers outlining teaching principles and techniques by a professional training consultant.

Each module takes about four hours to present and utilizes videos, assignments, group discussions, real life examples, demonstrations and lectures to emphasize the desired skills outlined by the advisory committee. All modules are followed by a 15-minute exam. The modules are usually presented once a week to the workers on a crew-change day. This allows on-going work projects to continue while the training course takes place.

We have only completed eight of the 27 modules and have already seen some favourable results, including:

- Increased awareness in day to day husbandry protocols;
- Improved communication flow between management and employees;
- Better on-site record keeping and environmental monitoring;
- More attention to small details around the farm;
- Intelligent questions being asked more often;
- Advanced interest in the business aspects of the job (e.g., they want to know the food conversion ratio (FCR), current price per pound, percent premium in harvest), etc.

We have implemented a database "feedback" system for the workers that shows fish performance on their site vs. performance at other sites and compares these numbers to other companies in the C.A.S.H. database. FCR are being tracked at each site and FCR and survival goals have been set.

The results should affect the bottom line and are reassuring because they fit the training programs mission statement, which is: practical training and or practical application of concepts and techniques wherever possible, couched in a farm economics framework so that all employees a have thorough understanding of the:

- Production process,
- Their impact on the production process and the product, and hence the viability of the operation producing them.

Nor Am's management has not been exempt from training programs either. Last year Nor Am implemented a management training course for its site managers. Managers went through an 8-week management course called "Effective Supervisory Management", produced by LMI and directed by a local contractor. The course stressed time management, organizational skills, motivating employees, handling and preventing problems with employees, and developing the potential of employees. I found, as a site manager, that this training made my life a lot easier as the the most frustrating and stressful part of my job was dealing with employees. This was because all my training had previously dealt with fish, not people. The purpose of this management course was to improve our "people skills" and to become more organized and efficient. Management training pays off. If site managers are not organized, you can hardly expect workers and general farm practices to be efficient. It was probably the best money our company has ever spent.

Salmon farming in British Columbia has recently been reclassified by the Worker's Compensation Board (WCB). As a result we are under an increasing number of regulations. Nor Am hired a consultant to help prepare us for the new regulations. The consultant developed a series of training manuals for our employees outlining operational procedures that could pass WCB scrutiny. The manuals outline everything from small boat handling skills, diving practices, special machinery operating instructions, fish husbandry, communication procedures, emergency procedures and are a part of an on-going program to introduce employees to the essential skills needed to operate a safe work place. It is the purpose of these manuals to reduce the chance of boating mishaps, WCB claims, and general liability by training and informing employees and by standardizing operational procedures. This should succeed in lowering cost of production accordingly. The consultant presented the manuals in training sessions at the farm site, interviewed divers and posted procedural posters in key locations on the farms.

In closing, the unique approach of the North Island College course to involve industry directly in the training process will be very effective. This unique partnership ensures that the curriculum meets with industry's needs and does not stray off the topic. Eventually it could be used as a criterion for hiring new employees. It has built-in flexibility, because it occurs at the site, and can enhance workplace learning in both experienced and new employees. It does, however, require a large financial commitment from the company. We are concerned that there is no funding in the works for continuing the program next year as there were interested employees in the industry turned away this year. But we are optimistic that the results of the program will speak for themselves. The training manuals, seem to be effective, but you cannot simply hand out a manual and expect people to read it and absorb it. Manuals should be gone over with employees and care should be taken not to patronize employees, or they will not take the manuals seriously. Management training is essential — it is the best money to spend on training programs. Effects of management training will filter through to the workers and you will see a quick return on investment.

The unique approach of North Island College to involve industry directly in the training process is very effective. The course has built-in flexibility, because it occurs at the site, and enhances workplace learning in both

Nor Am feels that training is an on-going process. With new technologies arriving in the industry every year, training will be paramount in maintaining a competitive advantage.

Jamie Bridge is with Nor Am Aquaculture, Inc., Box 837, 1495 Baikie Drive, Campbell River, BC V9W 6Y4.

Calendar

•**7th Annual Atlantic Universities Aquaculture Conference**, 7-9 March, 1997, Nova Scotia Agricultural College, Truro. Priority for oral presentations is given to students, but other submissions are considered. Awards are given for the best student presentations at the undergraduate abd graduate levels. Information: Dr. Derek M. Anderson (tel 902 893-6651; fax 902 895-6734; DAnderson@NSAC.NS.CA

• **International Seafood Show,** 18-20 March, 1997, Hynes Convention Center, Boston, USA. Information: M. Larkin, Boston Seafood Show (tel 207 842-5504; fax 207 842-5505).

•**California Aquaculture Association Annual Conference and Trade Show**, 20-22 March 1997, at the Fresno Hilton Inn, Fresno, California. Information contact CAA at (619) 359-3474 or P.O. Box 1004, Niland, CA 92257

•**European Seafood Exposition**, 15-17 April, 1997, Brussels, Belgium. Exposition of live, fresh, frozen and value-added branded and private label seafood products. Information: Lisa Murray, European Seafood Exposition, Portland, Maine (tel 207 842-5504; fax 842-5505).

•**Great Atlantic Shellfish Exchange,** 17-19 April, Truro, Nova Scotia. Sponsored by Atlantic Fish Farming in co-operation with the Aquaculture Association of Nova Scotia. Information: Atlantic Fish Farming tel 902 838-2515; fax 902 838-4392.

•**Martinique '97,** 5-10 May, 1997, Martinique. Tropical fish culture, tilapia in marine waters, shrimp and molluscs; business planning, marketing, quality control; seafood technology; socio-economics of aquaculture in island environments; environmental impact of culture in coral reef ecosystems; cage design and engineering, open-sea farming, anti-hurricane technology; ornamental species. Information: European Aquaculture Society (tel 32 9 2237722; fax 32 9 2237604).

•**Second Asia-Pacific Marine Biotechnology Conference and the Third Asia-Pacific Conference on Algal Biotechnology**, 7-10 May, 1997, Phuket, Thailand. Topics: algal biotechnology, aquaculture biotechnology, environment biotechnology, marine natural products, marine microbial ecology and physiology. Information: APMBC & APCAB '97 Secretariat, National Center for Genetic Engineering and Biotechnology (BIOTEC), Ministry of Science, Technology and Environment Building, Rama VI Rd., Bangkok 10400, Thailand.

•**Aquaculture Canada '97,** the 14th annual meeting of the Aquaculture Association of Canada, 10-13 June 1997, Radisson Hotel, Quebec City, Canada. Proposed sessions: Harmful marine algae and aquaculture management, Marine finfish aquaculture in Eastern Canada, Aquaculture: what does the consumer want? Information: Yves Bastien, MAPAQ, 96 Montée Sandy Beach, C.P. 1070, Gaspé G0C 1R0 (tel 418 368-7656; fax 418 368-8400) or AAC, Box 1987, St. Andrews, NB Canada EOG 2XO (tel 506 529-4766; fax 506 529-4609).

• **10th Atlantic Aquaculture Exposition,** 19-22 June 1997, St. Andrews, New Brunswick. Theme: *Adding Value.* Workshops on feeding methods and strategies, and value-added processing. Information: Master Promotions (tel 506 658-0018; fax 506 658-0750).

•**1st International Symposium on Stock Enhancement and Sea Ranching,** 8-11 September, 1997, Bergen, Norway. Hosted by the Norwegian Sea Ranching Program. Deadline for abstracts: 1 February 1997. Information: PUSH, Bontelabo 2, N-5003 Bergen, Norway (fax 47 55 317395; e-mail borthen@telepost.no).Internet: http://www.imr.no/sear/hav97.html

•**8th International Conference on Diseases of Fish and Shellfish,** 14-17 September 1997, Edinburgh, Scotland. Diseases in aquaculture of fish and shellfish, with emphasis on pathology

Aquaculture Canada '97

10-13 June 1997, Radisson Hotel, Quebec City

14th Annual Meeting of the Aquaculture Association of Canada

Theme: From Research to Market

Special sessions

- genetics in aquaculture and the public's perception of genetically manipulated species
- marine finfish culture
- Arctic charr culture
- walleye culture
- economics of rainbow trout culture
- management of aquaculture sites in relation to biotoxins
- nutrition of larval freshwater finfish
- marketing
- bivalve hatchery developments
- progress in technology: open-ocean farming, genetic markers and water recycling technology

There are few locations in North America as charming as Quebec City — it has been designated a World Heritage Site by UNESCO. It will seduce you with its warm atmosphere, museums, cafés, terraces and its renowned haute cuisine. Outstanding night life, casual strolls or carriage rides through the quaint streets of "Vieux Quebec", artists' quarters and many other attractions will make your stay unforgettable!

Abstract deadline: 15 February 1997. Conference information and instructions for authors available from AAC (fax 506 529-4609; tel 506 529-4766; e-mail aac@wolves.sta.dfo.ca)

of wild stocks in European waters and relationships with pollution and aquaculture. Information: Dr. Eva-Maria Bernoth, CSIRO Animal Health Laboratory (tel 61 (52) 27 5000; fax 61 (52) 27 5555; e-mail eva@aahl.dah.csiro.au).

•**Summit of the Sea**, a series of conferences and workshops being held in St. John's, Newfoundland, September 1997. Theme: *Sustainable development of ocean resources.* The various conferences will examine topics ranging from fisheries to marine mining to offshore oil development. Technical, socio-economic, regulatory and cultural perspectives will be taken. Summit is part of the celebrations of the 500th anniversary of the landfall of John Cabot on Newfoundland in 1497. Information: D. Finn, Coordinator, Summit of the Sea, P.O. 1997, 1 Crosbie Place, St. John's, NF Canada A1C 5R4 (tel 709 579-1997; fax 709 579-2067). davidfinn@porthole.entnet.nf.ca; http://www.newcomm.net/cabot500/summit.htm.

•**ISTA IV** — 4th International Symposium on Tilapia in Aquaculture, 9-12 November 1997, Disney World, Orlando, Florida. Sponsored by ICLARM and The American Tilapia Association; hosted by the Florida Aquaculture Association. First of the symposia to be held in the western hemisphere. Information: Kevin Fitsimmons, ISTA IV, University of Arizona, 2601 E. Airport Drive, Tucson, Arizona 85706.

•**Aquaculture '98**, 14-19 February 1998, Las Vegas, Nevada. Annual meetings of the World Aquaculture Society, the National Shellfisheries Association, and the American Fisheries Society. Information: Aquaculture '98, 21710 7th Place West, Bothell, Washington 98021 (tel 206 485-6682; fax 206 483-6319).

Aquaculture Canada '96

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