CANADIAN RIVERS INSTITUTE

PROGRESS REPORT

JANUARY 1, 2001 TO DECEMBER 31, 2003

Report Prepared for UNB Board of Governors

UNB

CANADIAN RIVERS INSTITUTE

Acknowledgements

The report was prepared by Christopher Blanar, Sandra Brasfield, Chad Doherty, Rachel Keeler, Jenny Reid and Rainie Sharpe. Final editing was done by Kelly Munkittrick and Deb MacLatchy.

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Progress Report
January 2001 to December 2003

Executive Summary

The Canadian Rivers Institute (CRI) was founded in 2000 as a collaboration of researchers at the University of New Brunswick Saint John and Fredericton campuses. The mandate of the CRI is to carry out multi-disciplinary basic and applied research focusing on river ecosystems, including their land-water linkages for the purposes of conservation and habitat restoration.

The objective of the CRI is to build a network of researchers with common interests in river science across universities, government, and industry. Initially founded with two Canada Research Chairs (CRCs) and two additional professors, the CRI has grown to include seven Fellows, 31 Associates, 15 staff, and 58 graduate students with linkages to scientists and researchers across Canada.

The CRI at Saint John focuses on the environmental impacts of industrial and agricultural operations with an Ecosystem Health Assessment Laboratory (K. Munkittrick) and a Fish Reproductive Physiology and Ecotoxicology Laboratory (D. MacLatchy). K. Kidd, a new CRC, will be located at Saint John and will result in the development of a research laboratory focused on the Chemical Contamination of Food Webs. The emphasis on the Fredericton campus is primarily on aquatic ecology through the New Brunswick Cooperative Fish and Wildlife Research Unit (A. Curry; Professor of Recreational Fisheries), the Stable Isotopes in Nature Laboratory (R. Cunjak) and the Laboratory on Mitigating Impacts of Hydroelectric Development (S. Peake, holder of a NSERC New Faculty position). The National Water Research Institute of Environment Canada houses four members of its staff in a Laboratory for Multistressor Effects on Aquatic Biodiversity (J. Culp, D. Baird).

The CRI has cooperative research agreements with Environment Canada's National Water Research Institute and the Atlantic Region, as well as with New Brunswick's Departments of Natural Resources and Environment and Local Government. We have collaborative industrial projects in forestry, pulp and paper, and oil refining. Research funding for the CRI totalled more than $3.8 M from 2001 to 2003. Partnership activities generated an additional $2.5 M in in-kind and matching funding.

Several of our collaborations have involved non-government agencies such as the Atlantic Coastal Action Plan, EMAN (Ecological Monitoring and Assessment Network), Trout Unlimited Canada, and local conservation groups across Atlantic Canada. We have developed and are developing research agreements with similar institutes in the USA, France, Australia, New Zealand and Chile.

We have a commitment to developing undergraduate and graduate training in river sciences, and also seek to develop field-based, training opportunities for students and professionals in areas of river restoration, ecosystem sciences, and ecotoxicology. We have created and presently teach 10+ undergraduate and graduate courses offered at UNB, but also offered across Canada and in Cuba, Australia, Portugal, and Ireland.

The CRI operates without core funding and interacts with interested parties through a variety of mechanisms. The CRI seeks to:

a) foster participation and support collaboration through access to our infrastructure by inviting scientists and graduate students to actively participate in existing projects;
b) conduct large river basin projects and develop a commitment to supporting common research methodologies so that the results of projects can be compared;

c) develop interdisciplinary field courses for training professionals in river sciences, and offer those courses across Canada and internationally; and
d) increase interuniversity collaboration in undergraduate and graduate teaching in river sciences.

Figure 1. View of the upper Saint John River near Moody Bridge, ME. (K. Munkittrick)

Introduction

Throughout Canada, and around the world, there is a growing trend to develop an ecosystem approach to correcting environmental problems in aquatic systems (e.g., Thames, Danube and Rhine River restoration projects, and Canada's Northern Rivers Basin Study). Atlantic Canada is home to a variety of river environments and 'river issues'. No other place in Canada has such ready access to wild, unregulated river systems such as the Miramichi, Humber, Margaree and Restigouche Rivers. We also have heavily regulated (hydro-electric development) and stressed (multiple-contaminant issue) waterways such as the Saint John River, which also has international implications. We are close to two diverse estuarine and coastal environments, the Gulf of St. Lawrence and the Bay of Fundy, each with its own unique stressors.

Human health problems associated with municipal water supplies and concerns about pesticide contamination are occurring with greater frequency in Canada. From an international perspective, many of the same environmental problems and resource management dilemmas faced by Canadians are also found in the USA and Europe. With many of the same species (e.g., Atlantic salmon, American eels) using rivers of both continents, there exists an opportunity for scientific, multi-national collaboration using large-scale, comparative approaches to tackle complex aquatic problems.

In the late 1990s, there were many ongoing research projects at UNB that were multidisciplinary in focus, including studies on mercury and metal contamination in fresh waters, cumulative impacts in the Saint John River catchment, forestry impacts on fish and wildlife, impacts of industrial effluents on freshwater and estuarine environments, and groundwater chemistry dynamics. The CRI was established to develop opportunities for carrying out large-scale, multidisciplinary research projects to enhance aquatic science and natural resource management. The idea was to have an institute for collaborative research, education and

professional training where biologists, hydrologists, foresters, conservationists, geochemists, water quality engineers and other researchers would have a common theme to facilitate working collectively to solve complex environmental problems related to river ecosystems in Canada and internationally.

The original objectives of the CRI were to address research issues and to increase educational and professional development opportunities. In terms of research, the aim of the CRI is to carry out multi-disciplinary basic and applied research focusing on river ecosystems, including their land-water linkages, for the purposes of protection, conservation and habitat restoration. The focus is on the biota of rivers and their valleys from headwaters to coastal marine environments, and the physical and chemical processes that influence ecosystem health. The emphasis of the CRI, as it develops, is to focus on multi-disciplinary approaches based on partnerships.

The CRI offers tremendous potential for teaching graduate students and training future professionals in the pure and applied scientific disciplines associated with river ecosystems. In Atlantic Canada, there is a great opportunity to develop educational curricula and research protocols related to the study of Canadian river environments because of our proximity to natural and altered basins. It is a goal of the CRI to develop courses from a uniquely Canadian perspective. Our developing courses and partnerships provide opportunities for students to become familiar (via field courses/co-op experience) with diverse river-types across the country.

The CRI operates without core funding and seeks to develop collaborations and partnerships that are based on a mutual interest to increase the breadth and strength of studies on rivers. To that end, we have developed partnerships with federal and provincial partners, other universities, and discussions are underway or formalized with research institutes in the USA, France, Chile, New Zealand

and Australia. Furthermore, we have associates working across Canada to collaborate on river studies.

In addition, the Fellows and Associates of the CRI are dedicated to the growth and development of the undergraduate and graduate programs of the university. Development of the CRI has occurred in concert with establishment and growth of the Environmental Biology major at UNB Saint John. In 2004, the CRI will lead the development of a bi-campus undergraduate course in Aquatic Biology to be video-conferenced between the two campuses. Enhancement of the CRI's research, partnership and training expertise will continue to directly benefit students of UNB and our academic partners, for example, by providing students opportunities to participate in national and international field courses and training in partner laboratories.

We see high potential for continued growth and expansion through development of increased local, national and international partnerships. The CRI is open to people interested in actively collaborating at our study sites, standardizing methodologies with existing studies at other existing sites, and developing additional associations that increase the potential for education and research related to rivers. This Progress Report is designed to give a detailed overview of the Canadian Rivers Institute (CRI), and the progress that we have accomplished since we were formed in December 2000.

Figure 2. Mine tailings entering Gossan Creek, NB (C. Blanar)

Director's Report

I was very pleased to be named the Acting Director of CRI in December 2003. When I first arrived at UNB to start the New Brunswick Cooperative Fish and Wildlife Research Unit (NBCFWRU) in 1995, there was only me. I sensed from my discussions with the UNB administration and the Department of Natural Resources (DNR) that there was a willingness and potential to grow those humble beginnings into a world class, aquatic science research institute. I wasn't sure how we would grow or what we would become, however, I am very proud of what we have worked together to create and I'm looking forward to the future goals we will set as the CRI.

The CRI exists because we had a collective desire to better understand aquatic ecosystem protection and rehabilitation. We are growing by adding like-minded individuals that are expanding our expertise and helping us to solve problems in both fundamental and applied science. The recent additions of Drs. Joseph Culp and Donald Baird and their team from the National Water Research Institute (NWRI) builds our foundation in ecosystem processes at lower trophic levels while giving the CRI a strong connection to national programs in cumulative effects and biodiversity monitoring. Dr. Stephan Peake's arrival in 2003 expands our ability to understand the effects of hydroelectric operations on fishes in rivers, courtesy of Manitoba Hydro and NSERC. Later this year, Dr. Karen Kidd, who is one of Canada's leading ecotoxicologists, will be bringing her research program on contaminants in food webs to the Saint John campus as a Canada Research Chair. One of our Associate Fellows at UNB Fredericton, Dr. Kerry MacQuarrie, was named a Canada Research Chair in 2003. Such designations demonstrate our achievement as a national research institute as well as UNB's commitment to our continued growth.

Our research is successful because we build teams of collaborating partners across a variety of research and regulatory sectors. Last year, CRI research expenditures at UNB alone were well over $1 M. We are thankful to have collaborating partners in Environment Canada, DNR, Department of Environment and Local Government, the Irving Family of businesses, and many other industries, and government and non-governmental agencies.

We have had many successes in our first years and we appreciate the efforts of the Board of Directors to guide our development. Similarly, it was the UNB Board of Governors that provided the commitment need to make the CRI successful and we look forward to a continued support from UNB.

Thank you to everyone who has provided the support and guidance during our early formative years. The CRI is particularly indebted to the efforts of its first directors, Drs. Rick Cunjak and Kelly Munkittrick, who as Director and Associate Director, sustained, and continue to do so, the day-to-day operations of the CRI.

Allen Curry, Acting Director (January 2004)

History and Future of the Canadian Rivers Institute

The CRI has its roots in several initiatives which began at UNB in the 1990s. The New Brunswick Cooperative Fish and Wildlife Research Unit (NBCFWRU) was the first formal step. It was created as a collaboration between New Brunswick Department of Natural Resources (DNR) and UNB in 1995. Its role was to provide the science support for assessment, conservation, and management of fish populations in New Brunswick. The NBCFWRU successes inspired DNR to develop a research chair in Recreational Fisheries, in collaboration with the Cloverleaf Foundation, through which Dr. Allen Curry was named Professor of Recreational Fisheries Research at UNB in 1997. In the same year, the Meighen-Molson Foundation and the Atlantic Salmon Federation also collaborated with UNB to develop a research chair in Atlantic Salmon Research to which Dr. Rick Cunjak was appointed. Dr. Kelly Munkittrick joined UNB in 1999 when an agreement was developed with Environment Canada's National Water Research Institute (NWRI) and Atlantic Region to initiate the Saint John River Project. Two Canada Research Chairs (R. Cunjak and K. Munkittrick) were committed to the CRI in 2000, and the Canadian Rivers Institute was formally established in December 2000, with the inclusion of A. Curry as well as Dr. Deborah MacLatchy of UNB Saint John, a fish reproductive ecotoxicologist.

Since its inception, the CRI has developed operational agreements with a number of organizations. The first agreements were with UPEI and Environment Canada (NWRI and Atlantic Region) in 2001. NWRI expanded its agreements with the CRI in 2002 and moved Dr. Joseph Culp and three other permanent staff to UNB, as well as Dr. Trefor Reynoldson to Acadia University in Wolfville, NS. We continue to develop agreements with other provincial and federal government departments, private industry, and consulting companies that will result in the assignment of key research personnel to the CRI and the development of in-kind

support levels essential to the success of CRI, such as the access to essential field sampling equipment through the NBCFWRU.

Some of our key development is in environmental impact assessment and environmental monitoring areas, a multi-billion dollar industry in Canada and abroad. Monitoring and environmental assessments are currently conducted across Canada with various objectives, by various organizations, and following a variety of protocols. It is our intention to work towards standardizing environmental monitoring requirements for a variety of purposes, including environmental impact assessment, cumulative effects assessment, environmental risk assessment and surveillance and monitoring, so that the data can be broadly used and applied for management decisions. The assembled expertise and ties into regulatory agencies will ensure that the research is timely, appropriate and adequate for use by the regulatory agencies.

It is anticipated that there will be a large expansion on the international demand for tools and approaches. This demand will be driven both by a desire for multi-national companies to work to North American environmental standards, by the probable development of Americas-wide trade agreements, and by a need to standardize environmental approaches in the face of the globalization of markets. In the international market, the focus of the CRI will be on the development of the understanding and need for these technologies.

Such applications require critical, fundamental knowledge of the physical and biological structure and processes of river ecosystems. The CRI's second major development area is building a solid pure science foundation within individual research groups and collectively through our existing research within the National Centre of Excellence's Canadian Water Network. New network proposals are also developing. The foundation built by both our pure and applied research will establish the CRI as an international leader in the field of aquatic environmental

sciences through numerous scientific publications and post-graduate students trained.

One of our core values is the development and training of undergraduate and graduate students within our growing number of collaborative research and educational activities. To date, we have grown to 7 Fellows, 31 Associates, and 12 staff persons. Fifty-eight graduate students have studied with us since our inception in 2000. We have high expectations that we will continue to grow the training of highly qualified personnel (HQPs) as our research activities expand.

Table 1. Summary of Canadian Rivers Institute personnel, 2001-2003.

	Existing	*Completed 2001-2003*	*Total*
Fellows	7		7
Associates	31*		
Staff	12	25**	37
Graduate Students			
Masters	31	14	45
Doctorate	11	2	13
Postdoctoral Fellows	3	2	5
	64	43	107

* not included in totals

** many of the staff worked for more than 1 year; total does not include staff that went on to graduate school within the CRI

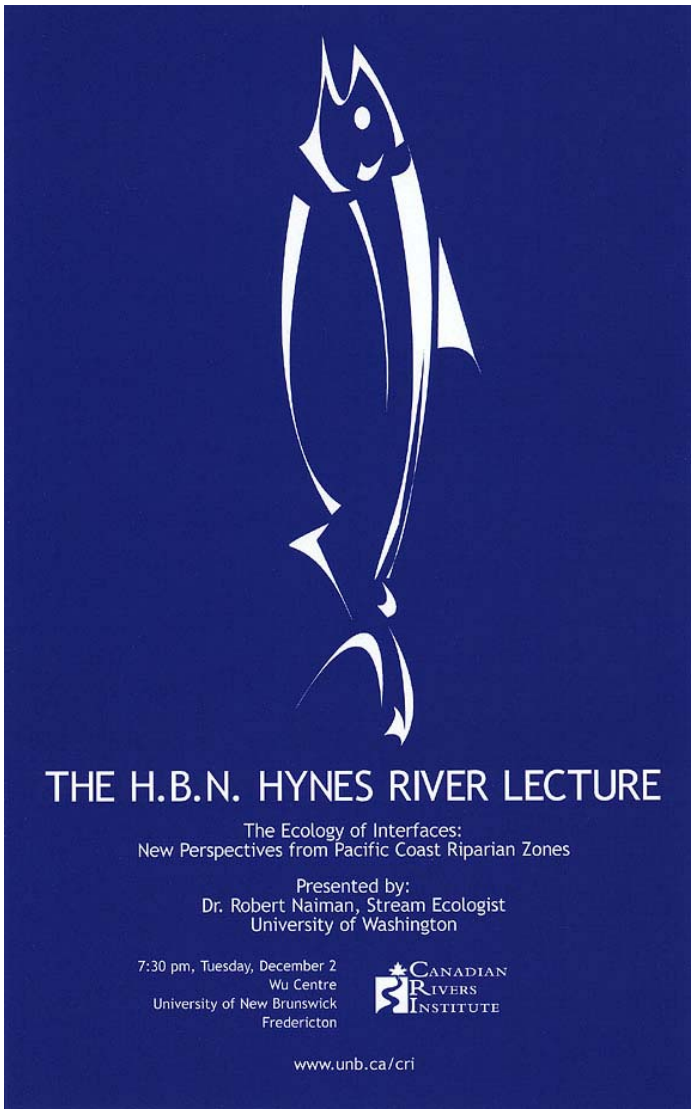
We are also committed to the dissemination of our research to other stakeholders, including government regulators, consultants and community organizations. Therefore, the CRI has initiated an annual “Rivers Day” to up-date our partners and other interested parties about our scientific findings and ongoing activities. In 2001 and 2004, “Rivers Day” was held in Fredericton, and in 2002 and 2003 in Saint John. In 2003 and 2004, “Rivers Day” was held in conjunction with national network meetings (Canadian Water Network in 2003 and the National EEM Scientific Meetings in 2004) to enhance our outreach.

H.B.N. Hynes River Lecture Series

Dr. H.B. Noel Hynes is the world's most renowned freshwater biologist and a Distinguished Emeritus Professor at the University of Waterloo. Referred to as "the father of running water ecology", he has published extensively, including his definitive textbook on river ecology, *The Ecology of Running Waters*. Dr. Hynes has conducted research around the world while holding six visiting professor appointments on three continents. He was awarded the Naumann-Thienemann Medal in 1998, the highest award available to an aquatic biologist by the Societas Internationalis Limnologiciae. Dr. Hynes is a Fellow of the Royal Society of Canada, and holds honorary degrees from his alma mater, the University of London, and the University of Waterloo.

In establishing a lecture series on river ecology, it was only fitting that the CRI select Dr. Hynes as its inaugural lecturer in October 2002. He graciously lent his name to the annual lecture series sponsored by the CRI. The CRI was very excited that UNB honoured Dr. Hynes with an honorary doctoral degree in 2003.

Figure 3. Dr. Noel Hynes (second from left) shown with Kelly Munkittrick (Associate Director CRI), Rick Cunjak (Director CRI) and Allen Curry (Currently Acting Director CRI)



The first H.B.N. Hynes River Lecture was given on December 2, 2003 by Dr. Robert Naiman, a stream ecologist at the University of Washington, entitled "The ecology of interfaces: new perspectives from Pacific coast riparian zones". Dr. Naiman is a world-renowned river ecologist focusing on the structure and dynamics of stream ecosystems, riparian vegetation, and the role of large animals in influencing ecosystem dynamics. He is a professor in the College of Ocean and Fishery Sciences at the University of Washington. He has been a research scientist and director of the Matamek Research Program at the Woods Hole Oceanographic Institution, director of the Center for Water and the Environment at the University of Minnesota, and director of the Center for Streamside Studies at the University of Washington.

CRI Award from the Miramichi Salmon Association

The internationally acclaimed Miramichi Salmon Association honoured the University of New Brunswick's Canadian River Institute (CRI) during its annual conservation dinner September 17, 2003. The Association recognized the work of the Canadian Rivers Institute and especially its mandate to carry out multi-disciplinary research focused on river ecosystems, including land-water linkages for the purposes of conservation and habitat restoration. Rick Cunjak and Kelly Munkittrick, the two senior Canada Research Chairs associated with the Institute, were part of a large UNB contingent at the dinner. The award recognized CRI's extensive research programs on watershed management and that the studies undertaken by CRI have a direct bearing on the welfare of the Miramichi River and its precious salmon stock.

The Miramichi Salmon Association presented UNB President John MacLaughlin with a framed print of “The Return” by Henry McDaniel, a 98-year-old artist from Quincey, MA, USA.

Figure 4. View of the Miramichi River (R. Cunjak).

List of Members of Management Board, Fellows and Associates

Members of Management Board

Gregory Kealey, Chair
Vice-President (Research), University of New Brunswick

Alex Bielak
Director, Science Liaison, NWRI, Environment Canada, Burlington, ON
Founding Member, National Resource Board of Trout Unlimited Canada
Member, Board of Directors, Canadian Science Writers' Association
Member, Council of Great Lakes Research Managers (IJC Appointment)

Bill Borland
Director, Environmental Affairs, J.D. Irving Ltd., Saint John, NB
Chair of Board of Directors, Canadian Water Network
Member, Premier's Round Table on Environment and the Economy
Member, National Round Table on Environment and the Economy

Peter Cronin
Manager, Fisheries/Natural Resources, NB DNRE, Fredericton, NB
Member, National Freshwater Fisheries Task Group and Recreational Fishing Task Group reporting to the Canadian Council of Fisheries and Aquaculture Ministers

Richard Cunjak
Director (January 2001-December 2003), CRI, UNB, Fredericton, NB

Keith De'bell
Dean, Faculty of Science, Applied Science & Engineering, UNB, Saint John, NB
Member, Atlantic Provinces Council on the Sciences
Member, Health Promotion and Research Committee, Atlantic Health Sciences Corporation

Susan Farquharson
Executive Director, Eastern Charlotte Waterways Inc., St. George, NB
NB Chair, Atlantic Wildlife Coalition
Chair, SWNB Clam Resource Committee
Chair, Fundy NB CAPP Committee

Deborah MacLatchy
Ex-officio, Treasurer, CRI, UNB, Saint John, NB

Kelly Munkittrick
Associate Director, CRI, UNB, Saint John, NB

Allan Sharp
Dean, Faculty of Science, University of New Brunswick, Fredericton, NB
Member, Board of Directors, Atlantic Cooperative Wildlife Ecology Network
Member, Board of Directors, Atlantic Environmental Sciences Network

Fred Wrona
Director, Aquatic Ecosystem Impacts Research Branch, NWRI, Victoria, BC
Member, Board of Directors, British Columbia Freshwater Institute (BCFI)
Member, Steering Committee, British Columbia Environmental Science Network

Allen Curry
Acting Director (January 2004-present), CRI, UNB, Fredericton, NB

Fellows

J. M. Culp, Ph.D.
NWRI, Fredericton, NB

R.A. Cunjak, Ph.D.
UNB, Fredericton, NB

R.A. Curry, Ph.D.
UNB, Fredericton, NB

D.L. MacLatchy, Ph.D.
UNB, Saint John, NB

K.R. Munkittrick, Ph.D.
UNB, Saint John, NB

R.W. Newbury, Ph.D.
Okanagan Centre, BC

S.J. Peake, Ph.D.
UNB, Fredericton, NB

Associates

T. Al, Ph.D.
UNB, Fredericton, NB

D. Baird, Ph.D.
NWRI, Fredericton, NB

S. Bunn, Ph.D.
Griffith U., Australia

P. Chambers, Ph.D.
NWRI, Burlington, ON

K. Clarke, M.Sc.
DFO, St.John's, NF

S. Courtenay, Ph.D.
DFO, Moncton, NB

S. Currie, Ph.D.
Mt.A. U., Sackville, NB

S. Dalton, Ph.D.
UNB, Fredericton, NB

K. Devito, Ph.D.
U. Alberta, Edmonton, AB

M. Dubé, Ph.D.
NWRI, Saskatoon, SK

K. Haralampides, Ph.D.
UNB, Fredericton, NB

S. Heard, Ph.D.
UNB, Fredericton, NB

M. Hewitt, Ph.D.
NWRI, Burlington, ON

D. Holdway, Ph.D.
UOIT, Oshawa, ON

J. Houlahan, Ph.D.
UNB, Saint John, NB

L. Jackson, Ph.D.
U. Calgary, Calgary, AB

K. Kidd, Ph.D.
DFO, Winnipeg, MB

J. Kieffer, Ph.D.
UNB, Saint John, NB

K. MacQuarrie, Ph.D.
UNB, Fredericton, NB

M. McMaster, Ph.D.
NWRI, Burlington, ON

D. Methven, Ph.D.
UNB, Saint John, NB

R. Parker, M.Sc.
EnvCan, Fredericton, NB

J. Parrott, Ph.D.
NWRI, Burlington, ON

J. Post, Ph.D.
U. Calgary, Calgary, AB

T. Reynoldson, Ph.D.
NWRI, Wolfville, NS

J.M. Roussel, Ph.D.
INRA, Brittany, France

D. Scruton, M.Sc.
DFO, St. John's, NF

K. Teather, Ph.D.
UPEI, Charlottetown, PEI

G. Van Der Kraak, Ph.D.
U. Guelph, Guelph, ON

R. Wissink, M. Phil.
Parks Canada, Alma, NB

Partnerships and Agreements

Research Agreements

Environment Canada National Water Research Institute (NWRI) and Environment Canada - Atlantic Region

Focus: To develop a national focal point for innovation that will be the departmental lead on Cumulative Effects on Aquatic Biodiversity. From Atlantic Canada, NWRI will lead a multidisciplinary, national program that bases integrated watershed management on the principles of Cumulative Effects Assessment (CEA) research. This research network will create research linkages with the federal government, universities, the provinces and industry.

http://www.nwri.ca/ and http://www.atl.ec.gc.ca/

University of Prince Edward Island

Focus: To encourage the exchange of students, faculty members, research fellows and visiting scholars to facilitate inter-institutional study and research, faculty development and the sharing of joint research interests. http://www.upei.ca/biology/

Laboratoire d'Ecologie, INRA, Rennes, France (both parties have agreed in principle to the agreement)

Focus: The areas of cooperation include all programs of mutual interest, especially in the areas of aquatic ecology and agricultural impacts. The agreement aims to facilitate the exchange of scientists and the promotion of joint research projects and training programs.

http://www.unb.ca/cri/associates/jean-marc_roussel.html

Conte Anadromous Fish Research Center, University of Massachusetts, USA

Focus: To encourage the exchange of graduate students carrying out joint research projects, and to facilitate inter-institutional research on river hydraulics, fish ecology, and biotelemetry. Research directed at resolving environmental problems in rivers that border the USA and Canada are of special interest to both parties.

http://www.lsc.usgs.gov/CAFLindex.asp

Centre for Riverine Landscapes, Griffith University, Australia

Focus: To encourage the exchange of graduate students carrying out joint research projects, to facilitate inter-institutional research on river ecosystems, and to facilitate teaching of field courses dealing with issues of mutual interest.

http://www.gu.edu.au/text/centre/riverlandscapes/

New Brunswick Department of Natural Resources, NBCFWRU

Focus: The New Brunswick Cooperative Fish and Wildlife Research Unit (NBCFWRU) was created by a collaboration of DNR and UNB to provide the science in support of managing and conserving the freshwater fisheries resources of NB.

http://www.unb.ca/nbcfwru/NBCFWRU.html

New Brunswick Department of Environment and Local Government, Letter of Cooperation

Focus: To develop a partnership with CRI and its affiliates to provide the Sciences Reporting Branch, Department of the Environment and Local Government (DELG), with information to stay abreast of emerging issues and advances in the areas of applied surface water research, and to increase scientific collaboration and technology transfer between the two agencies.

http://www.gnb.ca/0009/index-e.asp

Partnerships

Canadian Water Network (CWN; a National Centre of Excellence): The CWN is a major partner in the Saint John River studies, and supports several partnering studies.

http://www.nce.gc.ca/nces-rces/cwn_e.htm

Fisheries and Oceans Canada (DFO): We are actively collaborating in several areas, including marine and estuarine EEM studies, fish mobility issues, fish community analyses, pesticide research projects, and fish bioassay development.

http://www.dfo-mpo.gc.ca/home-accueil_e.htm

Department of Environmental Protection (DEP) Maine, USA: We are actively collaborating on research projects related to the Saint John, Androscoggin and Aroostook Rivers, ME.

http://www.maine.gov/dep/index.shtml

Agriculture Canada: We have initiated some research partnerships on the issues of pesticide impacts on river systems, through the Potato Research Centre in Fredericton.

http://res2.agr.gc.ca/fredericton/index_e.htm

Acadia University, Wolfville, NS: There are a number of initiatives linked to the Acadia Centre for Estuarine Research.

http://ace.acadiau.ca/science/cer/home.htm

University of Calgary, Calgary, AB: We are actively collaborating with several key people (Lee Jackson, John Post, Ed McCauley) involved in the Alberta Ingenuity Centre for Water Research.

http://www.albertaingenuity.ca/news_publications/media_release/2003-10-5.php

EULA Research Center, Concepcion, Chile: We have begun discussions on collaborations with the EULA centre on research related to the BioBio River, which has extensive pulp mill and hydroelectric development, similar to the Saint John River.

http://www.eula.cl

Centro de Investigaciones Marinas, Universidad de La Habana, Havana, Cuba: We have a number of active collaborations with this group related to environmental assessment and monitoring of river discharge impacts on coral reefs and nearshore areas.

http://www.gulfbase.org/organization/view.php?oid=cim

International and Field Courses

River Habitats and Hydraulics. R. Cunjak, B. Newbury, S. Bunn and J. Culp
Description – The course provides theoretical and practical understanding of the hydrology and ecology of natural river ecosystems. (Listed as UNB BIOL 6183 and simultaneously offered for working professionals.)
Locations – Fundy National Park, NB and Crystal Waters, Australia (2004); previously, Kananaskis, AB (2003), Miramichi, NB (2002, 2001).

Advanced Ecotoxicology Workshop. D. MacLatchy and K. Munkittrick
Description – The course is a two-week, team-taught professional development workshop for marine biologists, chemists, and engineers.
Location – Havana, Cuba (2001).

Applied Marine Ecology Field Course. A. Curry and D. MacLatchy
Description – The course is designed for students to get practical experience in applied ecology problems of coastal marine environments in the Caribbean. (UNB BIOL 4373.)
Location – Havana, Cuba (2002).

Fish Habitat Restoration Workshops. R. Cunjak and R. Newbury
Description – This workshop is directed at government biologists and engineers and consultants.
Location – Offered at Fundy National Park (2002), University of Waterloo (2001).

Stream Ecology and Hydraulics (Conservacion de Especies Piscicolas Continentals y de sus Habitats) R. Cunjak, G. de Leaniz and B. Newbury
Description – The course was directed at graduate students, government biologists and engineers. It was funded and sponsored by the Cantabria Agency for Natural Resources.
Location – Laredo, Spain (2001).

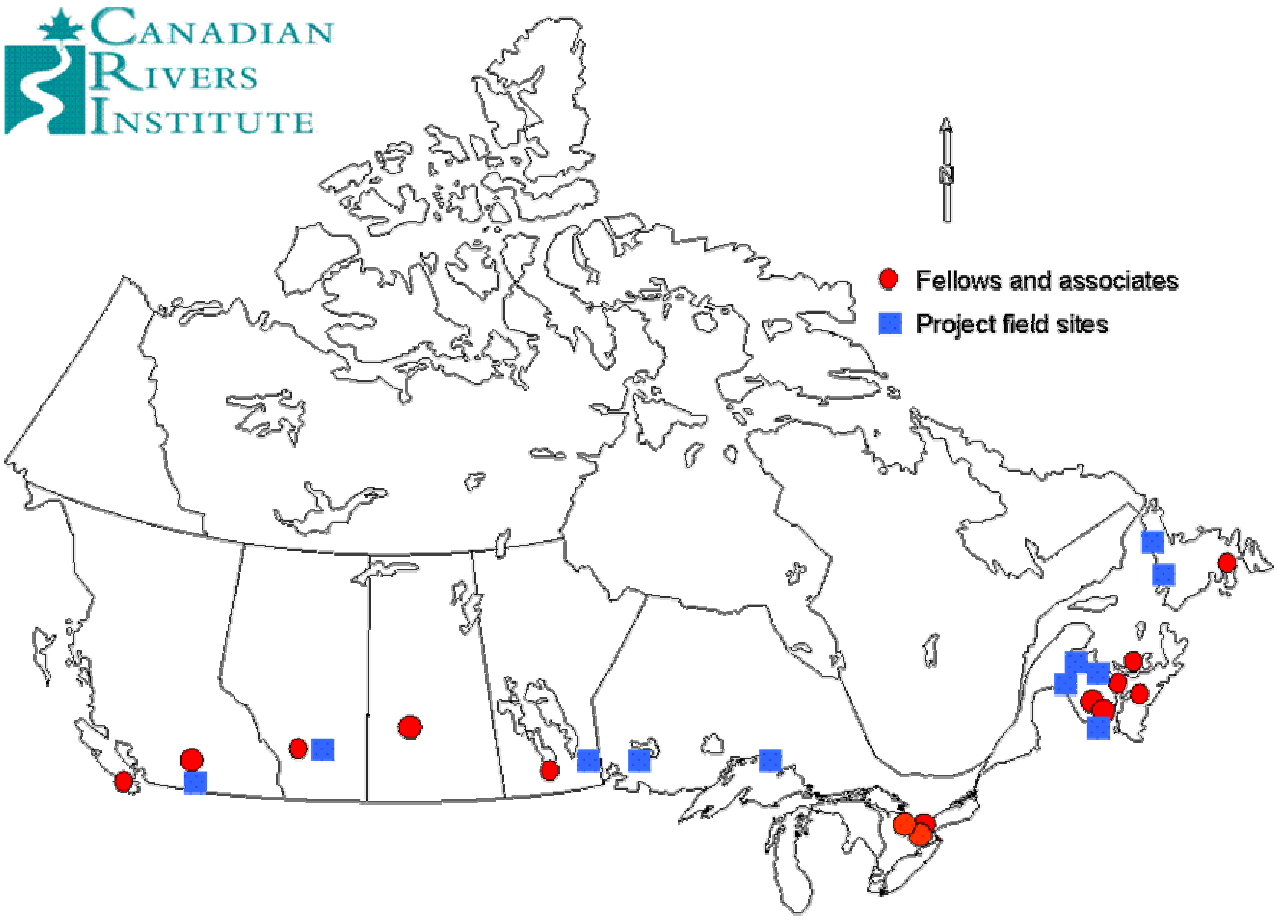


Figure 5. Locations of members of the Canadian Rivers Institute and the associated research projects by graduate students.

Figure 6. Fall view of the Digdeguash River (C. Blanar)

Fellows

Joseph Culp

Chief, Cumulative Effects on Aquatic Biodiversity Project, NWRI
Fellow, Canadian Rivers Institute (2002-2003)
Research Professor, UNB, Fredericton and Saint John, NB
http://www.unb.ca/fredericton/science/biology/Faculty/culp.html

Research Interests

Dr. Culp's research program attempts to blend applied and basic science with the goal of generating a better understanding of human impacts on riverine ecosystems. He investigates the effect of multiple stressors and nutrient-contaminant interactions on riverine food webs and develops field bioassays for use in environmental effects assessment. His current research evaluates the efficacy of cumulative effects methodologies for determining ecological risk, as well as determining Canadian guidelines for dissolved oxygen in aquatic ecosystems.

Major Projects

Mesocosm research

Dr. Culp has worked on developing and applying novel experimental streams, called mesocosms, for use in environmental effects assessment in both the university and private sector. This technology allows researchers to simulate benthic food webs in experimental systems situated alongside river ecosystems so that the ecological impacts of nutrient and contaminant stressors can be examined in a controlled (but natural) environment. Recently, this mesocosm technology has be used to determine the impacts of industrial and municipal effluents on river ecosystems across Canada.

Pesticide effects on benthic food webs of rivers

The project examines the ecological risk of a common insecticide, imidacloprid, under field conditions of nutrient enrichment to determine the effect of this relatively new pesticide on aquatic ecosystems. This research will produce new ecotoxicological information for imidacloprid, including chronic and life-cycle toxicity data that will

directly relate to regulatory needs for this pesticide. By using mesocosm technology, the study will improve ecological risk assessment by providing novel approaches for generating chronic toxicity data at the level of aquatic food webs. This research will allow for a more scientifically-sound assessment of risk of imidacloprid to Canadian aquatic ecosystems through risk calculation based on measured environmental exposure concentrations in eastern Canada and chronic toxicity to non-target aquatic invertebrates. This study was initiated during the Fall of 2003 at the Potato Research Centre in Fredericton, New Brunswick. The initial study included control (no pesticide), 5 ppb and 15 ppb exposures of imidacloprid. The study will continue through 2005.

Effects of Multiple Stressors

Dr. Culp has conducted cumulative effects assessments on several large river systems in Canada. His studies have included examining the ecological effects of stressors on the primary producers and consumers of benthic food webs. He is particularly interested in researching the effects of nutrient-contaminant interactions on benthic food webs of large rivers. Additionally, he has investigated agricultural impacts (i.e., sedimentation, pesticides, nutrient enrichment) on benthic invertebrate communities, assessed the adequacy of CCME dissolved oxygen guidelines for fish habitat protection, and developed volunteer monitoring programs that use benthic invertebrate communities for the assessment of ecosystem health.

Food Web Interactions

Dr. Culp uses stable isotope techniques to trace contaminant pathways in food webs and for measuring ecosystem productivity. He has investigated the effects of forest harvesting on benthic communities in stream ecosystems. Previous research focused on understanding the role of benthic predator-prey interactions in structuring riverine communities.

Funding

Culp, J.M. NSERC Disovery grant. $14,000. 2003-2004.

Culp, J.M., and R.A. Curry. New Brunswick Environmental Trust Fund, Nutrient status of Saint John River. $15,000. 2003-2004.

Culp, J.M., K. Liber, A. Cessna and K. Doe. Pesticide Science Fund (Environment Canada), Ecological Risk Assessment of Imidacloprid in Aquatic Ecosystems. $160,000. 2003-2005

Culp, J.M. (PIs, B. Ernst and M. Hewitt). Pesticide Science Fund (Environment Canada), Reducing Pesticide Impacts in Aquatic Systems of PEI. $19,000. 2003-2005.

Culp, J.M. Weyerhauser Canada. Use of Mesocosms to Study the effect of Multiple Stressors and Nutrient-Contaminant Interactions on Benthic Food Webs of Large Rivers. $100,000. 2002-2004.

Project Partners

Agriculture and Agri-Foods Canada
Canadian Foundation for Innovation and New Brunswick Innovation Fund
New Brunswick Department of Environment and Local Government
University of New Brunswick
University of Saskatchewan
Weyerhauser Canada

Figure 7. View of the mesocosm set-up on the banks of the Saint John River at Edmundston (J. Culp)

Personnel

Staff

Donald Baird, Research Scientist

A recent addition to the NWRI team, Dr. Baird is establishing his research program in the area of multistressor effects on aquatic biodiversity. Previously, he managed a large research group studying the interface between aquatic ecology and applied water management issues at the University of Stirling, Scotland.

Eric Luiker, Aquatic Biologist

Mr. Luiker is an aquatic biologist with NWRI/CRI, who has recently joined Environment Canada after 10 years of consulting. Mr. Luiker is currently involved in several studies, with a focus on cumulative impacts to the aquatic environment. His expertise includes work on large ecosystem initiatives, database design, and the management of remote field surveys. In addition, he manages a project that investigates the relationship among nutrient levels, primary production and water quality along the Saint John River.

Dave Hryn, Aquatic Technician

Mr. Hryn is an aquatic resource technician with Environment Canada who has recently joined NWRI/CRI in Fredericton. Mr. Hryn has a background in engineering, the operation of field mesocosms, and field surveys of rivers. He is responsible for all technical duties within the NWRI lab.

Figure 8. The Saint John River near Edmundston, NB (K. Munkittrick)

Post-Doctoral Fellows

Dave Riddell (2003 - present)

Sub-lethal effects of metal mine effluent on aquatic communities

Research by Dr. Riddell on metal-impacted streams in northern New Brunswick has revealed altered foraging behaviour and reduced growth rates in resident brook trout populations. The nature of the observed behavioural changes may act to further increase and prolong exposure to contaminants, resulting in reduced trout population stability and altered aquatic community structures. By examining trout movement, morphology, and diet in relation to aqueous and food-borne metal concentrations, Dr. Riddell's current research attempts to explain differences in habitat use between fish from metal-contaminated and uncontaminated streams and its implications for natural resource management.

Graduate Students

M.Sc.

Alexa Alexander (2003 - present)

Effects of imidacloprid on benthic and invertebrate communities

The principal objectives of this project are to examine human impacts on riverine ecosystems, in particular the fate of pesticides in sediments. Using experimental streams to characterize the benthic riverine community we can examine the impacts of exposure to pesticides on insect and algal species diversity. In collaboration with the University of Saskatchewan, the effects of environmentally-realistic concentrations of one particular insecticide, imidacloprid, on the benthic invertebrate community will be determined.

Ph.D.

Laura Noel (2004 - present)

Nutrient loading and food webs in large multiuse rivers.

Ms. Noel will investigate the effect of nutrient loading on benthic food webs of the Saint John River from headwaters in Maine to southern New Brunswick. This study will integrate field observation, modeling, Global Information Systems (GIS), and field and *ex situ* experimentation. Her objectives are to: a) determine how natural and anthropogenic nutrient enrichment affects riverine primary producers and food web interactions in large multiuse rivers; b) identify reaches of the Saint John River that are threatened by excessive nutrient loading; and c) develop action plans to begin river habitat restoration.

Undergraduate Students

Olivia Logan

Ms. Logan was a summer student in 2003. She assisted in field study preparation, field surveys, benthic invertebrate identification, data entry and literature reviews. Projects included the Saint John River nutrient study and pesticide runoff project in New Brunswick.

Figure 9. View of the laboratory trailer set-up at Edmundston, NB (K. Munkittrick)

Service

Positions/Committees

Chair of Elections Committee, North American Benthological Society (2002)

Associate Editor for Scientific World (2002)

Member of international expert panel to review the state of aquatic science and grant proposals for the Government of Portugal (2001-present)

President of the North American Benthological Society (2001)

Review committee for the joint Environment Canada-Health Canada Toxic Substance Research Initiative (TSRI) (1999-2002)

Invitations

Invited presentation, "Insight into pollution effects in complex riverine habitats: the role of food web experiments", November 10-14, 2003. Food Webs 2003, Giessen, Germany.

Canadian representative and Co-Chair of UNEP's Expert Working group on the rapid assessment of biodiversity, December 2-4, 2002.

Invited address, Canadian experiences in large ecosystem environmental assessments. CIDA workshop, "Stressors in aquatic environments: Cuban and Canadian Perspectives". November 28-29, 2002. Havana, Cuba.

Lecture series, "Concepts of Ecological Effects Assessment". September 30 to October 11, 2002. University of Coimbra, Coimbra, Portugal.

Presidential address, "The role of freshwater benthologists in translating science to decision-makers. 49th Annual Meeting of the North American Benthological Society, La Crosse, USA, May 2001.

Fellows

Richard A. Cunjak

Canada Research Chair in River Ecosystem Science
Director, Canadian Rivers Institute (2001-2003)
Fellow, Canadian Rivers Institute (2001-present)
Professor, Department of Biology, and the Faculty of Forestry & Environmental Management, University of New Brunswick, Fredericton, NB
Director, Catamaran Brook Habitat Research Project
Director, Stable Isotopes in Nature Laboratory, UNB, Fredericton, NB
http://www.unb.ca/cri/cunjak.html

Research Interests

The principal aim of Dr. Cunjak's research program is the ecology of riverine fishes with special interest in the conservation of Atlantic salmon rivers. There are three main areas of focus for his research: winter biology, anthropogenic impacts and critical habitats in large rivers. His research approach to winter biology involves studies of fish movement and habitat-use, energetic costs of overwintering, and the impact of river ice on egg survival and habitat availability. A major research focus has been the quantification of forestry and agriculture impacts in stream ecosystems. These anthropogenic impacts have been considered in relation to hydrology, sediment loading, stable isotope analysis, nutrient cycling and water temperature. In addition, his research has examined factors related to critical habitats in large rivers. Specifically, his research has quantified and considered the importance of refugia in large river environments during in-stream stressor events (e.g., floods, ice break-up, high temperature) using Atlantic salmon as indicator species for population-level responses.

Major Projects

Winter behaviour of stream fishes

In most of Canada, winter (and its concomitant features of ice and freezing temperatures) is the dominant season. However, the winter biology of aquatic species is poorly known despite the recognition that winter is a critical period for survival. Dr. Cunjak has been publishing on the winter biology of fishes for 15 years with the focus on quantifying winter behaviour and survival of fishes in running waters (e.g., Heggenes *et al.* 1995, 1999; Cunjak 1996, 1997; Cunjak *et al.* 1998). Generally, fishes tend to select habitats where energy expenditure is minimized but where food is still available and/or where refuge from adverse physical conditions is possible. Location of suitable habitat may require significant in-stream movement (Cunjak 1996; Caissie *et al.* 1997) including into tidal water (Komadina-Douthwright *et al.* 1997) often in response to ice (Cunjak *et al.* 1998). An understanding of the environmental complexities inherent to winter as well as the survival, habitat needs and behaviour of aquatic biota are essential for ensuring conservation and successful resource management (Cunjak 1996; Heggenes *et al.* 1999).

Catamaran Brook Forestry Impact Project

This continuing, long-term (20-year), multi-disciplinary project is aimed at quantifying forestry impacts to a sub-catchment of the Miramichi River (Cunjak 1995). Dr. Cunjak initiated this project in 1990 while a research scientist at DFO, and he continues to direct and manage the scientific activities from UNB. As well as the long-term objective (forestry impacts), the project structure also encourages short-term research studies such as testing in-stream habitat models (Bourgeois *et al.* 1996), stable isotope analyses of food webs (Doucett *et al.* 1996), invertebrate studies (Johnston and Cunjak 1999) and hydrograph separation techniques using water chemistry (Caissie *et al.* 1995). Collectively, such studies contribute to a better understanding of river ecosystem processes. This unique, comprehensive, long-term data-set (10 years now) has already proven valuable for Atlantic salmon management in eastern Canada, and for monitoring environmental change, at the regional scale. To date, 15 international

universities and colleges have been involved in the project; 58 scientific papers and 31 theses have been written. Recently, Dr. Cunjak was invited to write a book chapter on eastern Canada's experience with fish-forestry interactions for a Canadian book on the topic. The project is planned to continue until 2010.

Atlantic salmon biology

This area of research focuses on Atlantic salmon as an indicator of ecosystem health. Dr. Cunjak's invited review papers (Cunjak 1996; Cunjak *et al.* 1998) highlighted the need to understand seasonal constraints to production and the need to protect habitat complexity to ensure survival of the species. Population models by Cunjak and Therrien (1996, 1997) have indicated relatively low egg-smolt survival (<0.5%) relative to previous research on the topic. Additional insights into the ecology of wild Atlantic salmon have come from research to predict abundance based on density-dependent relations at a variety of spatial scales (Grant *et al.* 1998). Very recently in his lab, a new technique for monitoring small-scale movements and growth of individual salmon parr in streams using passive integrated transponder (PIT) technology (Roussel *et al.* 2000) has been developed. Ultimately, such research will provide better information for improving salmon management and conservation (Dodson *et al.* 1998).

Physical factors influencing fish survival and growth in rivers

This research topic attempts to distinguish the importance of density-independent (environmental) variables in regulating stream fish populations in relation to natural and anthropogenic events. Cunjak et al. (1998) used hydro-climatological data to link salmon egg survival and winter streamflow, and to demonstrate the significant effect of ice break-up. Other related research has attempted to link flood events to changes in stream habitat quality (St. Hilaire *et al.* 1997) and growth (Arndt *et al.* 1996). More recently, the impacts of sediment-loading from land-use activity (agriculture) have been shown to be detrimental to survival of eggs and alevins of salmon and brook trout in PEI streams (Cunjak *et al*. 2000). The noteworthy aspect of that study was the use of a simple technique for quantifying the relation between sediment loading and egg/alevin

survival *in situ*. This line of research was further pursued, in the Saint John and Miramichi River catchments of NB, as part of the Toxic Substances Research Initiative (TSRI) program (Munkittrick *et al.* 1999). The influence of elevated water temperature on the physiological condition of smolting Atlantic salmon has also been studied in East Coast rivers (McCormick *et al.* 1999) and has special relevance for salmon survival according to predicted climate changes for the region, and from human impacts related to construction of hydro dams.

Stable Isotope Analysis for Environmental Research

This is a new direction for Dr. Cunjak's research. Based on a successful Canada Foundation for Innovation (CFI) grant received in 1999 (for which he was principal investigator), he has set up a lab at UNB Fredericton (Biology) for carrying out stable isotope analysis (SIA) of carbon (δ 13C), nitrogen (δ 15N), and sulfur (δ 34S) in tissue samples from fish and wildlife. This is a very powerful tool to assist ecologists in determining nutrient pathways between terrestrial and aquatic environments (e.g., Doucett *et al.* 1996), food source origins and, hence, migration routes, as well as for identifying food web complexity and environmental contaminant pathways. Presently, SIA is being used to determine salmon egg predation in the wild, physiological turnover of food in different body tissues, and for tracing the impacts of contaminants in aquatic ecosystems to organisms such as slimy sculpin (Munkittrick *et al.* 1999).

Funding

Cunjak, R.A. Canada Research Chair in River Ecosystem Science. $200,000. 2001-2007.

Cunjak, R.A. (co-applicant). Norwegian Research Council. Collaborative project with SINTEF Energy (Norway) and DFO (NF). Project title: Effects of winter and ice conditions on Atlantic salmon. $127,200. 2002-2006

Munkittrick, K.R. (PI). NCE Canadian Water Network, Estimating the assimilative capacity of the Saint John River, with collaborating partners, R.A. Curry, K.

Haralampides, D. MacLatchy (UNB), K. Teather (UPEI), G. Daborn (Acadia). Total grant $154,427. 2001-2003.

Cunjak, R.A. (co-applicant). NCE /NSERC, Collaborative Mercury Research Network (COMERN). $24,000. 2001-2006.

Cunjak, R.A. NSERC Discovery Grant, winter stream biology. $17,200. 1998-2002.

Cunjak, R.A. NB Environmental Trust Fund for the Catamaran Brook project. $10,000. 2002-2003.

Cunjak, R.A. Canada Foundation for Innovation, Infrastructure grant to purchase an isotopic ratio mass spectrometer. $125,000. 2001-2002.

Cunjak, R.A. NB Environmental Trust Fund for the Catamaran Brook project. $20,000. 2001-2002.

Cunjak, R.A. and J. Ritter (DFO). Catamaran Brook joint research project (DFO-UNB partnership Agreement). $ 20,000. 1997-2002.

Cunjak, R.A. Meighen-Molson Professorship, UNB for professorship in Atlantic salmon research. $20,000. 1997-2002.

Project Partners

J.D. Irving, Ltd.
SINTEF Energy (Norway)
Norway Research Council
DFO
NB Environmental Trust Fund
Meighan-Molson
COMERN
Miramichi Salmon Association
American Society for Fisheries
Parks Canada (Fundy National Park)

Environment Canada (Atlantic Region)

NWRI

NBFWCRU

University of New Brunswick

Acadia University (Faculty of Science and Centre for Estuarine Research)

Conte Anadromous Fish Research Center

INRA, Laboratoire d'Ecologie, Rennes, Brittany, FRANCE

Personnel

Staff

Aaron Fraser, Aquatic Biologist 2001 - present

Terra McMullen, Field Biologist 2003

Peter Batt, Summer Field Technician 2003

Vanessa Kilburn, Summer Field Technician 2003

Craig Knickle, Summer Field Technician 2002

Dan Cartwright, Summer Field Technician 2001-02

Anne McGeachy, SINLAB Lab Manager

Tim Jardine, SINLAB Scientific Manager

Christine Paton, SINLAB Technician

Mireille Savoie, SINLAB Technician

Figure 10. 18 mile Brook, a tributary of the Upsalquitch River, NB (C. Blanar)

Post-Doctoral Fellows

Douglas Peterson, Ph.D. (2003 - present)
Dynamics of Atlantic salmon in Miramichi River

Dr. Peterson's research is focused on exploring the dynamics of juvenile Atlantic salmon in the Miramichi River system, NB, using more than 30 years of abundance monitoring data collected by Fisheries and Oceans Canada. The goal of his research is to assess spatial and temporal trends in fry and parr abundance and to identify bottlenecks in production. His doctoral research focused on the population ecology of stream salmonid invasions, specifically the invasion by brook trout in streams of the western US and effects on native inland cutthroat trout.

Jean-Marc Roussel, Ph.D. (2001-2002)
Atlantic salmon studies in Catamaran Brook

Using field and laboratory investigations, Dr. Roussel's research focused on the integration of individual behaviour to explain mechanisms underlying population processes (resource selection, competition, emigration, and predation). A new method for tracking small fishes in rivers using passive integrated transponder (PIT) technology was developed and field-tested. This technology was used to examine the habitat use, movements, and behaviour of Atlantic Salmon parr under extreme environmental conditions at Catamaran Brook, New Brunswick.

Presently: Research Scientist, Laboratoire d'Ecologie Aquatique, INRA, France

Richard Doucett, Ph.D. (2001-2002)
Stable isotope studies on feeding ecology of Atlantic salmon

Dr. Doucett used stable isotope analysis (SIA) to understand the life history and feeding ecology of salmonid fishes and aquatic invertebrates. Specific project objectives included: establishing diet-tissue isotopic fractionation and turnover times in juvenile salmon, assessing the relative importance of egg-predation to the diet of

precocious parr and identifying anadromy in adult brook trout and their young-of-the-year progeny.

Presently: Lab Manager, Stable Isotope Lab, North Arizona University, Flagstaff, AZ

Graduate Students

Ph.D.

Cindy Breau (2003 - present)

The effects of high water temperatures on the ecophysiology and behaviour of juvenile Atlantic salmon (*Salmo salar*)

Salmonid rivers are more commonly experiencing temperatures (24-26ºC) that are potentially lethal for coolwater fishes. During high temperatures, salmon parr abandon territorial behaviour and aggregate at cool water sources (e.g., springs and confluence of cooler brooks). However, the physiological mechanisms and the ecological consequences of juvenile salmonid aggregations are not well understood. During the next few years, laboratory experiments and field observations will be conducted to determine the potential causes and consequences of salmonid aggregations during thermal stress. Why do juvenile salmon abandon territorial behaviour at high temperatures? Measurement of various physiological parameters such as muscle lactate will be examined to assess possible causes related to the behavioural changes observed. In the Little Southwest Miramichi River, individual salmon will be tagged using PIT technology. Both stationary and portable antennae will enable the movement and the behaviour of tagged fish to be monitored. The distance that fish travel to find cool water sources will be determined. In addition, the temperatures leading to the formation and breakdown of the aggregations will be determined.

Tommi Linnansaari (2003 - present)

Effects of Ice on the winter behaviour and habitat of juvenile Atlantic salmon (*Salmo salar* L.) in small rivers – EIJAS project

The main objective of this project is to understand the movements and other responses of juvenile Atlantic salmon parr related to the prevailing physical conditions in small rivers during the winter. A special interest is on different ice forms and their effect on salmon parr movements and ice-induced changes to habitat availability and suitability on winter. Changes in meso- (the overall habitat type) as well as micro- (the biota directly affecting fish, scale within $1m^2$) habitat will be studied. Study sites are located in Catamaran Brook, New Brunswick, and in the Sokna River, Norway. The work will be done using passive integrated transponder (PIT) technology. Movement of the fish will be recorded in early, mid and late winter, and possible changes in diel activity will also be studied. The EIJAS project will produce basic understanding on the bio-physical relations between river ice forms and Atlantic salmon parr. The results will describe salmon parr winter habitat, which have to be taken into consideration in rehabilitation and enhancement projects, in order to make suitable winter habitats for salmon parr in degraded rivers where the suitable overwintering habitat might be partially lost.

Douglas Sigourney (U.Mass. Amherst, co-supervised with Dr. Ben Letcher; 2001-present)

Addressing growth rate variation in three populations of Atlantic salmon distributed along a latitudinal gradient

The goal of this project is to address the reasons for size variation in cohorts of juvenile Atlantic salmon both within and among systems through the development of a growth model. Data on size trajectories of individually-marked individuals will be used in order to develop a model that will capture these trajectories. The parameters will be estimated directly from field data. Analysis will be conducted on the parameters estimated for different populations to learn more about what mechanisms may be

responsible for growth variation. In addition, seasonal differences in growth will be considered. Because individuals were marked with unique identifiers, a vast array of mark-recapture models will be used to address questions of survival. An exploration of whether or not there is evidence of size selection among these systems that may be contributing to this pattern of size variation will be conducted through the use of survival models.

Sean C. Mitchell (2001 - present)

Fish production-habitat relationships in two East Coast streams

Fish production, defined as the elaboration of fish tissue by a population between two sample periods, is a valuable measure of the relative "health" of a fish species or community as it integrates both abundance of the species (or number of species) and biomass. By relating this measure to habitat variables, the objective is to understand how habitat affects fish population dynamics and body size of both individual species and of the community as a whole. Such understanding will greatly improve our ability to estimate stream production of fish based on habitat measurements, and also provide realistic targets for habitat manipulation such as restoration and rehabilitation projects, or to estimate loss of production due to habitat degradation. Two streams, Catamaran Brook in north central New Brunswick and Northeast Brook, Trepassey, on the Avalon Peninsula of Newfoundland, each provide long-term (13+ years) data sets of high intensity fish sampling and habitat measurements. Using these data sets, and published data from other systems in the Maritimes and Atlantic Canada, the research aims to define fish production-habitat relationships and evaluate the generality with which results determined from one system may be applied to others.

Ph.D. Completed

Michelle Gray (2003; co-supervised with Dr. Kelly Munkittrick)

M.Sc.

Sherisse McWilliam (2003 - present)
Food web dynamics of Inner Bay of Fundy river systems

The Atlantic salmon populations of the Inner Bay of Fundy rivers have recently been identified as "species-at-risk" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Restoration efforts require an ecosystem approach with an understanding of energy flow and ecological interactions. The aim of this research is to identify the food web relationships within the Upper Salmon, Big Salmon and Point Wolfe rivers, with a primary focus on those energy pathways leading to Atlantic salmon. Within this objective are three specific goals. First, to differentiate between relative contributions of terrestrially-derived (allochthonous) carbon sources versus aquatically-derived (autochthonous) carbon sources sustaining populations of fish throughout the river system. Second, to determine trophic relationships of different aquatic taxa and age-classes of fish in these rivers. Finally, to identify the contribution of marine-derived nutrients to the freshwater food web via inputs (e.g., eggs) from diadromous (i.e., having both freshwater and marine life stages) species. Stable isotope analysis (SIA) will be used in order to meet these specific goals. The SIA method using carbon, nitrogen, and sulphur has proven very useful in analyzing food web relationships (i.e., predator-prey interactions). Inferences about a consumer's diet are made by comparing its isotopic ratios with those of other species in its food web. There are many initiatives to re-establish natural salmon population levels in the Inner Bay of Fundy rivers. This project will determine baseline ecosystem interactions to aid in the restoration of Atlantic salmon.

Rachel Keeler (2003 - present)

Mobility and microhabitat preferences of the slimy sculpin (*Cottus cognatus*) in small New Brunswick streams

The purpose of this research is to learn more about the ecology of the slimy sculpin, *Cottus cognatus*. It is believed that sculpin species are sedentary and, therefore, would be useful in monitoring the environmental effects of anthropogenic impacts. The main objectives of this study are to determine the home range of the species and to consider environmental factors that may increase movement levels for sculpin inhabiting small New Brunswick streams. Individual sculpin are tracked with PIT (passive integrated transponder) tags that are implanted into the body cavity of adult sculpin. PIT tags are radio frequency devices that provide a unique numeric code for each tagged sculpin when powered by a PIT tag reader. In this study, the sculpin are tracked with a PIT tag antenna that is capable of reading the PIT tag without removing the sculpin from the stream. This technique is effective because detection rates are much higher and disturbance to the normal movement levels is lower than methods used in the past. It will also be possible to consider factors that may change movement levels by comparing individual sculpin home ranges at different times of the year and at different sites. Microhabitat preferences will be determined by comparing the habitat used by sculpin (water depth, substrate type, etc.) to the habitat availability.

Karilyn Long (co-supervised with Dr. Bob Newbury; 2002 - present)

Megan Mathews (2002 - present)

Atlantic salmon juvenile emigration strategies and subsequent adult returns of Clearwater Brook

This research is investigating survival and morphological differences between Atlantic salmon juvenile emigration strategies, the spring smolt and the fall presmolt, and the subsequent returning adults. Passive integrated transponder (PIT) tags are used to allow identification of individuals. Clearwater Brook, a headwater tributary of the Main Southwest Miramichi River, New Brunswick, will be studied and compared with a sister

tributary, Rocky Brook. Preliminary data of both brooks indicates differences in emigration timing. Stable isotope analysis will be used to assess correlations between emigration strategies and rearing location within Clearwater Brook.

Stephanie Ratelle (co-supervised by Dr. Tillman Benfey, 2001 - present)
Ecological interactions between juvenile diploid and triploid Atlantic salmon, *Salmo salar*

This study was designed to determine the effects of sterile triploid salmon on wild salmon in fresh water. The competitive abilities of juvenile diploid and triploid salmon will be observed and quantified in semi-natural tanks set up at the Mactaquac Fish Culture Station, in New Brunswick.

Christopher Connell (1998 - present)
Pre-spawning movements and behaviour of translocated adult Atlantic salmon in Clearwater Brook, NB (Miramichi)

This project extended over three years and focused on the movement patterns of wild and stocked adult salmon in different parts of the river during their pre-spawning upstream migration phase. Specifically, the research investigated if under-used portions of the upper reaches could be 'enhanced' in order to attract spawning salmon, and to increase production. PIT (passive integrated transponder) technology was used to monitor movements of adult salmon.

Reagan Sutherland (1998 - present)
Relationship between stream order and invertebrate prey availability to brook trout

The rivers draining into the north shore of the Bay of Fundy are high-energy streams with steep lst, 2nd, and 3rd order tributaries. Many of these tributaries are inaccessible to fish due to the gradient and waterfalls, creating natural fragmentation. Fish densities, by observation, appear to be in reverse order of the stream size. The productivity of the system is being investigated based on stream order using: a)

invertebrate population abundance; b) use of invertebrates by brook trout; and b) tracing of nutrient sources through the system by stable isotope analysis. This research is being carried out within Fundy National Park.

M.Sc. Completed

Valerie Bujold (2003)
Egg-to-fry survival and drifting fry behaviour of wild Atlantic salmon (Salmo salar L.) in Western Brook, Gros Morne National park, NF

This is one of two completed graduate projects aimed at meeting the project goal of determining the sustainability of a recreational salmon fishery in Western Brook. This project focused on the estimation of survival of eggs laid by spawning salmon, and the behaviour of recently-emerged salmon fry in different parts of the river basin.

Presently : Biologist, Ministere de la Faune et Parcs, Quebec City, QC

Jay Dietrich (2003)
Smolt ecology and production in Western Brook, Gros Morne National Park, NF

This research focused on investigating the ecology of salmon parr and smolt in the Western Brook system of Gros Morne National Park in western Newfoundland. This unique inland fjord system has a relatively small and little-studied salmon population. From a National Parks perspective, such an understanding is critical to the conservation of this unique ecosystem. This study focused on quantifying the relative smolt production of each of the sub-basins in the river system using mark-recapture techniques.

Presently: Biologist, Ontario Ministry of Natural Resources, Pictou, ON

Jason Flanagan (2003)

Factors influencing survival of fry and emergent fry of Atlantic salmon

This study investigated the impact of man-made disturbance on the survival of eggs and alevins of wild Atlantic salmon. Specifically, the impact of sedimentation from forestry activity near a salmon stream (Miramichi) and the disturbance effect of streamflow regulation (upper Saint John River) were determined.

Presently: Contract Biologist, Fisheries and Oceans Canada, Moncton, NB

Patricia Edwards (2002)

Utility of slimy sculpin as an indicator of land-use disturbance in stream catchments.

This project was designed to measure changes in fish abundance, density, distribution and age structure due to physical habitat alteration. Specifically, the impacts from logging were compared with natural disturbance effects (e.g., ice break-up, high water temperature). The slimy sculpin (*Cottus cognatus*), was chosen for study. It was believed that this sedentary, habitat specialist would demonstrate an earlier response to habitat alteration than would more mobile species such as salmon and trout.

Presently: Biologist, Ontario Ministry of Natural Resources, Peterborough, ON

Undergraduate Students

Dan Cartwright

Vanessa Kilburn

Peter Batt

Visiting Researchers

Jean-Marc Roussel, Ph.D.
Research Scientist, INRA, Unité Mixte de Recherche en Ecobiologie et Qualité des Hydrosystèmes Continentaux (UMR EQHC), Laboratoire d'Ecologie Aquatique, France

Dr. Russel visited during the summer of 2003 to continue collaborations with CRI established during his postdoctoral fellowship. He provided technical advice and assistance to graduate students and researchers working with passive integrated transponder (PIT) technology. He is also collaborating on research projects in France and Norway.

Stuart Bunn, Ph.D.
Director, Centre for Riverine Landscapes, Faculty of Environmental Sciences, Griffith University, Brisbane, Australia

Dr. Bunn came to Canada for several months in 2002 to co-instruct the river hydraulics and habitat field course, and to initiate collaborative projects and a partnership agreement between our respective institutions. His expertise in stable isotope analysis and riverine production was an invaluable contribution to the students and scientists at the CRI.

Service:
Positions/Committees

Member, American Fisheries Society

Member, Atlantic Salmon Association

Member, Miramichi Salmon Association

Member, North American Benthological Society

Member, Board of Directors, New Brunswick Aquatic Data Warehouse

Member, Technical Advisory Group, Miramichi River Environmental Assessment Committee (2001-present)

Member, Technical Committee, Fredericton Area Watershed Association (2002-present)

Invited Lectures

Cunjak, R.A. 2003. Studying fish ecology in Atlantic rivers. Invited seminar, Department of Biology, St. Francis Xavier University, Antigonish, NS. March 12, 2003.

Cunjak, R.A. 2003. Studying fish ecology in Atlantic rivers. Invited seminar, Department of Biology, Université de Québec à Trois Rivières, QC. February 20, 2003.

Cunjak, R.A. 2002. The Catamaran Brook Project: Update of research, 1990-2001. Invited presentation to the Miramichi River Environmental Assessment Committee (MREAC), Miramichi, NB. December 02, 2002.

Cunjak, R.A. 2002. Fish movement and distribution patterns in running waters. Invited seminar, Department of Biology, Mount Allison University, Sackville, NB. November 18, 2002.

Cunjak, R.A. 2002. The use of PIT technology and stable isotopes to study fish movements and habitat use in rivers. Invited seminar, Department of Geography, Université de Montréal, Montreal, QC. February 15, 2002.

Fellows

R. Allen Curry

Associate Professor, Biology and Forestry and Environmental Management, University of New Brunswick, Fredericton, NB
Fellow, Canadian River Institute (2001-present)
New Brunswick Department of Natural Resources/Cloverleaf Professor of Recreational Fisheries Research
Assistant Director, New Brunswick Cooperative Fish and Wildlife Research Unit
http://www.unb.ca/cri/curry.html

Research Interests

Dr. Curry's research program is a mix of both applied and theoretical questions in fish and aquatic ecology with a strong emphasis on the application of science to the conservation and management of natural resources. Brook trout (*Salvelinus fontinalis*) and smallmouth bass (*Micropterus dolomieu*) are two major focus species of this research. The research into the ecology of anadromous and resident forms of brook trout involves early life history work and tracking via radio and sonic techniques, as well as analyses of strontium in bone structures. Smallmouth bass research was initiated with the completion of the first survey of populations in New Brunswick. Since then, projects have been examining winter habitat and survival of young-of-the-year, interactions, potential impacts of alewife (*Alosa pseudoharengus*) on bass, and the influence of trophic structure and complexity (stable isotopes) on bass production in lakes.

Other major research interests include assessing and understanding biodiversity of fishes and benthic macroinvertebrates as it pertains to protecting the ecological integrity of aquatic ecosystems. This includes work assessing the mobility of potential biosentinel species such as the white sucker (*Catostomas commersoni*) and mummichog (*Fundulus heteroclitus*) and potential impacts of forestry, agriculture and recreational fisheries on fish populations. Other projects include studies of the reinvasion of Atlantic Canada by freshwater biota, ecology of the smelt complex of Lake Utopia, analyses of trophic structure and mercury pathways in NB lakes, and

rockweed (*Ascophylum nodusum*) as fish habitat in the Bay of Fundy. At present, this involves eight graduate students at various stages with funding sources that have included a NSERC Strategic Grant, New Brunswick Wildlife Trust Fund and Environmental Trust Fund, Canadian Water Network, and J.D. Irving, Ltd.

Major Projects

Brook trout ecology

Past and current research initiatives have focused on examining the genetic composition, physiological traits, recruitment, and migration ecology of resident and sea-run trout in eastern Canada. The survival of brook trout embryos/alevins and abundance of young-of-the-year can be affected by heavy sediment loads in agricultural catchments. The role of this was assessed in PEI where early development was unaffected and most mortality occurred at late embryo stages, possibly due to oxygen deprivation within redds. The accumulating fine sediments in redds significantly reduced survival of free-embryos and alevins. Discharging groundwater reduced fine sediment accumulations and enhanced survival. Estimates of young-of-the-year and benthic macroinvertebrates production suggested a density-dependent migration from incubation areas occurred. Examining individual cohorts from fertilization to free-swimming young-of-the-year demonstrated survival bottlenecks and variability in behavioural tactics. The results also illustrate the importance of targeting multiple life history stages and habitat scales for ecologically appropriate and, therefore successful planning in natural resource management. Investigation into the spatial and temporal patterns of movement have been conducted via radio and acoustic tracking as well as strontium analyses of bone tissues in the Kennebecasis (NB), Petit Cascapedia (PQ), and Laval (PQ) Rivers and their estuaries. This increasing knowledge of the spatial and temporal scales of behaviour may hold keys to our understanding of the ecology of migration and ultimately the evolution of diadromy in this species and its relatives. Current research interests are focusing on the early developmental characteristics of sea-run and resident brook trout in efforts of fill some of the remaining gaps.

Smallmouth bass ecology

Smallmouth bass in New Brunswick now support the fastest and perhaps only growing recreational fishery, contributing an estimated $10 M to the New Brunswick economy each year. The growth rates of smallmouth bass are generally limited in areas of Canada because they are at the northern limits of their distribution. Variability in growth among populations occurs at this northern limit, including here in New Brunswick. This is an important aspect of bass biology that fisheries managers are struggling to understand in order to develop best management plans and protect populations for sustainable sport fisheries. One project was designed to begin a regional examination of the complexity of fish communities where smallmouth bass occur and generate hypotheses about the impacts of community structure on smallmouth bass growth in New Brunswick lakes. The objectives were to examine the structure of smallmouth bass populations and the fish communities in four lakes with generally similar limnological characteristics, but with known differences in bass growth rates. This information provides the foundation needed to better understand how community structure is affecting smallmouth bass populations in our region.

Fish and Macro-invertebrate Community Structure

Assessment and understanding of fish and macro-invertebrate community structure has become an important element of recent and on-going research. Surveys of five rivers varying in size throughout New Brunswick have recently been done to address numerous ecological questions and for incorporation into applied research associated with environmental assessment of running waters in the province. These included the Saint John River, Big Salmon River, Miramichi River, Restigouche, and Little River (near Grand Falls, NB). Lake fish community structure as it relates to sport fish and mercury levels have been assessed as well as in one study in the marine environment. Commercial harvesting of rockweed (*Ascophyllum nodosum*) potentially alters the intertidal architecture influencing fish populations inhabiting the rockweed. The impact on these fish communities cannot be assessed until an inventory of species and a description of their microhabitat use have been compiled. Thirteen separate species of

fish from varying age classes were observed. Juvenile pollock dominated the community with results providing a preliminary guideline for assessing the harvest impacts on fishes and the sustainability of rockweed harvesting in the Bay of Fundy. Most recently, a fish survey in the Nackawic area of the reservoir portion on the Saint John River, generated by the Mactaquac hydroelectric facility, was conducted in relation to human development and for comparison with other sites along the Saint John River gradient.

Forestry and Aquatic Ecosystems

The forests and their lakes and streams are dominant features of the eastern North American landscape. As natural resources they have sustained the societies and economies of the East since even before the arrival of the first European settlers. This intimate connection between forests and humans is a defining characteristic of this region. For this reason, there is a concerted effort made by all users of these resources to work together to protect and conserve the integrity of the landscape. As forestry practices evolved into the mechanized harvests of today, there was a period of transition when dramatic losses of aquatic habitats occurred. Operations tactics improved to correct problems, but concerns persist about the preservation of habitats and biodiversity of fishes.

The impacts that persist in today's forests are acute incidences of sediment deposition, e.g., water course crossing failures, poor understanding and design of buffer strips, and the chronic and cumulative effects of not protecting small, headwater water courses and watersheds. The direct impacts are sediment deposition and alteration of thermal regimes at small scales we have yet to recognize as significant. Moreover, we have yet to determine how we translate scale level effects across multiple scales, or what the cumulative effects of changes at small scales on the larger ecosystem are. Until these problems are resolved, the effects on fishes must be accepted as real threats. Studies in the Catamaran Brook watershed (Miramichi River, NB) are demonstrating residence in small tributary streams of brook trout, Atlantic salmon, and slimy sculpins, of which the first two are spawned in the main river. The small streams

appear to provide stable, coldwater refugia during summer and potential warmwater refugia in winter because of their forested catchments, which sustain groundwater regimes and block direct solar inputs to the streams. The effects of sediment inputs are well established, particularly for salmon and trout and benthic species such the slimy sculpin. Other species also use smaller streams as spawning and incubation habitats. In Lake Utopia of southwestern NB, the “threatened” dwarf smelt is dependent on two such small streams. Such evidence demonstrates that small water courses in forested landscapes provide significant habitats for fishes.

Ecology of Fish Movement

Numerous fish species have adapted to limited habitat availability by evolving life history strategies that utilize different habitats commonly on a seasonal or annual basis. For many species, this means that migrations take place for the purpose of feeding, spawning, and/or over-wintering. Human development can restrict fish movements and/or habitat accessibility. The possible effects of altered flow regimes are often made more complex with the presence of industrial and municipal discharges. The movement patterns of fish subject to cumulative stressors, are of ecological importance to recreational fisheries management and vital to the environmental assessment of aquatic receiving environment. In addition to the brook trout movement studies, focused research into describing spatial and temporal patterns of movement of two Saint John River species, an introduced exotic, the muskellunge and the benthic dwelling, white sucker, have occurred. Questions arose as to what impacts the addition of muskellunge to the fauna of the Saint John River may have on the native fish community and overall aquatic ecosystem. Only a handful of movement studies have been conducted on muskellunge involving radio or acoustic telemetry. These were typically done in lake environments and none were in close proximity to a hydroelectric facility. White sucker, one of the most common and abundant species within the Saint John River system, has been widely used across Canada for pulp and paper Environmental Effects Monitoring (EEM). Concerns over issues of mobility, and thus exposure, resulted in questions over the suitability of this species as a sentinel organism.

Lake Utopia Dwarf Smelt (LUDS)

Research into the ecology of LUDS was first done in collaboration with people at other universities, the province's DNR and DFO. These studies were conducted in the late 1990s, and made important contributions to our knowledge of smelt in Lake Utopia and stimulated desire to continue smelt research. Long-term interest and data on the ecology of LUDS allow questions of both conservation and management to be addressed. The most recent project and its goals look to further expand and address gaps in the current knowledge regarding dwarf smelt ecology and conservation in Lake Utopia.

Funding

Munkittrick, K.R. (PI) NCE Canadian Water Network. Estimating the assimilative capacity of the Saint John River, with collaborating partners, K. Haralampides, R.A. Curry (UNB), K. Teather (UPEI). Total grant $198,000. 2003-2005.

Curry, R.A. IDRC/AUCC. Latin America Exchange. $5,000. 2003.

Curry, R.A. Big Salmon River Anglers Association. Water quality and fish community assessment for the Big Salmon River. $34,300. 2002-2003.

Munkittrick, K.R. (PI) NCE Canadian Water Network, Estimating the assimilative capacity of the Saint John River, with collaborating partners, R. Cunjak, K. Haralampides, D. MacLatchy (UNB), K. Teather (UPEI), G. Daborn (Acadia). Total grant $154,427. 2001-2003.

MacLatchy, D.L. Irving Oil. Development of monitoring techniques for Little River, Saint John, NB, with K. Munkittrick and R.A. Curry (UNB). $52,000 over two years. 2002-2004.

Curry, R.A. Ste. Anne Pulp and Paper. Fish community of Mactaquac. $32,000. 2002-2003.

R. A. Curry. NSERC Strategic Grant. Towards a sustainable exploitation of anadromous brook charr in eastern Canada, with L. Bernatchez (Laval), C. Audet (INRS), and F. Whoriskey (ASF), Year 3 of 4, $19,000 + $21,000 joint with Whoriskey at UNB (total = $62,000 over 4 years). 1997-2002.

Curry, R.A. Environment Canada. Mummichog as indicators of industrial impacts in estuaries. $15,500. 2002.

Curry, R.A. AMEC. Fish passage. Petitcodiac River $15,000. 2002.

Curry, R.A. NB Environmental Trust Fund. Nutrients in the Saint John River. $29,000. 2002.

Curry, R.A. NB WTF. Dwarf Smelt. $18,000. 2002.

Curry, R.A. DFO Science Subvention/Youth Internship. Mummichog movements. $29,000. 2001-2002.

Curry, R.A. NB Wildlife Trust Fund (WTF). Brook trout anadromy. $18,000. 2001.

Curry, R.A. International Joint Commission. Smallmouth bass and alewife interactions. $15,000. 2001.

Curry, R.A. Science Horizons (Environment Canada). Development of a cumulative effects strategy for the Saint John River. $24,000. 2001.

Curry, R.A. NB WTF. Smallmouth bass growth in relation to trophic status. $20,000. 2001.

Curry, R.A. NB WTF. Modeling brook trout production in New Brunswick. $20,000. 2001-2002.

Curry, R.A. Atlantic Canada Action Programme, Bedeque Bay. Mummichog as indicators of estuarine and river health. With K. Munkittrick. $15,000. 2001.

Curry, R.A. Sir James Dunn Wildlife Centre. Equipment grant (radio receiver). $ 9,000. 2001.

Curry, R.A. Atlantic Salmon Federation Olin Fellowship. Preserving Atlantic salmon of the inner Bay of Fundy. $3,000. 2001.

Munkittrick, K.R. (PI) Development of a cumulative effects strategy for the Saint John River-Toxic Substances Research Initative with R.Cunjak (UNB), and M. Hewitt (EC), Year 3 of 3, $34,000 to Curry (total = $436,000 over 3 years). 2001.

Curry, R.A. Cloverleaf Foundation. Professor of Recreational Fisheries Research. $26,000. 2001.

Curry, R.A. ACAP, Eastern Charlotte Waterways, Inc. Stream fish responses to blueberry production: searching for indicators of human-induced stress. $12,000. 2001-2002.

Curry, R.A. Sir James Dunn Wildlife Centre. Equipment grant (Isomet saw). $3,000. 2001.

MacLatchy, D.L. (PI) CIDA Tier 2 UPCD, Human Resource Development in the Cuban Marine Biology Sector, with J. Johnson, A. Logan, T. Chopin, K. Munkittrick and A. Curry. $710,430 total. 1997-2003.

Project Partners:

Atlantic Canada Action Program – Bedeque Bay
Atlantic Canada Action Program – Eastern Charlotte Waterways Inc.
Atlantic Salmon Federation
Atlantic Salmon Federation Olin Fellowship
AMEC
Big Salmon River Anglers Association
Cloverleaf Foundation

Fisheries and Oceans Canada
Environment Canada
Fundy Model Forest
Hammond River Anglers Association
Indian Bay Ecosystem Corp.
J.D. Irving, Ltd.
New Brunswick Department of Fisheries and Aquaculture
New Brunswick Department of Natural Resources
New Brunswick Department of Local Government and Environment
New Brunswick Sportfishing Association
PEI Department of Environmental Resources
PEI Flyfishers Association
Sir James Dunn Wildlife Centre
Ste. Anne Pulp and Paper
Sussex Fish and Game Association
Trout Unlimited Canada
Western Newfoundland Model Forest

Personnel

Staff

Kristie Heard, M.Sc. (2001 - present)
Aquatic Biologist
Invertebrate assessment of the Saint John River and Restigouche River Systems

This assessment will be combined with water quality data, algae, fish surveys, and isotope analysis of fish, insects, and algae to put together an accurate picture of the condition of these waters. This will be used for further study to establish a management plan in order to preserve and protect the waters of New Brunswick for future use and enjoyment. Data management is an issue in many sectors of research both in the academic and government environment. Generation of an Access®

database for long term data storage and analysis, including that of the Saint John, Restigouche, Little (near Grand Falls), and Big Salmon Rivers is a key component of ongoing work.

Mark Gautreau, B.Sc. (2001 - present)
Environmental Technologist
Associate on field and laboratory studies

As a technician for the CRI, Mr. Gautreau has had the opportunity to assist many of the graduate student projects both in the field and lab. He has participated in the collection and preparation of fish samples from the many rivers (Big Salmon, Restigouche, Saint John and Little) for stable isotope analysis. Over the past three years he has assisted with the radio/acoustic tagging and tracking of muskellunge, brook trout, and white sucker. Most recently, he assisted with a fish community survey and assessment of whole organism responses associated with environmental effects monitoring on the Saint John River, NB and Red Deer River, AB.

Other Staff

Kirk Roach – Science Horizons
Marcia Chiasson – DFO Youth and Science Internship
Coral Cargill – Student Career Placement
Jessica McPhee – Female Mentorship
Terra McMullen – Student Career Placement
Megan Finley – Student Career Placement
Tim Reese – Student Career Placement
Jennifer Flann – Female Mentorship
Nicole Duke – Science Horizons
Andrew Halford – Student Career Placement
Gordon Yamazaki - Fish Key Design

Graduate Students

M.Sc.

Eric Chernoff (2003 - present)
Early life history characteristics of sea-run and resident brook trout (*Salvelinus fontinalis*)

Sea-run and resident forms of brook trout (*Salvelinus fontinalis*) co-exist in several watersheds throughout Canada. Little is known about why some individuals within a population travel to salt water to feed and why others remain in fresh water their entire lives. The objective of the proposed research is to compare early developmental characteristics of sea-run and resident brook trout. Parameters to be examined include spawning date, emergence date, incubation period, size-at-emergence and growth rates in young-of-the-year brook trout. Stable isotope analysis will also be used to assess the reproductive contribution of the sea-run and resident forms. This research is being conducted in collaboration with J.D. Irving, Ltd. and with the financial support of the NB Wildlife Trust Fund.

Jonathan Freedman (co-supervised by Dr. Kelly Munkittrick, 2003 - present)
Effects of pulp mill effluent on fish communities and movements

Fish movements and the trophic dynamics of fish communities are susceptible to changes in their environment. Human impacts, such as sewage discharge and effluent from pulp and paper mills, can affect these changes. The headpond of Mactaquac Lake at Nackawic, NB, has inputs from a bleached kraft hardwood pulp mill, sewage treatment plant discharge from a local town, as well as the cumulative effects of upstream inputs, resulting in mild eutrophication in the receiving environment. This research is looking at the effects of these inputs on community dynamics and fish mobility via stable isotope analysis between reference and exposure sites.

Jennifer Shaw (2003 - present)

Growth of the sympatric rainbow smelt (*Osmerus mordax*) complex of Lake Utopia, New Brunswick

Lake Utopia has three distinct and sympatric morphotypes of rainbow smelt. The early 'giant' form spawns first, followed by the later spawning 'normal' form and the latest spawning 'dwarf' form that overlaps in spawning with the normal form. The dwarf morphotype has been listed as a threatened species in Canada under COSEWIC (Committee on the Status of Endangered Wildlife in Canada). The objective of this study is to compare the growth rates of the three different forms of smelt in the lake. Adults and young-of-the-year were collected in 2003. Otoliths were removed, growth increments measured and back-calculations performed to determine age and growth rates. Young-of-the-year will be collected in 2004 to compare annual variation in growth rate. An experiment to determine growth of the three forms of larval smelt in the lake environment will also be conducted.

Marc Skinner (co-supervised by Dr. Simon Courtenay, DFO Moncton; 2002 - present)

Mummichog movement in the Miramichi estuary during the ice-free period

In 2002-2003, fieldwork investigated the extent of movement of mummichog (*Fundulus heteroclitus*) within the upper Miramichi estuary. This consisted of a mark-recapture study and collection of mummichog and benthic algae samples for stable isotope analyses. This information is being analyzed to validate the use of this fish as a sentinel species in environmental effects monitoring (EEM) fish surveys in Atlantic Canada.

Chad Doherty (co-supervised by Dr. Kelly Munkittrick; 2001 - present)

Tracking fish movements and physiological changes

Fieldwork associated with this research was completed and consisted of continued radio and acoustic tracking of adult white sucker in the Saint John River. With two years of white sucker performance assessment completed and tracking coming to an end, a considerable shift of focus onto completing data analysis and writing began in

2003. Significant progress on the thesis has been made, with numerous conference presentations and an associated manuscript, for a proceedings publication submitted. As a result, the thesis should be completed by spring 2004 with submission of manuscripts to follow soon after. Outside of the direct research associated with the completion of the M.Sc., increased responsibilities for the general operations of the Curry lab were assumed while Dr. Curry was on sabbatical and out of the province for approximately two months. During this time, supervision associated with various aspects of multiple new projects including design and execution of fieldwork (consultants/new graduate students/sport fishing organization), hiring and scheduling of personnel, and submission of paperwork for funding/permits.

Erin Barry (1999 - present)

Mercury pathways and trophic interactions in New Brunswick lakes

Twenty lakes of varied geomorphological and fish community structure were surveyed to determine how mercury moves through lake ecosystems in southwestern NB. This study combines analyses of total and methyl mercury with stable isotopes across trophic levels from benthic invertebrates and amphibians through all fishes within a lake.

Rob Pritchett (1999 - present)

Use of otolith shape and growth rates for stock separation of brook trout

Stock discrimination is an important element of managing mixing populations of fish. Fourier analysis is being used to examine otolith shape as an indicator of separate stocks in a series of lakes in the Indian Bay watershed of Newfoundland. Growth rates among lakes are also being examined to separate stocks while controlling for natural variations in environmental conditions.

Jacob vandeSande (1999- present)
Tracking movements of anadromous brook trout in rivers and estuaries

The ecology of movement of anadromous fishes has relied on static sampling primarily within the fresh waters of rivers. We are using radio and acoustic tags to monitor the movement patterns of anadromous brook trout in several rivers of eastern Canada. This is one element of a multi-partnership, strategic grant also examining the genetic and physiological characteristics of anadromous brook trout.

M.Sc. Completed

Sean Corrigan (M.Sc. 2002)
Temporal use of rockweed by fishes in the Bay of Fundy

Rockweed is a dominant feature of the intertidal zone in the Bay of Fundy. The ecology of fishes associated with rockweed is unknown in areas targeted for a developing rockweed harvesting industry. This study examined the spatial and temporal use of rockweed by fishes throughout the entire year.

Presently: Ship's Captain, Mary O, UNB, Saint John, NB

Dale Hanson (M.Sc. 2002)
Interactions of alewife and smallmouth bass and the implications for fisheries management

Smallmouth bass coexist with anadromous river herring (Gaspereau or alewife and blueback herring) in many river systems of eastern North America. This leads to conflicting management objectives because of the recreational importance of bass and the commercial significance of herring. The interaction of the species were examined in both natural lakes and reservoirs to determine the most appropriate options for managing these integrated fisheries.

Presently: Biologist, US FWS, Wisconsin, USA

Scott MacNeill (M.Sc. 2001)
The impacts of agriculture on brook trout reproduction in streams on PEI

Potato farming has become the most dominant feature of the landscape on PEI. It has expanded rapidly in recent years, but the concurrent protection of aquatic ecosystems has lagged behind. In this study, the reproductive success and production of young-of-the-year brook trout in island streams with various levels of agricultural impacts was examined.

Presently: Biologist, Dillon Consulting Limited, Yellowknife, NW

David Courtemanche (M.Sc. 2001)
Strontium as an indicator of estuarine residence in anadromous brook trout

It is very difficult and costly to determine and monitor growth of anadromous fishes in both their freshwater and marine residency periods. The concentration of strontium in fish scales was measured by wavelength dispersive X-ray spectrometer (WD-EM) on an electron microprobe (JEOL 733) to identify the two periods. A series of scale samples from brook trout populations across eastern Canada are being examined to determine how much ecological information can be derived from such analyses.

Presently: Biologist, DFO, QC

Ph.D.

Brendan Galloway (co-supervised with Dr. Allen Curry, 2001 - present)
Responses of different fish species to anthropogenic contamination in the Saint John River

Undergraduate Students

Halford, A. (Biology). Spatial and temporal movements of muskellunge in the Saint John River.

Reardon, B. (Forestry). Impacts of beavers on salmonid fishes.

Findley, M. (Biology). A comparison of invertebrate communities in forested and agricultural streams.

Roach, K. (Forestry). The status of mummichogs in agricultural dominated watersheds of PEI.

Pilgram, T. (Forestry). Management of small river in Newfoundland forests.

Senior Research Project

LeBlanc, N. (Biology).Taxonomy of New Brunswick's benthic macroinvertebrates.

Visiting Faculty

Consuelo M. Aguilar Betancourt, Centro de Investigaciones Marinas, University of Havana, Havana, Cuba

Ms Betancourt visited the CRI in the summer of 2003 to carry out stable isotope analysis of samples collected in Cuban marine waters. The goal of her study is to determine the food web relationships of contaminated and pristine coral reefs of Cuba.

Figure 11. Sampling on the Saint John River (C. Doherty)

Fellows

Deborah L. MacLatchy

Professor of Biology, UNB, Saint John, NB
Fellow, Canadian Rivers Institute (2001-present)
Director, International Office, UNB Saint John (2001-2003)
Acting Director, Saint John College (2003-present)
http://www.unb.ca/cri/maclatchy.html

Research Interests

Dr. MacLatchy's research primarily concerns contaminant effects on endocrine (hormone) systems in fish. She is interested in the effects, and mechanisms of action, of environmental endocrine disrupting substances (EDSs). EDSs are compounds that mimic the natural hormones of animals, thereby altering the normal functioning of endocrine systems which control important processes such as reproduction, development, and growth. There are widespread observations of endocrine-related effects in wild, caged, and laboratory fish exposed to hormone-active compounds from a variety of sources, including sewage and pulp mill effluent. However, it is not known how EDS effects are manifested, including how effects are integrated and realized at different levels of biological organization and the extent of species differences. Ongoing research projects in her lab include: investigation of the effects of wood-derived phytoestrogens and their mechanisms of action on gonadal steroid biosynthesis in goldfish; the use of the mummichog (*Fundulus heteroclitus*), rock gunnel (*Pholis gunnellus*) and other fish species as indicator species for environmental effects in Saint John Harbour waters (a system exposed to treated and untreated municipal sewage, pulp and paper mill effluents, refinery and brewery wastes, etc.) and tributaries; the effects and mechanisms of action of EDSs on growth and growth hormones in smolting Atlantic salmon (*Salmo salar*); the development of a mummichog life-cycle assessment bioassay to detect contaminant effects; the development of portable, land-based flow-through mesocosm (artificial stream) systems for field-based assessments of fish health; laboratory protocols to investigate the effects of various pulp and paper mill effluent process streams on mummichog and fathead minnow

(*Pimephales promelas*) reproductive endocrine status; and the use of fish and fish parasites to identify freshwater ecosystems experiencing environmental stressors.

Major projects

Pulp and Paper

These projects centre on the identification and mechanisms of action of EDSs in pulp and paper mill waste streams. Since 1997, mummichog have been used in an investigation of cause approach to identify specific wastestream products from a pulp and paper mill in Saint John, NB. Similar work began in 2003 at a mill in Ontario using the fathead minnow.

Mechanisms of Action of EDSs

Studies on the mechanisms of action of plant-derived hormone mimics in fish, including reproductive consequences, are ongoing. Plant compounds enter receiving environments downstream of pulp and paper mills because of the wood furnish required by mills to produce paper products. Other work is examining the effects of model EDSs (estrogens and androgens) on sea water adaptability, growth and survival of salmon smolts, in collaboration with Fisheries and Oceans Canada and Environment Canada. Smoltification, as a hormone-controlled process, could be particularly susceptible to EDSs.

Ecotoxicology

Studies using rock gunnel, mummichog, and other fish species are being conducted to determine their usefulness as monitoring species in the Saint John Harbour and its tributaries. For the past six years, efforts to transfer monitoring methodologies to partners working at the University of Havana on coastal issues have been ongoing. As well, the lab is beginning to support studies determining how host fish-parasite interactions change in contaminated environments.

Novel Approaches

Significant contributions of this laboratory include the development of whole-animal laboratory testing methods for EDSs in fish, and the development of alternative approaches for cumulative effects bioassessment, particularly the use of artificial stream technology. As well, fish caging studies in Havana Harbour and Saint John Harbour have provided information unique to these systems.

Figure 12. Mesocosm set-up for the mummichog exposures at Saint John, NB (M. Dubé).

Funding

MacLatchy, D.L. NSERC Discovery Grant. EDS effects in fish: mechanistic linkages among different levels of biological organization. $31,000/year. 2003-2007.

Munkittrick, K.R. (PI) NCE Canadian Water Network. Estimating the assimilative capacity of the Saint John River, with collaborating partners, K. Haralampides, R.A. Curry (UNB), K. Teather (UPEI). Total grant $198,000. 2003-2005.

MacLatchy, D.L. NSERC Collaborative Research Development Grant. Identification of contaminants from pulp and paper mills causing reproductive dysfunction in fish using an investigation of cause approach, with M. Dubé and M. Hewitt, Environment Canada $82,304/year 1; $45,620/year 2; Matching: $30,000/2 years Irving Pulp and Paper, Ltd.; $45,000/2 years Kimberly-Clark, Ltd. 2002-2004.

MacLatchy, D.L. Irving Oil. Development of monitoring techniques for Little River, Saint John, NB, with K. Munkittrick and R.A. Curry (UNB). $52,000 over two years. 2002-2004.

Munkittrick, K.R. (PI) NCE Canadian Water Network. Estimating the assimilative capacity of the Saint John River, with R.A. Curry, R. Cunjak, K. Haralampides (UNB), K. Teather (UPEI), G. Daborn (Acadia). Total grant $154,427. 2001-2003.

Munkittrick, K.R. (PI) NSERC International Opportunities Fund. Development of an international team for effects-based assessment of contaminated sites in Latin America, with J. Culp and R.A. Curry (UNB), C. Metcalfe (Trent), M. Hewitt and G. Van Der Kraak (Guelph), M. Dubé (Saskatchewan), K. Devito (Alberta). $56,200 over two years. 2001-2003.

MacLatchy, D.L. NSERC Research Grant. Mechanisms of action of plant-derived hormone mimics on fish: individual and population-level consequences. $24,150/y. 1999-2003.

MacLatchy, D.L. Environment Canada, Grande Prairie Mesocosm Project. Technical support and whole body method development and steroid analysis. $33,000. 2001-2002.

MacLatchy, D.L. JD Irving, Ltd. Effects of Irving Paper mill and Lake Utopia Paper mill effluents on reproductive endocrine status of mummichog. $15,000. 2001.

MacLatchy, D.L. UNB Dunn Wildlife Fund. Potential impacts of EDCs on flounders resident in Saint John Harbour. $3,000. 2000-2001.

MacLatchy, D.L. Environment Canada Science Horizon Youth Internship Program. Funding for technical assistant (Lottie Vallis). $12,000. 2000-2001.

G. Van Der Kraak (PI; U of Guelph. Toxic Substances Research Initiative (TSRI), Whole animal laboratory testing methods for EDCs in fish, with S. Courtenay and R. Devlin (DFO), C. Metcalfe (Trent), J. Parrot (Environment Canada). $21,500/y to DLM. Total Grant: $140,000/y. 1999-2002.

S. Brown (PI, Environment Canada). TSRI. The effects of endocrine disruptors on sea water adaptability, growth and survival of salmon smolts, with W. Fairchild, K. Haya and R. Evans (DFO), G. Eales (Manitoba), J. Sherry, D. Bennie, K. Burnison (Environment Canada). $25,000/y to DLM. Total Grant: $180,000/y. 1999-2002.

Culp, J.C. (PI, Environment Canada) TSRI. Development of alternative approaches for cumulative effects bioassessment, with collaborating partners, M. Dubé, N. Glozier and K. Cash (Environment Canada). $15,000/y to DLM. Total Grant: $154,000/y. 1999-2002.

MacLatchy, D.L. (PI) CIDA Tier 2 UPCD, Human Resource Development in the Cuban Marine Biology Sector, with J. Johnson, A. Logan, T. Chopin, K. Munkittrick and A. Curry. $710,430 total. 1997-2003.

Project Partners

Environment Canada, National Water Research Institute

Fisheries and Ocean Canada (Moncton and St. Andrews)

AMEC (formerly Washburn & Gillis Associates)

ACAP Saint John

Pulp and Paper Research Institute of Canada (Paprican)

JD Irving, Ltd. (including Irving Pulp & Paper, Ltd., Lake Utopia Paper and Irving Paper)

Kimberly-Clark Corp. (Terrace Bay mill)

Irving Oil

Personnel

Staff

Jennifer Adams, summer research assistant (2003)

Jennifer Ings, summer research assistant (2002, 2003)

Mike Beyea, summer research assistant (2001, 2002, 2003)

Jason Beyea, summer research assistant (2001)

Cary McNeil, summer research assistant (2001)

Graduate Students

M.Sc.

Kevin Shaughnessy (2003 - present)

<u>Use of a mummichog bioassay to isolate substances in pulp mill condensates that reduce sex steroid production in fish</u>

The overall objective of this work is to isolate and identify hormonally-active substances within a specific pulp mill waste stream at Irving Pulp and Paper in Saint John. This is a collaborative effort with Dr. Mark Hewitt and M.Sc. student Andrew Belknap at the National Water Research Institute in Burlington, ON. The substances in question have been shown to decrease sex steroid levels in the mummichog, and are

removed by reverse osmosis technology. The overall goal of the research is to increase current knowledge on the sources and treatment of hormonally-active substances. This may lead to the implementation of new treatment technologies in pulp mills throughout Canada.

Geneviéve Valliéres (co-supervised with Dr. Kelly Munkittrick; 2002- present)

Rebecca Ibey (2001 - present)

Development of a full life-cycle bioassay for *Fundulus heteroclitus* for use in endocrine disruption studies

This project involves the development of a full life-cycle bioassay for the mummichog (*Fundulus heteroclitus*) for use in endocrine disruption studies and builds on previous work done with freshwater species. The mummichog is an estuarine fish species native to the North Atlantic seaboard. Preliminary studies indicate that adult mummichog have altered reproductive endocrine profiles when exposed to endocrine disrupting substances. She has exposed adult mummichog and their offspring to ethynylestradiol, a synthetic estrogen that is a principal component of the birth control pill and which is found in treated and untreated sewage effluents. Focus is on looking at critical endpoints in each life stage such as: gonadal steroid production, plasma steroid levels, vitellogenin induction and fecundity in adults; and hatching time and other developmental endpoints in eggs and juveniles. This work will further our understanding of population-level impacts in fish of exposure to estrogenic compounds.

Figure 13. Mummichog

M.Sc. Completed

Lottie Vallis (2003; co-supervised with Dr. Kelly Munkittrick)

Timothy Jardine (2003; co-supervised by Dr. Scott Brown, NWRI, Burlington, ON)
Summer feeding and growth of Atlantic salmon (*Salmo salar*) smolts after estuarine caging: a stable isotope study.

This study examined whether Atlantic salmon are potentially affected by anthropogenic contaminants in the Miramichi estuary. Fish were caged in the estuary for a short-period and then grown out in clean hatchery water. Fish growth and feed assimilation (through stable isotope analysis) were measured during the summer grow-out period.

Presently: Scientific Manager, Stable Isotopes in Nature Laboratory, Department of Biology, University of New Brunswick, Fredericton, NB.

Kimble Costain (2002)
Reproductive status of sex-reversing wrasses (Labridae) exposed to contaminated waters of Havana, Cuba

Although the reproductive status of gonochoristic fish has been well-studied in contaminated temperate environments during the last decade, little is know about the potential for contaminants in tropical marine waters to affect fish reproductive status. This project examined the morphological and reproductive status of sex-reversing protogynous fish living on pristine and contaminated reefs off-shore of Havana, Cuba.

Presently: Management Trainee, Government of Canada Program, Agriculture Canada, Ottawa, ON.

Frederic Leusch (2001)
Mechanisms of action of phytosterols on goldfish (*Carassius auratus*) gonadal steroidogenesis

This work was able to determine that the ability of β-sitosterol to inhibit steroidogenesis is due to inhibition of cholesterol transfer across mitochondrial membranes in fish gonadal tissue.

Presently: PhD. student, Lincoln University, Canterbury, New Zealand.

Ph.D.

Karen Gormley (co-supervised with Dr. Kelly Munkittrick; 2003 - present)
Comparison of the effects of a pulp mill effluent on three freshwater fish species

Pulp mill condensates have been previously investigated by CRI researchers and have been found to cause disruptions in steroid hormones in a native estuarine species, the mummichog (*Fundulus heteroclitus*). This species is a relevant test organism, as it can be found in pulp mill effluent receiving areas, and is thought to have a small home range, increasing its duration of exposure. However, the relative sensitivity of this species to other fish species exposed to pulp mill effluent is not known. Two other small-bodied fish species will be compared to the mummichog in the first part of this project. The fathead minnow (*Pimephales promelas*) is a freshwater fish that has been used in numerous laboratory studies to assess the effects of pulp mill effluent and other anthropogenic compounds. Although it is not indigenous to New Brunswick, it is found throughout other areas of Canada, including pulp mill effluent receiving areas. The slimy sculpin (*Cottus cognatus*) is a freshwater fish that is found in New Brunswick. It is currently being examined as a sentinel species for pollution in field research, including a few projects at CRI. Some pulp mills discharge their effluent into estuarine environments. These areas have a range of salinities but the effect of different salinities on endocrine disruption in fish by pulp mill effluent is not known.

The second part of this project will assess the susceptibility of mummichog to endocrine disruption by pulp mill condensates in a range of salinities.

Christopher Blanar (2001 - present)

Interaction of parasitism and transient heavy metal exposure in juvenile Atlantic salmon (*Salmo salar*)

Although parasites and pollution have both been listed as potential stressors for Miramichi Atlantic salmon, their combined effects on fish health have not been examined. This is a critical knowledge gap because there is evidence that parasite infections may drastically increase the sensitivity of fish to pollutants and other stressors. It is not known whether the parasite infections in Miramichi Atlantic salmon decrease their ability to survive the drastic changes in temperature, current velocity, salinity and water quality that they experience during their seaward migration. The study is examining the effects of a gill parasite and heavy metal toxicity, alone and in combination, on Atlantic salmon smolt performance, physiology and survival. During the past year a laboratory culture of a gill parasite (*Discocotyle sagittata*) has been established. This species is ideally suited for experimental work because a) it is a common parasite of young salmon in the Miramichi system and b) it is a large external parasite (up to 1cm), making it relatively easy to assess host parameters (susceptibility, growth, physiology) and parasite parameters (infectivity, growth, maturity, reproduction, feeding activity) without killing either. Subsequent field work to verify that patterns observed in the laboratory are also present in the natural system will be conducted.

Rainie Sharpe (2000 - present)

Cholesterol metabolism in steroidogenic tissues of goldfish (*Carassius auratus*) exposed to β-sitosterol and 17β-sitosterol

This Ph.D. research focuses on cholesterol homeostasis and the effects of β-sitosterol (β-sit) on fish endocrine systems. Following the processing of wood products at pulp and paper mills, the phytosterol β-sit is released as a component of the effluent. Fish

exposed to β-sit have been shown to experience effects such as decreased levels of circulating sex steroids, decreased gonadosomatic index (GSI), and decreased steroid production. The most interesting detail of the biochemistry of β-sit is its structure – it is very similar to cholesterol. β-sit acts with estrogenic properties, but resembles cholesterol. Using goldfish (*Carassius auratus*) as a model species, cholesterol homeostasis is being examined to determine the mechanism of action of β-sit. Research to date suggests β-sit is affecting the movement of cholesterol across the mitochondrial membrane in the gonads of exposed fish, limiting cholesterol's availability to the steroidogenic machinery. Estradiol is being used in parallel exposures as a positive control for estrogenic effects.

Consuelo Aguilar (co-supervised with Dr. Gaspar Gonzalez, University of Havana; 2000 - present)

<u>Fish assemblages on fringe coral reefs of the northern coast of Cuba near Havana Harbour</u>

It is difficult to separate effects on fish community assemblages due to anthropogenic stressors from natural factors. This work examines small-bodied fish along the northern coast of Cuba near Havana Harbour during the dry and wet seasons. Over 35,000 individual fish were visually counted at 15 sites along the coast in three areas located 0-2.4 km, 2.4-6.1 km and 6.1-10.3 km from the entrance to Havana Harbour. Fish communities in four substrate biotopes do not vary significantly between wet and dry seasons, but do vary with water depth. Proximity to Havana Harbour is the second most important factor affecting fish assemblages, and sites closest to the harbour had reduced populations of the bluehead wrasse (*Thalassoma bifasciatum*) and an increased abundance of slippery dick (*Halichoeres bivittatus*). More studies are required at the population and individual levels to link stressors (e.g., contaminants, siltation) directly to observed effects. Present focus is on the bicolour damselfish (*Stegastes partitus*) to determine if there are population- and individual-level effects of exposure to Havana Harbour waters.

Jacqueline Arsenault (1999 - present)

Effects of estrogenic and androgenic water-borne exposures during parr-smolt transformation on growth and plasma IGF-I of Atlantic salmon (*Salmo salar* L.)

Parr-smolt transformation (PST) is a critical developmental life stage which occurs when juvenile salmon in fresh water (FW), called parr, undergo a series of morphological and physiological changes to become seawater (SW)- adapted smolts which then migrate to sea to complete their growth and develop into adults. PST is associated with complex hormonal changes and rapid growth. Growth hormone (GH) plays a central role in PST because of its direct and indirect effects on stimulating somatic growth and on enhancing SW adaptation. Many of the effects of GH are indirectly mediated by insulin-like growth factor-I (IGF-I). GH stimulates the synthesis of IGF-I by binding to GH receptors found on the cell surface of many different tissue types, with the liver being the primary site of IGF-I production. Water-borne exposure experiments to date, using hatchery reared smolts, have shown that a portion of the smolts exposed to estrogen (E_2), 4-nonylphenol (4-NP) (a synthetic compound capable of mimicking the action of E_2), or testosterone, during the final stages of PST, experience compromised growth once transferred to sea water. However, the mechanism by which these compounds affect growth is presently unknown. The main objective is to determine if poor growth in Atlantic salmon smolts exposed to estrogenic and androgenic substances during the final stages of PST is related to disruption of the GH/IGF-I axis. Results obtained to date suggest the mechanism of action of E_2, 4-NP and testosterone does involve disruption in the GH/IGF-I axis. The effects of these substances on growth and plasma IGF-I concentrations observed in this study evoke concerns for successful growth and survival of wild salmon smolts exposed to low levels of estrogenic and androgenic substances that may occur from current discharges into rivers supporting sea-run salmon stocks.

Undergraduate students

Honours Theses

G. Sreedharan. In progress, 2003. The effects of a pulp mill effluent from Ontario on plasma and gonadal steroids in mummichog (*Fundulus heteroclitus*). University of New Brunswick (Saint John). To be completed May 2004.

J. Ings. 2003. The effects of ethinylestradiol on mummichog (*Fundulus heteroclitus*) fecundity and hatching. University of New Brunswick (Saint John). May 2003.

J. Beyea. 2001. The effects of coumestrol on ovarian production of steroids in female goldfish (*Carassius auratus*). University of New Brunswick (Saint John). May 2001.

C. McNeil. 2001. The effects of genistein on ovarian production of steroids in female goldfish (*Carassius auratus*). University of New Brunswick (Saint John). May 2001.

Service

Positions and Committees

Treasurer and ex-officio member, CRI Management Board (2003-present)

Acting Director, Saint John College, UNB (2003-present)

President, Canadian Society of Zoologists (2003-2004); 1st Vice-President, Canadian Society of Zoologists (2002-2003); 2nd Vice-President, Canadian Society of Zoologists (2001-2002)

Member, UNB President's Advisory Committee (2003-present)

Member, UNB VP's Task Force on Internationalization (2003-present)

Member, UNB VP Research Office External Review Committee (2002)

International Liaison Officer, UNB (2001-2003); Director, UNB Saint John International Office (2001-2003)

Member, as Director International Liaison Office, UNB Saint John Vice-President's Advisory Council (2001-2003)

Member, UNB Saint John, Gender Studies Curriculum and Coordinating Committees (2001-present)

Coordinator, Environmental Biology B.Sc., Biology, UNB Saint John (2000-2003)

Member, UNB Radiation Safety Committee (1999-present)

Faculty rep, UNB Executive Committee of the Graduate School (1998-2003)

Coordinator, CIDA Tier 2 Project, Human Resource Development in the Cuban Marine Sector (1997-2003)

Member, Graduate Academic Committee, UNB Saint John Biology (1997-2002)

Invitations

MacLatchy, D.L. A fishy perspective: Are we making progress on endocrine disruptor research? Department of Biology, UNB Fredericton, NB. September 2003.

MacLatchy, D.L. 2003. A fishy perspective: Are we making progress on endocrine disruptor research? EDC Workshop. Society for Environmental Toxicology and Chemistry, Asia-Pacific Section, Christchurch, NZ. September 2003.

MacLatchy, D.L. 2003. Progress on Environmental Matters in Saint John, Presentation and Panel, Saint John Community Foundation, Saint John, NB. June 2003.

MacLatchy, D.L. 2003. From the Bay of Fundy to the Bay of Pigs: A New Brunswick perspective on endocrine disruption in fish. Department of Biology, Trent University, Peterborough, ON. May 2003.

MacLatchy, D.L. 2003. From the Bay of Fundy to the Bay of Pigs: A New Brunswick perspective on endocrine disruption in fish. Department of Biology, St. Francis Xavier University, Antigonish, NS. February 2003.

Facilitator and Chair, Final Symposium, CIDA Tier 2 Cuba, Human Resource Development in the Cuban Marine Sector, November 2002.

MacLatchy, D.L. 2002. From the Bay of Fundy to the Bay of Pigs: A New Brunswick perspective on endocrine disruption in fish. Deptartment of Biology, McMaster University, Hamilton, ON. October 2002.

Hewitt, M., Dubé, M., Culp, J., MacLatchy, D. and Munkittrick, K. 2002. Definition of cause in pulp and paper EEM: A proposed strategy and research needs. Invited Presentation, EEM Regulators meeting. Ottawa, ON. March 2002.

MacLatchy, D.L. 2001. From the Bay of Fundy to the Bay of Pigs: A New Brunswick perspective on endocrine disruption in fish. Department of Biology, Mt. Allison University, Sackville, NB. October 2001.

MacLatchy, D.L. 2001. From the Bay of Fundy to the Bay of Pigs: A New Brunswick perspective on endocrine disruption in fish. Institute of Environmental Toxicology, Clemson University, Pendleton, SC. April 2001.

Dubé, M.G., Hewitt, M.L. and MacLatchy, D.L. 2001. Evaluating reverse osmosis treatment for removal of compounds from recovery condensates at a bleached kraft mill that affect fish hormone control. University of Toronto Pulp and Paper Consortium Annual Meeting. Toronto, ON. April 2001.

MacLatchy, D.L. 2001. From the Bay of Fundy to the Bay of Pigs: A New Brunswick perspective on endocrine disruption in fish. Department of Biology, Acadia University, Wolfville, NS. January 2001.

Fellows

Kelly R. Munkittrick

Canada Research Chair in Ecosystem Health Assessment
Associate Director and Fellow, Canadian Rivers Institute (2001-present)
Professor, Department of Biology, University of New Brunswick, Saint John, NB
http://www.unb.ca/cri/munkittrick.html

Research Interests

There are a wide variety of stressors that affect aquatic ecosystems, and Dr. Munkittrick's research interests are concentrated on identifying the responses of aquatic systems to stress, isolating the primary stressors responsible for those changes, and understanding the mechanisms through which the stressors are exerting their effects. The focus of this research is related to understanding the responses of aquatic ecosystems when there are multiple stressors affecting a system. While changes can be identified at a range of ecological levels, his work has involved developing an approach to aquatic cumulative effects assessment focussing on the responses of fish populations (Munkittrick *et al.* 2000a,b). This approach is now defined as an “effects-based” approach to differentiate it from the more common stressor-based or values-based approaches to cumulative effects assessment.

Effects-based assessment involves examining factors associated with the status of fish populations in developed and undeveloped reaches of a large river basin. The approach uses an iterative assessment program to define the integrated response of organisms to existing conditions, and to determine the factors currently limiting fish performance in the system. The main objectives of an effects-based assessment of cumulative effects are to document the baseline conditions of fish performance, to examine yearly variability, and to examine trends in responses over time in order to make some assessment of the existing "accumulated environmental state". It does not make sense to focus post-operational monitoring programs or mitigation on fish reproduction in a system that is food-limited, nor does it make sense to make predictions based on food availability in cases where toxic chemicals are limiting performance. The identification of factors that are limiting (or enhancing) the existing

performance is critical to subsequent attempts at predicting the consequences of changes, the design of potential mitigation strategies, and the design of post-operational monitoring strategies. These factors are presently ignored in existing stressor-based approaches to cumulative effects assessment.

The overall approach uses fish population characteristics such as growth rates, reproductive rates, survival, and energy storage to identify areas where fish performance is different from that seen at reference sites. These identified areas of concern become the sites where detailed, hypothesis-driven research is conducted to identify the stressors responsible for the changes. The last 15 years have been spent developing a set of population response patterns based on estimates of survival (mean age or mortality), energy use (growth, reproduction) and energy storage to derive hypotheses for directing follow-up studies.

Major Projects

Development of a cumulative effects assessment framework for the Saint John River

The studies were initiated in 1999 to use the performance characteristics of fish to help understand the level of stress on a river reach. The freshwater component of the study is examining the performance of slimy sculpin, white sucker and yellow perch in the upper (freshwater) Saint John River basin to develop a strategy for increasing the level of understanding of the system. The data will be used to give a relative indication of performance within the system and to prioritize areas of concern within the river basin. The final analyses will evaluate the relative strengths of fish and benthic community data, population estimates and fish performance evaluations, for determining the health of the system. There are more difficulties in dealing with estuarine and marine areas, and work is ongoing in the estuary to expand the applicability of the framework.

Fish health in high-pesticide use areas

The original objective of this research project was to assess whether fish populations in areas of potato cultivation responded to changes in environmental conditions. An effects-based assessment was conducted in the ‘potato belt’ of northwestern New

Brunswick in the Little River (near Grand Falls) catchment from 1999-2002, monitoring the health and performance of slimy sculpin (Cottus cognatus). Additional graduate students have been initiated to try and discriminate the relative roles that sediment, nutrients, temperature, flow changes and pesticide impacts play in the impacts that have been detected.

Fish health near the Edmundston pulp mill

These studies will compare the responses of the species to the stressors and will provide basic life history information. Key indicators will be age distributions, mortality estimates, growth rates, reproductive investments, and energy storage (condition factor, liver size, lipid levels). Key life history information will be collected on fecundity, age to maturity, habitat requirements, diet and spawning times. Current studies have demonstrated population-level responses in fish species near Edmundston, NB, where the Saint John River receives effluent from pig and poultry farms, four sewage discharges, a pulp mill and a paper mill. Preliminary studies indicated that white sucker (*Catostomus commersoni*; large-bodied) and slimy sculpin (*Cottus cognatus*; small-bodied species) showed dramatically different responses, with the sculpin apparently integrating impacts within a much smaller area.

Health of fish in the Saint John River estuary

The harbour at Saint John, New Brunswick (SJH) receives waste from both municipal and industrial sources. A recent project has worked to determine whether rock gunnel (*Pholis gunnellus*) would be a suitable sentinel species for documenting contamination levels around SJH. The growth and reproductive development of rock gunnel were examined along three shores of SJH where past records indicate differing levels of contamination. There were no differences in steroid levels among sites, nor was there a difference in liver enzyme activity levels among sites, but rock gunnel collected at sites with the highest contamination were larger, had higher condition factors and larger relative liver sizes. Liver size differences among sites were not evident in spring when fish returned from offshore spawning. There was also a decease in the number

of juveniles present at the most contaminated site. Larger sizes could be an indication of eutrophication due to sewage inputs at the contaminated sites.

Review of Cycle 2 pulp and paper EEM study results for the adult fish survey

The second cycle of the pulp and paper EEM reported its results and preliminary analysis of the fish survey have been conducted. The EEM program is a cyclical evaluation of the receiving water impacts associated with the discharge of effluents, consisting of evaluations of fish populations, benthic invertebrate communities, effluent toxicity and other components. New developments in the program reflect some of the adaptations developed for metal mining EEM, including: a) setting alpha and beta equal and determining the consequences for study design and interpretation; b) discussion of the role of effect size in power analysis and study design; and c) non-lethal sampling protocols for EEM.

Development of guidance for effects-based cumulative effects assessment programs

Recent studies conducted in this lab have suggested that small-bodied species can be more sensitive to effluent exposure (Gatineau River, Saint John River studies, in prep.) but a previous Ph.D. student (Gibbons, 1997) demonstrated different responses of populations of white sucker and trout-perch exposed to pulp mill effluent. The population responses are compared against a hypothetical response framework, and these response patterns are used to derive follow-up hypotheses aimed at defining the stress associated with the current population status (i.e., food limitation, recruitment failure, or metabolic disruption), but these response frameworks were developed based on the responses of large species. Population assessment is presently conducted on adult fish using indirect estimates of survival (mean age), energy use (size-at-age, fecundity, egg size) and energy storage (condition factor, liver size) collected on samples of relatively small numbers of adult male and female fish. It is possible to collect large numbers of small-bodied fish species, and it is also possible to collect direct estimates of survival (mortality rates, recruitment), energy use (growth estimates using repeated or end-of-season size measures) and energy storage (condition factor).

The capacity of non-point stressors associated with agriculture to impact populations of fish in terms of altered survival, growth rates and condition (Gray 2003) has now been demonstrated. Future projects will compare the information obtained by non-lethal sampling in three species of fish to the value of information obtained by traditional lethal sampling to evaluate the relative strengths of the data interpretation.

Funding

Munkittrick, K.R. NCE Canadian Water Network. Estimating the assimilative capacity of the Saint John River, with A. Curry, D. MacLatchy, K. Haralampides (UNB), K. Teather (UPEI). Total grant $198,000. 2003-2005

MacLatchy, D.L. (PI) Irving Oil, Development of monitoring techniques for Little River, Saint John, NB, with R.A. Curry, UNB. $52,000 over two years. 2002-2004.

Munkittrick, K.R. Canada Research Chairs Grant. $200,000/y. 2001-2007.

Munkittrick, K.R. CFI and matching funds for equipment. $250,000. 2001-2002.

Munkittrick, K.R. New Brunswick Innovation Fund Graduate Research Initiative. Funding for student support. $20,000/2y. 2002-2004

Munkittrick, K.R. NSERC International Opportunities Fund. Development of an international team for effects-based assessment of contaminated sites in Latin America, with collaborating partners J. Culp, R.A. Curry, D.L. MacLatchy (UNB), C. Metcalfe (Trent), M. Hewitt and G. Van Der Kraak (Guelph), M. Dubé (Saskatchewan), K. Devito (Alberta).$56 200 over two years. 2001-2003.

Munkittrick, K.R. NCE Canadian Water Network. Estimating the assimilative capacity of the Saint John River, with D. MacLatchy, R.A. Curry, R. Cunjak, K. Haralampides (UNB), K. Teather (UPEI), G. Daborn (Acadia). Total grant $154,427/y. 2001-2003.

Munkittrick, K.R. Canadian Network of Toxicology Centres. Quantification of sediment-associated EDSs in agricultural areas, and their potential biological impacts on fish, with L.M. Hewitt (EC), K. Teather (UPEI), D. MacLatchy (UNB), and G. Van Der Kraak (Guelph). $53,900. 2001-2002.

MacLatchy, D.L. (PI) CIDA Tier 2 UPCD, Human Resource Development in the Cuban Marine Biology Sector, with J. Johnson, A. Logan, T. Chopin and A. Curry. $710,430 total. 1997-2003.

Munkittrick, K.R. Development of a cumulative effects strategy for the Saint John River - Toxic Substances Research Initative with R.A. Curry (UNB), R.Cunjak (UNB), G. Van Der Kraak (U Guelph) and M. Hewitt (EC), Year 3 of 3, $142,000 (total = $436,000 over 3 years).

Figure 14. Potato fields in the Grand Falls area of northwestern NB (M. Gray).

Project Partners

NWRI

Environment Canada (Atlantic Region)

NBCFWRU

Fraser Papers

Noranda Technology Centre

Crop Protection Institute

Sir James Dunn Wildlife Research Centre

New Brunswick Wildlife Council Trust Fund

PEI Wildlife Conservation

BBEMA ACAP funding

ACAP Saint John

NB Department of Environment and Local Government

NB Department of Natural Resources

Maine Department of Environmental Protection

Agriculture Canada

Fisheries and Oceans Canada

Maine Chapter of the Nature Conservancy

Personnel

Staff

Lisa Peters, M.Sc. (2001 - present)

Lab Manager

Ms Peters is involved in the management and operation of the Ecosystem Health Assessment Laboratory. Project participation has included two studies in the Saint John Harbour, and one each on the Red Deer River, AB, and the Androscoggin River, New Hampshire. Here in Saint John the first project is with the Irving Oil Refinery investigating possible impacts of their effluent on the health of Little River. The second is looking for histopathological abnormalities in the gonadal tissue of winter flounder living within the Saint John River estuary, as well as assisting Dr. David Methven in his

study of diurnal and seasonal changes in the nearshore fish community abundance and structure in the harbour. In Alberta, the Red Deer River project is examining the effects of municipal effluent discharges on the performance and reproductive health of longnose dace in that system. In New Hampshire, there are separate pulp and paper facilities on the Androscoggin River which initiated production within the past year. Upstream and downstream samples of small-bodied fish were collected before the mills began discharge to be compared to fish collected during operation. Performance and reproduction parameters will be used to investigate possible mill effects, as well as those from a nearby sewage effluent outfall.

Figure 15. The Rio Biobio, upstream from Concepcion, Chile.

Graduate Students

M.Sc.

Collin Arens (co-supervised with Dr. David Methven, 2003 - present)

Nearshore fish community structure in the southern Bay of Fundy: comparing nearshore fish assemblages over large spatial and temporal scales

The objectives of this study are to examine the variation among nearshore fish assemblages over large spatial and temporal scales and to identify patterns within the species and community components of these ecosystems. This information will lead to a better understanding of how nearshore communities function and permit predictions of community succession. These capabilities are fundamental in interpreting data and extrapolating results from dynamic ecological systems and will prove essential for management of coastal and estuarine habitats. While addressing these objectives, this research will: a) involve the collection of nearshore fish community data from sites located along the east coast of Atlantic Canada and the New England states; b) describe the species and community components of these estuarine fish assemblages; c) examine variation among these nearshore fish communities; and d) determine whether patterns exist among assemblages over large spatial and temporal scales.

Geneviève Vallières (co-supervised with Dr. Deborah MacLatchy; 2002 - present)

Assessing the health of fish populations in a small estuarine stream receiving oil refinery effluent.

The objective of the study is to assess potential effects of an oil refinery effluent discharge on fish health in the receiving waters. The effluent is discharged in a tide-influenced area. Estuaries are known to be more complex than freshwater systems, with more mobile fish populations and inconsistent exposure scenarios, increasing the difficulty to link potential effects on fish health to effluent exposure. The first part of the study will look at fish communities and plume profile at high and low tides throughout seasons. In the next part of the study, two small body species will be selected and 20

males and females from exposed and reference sites will be collected and sampled. Measurement of different endpoints such as gonadal somatic index (GSI), liver somatic index (LSI) and condition factor will be used to assess the health of the fish.

Karma Tenzin (2002 - present)

Measuring the impacts of hydroelectric developments on the growth of fish

Hydroelectric dams are one of the greatest physical structures impacting river systems. The Saint John River is a highly impacted river; in addition to the five hydroelectric dams, there are many other effluents. This study focuses on the effects of river fragmentation by hydroelectric dams on the performance of fish populations. The overall goal of this study will be to contribute towards the development of non-lethal techniques (back-calculation of fish growth by scales) for fish assessment in ecological field studies. This project will enable Mr. Tenzin to take the tools and skills he has developed back home to Bhutan to apply to his fisheries work there.

Jennifer Peddle (2001-present)

Biodiversity and community ecology of the parasites of the three-spine stickleback, *Gasterosteus aculeatus*, in the southern Gulf of St. Lawrence (sGSL)

This project examines the ecto- and endoparasites of the three-spine stickleback, *Gasterosteus aculeatus*, in the Southern Gulf of St. Lawrence (sGSL). The work examines the parasites on two different levels. Types and species of parasites found in the estuaries of the sGSL will be determined in order to create a biodiversity inventory for this species. Subsequently, this project will examine the parasites to determine how they relate to one another at different community scales (infra- and meta-community). For example, how the parasite communities of individual fish at a site compare to one another, as well as how the parasite communities of different estuaries compare to one another.

Chad Doherty (co-supervised with Dr. Allen Curry; 2001-present)

M.Sc. completed

Lottie Vallis (2003; co-supervised with Dr. Deborah MacLatchy)
The potential use of rock gunnel as a biondicator in Saint John harbour, New Brunswick, Canada

The harbour at Saint John, New Brunswick (SJH) receives waste from both municipal and industrial sources. The growth and reproductive development of rock gunnel were examined along three shores of SJH where past records indicate differing levels of contamination. Rock gunnel collected at sites with the highest contamination were larger, had higher condition factors and larger relative liver sizes. Larger sizes could be an indication of eutrophication due to sewage inputs at the contaminated sites.

Presently: Contract Biologist, Environment Canada, Dartmouth, NS

Ph.D.

Karen Gormley (co-supervised with Dr. Deborah MacLatchy; 2003 - present)

Sandra Brasfield (2002 - present)
Use of fish populations in an effects based assessment to evaluate non point stressors associated with agriculture

In most situations, discharges from non-point sources, such as agriculture, are complex mixtures, the concentrations of toxicants are difficult to characterize, and rates and timing of discharges are difficult to predict. Along the Little River watershed, located north of Grand Falls, NB, differing agricultural intensities at sites along the Little River reach provide a gradient to assess cumulative effects of agriculture. An effects-based approach will be used to determine the role that various stressors play in the population-level impacts on survival and reproduction of slimy sculpin (*Cottus*

cognatus). Previous studies have shown decreased gonad size, fecundity, nest size and density and young-of-the-year (YOY) densities downstream of agricultural practices. Although it is probable that sediment runoff is playing a role in the decreased performance of fish in the agricultural areas, there are also other factors involved with these events, including increases in temperature, nutrients, and pesticides. Prior studies on this system documented year class failures in the agricultural areas, however, YOY survival was not affected in a year of little rainfall or when summer heavy summer storms preceded pesticide use. This research is significant because of several key aspects, including: the fish are exposed *in situ* in the wild; the sediment accumulation of chlorinated and non-chlorinated pesticides can be quantified; and developmental and endocrinological endpoints can be assessed.

Brendan Galloway (co-supervised with Dr. Allen Curry, 2001 - present)

Responses of different fish species to anthropogenic contamination in the Saint John River

This project is building on previous studies that focused on assessing the suitability of small-bodied fish species for monitoring rivers receiving pulp mill effluent. One of the key components of the EEM program is the collection of wild fish. Typically, white sucker have been used to monitor the impacts of pulp mill effluent in freshwater environments. However, there is concern about this since there is potential for white sucker to move beyond effluent exposure areas. Slimy sculpin can be used as an alternative to the white sucker. Sculpin are less mobile relative to white sucker, have a smaller home range, and exhibit territorial behaviour. Together, these characteristics increase the probability that the measured responses in sculpin will reflect the environmental conditions where they were captured. Preliminary results indicate slimy sculpin and white sucker collected at the same sites on the Saint John River show different whole-organism responses. This project will continue to expand on earlier studies to examine whether there are ecological explanations for the differences between species in responses.

Ph.D. completed

Michelle Gray (2003; co-supervised with Dr. Rick Cunjak)
Agricultural and forestry impacts on slimy sculpin

This research has involved assessing environmental impacts from potato cultivation activities in northern New Brunswick streams. Specifically, this project studied the comparative population dynamics and reproductive physiology of slimy sculpin populations in forested and agricultural regions, but also monitored individual movements and food web dynamics using stable isotope analysis. Major results have included increased sizes of sculpin and reduction in young-of-the-year (YOY) sculpin in agricultural portions of the Little River in Grand Falls, NB. This was confirmed through another study that looked at sculpin abundance in agricultural streams throughout northwestern NB. Eight of 10 streams had no YOY sculpin present. Sediment deposition and temperature profiles were also monitored at each stream. We were able to show a more significant correlation between sculpin size and density with temperature, rather than sedimentation.

Currently active as NSERC Post-Doctoral Fellow, University of Manitoba

Figure 16. Collecting sculpin along the Little River, NB (K. Munkittrick).

Undergraduate Students

Honours thesis

Collin Arens. 2003. Distribution and abundance of neustonic *Urophycis tenuis* (white hake) in the Southern Gulf of St Lawrence: a comparison of 1979 and 2002. University of New Brunswick (Saint John). May 2003.

Visiting Researchers

Olof Sandström, Ph.D.
Fisheries Consultant, Oregrund, Sweden

Dr. Sandström visited the CRI from Sweden in the spring and summer of 2003 to further collaborations between research groups in the areas of environmental monitoring and regulation development. He gave seminars to the department regarding the development and evolution of Swedish environmental monitoring programs and how they relate to those here in Canada. He also traveled to Northern Ontario to one of the most studied freshwater systems with regard to pulp and paper impacts on fish populations. There he met and worked with scientists and students from government and academia on the progress of this issue.

Gaspar Sanson-Gonzalez, Ph.D.
Professor, University of Havana, Havana, Cuba

Dr. Gonzalez visited the CRI in the summer of 2002 to allow for planning and development of joint field courses between UNB and his institute at the Universidad de La Habana in Cuba.

Service

Positions and Committees

Member of International Scientific Committee for 5th International Conference on Fate and Effects of Pulp and Paper Mill Effluents, June 1-4, 2003, Seattle, WA.

Elected Member of Board of Directors for Canadian Water Network (2002-present)

Elected to the SETAC World Council (Board of Directors) (2001-2004)

Chair, SETAC International Programs Committee (1999-present)

Associate Editor, Journal of Aquatic Ecosystem Health and Management (1996-present)

Member of SETAC Board of Directors, 1998-2001

Invitations

1er Congreso de Ecotoxicologia, Universisdad Autonoma Metropolitana, Iztapalapa, Mexico, 10 y 11 Octubre, 2002. Presentation.

"Using an effects-based approach for examining the impacts of multiple stressors on fish populations in large watersheds" Christchurch, New Zealand, September 30, 2003. Plenary.

“The St. John – A River Without Borders”, Fort Kent, ME, September 27, 2002. Plenary.

V Reunião SETAC Latino-Americano y VII Congresso Brasileiro de Ecotoxicologia, de 06 a 9 outubro de 2002, Vitòria, Brasil. Plenary.

Stressors in Aquatic Environments, La Habana, Cuba November 28-29, 2002. Plenary.

4th Annual SETAC Latin America meeting, Buenos Aires, Argentina, October 22-25, 2001. Plenary.

Invited to Chair and organize a session, “Enfoque ecotoxicologico para objetivos de proteccion ambiental: la experiencia en América del Norte”, 4th Annual SETAC Latin America meeting, Buenos Aires, Argentina, October 22-25, 2001.

Fellows

Bob Newbury

Principal, Newbury Hydraulics
Fellow, Canadian Rivers Institute (2001-present)
Association of Professional Engineers and Geoscientists of British Columbia
Association of Professional Engineers of New Brunswick (license)
http://www.newbury-hydraulics.com

Research Interests

Hydrology, limnology and fish habitat requirements have been the focus of Dr. Newbury's 40-year career in Canada as a Professor, senior Research Scientist (DFO Freshwater Institute), and Civil Engineer. Since 1987 most of his teaching and research has been concerned with the analysis and design of fish passage and stream habitat restoration works.

Teaching

Dr. Newbury is currently conducting special courses at five universities in a variety of Adjunct and part-time positions (SFU, OUC, U/C, U/Wat., UNB). In addition, professional upgrade courses are held each year through Newbury Hydraulics for agencies such as the Water Survey of Canada, Parks Canada, Fisheries and Oceans Canada, US and State Environmental Protection Agencies and the US Army Corps of Engineers (Mississippi). Between 2001 and 2003, three undergraduate courses, three graduate courses and nine professional short courses have been completed in streams and rivers located in BC, Alberta, Saskatchewan, Manitoba, Ontario, New Brunswick, Illinois, Arkansas and Spain.

Major Projects

Dr. Newbury established the Experimental Lakes hydrological monitoring system in NW Ontario and the Churchill River diversion physical monitoring program in northern Manitoba. Recent projects include fish passage works for dams on the Little

Saskatchewan River for Manitoba Fisheries, on the Okanagan River for the Okanagan First Nations and on the Sakinaw River for the Sechelt Indian Band. Dam removal works have been completed for the Coursier Lake hydroelectric dam on Cranberry Creek, BC.

Dr. Newbury continues to assist with a number of river restoration projects throughout the country and internationally. Some of his Canadian restoration projects include: Twin Creeks diversion and habitat restoration, Campbell River gravel recruitment, SW Miramichi River holding pool restoration, Rafting Ground Brook Restigouche River stabilization, and the Dickson Brook reconstruction project in Fundy National Park.

Funding

Funding sources for teaching are derived from sponsoring agencies, universities and the Canadian Rivers Institute. Research is primarily self-funded through professional design works by Newbury Hydraulics Inc.

Project Partners

Okanagan First Nations
BC Ministry of Environment
BC Hydro
Sechelt Creek Contracting
Fisheries and Oceans Canada
Sutter Salmon Club
Runnymede Lodge
Atlantic Salmon Federation
Sechelt Indian Band
Terminal Forest Products
USEPA
Illinois State Water Survey
Water Survey of Canada

Sandy Hook Community Association
Toronto and Region Conservation Authority
US Corps of Engineers
Waterloo Education
BC Freshwater Institute.

Personnel

Graduate Students

M.Sc.

Karilyn Long (co-supervised with Dr. Rick Cunjack, 2002 - present)
Egg survival as a function of the geometry and hydraulics of sockeye salmon redds in the Okanagan River

Although the water depth, velocities and substrate composition for sockeye spawning are well documented, the hydraulics have not been recorded. By the process of building the nest and moving gravel, it is hypothesized that salmon create both a shape and distribution of substrate that facilitates survival of the eggs (i.e., sufficient aeration) and effective emergence from the nest. The first objective of this study is to quantify the specific hydraulic conditions of a sockeye spawning nest in both the natural and channelized sections of the Okanagan River. The second objective is to relate the hydraulics to egg survival and alevin emergence from the gravel nest. This will be tested by placing known numbers of sockeye eggs in incubation baskets in both natural and channelized sections for assessing relative survival.

M.Sc. Completed

Tricia Gribling, (2002)
Community involvement in the Fraser River Plan

Ph.D. Eng. Completed

Daniel Walker (2002)
Hydraulic and design aspects of natural and constructed riffles in gravel-cobble bed rivers

Selected Invitations

Newbury, R. 2003. Plenary address: riparian and floodplain restoration in the Okanagan valley. Fourth Annual Okanagan Riparian Group Meeting.

Newbury, R. 2002. Seminar. UNB Department of Civil Engineering/Association of Professional Engineers of New Brunswick.

Newbury, R. 2001. Plenary address: Canadian Heritage Rivers Conference, Fredericton, NB.

Figure 17. Tributary to the Upsalquitch River, NB (C. Blanar).

Fellows

Stephan J. Peake

Assistant Professor, Department of Biology, UNB, Fredericton, NB
Fellow, Canadian Rivers Institute (2003-present)
http://www.unb.ca/fredericton/science/biology/Faculty/peake.html

Research Interests

Dr. Peake's position at UNB is currently supported through the NSERC New Faculty Support Program with Manitoba Hydro as the industrial partner. Current research projects in Manitoba focus on ecological problems related to hydroelectric activities. Examples of these include exercise physiology, behaviour and performance of fish relative to passage through (and over) culverts and fishways, effects of sedimentation on fish and aquatic invertebrates, and ecology and aquaculture of lake sturgeon. Dr. Peake and his students study fish in the field, under conditions that allow individuals to use their full range of behavioural strategies to deal with various stressors and locomotory challenges.

Major Projects

Lake Sturgeon Aquaculture and Conservation

Dr. Peake conducts research in relation to conservation of lake sturgeon in Manitoba, with ecology, habitat requirements, and aquaculture being his main points of interest. Past research has focused on substrate selection and habitat preference of juvenile lake sturgeon. Current research will be directed at improving rearing techniques for this species.

Sedimentation, Gait Transition and New Fishway Design

These projects are currently being carried out in Dr. Peake's field station in Manitoba.

Funding

Peake, S. CFI – Establishment of a Canadian Rivers Institute Field Station in Manitoba. $415 000. 2004.

Peake, S. NSERC New Faculty Award Program with Manitoba Hydro. $450,000. 2003-2005.

Project Partners

Manitoba Hydro

Deep River Science Academy

Figure 18. Experimental fishway along the Winnipeg River, MB (S. Peake)

Personnel

Graduate Students

M.Sc.

Alison Johnson (2003 - present)
Fish movement through culverts

This study examines gait transition dynamics of brook trout in relation to fish size, swimming velocity and water temperature. With these data, a better way to establish culvert water velocity criteria will be developed.

Eva Walker (2003 - present)
The effects of acute sedimentation on behaviour and survival of fish and benthic macroinvertebrates in an artificial stream mesocosm

This project is based in Pinawa Manitoba on the Pinawa channel. It examines acute suspended sedimentation events such as those that would be caused by bank slumps, clear-cut harvesting, construction or pulse releases from hydro dams. It also examines the effects of these events on the survival and behaviour of fish and benthic macroinvertebrates, such as snails and insects. Experiments will be carried out in a large artificial stream mesocosm, a controlled representation of an ecosystem containing characteristic organisms in the form of a flow through stream.

Jenny Reid (2003 - present)
Designing a new fishway for nonsalmonids

Previous fishway designs have been based on the swimming performance and behaviour of salmonids. In general, these fish are strong, highly motivated swimmers when compared to nonsalmonids. Therefore, the velocities and hydraulics within these fishways may not be optimal for the passage of nonsalmonids. In this study, a new fishway baffle will be designed based specifically on the behaviour and swimming

capacity of nonsalmonids. Currently, a prototype model fishway is being constructed at UNB to develop a new baffle type that may improve the passage of nonsalmonids. During the field season, a full-scale fishway will be built to test fish performance of the new baffles against pre-existing baffles (Denil and vertical slot) that were designed primarily for salmonids.

Cheryl Klassen (2003 - present)

Potential of black fly larvae as an alternative food source for hatchery production of lake sturgeon (*Acipenser fulvescens*)

Artificial propagation is believed to be an effective means to increase lake sturgeon populations, which have become depleted due to commercial exploitation, habitat degradation and blocked migratory paths. Success of current rearing methods has been inconsistent and costly. Preliminary studies incorporating black fly larvae, a natural prey item, into the diets of juvenile lake sturgeon increased survival and growth rates when compared to sturgeon reared using traditional methods. Comparisons of hatchery survival and growth rates between fish fed black fly larvae and those raised traditionally will continue. In addition, stamina tests (swimming ability, disease resistance) and short-term survival and growth rates of juveniles placed into artificial streams will be compared between the two groups. It is hoped that this research will lead to an efficient and cost effective means of rearing healthy lake sturgeon for the purpose of successful restocking.

Figure 19. Tagging lake sturgeon along the Winnipeg River, MB (S. Peake)

Associates

Tom Al
Professor, Department of Geology, University of New Brunswick, Fredericton, NB
http://www.unb.ca/geology/index3.htm

Dr. Al's research focuses on determining the nature of reactions that control the concentrations and transport of inorganic species in groundwater. This involves aqueous geochemistry, mineralogy and hydrogeology which are the principal disciplines that he and his co-workers have employed in previous research that has been conducted in groundwater settings affected by the disposal of mine tailings and waste rock.

Nelson, M.D., B.L. Parker, T.A. Al, J.A. Cherry and D. Loomer. 2001. Geochemical reactions resulting from *in situ* oxidation of PCE DNAPL by $KMnO_4$ in a sandy aquifer. Environ. Sci. Technol. 35:1266-1275.

Donald Baird
Research Scientist, NWRI, University of New Brunswick, Fredericton, NB
djbaird@unb.ca

Dr. Baird's research interests focus on the developments of methods and approaches to understand how animals within aquatic food webs respond to the impacts of multiple stressors. A particular focus of the research is to study how ecological characteristics of species, particularly their feeding behaviour, can influence their susceptibility to stress, and how this might be used in statistical models to diagnose causes of ecosystem impairment. In addition, a new line of research will study the effects of spatial and temporal scale on the assessment of biodiversity within large river watersheds, and how local community participation can support scientific goals for the protection of rivers. In addition to this research in Canada, he is also working on international collaborative projects in Europe (on methods for assessment of ecosystem function in rivers), SE Asia (risk assessment of pesticide use in Sri Lanka and Thailand) and Latin America (land-use impacts on watersheds of the Colombian Andes; pesticide impacts on tropical wetlands).

Baird, D.J., T.C.M. Brock, P.C. de Ruiter, A.B.A. Boxall, J.M. Culp, P. Eldridge, U. Hommen, R.G. Jak, K.A. Kidd and T. Dewitt. 2001. The food web approach in the environmental management of toxic substances. In: *Ecological Variability: Separating Anthropogenic from Natural Causes of Ecosystem Impairment* (Eds., D.J. Baird and G.A. Burton). SETAC Press, Pensacola, USA. pp 83-122.

Stuart Bunn
Director, Centre for Riverine Landscapes, Faculty of Environmental Sciences, Griffith University, Brisbane, Australia
http://www.gu.edu.au/centre/riverlandscapes

The major focus of Dr. Bunn's research is on understanding the pattern of energy and nutrient flux in aquatic ecosystems, and the structure of aquatic food webs. His research group has taken a leading role in Australia in the application of multiple stable isotope tracing in the study of aquatic ecosystems. This approach underpins much of his research on energy and nutrient flux, and has involved both natural abundance and enriched isotope tracing techniques.

Bunn, S.E., P.M. Davies and M. Winning. 2003. Sources of organic carbon supporting the food web of an arid zone floodplain river. Freshwater Biol. 48:619-635.

Patricia Chambers
Chief, Human Impacts on Aquatic Ecosystem Processes Project, NWRI, Environment Canada, Burlington, ON
http://www.nwri.ca/staff/patriciachambers-e.html

The research in Dr. Chamber's lab focuses on the effects of point and non-point source pollution on nutrient and dissolved oxygen dynamics in rivers, and aquatic plant ecology. Her research has involved studies on: a) the impact of pulp mill effluent and municipal sewage on nutrient and oxygen dynamics and periphyton and macrophyte abundance rivers and lakes; b) the effects of nutrient loading from agricultural activities on stream water quality; and c) the effects of land use changes (timber harvesting and wildfire) on the structure and function of stream ecosystems.

Prepas E.E., B. Pinel-Alloul, P.A. Chambers, T.P. Murphy, S. Reedyk, G. Sandland and M. Serediak. 2001. Lime treatment and its effects on the chemistry and biota of hardwater eutrophic lakes. Freshwater Biol. 46:1049-1060.

Keith D. Clarke
Habitat Research Biologist, Fisheries and Oceans Canada, Science, Oceans and Environment Branch, St. John's, NF
Clarkekd@dfo-mpo.gc.ca

Keith Clarke's research attempts to understand the effects of human developments on fish and their habitat, including applied research on land-use, fishery interactions. Basic research into habitat utilization patterns and habitat productive capacity is also ongoing. His work is conducted under the mandate to provide scientific advice to managers under DFO's Policy for Habitat Management.

Robertson, M.J., K.D. Clarke, D.A. Scruton and J.A. Brown. 2003. Interhabitat and insteam movements of radio-tagged Atlantic salmon parr in winter. J. Fish Biol. 63: 1208-1218.

Simon C. Courtenay
Research Scientist, Fisheries and Oceans Canada, Gulf Fisheries Centre, Moncton, NB
courtenays@dfo-mpo.gc.ca

Dr. Courtenay's research has centered on the uses that fish make of estuaries and the impacts on these activities of anthropogenic effluents. His team has included technicians, postdoctoral fellows, and graduate students from several universities. In addition he has enjoyed excellent collaborations with colleagues from DFO, Environment Canada, Parks Canada and a number of universities.

Munkittrick, K.R., S.A. McGeachy, M.E. McMaster and S.C. Courtenay. 2002. Overview of freshwater fish studies from the pulp and paper Environmental Effects Monitoring program. Water Qual. Res. J. Canada. 37:49-77.

Suzie Currie
Associate Professor, Department of Biology, Mount Allison University, Sackville, NB
http://www.mta.ca/faculty/science/bio/suzannecurrie.html

Dr. Currie is interested in the physiological and molecular mechanisms that allow organisms to cope with environmental stress. Much of her work focuses on the role of stress or heat shock proteins (hsps) in the survival and recovery of fish and/or fish cells from exposure to high temperature, low oxygen or environmental contaminants.

Currie, S., C.D. Moyes and B.L. Tufts. 2000. The effects of heat shock and acclimation temperature on hsp70 and hsp30 mRNA expression in rainbow trout, *Oncorhynchus mykiss*: *in vivo* and *in vitro* comparisons. J. Fish Biol. 56:398-408.

Shawn E. Dalton
Research Associate, Environment and Sustainable Development Research Centre, University of New Brunswick, Fredericton, NB
sdalton@unb.ca

Dr. Dalton's research concerns how the nature and structure of the relationships among the public, private, and non-profit sectors affect a) the ability of groups of stakeholders to integrate resource management activities at the watershed scale; and b) the development and implementation of public policy related to watershed management. She is currently pursuing these related research themes in the context of two watershed groups: the Fredericton Area Watersheds Association in New Brunswick's capital city, and the Canaan-Washademoak Watershed Association, in a rural area in south-central New Brunswick.

Kevin Devito
Associate Professor, Department of Biological Sciences, University of Alberta, Edmonton, AB
http://www.biology.ualberta.ca/faculty/kevin_devito/

Dr. Devito and his graduate students conduct research covering a wide range of topics, which include: wetland ecosystems, biogeochemistry and hydrology; land water linkages and influence of hydrogeology on ecosystem processes; soil nutrient dynamics; forestry and hydrochemistry interactions; and the role of anthropogenic and natural stresses on terrestrial and aquatic ecosystems. Dr. Devito is lead PI on a NSERC-CRD funded multidisciplinary project examining the Hydrology, Ecology and the role of Disturbance on Western Boreal Wetlands (HEAD) and is currently a member of Western Boreal Hydrology group. This group is examining the influence of landscape and climate on nutrient status and the ecological integrity of aquatic systems in the western boreal forests. They are developing landscape frameworks to assess the scale to which aquatic ecosystems interact with their surroundings and ultimately assess the susceptibility of aquatic systems to a range of natural and anthropogenic stresses.

S.L. Schiff, K.J. Devito, R.J. Elgood, P.M. McCrindle, J. Spoelstra and P. Dillon. 2002. Two adjacent catchments: dramatically different nitrate export. Water Resources Res. 38:1278-1292.

Monique Dubé
Research Scientist, Aquatic Ecosystem Impacts Research Branch, NWRI, Environment Canada, Saskatoon, SK
http://www.nwri.ca/staff/moniquedube-e.html

Dr. Dubé's expertise includes effects assessment of industrial and municipal effluents on riverine food webs and development of mesocosm and stable isotope approaches for environmental effects monitoring. She has also developed a regional cumulative effects assessment framework for aquatic ecosystems and an associated software system for framework implementation.

Dubé, M.G., J.M. Culp, K.J. Cash, N.E. Glozier, D.L. MacLatchy, C.L. Podemski and R.B. Lowell. 2002. Artificial streams for environmental effects monitoring (EEM): development and application in Canada over the past decade. Water Qual. Res. J. Canada. 37:155-180.

Katy Haralampides
Associate Professor, Department of Civil Engineering, University of New Brunswick, Fredericton, NB
http://www.unb.ca/civil/katy/katy.htm

Physical and numerical modelling in environmental hydraulics is the focus of study undertaken by Dr. Haralampides. She is interested in projects that help to understand the processes governing the hydrodynamics, sediment transport, and subsequently the health and quality of surface water ecosystems.

Haralampides, K., J.A. McCorquodale and B.G. Krishnappan. 2003. Deposition properties of fine sediment. J. Hydraul. Eng- ASCE 129: 230-234.

Stephen Heard
Assistant Professor, Department of Biology, University of New Brunswick, Fredericton, NB
http://www.unb.ca/fredericton/science/biology/Faculty/Heard.html

Dr. Heard's research interests are broad, and include the ecology and evolution of population interactions in both aquatic and terrestrial systems. His freshwater interests are centred on interguild interactions in benthic stream invertebrates and how these interactions are shaped by biotic and abiotic processing of resources (algae, CPOM, and FPOM). Dr. Heard's laboratory has conducted experimental studies of shredder-collector and grazer-collector interactions, as well as studying mixing in stream channels, FPOM production by mechanical abrasion of CPOM, and fine-scale spatial structure of stream invertebrate communities.

Heard, S.B. and C.K. Buchanan. 2004. Grazer-collector facilitation hypothesis supported by laboratory but not field experiments. Can. J. Fish. Aquat. Sci.. In press.

Mark Hewitt
Research Scientist, National Water Research Institute, Environment Canada, Burlington, ON
http://www.nwri.ca/staff/markhewitt-e.html

Dr. Hewitt is an expert in the analytical toxicology of complex mixtures. He also has strong expertise in the area of endocrine disruption, method development for environmental contaminants and their environmental chemistry. He is currently interacting with Fellows, Associates and graduate students of the CRI on projects relating to pulp and paper effluents, pesticide runoff and internationally with efforts at initiating projects in these areas in Cuba and Chile.

Hewitt, L.M., A.C. Pryce, J.L. Parrott, V. Marlatt, C. Wood, K. Oakes and G.J. Van Der Kraak. 2003. Accumulation of ligands for Ah and sex steroid receptors in fish exposed to treated effluent from a bleached sulphite/groundwood pulp and paper mill. Environ. Toxicol. Chem. 22:2890-2897.

Douglas Holdway
Professor of Ecotoxicology, School of Science, UOIT, Oshawa, ON
http://www.uoit.ca/schoolofscience/Faculty&Staff/d_holdway_main.html

Dr. Holdway's research interests lie in the development of methods for assessing the toxicity of xenobiotics to aquatic organisms including both invertebrates and fish. Of special interest are the short and long-term impacts of pulse-exposures to agricultural chemicals such as pesticides and the effects of important modifying factors such as feeding, life-stage and species on both direct and indirect toxicity. Additionally, he is interested in the development and application of molecular and cellular biomarkers of xenobiotic exposure and effects in both fish and aquatic invertebrates relative to pollution gradients in rivers.

Pollino, C.A. and D.A. Holdway 2003. Hydrocarbon-induced changes to the metabolic and detoxification enzymes of tissues in the Australian crimson-spotted rainbowfish (*Melanotaenia fluviatilis*). Environ. Toxicol. 18:21-28.

Jeff Houlahan
Assistant Professor, Department of Biology, University of New Brunswick, Saint John, NB
jeffhoul@unbsj.ca

Dr. Houlahan's research has focused on: a) the effects of adjacent land-use on wetland diversity; b) global amphibian population trends; and c) the effects of scale on ecological processes. His long-term objectives are to determine how habitat loss, degradation, and fragmentation affect biological communities; how changes in biological communities affect ecosystem function; and how the relationships among anthropogenic impacts, biological communities, and ecosystem function change across spatial and temporal scales. In the short term (4-5 years), research is concentrating on pond communities (mainly amphibians) and asking three questions. What are the most important causes of widespread amphibian declines? How do anthropogenic land-uses, in particular forestry, affect amphibian communities? How do species extirpations affect pond food-webs and water quality? Amhibians are the focus because there is convincing empirical evidence that amphibians are declining and because ponds are one of the few systems where replicated, whole-system experiments are feasible.

S. Pribil and J.E. Houlahan. 2003. Life-history strategies associated with local population variability confer regional stability. Proceed. Royal Soc. (London): 270B: 1419-1424.

Leland J. Jackson
Associate Professor, Ecology Division, Department of Biological Sciences, University of Calgary, Calgary, AB
http://www.bio.ucalgary.ca/divisons/ecology/jackson.html

Dr. Jackson's general interests center on how the structure of ecological communities and ecosystems affects their function. Structure may be biological, chemical, or physical, and function relates to rates of processes. Current research in his laboratory is examining how sustainable development will affect water quantity and quality in south Saskatchewan headwater rivers (Red Deer, Bow and Oldman). This research is

attempting to evaluate how land use affects the delivery of matter (e.g., nutrients, herbicides, pesticides) to the rivers, and how riverine ecology affects in-stream processing of this matter.

Post J.R., M. Sullivan, S. Cox, N.P. Lester, C.J. Walters, E.A. Parkinson, A.J. Paul, L.J. Jackson and B.J. Shuter. 2002. Canada's recreational fisheries: the invisible collapse? Fisheries. 27:6-16.

Karen Kidd
Research Scientist, Fisheries and Oceans Canada, Central and Arctic Region, Winnipeg, MB
kiddk@dfo-mpo.gc.ca

Dr. Kidd's research interests include the fate of persistent contaminants in fresh waters, the use of stable carbon and nitrogen isotopes to characterize energy flow and trophic interrelationships of food webs, and the effects of pharmaceuticals on both invertebrates and fish in receiving waters. This research has developed the use of stable carbon and nitrogen isotopes for assessing the accumulation of mercury and persistent organic pollutants such as DDT in freshwater food webs and contrasting systems that differ in climatic regimes, productivity and species composition.

Kidd, K.A., H.A. Bootsma, R.H. Hesslein, D.C.G. Muir and R.E. Hecky. 2001. Biomagnification of DDT through the benthic and pelagic food webs of Lake Malawi, East Africa: Importance of trophic level and carbon source. Environ. Sci. Technol. 35:14-20.

Jim Kieffer
Associate Professor, Department of Biology, University of New Brunswick, Saint John, NB
http://www.unbsj.ca/sase/biology/kiefferlab/

Research in Dr. Kieffer's laboratory focuses on several general areas of fish physiology, including: importance of endogenous (body size, exercise) and exogenous (hypoxia, temperature) factors on the physiological response to exercise in fish (mainly salmonids, sturgeon, bass); effect of temperature on the respiratory physiology of fish;

effect of ploidy on the physiology of fish; aerobic metabolic fuel use in larval fish; effectiveness of catch and release angling in Atlantic salmon and bass; growth and development in fish (sturgeon, haddock); and physiology and behaviour of Atlantic and shortnose sturgeon.

Galloway, B. and J.D. Kieffer. 2003.The effects of an acute temperature change on the metabolic recovery from exhaustive exercise in juvenile Atlantic salmon (*Salmo salar*). Physiol. Biochem. Zool. 76:652-662.

Kerry MacQuarrie
Canada Research Chair in Groundwater-Surface Water Interactions, Department of Civil Engineering, University of New Brunswick, Fredericton, NB
http://www.unb.ca/civil/macquarr/macquarrie.htm

Dr. MacQuarrie conducts research related to the transport and fate of contaminants in the subsurface, particularly reactive contaminants such as mercury, pesticides and nitrate. His research integrates field studies with the development and application of computer models to investigate contaminant transport and fate, and processes occurring at the groundwater-surface water interface. He is also involved in several research projects that deal with the evaluation and prediction of thermal interactions between groundwater and rivers, both in the context of coldwater fish habitat and safe drinking water supply.

Keizer, J.P., K.T.B. MacQuarrie**,** P.H. Milburn, K.V. McCully, R.R. King and E.J. Embleton. 2001. Long-term groundwater quality impacts from the use of hexazinone for the commercial production of lowbush blueberries. Ground Water Monitoring and Remediation. 21:128-135.

Mark McMaster
Research Scientist, National Water Research Institute, Environment Canadda, Burlington, ON
http://www.nwri.ca/staff/markmcmaster-e.html

Dr. McMaster is a reproductive toxicologist whose work focuses on the effects of contaminants on the reproductive status of fish populations in aquatic receiving environments. He has played a key role in the development of the Environmental Effects Monitoring (EEM) program for both the pulp and paper and metal mining sectors and is a member of the National EEM team and the Science EEM committee. He was also a member of a team that developed a cumulative effects assessment framework using fish populations for the Moose River Basin, which may now be adapted to the Saint John River.

Tetreault, G. R., M.E. McMaster, D.G. Dixon and J.L. Parrott. 2003. Monitoring the aquatic environment in the Alberta Athabasca Oil Sands using reproductive endpoints in small fish species. Environ. Toxicol. Chem. 22:2775–2782.

David Methven
Assistant Professor, Department of Biology, University of New Brunswick, Saint John, NB
dmethven@unbsj.ca

David Methven is a fish biologist and ecologist. His research focuses on processes that influence variability in density and size structure of fishes at different spatial and temporal scales. Other research includes questions on life history, taxonomy and conservation biology of species at risk. Field work addresses questions at community and population levels and focuses on juvenile fishes in estuarine habitats. Current student projects of interest to the Canadian Rivers Institute include investigations of seasonal variability in size structure and species composition of fishes at several sites in the Saint John and St. Croix River estuaries, Bay of Fundy.

Methven, D.A., D.C. Schneider and G.A. Rose. 2003. Spatial pattern and patchiness during ontogeny: post-settled *Gadus morhua* in coastal Newfoundland. ICES J. Mar. Sci. 60:38-51.

Roy Parker
Environmental Protection Branch, Environment Canada, Fredericton, NB
roy.parker@ec.gc.ca

Roy Parker's primary areas of interest are the impacts of human activities on aquatic ecosystems. For the past 15 years, he has focused his efforts on measuring biological and chemical effects of effluent discharges from larger industries such as pulp and paper mills and mining operations. He has been actively involved in the development and implementation of federally-regulated environmental effects monitoring (EEM) programs for both of these industrial sectors. He has also worked on the development of alternative environmental effects monitoring techniques and approaches for application in these EEM programs. He continues to conduct studies that examine the fate and effects of persistent chemical contaminants such as PCBs, PAHs, and metals in several New Brunswick watersheds. In recent years, he has been involved with the development of environmental management approaches and environmental monitoring programs for the marine finfish aquaculture industry in the Bay of Fundy. Of particular interest are the chemicals (e.g., pesticides, disinfectants, antifouling agents) that are used at the salmon farms and the fate and effects of those chemicals in the marine environment.

R. Parker and C. Dumaresq. 2002. Effluent characterization, water quality monitoring and sediment monitoring in the metal mining EEM program. Water Qual. Res. J. Canada. 37: 219-228.

Joanne Parrott
Research Scientist, National Water Research Institute, Environment Canada, Burlington, ON
http://www.nwri.ca/staff/joanneparrott-e.html

Dr. Parrott's research goal is to examine and understand the physiological impacts of toxicants on fish. Her research uses laboratory exposures of fish to determine the impacts of various toxicants. She also make use of biochemical indicators in fish (liver enzymes, blood steroids) to assess toxicant impacts and mechanism of action. In the lab, efforts have focused on the development of fish lifecycle and partial lifecycle tests for the assessment of reproductive toxicants or endocrine disrupting substances. She and her colleagues are examining individual toxicants, complex effluents (such as the pulp mill discharging to the Saint John River in NB) and industrial and municipal waste waters for their ability to disrupt fish reproduction. The goal of these studies is to link early warning biochemical changes ("bioindicator"-type responses) with real-life meaningful endpoints (such as changes in growth, development or reproduction). Tests that can assess potential reproductive dysfunction in lab fish are useful for teasing out the effects of complex effluents in multi-discharge settings, and are useful for assessing the environmental safety of chemicals (such as pesticides and industrial chemicals) prior to registration and use in Canada.

Parrott, J., M. Wade, G. Timm and S. Brown. 2001. An overview of testing procedures and approaches for identifying endocrine disrupting substances. Water Qual. Res. J. Canada. 36:273-291.

John R. Post
Chair, Division of Ecology, Department of Biological Sciences, University of Calgary, Calgary, Alberta
http://www.bio.ucalgary.ca/divisions/ecology/post.html

The primary goal of Dr. Post's research program is to understand the suite of processes that control growth and survival of juvenile fishes and lead to variability in recruitment into adult stocks. Applied studies include assessments of impacts of climate change on thermal behaviour, energetics and population dynamics of northern

fishes in lakes and rivers. Associated inquiries deal with the loss of recruitment potential through fish entrainment in agricultural water diversions from Prairie rivers and the in-stream flow needs of river fishes.

Post, J.R., M. Sullivan, S. Cox, N.P. Lester, C.J. Walters, E.A. Parkinson, A.J. Paul, L. Jackson and B.J. Shuter. 2002. Canada's recreational fisheries: the invisible collapse? Fisheries. 27:6-17.

Trefor Reynoldson
Research Scientist, NWRI, Environment Canada, Wolfville, NS
http://www.nwri.ca/staff/treforreynoldson-e.html

Dr. Reynoldson's research has focused on the development of a national biomonitoring network, the integration of biomonitoring programs, the significance of sediment-associated contaminants, and decision-making frameworks integrating various types of biological information. His current research activities are in the development of a Canadian Aquatic Biomonitoring Network (CABIN), and in particular working with community groups in Atlantic Canada. He has also published widely on predictive models of community structure and the development of biological guidelines for assessing sediment contamination and the development of weight of evidence approaches using benthic communities in rivers.

Reynoldson T.B., E.P. Smith and A.J. Bailer. 2002. A comparison of three weight-of-evidence approaches for integrating sediment contamination data within and across lines of evidence. Human Ecol. Risk Assess. 8:1613-1624.

Jean-Marc Roussel
Research Scientist, INRA, Unité Mixte de Recherche en Ecobiologie et Qualité des Hydrosystèmes Continentaux (UMR EQHC), Laboratoire d'Ecologie Aquatique, Rennes cedex, France
roussel@roazhon.inra.fr

Using field and laboratory investigations, Dr. Roussel's research focuses on the integration of individual behaviour to explain mechanisms underlying population processes (resource selection, competition, emigration, predation). Some applied

research deals with agriculture impacts to river habitats such as sedimentation and food behaviour, animal movement monitoring, and fish habitat assessment in streams.

Roussel J-M., A. Haro and R.A. Cunjak. 2000. Field-test of a new method for tracking small fishes in rivers using passive integrated transponder (PIT) technology. Can. J. Fish. Aquat. Sci. 57:1326-1329.

David A. Scruton
Head, Environmental Sciences, Fisheries and Oceans Canada, Science, Oceans and Environment Branch, St. John's, NF
scrutond@dro-mpo.gc.ca

Current research studies include: a) migration (up- and down-stream) of Atlantic salmon and the effectiveness of fish bypass systems, b) response of juvenile salmonids to hydropeaking, c) improvement of biological models used in habitat hydraulic modeling, d) effect of pulp and paper effluents on salmon cardiac function, e) effectiveness of no-harvest and variable retention buffers in protecting fish habitat, and f) developments of methods and metrics of habitat productive capacity.

Scruton, D.A., K.D. Clarke, N.L.M. Ollerhead, D. Perry, R.S. McKinley, K. Alfredsen, and A. Harby. 2002. Use of telemetry in the development and application of biological criteria for habitat hydraulic modeling. Hydrobiologia. 483:71-82.

Kevin Teather
Associate Professor and Chair, Department of Biology, University of Prince Edward Island, Charlottetown, PEI
http://www.upei.ca/biology/teather.htm

Dr. Teather's research is focused on how environmental conditions faced by developing animals may affect their subsequent life histories. In addition to the theoretical questions pertaining to this topic, there are a number of practical applications. For example, "how does exposure to certain pesticides during development affect fish over the long term?". Questions such as these are important on PEI where pesticide runoff into local waterways has resulted in numerous fish kills over the past decade.

Teather, K., M. Harris, J. Boswell and M. Gray. 2001. Effects of Acrobat MZ and Tattoo C on Japanese medaka (*Oryzias latipes*) development and adult male behaviour. Aquat. Toxicol. 51:419-430.

Glen Van Der Kraak
Associate Dean of Research, College of Biological Science, University of Guelph, Guelph, ON
http://www.uoguelph.ca/zoology/department/people/faculty/g_vanderkraak

Dr. Van Der Kraak's research is concentrated in two main areas: multifactorial regulation of ovarian function in teleosts and evaluation of reproductive fitness in fish. Current research focuses on the hormonal control of growth, atresia and functional competence (in terms of hormone biosynthetic capacity and responsiveness) of goldfish and trout ovarian follicles during development. Other research focuses on the development of short-term *in vitro* techniques through to whole animal test methods applicable in lab and field settings to evaluate the effects of chemicals on reproductive physiology of fish. The long term goal of this work is to establish whether chemicals which are identified on the basis of *in vitro* bioactivity are predictive of effects *in vivo* and to determine which endocrine responses are most sensitive in terms of whole animal and population-levels effects.

Van Der Kraak, G., K.R. Munkittrick, M.E. McMaster and D.L. MacLatchy. 1998. A comparison of bleached kraft pulp mill effluent, 17β-estradiol and β-sitosterol effects on reproductive function in fish. In: *Principles and Processes for Evaluating Endocrine Disruption in Wildlife.* (Eds., R.J. Kendall, R.L. Dickerson, W.A. Suk and J.P. Giesy). SETAC Press, Pensacola FL. pp 249-265.

Renee Wissink
Park Ecologist, Parks Canada, Fundy National Park of Canada, Alma, NB
Renee.Wissink@pc.gc.ca

As Ecosystem Scientist for Fundy National Park, Renee Wissink has a broad interest in the areas of ecosystem research and monitoring as it applies to the management of protected areas. More specific to the CRI, Renee is a member of the Recovery Team

for endangered Inner Bay of Fundy Atlantic Salmon, a population that was listed as endangered by COSEWIC in May 2001. Since 2001, Fundy National Park has participated in the National Recovery Strategy for this population and has initiated an ambitious recovery program. After an initial two-year period of intensive assessment and population monitoring, the park recovery program has now entered an innovative phase of gene banking, captive rearing and breeding, and reintroduction of various life stages. At present, he co-supervises Ms. Sherisse McWilliam, a CRI graduate student carrying out stable isotope research which aims to quantify and describe food web relationships in relation to Atlantic salmon in the Upper Salmon, Point Wolfe and Big Salmon Rivers. In addition to salmon research, he is interested in monitoring of freshwater systems including populations of Brook trout, aquatic invertebrates, and freshwater mussels. As part of its Ecosystem Monitoring Program, Fundy National Park would also like to develop an Index of Aquatic Integrity which would gauge the pulse of entire watersheds.

Babaluk, J.A., H. R. Wissink, B.G. Troke, D.A. Clarke and J.D. Johnson. 2001. Summer movements of radio-tagged Arctic char (Salvelinus alpinus) in Lake Hazen, Nunavut, Canada. Arctic. 54:418-424.

Figure 20. Southeast Upsalquitch River, NB (C. Blanar)

Affiliated Research Groups/Labs

Stable Isotopes in Nature Laboratory (SINLAB)

The Stable Isotopes in Nature Laboratory (SINLAB) was established in June 1999 with funding from the Canadian Foundation for Innovation (CFI) and the Atlantic Canada Opportunities Agency (ACOA). The lab is currently equipped with a Finnigan-Mat Delta Plus mass spectrometer interfaced via continuous flow to an NC2500 elemental analyzer that is used in the analysis of naturally occurring ratios of carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$). Stable Isotopes are used to primarily address academic and applied questions in ecology, including defining energy pathways and food-web structure. Today, the use of stable isotopes are preferred where strong conservation efforts are necessary, since this type of testing allows for non-lethal sampling and requires only milligram quantities of sample material. Current techniques being developed by SINLAB include organic sulphur analysis ($^{34}S/^{32}S$), and Oxygen ($^{18}O/^{16}O$)/Hydrogen ($^{2}H/^{1}H$) analysis. Oxygen-18 and deuterium will be analyzed using a recently acquired Finnigan-Mat delta Plus XP interfaced with a TC/EA.

Since its inception the demand on the lab has increased with 19 researchers (from seven Canadian provinces and three international locations) submitting close to 5000 samples for carbon and nitrogen isotope analysis in 2003. With the development of the SINLAB website (*www.unb.ca/cri/sinlab)*, the number of inquires continues to increase. As well, the number of referrals increases as the lab develops a reputation for efficient and quality performance. SINLAB staff currently includes Director Rick Cunjak (Ph.D., University of Waterloo), Lab Manager Anne McGeachy (M.Sc., University of New Brunswick), Technicians Christine Paton (B.Sc., Memorial University) and Mireille Savoie (B.Sc., Saint Mary's University), and Science Manager Tim Jardine (M.Sc., University of New Brunswick).

http://www.unb.ca/cri/sinlab/index.html

NB Cooperative Fisheries and Wildlife Research Unit (NBCFWRU)

The NBCFWRU was established in April 1989 at the University of New Brunswick (Fredericton) within the Faculties of Forestry, and Science, as a cooperative effort between the university and the NB Department of Natural Resources and Energy. The Unit has been modeled after the many successful cooperative fish and wildlife research units within the USA and is the only one of its kind in Canada. http://www.unbf.ca/forestry/centers/cwru.htm

New Brunswick Aquatic Data Warehouse (NBADW)

The New Brunswick Aquatic Data Warehouse (NBADW) is a GIS-based repository of fisheries and aquatic information for the Province of New Brunswick. Its purpose is to support ecosystem-based resource management by coordinating the management and sharing of aquatic resource data among provincial and federal governments, NGOs, industry and the public. Data ownership is retained by the originating agency, but the NBADW is authorized to disseminate data.

The NBADW began in 1996 as a pilot project at the Atlantic Salmon Museum, Doaktown, NB and joined the Canadian Rivers Institute in 2003. The NBADW has three primary partners (the NB Deptartment of Natural Resources, the NB Deptartment of Environment and Local Government, and Fisheries and Oceans Canada) but works with a number of other agencies including universities, conservation organizations, community-based watershed organizations, and the forestry industry. All of these agencies collect valuable data on the province's water and fishery resources, yet their data are stored internally in stand-alone computers. The NBADW adds value to their data by inserting the information into a standardized database, assigning standard codes and identifiers, and georeferencing data collection sites. The NBADW currently has two staff, a manager/system architect and a programmer/analyst.

Research Publications

Agriculture

Cunjak, R.A., D. Guignion, R.B. Angus and R. MacFarlane. 2002. Using incubation baskets to assess salmonid egg/alevin survival in relation to fine sediment deposition, In *Effects of Land Use Practices on Fish, Shellfish, and their Habitats on Prince Edward Island*. (Ed., D.K. Cairns). Can. Tech. Report. Fish. Aquat. Sci. Vol. 2408. pp 82-91.

Curry, R. A. and S. MacNeill. 2004. Early life history success of brook charr in agricultural watersheds. J. N. Am. Benth. Soc. In press.

Peake, S. 2004. Swimming capacity of juvenile northern pike in relation to impingement on irrigation intake screens. N. Amer. J. Fish. Man. In press.

Anthropogenic Stress

Curry, R.A. and **K.R. Munkittrick**. 2004. Fish community responses to multiple stressors along the Saint John River, New Brunswick, Canada. In *Changes in Large River Fish Assemblages in North America: Implications for Management and Sustainability of Native Species.* (Eds., J.N. Rinne, R. Calamusso and R. Hughes). N.Am. J. Fish. Manage. In press.

Development of Indicator Species

Boudreau, M., S.C. Courtenay, **D.L. MacLatchy**, C.H. Bérubé, J.L. Parrott and G.J. Van Der Kraak. 2004. Utility of morphological abnormalities during early-life development of the estuarine mummichog, *Fundulus heteroclitus*, as an indicator of estrogenic and antiestrogenic endocrine disruption. Environ. Toxicol. Chem. In press.

Gray, M.A., **R.A. Curry** and **K.R. Munkittrick.** 2002. Non-lethal sampling methods for assessing environmental impacts using a small-bodied sentinel fish species. Water Qual. Res. J. Canada. 37:195-211.

MacLatchy, D.L., S.C. Courtenay, C.D. Rice and G.J. Van Der Kraak. 2003. Development of a short-term reproductive endocrine bioassay using steroid hormone and vitellogenin end points in the estuarine mummichog (*Fundulus heteroclitus*). Environ. Toxicol. Chem. 22:996-1008.

Ecology

Aguilar, C., G. Gonzalez-Sanson, **K.R. Munkittrick** and **D.L. MacLatchy.** 2004. Changes in fish coral reef assemblages on the northern coast of Cuba according to season, habitat zone and distance from Havana Harbour. Ecotoxicol. Environ. Saf. In press.

Baird, D.J., T.C.M. Brock, P.C. de Ruiter, A.B.A. Boxall, **J.M. Culp**, P. Eldridge, U. Hommen, R.G. Jak, K.A. Kidd and T. Dewitt. 2001. The food web approach in the environmental management of toxic substances. In *Ecological Variability: Separating Anthropogenic from Natural Causes of Ecosystem Impairment*. (Eds., D.J. Baird and G.A. Burton). SETAC Press, Pensacola, USA. pp 83-122.

Bujold, V. and **R.A. Cunjak**. 2004. Drifters versus residents: assessing size and age differences in Atlantic salmon fry. Can. J. Fish. Aquat. Sci. In press.

Charles, K., J.-M. Roussel and **R.A. Cunjak**. 2004. The use of stable isotopes to distinguish relative production by anadromous and freshwater resident brown trout. Mar. Freshw. Res. In press.

Courtemanche, D., **R.A. Curry** and F.G. Whoriskey, Jr. 2004. A non-lethal approach to distinguish periods of marine and freshwater residency using strontium in scales. J. Fish Biol. In press.

Courtemanche, D., **R.A. Curry** and F.G. Whoriskey, Jr. 2004. Assessing anadromy in brook charr *Salvelinus fontinalis* using Sr/Ca in scales. Can. J. Fish. Aquat. Sci. In press.

Curry, R.A., C. Brady and G.E. Morgan. 2003. Population dynamics of exploited lake-dwelling brook trout (*Salvelinus fontinalis*). N. Am. J. Fish. Manage. 23:35-47.

Curry R.A., S.L. Currie, R. Saint-Laurent and L. Bernatchez. 2004. The reproductive ecology and genetics of multiple forms of rainbow smelt in Lake Utopia, New Brunswick. Environ. Biol. Fishes. In press.

Curry, R.A., D. Sparks and J. VandeSande. 2002. Movement patterns of a riverine population of brook trout. Trans. Amer. Fish. Soc. 131:551-560.

Hanson, S.D. and **R.A. Curry**. 2004. Effects of river herring management in the Saint John River, New Brunswick on trophic interactions with age-0 smallmouth bass. Trans. Amer. Fish. Soc. In press.

Jardine, T.D., **D.L. MacLatchy**, W.L. Fairchild, **R.A. Cunjak** and S.B. Brown. 2004. Stable isotopes of wild Atlantic salmon during smolt migration, and changes attributable to growth and metabolic turnover. Hydrobiologia. In press.

Rogers, S.M. and **R.A. Curry.** 2004. Evidence for a metapopulation structure in brook charr inhabiting a large river with potential anadromous forms: inferences from microsatellites. Trans. Amer. Fish. Soc. In press.

Endocrine Disruptors

Gilman, C.L., F.D.L. Leusch, W.C. Breckendridge and **D.L. MacLatchy**. 2003. Effects of a phytosterol mixture on male fish plasma lipoprotein fractions and P450scc activity. *Gen. Comp. Endocrinol.* 130:172-184.

Leusch, F.D.L. and **D.L. MacLatchy**. 2003. Implants of β-sitosterol impede cholesterol transfer across gonadal mitochondrial membranes isolated from male goldfish (*Carassius auratus*). *Gen. Comp. Endocrinol.* 134:255-263.

McMaster, M.E., J.J. Jardine, G.T. Ankely, W.H. Benson, M.S. Greeley, T.S. Gross, L.J. Guillette, Jr., **D.L. MacLatchy,** E.F. Orlando, G.J. Van Der Kraak and **K.R. Munkittrick.** 2001. An interlaboratory study on the use of steroid hormones in examining endocrine disruption. Environ. Toxicol. Chem. 20:2081-2087.

Munkittrick, K.R. 2001. Assessment of the effects of endocrine disrupting substances in the Canadian environment. Water Qual. Res. J. Canada. 36:293-302.

Sharpe, R.L., **D.L. MacLatchy**, S.C. Courtenay and G. J. Van Der Kraak. Effects of a model androgen (methyl testosterone) and a model anti-androgen (cyproterone acetate) on reproductive endocrine endpoints in a short-term adult mummichog (*Fundulus heteroclitus*) bioassay. Aquat. Toxicol. In press.

Van Der Kraak, G., M. Hewitt, A. Lister, M.E. McMaster and **K.R. Munkittrick**. 2001. Endocrine toxicants and reproductive success in fish. Human Ecol. Risk Assess. 7:1017-1025.

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Peake, S. and A.P.F. Farrell. 2004. Physiology and oxygen consumption in relation to swimming speed and gait transition in smallmouth bass (*Micropterus dolomieu*) following a voluntary ascent through an experimental raceway. J. Exp. Biol. In press.

Walker, D.R., R.G. Millar and **R.W. Newbury.** 2004. Energy profiles across constructed riffles. ASCE J. Hydraul. Eng. In press.

Forestry

Cunjak, R.A., **R.A. Curry,** K. Clarke and D.A. Scruton. 2004. Fish-forestry studies in Atlantic Canada. In *Fishes and Forests: an Approach to Fish-Forestry Interaction* (Eds., T.G. Northcote and G.F. Hartman). Blackwell Science. Oxford. p. 439-462.

Curry, R.A., D.A. Scruton and K.D. Clarke. 2002. The thermal regimes of brook trout, *Salvelinus fontinalis*, incubation habitats and evidence of changes during forestry operations. Can. J. For. Res. 32:1200-1207.

Heavy Metals

Culp, J.M., M.E. Wiseman, R.C. Bailey, N.E. Glozier, R.B. Lowell, T.B. Reynoldson, L. Trudel and G.D. Watson. 2003. New requirements for benthic community assessments at Canadian metal mines are progressive and robust: reply to Orr et al. SETAC Globe 4:31-32.

Friedman, A.S., E.K. Costain, **D.L. MacLatchy**, W. Stansley and E.J. Washuta. 2002. Effect of mercury body burden on general and reproductive health of largemouth bass (*Micropterus salmoides*) from three lakes in New Jersey. Ecotox. Environ. Saf. 52:117-122.

Glozier, N.E., **J.M. Culp**, T.B. Reynoldson, R.C. Bailey, R.B. Lowell and L. Trudel. 2002. Assessing metal mine effects using benthic invertebrates for Canada's Environmental Effects Program. Water Qual. Res. J. Canada. 37:251-278.

Irving, E.C., D.J. Baird, and **J.M Culp**. 2003. Ecotoxicological responses of the mayfly *Baetis tricaudatus* to dietary and waterborne cadmium: implications for toxicity testing. Environ. Toxicol. Chem. 22:1058-1064.

Swanson, H.K., T.A. Johnston, W.C. Leggett, R.A. Bodaly, R.R. Doucett and **R.A. Cunjak.** 2003. Trophic positions and mercury bioaccumulation in rainbow smelt (*Osmerus mordax*) and native forage fishes in northwestern Ontario lakes. Ecosystems. 6:289-299.

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Arndt, S.K.A., **R.A. Cunjak** and T.J. Benfey. 2002. Effect of summer floods and spatio-temporal scale on growth and feeding of juvenile Atlantic salmon in two New Brunswick streams. Trans. Amer. Fish. Soc. 131:607-622.

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Milner, A.M., M. W. Oswood and **K. Munkittrick**. 2004. Rivers of Hudson Bay drainage. In *Rivers of North America* (Eds. A.C. Benke and C.E. Cushing). Academic Press, San Diego, CA. In press.

Prowse, T.D. and **J.M. Culp**. 2003. Ice breakup: a neglected factor in river ecology. Can. J. Civ. Engin. 30:128-144.

Mesocosms

Culp, J. M., N.E. Glozier, K.J. Cash, M.G. Dubé, M. Waiser, **D.L. MacLatchy** and B.K. Firth. 2004. Cumulative effects investigation of pulp mill and sewage effluent impacts on benthic food webs: a mesocosm example. In *Proceedings, 5th Int. Conf. on Fate and Effects of Pulp Mill Effluents.* (Ed., D. Borton). DEStech Publications, Lancaster, PA. 10pp. In press.

Dubé, M.G., **J.M. Culp**, K.J. Cash, N.E. Glozier, **D.L. MacLatchy**, C.L. Podemski and R.B. Lowell. 2002. Artificial streams for environmental effects monitoring (EEM): Development and application in Canada over the past decade. Water Qual. Res. J. Canada. 37:155-180.

Dubé, M., **D. MacLatchy, J.M. Culp**, G. Gillis, R. Parker, S. Courtenay and C. Gilman. 2002. Utility of mobile, field-based artificial streams for assessing effects of pulp mill effluents on fish in the Canadian environmental effects monitoring (EEM) program. J. Aquat. Ecosyst. Stress Recov. 9:85-102.

Dubé, M.G., **D.L. MacLatchy**, B.K. Firrth, **J.M. Culp**, N.E. Glozier and K.J. Cash. 2004. Using mesocosms to explore confounding factors influencing longnose dace (*Rhinichthys cataractae*) responses to kraft mill effluent on the Wapiti river, AB, Canada. In *Proceedings, 5th Int. Conf. on Fate and Effects of Pulp Mill Effluents.* (Ed., D. Borton). DEStech Publications, Lancaster, PA. 10pp. In press.

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Cash, K.J., **J.M. Culp**, M.G. Dubé, R.B. Lowell, N.E. Glozier and R.B. Brua. 2004. Integrating mesocosm experiments with field and laboratory studies to generate weight-of-evidence risk assessments for ecosystem health. J. Aquat. Ecosys. Health Manage. In press.

Dubé, M.G. and **K.R. Munkittrick**. 2001. Integration of effect-based and stressor-based approaches into a holistic framework for cumulative effects assessment in aquatic ecosystems. Hum. Ecol. Risk Assess. 7:247-258.

Hewitt, L.M., M.G. Dubé, **J. Culp**, **D. MacLatchy** and **K.R. Munkittrick**. 2003. A proposed framework for investigation of cause in environmental effects monitoring. Hum. Ecol. Risk Assess. 9:195-211.

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