FRASER RIVER ACTION PLAN

PROCEEDINGS

RESEARCH PROGRAM WORKSHOP

NOV. 29-30, 1994
NORTH VANCOUVER, B.C.

DOE FRAP 1995-02

Environment Canada Environnement Canada

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Janet Landucci

Science Division
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October 1995

DISCLAIMER

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Abstract

The overall goals of the Fraser River Action Plan (FRAP) are to clean up pollution, restore the productivity of the natural environment, and put in place a management program to ensure the basin's sustainability. This seven-year plan, announced June 1, 1991 by the federal ministers of Environment and Fisheries and Oceans, is jointly managed by these two departments. The Department of Fisheries and Oceans (DFO) is primarily concerned with rebuilding salmon stocks and protecting fish habitat. Environment Canada (DOE) focusses on wildlife habitat, cleaning up the ecosystem and determining environmental quality or the health of the river.

Environment Canada's Environmental Quality Program supports a research network comprised of scientists from federal, provincial and university research communities. The objective of this component of FRAP is to define the health of the river and provide a baseline against which to measure efforts to curb pollution and to achieve sustainability. The effects of pollution on environmental quality are being examined and targets, or "ecosystem objectives," are being developed to guide pollution abatement efforts.

Research activities directed at supporting these goals are ongoing and focus on: (1) Basin-wide assessment of pollution impact on aquatic quality; (2) Assessment of environmental impacts of specific pollution sources; (3) Chemical criteria development; and (4) Ecosystem objectives development.

The workshop held on November 29-30, 1994 provided a forum for the scientists in the FRAP research program to present the progress and status of each project and to share preliminary research results. The material presented at this workshop is the subject of this report. The information has not been peer reviewed and caution is advised when interpreting the results.

Acknowledgements

The editor wishes to thank M. Church, J. Culp, B. Duncan, P. Harrison, L. Harding and M. Healey for chairing workshop sessions and all the participants for their contribution to the workshop and for providing abstracts, papers and presentation summaries. The professional services of Betsy Gordon of Gordon Enterprises in preparation of the manuscript is gratefully acknowledged.

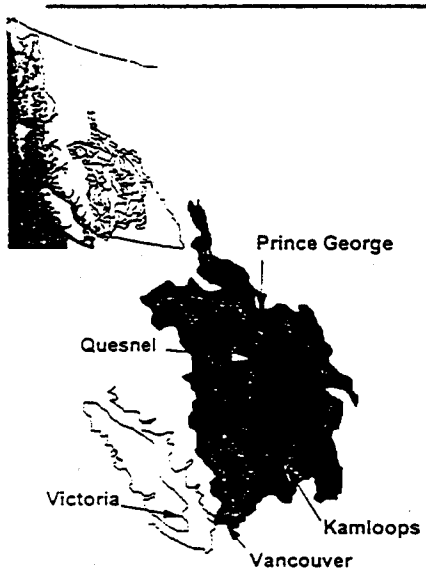
Overview of The Fraser River Action Plan Environmental Quality Progam

1. Introduction

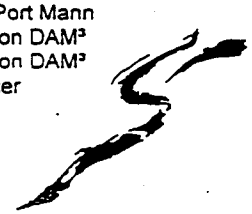
The Fraser River Action Plan is intended to demonstrate sustainable development in the Fraser River Basin. To do so, the Fraser River Action Plan (FRAP) will achieve three objectives:

- Develop a management program for sustainable development in the Fraser River Basin in partnership with the provincial and local governments and other stakeholders in the basin.
- Arrest and reverse the existing environmental contamination and degradation of the Fraser River ecosystem by developing targets and strategies to reduce pollution, and by substantially reducing the discharge of priority persistent toxic substances in the basin.
- Restore the productivity of the natural environment by restoring and enhancing environmental quality and the natural productive capacity of the Fraser River ecosystem.

The Fraser River Basin



- River Length 1,375 km
  - fifth longest river in Canada
- Drainage basin 234,000 km²
  - 1/4 of B.C.
- Population 1.8 million
  - 2/3 of B.C.
- Lower Fraser pop. 1.53 million
  - 84% of basin
- Avg. Annual Flow 3,972 m³/s
  - 3rd largest Canadian river
- Discharge at Port Mann (1965 - 1992)
  - lowest 621 m³/s
  - highest 14,800 m³/s
- Annual water yield at Port Mann
  - 1992 103 million DAM³
  - mean 114 million DAM³
- World's largest producer of salmon
- Breeding ground for 21 waterfowl species



2. Environmental Quality Program

Environment Canada's FRAP Environmental Quality Program is designed to contribute to the achievement of all three objectives by complementing the efforts of partners to assess the health of the river's ecosystem and measure the effectiveness of efforts to achieve sustainable use of the river.

Environment Canada's FRAP Environmental Quality Program is designed to contribute to answering questions such as:

- How healthy is the Fraser River's ecosystem?
- What is the baseline against which the sustained use and health of the river can be judged, now and in the future?
- What indicators do we have of the effects of pollution and its abatement, and other stresses on the river's aquatic ecosystem?

To assess the river's physical and biological health, now and in the future, an understanding of the river's ecosystem is needed. Although specific aspects of the Fraser River have been studied, when FRAP started little was known about the state of health of the Fraser River as a whole, or about the myriad interconnected ecosystems that make up the web of life in the river and basin. FRAP scientists are studying the river's ecosystem, and developing indicators to help measure the environmental health of the river.

To measure, assess and understand the Fraser River ecosystem in detail is impossible. It is too big and too complex. So Environmental Quality Program scientists have chosen to study selected physical and biological indicators of the health of the aquatic environment, the life forms that depend on it, and the effects of pollution or other stresses on the environmental health of the system. The knowledge and methods developed through these studies can be used to set environmental quality objectives against which the effects of human activity and other stresses on ecosystem health can be measured, and progress toward sustainable development can be assessed.

Environmental quality scientists are utilizing a suite of physical, chemical and biological measures to assess environmental health and specify criteria for decisions on environmental quality objectives. These include the physical and chemical characteristics of contaminants in water, sediments and air, and the condition and health of benthic, amphibian, fish and bird populations in the basin.

3. Environmental Quality Program Objectives and Deliverables

The objectives of Environment Canada's FRAP Environmental Quality Program are to:

1. Respond to client needs by developing, demonstrating and applying knowledge and methods in the Fraser River Basin to:
   - develop criteria, objectives and indicators of ecosystem health;
   - measure, assess and report on the health of the aquatic ecosystem;
   - determine and assess the effects of major sources of pollution stress, and their abatement, on the ecosystem; and
   - develop the capability to predict pollution problems.
2. Develop and strengthen partnerships with agencies in the province, other federal departments, academic institutes, NGOs and municipalities for program delivery.
3. Deliver the data and information to people working toward achievement of sustainable development in the Fraser Basin, particularly those working toward FRAP's objectives.
4. Contribute to informing the public about the Fraser Rivers Basin's ecosystem, and how its health can be sustained.

The following Environmental Quality Program deliverables were specified in the December 1993 Management Contract (based on DOE re-cast exercise)[1].

18. To provide new knowledge for environmental quality assessments and the development of objectives.
19. To measure and report on the condition of the basin.
20. To develop water quality objectives and criteria for contaminants of concern in the four main sub-regions of the basin.
21. To provide a provisional framework for developing ecosystem objectives.

22. To initiate a pilot project for ecosystem objectives.

23. To assess water quality relative to water quality objectives.

24. To assess contamination from major pollution sources.

25. To assess and report on the effectiveness of selected pollution abatements relative to the environment.

The Environmental Quality Program will also deliver communications and education tools such as fact sheets, reports and a video that contribute to the FRAP program deliverable of exposing 40% of the basin's population to the principles of sustainable development.

Further details on the Environmental Quality End-of-Program deliverables are shown in the attachment. The area column indicates whether the work is in research (R), assessment (A) or objectives (O).

4. Consultation, Contributors and Partners

Like FRAP's objectives, the successful achievement of the Environmental Quality Program objectives will require the advice, support and knowlege of many partners and experts. Consequently, the Environmental Quality Program has held consultation workshops to design the program, and has extensive intra- and extra-departmental agreements and working arrangements with universities, the Royal BC Museum, DFO, other federal and provincial departments, research institutes, and other regional branches of Environment Canada. This effort will continue to the end of FRAP.

The Environmental Quality Program contributors and partners have strengthened the program far beyond what Environment Canada could provide alone. Environment Canada will continue to rely on the efforts of those partners, contributors and contractors for the effective implementation of the Environmental Quality Program to achieve its objectives and deliverables.

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[1] Subsequent to the December 1993 Management Contract, the federal government has reduced budgets in response to fiscal concerns. Work plans and deliverables are being reviewed and are subject to amendment or termination.

DOE - Environmental Quality Program	FRASER RIVER DELIVERABLES	Draft Sept. 20, 1994
END-OF PROGRAM DELIVERABLE	**SPECIFIC RELATED DELIVERABLE**	**AREA**
3. Expose 40% of the basin's population to the principles of sustainable development.	1. Information on the Fraser Estuary ecosystem is communicated to the public through the publication and distribution of Discover Your Estuary book (1992) and the production of the Discover Your Estuary educational kit. (Dec/94)	A
	2. The public of the Salmon River Watershed (Salmon Arm) are exposed to sustainable development through a pilot project to develop ecosystem objectives.	O
	3. Results of the Environmental Quality Program are assessed, summarized and reported to the FBMP and public. (interim report: 1995)	AOR
18. Provide new knowledge for environmental quality assessments and the development of objectives.	1. BASIN-WIDE ASSESSMENT	
	1.1 Sediment Assessment	
	a) Sediment sources and deposition zones in the Fraser mainstem (Mar/94) & estuary (Dec/94) are determined.	A R
	b) Contamination baseline for suspended and settled sediments established.	A
	c) Sediment transport and settling process are identified.	R
	d) Suspended sediment and contamination plume interactions are described and modelled for the near field.	R
	e) Suspended sediment interactions with 2 representative contaminants described.	R
	1.2 Sentinel Species Development	
	a) Sentinel species for monitoring the contamination of the aquatic ecosystem developed with representative fish, amphibians, birds and mammals. (eg. Starry Flounder, Rocky Mountain Whitefish, Double Crested Cormorant, Spotted Frog, Osprey).	R
	b) Effects of contaminant exposure on these sentinel species are identified.	R
	c) Fish health indicator for resident fish developed.	A
	d) Biomarkers for contaminant exposure are developed for selected benthic organisms.	A
	1.3 Community Structure	
	a) A multivariate technique for predicting benthic population assemblages for impacted and non-impacted zones is developed for the Fraser above the estuary.	A
	b) Historical fish population structure is reviewed and compared with present populations.	R
	c) Primary and secondary benthic production on delta foreshore is measured and linkages to shorebird food webs is established.	R
	2. SPECIFIC POLLUTION SOURCE ASSESSMENT	
	2.1 Indicator Development	
	a) Chemical indicators of pulp mill contaminants on suspended sediment identified (Mar/95).	A
	b) Biochemical indicators of exposure to pulp mill effluents developed for selected biota e.g. Peamouth chub Osprey, swallows.	R
	c) Benthic and amphibian community indicators of exposure to non-point source contaminants from agriculture runoff developed.	R
	d) Benthic and amphibian community indicators of exposure to non-point source contaminants from urban run-off developed.	R
	e) Chemical indicators of urban air pollution identified in urban run-off and precipitation.	AR
	2.2 Identification of Effects	
	a) Effects of exposure to pulp mill effluents are identified for selected species of fish and aquatic based birds.	R
	b) Effects of STP and pulp mill effluent on microbial metabolism and benthic community structure are identified.	R
	2.3 Mesocosm Technology	
	a) Portable mesocosm technology developed to assess effects of complex contaminant sources (eg. Pulp Mill & STP effluent) on benthic communities.	R
	2.4 Predictive Models	
	a) Model to assess and predict transport and partitioning of selected contaminants among water, sediment and biota is developed.	R

A - Assessment, R - Research, O - Objective

DOE - Environmental Quality Program	FRASER RIVER DELIVERABLES	Draft Sept. 20, 1994
END-OF PROGRAM DELIVERABLE	**SPECIFIC RELATED DELIVERABLE**	**AREA**
	3. CRITERIA DEVELOPMENT 3.1 Toxicity Testing on Resident Biota. a) Toxicity of DDAC (Anti-sapstain chemicals) on aquatic organisms is assessed. b) Toxicity of 3 chlorophenols on eggs and early development of White Sturgeon is assessed. 3.2 Environmental Information Needs a) Methods for Analyzing low levels of DDAC in water developed (Mar/94).	 R R R
	4 ECOSYSTEM OBJECTIVE DEVELOPMENT 4.1 Information Management a) Development of GIS based tool for evaluating the effects of different land use scenarios on loading of contaminants	 R
19. Measure and report on the condition of the basin.	1. Through consultation with other parties, conceptual design developed for assessing the status of environmental quality in the basin and changes in quality due to abatement measures. (Jul/93)	A
	2. Historical and current information on environmental quality in the basin is summarized, published and distributed. (Jan/95)	A
	3. Report on Water Quality in the basin from 1985 to 1990 relative to trends, objectives and criteria. (Dec/94)	A
	4. Report on Water Quality in the basin from 1985 to 1996 relative to trends, objectives and criteria.	A
	5. Organochlorine contaminants in aquatic-based wildlife are assessed, summarized and reported (Oct/94)	R
	6. Reference collection of biological samples, and database of the collection, is developed for quality assurance. A report on the protocols published (Mar/95)	A
	7. All recent sources of information related to environmental quality in the basin are compiled in a bibliography. (Aug 92; Nov/94; Mar/97)	RA
	8. Historical and current data sets on organic contaminants in the basin are rated relative to data quality, indexed in a software system as a reference base (Mar/94) and summarized in two reports (May/94).	A
	9. Historical and current datasets of benthos data in the basin are rated relative to data quality, indexed in a software system as a reference base and summarized in a report. (Sept/94)	A
	10. Quality assurance/quality control documents on sampling and analysis are compiled in an inventory as a source of information for program design. (1993)	A
	11. Status report of environmental quality in the FREMP area is published based on Cycle I sampling in FREMP Water Quality Plan (Mar/96). Data report on water quality measured from Jan/93 to Mar/93 is published (Mar/94). Report on the water quality monitoring component from Jan/93 to Mar 94 published (Dec/94). Fish condition measured in 1994.	A
	12. Diversity and abundance of benthic invertebrates in the Salmon River (Salmon Arm) are measured and reported in support ecosystem objective pilot project. (Mar/96)	O
	13. Sediment quality in the basin is measured, assessed relative to historical data and reported.	A
	14. Benthos condition, measured by community structure and biochemical biomarkers is assessed and reported.	A
	15. Resident fish condition, based on contaminant content and other health indicators, is measured, assessed and reported.	AR
	16. Condition of sentinel species of aquatic-based birds is measured, assessed relative to historical data and reported.	R

A - Assessment, R - Research, O - Objective

DOE - Environmental Quality Program	FRASER RIVER DELIVERABLES	Draft Sept. 20, 1994
END-OF PROGRAM DELIVERABLE	SPECIFIC RELATED DELIVERABLE	AREA
	17. Results of the Environmental Quality Program are assessed, summarized and reported to the FBMP and public. (interim report: 1995)	ARO
20. Develop water quality objectives and criteria for contaminants of concern in the four main sub-regions of the basin in cooperation with BC Environment and other agencies. Plans for 1 and 2 are being confirmed with B.C.	1. Provisional water quality objective are formulated with the Province. i) Salmon River (Salmon Arm) Mar/95 ii) Fraser River from Moose Lake to Hope - Mar/95	O
	2. Water quality objectives are developed and reviewed for the following basins: i) Fraser River from Hope to the estuary ii) Thompson River iii) Nechako River	O
	3. Guidelines/criteria/objectives/toxicity information for contaminants of concern are reviewed and summarized. a. Existing guidelines/criteria/objectives are reported for contaminants of concern. (Oct/94) b. Water quality criteria for selected priority compounds of concern are developed where sufficient toxicity information exists. (The number of contaminants that can be completed is dependent on funding. Cost approximately $20.0K per contaminant if toxicity information exists. Pending Loop Group discussions.)	 O O
	4. Criteria for selected chemicals which are used or discharged in the Fraser Basin (e.g. DDAC, chlorinated phenolics are developed based on new toxicity information).(see 18.5)	R
21. Provide a provisional framework for developing ecosystem objectives.	1. Workshop held to provide direction for the formulation of ecosystem objectives in the Fraser River Basin and report published. (Sept/93)	O
	2. A strategic and communications plan is developed and implemented by the Ecosystem Objective Steering Committee to establish and test a process for formulating ecosystem objectives.	O
	3. A step by step process for developing ecosystem objectives is recommended. (Dec/96)	O
22. Initiate a pilot project for ecosystem objectives.	1. Historical stressors in the Salmon River Basin are identified and reported (Salmon Arm). (Sept/95)	O
	2. Ecosystem objectives are developed through a visioning workshop. (Sept/95)	O
	3. Ecosystem objectives are evaluated using information generated from knowledge base and interactive GIS for Salmon River (Salmon Arm) (Mar/96)	O
	4. Indicators selected for monitoring attainment of ecosystem objectives. (June/96)	O
	5. Pilot project is evaluated. (Dec/96)	O
23. Assess water quality relative to water quality objectives.	1. Status report of environmental quality in the FREMP area is published based on Cycle 1 sampling in FREMP Water Quality Plan (Mar/96). Data report on water quality measured from Jan/93 to Mar/93 is published (Mar/94). Report on water quality monitoring component from Jan/93 to Mar/94 published. (Dec/94)	A
	2. Report on Water Quality in the basin from 1985 to 1990 relative to trends, objectives and criteria. (Dec/94)	A
	3. Report on Water Quality in the basin from 1985 to 1996 relative to trends, objectives and criteria.	A
24. Assess contamination from major pollution sources.	1. The effects of pulp mill contaminants on the following media and biota in the Fraser Basin are measured and assessed: - suspended sediment (Dec 94, Mar 95, Mar 97) - benthos (using mesocosm) - resident fish - aquatic based birds.	 A R R R
	2. The effects of contaminants in STP effluent on microbial and benthic communities are identified at one site in the interior using mesocosm technology.	R

A - Assessment, R - Research, O - Objective

DOE - Environmental Quality Program	FRASER RIVER DELIVERABLES	Draft Sept. 20. 1994
END-OF PROGRAM DELIVERABLE	SPECIFIC RELATED DELIVERABLE	AREA
	3. The effects of waste water treatment or (heavy wood preservative) facilities on environmental quality are assessed at one lower-Fraser site. Source to be confirmed.	A
	4. The effects of contaminants in agricultural runoff in the Sumas basin on benthos, fish , amphibians and their communities are identified.	R
	5. The effects of contaminants from urban runoff in the Brunette River basin on benthos, fish amphibians and their communities are identified.	R
	6. The contribution of selected contaminants from atmospheric sources on contaminant levels in urban runoff is estimated .	AR
	7. Input of contaminants to basin headwater lakes through atmospheric input is evaluated and report is published.	AR
	8. River model developed (see 18.2.4) to assess and predict transport and partitioning among water, sediments, and biota of contaminants along the mainstem and major tributaries.	AR
25. Assess and report on the effectiveness of selected pollution abatements relative to the environment.	1. Pulp mill contaminants in sediment, water and biota in the Fraser basin receiving environments before and after pulp mill changes are measured (Dec/94; Mar/95; Mar/97)	A
	2. The effects of changes in agricultural activities on the aquatic environmental quality of the Sumas basin until 1996 are reported.	R
	3. River model available to test abatement options and implementation scenarios. Model also predicts clean up rate for sediment and biotic reservoirs of contaminants.	R
	4. Responses of benthic primary and secondary productivity on Sturgeon Bank to diversion of Iona Island STP effluent and secondary treatment at the Lulu Island STP are described.	R

A - Assessment, R - Research, O - Objective

INTRODUCTORY REMARKS

C. B. Gray
Environment Canada

The Research Program has been designed to support the Assessment and Objectives components of the Environmental Quality Program. Its major contributions will be in generating new knowledge on processes controlling the transport, fate, and effects of contaminants in our unique Fraser River ecosystem and delivering new tools for monitoring the status of this ecosystem after the Plan comes to an end in March 1997. It will also provide toxicology information for criteria development on selected chemicals and expertise for developing ecosystem objectives.

At the present time, 24 research projects are underway expanding our information in the knowledge gap themes listed on page xviii. In concert with the field investigations, many of the projects are also developing new assessment tools listed on the same page. While most project goals and activity plans were described at last year's workshop, the presentations today should be our first chance to see the kind of data that the researchers have been able to realize from those plans. In effect the results will reflect the efforts of the first full field season for most of the projects.

The underlying strategy of the whole program is to focus research activities at fewer locations and on a few over-riding processes (eg. suspended sediment dynamics) so that multidisciplinary teams can jointly create interdisciplinary projects. Accordingly, the second day of this workshop will be devoted to fostering this process. The expertise to undertake the program has been assembled from federal government research institutes in the departments of Environment and Fisheries & Oceans and from universities. Many of the projects depend on partnerships among these players.

About half the projects are clustered in 5 areas; upstream and downstream of Prince George & Kamloops, Sumas R., Brunette R., and the delta foreshore. Other projects investigate aspects of ecosystem structure and contamination at many locations throughout the basin. A comprehensive summary of the activities and outputs expected for each of the projects over the next three years is tabulated on pages xxi-xxv.

The 3 matrices on page xx illustrate the linkages that will occur among the studies evaluating specific media or trophic level with respect to the sources of contaminants, their transport & fate, and selected ecosystem attributes. This is just a preliminary view which only depicts the most obvious connections. Based on the number of studies in each matrix row, one can see that effects of pulp mill effluents, contaminant transport and modelling, and the identification of effects at different levels of biological organization are the dominant themes of the program.

I should touch on the time lines that need to be met for each major generic research and application activity if the knowledge products are to be used and described by the end of FRAP (page xix). To complete the analysis of data in a time that allows a proper synthesis of the knowledge, it will be essential that

the field projects are complete by the beginning of summer in 1996. (of course, some confirmatory sampling may occur as late as November) As a comprehensive synthesis of new and existing knowledge is required by the Environmental Quality Program by December 1996, initiating the process in September of 1995 should provide sufficient time for an exhaustive mining of the data. We plan to involve many of you in this essential task.*

At the end of the workshop there will a discussion of research gaps and the projects that could address them. I have provided a preliminary list of potential projects(page xix) that have been discussed by our Working Group or suggested to us by researchers in the program. It would be useful to identify and discuss other gaps during the breakout sessions tomorrow.

** In March 1995 FRAP resources were re-profiled and extended until March 1998. This has resulted in significant program adjustments including several cancellations. Details of the reprofiling are available upon request.*

Assessment & Objective Development Research Needs

- Knowledge Gaps:
  - Transport & fate of contaminants
  - Effects at individual, population & community levels
  - Structure and function of aquatic ecosystems
  - Biology of selected species
  - Toxicology of contaminants unique to the basin
  - Non-point source contaminants
- New Tools:
  - Sentinel species
  - Functional and structural indicators of ecosystem health
  - Mesocosm techniques
  - Predictive models of contaminant transport, fate and effect

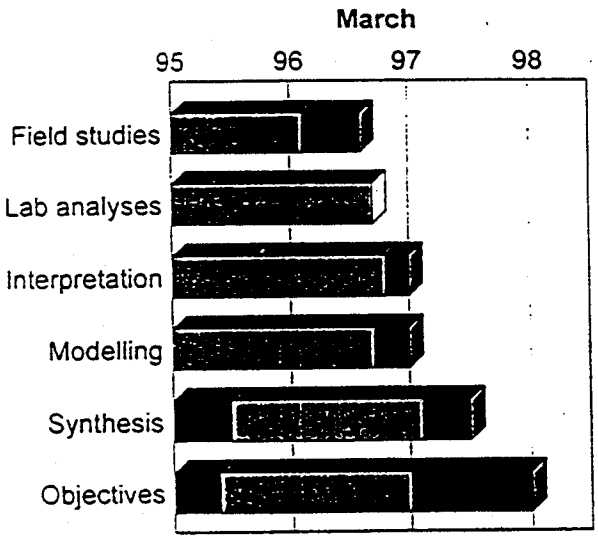
Strategy

- Multi-disciplinary → inter-disciplinary
- Biological effect focus
- Ecosystem context
- Research study nodes
- Partnerships
  - universities/ institutes
  - federal/ provincial
  - DOE/ DFO

Research Projects Supporting EQ Components

- Basin-wide assessment
  - 10 projects
- Chemical criteria development
  - 2 projects
- Specific pollution source assessment
  - 11 projects
- Ecosystem objectives development
  - 1 project

Program Time Lines



Potential New Projects

- MFO induction by particles (NWRI)
- Relative toxicity of PM effluents (NWRI/U.Guelph)
- Toxaphene in burbot (BCMELP/ DOE/ DFO)
- Relative toxicity of STP effluents (?)
- Dynamics of metals in the delta (SFU)
- Mesocosm for NPS assessment (UBC)
- DDAC/ IPBC survey (?)
- Contaminants in snow (?)

PROJECT LINKAGES

MEDIA/BIOTA	WATER/ SEDIMENT	ALGAE/BACTERIA	INVERTEBRATES	FISH	WILDLIFE
POLLUTION SOURCE					
PULP MILLS	- Sekela	- Culp *et al.*	- Culp *et al.*	- Munkittrick - Addison & Bandiera	- Whitehead
SEWAGE TREATMENT PLANT		- Harrison & Levings	- Harrison & Levings		
AGRICULTURE	- Hall & Schreier		- Hall & Schreier - Vadas	- Hall & Schreier - Vadas	- Orchard - Vadas
URBAN	- Hall & Schreier		- Hall & Schreier	- Hall & Schreier	- Orchard
SAWMILLS			- Farrell & Kennedy	- Farrell & Kennedy	
MINES					
ATMOSPHERIC	- Macdonald - Belzer				

MEDIA	SEDIMENT	SUSPENDED SEDIMENT	WATER	PRECIPITATION & DEPOSITION
ACTIVITY				
CONTAMINANTS	- Macdonald - Hall & Schreier	- Sekela		- Belzer
TRANSPORT	- Church - Krishnappan	- Lawrence - Church - Krishnappan	- Lawrence - Krishnappan	
TRANSFORMATION		- Krishnappan		
SEDIMENT/ CONTAMINANT		- Lawrence		
MODELLING	- Gobas - Krishnappan	- Gobas - Krishnappan - Lawrence	- Gobas - Lawrence	

BIOTA	ALGAE & BACTERIA	INVERTEBRATES	FISH	AQUATIC WILDLIFE
ATTRIBUTES				
PRODUCTION	- Culp *et al.* - Harrison & Levings	- Culp *et al.* - Harrison & Levings		
STRUCTURE		- Reynoldson *et al.* - Hall & Schreier - Vadas	- McPhail - Hall & Schreier - Vadas	- Orchard - Vadas
FOOD WEB LINKAGE		- Culp *et al.* - Harrison & Levings	- Vadas	- Sewell - Whitehead
SENTINEL SPECIES			- McPhail - Raymond	- Harding *et al.*
CONTAMINANTS	- Culp *et al.* - Harrison & Levings	- Levings & Richardson	- Raymond	- Whitehead *et al.*
EXPOSURE MEASUREMENT		- Reynoldson *et al.*	- Munkittrick *et al.* - Addison & Bandiera	- Whitehead *et al.*
EFFECTS Individual/Population/ Community	- Culp *et al.* - Harrison & Levings	- Reynoldson *et al.* - Hall & Schreier - Farrell & Kennedy	- Munkittrick *et al.* - Farrell & Kennedy - Hall & Schreier	- Whitehead *et al.*

ENVIRONMENTAL CONSERVATION BRANCH
SCIENCE DIVISION

FRASER RIVER ACTION PLAN - RESEARCH PROGRAM

DELIVERABLES	1994-1995 ACTIVITIES/OUTPUTS	1995-96 ACTIVITIES/OUTPUT	1996-97 ACTIVITIES/OUTPUTS
A. BASIN-WIDE ASSESSMENT OF POLLUTION IMPACT ON AQUATIC QUALITY			
1. Benthic Invertebrate Community Structure as an Indicator of Ecosystem Health (Reynoldson & Day NWRI) Deliverable #	1. Sampling at 50 sites 2. Develop method for sampling at mainstem sites 3. Continue development of functional toxicity tests 4. Conduct workshop	1.Sampling in mainstem and two watersheds 2. Submit benthic data sets	1. Conduct sampling on mainstem and repeat other sites 2.Submit benthic data sets
2. Fish Community Structure and Sentinel Species Development for tracking Aquatic Ecosystem Contamination (McPhail UBC & Slaney BC MOELP)) Deliverable #	1. Resampling of fish communities at established reference sites 2. Initiation of migration and feeding study of Rocky Mountain Whitefish in the upper Fraser	1.Continue life history and distribution studies of sentinel species 2.Radio telemetry , abundance , age and growth surveys completed	1. Complete tracking and tag recovery 2.Data analysis and recommendations 3. Distribution maps and life histories of all native species completed
3. Aquatic wildlife food-web interactions and sentinel species development Part A. Contaminant Sentinel Species Development 1. Estuarine Cormorant \Seasonal Movement Study (Whitehead DOE) Deliverable # 2. Estuarine Cormorant Food-Web Interactions (Butler, Whitehead DOE & Cheng UBC) Deliverable # 3. Sampling Candidate Sentinel Species (Whitehead & Elliot DOE) Deliverable # Part B. Food-web Interactions and Ecological Context Setting (Elner DOE & Cook SFU) Deliverable #	1. Place radios and monitor seasonal movements 2. Complete food preference study (Msc. Thesis Sullivan) 3. Complete Eagle Fieldwork 1. Estuarine Project 2. Upper Fraser Basin Project	1. Expand monitoring to daily movements during pre-nesting period 2. No furthur work 3: Report results; assess productivity	1. Continue monitoring and report results 3. Assess Productivity; report results

ENVIRONMENTAL CONSERVATION BRANCH
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FRASER RIVER ACTION PLAN - RESEARCH PROGRAM

DELIVERABLES	1994-1995 ACTIVITIES/OUTPUTS	1995-96 ACTIVITIES/OUTPUT	1996-97 ACTIVITIES/OUTPUTS
4. Transport and Sedimentation of Contaminants Part A. Field and Lab studies of Transport and Sedimentation (Church UBC) Deliverable #	1. Characterization of principal sources and sinks of fine grained sediment		
Part B. Suspended sediment and contamination plume interactions (Lawrence UBC) Deliverable #	1. Development of near field mixing model		
Part C. In River Flocculation Processes and Transport Characteristics (Krishnappan ,Engel, StephensNWRI) Deliverable #	1.Field experiments to determine the influence of pulp mill effluent on Fraser River sediment flocculation potential	1. Conduct large scale adsorption\desorption experiments in the laboratory	1.Conclude field and lab experiments 2. Recommendations for modelling suspended sediment \ contaminants
B. ASSESSMENT OF ENVIRONMENTAL EFFECTS OF SPECIFIC POLLUTION SOURCES			
1. Effects of Pulp Mill and Sewage Treatment Plant effluent on Benthic Communities (Culp , Cash & Wrona NHRI) Deliverable #	1. Establish a mesocosm facility at Prince George to assess effects of effluent on benthic communities		
2. Effects of Pulp Mill Effluent on Resident Fish Species in the Fraser and Thompson Rivers Part A. Development of Sentinel Species for Assessing Effects (Taylor,Waterloo;Munkittrick,GLLFAS; Hodson,NWRI;Gibbons,Waterloo) Deliverable #	1. Intensive sampling of sentinel fish species	1. Evaluation of temporal variability of fish responses 2. Define monitoring characteristics of sentinel species and effluent exposure markers	1. Development of Monitoring framework
Part B. Development of A Bio-chemical Assay for the induction of Cytochrome P450 1A1 as an indicator of exposure to Halogenated Hydrocarbons (Bandiera,UBC&Addison,IOS) Deliverable #	1. Identification of antibodies for routing exposure screening	1. Complete purification of fish cytochrome P450 1A1 2. Complete preparation of antibody against fish cytochrome P450 1A1	

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FRASER RIVER ACTION PLAN - RESEARCH PROGRAM

DELIVERABLES	1994-1995 ACTIVITIES/OUTPUTS	1995-96 ACTIVITIES/OUTPUT	1996-97 ACTIVITIES/OUTPUTS
3. Effects of Pulp Mill Contaminants on Aquatic Based Wildlife (Whitehead DOE) Deliverable #	1. Establish swallow bio-monitoring 2. Osprey reproduction and growth assessment in Kamloops and Quesnel	1. Report on monitoring sites in Prince George area (50 sites). Complete Year 2 of monitoring 2. Radio tag females from selected nests; assess productivity; sample eggs for toxics 3. * Sample River Otter & Mink for contaminants	1. No further work 2. Sample eggs for contaminants; monitor migration
4. Non Point Source Contaminant Impacts on Benthic Invertebrates and Fish Communities (Hall & Shreler UBC) Deliverable #	1. Intensive sampling of benthos and sediments in the Brunette and Sumas Rivers 2. Identification of stream reaches exposed to highest run-off from agricultural sources		
5. Non Point Source Contaminant Effects on Aquatic Based Wildlife (Harding, Elliot DOE & Orchard B.C. Museum) Deliverable #	1. Establish research transects in the Brunette and Sumas River basins and choose an appropriate suite of amphibian species as sentinels for contamination	1.Population monitoring and food web interaction study 2. Intensify assessment work of contaminant burden and population health	1. Apply techniques to upper basin
6. Assessment of Atmospheric Input of Heavy Metals and Persistent Organic Compounds to the Upper Drainage Basin (Macdonald & Paton IOS)	1. Analysis of lead, organochlorines, PAH's, and selected radionuclides in sediment cores collected in seven lakes completed	1. Sediment analyses completed	
7. Long Term response of Benthic Communities at Iona Is. after STP Diversion and status of Communities currently Exposed to Annacis and Lulu STP effluent (Harrison UBC & Levings DFO) Deliverable #	1. Establish research transects to evaluate primary and secondary production at Iona, Lulu and Westham Is.		

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FRASER RIVER ACTION PLAN - RESEARCH PROGRAM

DELIVERABLES	1994-1995 ACTIVITIES/OUTPUTS	1995-96 ACTIVITIES/OUTPUT	1996-97 ACTIVITIES/OUTPUTS
8. Modelling the Fate of Contaminant Discharges to Fraser River (Gobas SFU) Deliverable #	1. Develop model for predicting the partitioning of contaminants among water, suspended and settled sediment and biota	1. Complete preliminary model of combined hydrodynamic,sediment, chemical and biological fate 2. Complete model testing against field data	1. Simulation of specific abatement scenario; 2. Delivery of results and user-friendly model for predictive modelling
9.The Integrity of Analytes Stored Frozen Over Time (Hamilton UVIC) Deliverable #	1. Final Report Delivered June 1994		
C. CHEMICAL CRITERIA DEVELOPMENT			
1. Anti-Sapstain Toxicological Studies (Farrell & Kennedy SFU) Deliverable #	1. Invertebrate life cycle tests completed and species specific criteria proposed for DDAC	1. Fish reproduction fitness experiments completed 2. Ecological impacts of DDAC	1. Fate of DDAC in water\ sediment \ biota 2. Biological Effects
2. Chlorophenol Effects on the Early Development and Growth of White Sturgeon (Farrell & Kennedy SFU) Deliverable #	1. Establish experimental protocols for assessing pulsed exposure to a chlorinated quaiacol, a catechol, and vanillan	1. Completion of chlorophenolic testing on sturgeon eggs from California	1. Replication of experiments using Canadian White Sturgeon
D. ECOSYSTEM OBJECTIVES DEVELOPMENT			
1. Combining Simulation Models with GIS as a Decision Support System for Multi-Resource Conflict Resolution (Schreier,Brown, Wernick UBC) Deliverable #	1. Complete decision support system for the Salmon River with scenario simulation and community interaction	1.Apply techniques to a different watershed 2. Generate new GIS database	1.Refine model for application to roundtable framework
E. NEW PROJECTS			
1. Mesocosm Technology for Agricultural Impact Assessment Richardson (UBC) Deliverable #	1. Equip and set up portable mesocosm for assessing non-point Source impacts in small tributaries	1. Establish site for experiments in NPS contaminant impacts on benthic and small fish communities in the Sumas River Basin	1. Redo experiments on a site in the Brunette\Salmon(LFV or Shuswap) with different substrate and seed population characteristics

ENVIRONMENTAL CONSERVATION BRANCH
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FRASER RIVER ACTION PLAN - RESEARCH PROGRAM

DELIVERABLES	1994-1995 ACTIVITIES/OUTPUTS	1995-96 ACTIVITIES/OUTPUT	1996-97 ACTIVITIES/OUTPUTS
2. Transport, geochemical dynamics and food-web interactions of Metals in the Main Arm Bendell-Young (SFU) Deliverable #	1. Survey selected heavy metals in fractions of bed, suspended sediments and in biota	1. Determine benthic metal-uptake interactions	1. Incorporate onformation from field studies into assessment of contaminant fate and effects in the estuary
3. Particulate MFO -Induction potential Hodson, Krishnappan (NWRI) Deliverable #	1. Establish laboratory based fish mesocosm system for experiments to examine MFO induction with whole effluent, effluent partitions and natural river water	1. Continue Experiments in lab 2. Initiate field sampling	Incorporate experimental results into assessment of pulp mill effluent effects on resident fish
4. Ambient Concentrations & Fate of DDAC & IPBC Deliverable #	1. Establish sampling protocols for measuring DDAC & IPBC on particles and in solution in Fr. River receiving environments	1.Establish event related and background concentrations of DDAC & IPBC in the LFV sections of the Fraser River 2. Provide Analytical support to impact\mesocosm study	Document and Report on the sources, transport and fate of DDAC & IPBC in the Lower Fraser
5.. STP Impact Methodology Development Deliverable #	1. Investigate feasibility of sampling contaminants in water and suspended sediments in complex receiving environments (Eg. Annacis\Lulu outfalls)	Investigate and apply mesocosm technology to the assessment of STP effluent impacts	Complete mesocosm experiments and recommend regional application
6. Distribution of Toxaphene in Selected Top Predator Fish Deliverable #	1. Obtain samples of Burbot at selected sites	Analyze livers for toxaphene, other oc's & mercury	Extend sampling and analysis
7. Atmospheric Deposition of Contaminants Deliverable #	1. Snow sampling on North side of LFV	Expand snow sampling survey to entire Fraser Basin	Complete analyses and incorporate info with lon term trends discovered in lakecoring

SESSION 1

BASIN-WIDE ASSESSMENT OF POLLUTION IMPACT ON AQUATIC QUALITY

Transportation and Sedimentation of Fine Grained Sediments

M. Church

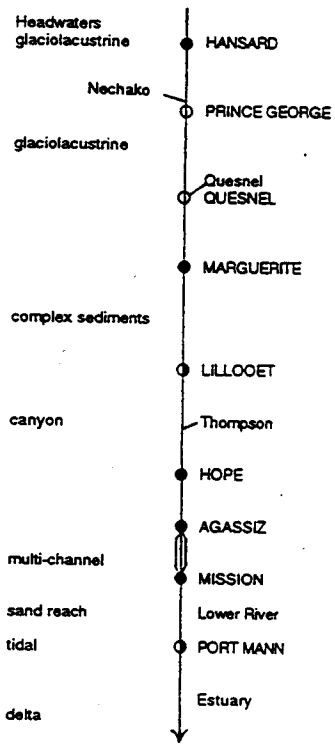
University of British Columbia

Objective

Mass balance model for fine sediment transfer in Fraser system.

Background

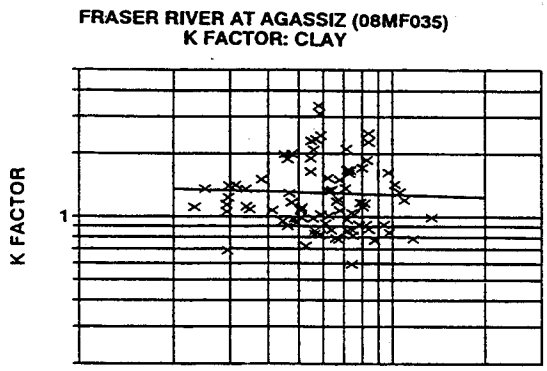
Water Survey of Canada maintained suspended sediment observing programs at 5 stations for 15-25 years.

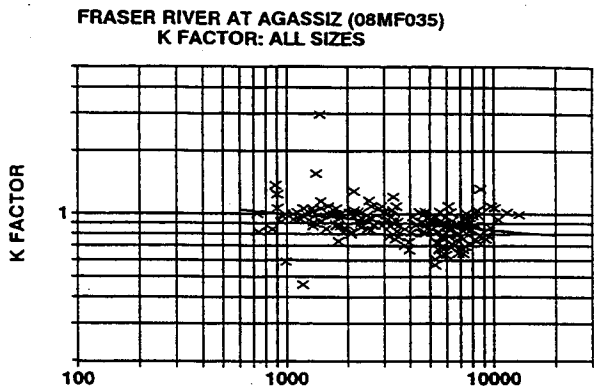


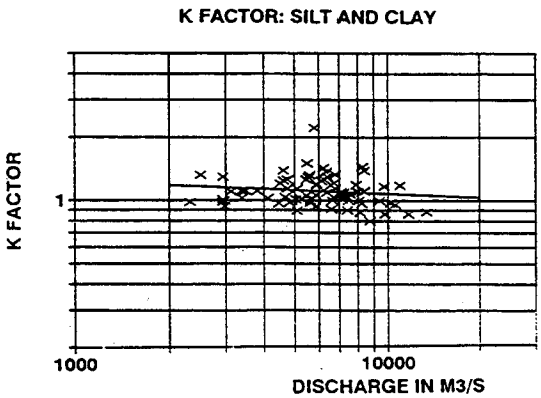
Analysis

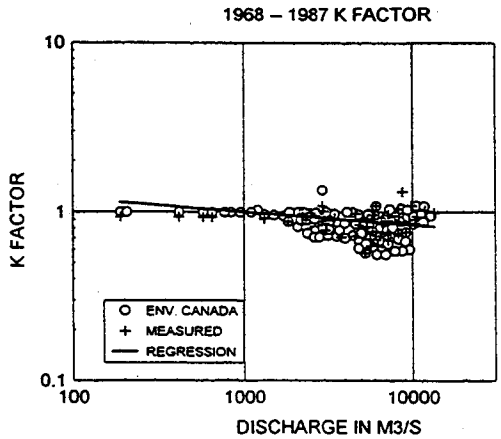
1) Verify observations
2) Construct ratings for stations
3) Compare reach mass balances with known sources and sinks
4) Link with dispersion models near sources
5) Compare mill fibre transport with clastic transport
6) Generalize model

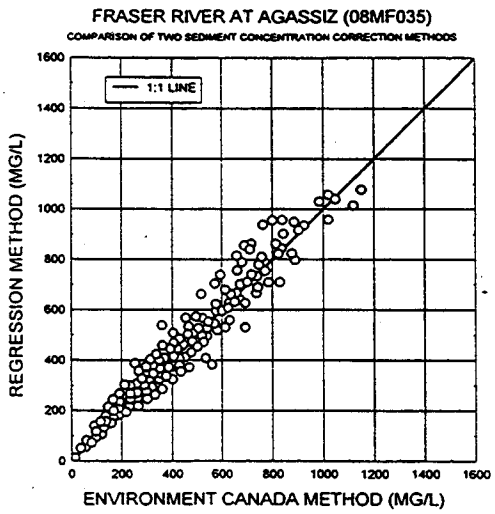
(The following overheads were presented.)

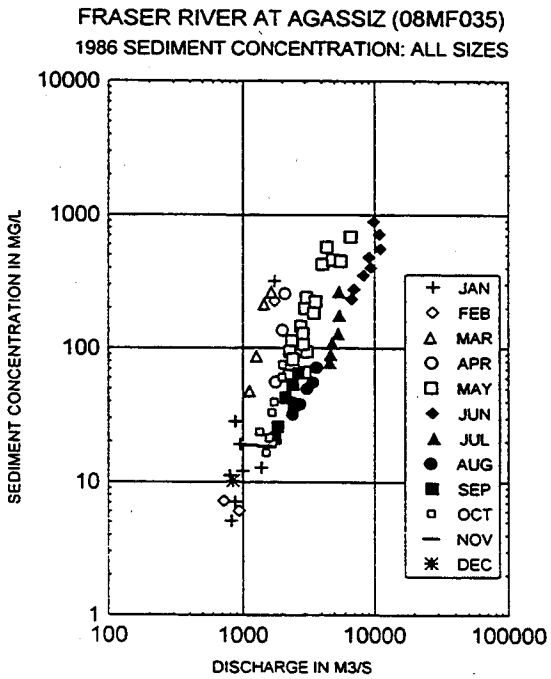

FRASER RIVER AT AGASSIZ (08MF035)
K FACTOR: CLAY
K FACTOR
1

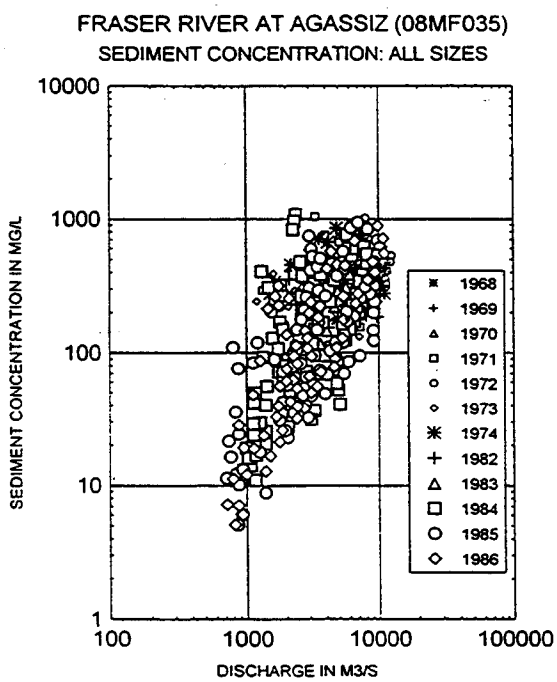

FRASER RIVER AT AGASSIZ (08MF035)
K FACTOR: ALL SIZES
K FACTOR
1
100
1000
10000


K FACTOR: SILT AND CLAY
K FACTOR
1
1000
10000
DISCHARGE IN M3/S


1968 – 1987 K FACTOR
K FACTOR
10
1
0.1
100
1000
10000
DISCHARGE IN M3/S
ENV. CANADA
MEASURED
REGRESSION

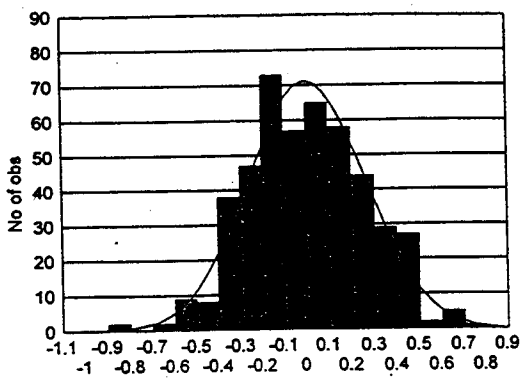

FRASER RIVER AT AGASSIZ (08MF035)
COMPARISON OF TWO SEDIMENT CONCENTRATION CORRECTION METHODS
1:1 LINE
REGRESSION METHOD (MG/L)
ENVIRONMENT CANADA METHOD (MG/L)
0
200
400
600
800
1000
1200
1400
1600


FRASER RIVER AT AGASSIZ (08MF035)
1986 SEDIMENT CONCENTRATION: ALL SIZES
SEDIMENT CONCENTRATION IN MG/L
DISCHARGE IN M3/S
10000
1000
100
10
1
100
1000
10000
100000
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC


FRASER RIVER AT AGASSIZ (08MF035)
SEDIMENT CONCENTRATION: ALL SIZES
SEDIMENT CONCENTRATION IN MG/L
DISCHARGE IN M3/S
10000
1000
100
10
1
100
1000
10000
100000
1968
1969
1970
1971
1972
1973
1974
1982
1983
1984
1985
1986

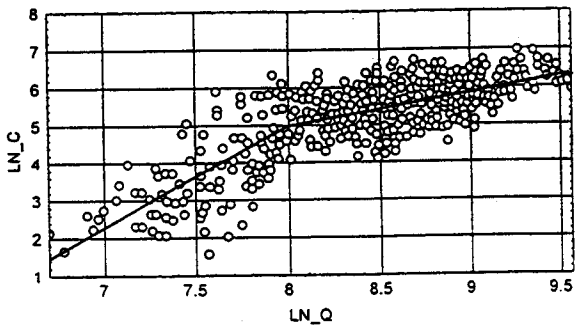
FRASER RIVER AT MISSION (08MF024)

Frequency Distribution: Residuals

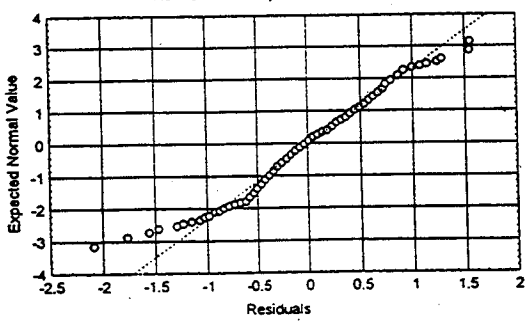


FRASER RIVER AT MISSION (08MH024)

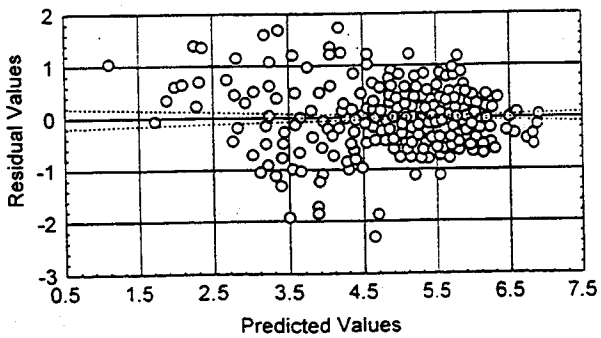
Model



Normal Probability Plot of Residuals



Predicted versus Residual Values



Development of Mixing Model

G. Lawrence, L. Gomm and J. Vine

University of British Columbia

The purpose of the research is to develop a model capable of predicting pollutant concentrations downstream of the pulp mill discharges. This model would include both the effects of jet mixing and turbulent diffusion as well as adsorption/desorption of the pollutant from the suspended sediment and/or flocculation of contaminated biosolids with sediment.

1. Near and Far Field Mixing Model

A near field jet mixing model has been developed based on laboratory experiments in a hydraulic flume. The purpose of this work was to investigate the influence of various factors on the initial dilution and trajectory of the discharge. Key factors influencing pulp mill discharges into rivers are buoyancy of the discharge and depth of the receiving water, with dilution being inhibited due to surfacing of the jet. Generally, the influence of a shallow free surface has been neglected when quantifying the behaviour of jets. Models predicting the mixing of river discharges should incorporate the presence of the free surface due to the relatively shallow depth. Empirical relationships have been developed for this near field mixing zone and will be incorporated into a far field mixing model.

For the far field model, initial work will focus on defining the geometry and flow of the river at each site. This will include defining cross-sectional shape (depth and width), slope, and using flow records available from Water Survey of Canada. Additional flow information may come from the UBC flow model available from Civil Engineering.

After definition of the geometry and parameters, work will focus on modelling the concentration distribution in the river. This will be attempted initially by using analytic solutions to the advective diffusion equation. Numerical solution may be attempted as well. The solution would also include the effect of suspended sediment acting as a sink/source of pollutant.

2. Association of Contaminants with Suspended Sediment

Pulp mill contaminants discharged into the Fraser River are found downstream associated with sediment and suspended sediment samples. There are various ways that these hydrophobic compounds can become associated with sediment in the river. One is sorption to the sediment from the water once discharged into the river. Another is sorption onto biological solids during treatment in the lagoons and subsequent flocculation of biosolids and sediment in the river.

Preliminary experiments carried out on Fraser River suspended sediment and pure compounds at neutral pH indicate that adsorption from the water compartment to the sediment in the river is minimal. Batch adsorption tests were done with DHA, tetrachloroguaiacol and 3,4,5-trichloroguaiacol. Given the characteristics of these compounds and the suspended sediment, minimal adsorption was expected. Therefore, another mechanism must be responsible: pulp mill biosolids.

Previous research done on the treatment of pulp mill effluent in aerobic lagoons indicates that part of the removal from solution is due to partitioning of the compounds to the biological solids (Amy *et al.*, 1988). Observed studies with both live and dead biomass resulted in removal of TOX and other hydrophobic compounds indicating that adsorption is a key process. Adsorption occurred rapidly with equilibrium within hours. As a result, a significant amount of the contaminants in the lagoon are associated with the solids.

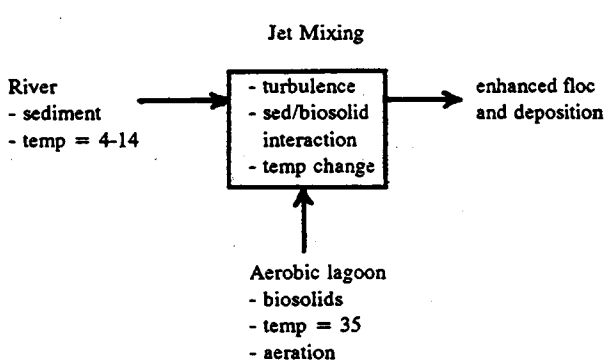
Under ideal conditions in the lagoon, these contaminated solids would flocculate and settle out in the bottom of the lagoon. This, of course, is not the case and some of these solids remain suspended and escape with the effluent. A study by Costa *et al.* (1980) indicated that 95% biosolids remained in suspension. Once in the river, these solids may interact with the river sediment, enhancing flocculation (as seen by Krishnappan), and eventually being deposited downstream. It has been shown as well, that these solids are consumed by lower forms of life, eventually

biomagnifying up the food chain to fish, birds and mammals.

Review of literature on bacteria, biosolids and colloidal chemistry indicates that there may be several factors influencing flocculation of biosolids. The following is a brief summary of some of these factors.

There are two theories as to what causes the colloidal stability of biosolids. The first is due to electrostatic forces and the second is due to stearic hindrance. In the former, it is believed that biosolids have a slight negative charge associated with them. This results in an electric double layer of opposite charge surrounding the biosolid. As like charges repulse, this layer inhibits flocculation of biosolids. The strength of this repulsion depends on the thickness of the double layer. If the layer is thin enough, the biosolids may be close enough that Van der Waal forces come into play and the particles floc. The thickness of the double layer is a function of many things, but the key one here is temperature. The higher the temperature, the thicker the layer. Therefore, in the lagoon where the temperature is 35°C, the biosolids are very repulsive and very stable. Once in the river, the cooler temperatures may be such that flocculation of the biosolids and biosolids/sediment can occur. In stearic hindrance, stability is due to the presence of compounds on the exterior of the biosolid. Stearic hindrance is also a function of temperature, decreasing as temperature decreases. Therefore, the same result.

Other than temperature, other factors that change from the lagoon to the river are the presence of suspended sediment and increased turbulence due to the jet mixing and river turbulence. Shear velocity (turbulence) is extremely important for flocculation. The greater the shear, the greater the probability of collision, up to a point. There is, of course, a point where if the shear is too strong, the flocs will break apart.



REFERENCES

Amy, G.L., C.W. Bryant, B.C. Alleman and W.A. Berkley, 1988: Biosorption of Organic Halide in a Kraft Mill Generated Lagoon. *J. Water Pollut. Control Fed.*, 60(8):1455.

Costa, H.S., J.J. McKeown and D.L. Borton, 1980: Fate of Suspended Biological Solids Discharged to Receiving Waters. *J. Water Pollut. Control Fed.*, 52(10):2432.

In River Flocculation Processes and Transport of Suspended Sediment

B.G. Krishnappan, P. Engel and R. Stephens

National Water Research Institute

1. Summary

In this presentation, the work carried out so far on flocculation and transport of suspended sediment in the Fraser River is described. The objective of the FRAP study is to quantify experimentally the transport parameters such as the critical shear stresses for erosion and deposition and the erosion and deposition rate functions that are needed for modelling the transport of the suspended sediment associated contaminants in the Fraser River system.

So far, we have carried out two field programs and one laboratory investigation. The first field program was carried out during October 1993 and it was done primarily to assess the extent of flocculation of the suspended particles in the upper reaches of the Fraser River near the pulp mills in the Prince George area. Flocculation was inferred by measuring the *in situ* size distribution using a submersible laser particle size analyzer and comparing it with the primary particle size distribution. The primary particle size distribution was measured in the laboratory after dispersing samples by sonication. The results from this survey showed that at a transect near Shelley (upstream transect), the suspended particles were transported in unflocculated form whereas at downstream transects and in the Nechako River they were transported in flocculated form.

In the laboratory investigation, the fine sediment deposited on the gravel bed in reaches upstream of the pulp mill was collected and brought to the laboratory in Burlington and was tested for transport parameters using a rotating flume. The influence of the pulp mill effluent was also tested. The results showed that the sediment had a tendency to flocculate when subjected to flow shear and the pulp mill effluent enhanced this flocculating tendency. The rotating flume experiments also provided quantitative information on erosion and deposition processes.

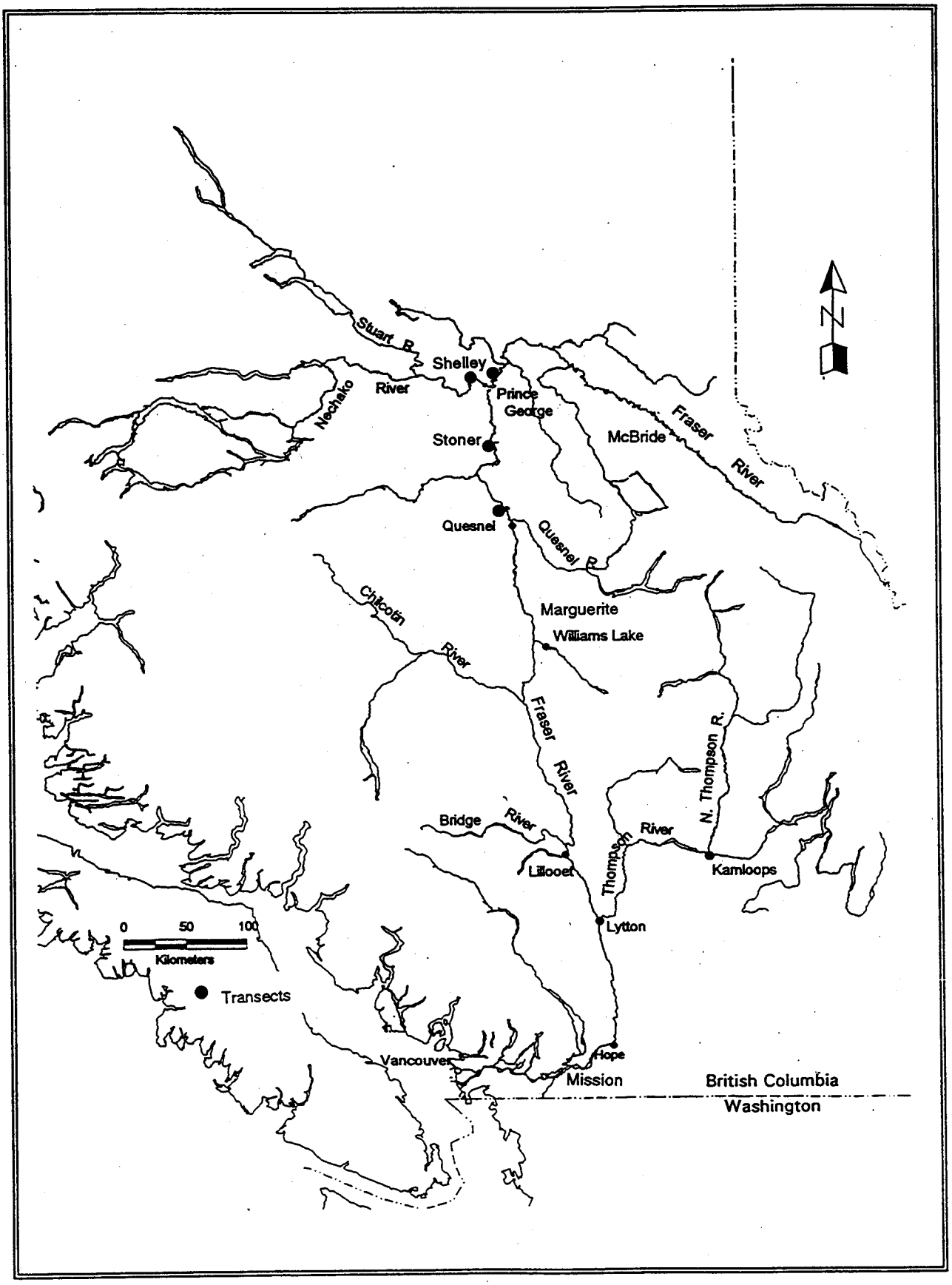
The second field program was carried out during 1994 October. This was a collaborative effort with Drs. Greg Lawrence and Michael Church of UBC. During this survey fourteen transects were sampled covering a long reach from Prince George to Mission. In the upstream reach near Prince George, a dense grid of transects was used to delineate the near field zone downstream of Northwood Pulp Mill outfall. Samples from this survey are still being analyzed but a preliminary examination of size distribution and concentration data in the near field zone shows the pulp mill effluent has promoted flocculation and has increased the sediment deposition rate.

2. Plans for Next Year

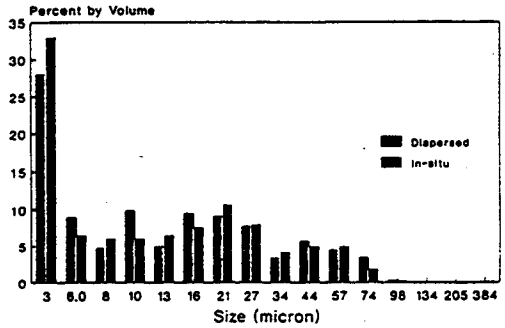
Continuation of rotating flume experiments to study the role of biosolids and field measurements in the estuary.

TABLE 1: Summary of Experimental Conditions

Test No.	Experiment Type	Shear Stress N/m^2	Initial Conc. mg/L	Age of deposit in hr.	Effluent Conc. % by vol.
1	Deposition	0.0563	200	n/a	0
2	Deposition	0.121	200	n/a	0
3	Deposition	0.169	200	n/a	0
4	Deposition	0.213	200	n/a	0
5	Deposition	0.0563	250	n/a	0
6	Deposition	0.121	250	n/a	0
7	Deposition	0.169	250	n/a	0
8	Deposition	0.213	250	n/a	0
9	Deposition	0.0563	250	n/a	3
10	Deposition	0.121	250	n/a	3
11	Deposition	0.169	250	n/a	3
12	Deposition	0.213	250	n/a	3
13	Erosion	n/a	n/a	114	0
14	Erosion	n/a	n/a	164	0
15	Erosion	n/a	n/a	40	2
16	Erosion	n/a	n/a	114	2

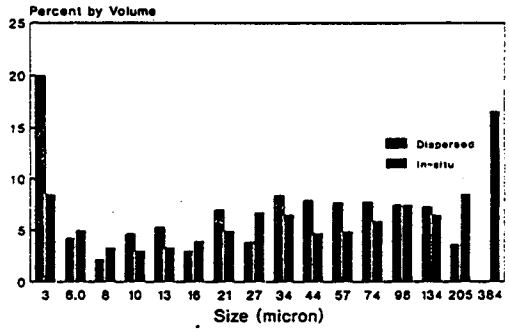

Stuart R.
Shelley
Prince George
Nechako River
Stoner
McBride
Fraser River
Quesnel
Quesnel R.
Chilcotin River
Marguerite
Williams Lake
Fraser River
N. Thompson R.
Bridge River
Lillooet
Thompson River
Kamloops
Lytton
0 50 100
Kilometers
Transects
Vancouver
Hope
Mission
British Columbia
Washington
N

Suspended Particle Size Distribution
Fraser River at Shelley



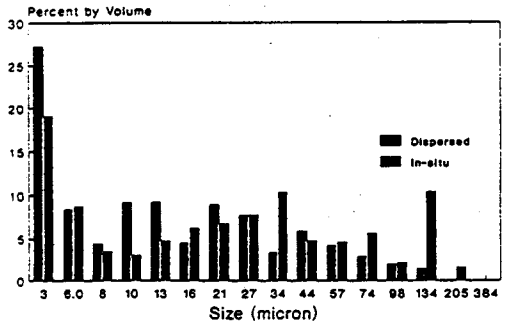
D50: in-situ=12; primary=12.3 (microns)

Suspended Particle Size Distribution
Nechako River at Prince George



D50: in-situ = 50; primary = 27 (microns)

Suspended Particle Size Distribution
Fraser River at Stoner



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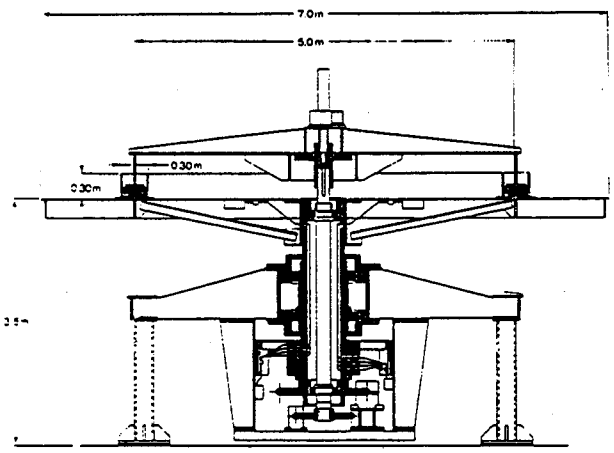
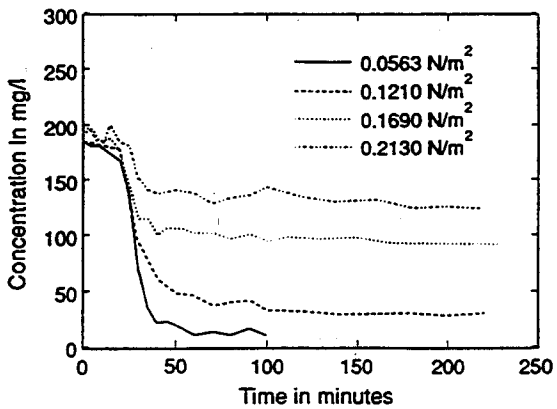
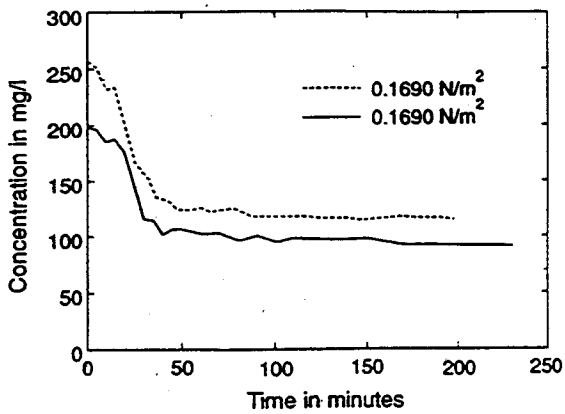
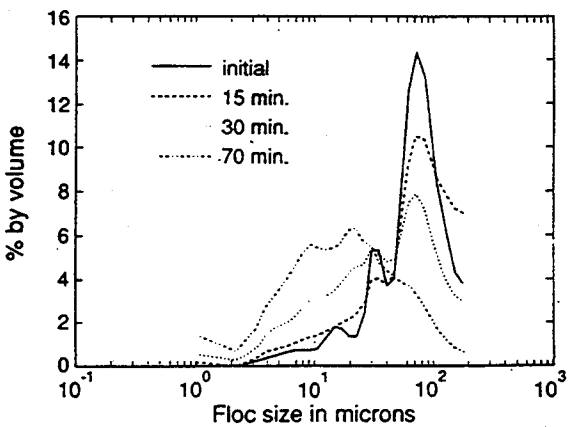




Variation of concentration for different shear stresses

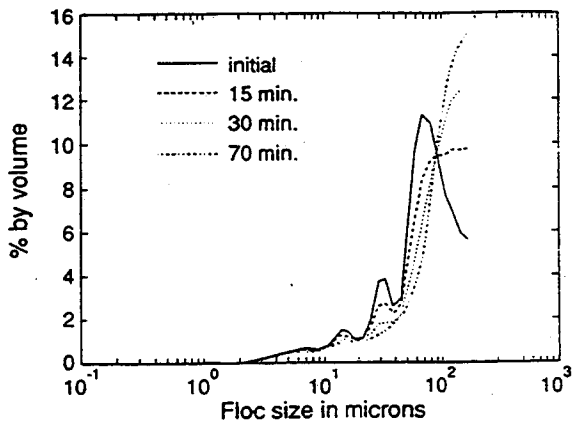


Variation of concentration for different initial concentrations



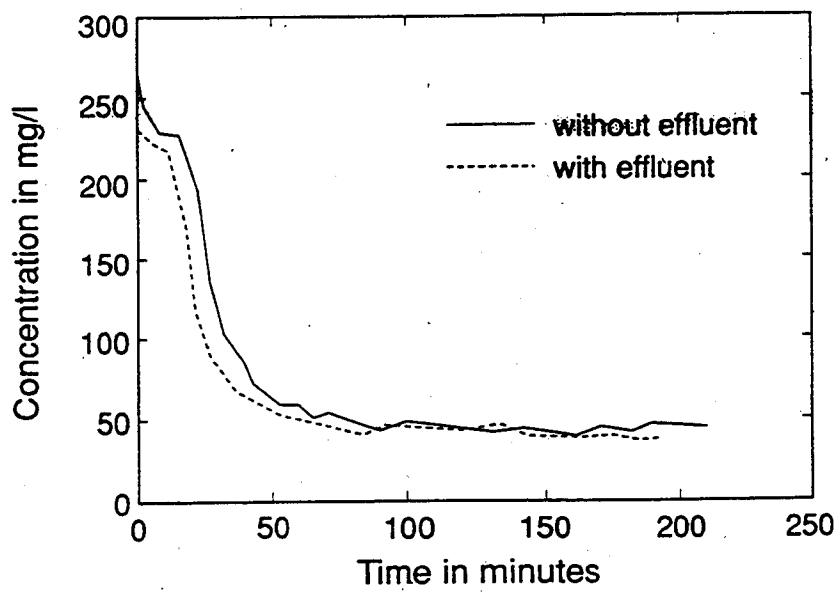
Size distribution of suspended sediment in Test No. 1

Initial concentration: 200 ppm
Bed shear stress: 0.0563 pascal

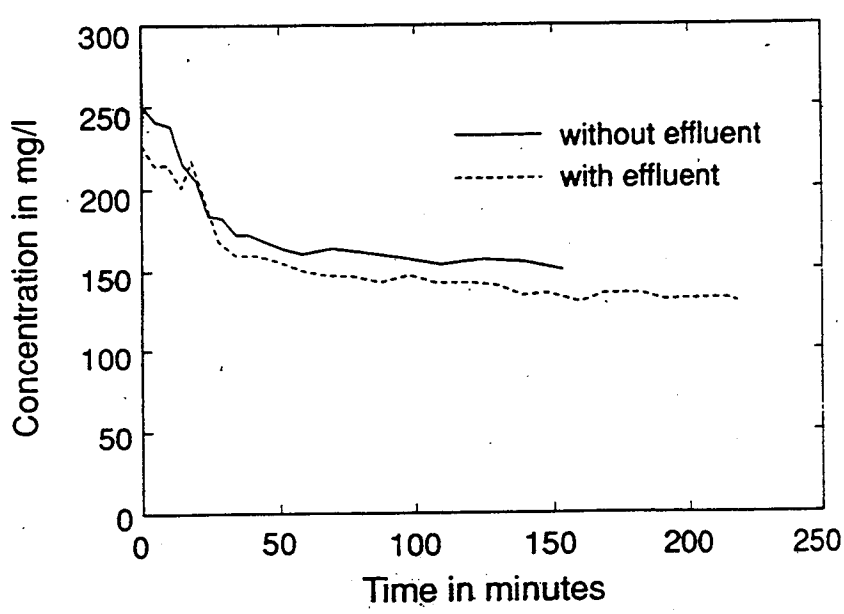


Size distribution of suspended sediment in Test No. 4

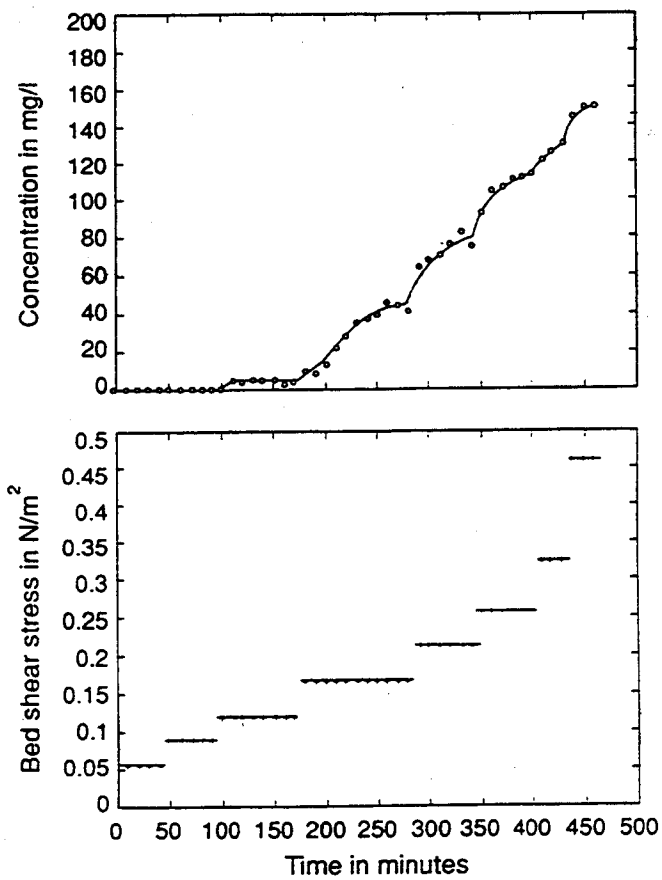
Initial concentration: 200 ppm
Bed shear stress: 0.213 pascal



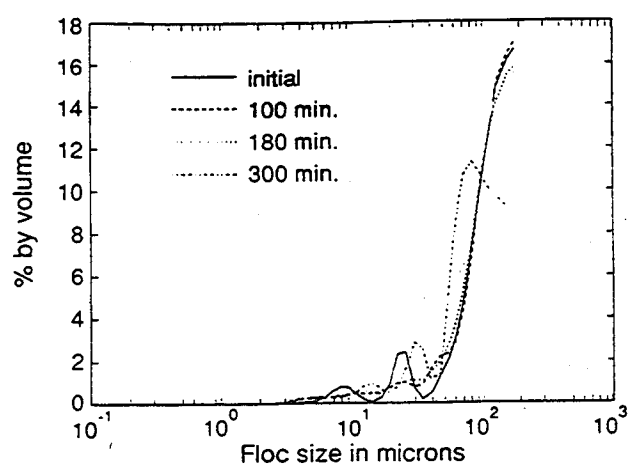
Effect of pulp mill effluent during deposition - shear stress = 0.121N/m^2



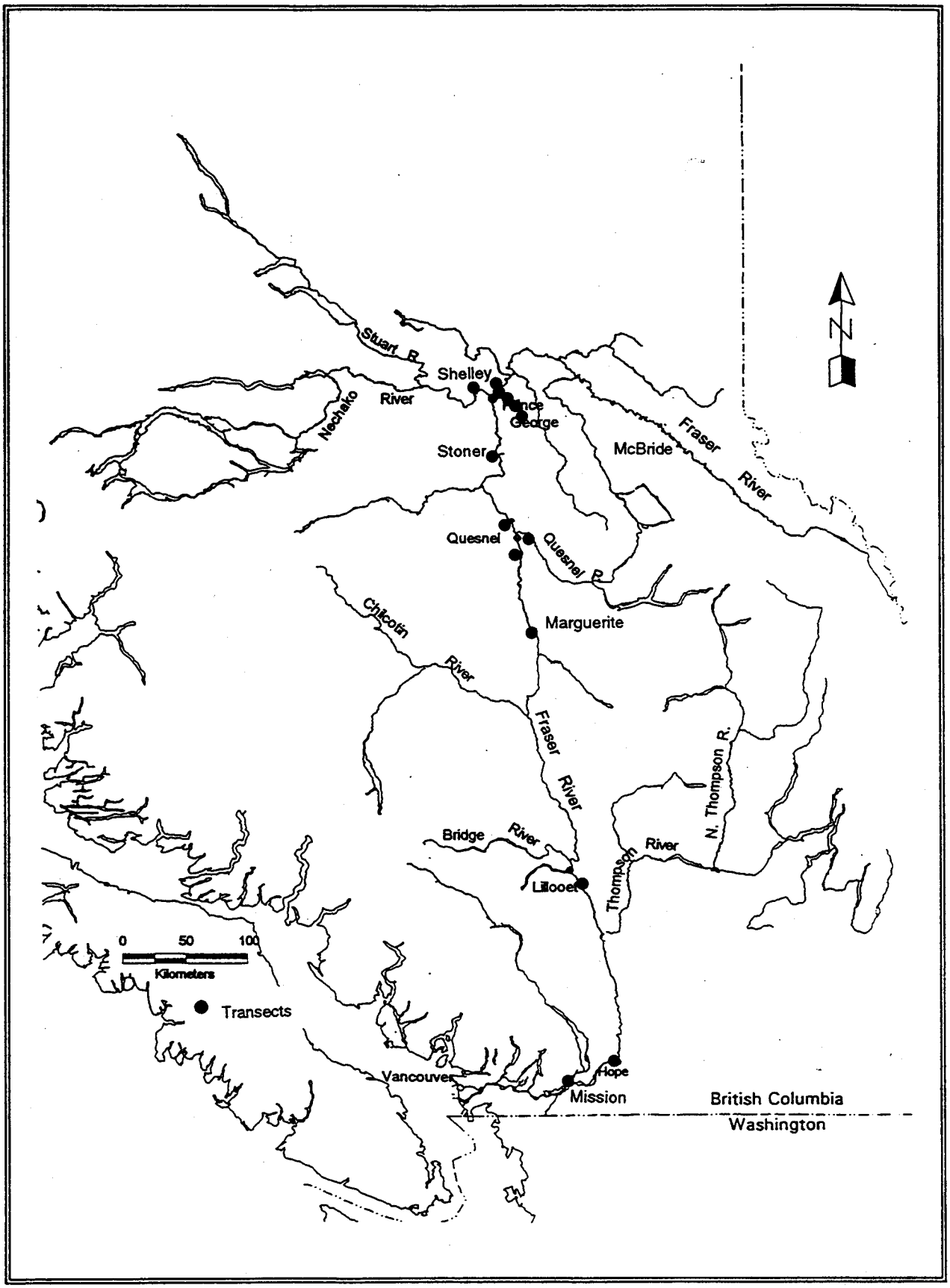
Effect of pulp mill effluent during deposition - shear stress = 0.213N/m^2



Erosion of Fraser River sediment - Age of deposit: 164 hours



Size distribution of suspended sediment in Test No. 14


Stuart R.
Shelley
Nechako
River
George
Stoner
McBride
Fraser
River
Quesnel
Quesnel R.
Chilcotin
River
Marguerite
Fraser
River
N. Thompson R.
Bridge
River
Thompson
River
Lillooet
0
50
100
Kilometers
Transects
Vancouver
Hope
Mission
British Columbia
Washington
N

MALVERN Series 2600 SB.09 Master Mode Mon 24 Oct 1994 8:05 am

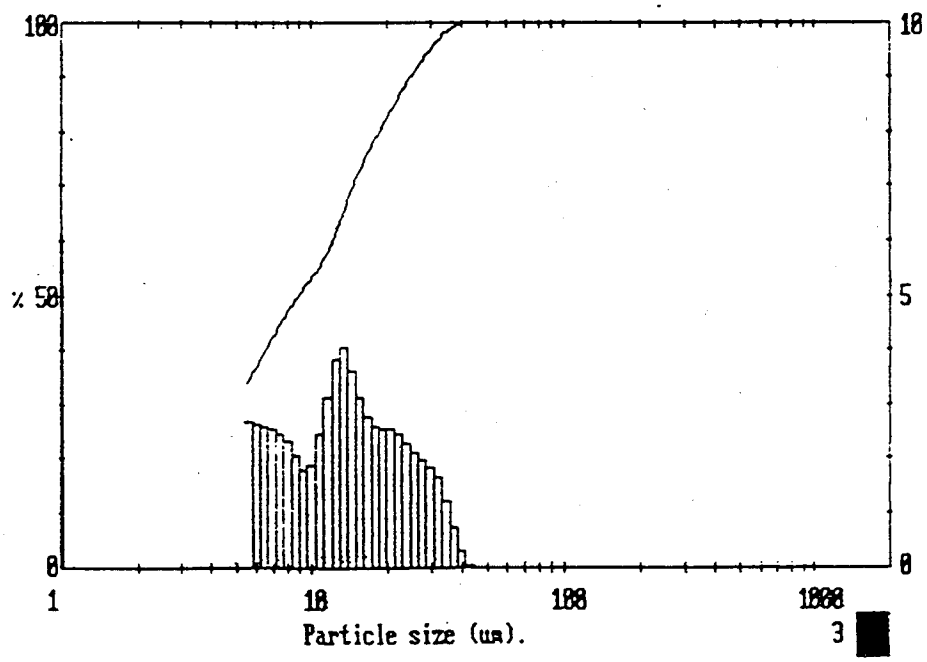
High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	Span 2.51
564	100	254	100	114	100	51.3	100	23.1	87.7	10.4	54.3	D[4,3] 11.25µm
524	100	236	100	106	100	47.7	100	21.4	85.2	9.64	52.4	
488	100	219	100	98.6	100	44.4	100	19.9	82.6	8.97	50.6	
454	100	204	100	91.7	100	41.2	100	18.5	80.0	8.34	48.5	D[3,2] 5.78µm
422	100	190	100	85.3	100	38.4	99.7	17.2	77.4	7.76	46.1	
392	100	176	100	79.3	100	35.7	98.9	16.0	74.6	7.21	43.7	
365	100	164	100	73.8	100	33.2	97.7	14.9	71.5	6.71	41.1	D[v,0.9] 24.81µm
339	100	153	100	68.6	100	30.8	96.0	13.9	67.8	6.24	38.5	
315	100	142	100	63.8	100	28.7	94.1	12.9	63.8	5.80	35.9	
293	100	132	100	59.3	100	26.7	92.1	12.0	59.9			D[v,0.1] 2.78µm
273	100	123	100	55.2	100	24.8	90.0	11.2	56.8			

Source = Res.:fraser94	Beam length = 10.0 mm	Model imdp	D[v,0.5] 8.79µm
Record No. = 4	Log. Diff. = 3.956		
Focal length = 300 mm	Obscuration = 0.6645	Volume Conc. = 0.0211%	
Presentation = pil	Volume distribution	Sp.S.A 1.0381 m²/cc.	

2560 pil lfu1479
Test data for 100 mm lens.

000000015

MALVERN Series 2600 SB.09 Master Mode Mon 24 Oct 1994 8:05 am



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Test data for 100 mm lens.

000000015

Upstream of Northwood outfall

MALVERN Series 2600 SB.09 Master Mode Mon 24 Oct 1994 8:12 am

High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	Span 2.59
564	100	254	100	114	100	51.3	99.7	23.1	76.7	10.4	43.8	D[4,3] 15.98µm
524	100	236	100	106	100	47.7	98.4	21.4	73.8	9.64	41.2	
488	100	219	100	98.6	100	44.4	96.4	19.9	70.5	8.97	38.7	
454	100	204	100	91.7	100	41.2	94.0	18.5	67.2	8.34	36.0	D[3,2] 8.06µm
422	100	190	100	85.3	100	38.4	91.4	17.2	64.0	7.76	33.0	
392	100	176	100	79.3	100	35.7	89.1	16.0	61.0	7.21	29.5	
365	100	164	100	73.8	100	33.2	87.1	14.9	57.9	6.71	25.8	D[v,0.9] 36.67µm
339	100	153	100	68.6	100	30.8	85.1	13.9	54.9	6.24	21.8	
315	100	142	100	63.8	100	28.7	83.3	12.9	52.0	5.80	17.9	
293	100	132	100	59.3	100	26.7	81.4	12.0	49.1			D[v,0.1] 4.92µm
273	100	123	100	55.2	100	24.8	79.2	11.2	46.4			

Source = Res.:fraser94	Beam length = 10.0 mm	Model indp	D[v,0.5] 12.28µm
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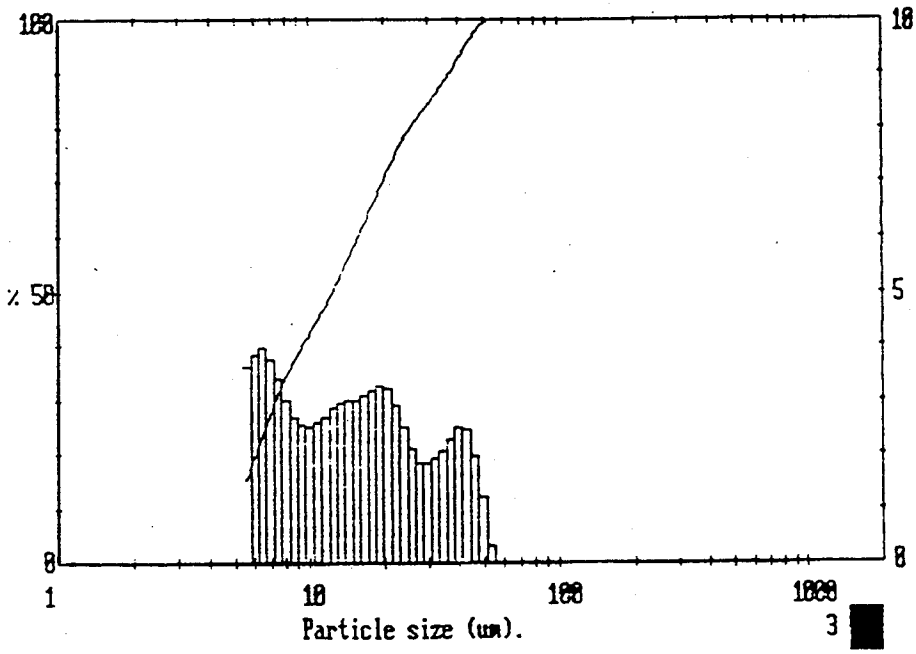
Presentation = pil	Volume distribution	Sp.S.A 0.7440 m²/cc.	

2560 pil lfu1479
Test data for 100 mm lens.

000000046

MALVERN Series 2600 SB.09 Master Mode Mon 24 Oct 1994 8:13 am



2560 pil lfu1479
Test data for 100 mm lens.

000000046

30 m d/s of outfall

MALVERN Series 2600 SB.09 Master Mode Mon 24 Oct 1994 8:17 am

High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	Span 3.49
564	100	254	96.4	114	96.4	51.3	87.8	23.1	63.1	10.4	34.0	D[4,3] 35.93µm
524	99.6	236	96.4	106	96.4	47.7	86.5	21.4	60.3	9.64	32.0	
488	99.1	219	96.4	98.6	96.4	44.4	84.9	19.9	57.5	8.97	30.2	D[3,2] 9.60µm
454	98.7	204	96.4	91.7	96.1	41.2	82.9	18.5	54.8	8.34	28.3	
422	98.3	190	96.4	85.3	95.5	38.4	80.8	17.2	52.1	7.76	26.3	
392	97.9	176	96.4	79.3	94.4	35.7	78.7	16.0	49.4	7.21	23.8	D[v,0.9] 62.07µm
365	97.5	164	96.4	73.8	93.0	33.2	76.3	14.9	46.6	6.71	21.0	
339	97.2	153	96.4	68.6	91.6	30.8	73.9	13.9	43.9	6.24	17.9	
315	96.9	142	96.4	63.8	90.4	28.7	71.4	12.9	41.2	5.80	14.8	D[v,0.1] 5.14µm
293	96.7	132	96.4	59.3	89.5	26.7	68.7	12.0	38.6			
273	96.5	123	96.4	55.2	88.7	24.8	65.9	11.2	36.2			

Source = Res.:fraser94
Record No. = 20
Focal length = 300 mm
Presentation = pil

Beam length = 10.0 mm
Log. Diff. = 3.554
Obscuration = 0.1804
Volume distribution

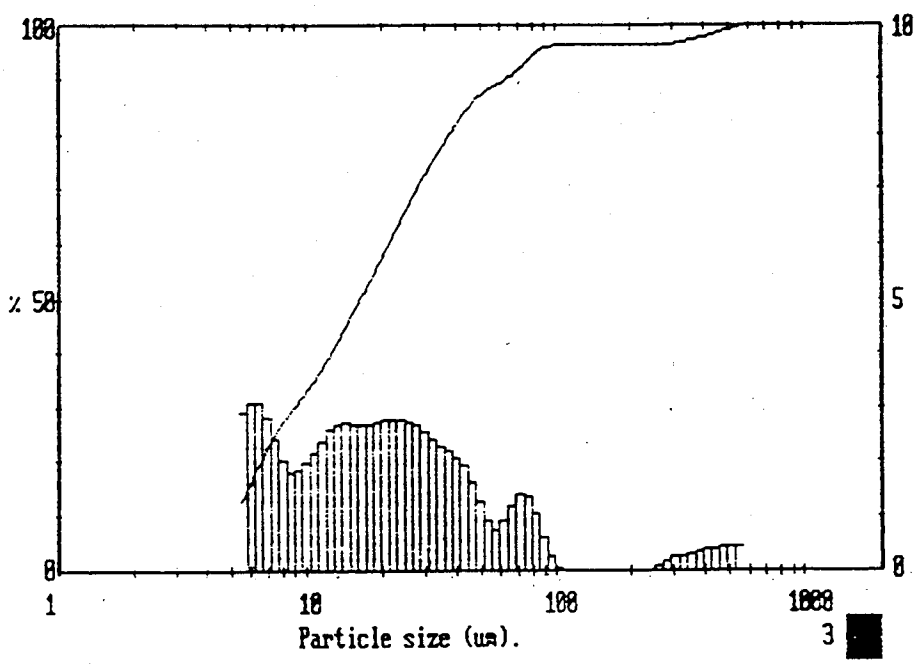
Model indp
Volume Conc. = 0.0064%
Sp.S.A 0.6248 m²/cc.

D[v,0.5] 16.32µm

2560 pil lfu1479
Test data for 100 mm lens.

000000070

MALVERN Series 2600 SB.09 Master Mode Mon 24 Oct 1994 8:17 am



2560 pil lfu1479
Test data for 100 mm lens.

000000070

100 m d/s of outfall

MALVERN Series 2600 SB.09 Master Mode Mon 24 Oct 1994 8:21 am

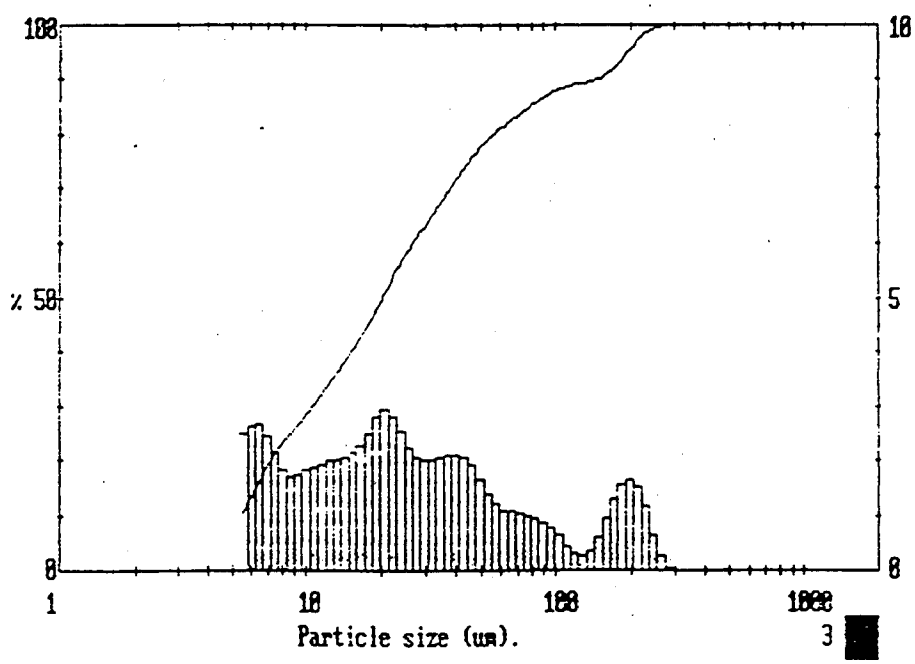
High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	Span 6.73
564	100	254	99.7	114	89.1	51.3	78.4	23.1	55.3	10.4	29.7	D[4,3] 42.58µm
524	100	236	99.0	106	88.7	47.7	76.7	21.4	52.5	9.64	27.8	
488	100	219	97.8	98.6	88.0	44.4	74.7	19.9	49.5	8.97	26.1	
454	100	204	96.2	91.7	87.2	41.2	72.6	18.5	46.7	8.34	24.4	D[3,2] 11.00µm
422	100	190	94.5	85.3	86.3	38.4	70.5	17.2	44.2	7.76	22.5	
392	100	176	93.0	79.3	85.3	35.7	68.4	16.0	41.9	7.21	20.3	
365	100	164	91.6	73.8	84.3	33.2	66.3	14.9	39.7	6.71	17.8	D[v,0.9] 141.25µm
339	100	153	90.6	68.6	83.2	30.8	64.2	13.9	37.6	6.24	15.1	
315	100	142	90.0	63.8	82.2	28.7	62.2	12.9	35.6	5.80	12.5	
293	100	132	89.7	59.3	81.0	26.7	60.1	12.0	33.6			D[v,0.1] 5.40µm
273	99.9	123	89.4	55.2	79.8	24.8	57.9	11.2	31.6			

Source = Res.:fraser94	Beam length = 10.0 mm	Model indp	D[v,0.5] 20.18µm
Record No. = 26	Log. Diff. = 2.401		
Focal length = 300 mm	Obscuration = 0.0704	Volume Conc. = 0.0027%	
Presentation = pil	Volume distribution	Sp.S.A 0.5453 m²/cc.	

2560 pil lfu1479
Test data for 100 mm lens.

000000094

MALVERN Series 2600 SB.09 Master Mode Mon 24 Oct 1994 8:21 am



2560 pil lfu1479
Test data for 100 mm lens.

000000094

300 m d/s of outfall

MALVERN Series 2600 SB.09 Master Mode Mon 24 Oct 1994 8:30 am

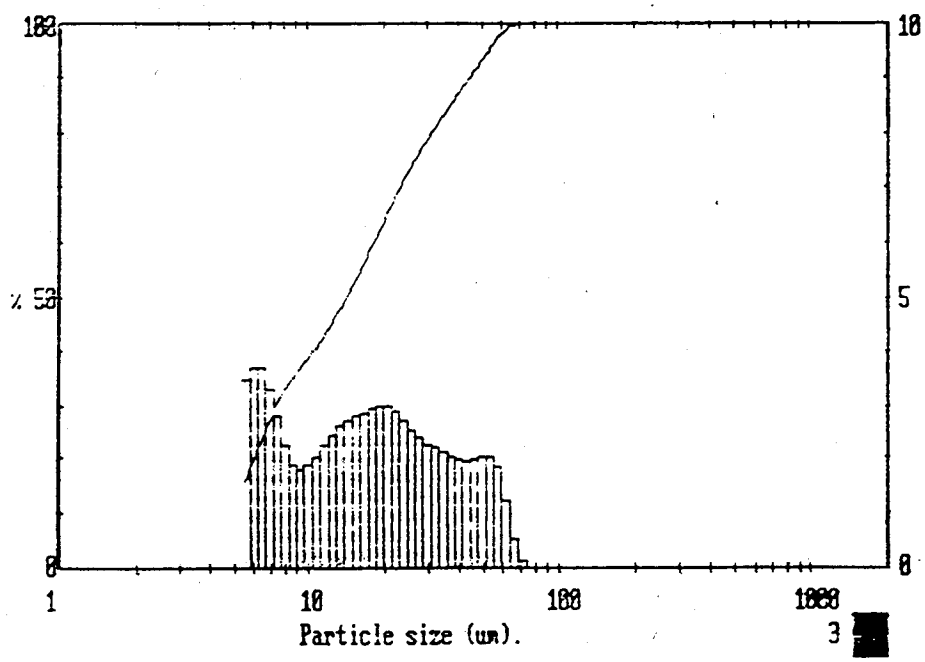
High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	Span 2.78
564	100	254	100	114	100	51.3	94.2	23.1	69.7	10.4	40.0	D[4,3] 18.80µm
524	100	236	100	106	100	47.7	92.2	21.4	66.8	9.64	38.1	
488	100	219	100	98.6	100	44.4	90.2	19.9	63.8	8.97	36.2	
454	100	204	100	91.7	100	41.2	88.2	18.5	60.6	8.34	34.3	D[3,2] 8.35µm
422	100	190	100	85.3	100	38.4	86.2	17.2	57.8	7.76	32.1	
392	100	176	100	79.3	100	35.7	84.2	16.0	55.0	7.21	29.3	
365	100	164	100	73.8	100	33.2	82.0	14.9	52.1	6.71	25.9	D[v,0.9] 44.06µm
339	100	153	100	68.6	99.9	30.8	79.8	13.9	49.4	6.24	22.2	
315	100	142	100	63.8	99.3	28.7	77.5	12.9	46.7	5.80	18.5	
293	100	132	100	59.3	98.1	26.7	75.1	12.0	44.2			D[v,0.1] 4.84µm
273	100	123	100	55.2	96.3	24.8	72.5	11.2	42.0			

Source = Res.:fraser94	Beam length = 30.0 mm	Model indp	D[v,0.5] 14.10µm
Record No. = 38	Log. Diff. = 3.505		
Focal length = 300 mm	Obscuration = 0.2815	Volume Conc. = 0.0031%	
Presentation = pil	Volume distribution	Sp.S.A 0.7183 m²/cc.	

2560 pil lfu1479
Test data for 100 mm lens.

000000132

MALVERN Series 2600 SB.09 Master Mode Mon 24 Oct 1994 8:30 am



2560 pil lfu1479
Test data for 100 mm lens.

000000132

1000 m d/s of outfall

MALVERN Series 2600 SB.09 Master Mode Mon 24 Oct 1994 9:08 am

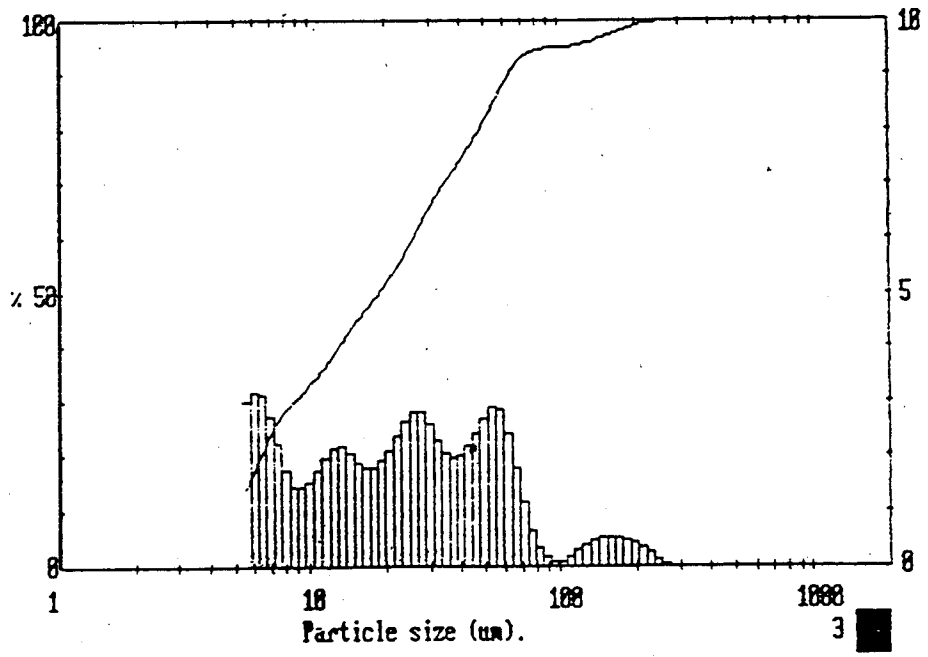
High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	Span 3.02
564	100	254	100	114	95.5	51.3	82.7	23.1	56.1	10.4	33.8	D[4,3] 30.37µm
524	100	236	99.8	106	95.3	47.7	80.0	21.4	53.7	9.64	32.3	
488	100	219	99.6	98.6	95.2	44.4	77.6	19.9	51.5	8.97	30.8	
454	100	204	99.2	91.7	95.1	41.2	75.4	18.5	49.6	8.34	29.3	D[3,2] 9.59µm
422	100	190	98.7	85.3	95.0	38.4	73.4	17.2	47.8	7.76	27.6	
392	100	176	98.2	79.3	94.6	35.7	71.4	16.0	46.0	7.21	25.3	
365	100	164	97.7	73.8	93.9	33.2	69.3	14.9	44.1	6.71	22.6	D[v,0.9] 61.87µm
339	100	153	97.2	68.6	92.7	30.8	67.0	13.9	42.0	6.24	19.4	
315	100	142	96.6	63.8	90.9	28.7	64.4	12.9	39.8	5.80	16.3	
293	100	132	96.2	59.3	88.5	26.7	61.6	12.0	37.6			D[v,0.1] 4.97µm
273	100	123	95.8	55.2	85.7	24.8	58.7	11.2	35.6			

Source = Res.:fraser94	Beam length = 80.0 mm	Model indp	D[v,0.5] 18.84µm
Record No. = 91	Log. Diff. = 3.271		
Focal length = 300 mm	Obscuration = 0.3299	Volume Conc. = 0.0016%	
Presentation = pil	Volume distribution	Sp.S.A 0.6256 m²/cc.	

2560 pil lfu1479
Test data for 100 mm lens.

000000300

MALVERN Series 2600 SB.09 Master Mode Mon 24 Oct 1994 9:08 am



2560 pil lfu1479
Test data for 100 mm lens.

000000300

Hope

MALVERN Series 2600 SB.09 Master Mode Mon 24 Oct 1994 9:13 am

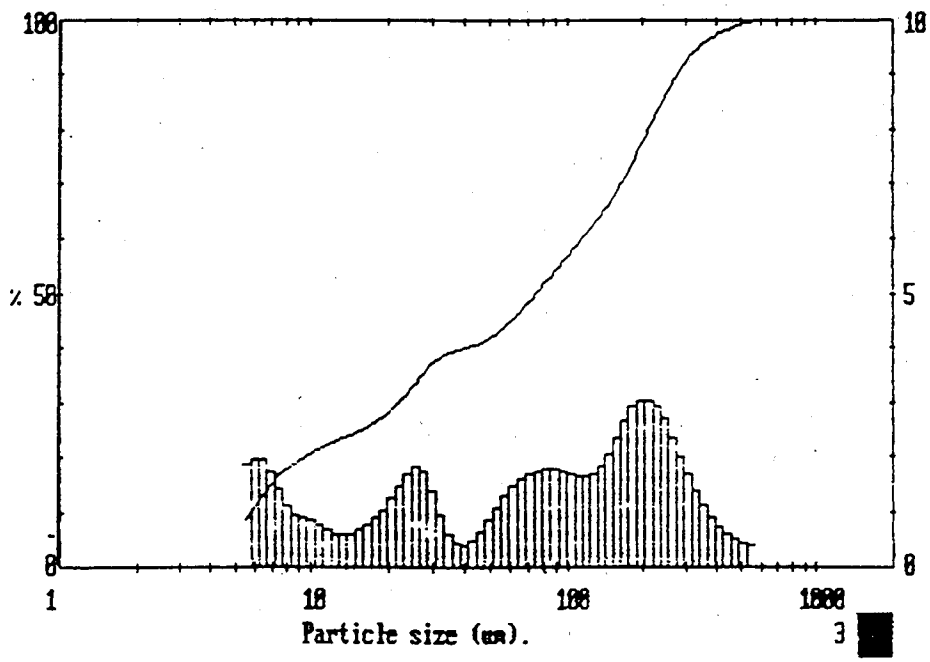
High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	High Size	Under %	Span 3.58
564	100	254	87.6	114	60.4	51.3	42.4	23.1	31.0	10.4	21.4	D[4,3] 112.57µm
524	99.6	236	84.9	106	58.7	47.7	41.5	21.4	29.5	9.64	20.5	
488	99.2	219	81.9	98.6	56.9	44.4	40.8	19.9	28.2	8.97	19.6	
454	98.7	204	78.8	91.7	55.1	41.2	40.3	18.5	27.2	8.34	18.6	D[3,2] 15.58µm
422	98.0	190	75.8	85.3	53.3	38.4	39.9	17.2	26.3	7.76	17.5	
392	97.3	176	72.8	79.3	51.5	35.7	39.4	16.0	25.5	7.21	16.0	
365	96.3	164	70.1	73.8	49.7	33.2	38.8	14.9	24.8	6.71	14.2	D[v,0.9] 272.81µm
339	95.2	153	67.7	68.6	48.0	30.8	37.8	13.9	24.1	6.24	12.3	
315	93.7	142	65.6	63.8	46.4	28.7	36.5	12.9	23.5	5.80	10.3	
293	92.0	132	63.7	59.3	44.8	26.7	34.7	12.0	22.9			D[v,0.1] 5.74µm
273	90.0	123	62.0	55.2	43.5	24.8	32.8	11.2	22.2			

Source = Res.:fraser94	Beam length = 80.0 mm	Model indp	D[v,0.5] 74.59µm
Record No. = 98	Log. Diff. = 3.581		
Focal length = 300 mm	Obscuration = 0.2273	Volume Conc. = 0.0017%	
Presentation = pil	Volume distribution	Sp.S.A 0.3851 m²/cc.	

2560 pil lfu1479
Test data for 100 mm lens.

000000321

MALVERN Series 2600 SB.09 Master Mode Mon 24 Oct 1994 9:13 am



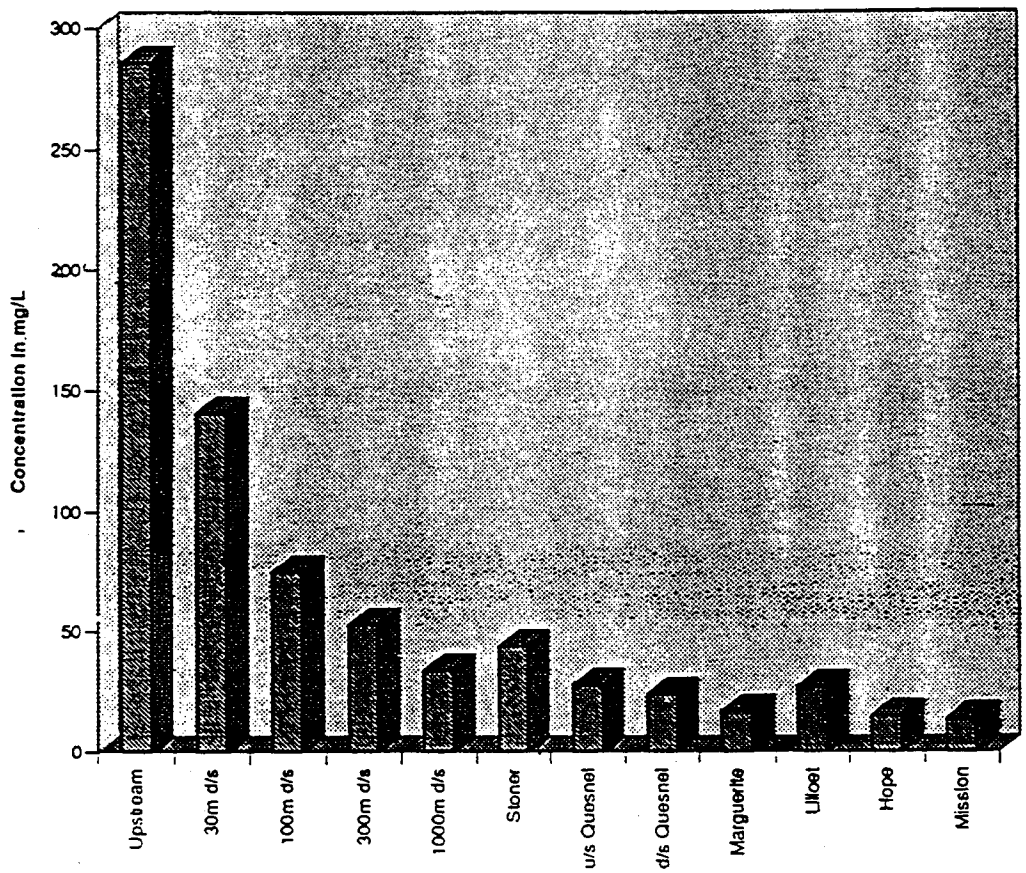
2560 pil lfu1479
Test data for 100 mm lens.

000000321

Mission

Transects	Concentration in mg/L
Upstream	286
30m d/s	141
100m d/s	75
300m d/s	53
1000m d/s	34
Stoner	44
u/s Quesnel	28
d/s Quesnel	24
Marguerite	17
Lilloet	27
Hope	15
Mission	14

Concentration of suspended particles along the Fraser River



Survey of Contaminants in Sediments in the Fraser River Basin

M. Sekela, C. Baldazzi, G. Moyle and R. Brewer

Environment Canada

1. Survey of Contaminants Related to Pulp Mill Effluents in the Fraser River Basin

The concentrations of trace organic contaminants were measured in suspended sediment samples collected upstream and downstream of six pulp mills located in the Fraser River basin. Sampling occurred at three hydrological periods; fall low flow, winter base flow (under ice) and spring freshet. Suspended sediments were analyzed for dioxins, furans, chlorinated phenolics and polycyclic aromatic hydrocarbons. Initial results indicate that:

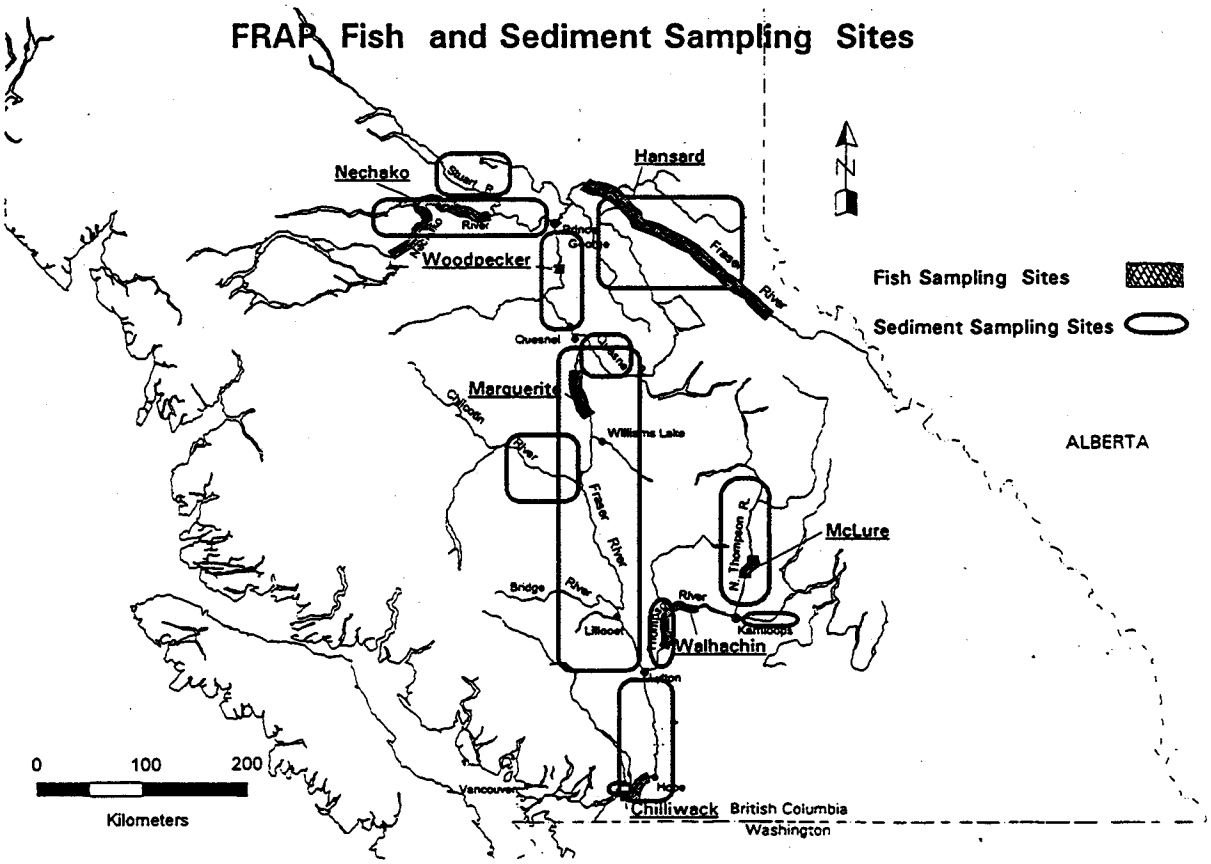
1) trace organic contaminants are detectable in suspended sediments collected over 225 river kilometres downstream of the nearest pulp mill;

2) the levels of 2,3,7,8-dioxin and 2,3,7,8-TCD-furan in Fraser River suspended sediments are lower in 1992 than they were in 1990;

3) there is a measurable increase in trace organic contaminant levels in Fraser River suspended sediments associated with the initial rise in the Fraser River hydrograph at freshet.

2. Survey of Contaminants in Bed Sediments in the Fraser River Basin

Bed sediment samples were collected from twelve reaches in the Fraser River basin. Samples will be analysed for trace organic and trace metal contaminants. All samples were collected during the 1994 fall low flow period using a minimum of five Ekman grabs per sample. Sampling sites were determined using the sediment depositional zones outlined in the *Determination of Sediment Deposition Zones Fraser River Basin* (Environment Canada, FRAP 1994-32) report.


FRAP Fish and Sediment Sampling Sites
Nechako
Hansard
Woodpecker
Marguerite
McLure
Walhachin
Chilliwack
Fish Sampling Sites
Sediment Sampling Sites
ALBERTA
British Columbia
Washington
0
100
200
Kilometers

Benthic Invertebrate Community Structure for the Fraser River Basin
November 29, 1994

T.B. Reynoldson[1], K.E. Day[1], D.M. Rosenberg[1],
R.C. Bailey[2], R.H. Norris[3] and V.H. Resh[4]

1. National Water Research Institute
2. University of Western Ontario
3. University of Canberra
4. University of California, Berkley

1. Study Objectives

- To develop a biological classification of unpolluted stream and river sites (approx. 250) of the Fraser River watershed based on macroinvertebrate structure and function.
- To determine whether the type of macroinvertebrate communities and functional attributes at unstressed sites can be predicted using chemical and physical features.
- To identify the degree of impact currently expressed by macroinvertebrates at sites that are expected to be most exposed to human stressors.
- To develop numeric targets from macroinvertebrate community structure and function that can be used to make environmental management decisions on the adequacy of current or proposed regulatory approaches.

2. Site Selection

Two levels for stratifying the basin based on hydrologic characteristics and geo-climatic considerations are being used. For the purposes of stratifying based on hydrologic characteristics, the Strahler stream ordering method will be used based on a 1:250,000 map scale. Geo-climatic stratification will be based on the ecoregions of British Columbia as delineated by the BC Ministry of Environment. A "site" is defined as a reach of river with a longitudinal distance that is 6 times the channel width.

Sites will be selected equally in all stream orders, up to order 1 on a 1:250,000 map scale. Eighteen major sub-basins have been identified, up to 7 stream orders and 12 ecoregions would be required to be sampled. Ideally sites should be located evenly between the stream orders and ecoregions resulting in 84 strata, thus each stratum will be assigned 2-3 sites.

The 50 sampling sites for the pilot study year were identified after a review of the level of impact in each sub-basin. Three impact categories were arbitrarily identified. Basis were subjectively assigned to each category based on personal knowledge. Of these basins the following potential reference basins were identified:

Basin	Ecoregion	Ecoprovince	Samp. Year
Fraser ups. Hansard	W. Continental Ranges	S. Interior Mountains	
Bowron upr.	S. Rocky Mountain Trench	S. Interior Mountains	
Stuart	Fraser Basin	Sub-boreal Interior	1994
West Road	Fraser Plateau	Central Interior	
Eucheniko	Fraser Plateau	Central Interior	
Chilcotin	Fraser Plateau	Central Interior	1994
Tyaughton	Chilcotin Ranges	Central Interior	
Stein	Int. Transition Ranges	Southern Interior	
Clearwater	S. Rocky Mountain Trench	S. Interior Mountains	1994
Nicola upper	Thomp. Okanagan Plateau	Southern Interior	
Chehalis	Lower Mainland	Georgia Depression	
Pitt upper	Pacific Range	Coast & Mountains	1994

Four sub-basins were selected for sampling in 1994 covering the widest range of geophysical conditions (four distinct ecoregions and ecoprovinces). In each of the four study areas the stream orders were identified using the Strahler method at a 1:250,000 scale. Two sites were randomly located on each stream order within the sub-basin:

Sub-basin	No. orders	No. sites	Type of site
Stuart	5	10	Ref
Chilcotin	5	10	Ref
Clearwater	4	8	Ref
Pitt	4	8	Ref
Fraser		5+5	Impacted
Salmon		4	Impacted
Total		**50**	

In addition, five sites were selected on the mainstem Fraser River. These are sites also being sampled by Environment Canada (Sekela) for sediment assessment and at each site a depositional and erosional sample will be taken. The location of the depositional sites is linked with sites being sampled by Pacific Region to link the results from this study with the organics programme. Finally four sites will be sampled on the Salmon River to be used as test sites.

These sites were sampled over the period October 13-27, 1994.

3. Environmental Variables

As well as establishing benthic invertebrate community structure at each site, a set of common environmental variables will be measured at each site. From these variables a sub-set will be selected to be used as predictors of invertebrate community structure. To identify the most appropriate variables for measurement, previous studies examining the relationship between community structure patterns and environmental characteristics were examined.

Based on this information four categories of variables were identified as being appropriate for measurement (see table; those in bold italic are available in a database, others are in process of being established).

Where possible existing protocols will be used for measurement of environmental characteristics; both provincial (BC) and Rapid Bioassessment Protocols (RBP) are available.

Map	Site	Channel	Water
Slope ***Latitude (longitude)*** ***Altitude*** ***Discharge - mean*** annual & variability Ecoregion Upstream drainage area Land use/Vegetation - predominant in surrounding 100 km^2	***Date - day*** ***Velocity*** ***Macrophyte cover*** ***Overhanging vegetation***	***Stream order*** ***Wetted channel width*** ***Wetted channel depth*** ***Sample depth*** ***Substrate heterogeneity*** ***Average substrate*** Particle size Biofilm/periphyton Leaf packets	***pH*** ***DO*** ***Conductivity*** ***Temperature*** Total phosphorus Nitrate Major ions Suspended solids

Fish Community Structure and Sentinel Species Development

J.D. McPhail

University of British Columbia

1. Movements of Mountain Whitefish in the Upper Fraser System

a. Objectives

Most fluvial fish species shift habitats as they grow, and many species migrate between mainstem rivers and tributaries either to spawn or forage. Such movements could influence the length of time and life history stages exposed to contaminants. This project was an attempt to document the movements and migrations of a potential sentinel species, the mountain whitefish (*Prosopium williamsoni*) in the upper Fraser system. The goal was to radio tag adults and follow them over the course of a year.

b. Progress

Several methods were used to sample fish: traps, gillnets, seines, and direct observations using snorkelling gear. Three mainstem trap sites were located at Shelley, three near the mouth of the Willow River, and three off the Northwood Pulp Mill outfall. Each of these sites was sampled six times from July to October. In addition, eight mainstem gillnet sites were monitored. One each at the mouths of the Willow, McGregor and Bowron rivers, one at Shelley, one each just below the upper and lower Canfor outfalls, one at the Highway 16 bridge, and one 500 m downstream of the bridge. Auxiliary trap data were collected from the lower Willow, Salmon and Nechako rivers. Seine samples were collected at five sites: the Salmon, Willow and Nechako rivers at their confluences with the Fraser, the Chilako River near its confluence with the Nechako River, and from the mouth of Stoner Creek. Float surveys were made on the Willow, Bowron and Salmon rivers.

The trap samples totaled 54 trap days in the mainstem and 15 trap days in tributaries. The traps caught large numbers (>100 individuals) of peamouth chub, redside shiners, squawfish and suckers (3 spp.), moderate numbers (<25) of bull trout and rainbow trout, and no whitefish. The gillnets were run every half hour. They also caught large numbers of peamouth chub, redside shiners, squawfish and suckers (3 spp.), moderate numbers of sturgeon, bull trout and rainbow trout, and a small number (5) of whitefish.

The seine hauls were the most efficient method of catching whitefish, but only late in the season (October). Most of the whitefish were collected near the confluence of the Nechako and Fraser rivers. The total whitefish catch was 256 individuals, of which two were slightly larger than 300 mm in fork length. From the literature on radio tagging whitefish, it is clear that fish less than 350 mm suffer high mortalities when tagged. We took lengths, weights and scales from our whitefish. The relationship between length and age in the upper Fraser sample (our sample supplemented with museum fish) is shown in the first figure. Clearly, upper Fraser mountain whitefish grow more slowly and reach a smaller adult size than either their Liard or Columbia counterparts. Apparently, very few mountain whitefish in the upper Fraser ever reach a size large enough to carry a radio tag. A possible solution to this problem is to use smaller tags. This will increase the probability of finding fish large enough to carry the tags but decreases the range and life of the tag.

The whitefish from the upper Fraser and its tributaries display a remarkable level of heterogeneity in body form. Two forms are worthy of comment: the "normal" form and the "Pinocchio" form. As the name implies, the "Pinocchio" form has an elongate snout. The second figure shows the snout-to-body size relationship in a sample from the Swift River. About 30% of the whitefish in this sample are the "Pinocchio" form. Mature males and females, as well as juveniles (100 mm or larger), occur in both the "normal" and "Pinocchio" forms. Interestingly, there is an association between body shape and snout length. On average the "Pinocchio" form has a slimmer body than the "normal" form (see third figure). It is not known if this difference in body form and snout length is inherited; however, the presence of both forms in juveniles and adults of both sexes suggests some form of complex foraging polymorphism. Since both forms occur in the mainstem Fraser and, if it is a foraging polymorphism, the two forms may be differentially exposed to contaminants ingested in their food.

Among the tributary rivers, the frequency of the "Pinocchio" form appears to vary. For example, the frequency in the Salmon and Nechako rivers is low while the frequency in some Quesnel River tributaries is high. This raises the possibility that there are different stocks of mountain whitefish in the different tributaries, and that the fish in the mainstem Fraser may be a "mixed" stock originating in several tributaries. Since I have a molecular genetics laboratory at UBC, we will collect some tissue samples from the main river and the major tributaries. These will be used to examine the possibility of a "mixed" stock in the main river at Prince George. The tissues will be collected during our routine sampling, but the processing and analysis of the samples will be financed by my NSERC grant.

2. Database on the Distribution of Fraser River Fish with Special Emphasis on Potential Sentinel Species

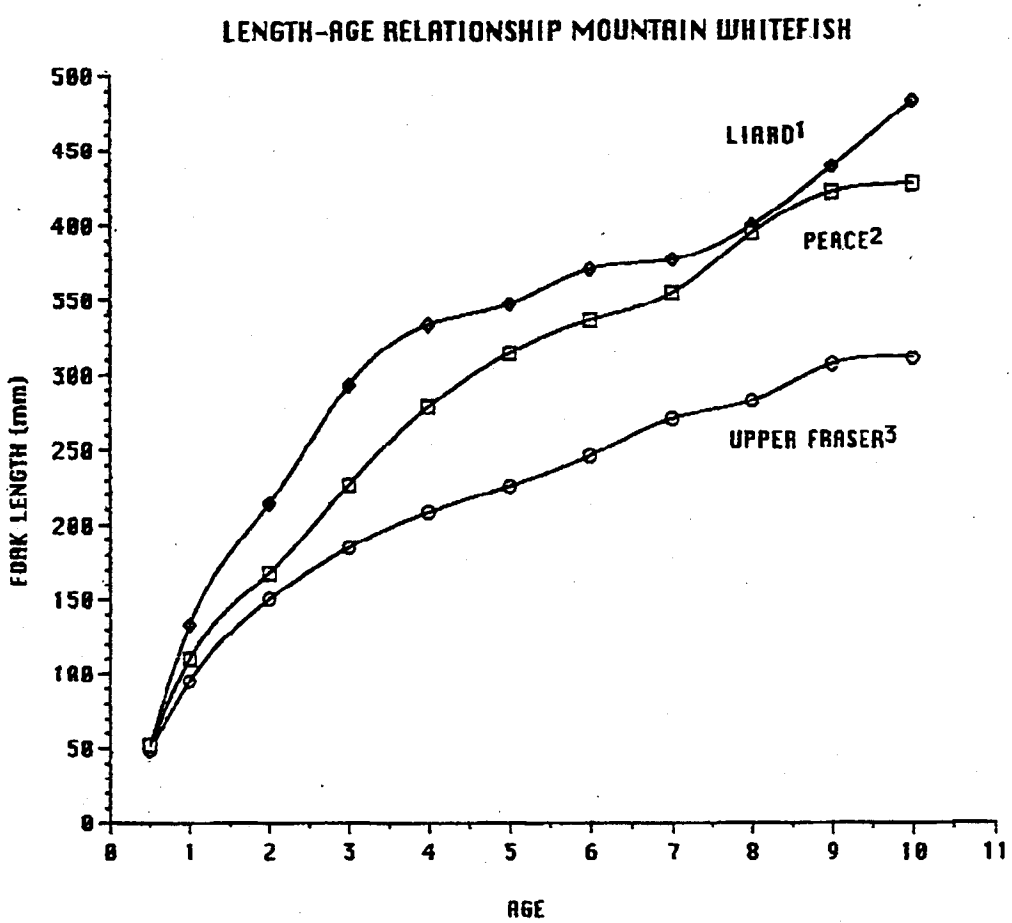
a. Objectives

A large historical database on the distribution, abundance, and community structure of Fraser fishes is stored in the files of the UBC Fish Museum and various government agencies. The goals of this project are to make the UBC files electronically accessible to government agencies, to integrate the UBC database with the Ministry of Environment, Lands and Parks database, and to use the combined databases to generate distribution maps and ecological data for Fraser fishes. In addition, an attempt will be made to determine if there have been detectable changes in native fish distribution or abundance over the last three decades. This will involve re-surveying some areas.

b. Progress

A beta version of the database program is now up and running. The database is compatible with the GIS system used by the MOELP and uses an electronic gazetteer, the provincial watershed code, mapping capability, and fields for ecological data. Fraser distribution maps for bull trout (*Salvelinus confluentus*), Dolly Varden (*S. malma*) and lake trout (*S. namaycush*) have been produced. These species were deliberately chosen to illustrate some of the advantages of such a database. First, Dolly Varden and bull trout are notoriously difficult to identify. Most of these records have been checked against specimens and thus provide a reliable measure of distribution; however, one or two of the records are odd and no specimens were available. In this case, the sites should be re-surveyed. Second, the data reveal an interesting pattern of distribution of lake trout and bull trout on the interior plateau. This region is within the geographic range of both species, and one or the other species is reliably reported from 86 lakes in the area; however, they coexist in only 20 of the largest lakes. Both species are top piscivores in lacustrine ecosystems, and in some lakes where lake trout have been introduced, bull trout have become extinct. This suggests that in some circumstances there is a competitive interaction between the species. Similarly, bull trout and Dolly Varden only coexist in areas where rivers that rise on the interior plateau flow through the Coast Mountains. In these regions of sympatry Dolly Varden appear to be confined to headwater streams or areas above barriers. Again, this suggests an interaction between the two species.

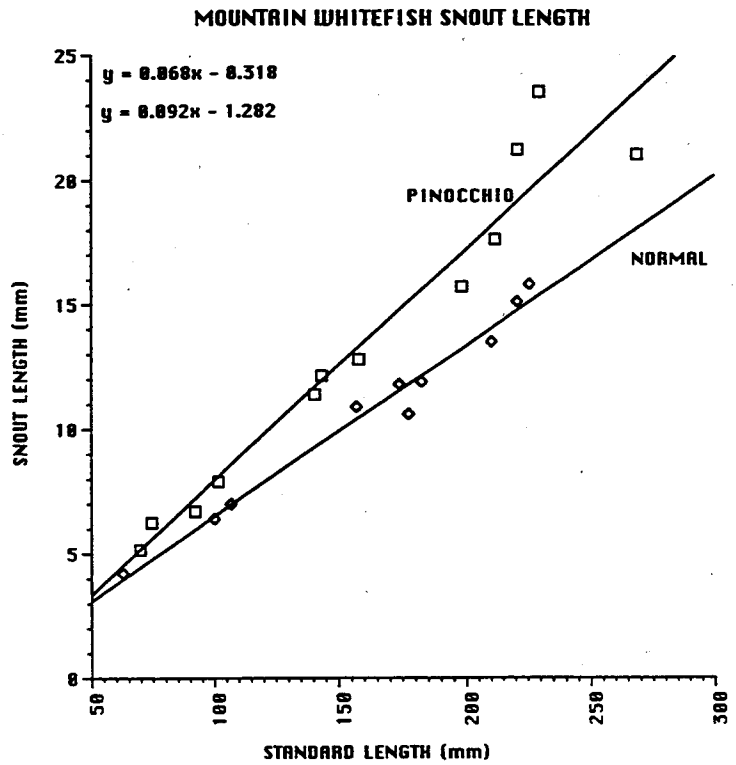
The major problem with the database is the time it takes to edit the entries. Undergraduates can enter the data, but someone who knows the local geography and is capable of detecting locality and identification errors has to edit the files. There seems to be no way of speeding this process up.

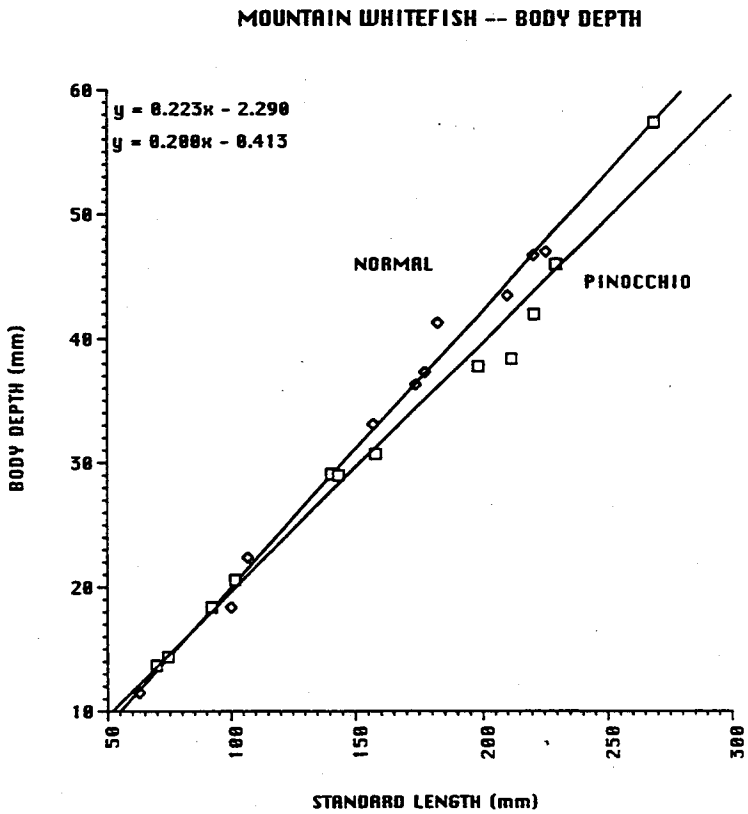


1 - data from O'Neil et al. 1981

2 - data from Pattenden et al. 1990

3 - original data supplemented with museum collections and data from McLeod et al. 1978


MOUNTAIN WHITEFISH SNOUT LENGTH
y = 0.068x - 0.318
y = 0.092x - 1.282
PINOCCHIO
NORMAL
SNOUT LENGTH (mm)
STANDARD LENGTH (mm)
0
5
10
15
20
25
50
100
150
200
250
300


MOUNTAIN WHITEFISH -- BODY DEPTH
y = 0.223x - 2.290
y = 0.200x - 0.413
NORMAL
PINOCCHIO
BODY DEPTH (mm)
STANDARD LENGTH (mm)
10
20
30
40
50
60
50
100
150
200
250
300

Fraser River Action Plan (FRAP) Basin-wide Resident Fish Condition and Contaminants Assessment

B. Raymond

Environment Canada

As part of FRAP's Environmental Quality Component, Environment Canada and the Department of Fisheries and Oceans are assessing the condition of selected resident fish species in the Fraser River Basin. Once the baseline conditions are known, the effectiveness of clean up actions can later be evaluated.

The purpose of the FRAP Fish Condition and Contaminants Assessment is to obtain information on fish condition in the mainstem and large tributaries of the Fraser River. Condition is based on health characteristics and contaminant levels of resident fish species. The assessment is modelled after the Department of Fisheries and Oceans (DFO) Columbia River fish health study on mountain whitefish (Jennifer Nener, DFO, pers. comm.) and Year Three of the FREMP Water Quality Monitoring Program.

The targeted resident species for this study are peamouth chub and mountain whitefish. Mountain whitefish were selected because of the large database on health and contaminant levels for western Canada. This species is also the target of a FRAP research project *Migration Strategies, Seasonal Habitat Preference, and Life History Studies of the Mountain Whitefish,* Prosopium williamsoni *(Girard), in the Upper Fraser, B.C.* Peamouth chub were selected because they are widely distributed and abundant in the Fraser River, are the target of fish condition research in the upper Fraser River, and will be used in the Environmental Effects Monitoring Program for pulp and paper mills on the Fraser River.

The health assessment index (HAI) of Adams *et al.* (1993) has been incorporated because it is being widely applied, for example, by Westwater Research in the Lower Fraser. This study is an opportunity to link the HAI to other variables such as contaminant levels and histology.

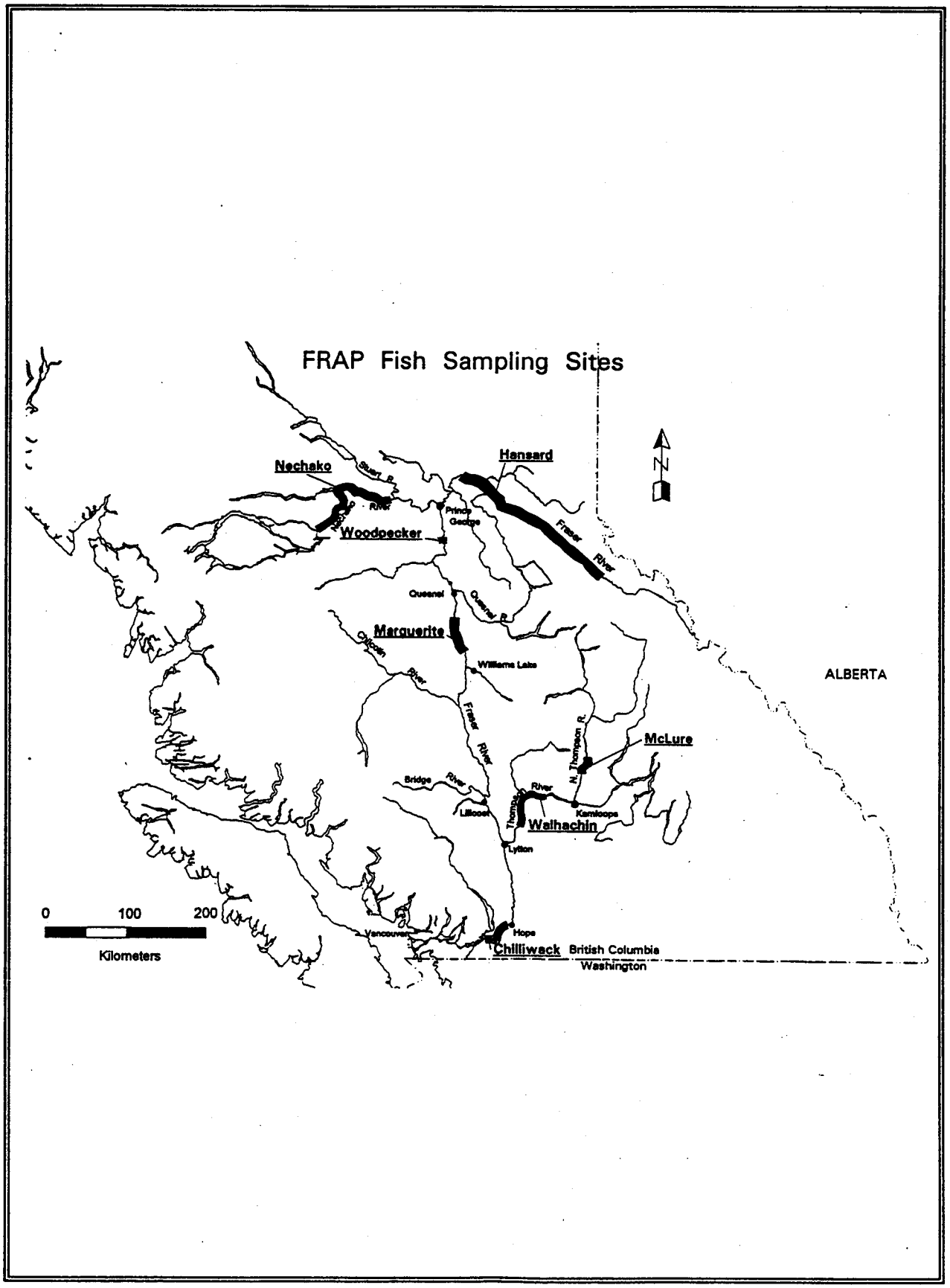
Sampling was conducted from mid-September to early November, 1994. The attached map shows the location of the seven sampled reaches. A total of 60 fish of each species was collected at each site. All fish were assessed for external and internal abnormalities according to the HAI. In addition, samples of liver, kidney, spleen, gill, hind gut, and pyloric caecae (when present) were collected, preserved in Davidson's Solution, and shipped to the Pacific Biological Station in Nanaimo for histological assessment. Otoliths were retained from every fish for aging.

Sub-samples of fish tissue were collected for contaminant and mixed function oxydase (MFOs) analyses. Four composite samples (five fish each) of both muscle and bile are being analyzed for contaminants for each species and reach. Two composites of liver tissue will be analyzed for each species and reach. Analyses are listed in the following table.

<u>Analyses</u>
Age
Condition Factor
Gonadosomatic Index
Hepatosomatic Index
Health Assessment Index
Histopathology
MFO activity
Cytochrome P4501A1
Trace Metals
PCBs and Pesticides
Chlorophenolics
Dioxins/Furans
PAH metabolites in bile
Chlorophenolics in bile
Resin/Fatty acids in bile

REFERENCE

Adams, S.M., A.M. Brown and R.W. Goede. 1993. A quantitative health assessment index for rapid evaluation of fish condition in the field. *Trans. Am. Fish. Soc.* 122:63-73.


FRAP Fish Sampling Sites
N
Nechako
Stuart R.
River
Nechako
Woodpecker
Prince George
Hansard
Fraser River
Quesnel
Quesnel R.
Marguerite
Chilcotin River
Williams Lake
Fraser River
N. Thompson R.
McLure
Bridge River
Lillooet
Thompson River
Kamloops
Walhachin
Lytton
Vancouver
Hope
Chilliwack
British Columbia
Washington
ALBERTA
0
100
200
Kilometers

OBJECTIVE

ESTABLISH BASELINE OF FISH CONDITION

BASED ON:

- RESIDENT FISH SPECIES
- MAINSTEM AND LARGE TRIBUTARIES
- HEALTH CHARACTERISTICS
- CONTAMINANT LEVELS

RESIDENT FISH SPECIES

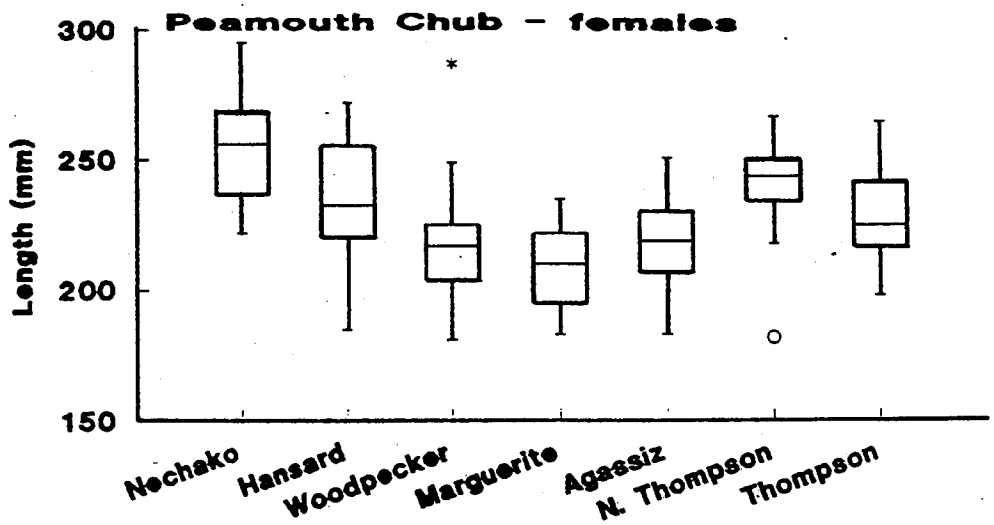
SPECIES	*WHY?*
PEAMOUTH CHUB (18-25 cm)	OCCURS ESTUARY TO HEADWATERS PULP MILL EFFECTS RESEARCH SMALL = LOW MOBILITY?
WHITEFISH (25-30 cm)	CONTAMINANT DATABASE LIFE HISTORY RESEARCH UNDERWAY

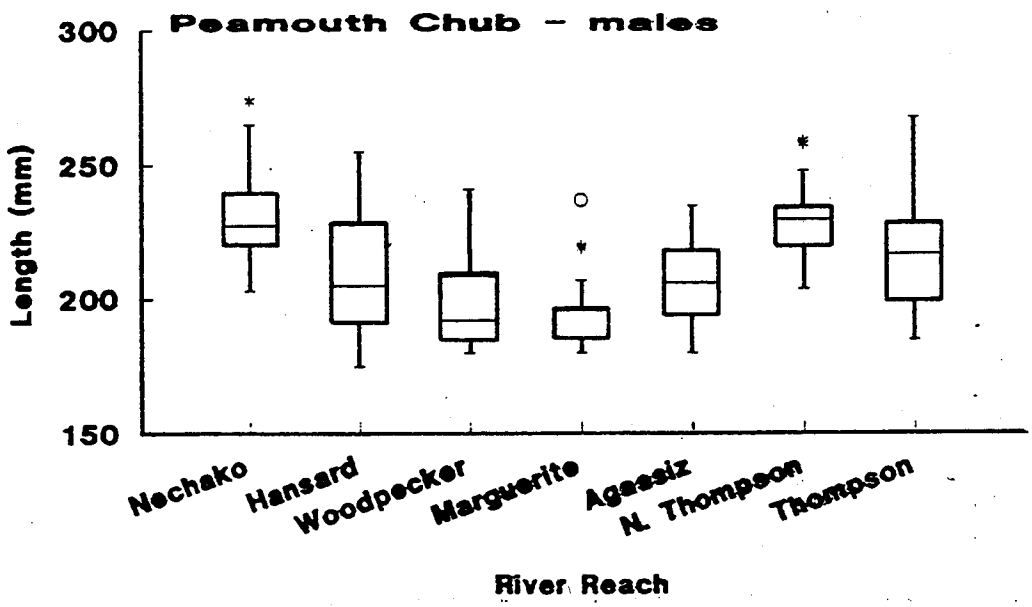
HEALTH CHARACTERISTICS

CONDITION FACTOR
GONADOSOMATIC INDEX
HEPATOSOMATIC INDEX
HISTOLOGY (*SUPPORTED BY DFO - FRAP, JENNIFER NENER*)

GILL	LIVER
SPLEEN	KIDNEY
PYLORIC CAECA	HIND GUT

HEALTH ASSESSMENT INDEX (RON GOEDE)


Peamouth Chub - females
300
250
200
150
Length (mm)
Nechako
Hansard
Woodpecker
Marguerite
Agassiz
N. Thompson
Thompson


Peamouth Chub - males
300
250
200
150
Length (mm)
Nechako
Hansard
Woodpecker
Marguerite
Agassiz
N. Thompson
Thompson
River Reach

PRELIMINARY RESULTS

SUCCESSFULLY COLLECTED 60 FISH IN DESIRED SIZE RANGE FOR MOST REACHES

SIZE DISTRIBUTION VARIED SLIGHTLY BETWEEN SITES

EXCEPT WHITEFISH AT MARGUERITE AND AGASSIZ

SAMPLING OVERLAPPED WITH WHITEFISH SPAWNING

LIVER MFOs

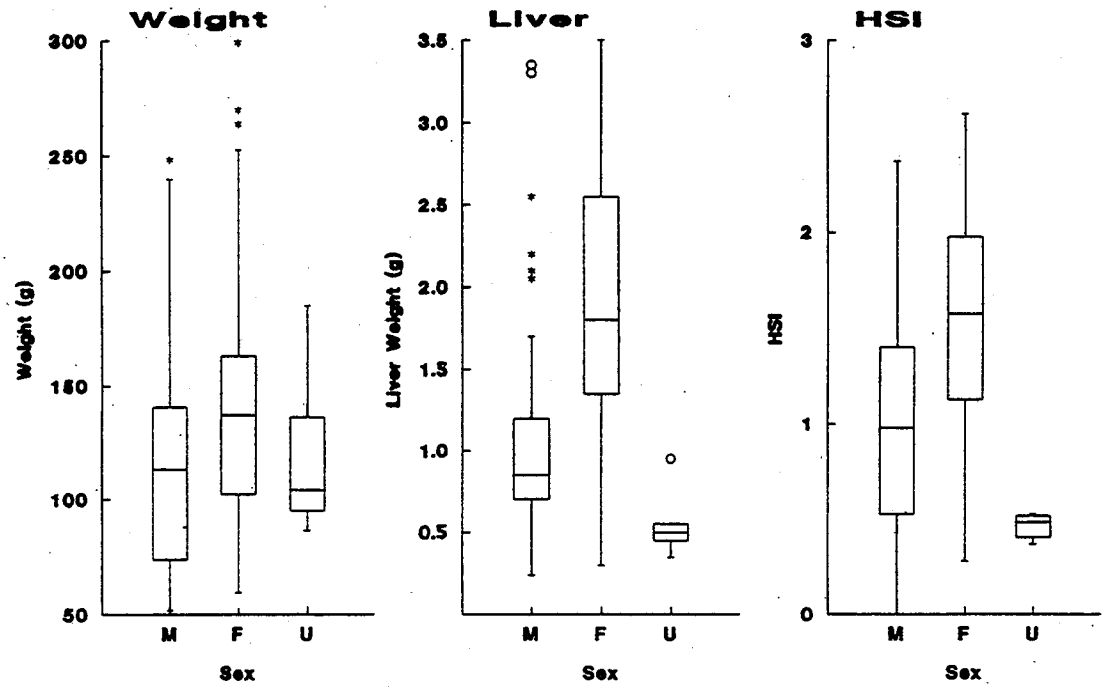
(IN COOPERATION WITH DFO - IOS, RICHARD ADDISON)

EROD AND CN-ECOD ACTIVITY
ANALYZED ACTIVITY ON MICROSOMAL PELLET
P4501A1 PROTEIN USING WESTERN BLOTTING

CONTAMINANTS IN BILE

CHLOROPHONICS
RESIN AND FATTY ACIDS
PAHs

Mountain Whitefish - Hansard



Variable	Condition	Field Desig
Bile	Yellow or straw colour; bladder empty or part-full	0
	Yellow or straw colour; bladder distended, full	1
	Light-green to "grass-green"	2
	dark green to dark blue-green	3
Liver	Normal; solid red or light red colour	A
	Normal: Light Red colour	B
	Fatty liver, coffee-with-cream colour	C
	Nodules in the liver; cysts or nodules	D
	Focal discolouration; distinct localized colour changes	E
	general discolouration; colour change in whole liver	F
	Other: not fitting above categories	OT
Mesenteric Fat	No fat around pyloric cecae; no fat in evidence in the visceral cavity	0
	Slight; less than 50% of each caecum covered in fat - might be just a trailing fat body.	1
	Moderate; about 50% of each caecum covered in fat	2
	Pyloric caecae more than 50% covered in fat	3
	Very Fatty; pyloric caecae completely covered with fat	4

CONTAMINANTS -- LIVER AND MUSCLE

DIOXINS AND FURANS (NOT AGASSIZ AND NECHAKO)
CHLOROPHENOLS (NOT AGASSIZ AND NECHAKO)
PCBs
ORGANOCHLORINE PESTICIDES
TOXAPHENE
TRACE METALS

MUSCLE - 4 COMPOSITES OF 5 FISH PER REACH AND SPECIES
LIVER - 1 OR 2 COMPOSITES PER REACH AND SPECIES

HEALTH ASSESSMENT INDEX

ORGANS ARE RATED AGAINST A "SCALE" AS NORMAL OR ABNORMAL

"SCALE" DEVELOPED FOR SALMON AND TROUT IN HATCHERIES

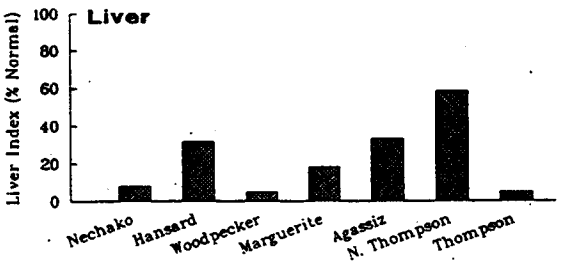
HIGH LEVEL OF "ABNORMALITIES" IN PRELIMINARY ASSESSMENT

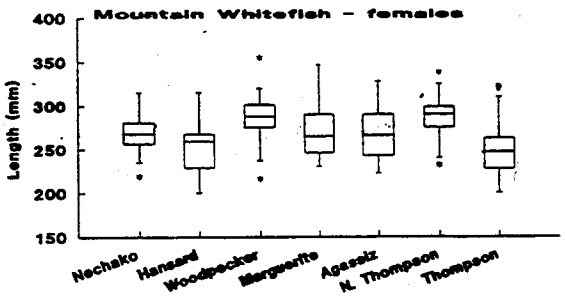
NEED TO MODIFY FOR PEAMOUTH CHUB AND MOUNTAIN WHITEFISH BASED ON REFERENCE SITES AND HISTOLOGY

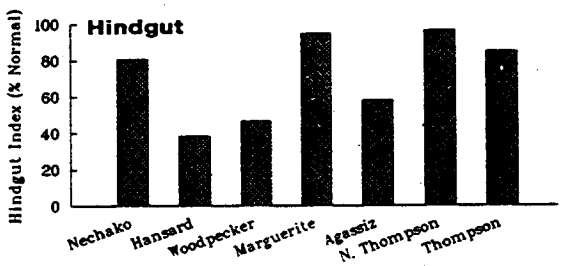
SOMATIC INDICES

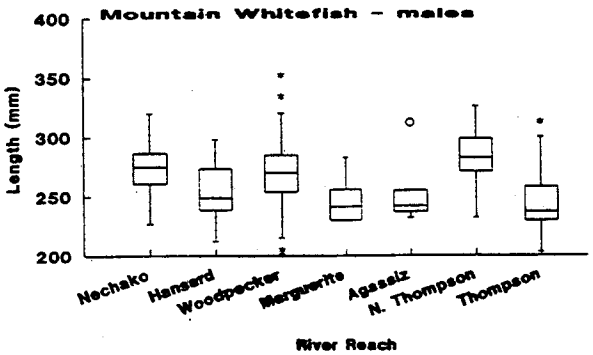
PRELIMINARY RESULTS INDICATE THAT VARIABLES SUCH AS MATURITY AND SEX MAY BE MORE IMPORTANT THAN REACH IN DETERMINING INDICES

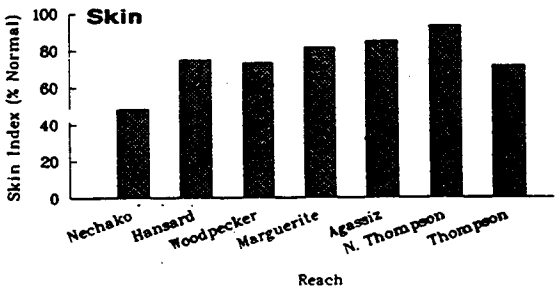
DATA NEEDS TO BE STRATIFIED BY AGE, MATURITY, ETC.











Peamouth Chub

Estuarine Wildlife Sentinel Species Studies and Aquatic-based Wildlife Food Web Interactions

P. Whitehead[1], I. Moul[2], T. Sullivan[3], J. Elliott[1], L. Wilson[1]

[1]*Environment Canada*
[2]*Foul Bay Ecological Research Limited*
[3]*University of British Columbia*

1. Cormorant Contaminant Levels and Seasonal Movements (Whitehead)

Cormorants have been selected as national SOE indicators of contaminant uptake in marine and aquatic ecosystems. Contaminant levels in Strait of Georgia colonies were analyzed in eggs as part of this continuing, national program. After a peak in about 1987, dioxin and furan levels declined commensurate with improved pulp mill bleaching processes and treatment of pulp mill effluent. However, in the last three years the concentrations in eggs have levelled off, and remain high enough for concern, based on toxicological studies.

Sampling of eggs from the colony in the Fraser River Delta was not completed because most birds failed to produce eggs.

Methods of capture and radio-tagging were developed during 1993-94, and applied during spring, 1994. Both tail mounts and implants were tried on birds from Mandarte Island and Chain Island colonies (birds from the Fraser River colony could not be captured because nesting was unsuccessful, as noted above). Of 6 tail mounts, 5 worked for periods of time ranging from 13 to 60 days. Of 7 implants, 6 birds survived the procedure, and these are still transmitting. Range of radios is from 1 to 10 nautical miles. So far, all birds monitored have remained near the nesting colonies. Their movements during winter will provide the necessary information of whether they remain near the nesting colonies all year, or disperse throughout the Strait of Georgia and Puget Sound (Report available).

2. Prey Selection and Movements (Sullivan)

About 350 coloured hands have been applied to birds from Five Finger Island, Mandarte Island, Fraser River Estuary and Crofton. A notice has been placed in the Association of Ornithologists Newsletter requesting sightings. Results will supplement those of radio-tracking as described above.

One instance of teratogenic effects was observed: a live chick with four legs was collected. The two extra legs were fully formed, but non-functional. It is not known if this effect is in any way related to toxic chemicals, but since better known effects of toxic chemicals such as cross-bills were not observed, such a link is believed unlikely. At any rate, considering the number of birds examined (thousands), the prevalence would be too low to be of concern.

Data on prey selection were collected at Five Finger Island, Fraser River Estuary and Mandarte Island, and expressed as percent by weight of each fish species at each site. Five Finger Island cormorants had more catholic diets, including relatively similar amounts of sculpins, pricklebacks, rock cod and other fish species.

3. Potential of Bald Eagles for Use as Sentinel Species for Contaminant Uptake from Aquatic-based Ecosystem (Elliott and Wilson)

Bald eagles are a top trophic level, resident predator and would make an excellent indicator of biomagnification of persistent contaminants if methods can be developed which do not harm the birds, while giving reliable information. Methods of safe (for birds and the investigators) capture of nestlings and blood sampling have been developed and tested. Samples from the lower Fraser River basin and reference sites on Vancouver Island have been collected and submitted for contaminant and biomarker analysis.

Bald Eagles: Fraser River Sentinel Species (from overheads)

1. Determining levels of persistent contaminants in eggs, blood and adult birds.

2. Monitoring breeding success.

3. Ecology of eagles wintering in Fraser Delta.

4. Investigating the effects of current in-use pesticides on bald eagles and other raptors.

Behaviour of Bald Eagles at Delta Landfill

1. *Loafing* 92% of time spent loafing

2. *Foraging* (821 observations)

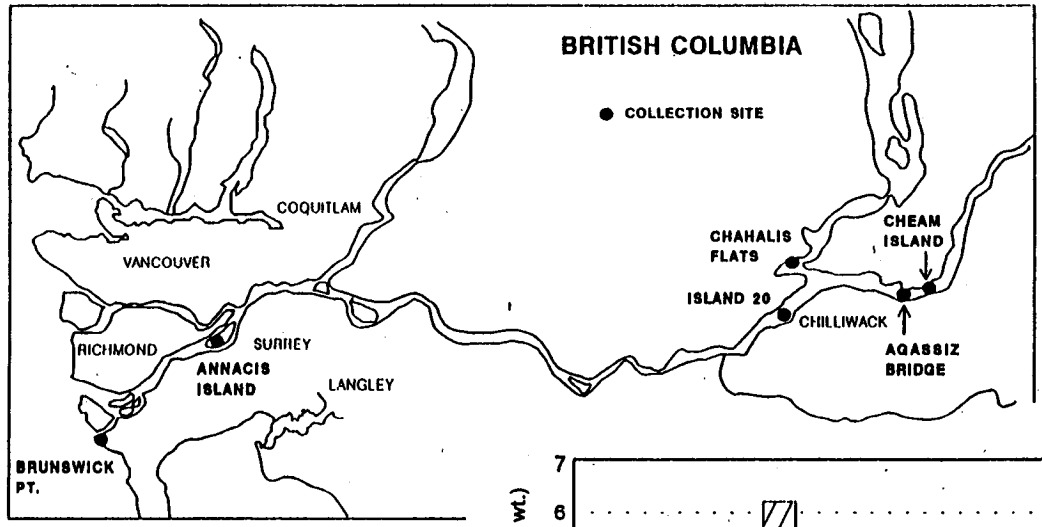
- pirating	32%
- scavenging	32%
- drinking	25%
- garbage picking	9%
- hunting	3%

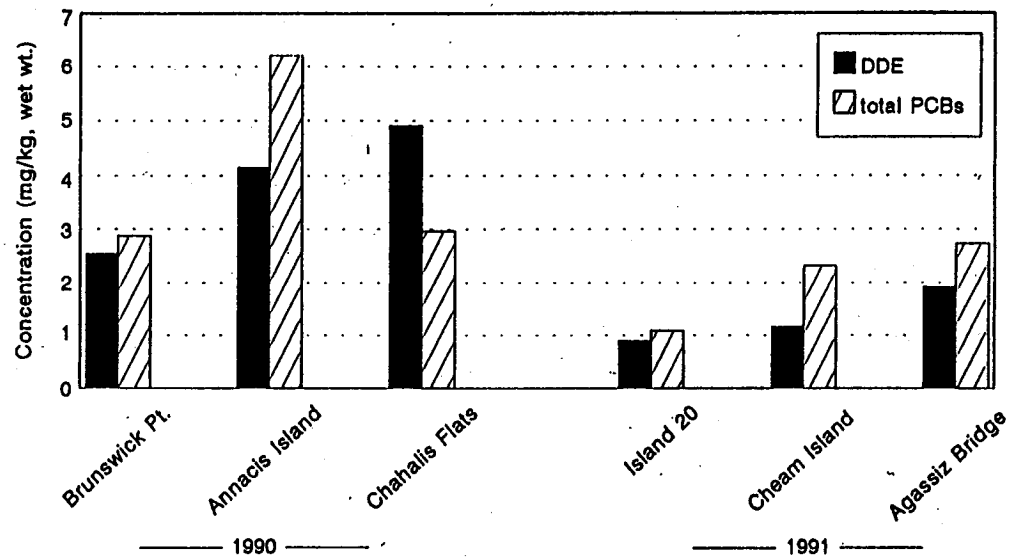
3. *Pirating* (260 observations)

- other bald eagles	96%
- gulls	3%
- crows	1%

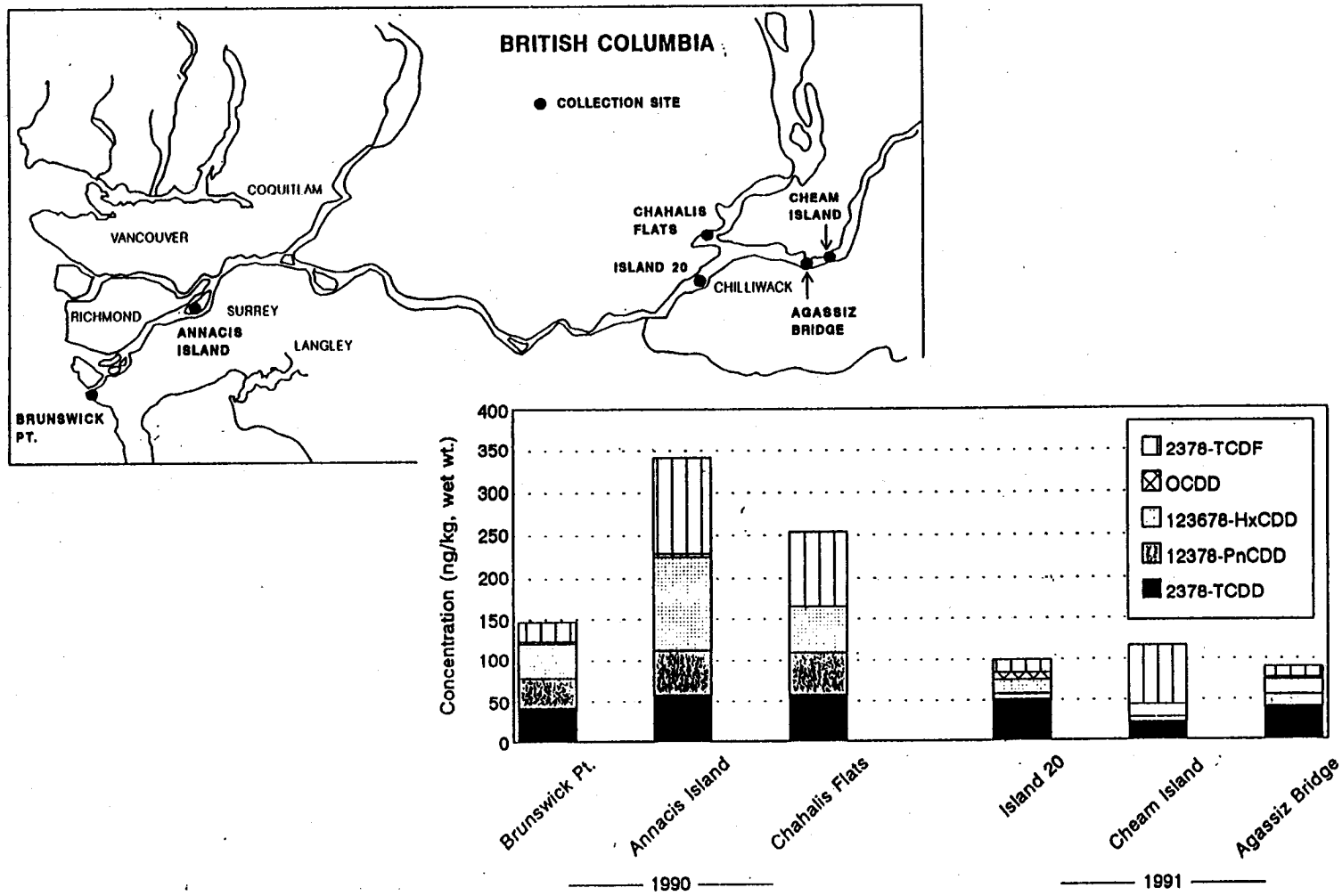
4. *Diet* (249 observations)

- unidentified	35%
- bones	27%
- meat	25%
- fat/gristle	4%
- gulls	2%
- fish	1%

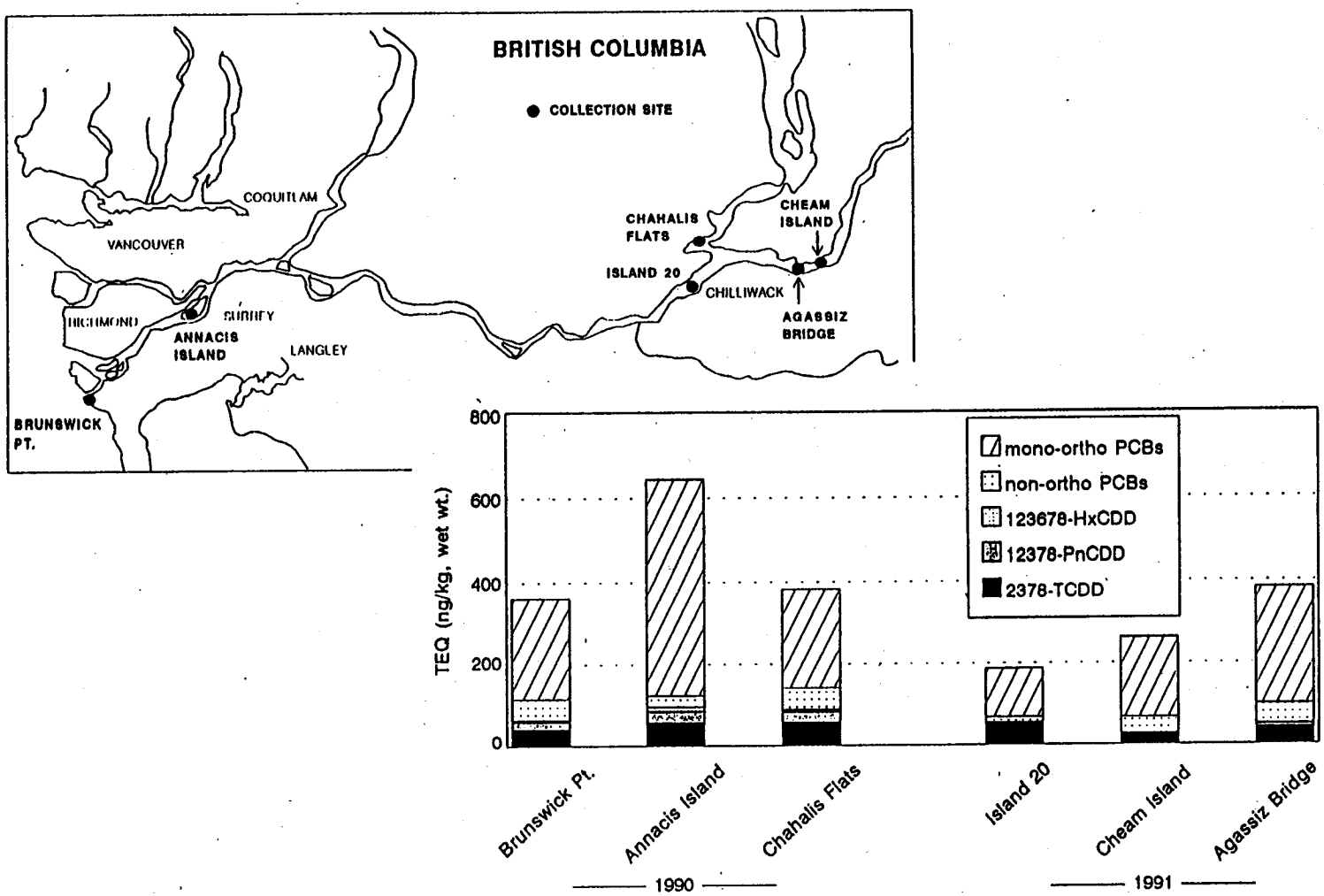




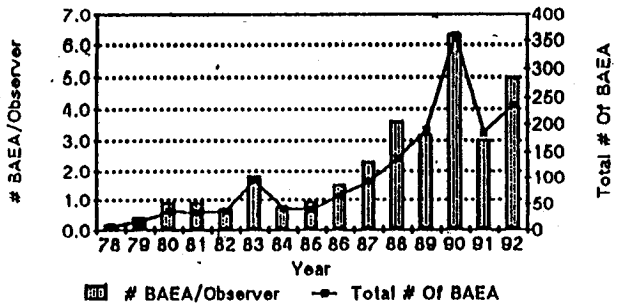
DDE and total PCBs in individual bald eagle eggs: Lower Fraser River, 1990 and 1991.

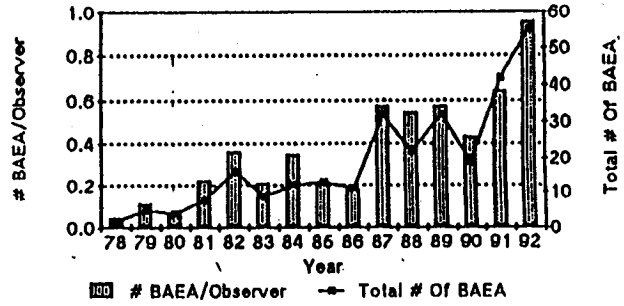


Major dioxins and furans in individual bald eagle eggs: Lower Fraser River, 1990 and 1991.

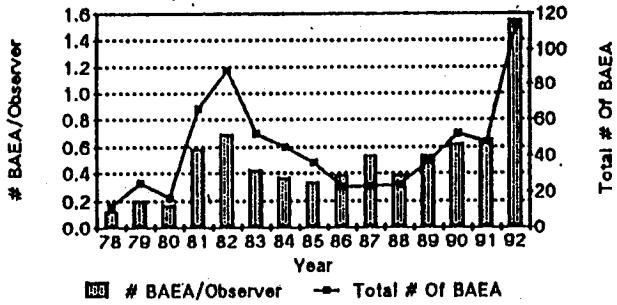


Toxic equivalents (TEQs) for major dioxins, furans and PCBs in individual bald eagle eggs: Lower Fraser River, 1990 and 1991.

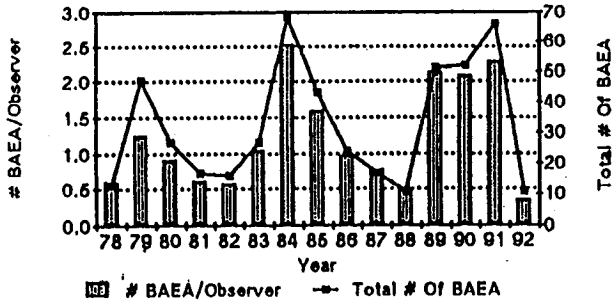




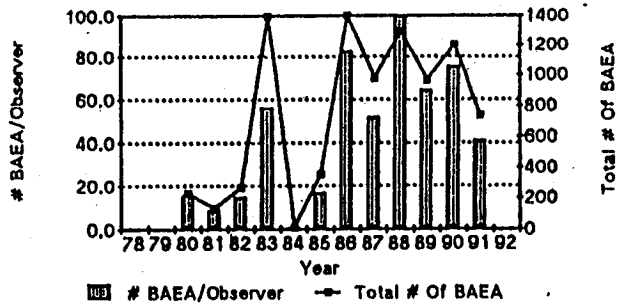
VANCOUVER



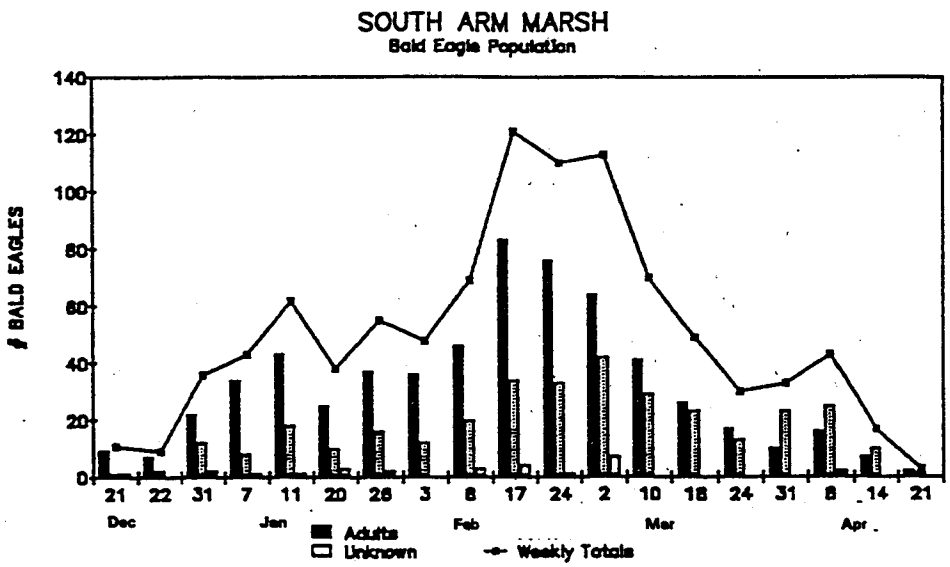
CHILLIWACK



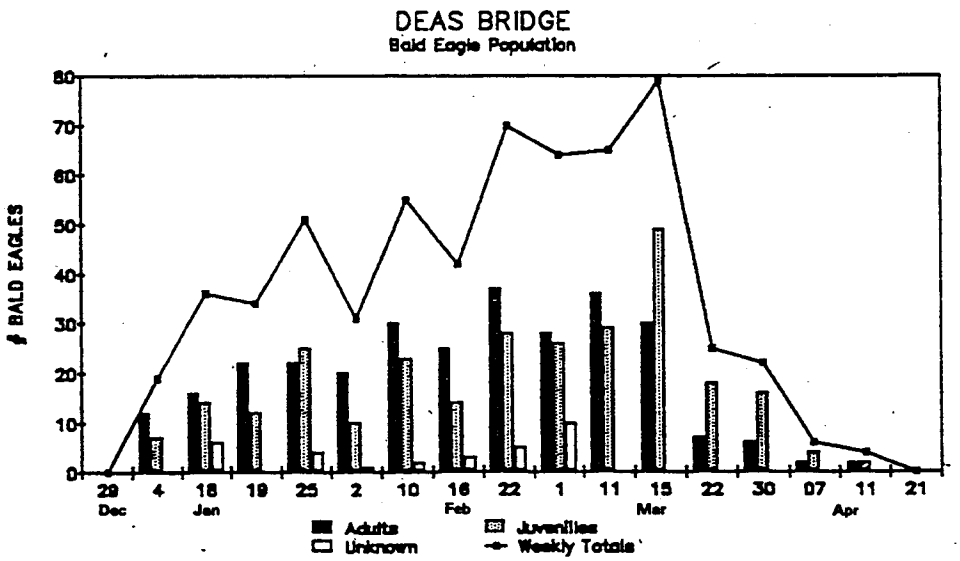
SQUAMISH



Christmas Bird Count Bald Eagle Populations From 1978 To 1992.

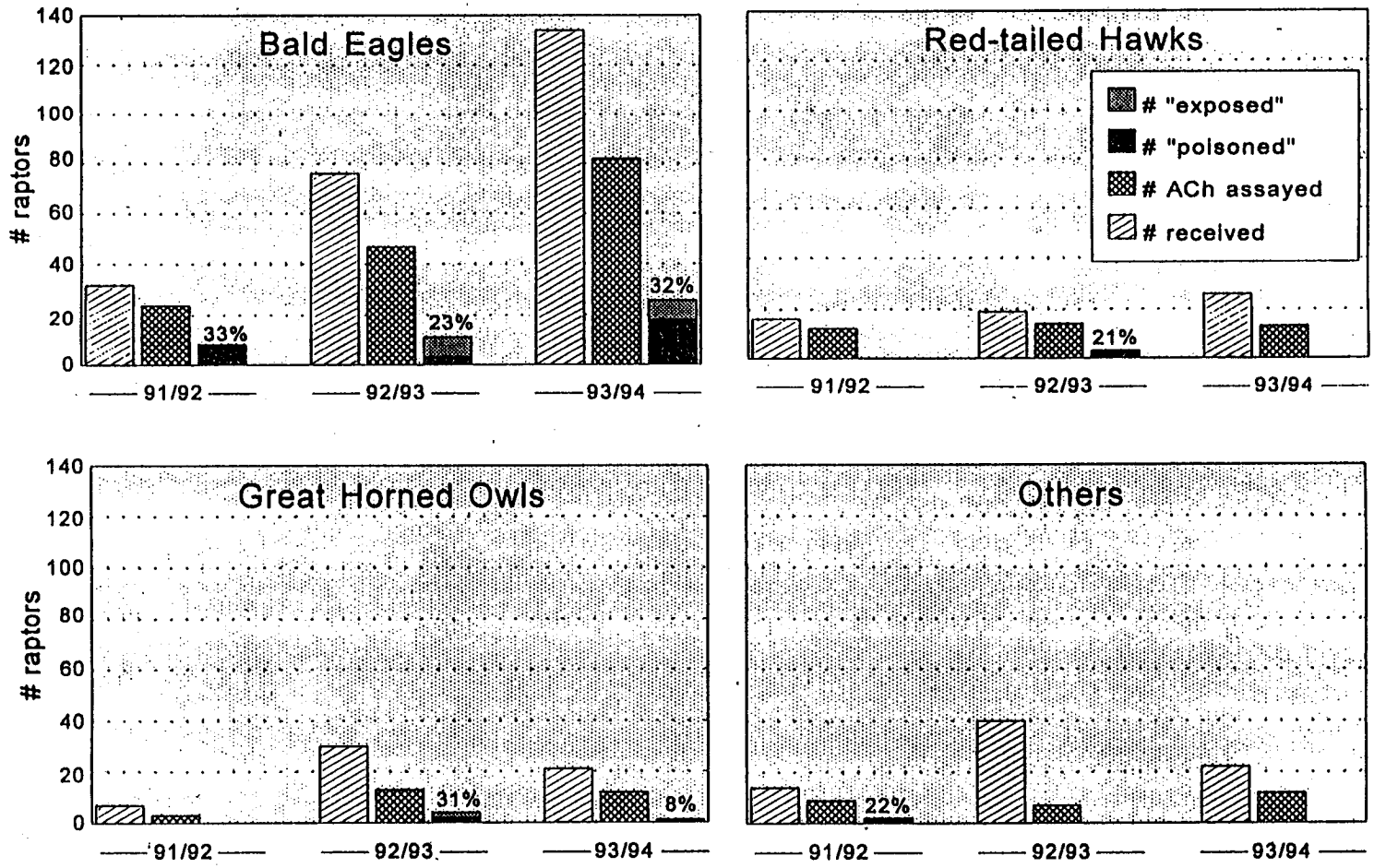


Number Of Bald Eagles Seen At The South Arm Marsh Communal Roost Site.



Number of Bald Eagles Seen At The Deas Bridge

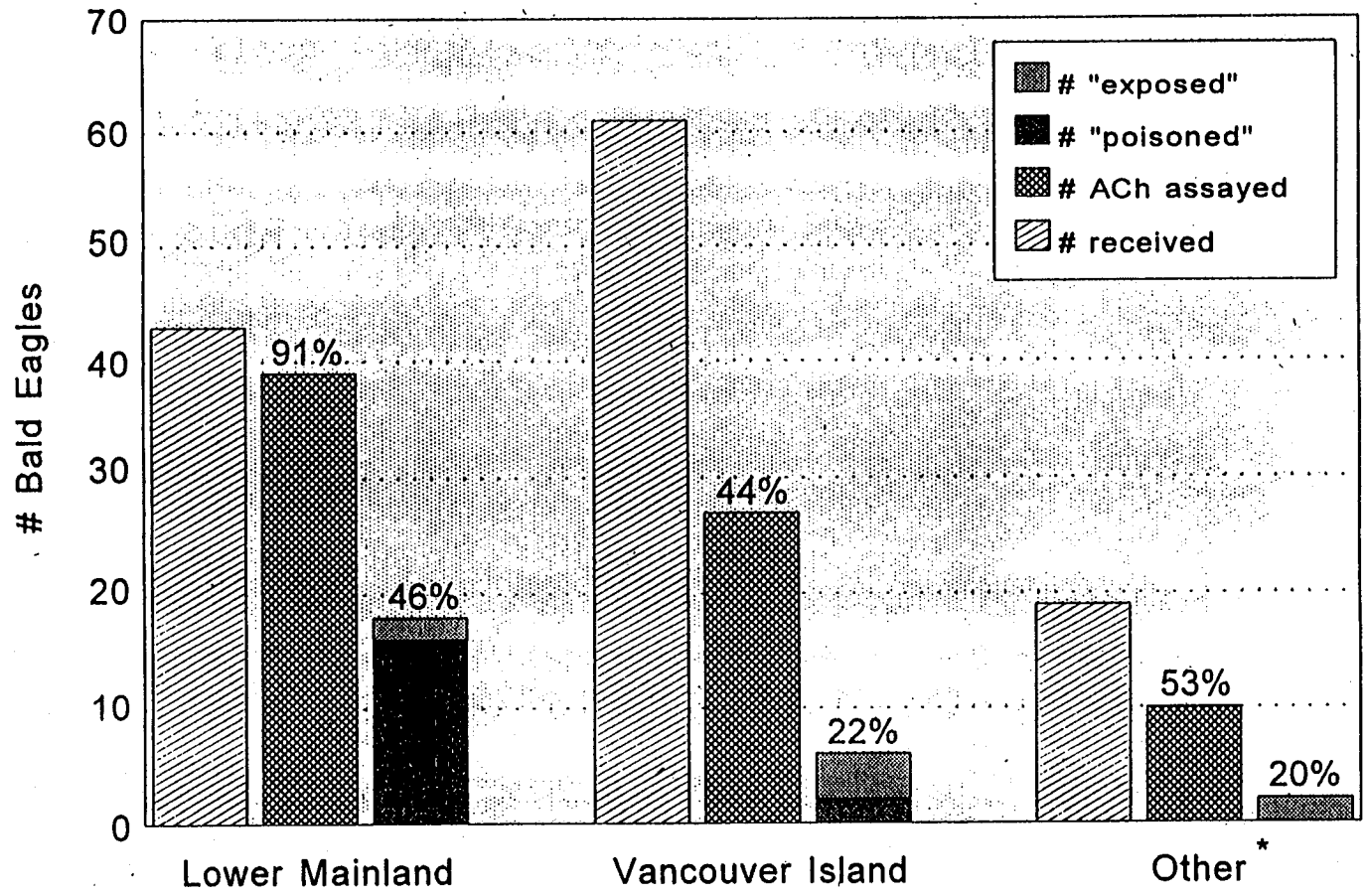
Raptors confirmed as pesticide poisoned/exposed by species.



"exposed" - AChE activity <2xSD of 'normal' level for species

"poisoned" - pesticide residues >0.2 ppm or AChE activity <50% of 'normal' for species

Bald eagles confirmed as pesticide poisoned/exposed by site, 1993-94 (n=123).



"exposed" - AChE activity <2xSD of 'normal' level for species

"poisoned" - pesticide residues >0.2 ppm or AChE activity <50% of 'normal' for species

* QCI, Sunshine coast, N. Interior

Ecosystem Structure in Relation to Agricultural Impacts in Two Central-Interior Streams of the Thompson River Drainage

R.L. Vadas, Jr.

Environment Canada

1. Introduction

The project is examining the ecology of aquatic and riparian habitat and wildlife in the Salmon and Nicola river valleys of the Central Interior. The main focus is on the integrity of riparian vegetation, but other agricultural and urban impacts (irrigation, pesticides, and eutrophication), as well as headwater mining and logging, may also be influential. The goal of the research is to compare ecosystem structure across sites, to assess the importance of riparian habitat integrity on the quality and diversity of lotic habitat, riparian animals and stream biota. 1994 sampling was only recently completed, and laboratory and computer analyses will be done this winter.

The various data sets collected will be compared to holistically assess stream health (biotic and habitat integrity) in the face of agricultural and other human impacts. Biotic analyses include examination of abundance and biodiversity of different animal assemblages, as well as the presence of pollution-sensitive organisms. The microhabitat data for benthic macroinvertebrates and fishes will also be used to formulate habitat-suitability curves for different species, to allow better prediction of agricultural impacts (e.g., in-stream flow reductions from irrigation) on stream fauna.

2. Methodology

In both rivers, mid-upper and mid-lower mainstem sections were each sampled at 3 nearby sites with different riparian conditions. Each site was 300-400 m in stream length. In the Salmon River, forested, partially forested, and bare sites were located between Falkland and Salmon Arm, and were sampled during late August and early September. In the Nicola River, partially forested, shrubby, and bare sites were located between Merritt and Spences Bridge, and were sampled during late September and early October.

We employed several complementary invertebrate sampling methods. These included Hess samplers for benthic macroinvertebrates and algae (periphyton), a sweep net for shoreline (riparian) invertebrates, emergent traps for adult insect "hatch," and drift nets for "pelagic" terrestrial and aquatic invertebrates. Most techniques worked well, although emergent trapping was ineffective and thus only used in the Salmon River. Large aquatic macroinvertebrates, especially dragonflies and stoneflies, were also collected during fish sampling (see below).

Five vertebrate taxa were assessed. Riparian amphibians, reptiles, birds and mammals were counted during stream walks, based on animal tracks, vocalizations and sightings. In contrast, we undertook fish sampling with seine nets and a streamside electroshocker. Although most fish specimens were identified and released on-site, specimens of each species were preserved for diet (gut) and growth (scale) analyses.

Habitat data collected were depth, velocity, substratum size and cover availability. These were concurrently collected with Hess and fish samples at small (microhabitat) spatial scales. Other environmental data collected included the location and abundance of different aquatic mesohabitat types (e.g., medium pool, shallow run and fast riffle), air and water temperature, and shoreline (riparian) vegetation (trees, shrubs, herbs and bare spots).

3. Results

Fish collections yielded salmonid, cyprinid and cottid species in both rivers, as well as burbot in the Salmon River and catostomids and lamprey in the Nicola River. Organic cover, namely woody materials (snags, roots and brush) and aquatic vegetation, provided good habitat for chinook and coho salmon (mostly juveniles), whitefish, most minnows, juvenile lamprey, prickly sculpin and some suckers. These limnophilic fish species inhabited moderately deep water with variable substrata, where large dragonfly nymphs were also abundant. The non-salmonid species, as well as dragonflies, were especially found in microhabitats with

fine (sandy or muddy) substrata, and may thus be most tolerant of sedimentation generated by agricultural activities. In contrast, juvenile salmon were more abundant at wooded sites, where organic cover was more common. Inorganic (boulder) cover provided good habitat for rainbow trout (inland and steelhead), adult longnose dace, some suckers, and 1 sculpin species. These rheophilic fish species appeared to be less sensitive to riparian conditions, as they inhabited moderately shallow water with coarse (especially cobble) substrata, along with large stonefly nymphs.

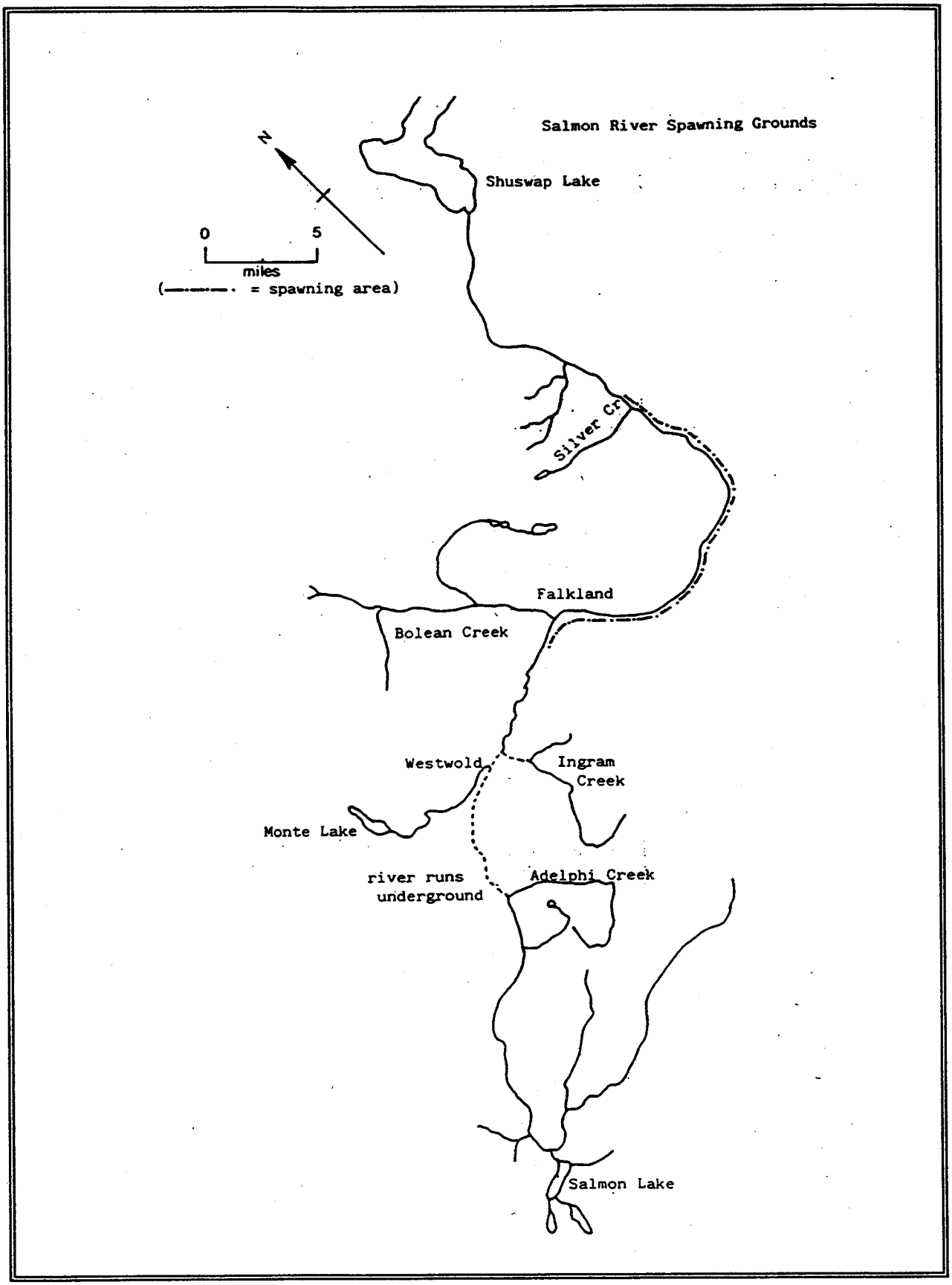
Several other trends were noted. First, pollution-sensitive aquatic insects, namely mayflies, stoneflies and caddisflies, were present at all 12 sites. Second, spotted frogs were present at most sites in the Salmon River, despite the decline of this species in the Okanagan region (S.A. Orchard, Royal British Columbia Museum, pers. comm., 1994). Third, the riparian-bird assemblage was dominated by crows and magpies, although waterbirds (mergansers, other ducks, geese, great blue herons, bald eagles and dippers) were occasionally seen.

4. Future Efforts

Given that the 1994 sampling was done during autumn, we plan to replicate the work during the summer of 1995, to examine a larger temporal window to more robustly examine agricultural impacts on lotic and riparian ecosystem structure. Birds and amphibians might show particularly great seasonal variation in assemblage structure. Either the same or new sites would be examined. We plan to compare the intensive habitat and biotic results to similar data being collected by the Westwater Research Centre and National Water Research Institute in other parts of the Fraser River basin. This should improve understanding of the salient and general characteristics of healthy basin sites.

There are 3 salient hypotheses developed from the 1994 research that will be tested in 1995. First, agricultural impacts may have detrimental impacts on various stream fishes. Loss of woody and other organic cover may be detrimental to salmon and other limnophilic fish species, because of the loss of shelter and deeper microhabitats (pockets). Second, rainbow trout and other rheophilic fish species may be sensitive to more extreme agricultural impacts, namely sedimentation caused by bank erosion and in-stream flow reductions, as cobble and boulder substrata could get smothered. Third, reductions in summer/fall flows may also adversely affect habitat availability for stream macroinvertebrates and fishes.

There are thus 2 research and management needs in the 2 study streams. First, in-stream flow studies need to be undertaken to complement our habitat-suitability data; such habitat/flow data are now being collected in the Salmon River. Second, recent efforts to protect and/or restore riparian vegetation in the Salmon and Nicola rivers need to be complemented by irrigation/groundwater management, to maintain instream flows. This approach will more effectively rehabilitate these lotic ecosystems.


Salmon River Spawning Grounds
N
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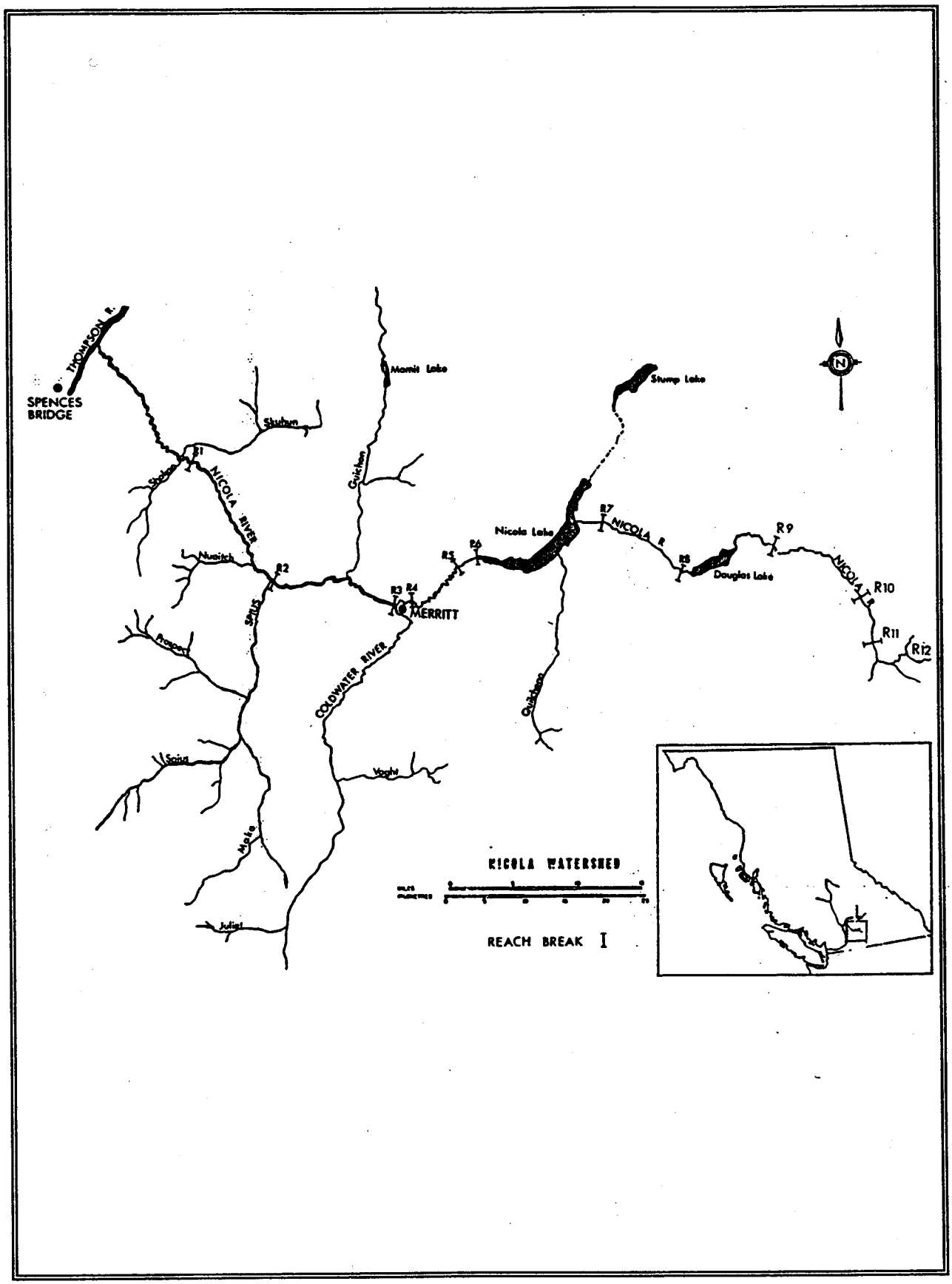
5
miles
(—·—·— = spawning area)
Shuswap Lake
Silver Cr
Falkland
Bolean Creek
Westwold
Ingram Creek
Monte Lake
river runs underground
Adelphi Creek
Salmon Lake


THOMPSON R.
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SPIUS
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Juliet
Guichon
Mamit Lake
R3
R4
MERRITT
COLDWATER RIVER
Voght
R5
R6
Nicola Lake
Stump Lake
R7
NICOLA R
R8
Douglas Lake
R9
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R11
R12
Quilchena
N
NICOLA WATERSHED
REACH BREAK

Food-web Interactions of the Western Sandpiper, *Calidris mauri*, on the Fraser Estuary

M.A. Sewell

Environment Canada

ABSTRACT

Research was conducted on the mudflats of the Fraser Estuary during spring and summer, 1994. Work involved 2 projects:

i) Impacts of Western Sandpiper (*Calidris mauri*) on marine invertebrates of the estuary: Samples from this experiment have been sorted and analysed and preliminary results will be presented at the FRAP Research Program Workshop.

ii) Scale of spatial variability of infaunal marine invertebrates in Boundary Bay: Sorting and analysis ongoing.

Impact of Western Sandpiper on Invertebrate Densities During the Spring Migration

The question was examined using (a) exclosure experiments, and (b) random sampling of invertebrates before and after migration. Research was conducted at 3 sites -- Westham Island, Brunswick Point, Boundary Bay -- that differ in physical characteristics (salinity, sediment composition), and importance as feeding sites for Sandpiper. Although the same general suite of invertebrates are found at all three sites, there are marked differences in abundance that appear correlated with sediment type. For example, the bivalve mollusc *Macoma* has a mean of 32 specimens per 10 cm diam. core at Westham Island, decreasing to 10 per core at Brunswick Point and 1 per core at Boundary Bay -- numbers declining with an increasing proportion of sand.

Preliminary statistical analysis of exclosure experiments on "impact" of Western Sandpiper feeding are challenged by problems in estimating invertebrate abundance. There are numerous species that show extreme variability in cores only 20 cm apart. For example, the polychaete *Manayunkia aestuarina* may have numbers differing by two orders of magnitude in adjacent cores (e.g., Brunswick Point, 3 replicates in exclosure cage = 324, 28, 1). Other species such as *Macoma* show more consistency (e.g., at Brunswick Point, 7, 5, 9).

Additional problems were encountered with "cage effects" in the exclosure experiment. Samples taken immediately outside the cage (at the corners) before birds arrived did not provide good estimates of invertebrate abundances in the cage at this time. Comparison of these samples to samples taken inside the cage after the birds had migrated through revealed significant differences for 9 of the 20 species examined. In all but one case there were lower numbers of individuals inside the cage, even in relatively non-mobile species. The exception was *Corophium* whioh appeared to be immigrating under the cages.

In general, no impact of bird predation has been detected at the study sites. Two significant differences were found between numbers of animals in the cage (protected from predation) and in adjacent areas outside the cages -- *Macoma* at Boundary Bay, and *Corophium* at Westham Island. The former had increased numbers outside the cages, and was at a site where there was little evidence for feeding by Western Sandpiper. This result emphasizes how small-scale spatial variability needs to be considered in such experiments. The numbers of *Corophium* did, however, decline in the areas outside the cages at Westham Island -- a site at which Western Sandpipers were observed to feed.

Future research on the Fraser Estuary will need to consider (a) the scale of patchiness of invertebrate distributions -- the second part of my study will go some way to addressing this; and (b) that statistical pilot studies examining the distributions of biota are essential prior to implementation of longer-term monitoring programmes.

1. Introduction

Research concerns estuarine invertebrate dynamics and particularly how the invertebrate populations are influenced by the impact of short-term, intense predation by the Western Sandpiper. As noted in my summary I also did a second project on scales of spatial variability in invertebrates in Boundary Bay -- these samples are now all sorted, but the results will not be discussed today.

One of the approaches used in examining an "impact" of shorebird predation is the application of predator exclusion devices; here the difference in standing crop inside and outside the predator exclosure after a period of predation is assumed to be due to predation. This approach is considered to be successful in short-term studies in areas with little environmental dynamics (e.g., sediment alteration), and during periods of heavy shorebird predation; all these seemed likely because of the numbers of birds, and the short period involved (3-4 weeks on the northward migration). In addition, I took random samples in sites before and after the migration to assess prey removal without artificial means; these results are still being analysed and I will not discuss these in detail today.

2. Research

1. The research was done at three sites: Westham Island, Boundary Bay, Brunswick Point. These sites differ in their sediment compositions and in the number of birds present. For example, Boundary Bay is a hard-packed sand with lower numbers of Western Sandpiper than Brunswick Point where there is deep mud. Sites were near to those that Bob Elner has established for down-shore monitoring and the Westham Island site is shared by Paul Harrison and Colin Levings who are examining primary and secondary production. All exclosures were placed about 500 m from shore -- this distance approached the distance to which it was possible to carry the sampled collected.

2. The exclosure design was modelled after Wilson (1994) who had done research on the impact of Western Sandpiper predation in Gray's Harbor, WA. His design was modified to include a greater degree of replication [e.g., he took 1 core per cage, I took 3, he compared 5 cages to 5 outside areas, I compared 5 cages to 12 outside areas]. However, the size of the exclosure (0.8x0.6 m) was the same, as was the spacing between the cages.

   We has 5 cages spaced 5 metres apart (see diagram). And in a regular pattern around these were 12 "imaginary" outside areas; these were known places but were not marked in any way. The arrangement of these outside areas followed research by Hurlbert and Chang to avoid the scenario where the birds may actively avoid the area surrounding the cages.

3. When the cages were set up in April, 3 cores were taken at the corners of each cage (black dots) and a sediment sample taken at the opposite corner as shown in diagram. After migration, 3 more cores were taken inside the cage (white dots), and the same arrangement of cores taken in the imaginary cage using a quadrat. For cages, there was also a second sediment sample.

   The total cores taken per site = 15 initial, 15 from cages at the end, 36 from outside. This gives a total of 66 per site, or 198 cores for the experiment.

4. Analyses of Invertebrate numbers. Two sets of analyses were conducted. (1) To compare the initial versus final numbers in the cage. This is a test of some kind of cage effect = a 2-way ANOVA. (2) To compare the cage vs outside = "impact" of predation = a nested ANOVA with position (cage vs outside), and no(position); i.e., the replicate cages or outsides were also compared. Analyses were done on species which were present in significant numbers, and which were easily identified. Also, $Log_{10}(x + 1)$ transformations were necessary so that assumptions of the ANOVAs were not violated.

5. Cage effects. In a soft-sediment environment it is usual to test for changes to sediment under the cage. Usually there is an increased silt content as water slows near the cage and there is deposition of finer material. The sediment samples I took at the beginning and end of the experiment are now being analysed, and the results will be available later.

   In the interests of time I will show only selected results. I have the results from all sites with me and you can view those later if you are interested.

   Significant cage effects were found at all sites, i.e., the numbers differed from inside the cage and

at the corners irrespective of any bird predation. The example here is from Brunswick Point where 7 species were used -- 1 mollusc, 3 polychaetes, 2 crustaceans. Five of the 7 seven species showed significant cage effects. And in 4 of these species the mean numbers declined with time.

Graph of Brunswick Point. Remember when we look at these that ideally these numbers should not change with time. The cores before were taken just outside the cage with the hope that they represented the numbers of invertebrates inside the cage. Black bars = before; white bars after.

Graph shows general declines in all species except *Corophium*. Here there is an increased value in the second sample and appears to be due to individuals migrating under the cage -- also found by Wilson.

Conclusion: That there are cage effects. Partly this is a sampling problem as significant differences were found for species that are not known to undergo huge movements, e.g., *Macoma*. However, for mobile species of crustaceans there are movements in (*Corophium*) and out (*Leucon*) of the cages. While the sediment analysis is not complete, there were also differences at the end of the experiment as species such as crabs were found in the cages that were not present before, and at Westham Island there was some scouring at the cage corners.

6. Predation. We can now go on to look at the effects of the birds. This was done by comparing inside the cage to immediately outside in areas where we know the birds were feeding. Significant differences were only found at two of the three sites: Boundary Bay and Westham Island.

1. Boundary Bay. Only one species (*Macoma*) showed a significant difference in numbers between inside the cage and outside. On the graph of Boundary Bay I have shown you 2 other species, the gastropod *Batillaria* and ostracods to emphasize why there are not significant differences in these species. For *Macoma*, numbers are in fact increased outside the cage -- but this species showed a difference in *Macoma* in the before/after comparison for the cage, i.e., we did not have a very good cage value. In the other 2 species, note the large standard deviations on some bars.

2. Westham Island. One species, *Corophium*, was significant. And there was a decline outside; i.e., in the direction expected if predation was occurring. In this species there was no significant cage effect; however, because of the large numbers of ANOVAs performed this may be a random significant value.

3. Conclusions

Based on the exclosure experiments, there is generally no detectable impact on invertebrate numbers by Western Sandpiper predation. There are two points that I wish to emphasize here:

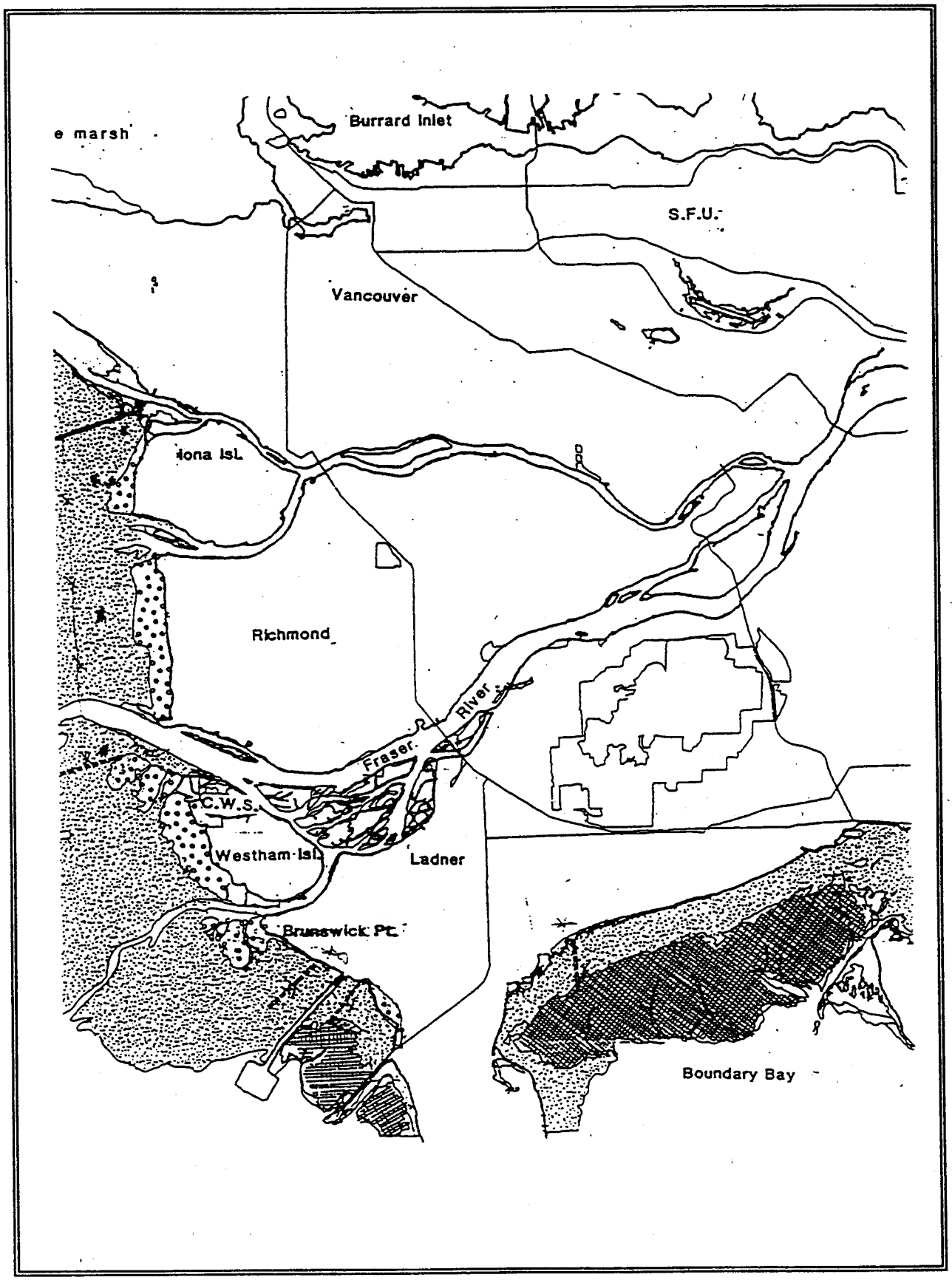
1. This experiment has shown no impact with a high degree of replication. For example, Wilson used only one core per cage/outside so did not measure the within cage/outside variability. He was unable to detect differences at Gray's Harbor when he did in the Bay of Fundy and concluded that "episodic" predation of migratory shorebirds have variable effects on prey abundance at different stopover areas. However, he did not consider spatial variability and if Gray's Harbor is like the Fraser, the degree of variability can be enormous.

This overhead (*Manayunkia* and *Corophium* bar graph) shows the degree of variability in the cages at the end of the experiment in May at Westham Island. I have shown the most extreme species -- the polychaete *Manayunkia*, and *Corophium* which showed a significant predation effect at this site. For *Manayunkia*, which Wilson considers too small to be prey, values range from 10 to 654 animals per core. Replicate cores within the cage (shown by the same colour bar) vary dramatically; e.g., Cage 1 = 397 to 10, Cage 5 = 92 to 654. *Corophium* shows less dramatic differences between replicates; however, note large differences in all cages in numbers per core.

Imagine for a moment that I had taken 1 core per cage. For example, a high value inside the cage paired with a low value outside would have led to the mistaken conclusion that there was a predation effect. Similarly, a low value inside and a high value out would have suggested migration from the cages. These results emphasize the care that needs to be taken with exclosure experiments, and the importance of replication to overcome small-scale variability in the distribution of the marine invertebrates.

2. Preliminary analysis of the random samples shows even more variability than that shown here resulting from the differences in scales. The area in which the exclosure experiment was conducted is 29 m long by 6 m wide – miniscule in comparison to the size of the mudflats of the Fraser. Random samples taken at three sites 100 m apart, but at the same tidal height, show even greater variability than that discussed here. And sampling conducted across the width of Boundary Bay on spatial scales at 1, 10, and 100 m, 1 km and 4 km, show even greater levels of variability again. So, my final conclusion is that we need to be very careful about what we say based on a small number of cores on a very small spatial scale. This research has only emphasized the importance of sampling protocols, replication and a good understanding of invertebrate distributions prior to hypothesis testing experiments such as exclosures.

Further analysis of the results obtained in this years sampling will continue through the winter. The information gained here, especially with regard to the scales of spatial variability in the marine invertebrates will be important in future research or monitoring studies on the Estuary. For example, my results are directly applicable to other studies such as that of Pippa Shepherd who is examining the diet of overwintering Dunlin, and we are working closely to design suitable protocols for her sampling.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Fraser
River
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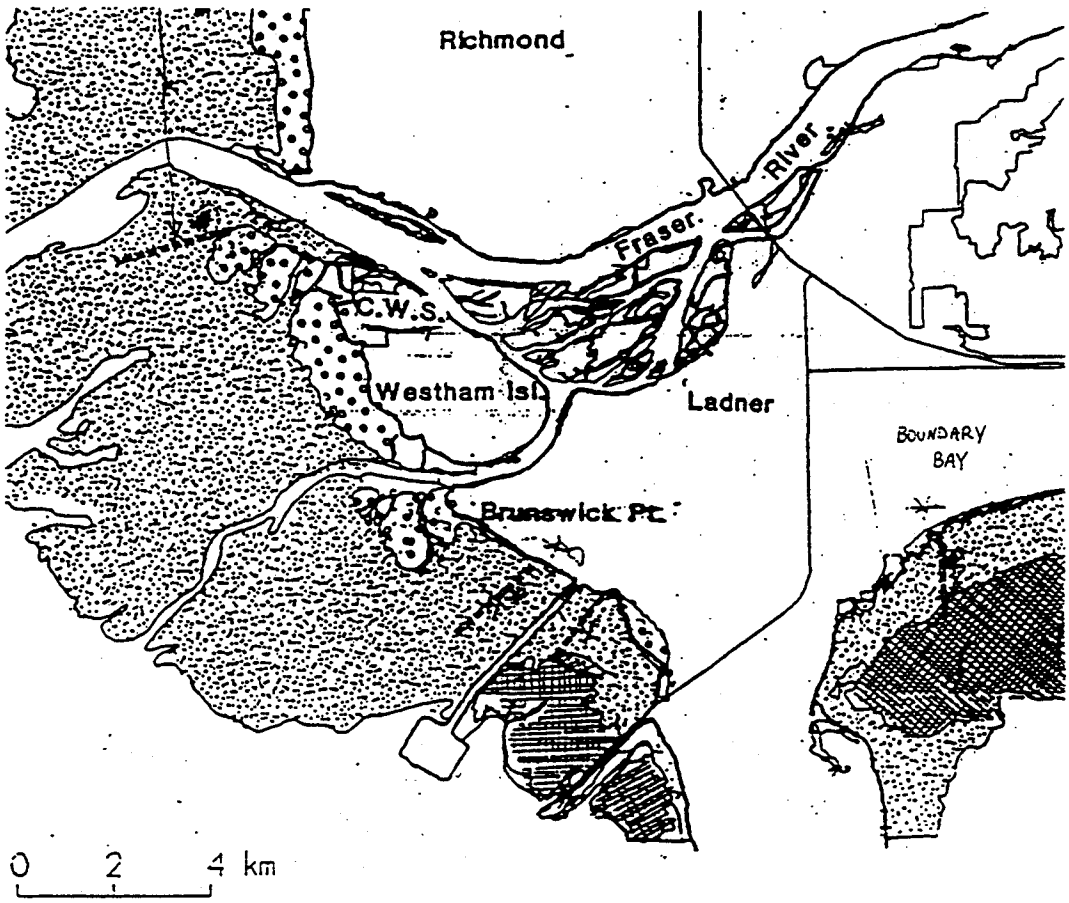
Westham Isl.
Ladner
Brunswick Pt.
Boundary Bay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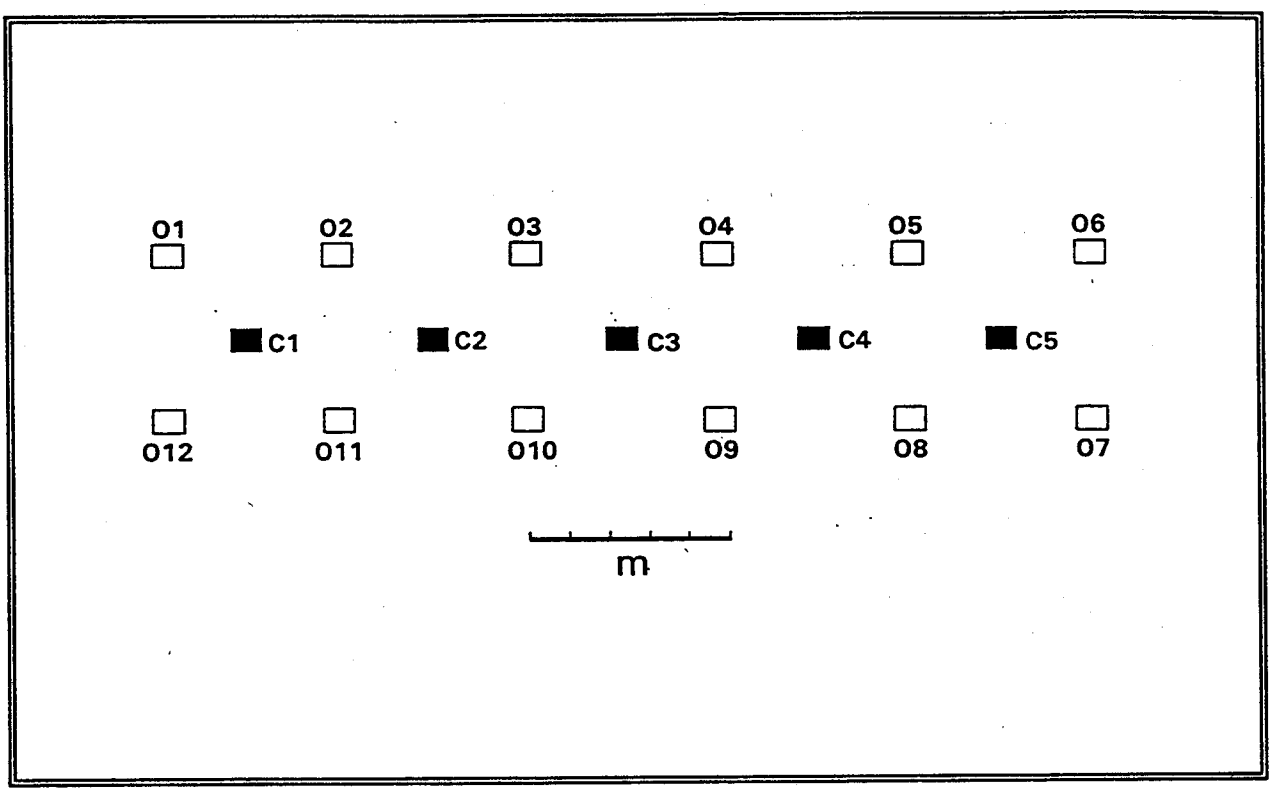
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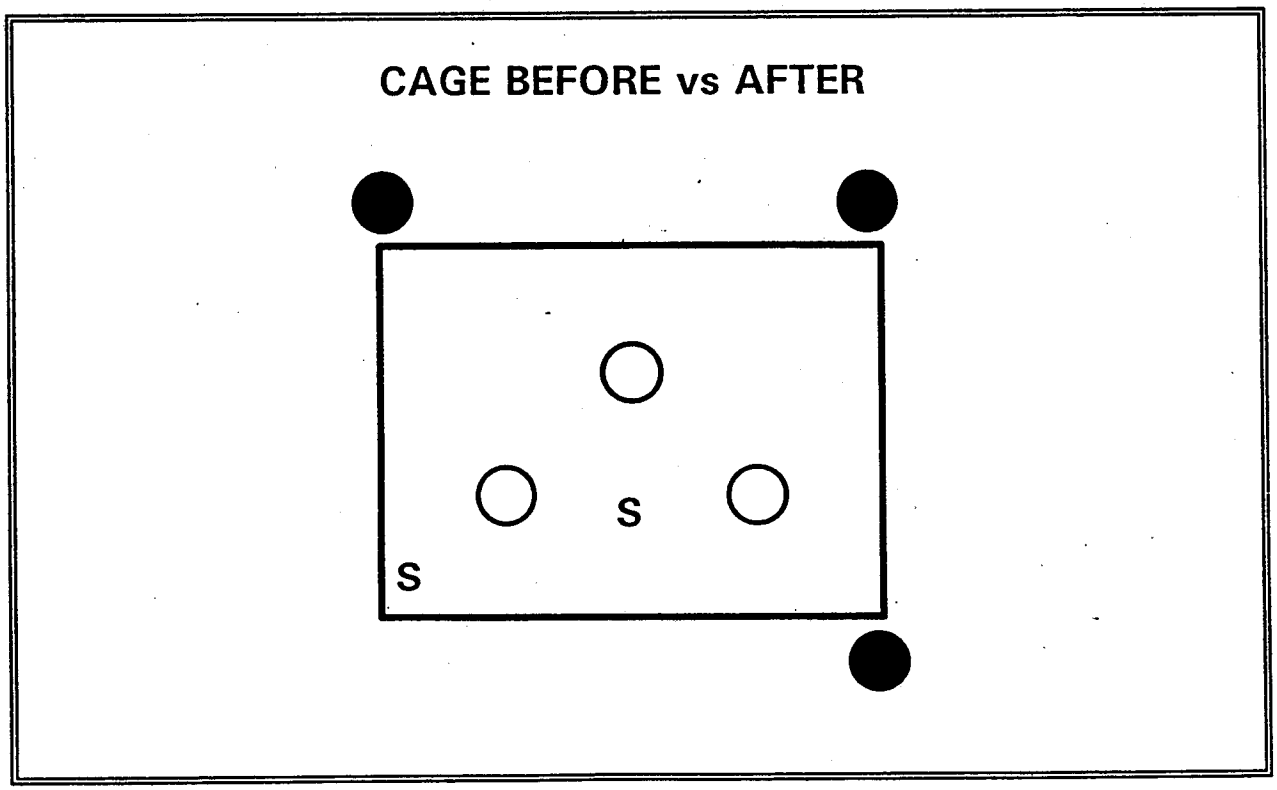

CAGE BEFORE vs AFTER
S
S

Statistical Analyses.

1. Cage Before vs After = a test of cage effects.

   Two way ANOVA. Effects Cage, Time, Interaction.

2. Cage vs Outside = a test of "impact" of predation.

   Nested ANOVA. Effects Position (in cage or outside), No. nested within position (compares cages 1-5, and outside 1-12).

Two-way ANOVAs comparing invertebrate numbers for cage B/A.

Brunswick Point. N = 7 species.

Species	Time	Cage	Cage* Time	Mean No's with Time
Macoma	*	-	-	↓
Manayunkia	*	-	-	↓
Eteone (Y)	-	-	-	
Hobsonia	-	*	-	
Leucon	*	-	-	↓
Sinelobus	**	*	-	↓
Corophium	**	*	-	↑

Numbers were transformed by $\log_{10}(x + 1)$ for analysis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Nested ANOVAs comparing invertebrate numbers for Cage vs Outside.

Boundary Bay. N = 5 Species.

Species	Position	No(Position)
Batillaria	-	-
Macoma	*	-
Eteone (Y)	-	-
Manayunkia	-	-
Ostracod	-	-

Numbers were transformed by $\log_{10}(x + 1)$ for analysis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

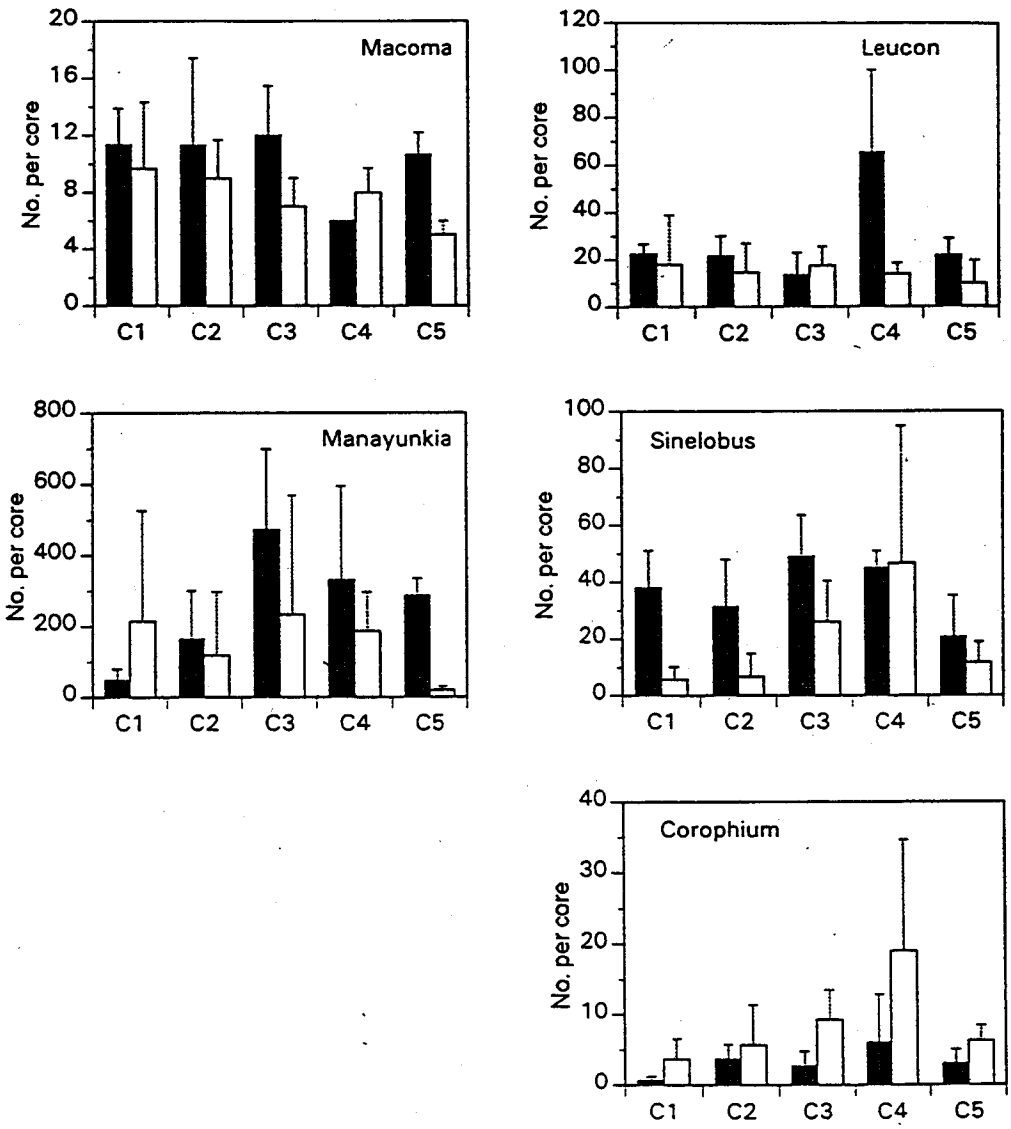
Nested ANOVAs comparing invertebrate numbers for Cage vs Outside.

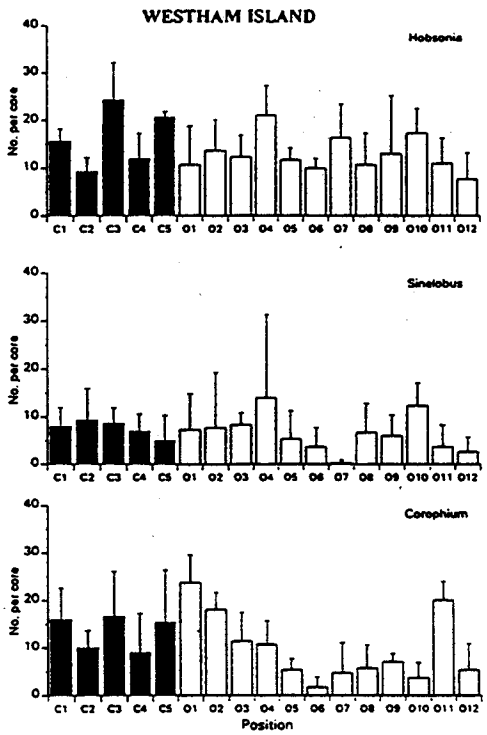
Westham Island. N = 8 species.

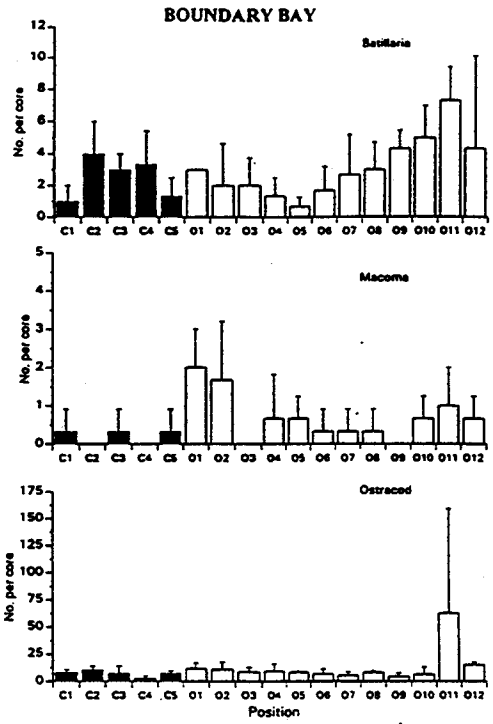
Species	Position	No(Position)
Macoma	-	-
Mya	-	
Manayunkia	-	-
Hobsonia	-	-
Leucon	-	-
Sinelobus	-	-
Corophium	*	*
Gammarids	-	*

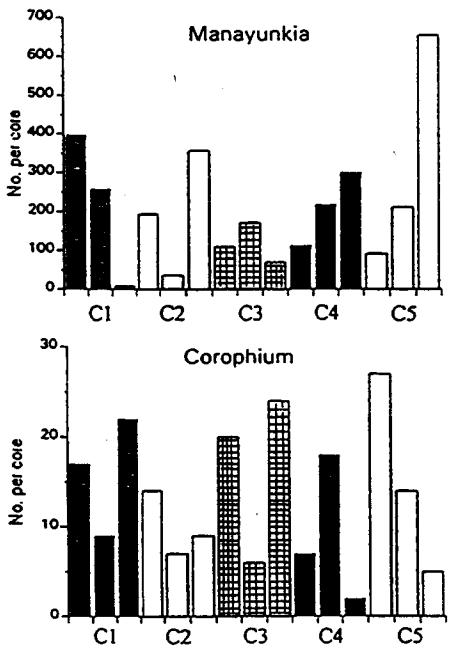
Numbers were transformed by $\log_{10}(x + 1)$ for analysis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

BRUNSWICK POINT




WESTHAM ISLAND
Hobsonia
Sinelobus
Corophium
No. per core
Position
C1 C2 C3 C4 C5 O1 O2 O3 O4 O5 O6 O7 O8 O9 O10 O11 O12


BOUNDARY BAY
Batillaria
Macoma
Ostracod
No. per core
Position
C1 C2 C3 C4 C5 O1 O2 O3 O4 O5 O6 O7 O8 O9 O10 O11 O12


Manayunkia
Corophium
No. per core
C1 C2 C3 C4 C5

SESSION 2

ASSESSMENT OF ENVIRONMENTAL IMPACTS OF SPECIFIC POLLUTION SOURCES

Impacts of Effluents on Benthic Food Webs of the Upper Fraser River

J.M. Culp

National Hydrology Research Institute

Our project task, as defined by FRAP, is to assess the environmental effects of effluents on benthic communities through a combination of field measurements and controlled experiments. We have been asked to (i) identify the benthic components most exposed to effluents; (ii) quantify the effects of effluents on the benthic food web; and (iii) establish effective criteria or indicators for assessing cumulative effects. We are meeting these objectives by undertaking an integrated assessment program which incorporates field observations on benthic food webs, bioassays which examine simple food chains, and mesocosm experiments capable of investigating the effects of complex effluents on food webs. All of our experiments are targeted to provide information on the current status of the environment as well as to give insight into the possible effects on ecosystem integrity of restoration scenarios (e.g., future reductions in effluent loadings).

Our field observation program has focused largely on the Thompson River and addresses three major areas. First, we have collated a long-term data set for this river and currently are examining interdecadal changes in benthic invertebrate communities which appear to be related to pulp mill effluent (PME) loadings. Secondly, our group has examined temporal and spatial changes in benthic food webs along the effluent gradient below Kamloops, B.C. These studies indicate that changes in mill operation have impacts on downstream indicators such as chironomid and algal abundance. Thirdly, we have identified food web pathways in the Thompson River through the use of stable isotopes of carbon and nitrogen. Surprisingly, this ecosystem is far more dependent on upstream carbon than was previously suspected. Taken together, these field studies indicate that PME loadings likely lead to enrichment effects in downstream benthic communities.

The responses of benthic invertebrates to biotreated, bleached kraft pulp mill effluent were evaluated through simple food chain bioassays. These studies indicate that the effluent stimulated significant increases in growth and development of the experimental animals (i.e., chironmids and mayflies). The reasons for this growth stimulation may include: (i) an effluent-related increase in nutritive value of food; (ii) the stimulation of larval feeding under effluent exposure; or (iii) the direct stimulation of growth by way of hormonal or other metabolic effects.

To examine the effects of PME on benthic food webs we developed a mobile mesocosm system. This system allows precise control over relevant environmental variables while providing adequate replication and trophic complexity under field conditions. Our initial experiments evaluated the ecological effects of PME on the benthos under loading scenarios that simulated present, increased and reduced conditions near Prince George, B.C. Community endpoints measured in these experiments include algal abundance and composition, uptake of contaminants by algae, microbial production, invertebrate abundance and community structure, and invertebrate growth. Field samples of the key variables were also collected to establish a linkage between mesocosms and the field. Future experiments will investigate the importance of seasonal changes and light imitation on the ecological impacts of PME.

A nutrient mass balance model for the Upper Fraser River is currently being constructed. This project will provide estimates of the importance of point source additions of nutrients from sewage and industrial effluents relative to the cumulative effects of nutrient inputs from various land use practices.

The project has pulled together 12 scientists from NHRI, DOE/P&Y, BC Environment and DFO. Strong linkages between this FRAP project and the Northern Rivers Basins Study have also enhanced the project. To date, we have produced three FRAP reports, four publications and three conference presentations.

Our special needs from other groups are related to data needed to extend our conclusions from the mesocosm research. These needs include (1) knowledge of spatial mixing patterns of the Northwood effluent plume, (2) chemical characterization of PME at the Northwood mill; and (3) samples of fish tissue for stable isotope analyses upstream and downstream of Northwood.

Suitability of Small Fish Species for Monitoring the Effects of Pulp Mill Effluent on Fish Populations of the Fraser River: Peamouth Chub (*Mylocheilus caurinus*) Response to BKME Exposure in the Upper Fraser River, B.C.

K.R. Munkittrick[1], W. Gibbons[2], W.D.Taylor[2] and P.V. Hodson[3]

[1]*Great Lakes Laboratory for Fisheries and Aquatic Sciences*
[2]*University of Waterloo*
[3]*National Water Research Institute*

ABSTRACT

Previous studies on wild fish in the Fraser River have documented effects on accumulation of persistent compounds and induction of liver MFOs. However, population level responses have been difficult to investigate due to the extreme mobility of large fish species with the Fraser system. This study was initiated to determine whether populations of a resident forage fish species (peamouth chub, *Mylocheilus caurinus*) exhibit whole organism (size-at-age, mean age, condition, gonad size, liver weight) and physiological (MFO induction, *in vitro* steroid production) responses to pulp mill effluent. Among immature fish, body metrics were not different upstream and downstream of the mill outfalls, however, there was a 2 to 2.5-fold EROD induction in exposed fish. Reproductive steroid analyses were not possible due to limited state of reproductive development at the time of the fall sampling period. Field sampling was conducted in the spring immediately prior to spawning in an effort to collect greater numbers of sexually mature fish. Analyses of the whole organism and physiological measurements were conducted for male and female fish and will be discussed. Additional samples of redside shiners (*Richardsonius balteatus*) were collected, but results are still under analysis. Water and effluent chemistry results are still under analysis. The results of field measurements will be compared with MFO activity and steroid levels (plasma and *in vitro* production) measured in goldfish and rainbow trout exposed to effluent from the pulp mills in Fraser River.

1. Objectives

Evaluate the suitability of small fish species (e.g. cyprinidae, cottidae) for monitoring the Fraser River. In particular:

- do small fish species show responses to effluent?
- are the responses (if any) similar to those reported in lab exposures or with larger fish species?
- are the responses reflective of localized environmental conditions (i.e., good dose/gradient responses)?
- is it possible to separate the effects of multiple discharges?
- is it possible to rapidly subsample fish populations to cost-effectively determine fish status?

2. Background

- Adult Fish Survey is part of the Canadian Environmental Effects Monitoring program for pulp and paper industry
- Concerns regarding the stationary behavior of sentinel fish species and subsequent exposure to mill effluent
- Demonstration of responses of wild fish to pulp mill effluent predominant in habitats where movement of fish has been restricted
- Smaller fish species are advocated as possible sentinel species because they exhibit limited mobility and possess a small home range
- Upper Fraser River was selected because:
  - pulp mills contribute a substantial proportion of the industrial effluent
  - concerns regarding effects of effluent on resident/migratory fish populations

3. Study Overview

- Peamouth chub (*Mylocheilus caurinus*) were collected downstream of two bleached kraft pulp mills (both with secondary treatment) and from a reference zone located upstream of both mills.

- Whole organism (size-at-age, condition, gonad size, liver weight) and physiological (MFO induction, plasma steroid levels, *in vitro* steroid production) responses were measured.

- Fish surveys were conducted in the fall (1993), and in the spring (1994) immediately prior to spawning.

- Supplemental laboratory exposures are also ongoing to compare the results of field measurements with MFO activity and steroid levels (plasma and *in vitro* production) measured in laboratory-exposed goldfish and rainbow trout.

4. Progress to Date

- September/October 1993 field survey
  Reported on last year, only peamouth chub present in sufficient numbers, some preliminary caging work from March 1993

- March 1993 effluent evaluation
  Sampled effluent from five mills on the Fraser and evaluated MFO potential, and preliminary steroid analyses; difficult to extrapolate these values since (1) we are unsure what null response means (SRF problems), and (2) assay still undergoing modifications (Dangerous to tell mills "no response" at this time)

- April/May 1994 field survey
  - Similar to 93 fall survey, sampled large number of sites, captured mature male and female peamouth chub prior to spawning to evaluate levels of MFO, steroids, growth rates, maturity rates, age and size structure, gonad size, liver size, fecundity (on-site close to one month, substantial sampling effort)
  - contaminant levels in effluent, water

- Still have some problems with capture of individuals within the exposed areas due apparently to habitat differences (fall '93 attempted exposed areas first).

- Still difficult to capture at reference sites, but can be done, and success varied a lot in the spring flow and location.

- Also captured significant numbers of shiners, but analysis not completed yet on those fish.

- July 1994
  Additional laboratory exposures to effluent. Several problems: courier lost the effluent samples for three weeks. Freezer malfunction and steroid samples lost. We are waiting for finalization of laboratory protocol to repeat this work.

  would like to repeat all 4 mills (require 8-10K)

- September/October field bioassays
  - due to low number of obvious changes, and difficulty in capture of fish close to the outfalls, decided on an on-site bioassay in cooperation with Culp and Chamber's group
  - collected 70-80 mature peamouth from reference sites, and caged for 8 d (after 4 d fungus and mortalities, so experiment terminated after 5 d), tried to coordinate collections with Bev Raymond and others, but everyone having trouble with peamouth collections
  - some data still under analysis

- Next year
  a) we would like to try again to increase adult sample sizes around the pulp mills
  b) we would like to compare growth data of redside shiners and peamouth chub from 1994/95 to MacPhail's 1950s collections
  c) complete the work on the mill comparisons
  d) participate in other studies on the system

5. Conclusions

- 100% effluent from both mills induced EROD activity in laboratory-exposed rainbow trout.

- Although seining, gill netting, electrofishing, set-lining and trap netting techniques were all tried, greatest numbers of peamouth were caught in eddy pools along the margins of the river using sinking, monofilament gill nets (2" mesh).

- Despite substantial sampling effort, numbers of mature male/female fish captured in exposure zones were limited.

- Generally responses of peamouth chub exposed to BKME were not different from reference fish; however, limited sample sizes of mature fish weakened comparisons.

- No steroid differences were observed and hCG does not appear to be a suitable GtH agonist for peamouth chub *in vitro* steroid tests.

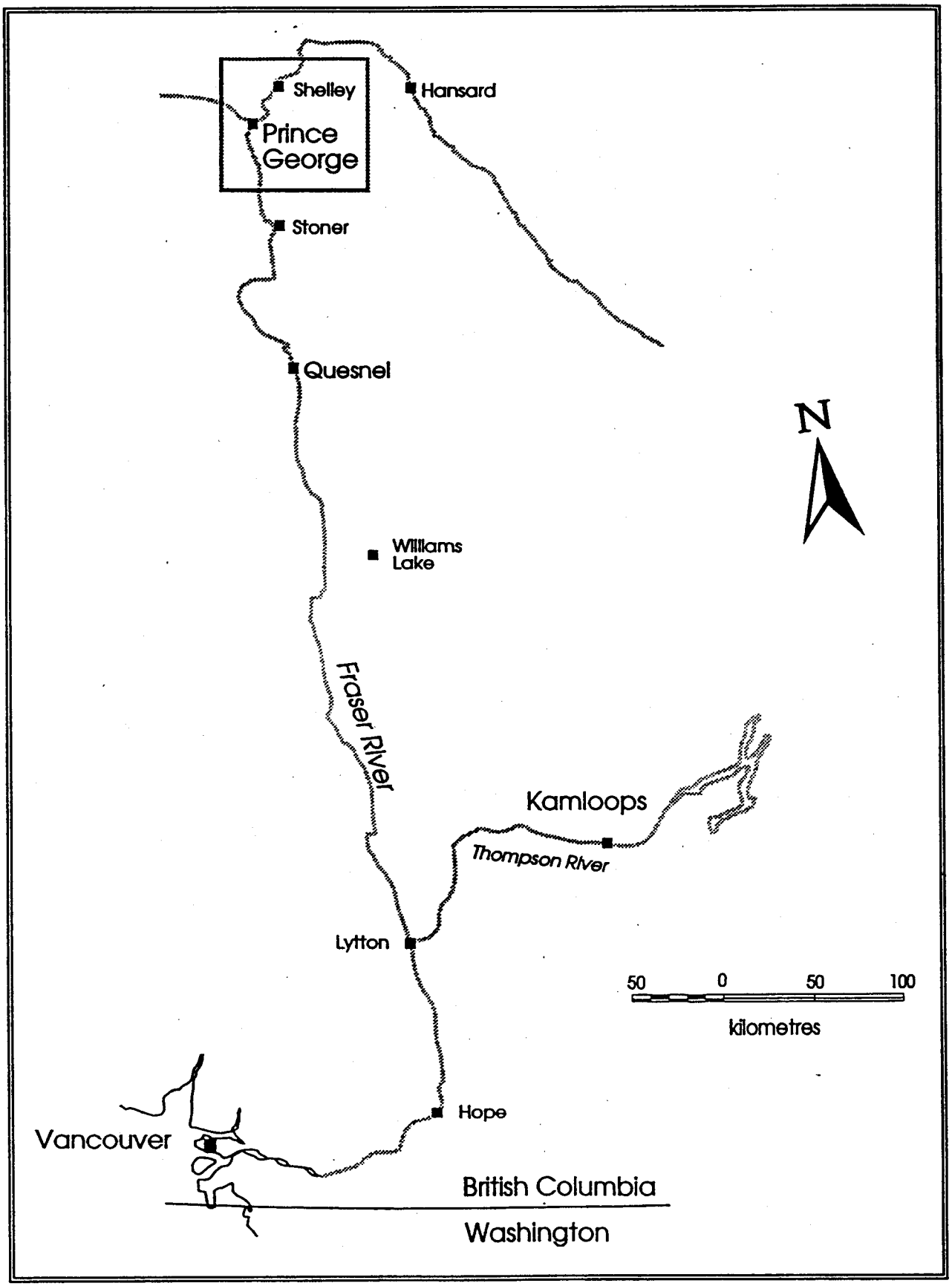
5. Recommendations

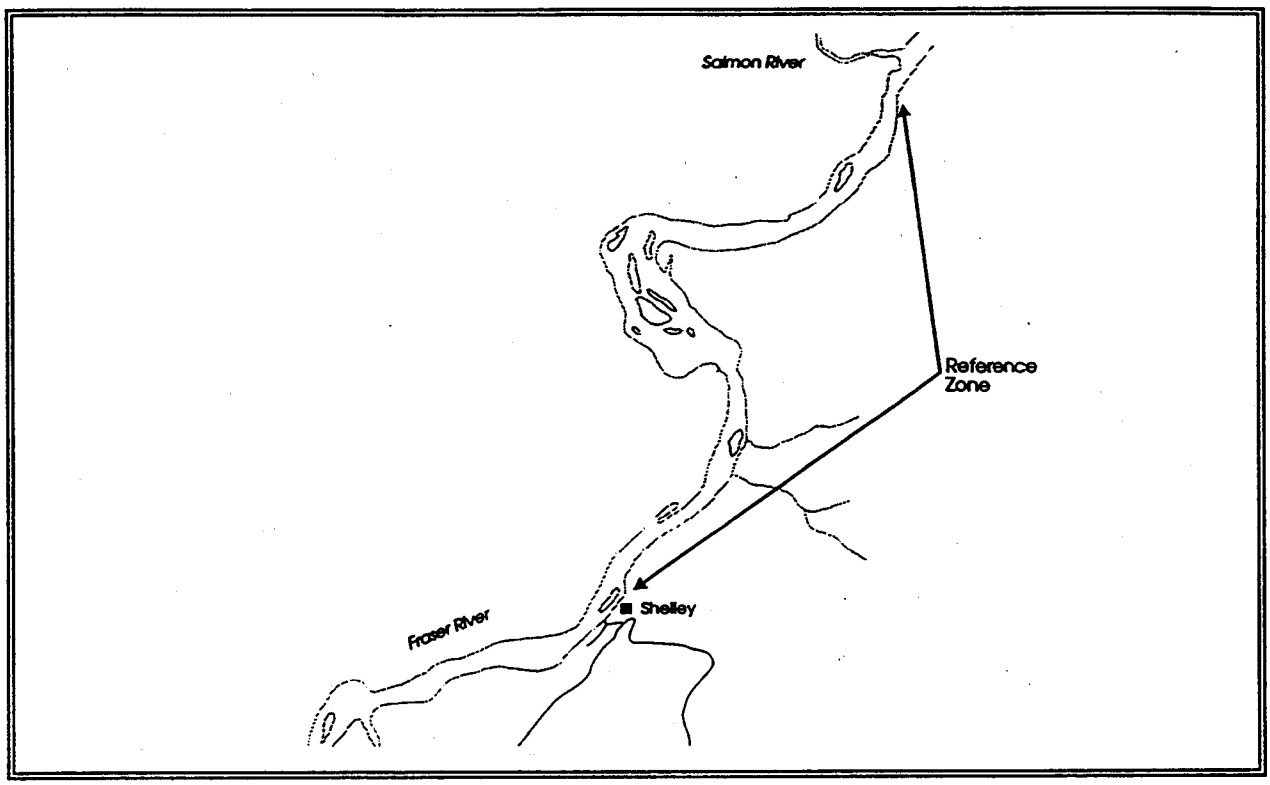
- Studies could be conducted to provide further understanding of habitat preferences, life history and mobility of peamouth chub.

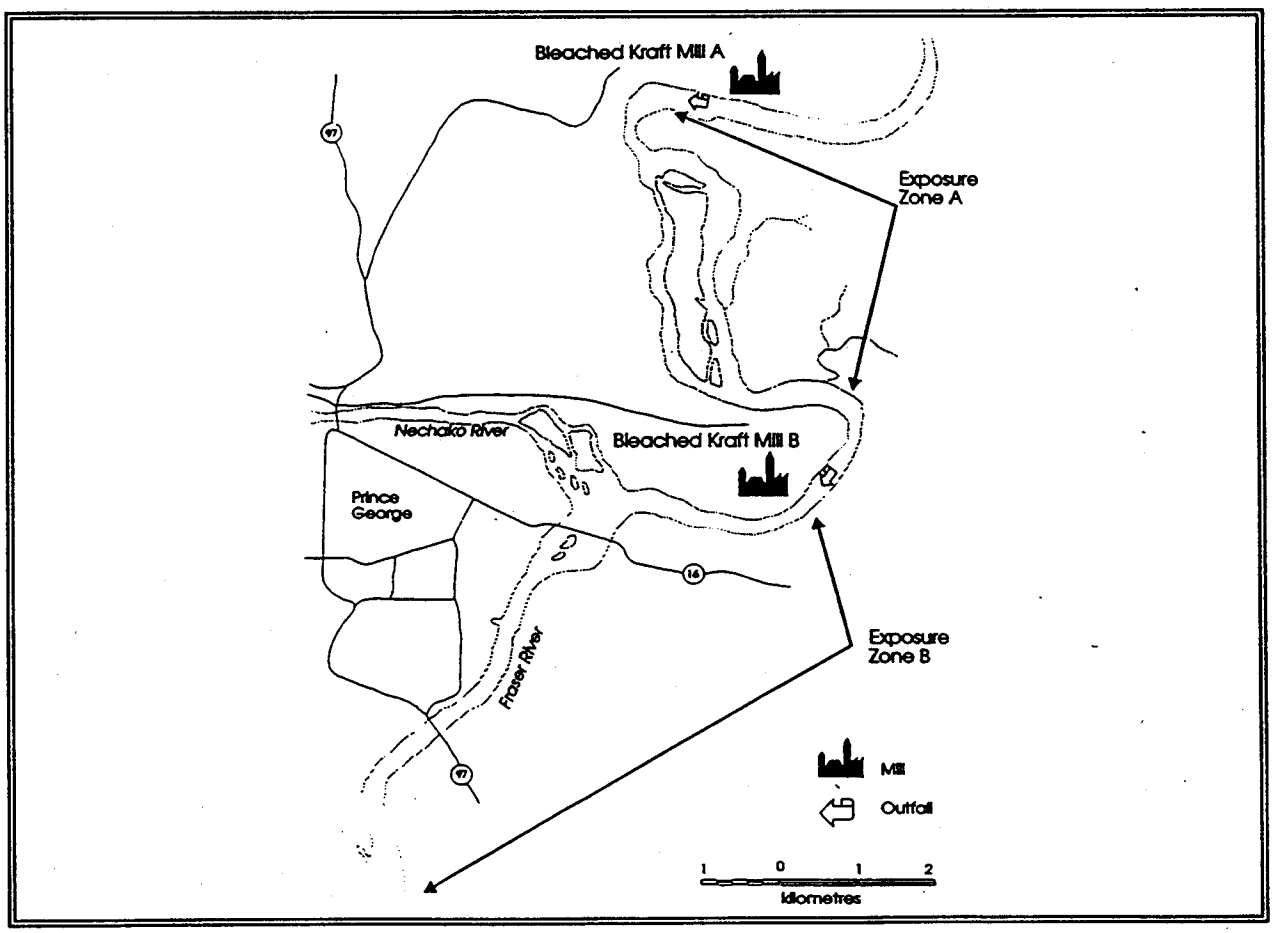
- Further work needs to be conducted to refine the *in vitro* steroid procedure for peamouth chub.

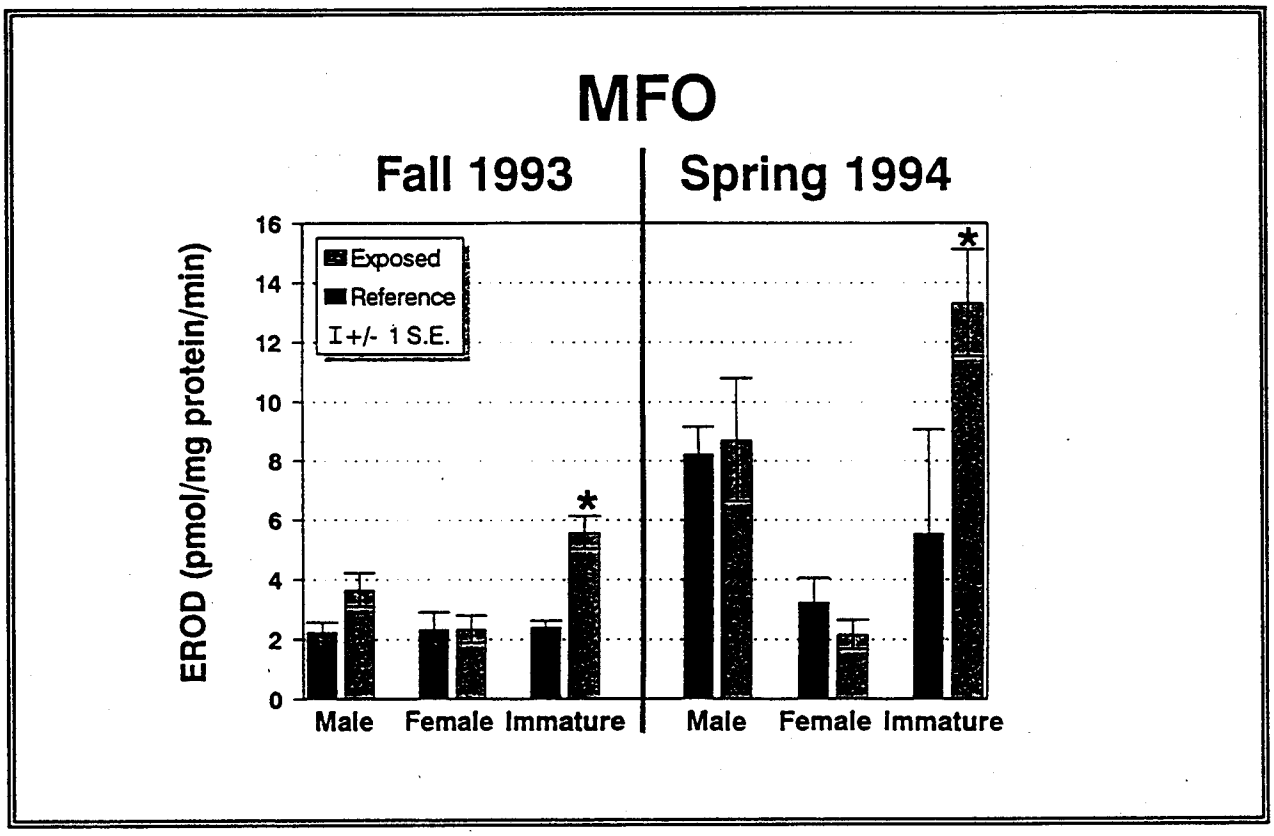
- Laboratory studies need to evaluate MFO and steroid dose/gradient responses to effluent.

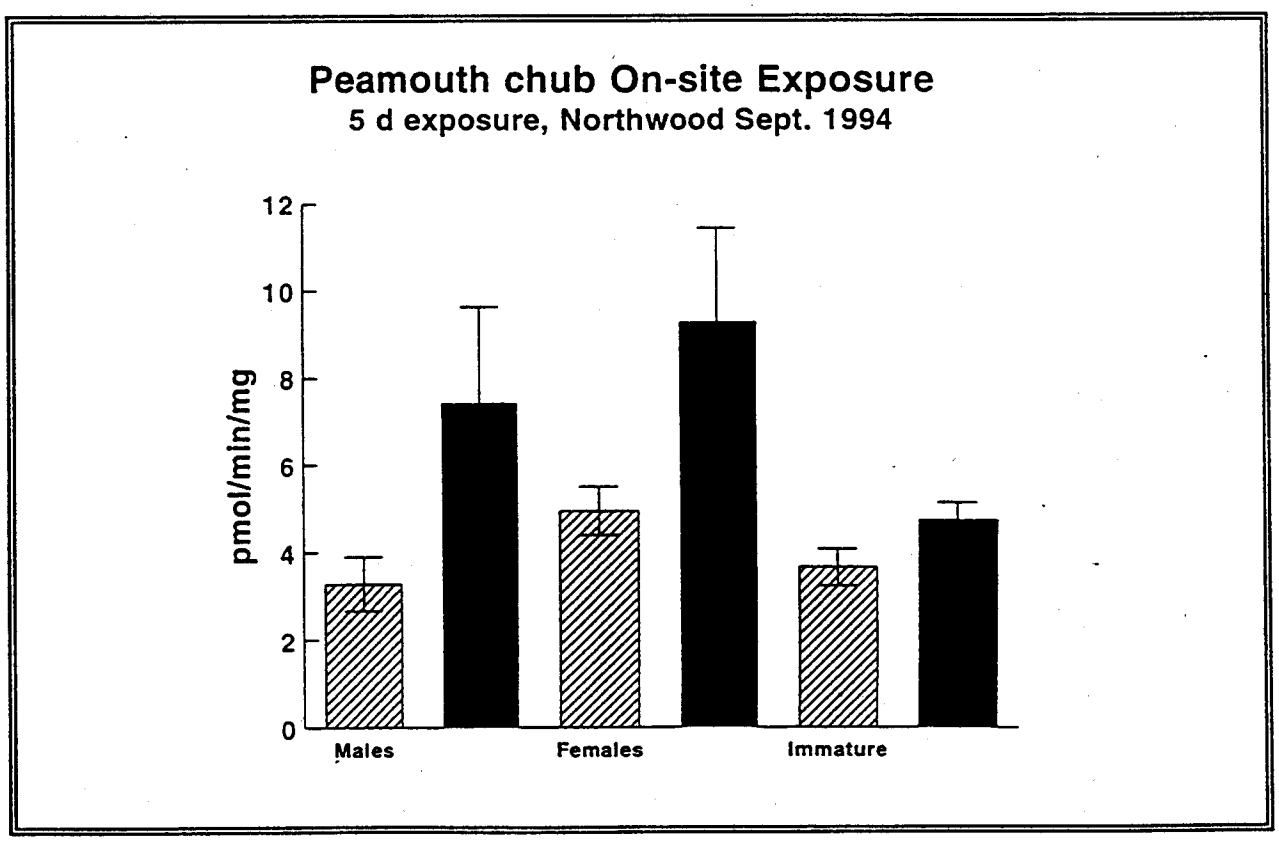
- Controlled exposure tests using peamouth chub would also provide useful information regarding the response of this species to BKME.


Shelley
Hansard
Prince George
Stoner
Quesnel
N
Williams Lake
Fraser River
Kamloops
Thompson River
Lytton
50 0 50 100
kilometres
Hope
Vancouver
British Columbia
Washington

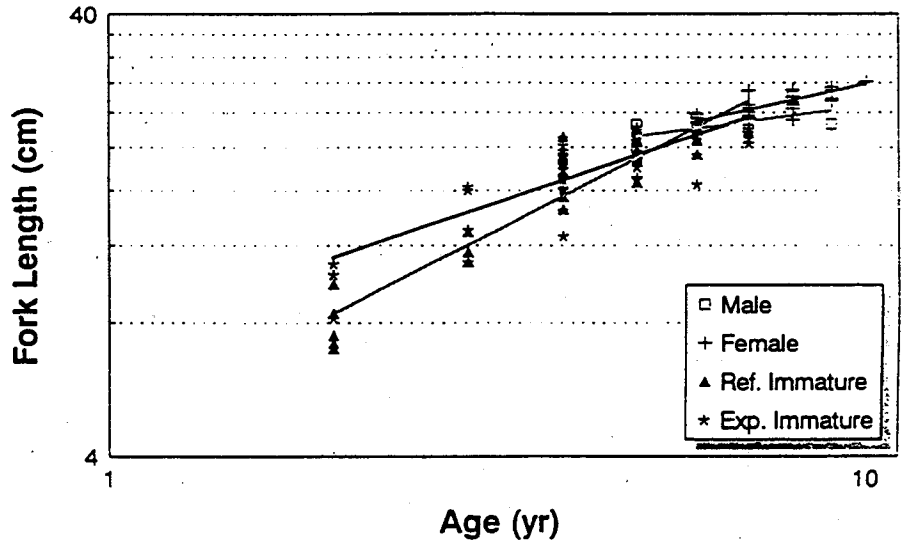

Salmon River
Reference Zone
Shelley
Fraser River


Bleached Kraft Mill A
Exposure Zone A
Nechako River
Bleached Kraft Mill B
Prince George
Exposure Zone B
Fraser River
Mill
Outfall
1 0 1 2
Kilometres

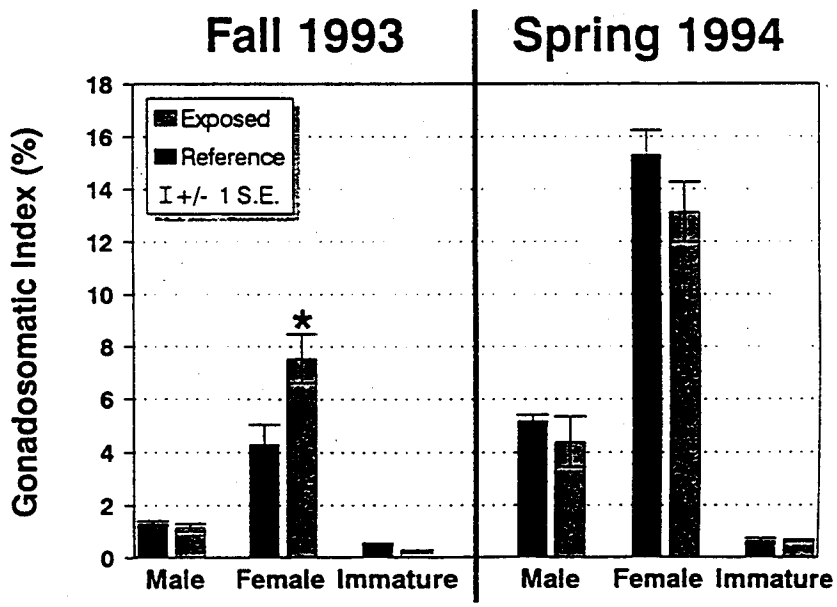

MFO
Fall 1993
Spring 1994
EROD (pmol/mg protein/min)
Exposed
Reference
I +/- 1 S.E.
16
14
12
10
8
6
4
2
0
*
*
Male
Female
Immature
Male
Female
Immature

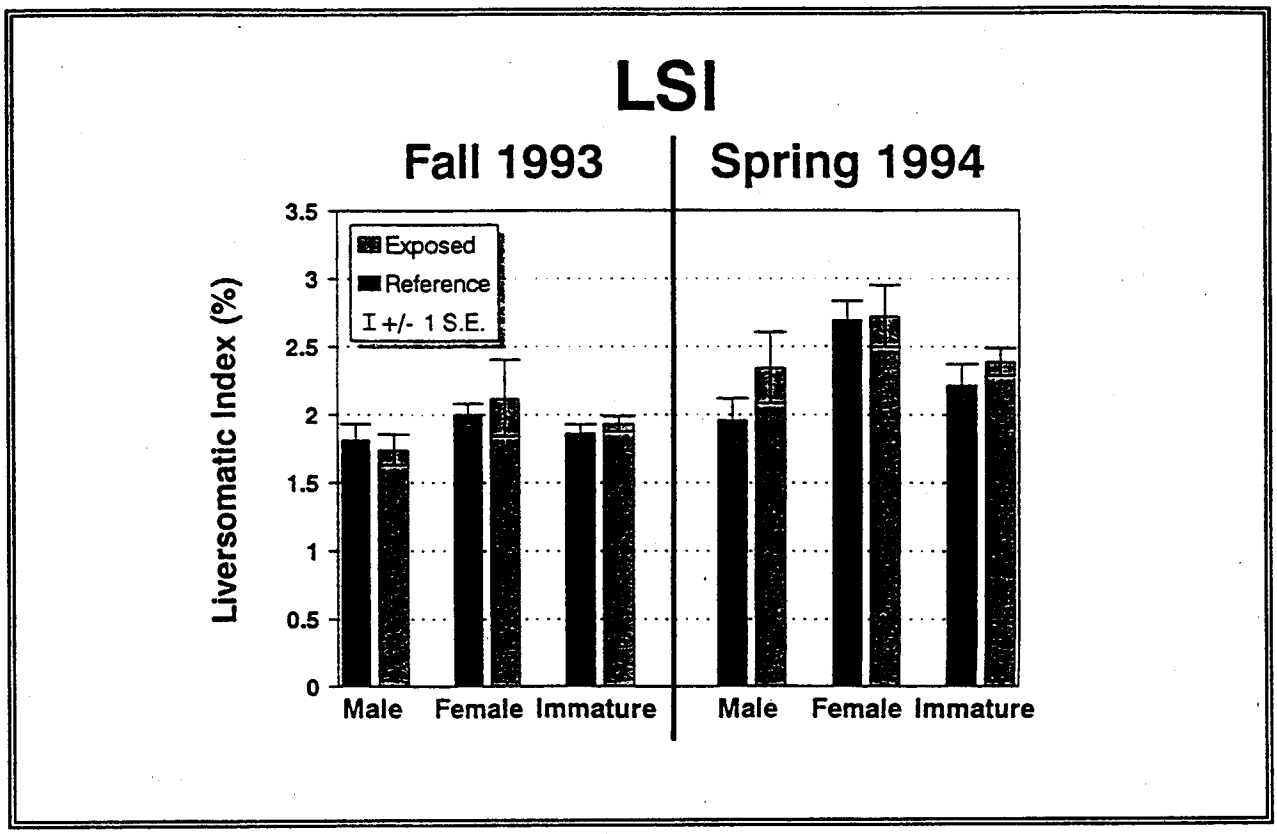

Peamouth chub On-site Exposure
5 d exposure, Northwood Sept. 1994
pmol/min/mg
12
10
8
6
4
2
0
Males
Females
Immature

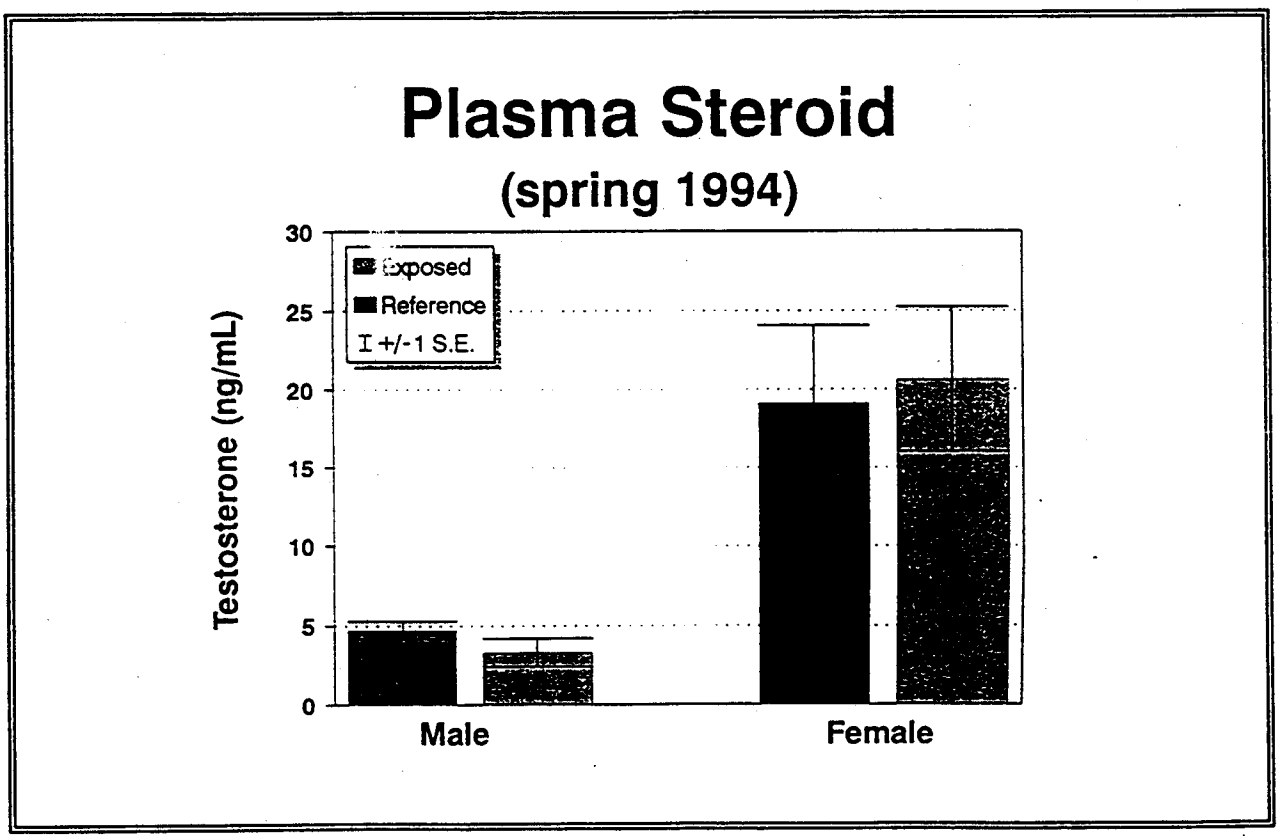
Size-at-Age
(prespawning)



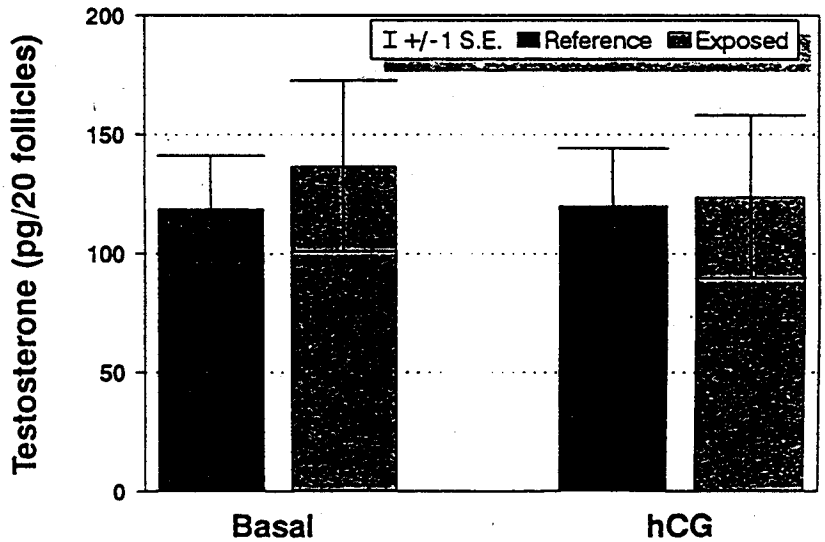
GSI




LSI
Fall 1993
Spring 1994
Liversomatic Index (%)
3.5
3
2.5
2
1.5
1
0.5
0
Exposed
Reference
I +/- 1 S.E.
Male
Female
Immature
Male
Female
Immature


Plasma Steroid
(spring 1994)
Testosterone (ng/mL)
30
25
20
15
10
5
0
Exposed
Reference
I +/-1 S.E.
Male
Female

In vitro Steroid
(spring 1994)



- Liver-carcass weight relationships for fall and prespawning fish were not different between zones

- Plasma levels of testosterone in prespawning peamouth chub were not different between zones
- High variability among fish within zones reduced the power of the comparison

- Testosterone production by ovarian follicles from prespawning females were not different between zones
- Ovarian follicles did not show steriodogenic responses in the presence of human chorionic gonadotropin (hCG)
- High variability among fish within zones again reduced the power of the comparison

Cytochrome P450 1A1 from Fish and Preparation of Antibody Against Fish Cytochrome P450 1A1

S.M. Bandiera

University of British Columbia

1. Research Results

The purpose of the project was to prepare antibody to cytochrome P450 1A1 as a probe to measure induction of cytochrome P450 1A1 in wild fish as a result of exposure to pulp mill effluents and other contaminants in the Fraser River. The first objective was to purify fish cytochrome P450 1A1 from an appropriate resident fish species of the Fraser River. The purified protein was to be used as an antigen to prepare antibody against cytochrome P450 1A1 and as a standard for immunoblotting. The antibody was to be provided to Dr. R.F. Addison, Institute of Ocean Sciences, Fisheries and Oceans, Sidney, B.C.

As we do not have access to facilities to raise or maintain fish, we were dependent on receiving fish treated with an inducer of cytochrome P450 1A1, such as β-naphthoflavone, from the Department of Fisheries and Oceans. We estimated that we would require 100-200 g of liver, from which we would obtain 5-10 g of microsomal protein, to yield approximately 5 mg of purified cytochrome P450 1A1. In the meantime, a research technician with experience in protein purification was hired to work on this project at 40% time. The technician, Song Lin, received additional training in the purification of cytochrome P450 proteins. In order to optimize a purification scheme and anticipate possible problems in the purification of fish cytochrome P450 1A1, cytochrome P450 1A1 was purifed from rats using a combination of anionic, cationic, and hydroxyapatite columns. At about this time, DFO informed us that it would not be possible to supply us with the number of fish that we required. Moreover, an appropriate resident fish species was never identified by the various research groups involved in FRAP. Consequently, Dr. R.F. Addison decided that instead of purifying cytochrome P450 1A1 from fish, which would take considerable time and resources, it would be simpler and more practical to have a peptide, corresponding to part of the known amino acid sequence of trout cytochrome P450 1A1 and that is conserved among various species, synthesized. The peptide could then be used to immunize rabbits to generate antibody against cytochrome P450 1A1.

The second objective was to raise and purify an antibody against fish cytochrome P450 1A1. Three female adult New Zealand rabbits were purchased and housed in the Animal Care Centre, UBC. The rabbits were immunized with the synthetic peptide conjugated to keyhole limpet hemocyanin supplied by Dr. Addison. Each rabbit was initially immunized with 200 μg of peptide-conjugate emulsied in Freund's complete adujuvant and administered subcutaneously. Four weeks later, the rabbits received a boost consisting of 50 μg of peptide-conjugate per rabbit, as a 1:1 emulsion in Freund's incomplete adjuvant administered by intramuscular injection into each of the upper hind legs. In addition, each rabbit received an intravenous injection, using the ear vein, of 50 μg of peptide conjugate dissolved in phosphate-buffered saline (PBS) solution. A small volume of blood (approx. 10 mL) was collected from each rabbit seven days later and the serum fraction was tested for the presence of antibodies to the peptide. The same boost procedure was repeated four weeks later, followed by collection of approximately 30 mL of blood from each rabbit seven days after the boost. Thereafter, the rabbits were boosted by intravenous injection on a monthly basis and bled a week later. The blood from each bleeding was allowed to clot and the serum was removed and saved at -20°C.

Once a sufficient volume of sera was collected, it was pooled and heated to 56°C for 60 min. to inactivate complement. Immunoglobulin G (IgG) was purified using a combination of caprylic acid precipitation followed by ammonium sulfate precipitation and final cleanup on a DEAE-Sephacel column. From an initial volume of approximately 400 mL of serum containing 11.84 g of protein, 1.96 g of purified IgG was recovered. The concentration of IgG was determined spectrophotometrically at 280 nm. After purification, the specificity of the IgG was assessed by enzyme-linked immunosorbent assay (ELISA) and on immunoblots, with purified rat cytochrome P450 isozymes, as well as liver microsomes prepared from various species. The anti-cytochrome P450 1A1 peptide IgG reacted strongly with purified rat cytochrome P450 1A1, but not with purified rat cytochromes P450 2A1, 2B1, 2E1, 2C13 or 3A1, on ELISA. It also reacted strongly with purified

KLH, but not with other proteins such as lysozyme or epoxide hydrolase. On immunoblots, the antibody recognized a single protein band corresponding to cytochrome P450 1A1 in hepatic microsomes from rainbow trout, whitefish, chinook salmon and chub, although the reaction with the chub sample was weak. It also reacted with a single protein band in hepatic microsomes from rats, chickens, quail and pigeons treated with 3-methylcholanthrene (a protype inducer of cytochrome P450 1A1). The antibody does not appear to recognize cytochrome P450 1A2, although it has not been specifically tested with the purified protein. In addition, the antibody does not inhibit ethoxyresorufin O-deethylase activity.

In summary, antibody to fish cytochrome P450 1A1 has been successfully prepared using a synthetic peptide corresponding to amino acids 277-294 of trout cytochrome P450 1A1 as the antigen of immunization. The antibody recognizes cytochrome P450 1A1 specifically in a variety of fish, mammal and bird species, and does not react with other forms of cytochrome P450. Therefore, the antibody is suitable as a probe to measure induction of cytochrome P450 1A1 in resident fish species in the Fraser River.

Approximately 650 mg of anti-cytochrome P450 1A1 IgG was delivered to Dr. R.F. Addison in December 1994, together with a small quantity of purified rat cytochrome P450 1A1, for use as an authentic standard for immunoblots.

2. Remaining Work

The antibody that we prepared reacts strongly with cytochrome P450 1A1 but also reacts strongly with KLH, an unrelated protein that was conjugated to the peptide. We retained approximately 1,310 mg of the antibody and will attempt to remove the reaction towards KLH by immunoadsorption so that the antibody will be truly specific for cytochrome P450 1A1 only. Moreover, two of the three rabbits that were used to generate the antibody remain healthy and continue to produce antibody to the cytochrome P450 1A1 peptide. In agreement with Dr. R.F. Addison, we will continue to boost the rabbits with the peptide-conjugate and bleed them on a regular schedule to maintain antibody production.

Fish Hepatic Mixed Function Oxidase Induction as an Indicator of the Effects of Pulp Mill Effluents

R.F. Addison

Institute of Ocean Sciences

ABSTRACT

The rationale for this project is that various organic contaminants, including some PAH, some PCBs, and chlorinated di-benzo-dioxins and furans induce liver microsomal cytochrome P450 1A1 (CYP 1A1) and its associated enzyme activity (ethoxyresorufin O-de-ethylase; EROD) both of which are described informally as "mixed function oxidase" (MFO) activity. The aim of this project is to use fish liver MFO induction to indicate environmental quality in general in the Fraser River, and specifically, the zone of influence of pulp mill effluents.

Juvenile chinook salmon were sampled at a reference site on the Nechako River free from any influence of industrial activity, and at sites at Prince George, Stoner, Longbar and Soda Creek on the Fraser, and on the Thompson. Indices of MFO induction were measured in the field and samples were retained for dioxin and PCB analysis. Samples from the Nechako had the lowest MFO activities and the lowest dioxin and furan concentrations; fish from Longbar, Soda Creek and the Thompson had the highest MFO activities. Fish from Prince George (at the Northwood mill site) had highest dioxin concentrations, but furans and mono-ortho substituted PCBs were highest at the Soda Creek and Thompson sites. A preliminary inspection of the data suggests that MFO activity is best correlated with PCB concentrations.

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1. Objectives

Examine MFO induction in fish as an indicator of the impact of pulp mill effluents in the Fraser system, by:

a) selecting a suitable monitoring species of fish, and characterizing its hepatic MFO system;

b) measuring indices of MFO induction in fish exposed adventitiously in the field to pulp mill effluents;

c) correlating MFO measurements in field-exposed fish with chemical analysis of appropriate residues in tissues.

2. Approach Taken

- Assess the suitability of juvenile chinook salmon (*Oncorhynchus tsawytscha*) as a monitoring species.
- Characterize hepatic MFOs in juvenile chinook (pH optimum. Km, etc.) for EROD and CN-ECOD.
- Develop methods for "Western blotting" of CYP 1A1 using specific antibodies (S. Bandiera).
- Measure MFOs in juvenile chinook from the field (spring 1994).

3. Results to Date

- Conditions for EROD and CN-ECOD assays in juvenile chinook established (IOS). Western blotting methods developed for isolation and detection of CYP 1A1 (IOS).
- Synthetic oligopeptide fragment of CYP 1A1 prepared. Injected to rabbits to raise antibodies to fish CYP 1A1 (UBC).
- EROD and CN-ECOD in juvenile chinook sampled from Fraser River in spring 1994 (IOS, with DFO Cultus Lake). Dioxin, furan and PCB residues measured in these samples (IOS).

4. Future Work

- Complete analyses of spring 1994 Fraser samples, with
  - (i) CYP 1A1 determinations on stored samples;
  - (ii) Multivariate analysis of indices of MFO activity (EROD, CYP 1A1) vs chemical residues.
- Begin experimental studies of dose-response relationship between CDD, CDF and PCB exposure and indices of MFO activity in juvenile chinook.
- Repeat juvenile chinook sampling in Fraser in Spring 1995.

Site	EROD (pmoles/ min/mg protein)	CDD	CDF	PCB	
				Copl	Mono
		(all pg/g, tissue, wet wt.)			
Nechako (Ref.)	4.00 ± 2.75	0.59	0.22	8.01	184
Northwood (mill site)	11.6 ± 7.27	3.70	1.32	9.64	122
Stoner (30 km down)	38.2 ± 16.0	1.89 2.13 2.85	0.51 0.68 0.80	28.0 21.1 25.8	355 566 425
Longbar (100 km down)	59.3 ± 39.5	1.48 1.17	0.80 0.70	16.7 13.5	347 373
Soda Ck. (150 km down)	60.6 ± 35.2	2.61 2.52	2.52 1.18	104 234	6,900 12,981
Thompson R.	55.8 ± 33.4	1.69	4.65	14.8	920

Fish weight and hepatic mono-oxygenase activity in juvenile chinook salmon (*O. tshawatscha*) at various sites downstream from Prince George. Data as Mean ± s.d. EROD: ethoxycoumarin O-de-ethylase; CDD, total dioxin; CDF, total furan; PCB, polychlorinated biphenyl; Copl, co-planar PCBs; Mono, mono-ortho-PCB

Effects of Pulp Mill Effluent on Aquatic-based Wildlife

P. Whitehead

Environment Canada

1. Swallows

Tree swallows are migratory, colonial-nesting birds that eat mainly insects whose larval stages are aquatic. We hypothesize that they may be good sentinel wildlife species at a low position in the aquatic food chain for contaminants of moderate persistence (such as chlorinated phenols) that may be "filtered out" at higher trophic levels. Nest boxes have been constructed and placed above and below mills on the upper Fraser River. Nestlings were collected and submitted to the National Wildlife Research Centre for organochlorine analysis. Additional funds are required to contract analyses for chlorinated phenolics.

2. Ospreys

Ospreys are long-distance migrants that return to the same nest sites annually. Their diet is exclusively fish, making them excellent sentinel organisms for bioaccumulation of persistent contaminants from aquatic ecosystems. An unusual pattern of dioxin and furan contaminants has been observed from certain nests, suggesting contamination in their wintering areas in South America. Therefore, a project has been initiated to implant satellite transmitters to determine migration routes and wintering areas. Implanting methods are still being worked out, and will be further developed during 1995-96. Osprey eggs were collected at selected nest sites on the Fraser and Columbia River systems above and below pulp mill locations for organochlorine analysis. Productivity (fledglings per nest) was also assessed.

3. River Otters and Mink

Preliminary discussions have been held with lower Mainland and Kootenay regions of B.C. Environment regarding the possibility of initiating a cooperative study or ongoing monitoring of contaminants in aquatic mustelids. Previous (1990-91) data have been reviewed. Two study objectives are being formulated: (1) compare dioxin and furan data with earlier data to test the hypothesis that levels have dropped commensurate with improved treatment at pulp mills on the Fraser and Columbia systems, and (2) test the hypothesis that coplaner PCB levels on the Columbia reflect the pattern seen in osprey eggs (acceptance of the hypothesis will suggest that ospreys and aquatic mustelids accumulate PCBs from the same ecosystems, i.e., local uptake; rejection will suggest that ospreys may accumulate PCBs from other ecosystems, i.e., on migration routes or winter ranges). Funds would have to be allocated for the project to proceed this year.

Non-point Source Contamination and Ecosystem Health: Case Studies of the Brunette and Sumas River Watersheds

K. Hall and H. Schreier

University of British Columbia

1. Objectives

The general objective of the research is to determine the effects of non-point source urban and agricultural contamination on the structure and function of aquatic communities and to develop indices of ecosystem health from which to diagnose such contamination.

Specific objective include:

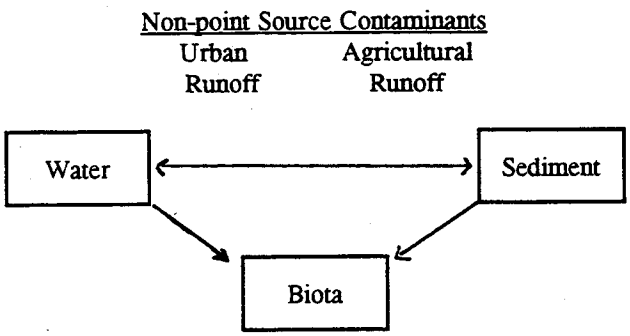
1) To determine the environmental quality (water, sediments and biota) in the Brunette and Sumas river systems and investigate the sources of contaminants in relation to land use activities within the basin.

2) To develop and test methods for indexing aquatic ecosystem health based on fish and invertebrate community structure and function and gross pathology of aquatic organisms in the Brunette and Sumas rivers.

3) To determine health of the aquatic ecosystems in both systems and relate these findings to the impacts of urban and agricultural development and wastes.

4) To collaborate with DOE and other government agencies in integrating indicators of ecosystem health into monitoring programs.

Environmental Quality and Pollution Sources



2. Water Quality Monitoring

a. Regular Monitoring - Baseline Conditions

Salmon & Sumas 8 times (Mar. to Nov. 1994)
Brunette 6 times (May to Nov. 1994)
- monitor all watersheds on same day

b. Detailed Monitoring - Events

Sumas Fall Storms, Manure Application 2-3x Oct., Nov.

Salmon Summer, Groundwater

Brunette Stormwater Runoff 7 events Jan. to Nov. 1994

3. Water Quality Parameters

a. Regular Monitoring

Field DO, Temp., Conductivity, pH

Lab Nutrients: NO_3, NH_3, PO_4, DOC, DI
Trace Metals: Cu, Mn, Pb, Zn
Other: Alkalinity, Turbidity, Cl, FC, FS, Microtox

b. Detailed Monitoring

Depends on concerns in watershed, for example:

Sumas nutrients
Salmon nutrients - nitrate, chloride
Brunette trace metals, hydrocarbons, suspended solids, BOD, COD

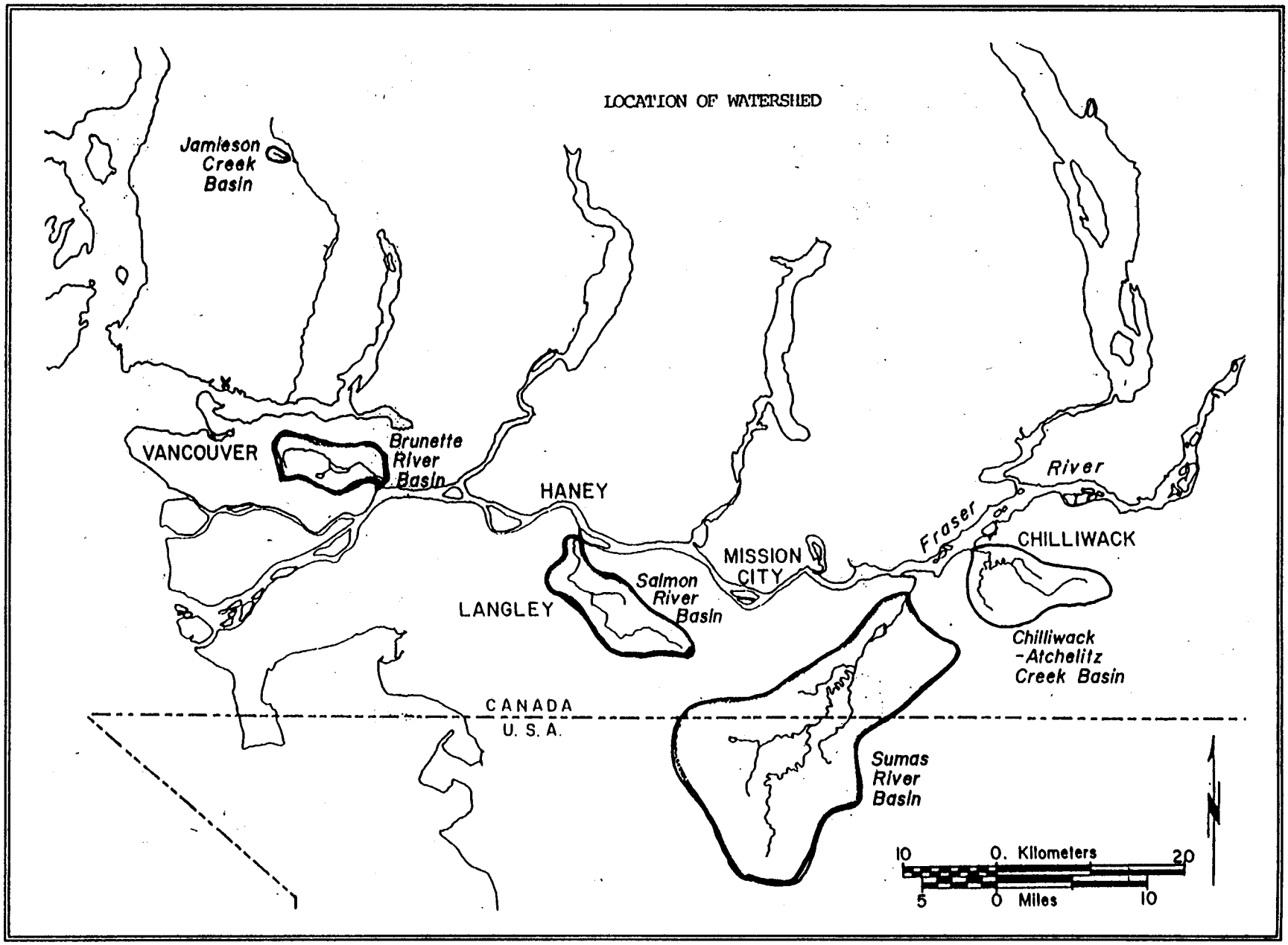
4. Sumas - Routine Water Quality

Dissolved Oxygen
- Arnold Slough consistently low (3-5 mg/L)
- Saar Cr. low October (1.5 mg/L).

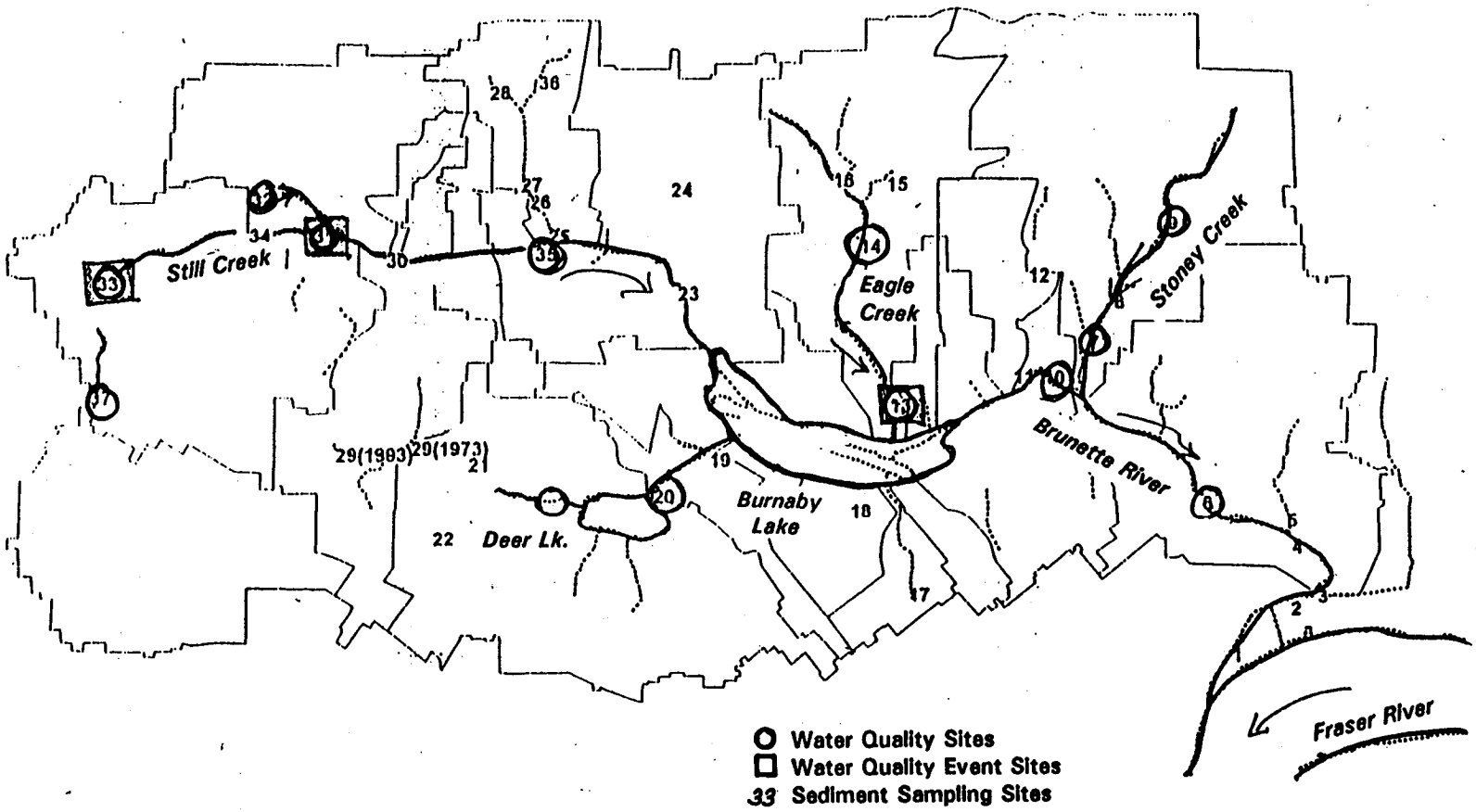
Nitrate
- Lonzo Cr. - high summer (4-7 mg/LN)
- other creeks - summer (1-4 mg/LN)

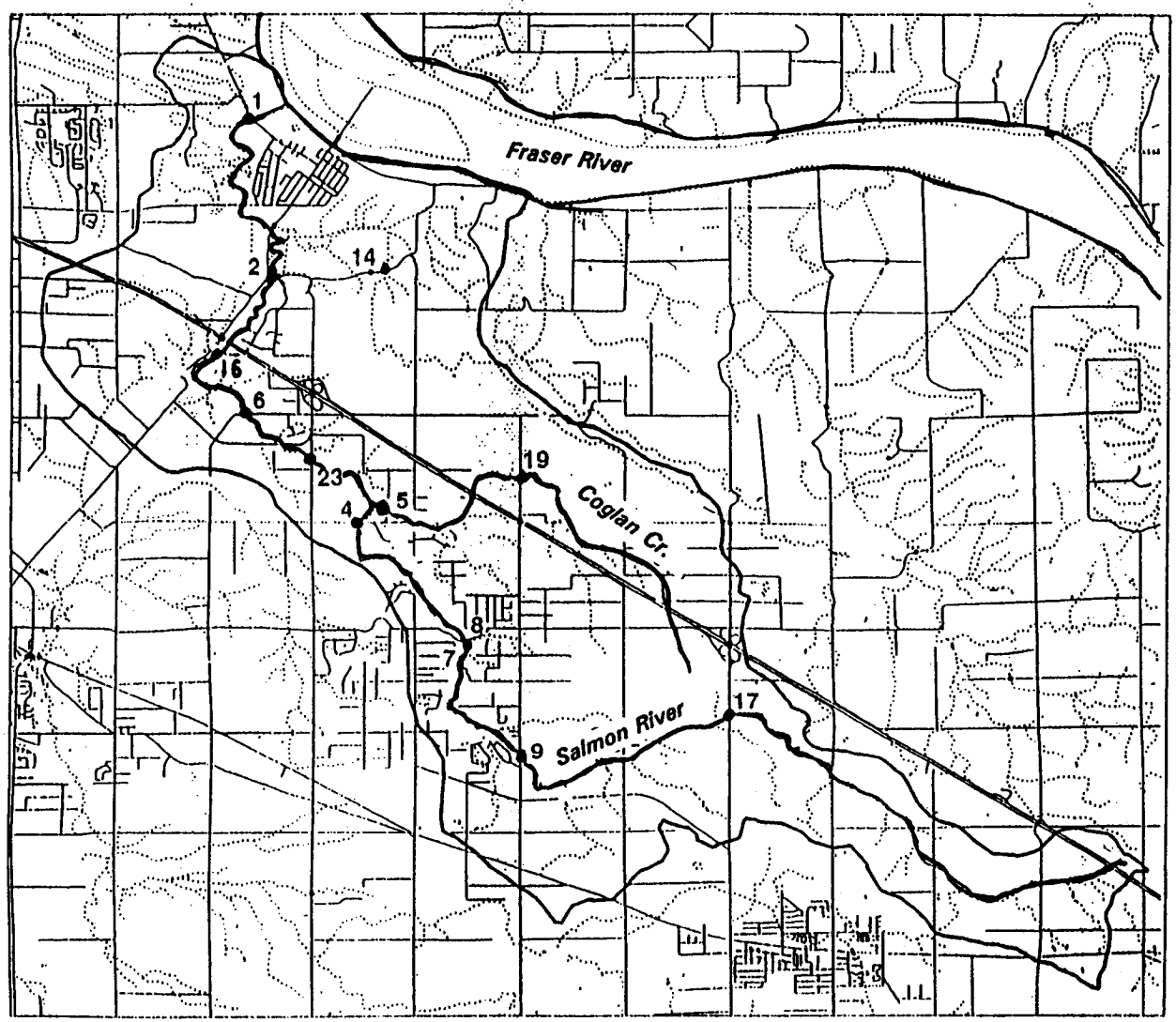
Ammonia
- Saar Cr., Arnold Slough - high (1-4 mg/LN)

Phosphorus
- event monitoring
- fall storms Nov. - up to 0.7 mg/LP which follows hydrograph profile


LOCATION OF WATERSHED
Jamieson Creek Basin
VANCOUVER
Brunette River Basin
HANEY
LANGLEY
Salmon River Basin
MISSION CITY
Fraser River
CHILLIWACK
Chilliwack -Atchelitz Creek Basin
CANADA
U. S. A.
Sumas River Basin
10 0. Kilometers 20
5 0 Miles 10

Brunette Watershed Stream, Water and Sediment Sampling Stations





Salmon River

(13) SAMPLING STATION

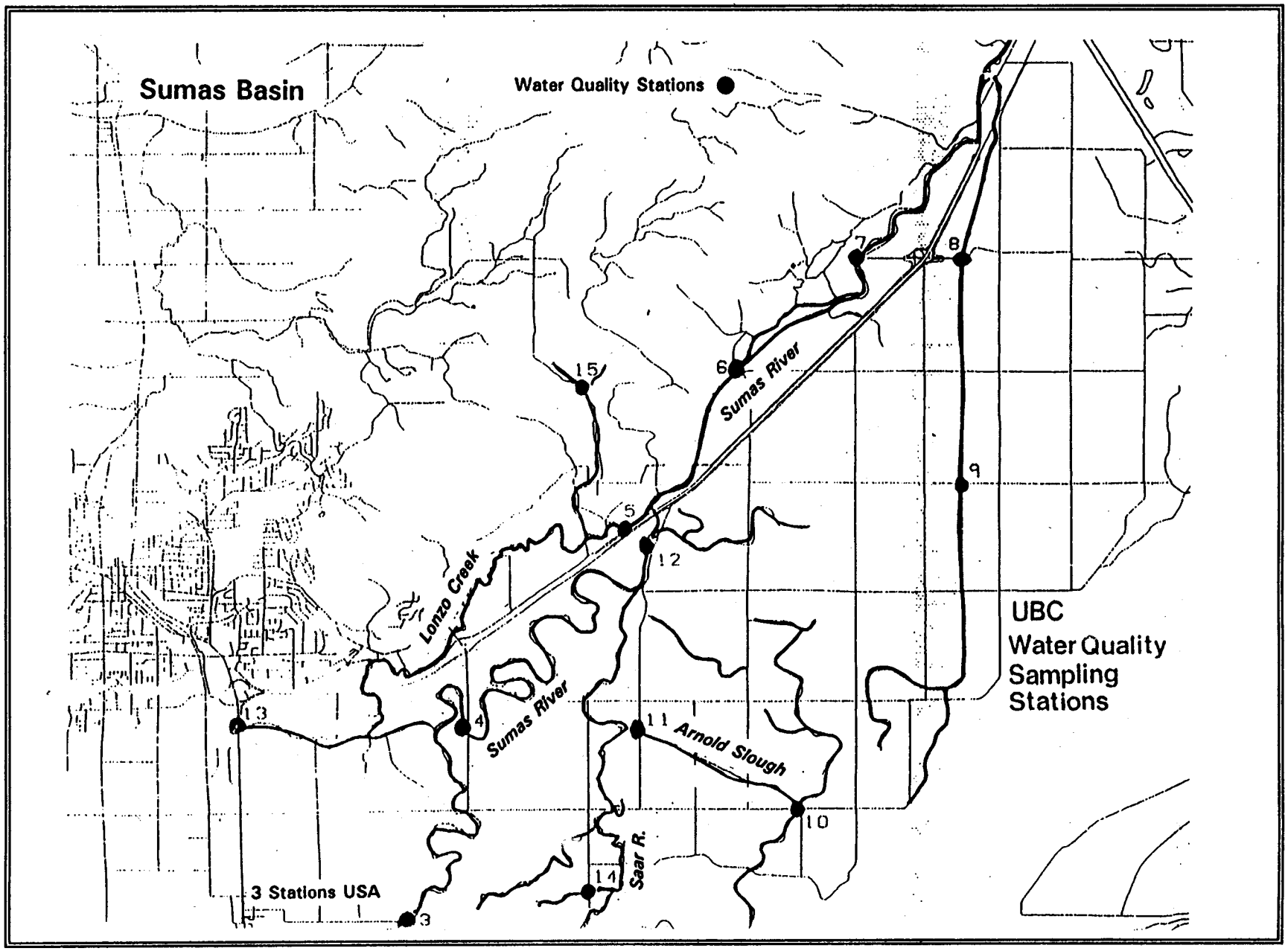
STREAM NETWORK

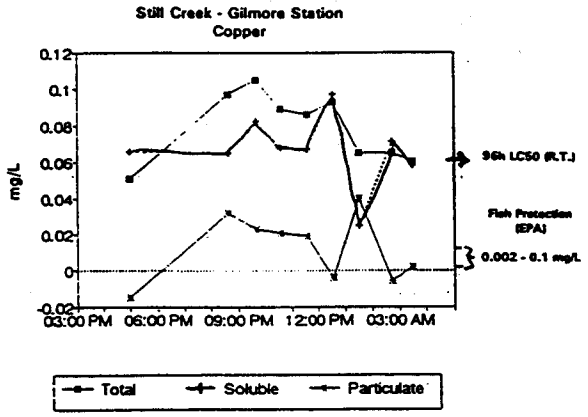
ROAD NETWORK

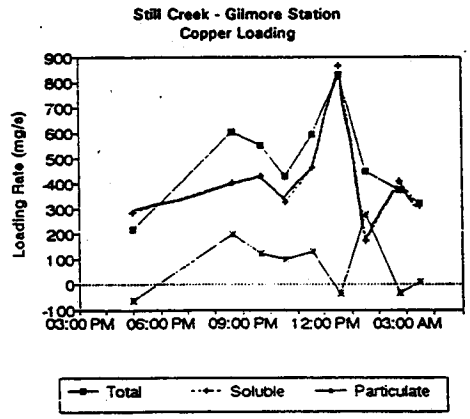
WATERSHED BOUNDARY

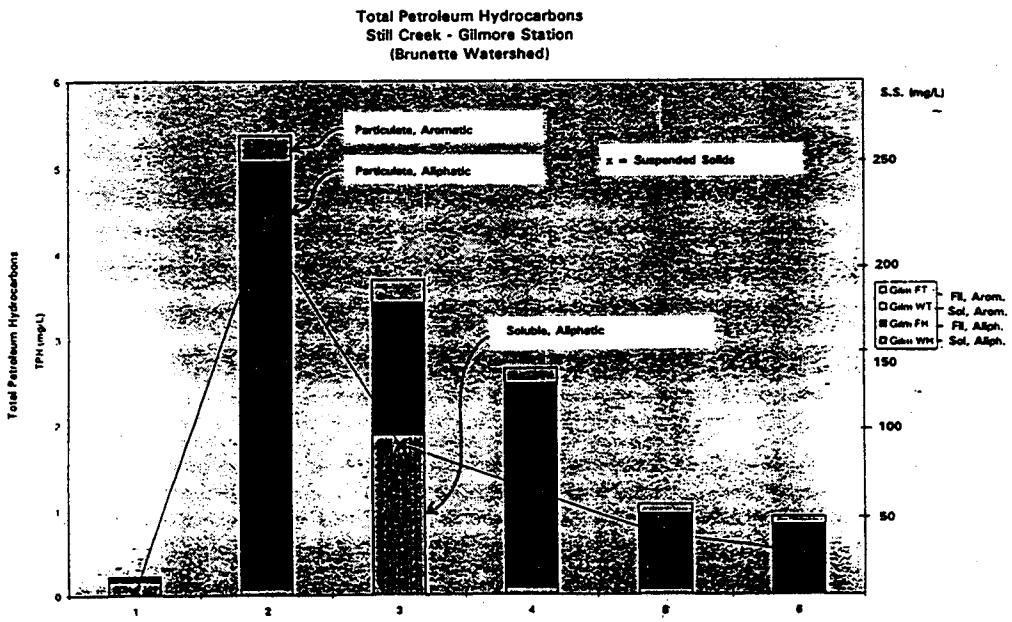
1 0 1 2 3 Km

UBC Water Quality Sampling Stations Hall and Schreier


Sumas Basin
Water Quality Stations
Sumas River
Lonzo Creek
Sumas River
Arnold Slough
Saar R.
3 Stations USA
UBC
Water Quality
Sampling
Stations
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

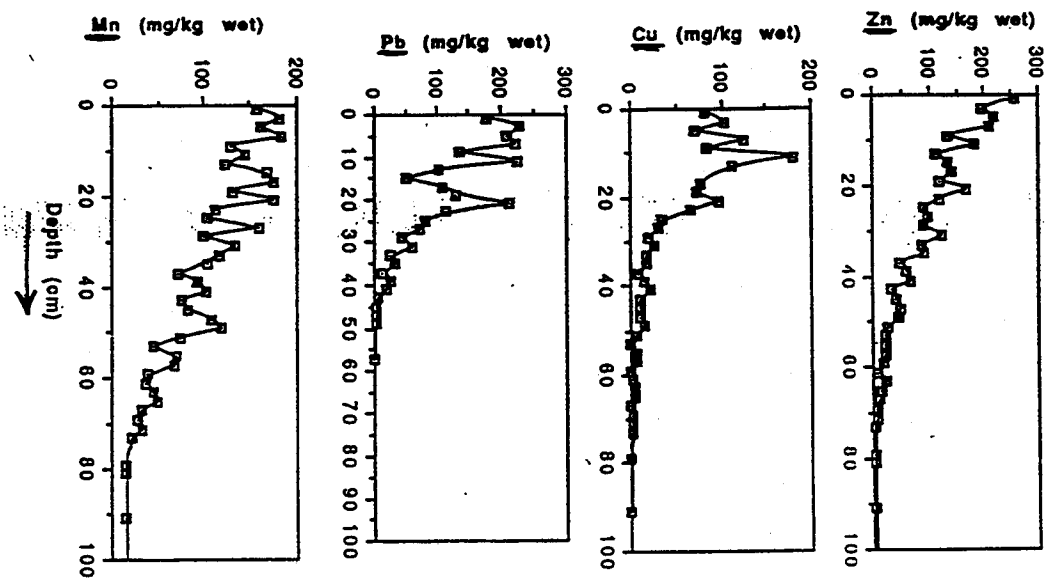

Still Creek - Gilmore Station
Copper
mg/L
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
03:00 PM
06:00 PM
09:00 PM
12:00 PM
03:00 AM
96h LC50 (R.T.)
Fish Protection
(EPA)
0.002 - 0.1 mg/L
Total
Soluble
Particulate


Still Creek - Gilmore Station
Copper Loading
Loading Rate (mg/s)
900
800
700
600
500
400
300
200
100
0
-100
03:00 PM
06:00 PM
09:00 PM
12:00 PM
03:00 AM
Total
Soluble
Particulate


Total Petroleum Hydrocarbons
Still Creek - Gilmore Station
(Brunette Watershed)
Total Petroleum Hydrocarbons
TPH (mg/L)
S.S. (mg/L)
Particulate, Aromatic
Particulate, Aliphatic
x = Suspended Solids
Soluble, Aliphatic
Gilm FT
Gilm WT
Gilm FH
Gilm WH
Fil. Arom.
Sol. Arom.
Fil. Aliph.
Sol. Aliph.
0
1
2
3
4
5
6
50
100
150
200
250

Brunette R. Watershed Trace Metals Study - Sediments

Burnaby Lake Core Analysis



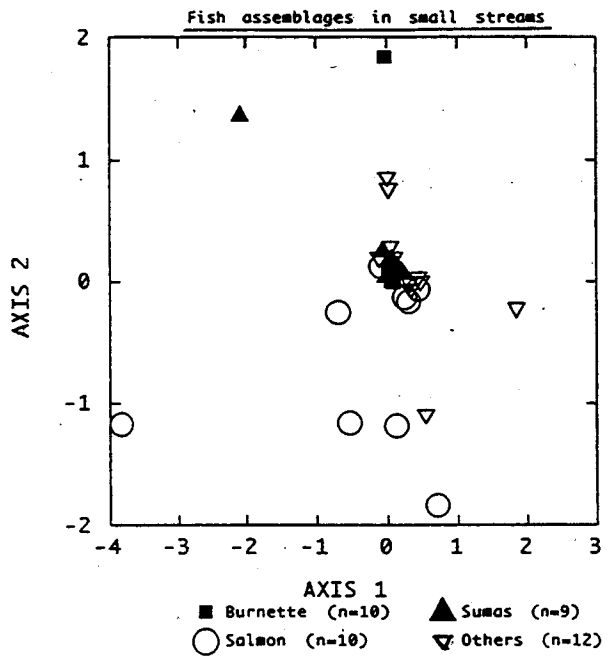
Pb^{10} dating being done

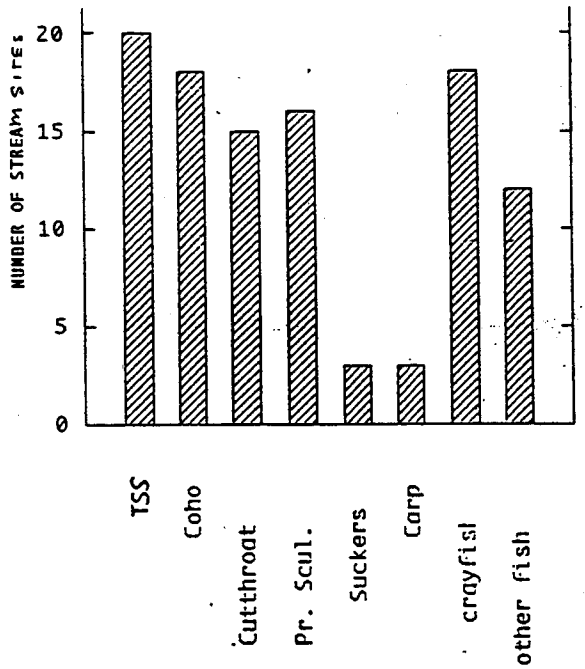
Streambed / Street Sediments

- 32 stream and 25 street stations sampled
- between 1973 and 1993 :
  - Pb decreased in 46 of 57 stations
  - Hg increased in 49 of 57 stations
  - Mn increased in 51 of 57 stations

Land Use

- digitized land use, land cover, and traffic volumes for 1973 and 1993 onto a GIS (Terrasoft)
- will attempt to correlate land use characterisitics to sediment metal concentrations



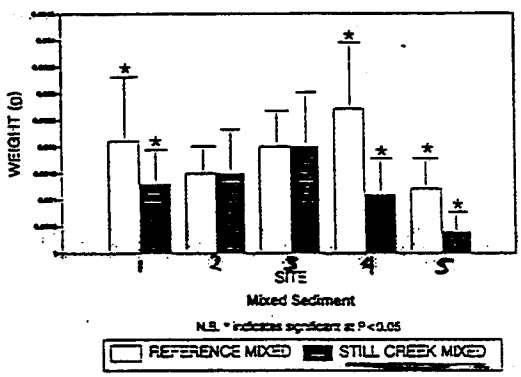


Fish in Lower Fraser Tributaries

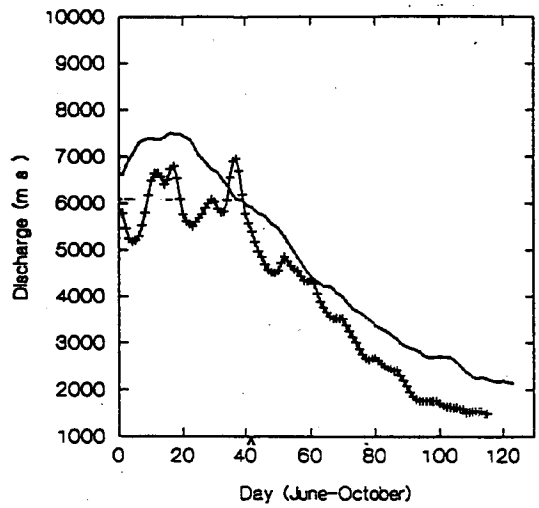
41 sites - Brunette (10), Salmon (10), Sumas (9), Others (12)
Results:

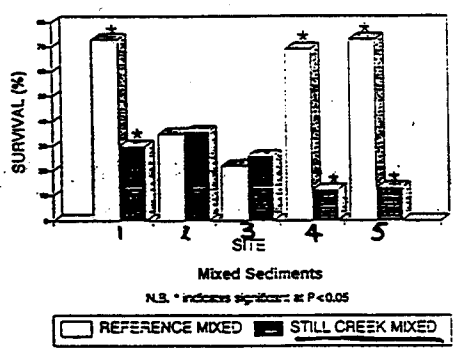
- **14 spp. of fish**
- **0 to 900+ fish/trap**
- **TSS most common**

Bioassays - Chironomids



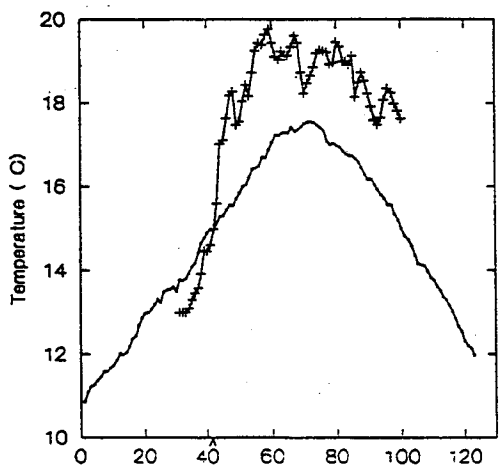
Chironomid Dry Weight (Growth)





Chironomid Survival

Sites:
1 Willingdon
2 Douglas
3 Atlin
4 Lougheed
5 Westburne



Air Deposition
Still Creek - Burnaby Lake - Brunette River

W. Belzer

Environment Canada

ABSTRACT

1. Objectives

The objective of the sampling program is to determine the contribution of the air pathway to the deposition of metals and PAHs to the Still Creek-Burnaby Lake-Brunette River watershed.

The sampling site will be at Burnaby Lake Rowing Facility, and will last from November 1994 to April 1995. Sampling will measure both wet and dry deposition at the sample site. Meteorological data will also be collected to aid in calculations and determination of possible source-receptor relationships.

Dry deposition will be measured with a MIC Rain Sampler. Rainfall will be analyzed for inorganic (Cd, Cr, Cu, Pb [low level]; Ag, Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Si, Sn, Sr, Ti, V, Zn) and organic constituents (PAHs, PCBs).

Dry deposition will be measured with either a Cascade Impactor (low pressure impactor) or a high volume/PUF sampler. The LPI will be used alternatively for inorganic particulate (Cd, Cr, Cu, Pb [low level] Ag, Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Si, Sn, Sr, Ti, V, Zn) or organic particulate+gas (PAHs, PCBs).

Metals and PAHs have been measured in the Still Creek-Burnaby Lake-Brunette River watershed by the Westwater Institute. Samples have been/are being taken from water and sediment sources. It should be possible to determine a relationship between sediment, water and airborne sources that effect this watershed.

If funding is available for 1995-1996, sampling will continue for these chemicals (and others, if required).

2. Deposition Methodology

For wet deposition we collect rainfall, measure content for PAHs or metals (different samplers), and calculate deposition rate from concentration and surface area of sampler.

For dry deposition, we collect particulate on filter media in separated size fractions, calculate volume of air sampled, calculate deposition rate from relationship with particle size (diameter).

From these, we calculate average atmospheric contribution to land and water areas by calculating the yearly dry deposition contribution, the yearly wet deposition contribution and then determine yearly airborne input of PAHs/metals to the Still Creek-Burnaby Lake-Brunette River watershed.

These data can then be used in possible mass balance to determine the relative contributions of the various pollution sources (air, water, etc.).

Amphibian Species as Sentinels for Contamination in the Fraser Basin

S. Orchard

Royal British Columbia Museum

ABSTRACT

Many amphibian species have been disappearing worldwide, mainly due to development of wetlands and waste disposal, and this links with a national assessment of amphibian status. In B.C. 75% of amphibian species occur in the lower mainland, where development pressures are most extreme. Because of their sensitivity, the disappearance of amphibians may also be an early warning of broader ecosystem malaise.

A study of the effects of contaminants on aquatic herptefauna (amphibians and aquatic reptiles) has been initiated in the Brunette and Sumas River basins in conjunction with other aquatic ecosystem studies. In the first year, a reconnaissance survey was completed to identify species present and their distribution, select potential sentinel species, and determine their population s status.

Historical Source Functions of Atmospherically Transported Contaminants to the Fraser Drainage Basin

R.W. Macdonald and D.W. Paton

Institute of Ocean Sciences

ABSTRACT

1. Objective

To determine the historical input of particle-active atmospheric contaminants into the Fraser drainage basin.

The approach taken has been to collect cores from 6 lakes selected from the Fraser system. The cores are then sectioned, dated and a suite of contaminants measured. Secondary objectives are to complete a broad-brush contaminant survey of the lake system by using the sediments as monitors. We expect to find both atmospheric inputs (e.g., Pb, Hg, PAH, highly chlorinated OCs) and contaminants that may have entered directly to lakes (e.g., Hg in Stuart Lake, pulp mill products in Kamloops Lake).

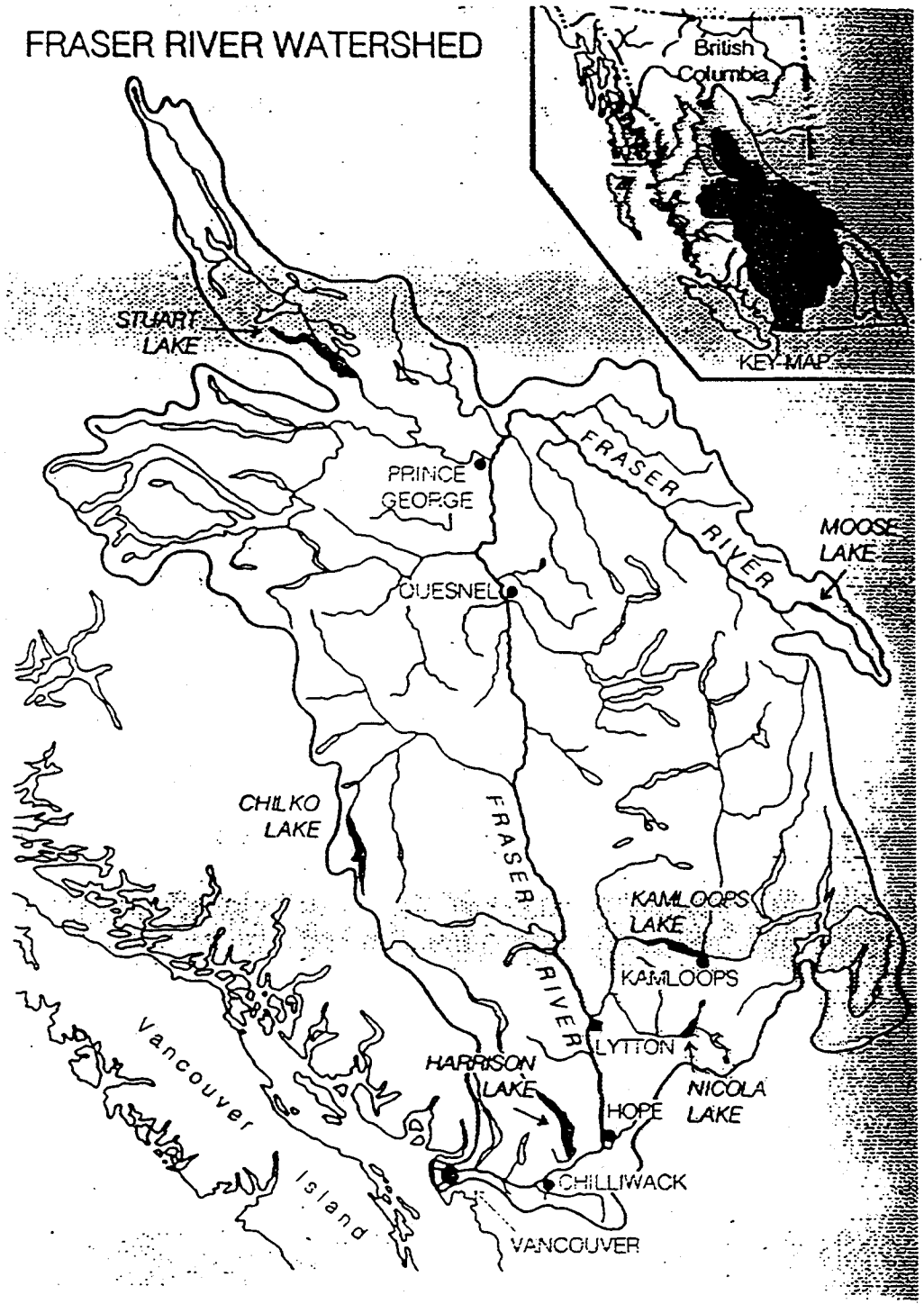
2. Progress to Date

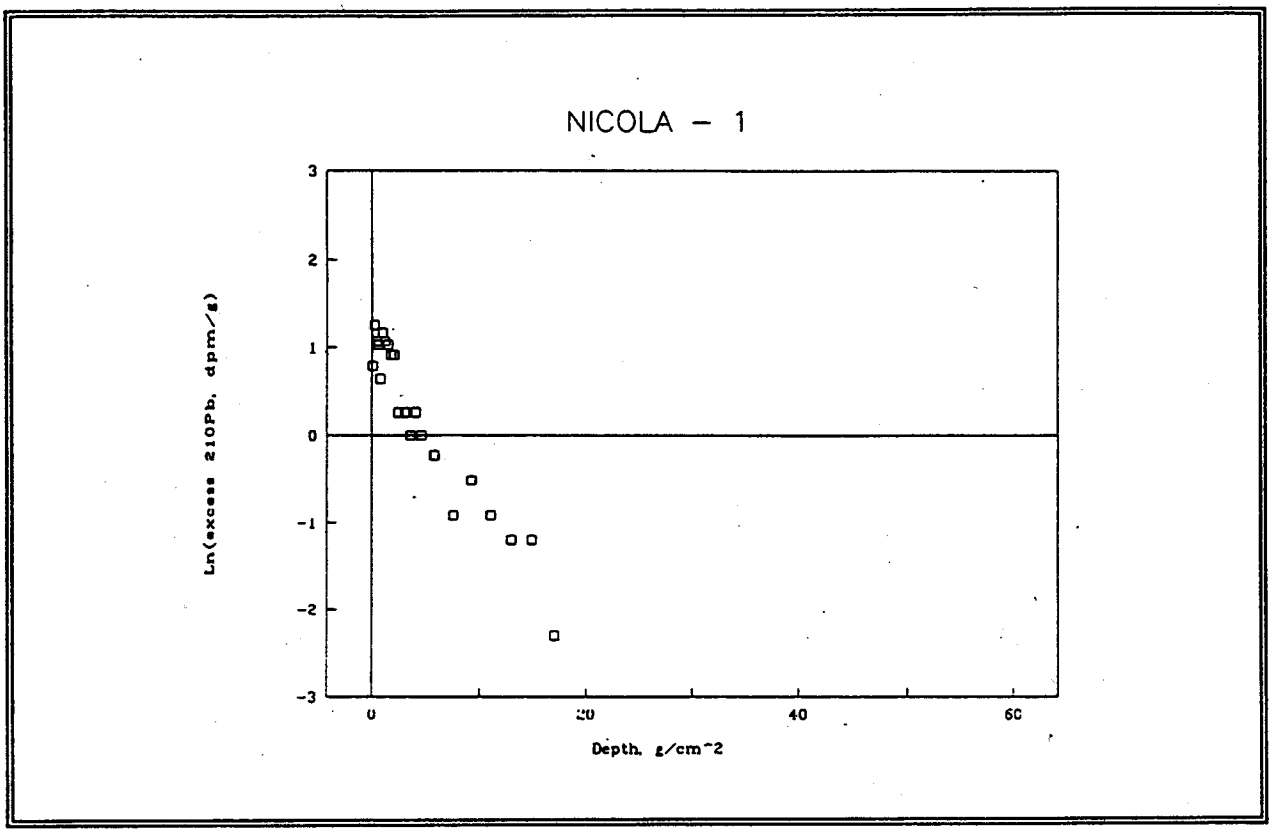
We have put together a whaler/corer system which was used to collect cores from 6 lakes selected in collaboration with the FRAP managers. These lakes are: Moose, Stuart, Kamloops, Chilko, Nicola and Harrison. For the first 4 lakes we have collected at least two cores for each lake, for the last two lakes we have collected only one core.

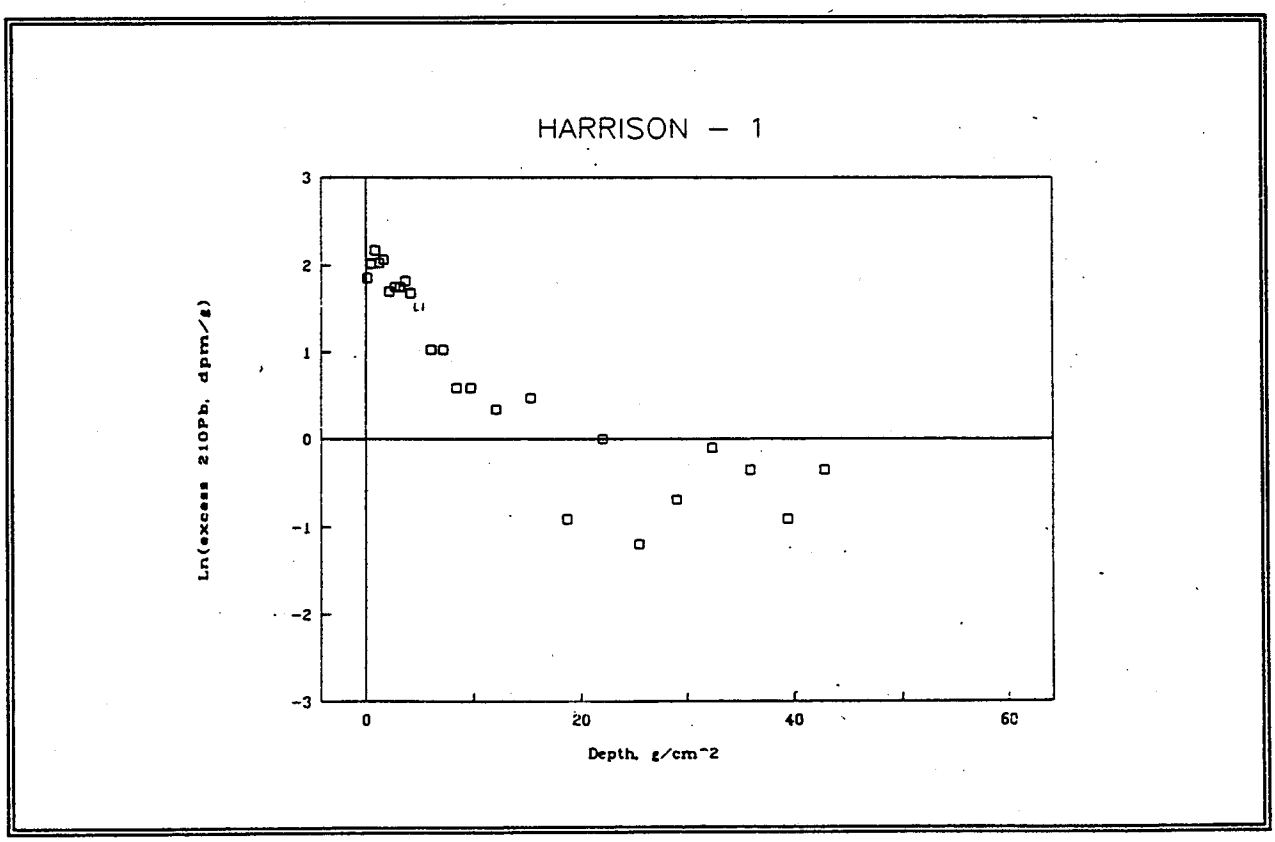
Samples have been analyzed for 210Pb to date the cores. Preliminary results show that for all of the lakes, we have retrieved sediments with reasonable properties to provide confident dating. In two of the lakes (Moose, Kamloops) the cores contained stratigraphy which indicates that mixing should not be a problem. Additionally, the stratigraphy should allow us a method to check the 210Pb dating. For some of the lakes, sedimentation rates appear to have changed near the surface of the core, perhaps reflecting alterations in the delivery of solids to the lake. Further work is required, however, to evaluate sensitivity of the dating to assumptions such as supported 210Pb background and choice of breakpoint in non-linear dating curves.

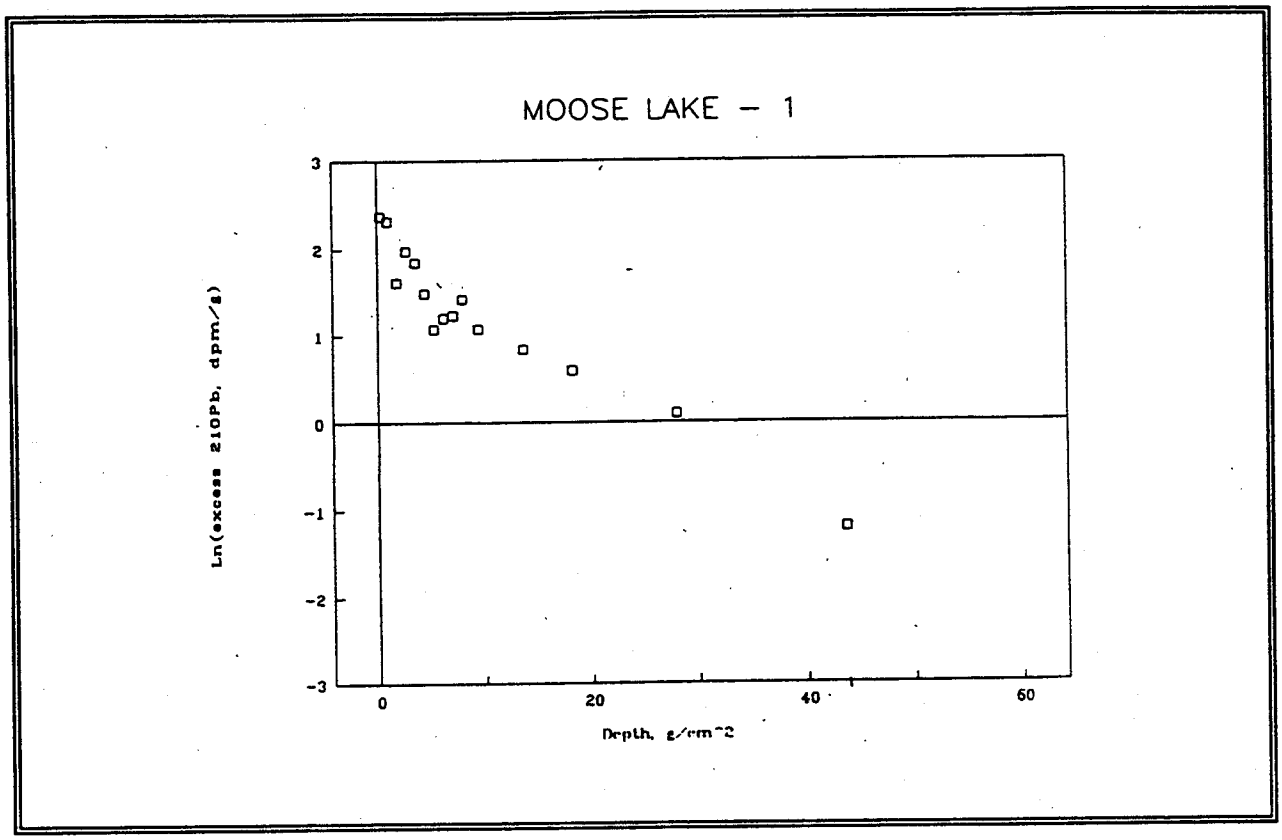
Samples are presently in progress to be analyzed for elements, OCs and PAH. We have initially selected a suite of samples to do a preliminary analysis which will subsequently be followed by a more complete analysis for cores which appear to have promising profiles. For the two cores where metal profiles have already been completed (Nicola and Harrison) we find Pb to be augmented near the surface. Preliminary dates on these cores suggest that this extra Pb started to enter the lakes after about 1930 which is in reasonable agreement with the known use of Pb in gasoline.

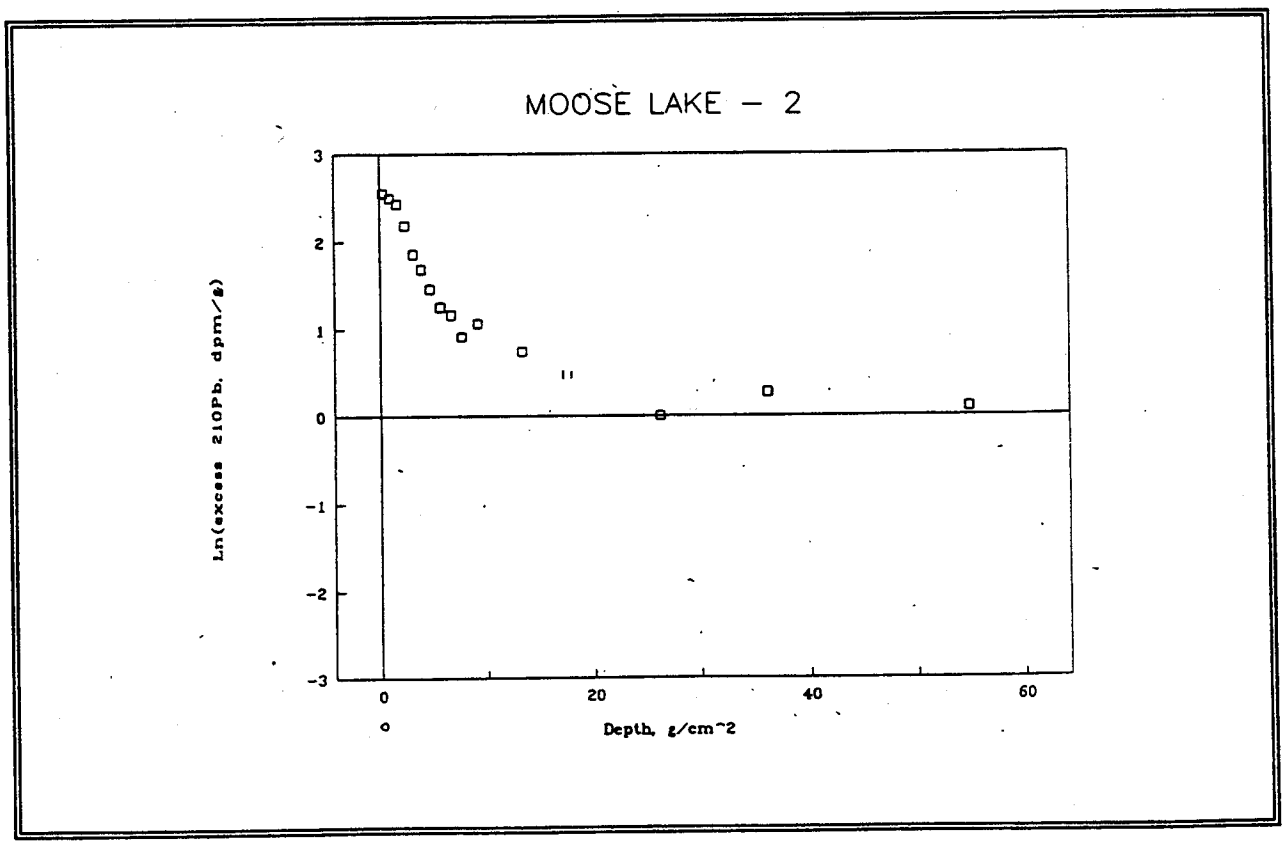
We expect to complete the preliminary round of determinations in this fiscal year; next fiscal year funds will be devoted to analyzing the cores more completely according to the preliminary findings.

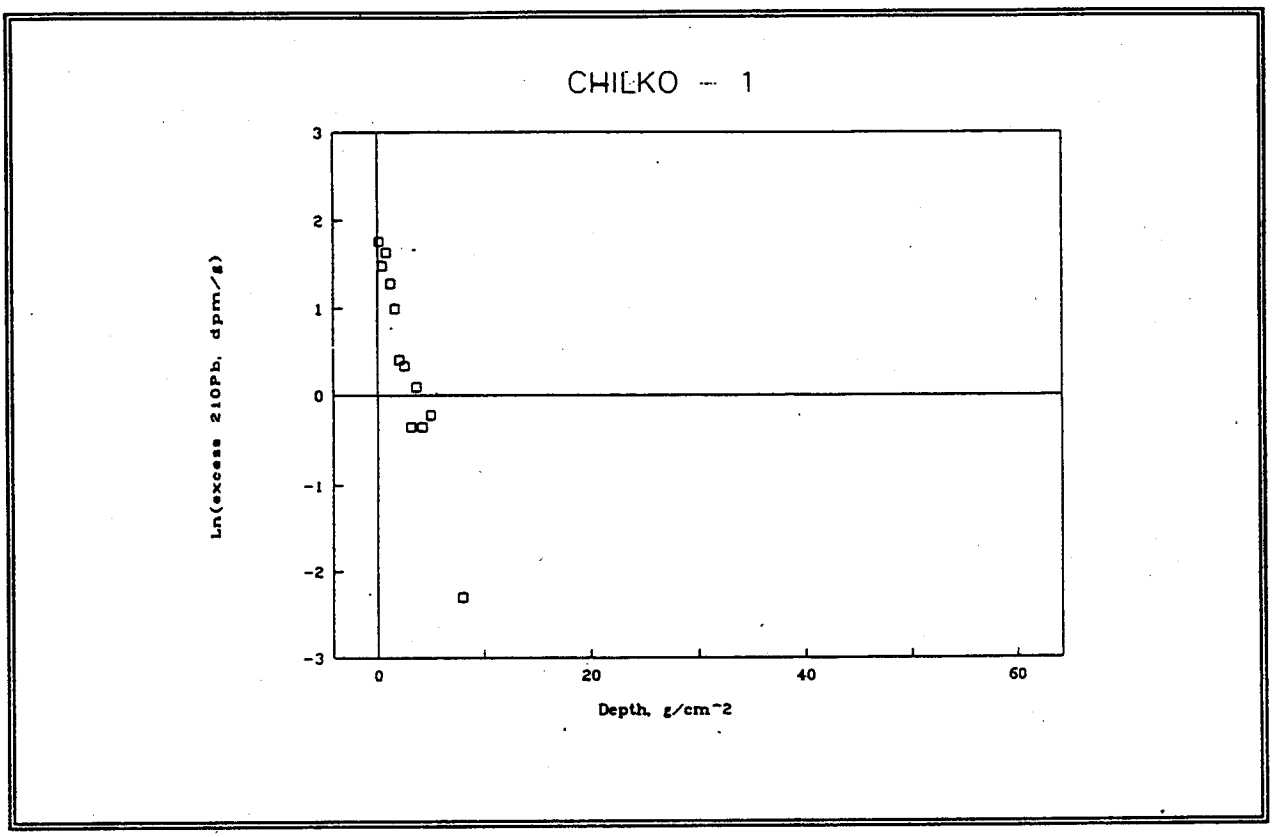

FRASER RIVER WATERSHED
British Columbia
KEY MAP
STUART LAKE
PRINCE GEORGE
QUESNEL
FRASER RIVER
MOOSE LAKE
CHILKO LAKE
FRASER RIVER
KAMLOOPS LAKE
KAMLOOPS
LYTTON
NICOLA LAKE
HARRISON LAKE
HOPE
CHILLIWACK
VANCOUVER
Vancouver Island

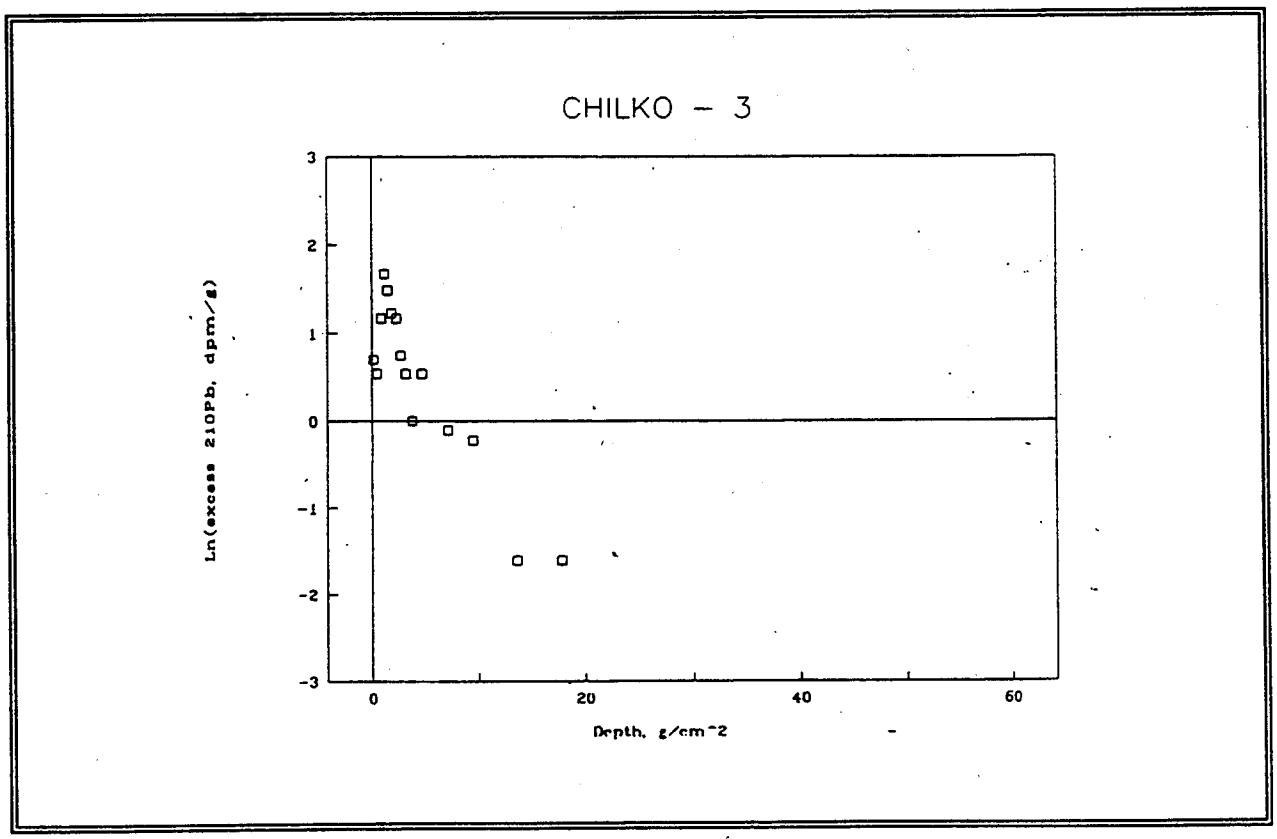

NICOLA – 1
Ln(excess 210Pb, dpm/g)
3
2
1
0
-1
-2
-3
0
20
40
60
Depth, g/cm^2

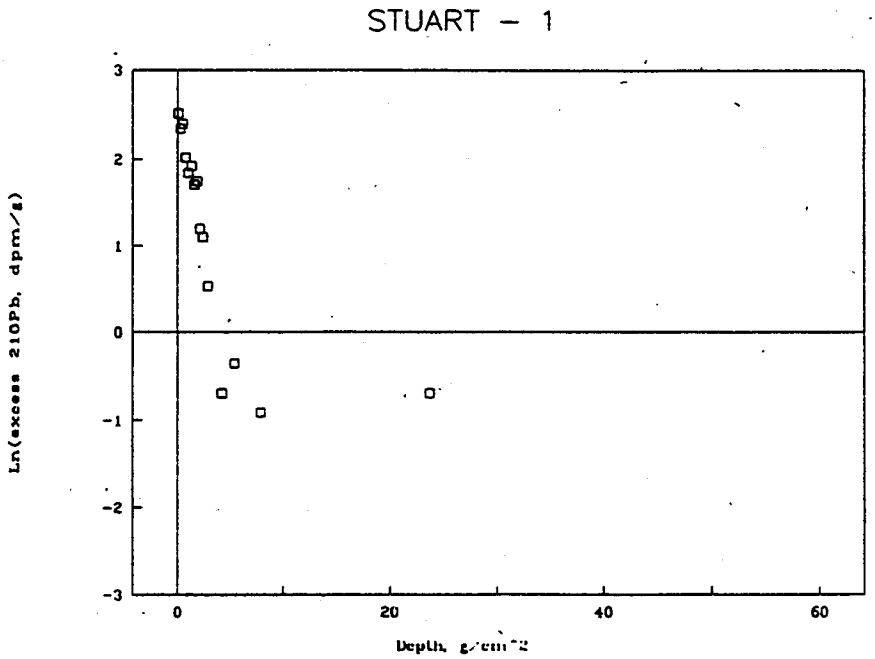

HARRISON – 1
Ln(excess 210Pb, dpm/g)
3
2
1
0
-1
-2
-3
0
20
40
60
Depth, g/cm^2

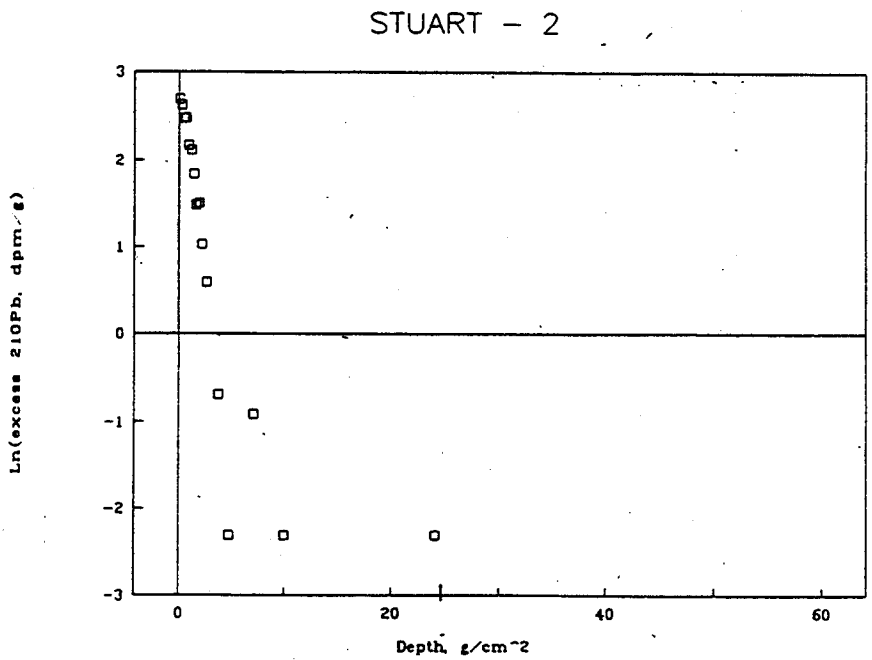

MOOSE LAKE – 1
Ln(excess 210Pb, dpm/g)
3
2
1
0
-1
-2
-3
0
20
40
60
Depth, g/cm^2

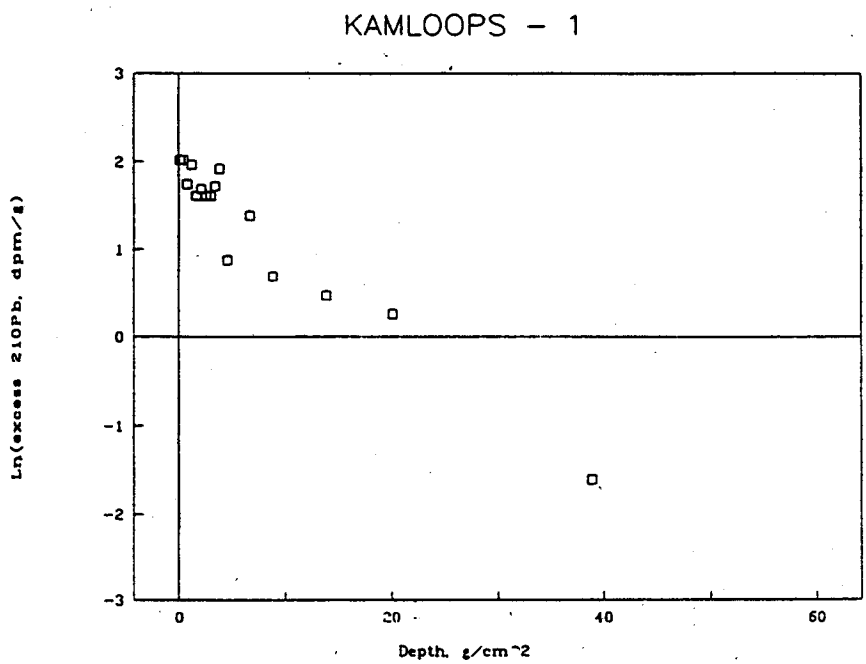

MOOSE LAKE – 2
Ln(excess 210Pb, dpm/g)
3
2
1
0
-1
-2
-3
0
20
40
60
Depth, g/cm^2

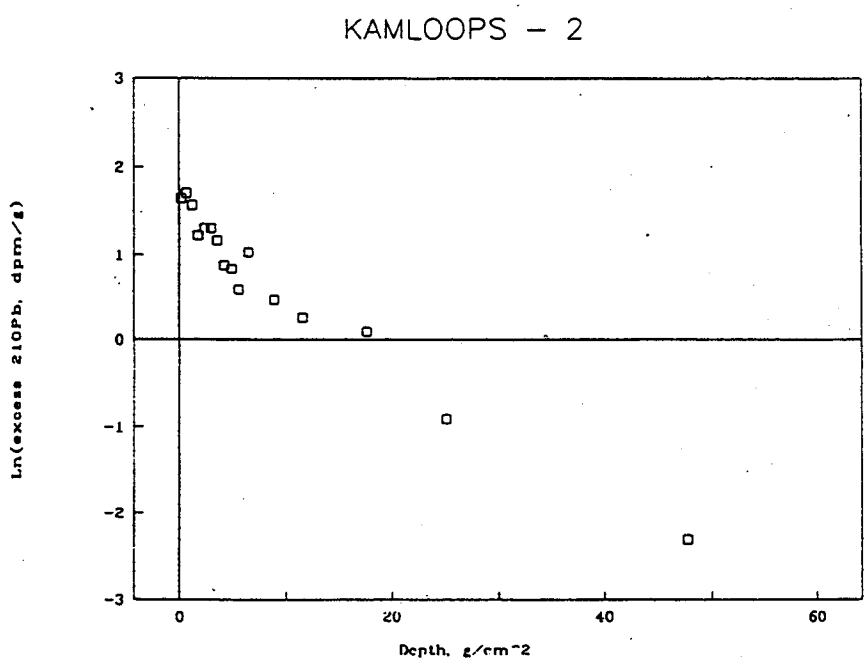

CHILKO – 1
Ln(excess 210Pb, dpm/g)
3
2
1
0
-1
-2
-3
0
20
40
60
Depth, g/cm^2

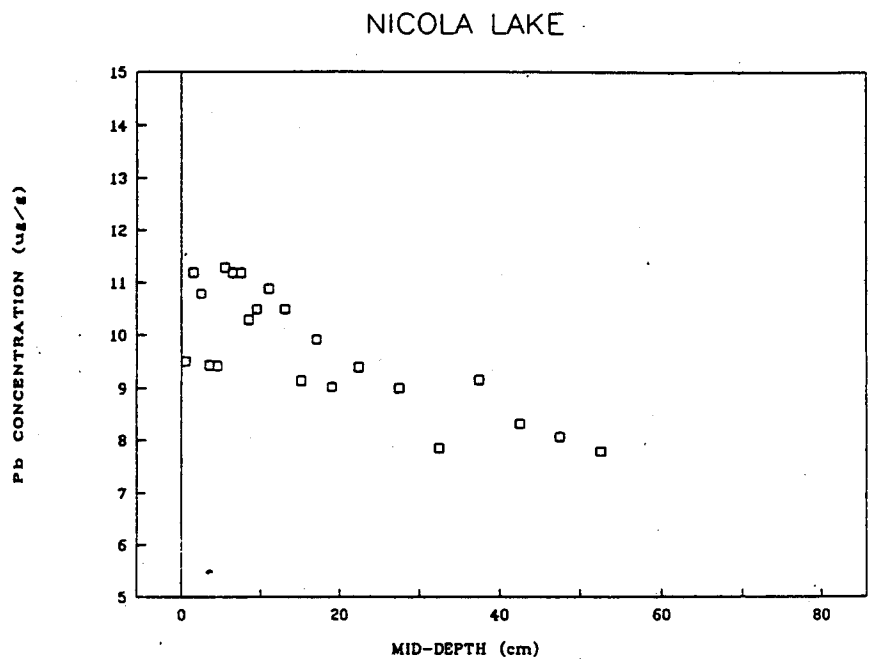

CHILKO – 3
Ln(excess 210Pb, dpm/g)
3
2
1
0
-1
-2
-3
0
20
40
60
Depth, g/cm^2

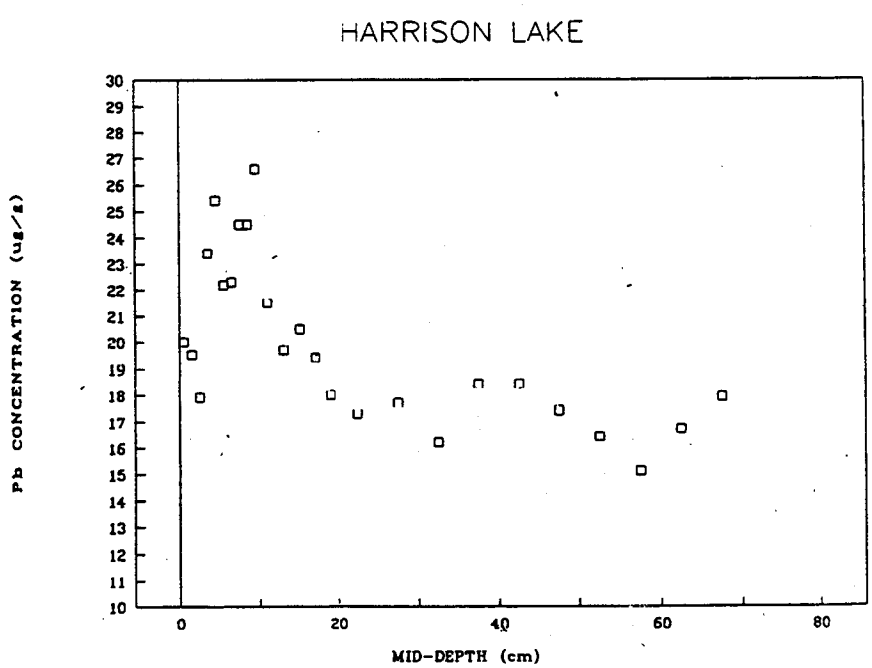

STUART - 1
Ln(excess 210Pb, dpm/g)
3
2
1
0
-1
-2
-3
0
20
40
60
Depth, g/cm^2

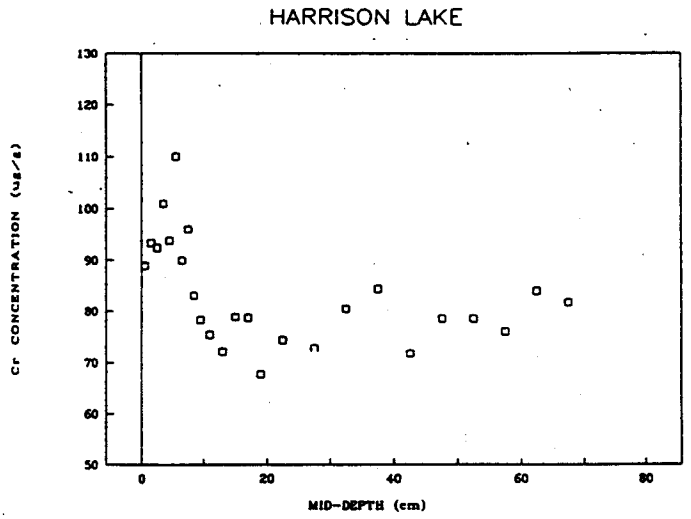

STUART - 2
Ln(excess 210Pb, dpm/g)
3
2
1
0
-1
-2
-3
0
20
40
60
Depth, g/cm^2

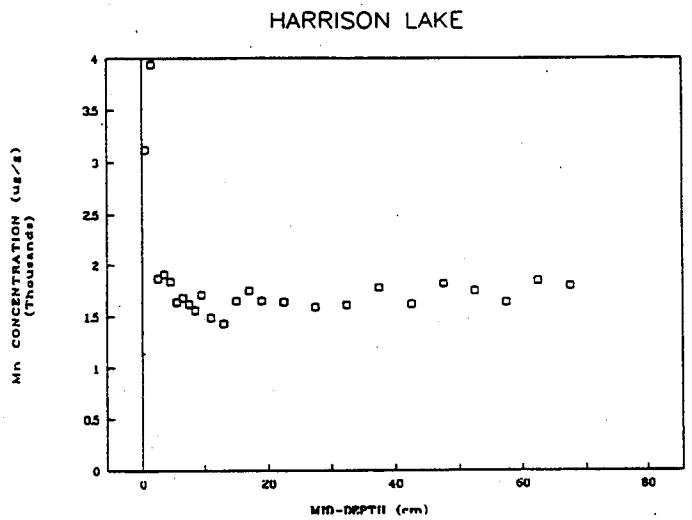

KAMLOOPS - 1
Ln(excess 210Pb, dpm/g)
Depth, g/cm^2
3
2
1
0
-1
-2
-3
0
20
40
60

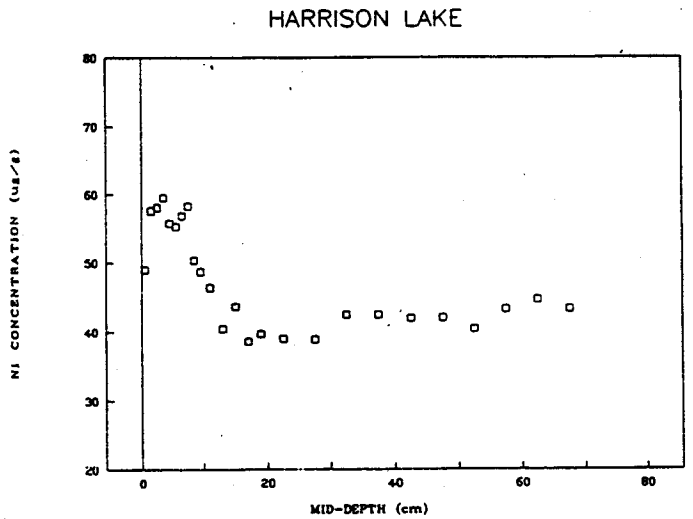

KAMLOOPS - 2
Ln(excess 210Pb, dpm/g)
Depth, g/cm^2
3
2
1
0
-1
-2
-3
0
20
40
60


NICOLA LAKE
Pb CONCENTRATION (ug/g)
15
14
13
12
11
10
9
8
7
6
5
0
20
40
60
80
MID-DEPTH (cm)


HARRISON LAKE
Pb CONCENTRATION (ug/g)
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
0
20
40
60
80
MID-DEPTH (cm)


HARRISON LAKE
Cr CONCENTRATION (ug/g)
MID-DEPTH (cm)


HARRISON LAKE
Mn CONCENTRATION (ug/g)
(Thousands)
MID-DEPTH (cm)


HARRISON LAKE
Ni CONCENTRATION (ug/g)
MID-DEPTH (cm)

Estuarine Benthic Ecology: Long Term Response to Diversion of Sewage Treatment Plant Effluent at Iona and Sea Islands

P.J. Harrison[1] and C. Levings[2]

[1]*University of British Columbia*
[2]*Fisheries and Oceans Canada*

1. Goal

To study primary and secondary production and community structure of intertidal communities on Sturgeon Bank, an area recovering from sewage pollution.

2. Background

- The intertidal ecosystem off Iona was exposed to sewage pollution (est. 22,900 kg of suspended solids per day) between 1962 and 1988.
- Now primary treated sewage is discharged subtidally at 100 m.
- Now have a rare opportunity to study recovery of a sewage polluted intertidal area.

3. Objectives

The objectives of this research are:

1) to determine changes in benthic invertebrate and algal community structure since the effluent from Iona Sewage Treatment Plant was diverted in 1988;

2) to estimate algal biomass and primary production so as to establish a long-term baseline for future comparisons;

3) to estimate secondary production of two important benthic invertebrates (a bivalve *Macoma balrica* and an amphipod *Corophium salmonis*) using cohort analysis;

4) to identify and quantify processes controlling inorganic and organic nutrient cycling and utilization;

5) to determine if contaminants (metals, OCs and PAHs) in surface sediments are affecting the productivity or structure of the investigated benthic communities.

4. Progress

a. Sampling

The four stations (see figure: A0, A10, A12 and A14) were selected on the mud flat of Sturgeon Bank and Roberts Bank. The sampling of invertebrates, Chl a, nutrients and total organic carbon and nitrogen in the sediment at the four stations started on May 10, 1994 via coastguard hovercraft. The samples were taken once every 2 weeks (usually during a spring tide) until August 19 and then once monthly, September to March.

For sampling of nutrients and Chl a in the water column, 10 stations were selected (see figure: W1 to W10). Five of them were at the 10 m depth contour further offshore and constantly under water. The other five were nearer the shoreline and covered by water during high tides and exposed to the air during low tides. The water was sampled during the late stage of a flood tide (water coming to the Bank) and during the middle stage of the following ebb tide (water leaving the Bank). The sampling frequency was the same as the sediment sampling.

Water Column	Sediment or Pore Water
T, S, O_2	NO_2, NH_4, PO_4
NO_3, NH_4, PO_4	Chl
Chl a	POC, PON

Contaminants	Sediment
Hg, Cd, Pb, Zn	Grain size
PAHs	

b. Primary Productivity

Clear (net primary productivity) and opaque (respiration) benthic chambers have been constructed and tested. A small pump, operated by a battery,

circulates the water inside the chamber. Oxyg concentrations are measured at the beginning and end the 3 to 4 h incubation period. We will begin measured benthic primary productivity and respiration in February 1995, the beginning of the field season. We will attempt to characterize seasonal species succession of main macroalgae and macrophytes.

c. Secondary Productivity

- Seasonal abundance
  a) amphipod *Corophium salmonis*
  b) bivalve Macoma baltic
- Cohort analysis of same two species
- 5 replicate cores 25x25 cm (0.06 m^2) and 10 cm deep -- sieved to 500 μm

d. Analysis

All the sediment samples of benthic invertebrates have been sieved and preserved. Only a small number of samples were enumerated (counted and length measurements). Nutrients (ammonium, phosphate and nitrite) in the sediment pore water have been determined for most samples. All the water column samples have been processed and Chl a and nutrients have been analyzed. We will take samples for contaminants in 1995.

5. Results

a. Invertebrates in Sediments

Among the four stations, A0 has the finest particles (clay), and A14 is next. A10 and A12 are mostly sand. The density of the amphipod *Corophium* was usually the highest at A0 (near the original Iona outlet of effluent) and A14 (on Roberts Bank). These stations appear to be favoured by those deposit feeders due to the higher organic content of the sediment. The density of *Corophium* was always the lowest at A12. The highest density of *Corophium* occurred during June and the first half of July. *Macoma* densities were consistently the highest at A14 and remained fairly stable over the summer period. In contrast, at A0 *Macoma* density was the lowest during the same period.

In summary, A0 had:

- higher NH_4 and PO_4; lower NO_2 in sediment
- lower Chl in sediment
- finest sediment (clay)
- highest amphipod abundance since highest organic content
- lowest bivalve abundance
- lowest O_2 in water column

b. Sediment Chl a and Pore Water Nutrients

In general, Chl a was always the lowest at A0 and the highest at two sandy stations (A10 and A12) over the entire sampling period (May-October). Chl a increased during the year and reached the highest levels in August at A10 and A12.

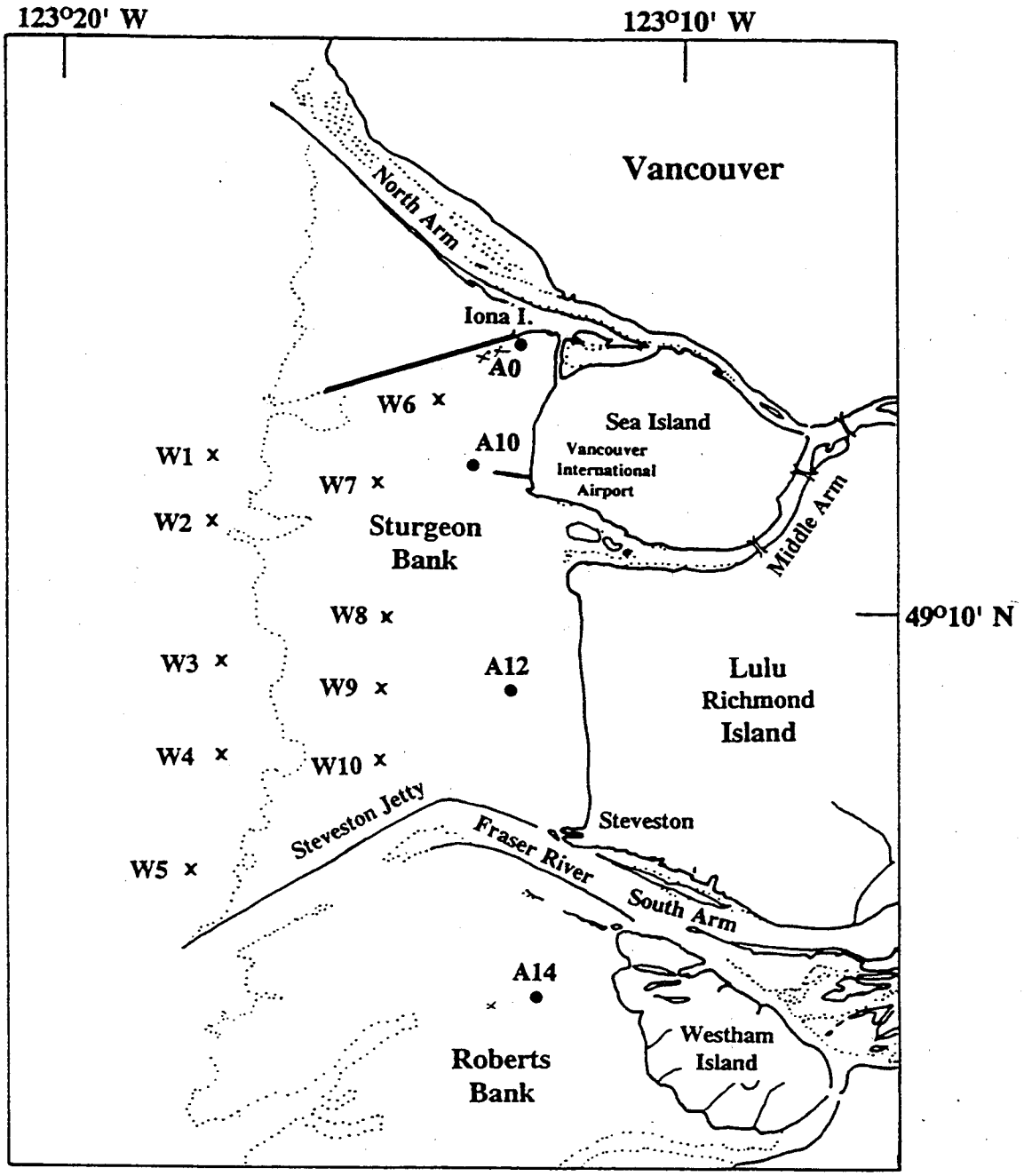
Nutrients (NH_4 and PO_4) in the sediment pore water were higher at A0 than at A14. NH_4 concentration increased during the year at both stations and reached 456 μM in August. While PO_4 concentration decreased in summer. There was so little pore water at A10 and A12 that high-speed centrifuging could not produce any supernatant.

c. Water Column Chl a and Nutrients

Salinity was usually higher during a flood than during an ebb tide. The same trend is true for Chl a, suggesting the Sturgeon Bank may be a sink for Chl a in the water column. However, NO_3 and NH_4 concentrations were usually lower during the flood tide than during the ebb tide. This suggests that the Bank may be a source for these two nutrients for the water column. There was no general pattern with PO_4 possibly due to its chemistry associated with sediment adsorption and desorption processes.

d. Linkages

- Nutrient and phytoplankton dynamics of the Fraser River estuary (Harrison)
- Results on invertebrate productivity will be relevant to CWS studies on shorebird feeding (e.g., Western sandpiper; Elner and Sewell)
- Breaching of McDonald Slough via Iona causeway (Hay and Co. consultants)
- Metal concentrations on Sturgeon and Roberts Banks (Bendell-Young, SFU)
- Sedimentation in the Fraser River estuary (Luternauer, Geological Survey of Canada)
- Benthic respiration calibration (Sea Consult)


123°20' W
123°10' W
Vancouver
North Arm
Iona I.
A0
W6
Sea Island
Vancouver
International
Airport
A10
W1
W7
W2
Sturgeon
Bank
Middle Arm
W8
49°10' N
W3
A12
W9
Lulu
Richmond
Island
W4
W10
Steveston Jetty
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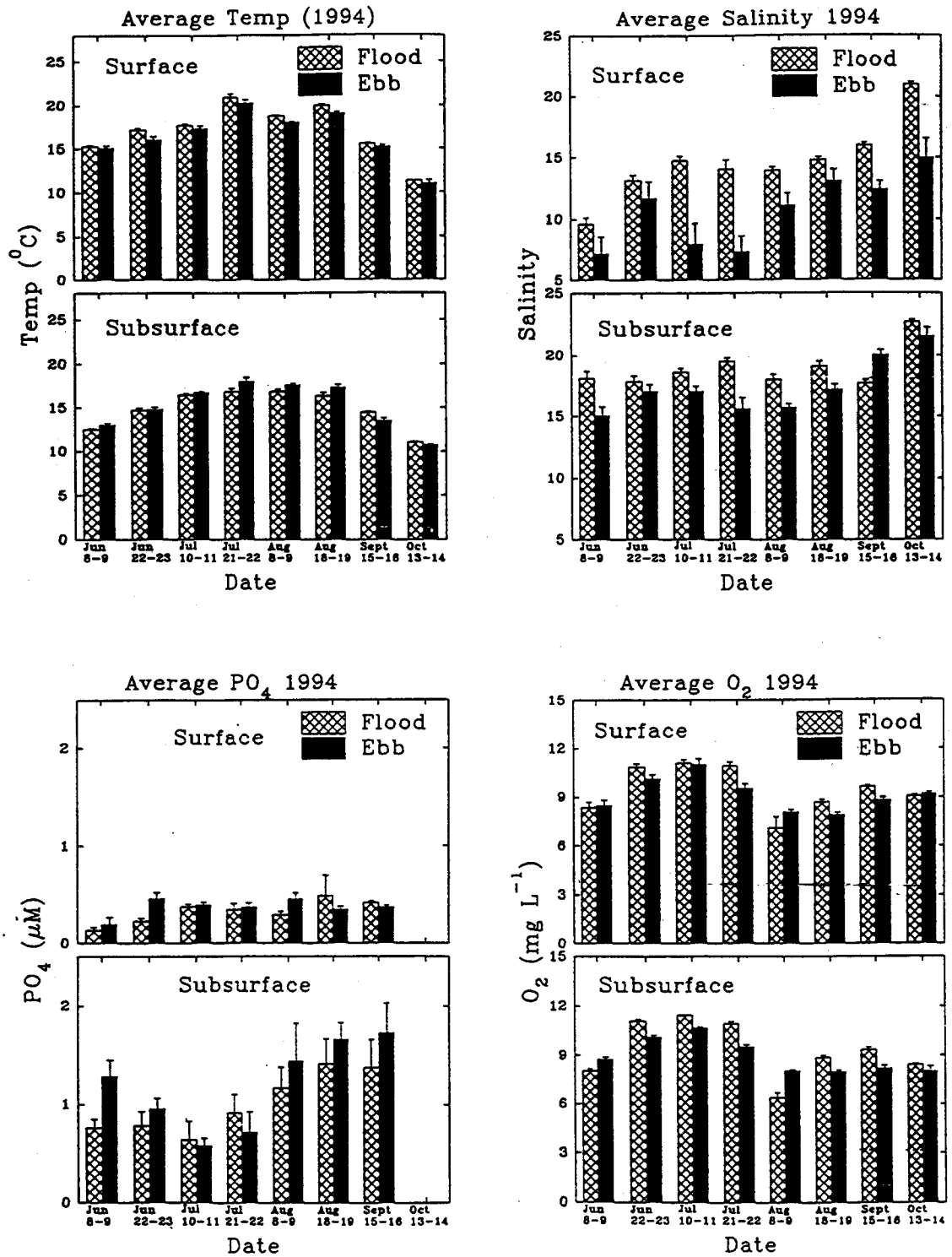
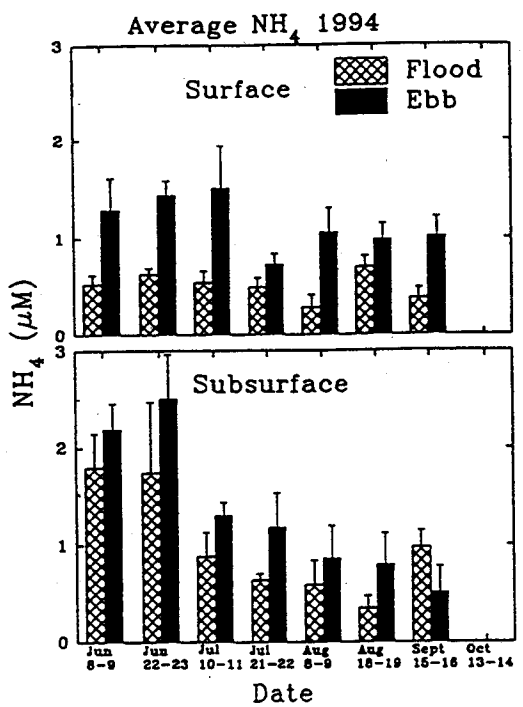
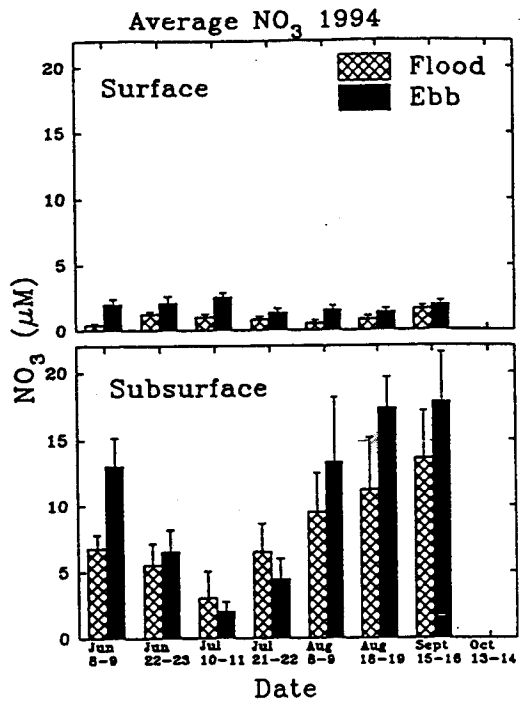
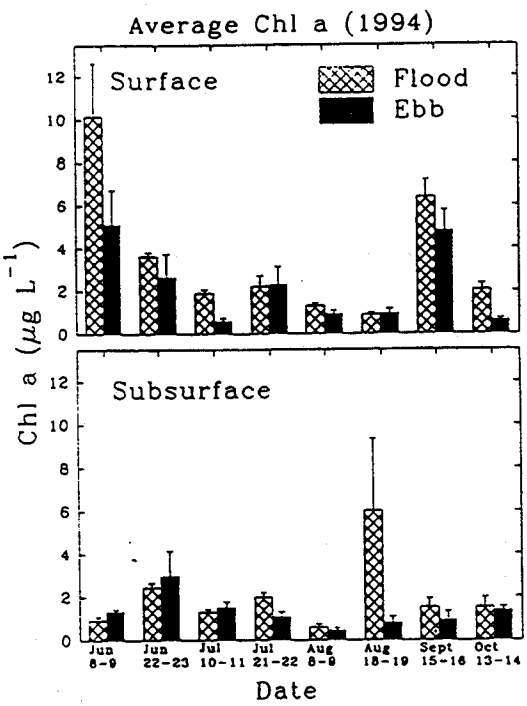
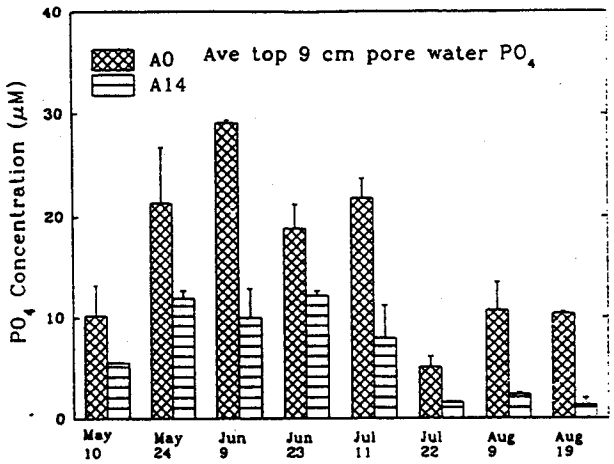
Fraser River
W5
South Arm
A14
Westham
Island
Roberts
Bank

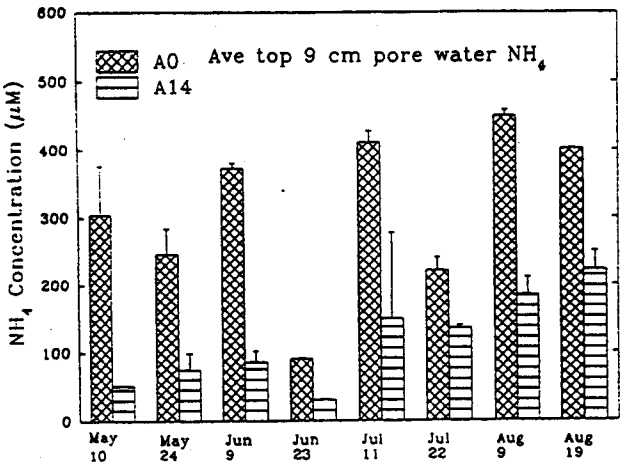

Average Temp (1994)
Surface
Subsurface
Flood
Ebb
Temp (°C)
Date
Average Salinity 1994
Salinity
Average PO4 1994
PO4 (μM)
Average O2 1994
O2 (mg L-1)
Jun 8-9
Jun 22-23
Jul 10-11
Jul 21-22
Aug 8-9
Aug 18-19
Sept 15-16
Oct 13-14


Average NH4 1994
Surface
Subsurface
Flood
Ebb
NH4 (μM)
Jun 8-9
Jun 22-23
Jul 10-11
Jul 21-22
Aug 8-9
Aug 18-19
Sept 15-16
Oct 13-14
Date

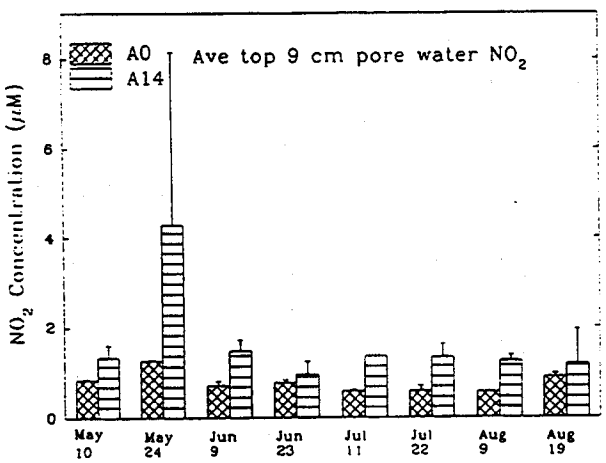

Average NO3 1994
Surface
Subsurface
Flood
Ebb
NO3 (μM)
Jun 8-9
Jun 22-23
Jul 10-11
Jul 21-22
Aug 8-9
Aug 18-19
Sept 15-16
Oct 13-14
Date

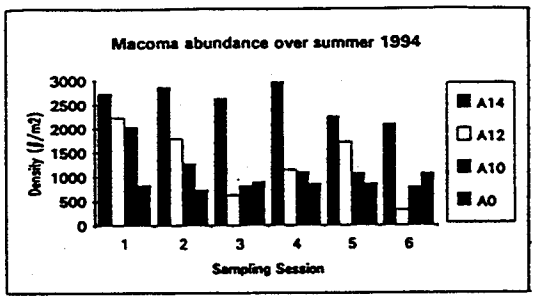

Average Chl a (1994)
Surface
Subsurface
Flood
Ebb
Chl a (μg L-1)
Jun 8-9
Jun 22-23
Jul 10-11
Jul 21-22
Aug 8-9
Aug 18-19
Sept 15-16
Oct 13-14
Date

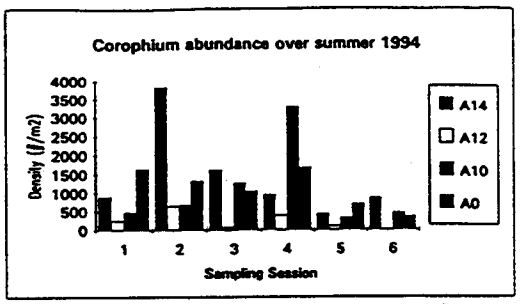


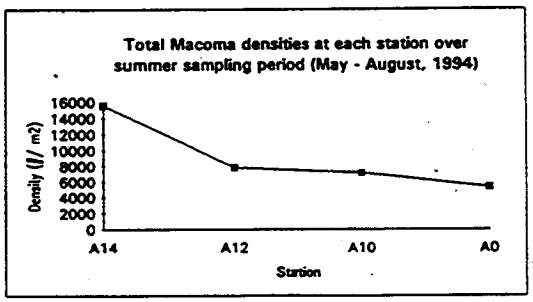


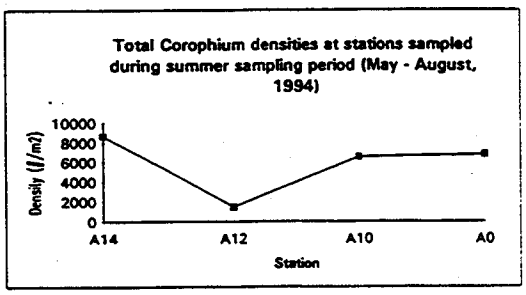
A0 = 2x A14; NH_4 is from organic-rich sediments

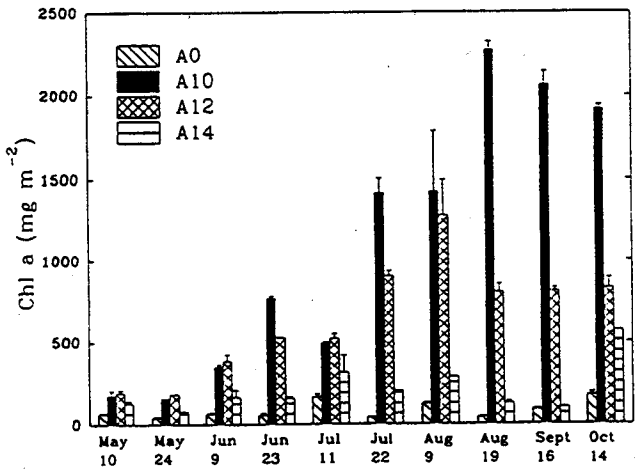



Macoma abundance over summer 1994
Density (I/m2)
3000
2500
2000
1500
1000
500
0
1
2
3
4
5
6
Sampling Session
A14
A12
A10
A0


Corophium abundance over summer 1994
Density (I/m2)
4000
3500
3000
2500
2000
1500
1000
500
0
1
2
3
4
5
6
Sampling Session
A14
A12
A10
A0


Total Macoma densities at each station over summer sampling period (May - August, 1994)
Density (I/ m2)
16000
14000
12000
10000
8000
6000
4000
2000
0
A14
A12
A10
A0
Station


Total Corophium densities at stations sampled during summer sampling period (May - August, 1994)
Density (I/m2)
10000
8000
6000
4000
2000
0
A14
A12
A10
A0
Station


Chl a (mg m-2)
2500
2000
1500
1000
500
0
A0
A10
A12
A14
May 10
May 24
Jun 9
Jun 23
Jul 11
Jul 22
Aug 9
Aug 19
Sept 16
Oct 14

Modelling the Environmental Fate and Food-Chain Bioaccumulation of Chemicals in the Fraser-Thompson River Basin

F. Gobas and K. Lien

Simon Fraser University

1. Introduction

The chief objective of this summary is to present the progress that we have made in developing and testing a computer simulation model that can be used to relate the emissions of chemical substances from pulp and paper mills in the Fraser-Thompson River Basin to resulting concentrations in water, sediment, air and various fish species in the Fraser and Thompson Rivers.

The computer simulation model consists of a chemical fate and a food-chain bioaccumulation model of the Fraser-Thompson River ecosystem. This model is a deterministic model, consisting of expressions that attempt to describe mechanistically the most important environmental fate and bioaccumulation processes controlling the distribution of chemicals in the river system. The expressions are parameterized to reflect the local environmental conditions, such as water flow rates, concentrations of suspended solids, organic carbon content, lipid content, etc. The model is not calibrated to make the model fit the observed data. The model should thus be viewed as an hypothesis or the compilation of best available knowledge regarding the fate of organic chemicals in the River system. This hypothesis is tested against field data in the study.

In this paper, we will present the progress in the model development, demonstrate the model's ability to predict concentrations of dioxins and furans in the Fraser-Thompson ecosystem against field observations, and, in our presentation, we will briefly illustrate the potential application of the model for managing chemical emissions in accordance with federal and provincial water quality criteria or guidelines.

2. Progress Made to Date

- We have recently developed a true time-dependent or dynamic model of the environmental fate and food-chain bioaccumulation of contaminants in the Fraser and Thompson River basin. This dynamic model differs from the earlier steady-state model in its ability to account for the effects of fluctuating environmental conditions on contaminant concentrations over time. The dynamic model can also calculate contaminant concentrations in different age-classes of fish. The steady-state model was not able to do this. This formulation of the model also allows us to perform more realistic food-chain bioaccumulation calculations where feeding preferences as well as other physiological parameters of the biological species can be varied over the life-time of the organisms.

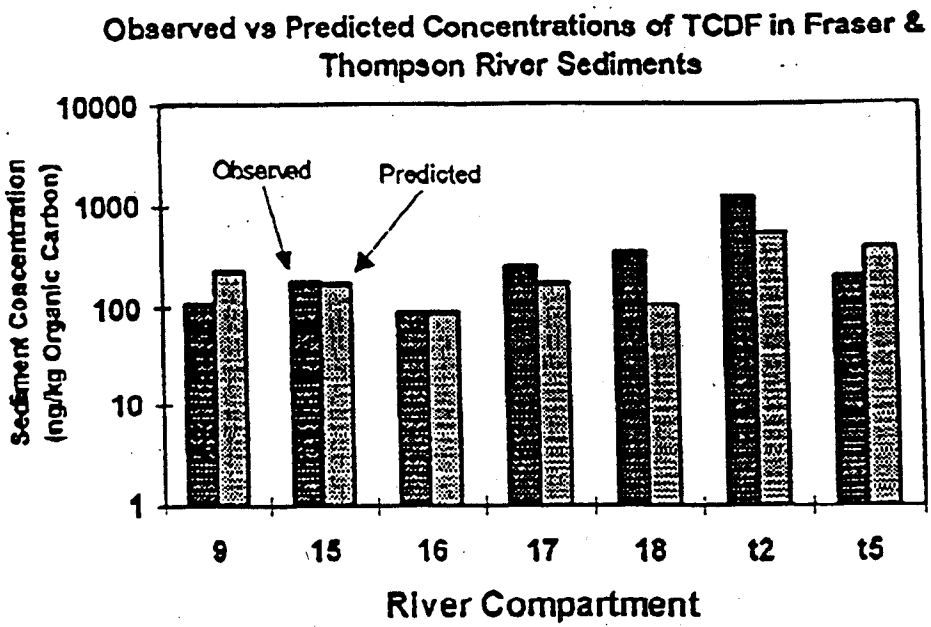
- We have performed an uncertainty analysis to characterize the uncertainty in the time-dependent model's predictions of contaminant concentrations in the water and sediments of the Fraser-Thompson Basin based on the natural variability in the environmental conditions within the Basin using Monte Carlo Simulation. We are exploring opportunities to conduct these calculations for the organisms of the Fraser and Thompson River food-chains.

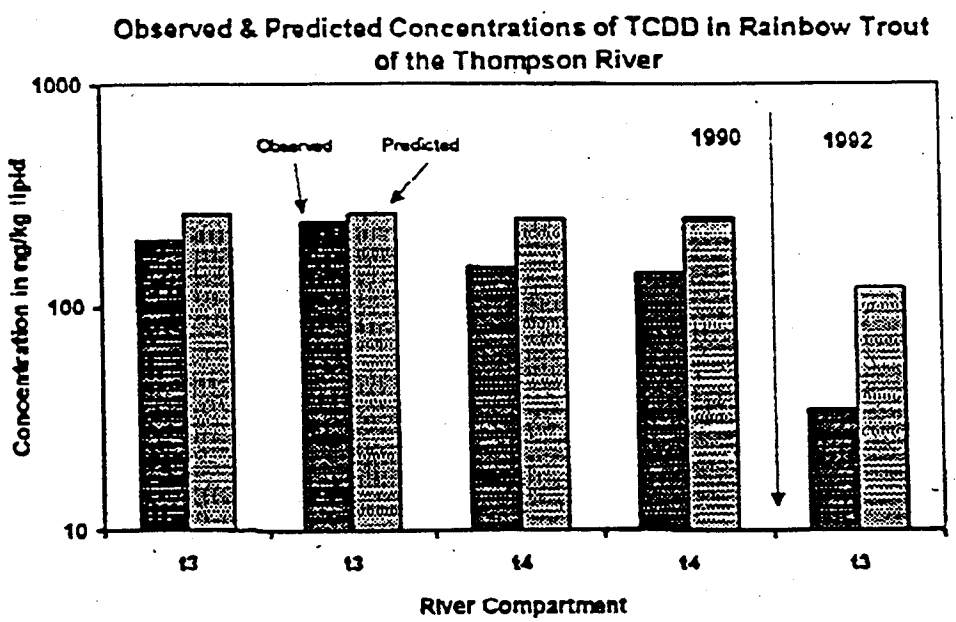
- We have also added and tested the USEPA and Health and Welfare Canada's algorithm for estimating the intake and associated health risk of contaminants by people through the consumption of Fraser and Thompson river fish. The purpose of this part of the model is to relate emission to potential human health risks from the consumption of Fraser and Thompson river fish.

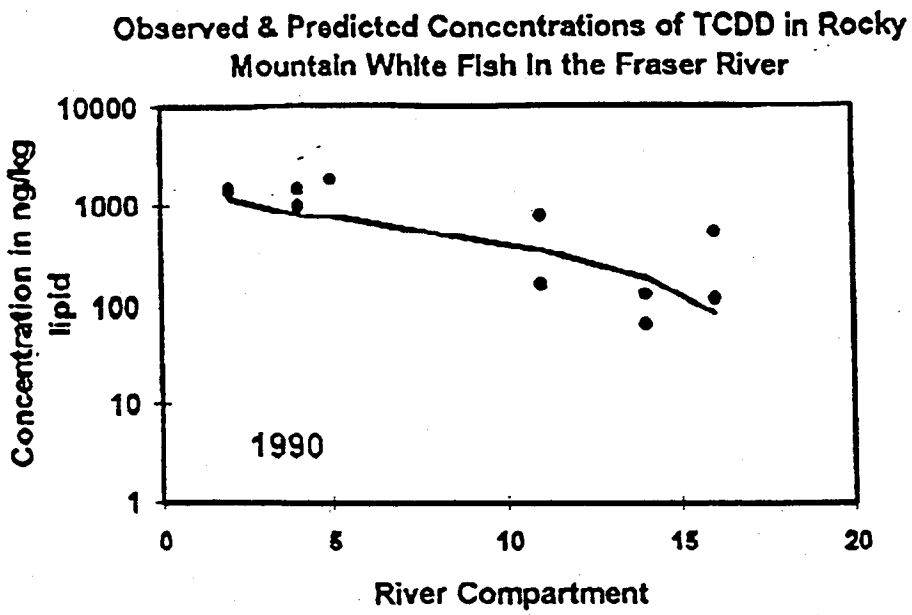
- With the help of funding provided by SFU, we have developed a geographical display system that is able to graphically depict spatial and temporal changes in contaminant concentrations resulting from pulp and paper mill effluents throughout the entire Fraser-Thompson river basin. This program graphically evaluates whether actual or proposed contaminant emissions by pulp and paper mills in the Fraser-Thompson river basin will meet environmental quality criteria within the basin.

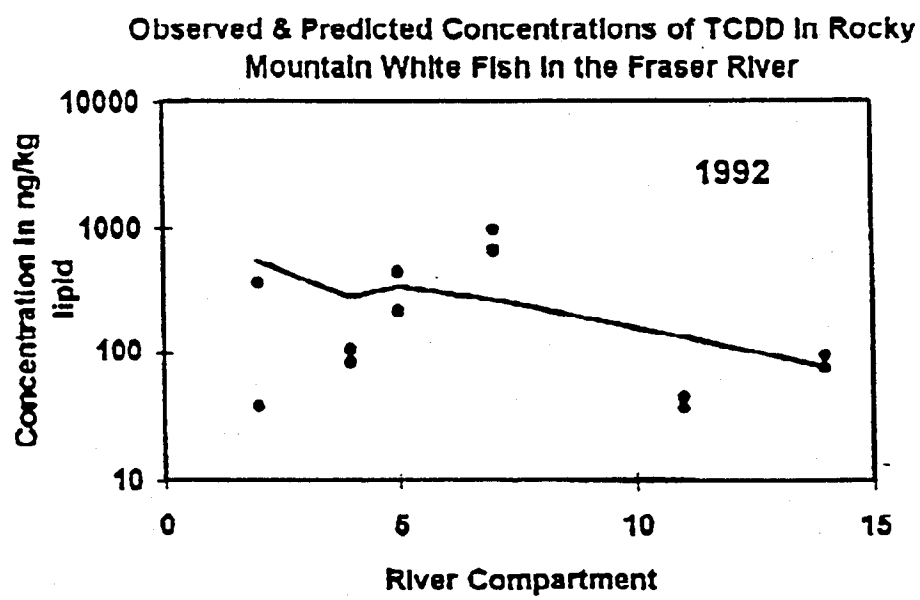
3. Model Validation

A graphical presentation of the predictive ability of the model is illustrated below for TCDD and TCDF in sediments, rainbow trout and mountain whitefish for the period from 1988 to 1992. The predictive ability is illustrated by the agreement between observed and predicted concentrations. It should again be stressed that the observed data were not used to calibrate or fit the model.


Observed vs Predicted Concentrations of TCDF in Fraser & Thompson River Sediments
Sediment Concentration (ng/kg Organic Carbon)
10000
1000
100
10
1
Observed
Predicted
9
15
16
17
18
t2
t5
River Compartment


Observed & Predicted Concentrations of TCDD in Rainbow Trout of the Thompson River
Concentration in ng/kg lipid
1000
100
10
Observed
Predicted
1990
1992
t3
t3
t4
t4
t3
River Compartment


Observed & Predicted Concentrations of TCDD in Rocky Mountain White Fish in the Fraser River
Concentration in ng/kg lipid
10000
1000
100
10
1
1990
0
5
10
15
20
River Compartment


Observed & Predicted Concentrations of TCDD in Rocky Mountain White Fish in the Fraser River
Concentration in ng/kg lipid
10000
1000
100
10
1992
0
5
10
15
River Compartment

SESSION 3

CHEMICAL CRITERIA DEVELOPMENT

Towards Criteria Development for Didecyldimethylammonium Chloride (DDAC)

C. Kennedy

Simon Fraser University

The approach and objectives of this long-term study are to identify and fill gaps in the knowledge base of chronic and acute toxic effects of DDAC (didecyldimethylammonium chloride) on fish, invertebrates and phytoplankton such that *in situ* mesocosm experiments can then be conducted and interpreted in a meaningful manner.

Both the short-term and long-term research plan are given in the flow diagram. This diagram also differentiates between completed experiments, those in progress and those planned for 1995-97.

1. Acute Studies in Fish and Invertebrates

The estimated LC50 value for trout, coho salmon and fathead minnow are given in Table 1. This value for rainbow trout is the lowest value reported for this or similar species. The value determined in our experiments is more realistic in terms of environmental conditions since our system is an intermittent flow system which replenishes the water and chemical in the test tanks every hour. Acute tests with coho salmon indicate that toxicity of DDAC increases with salinity (Table 1). For acute toxicity tests in Y1 and reproduction tests in Y2 with invertebrates, it has been necessary to set up continuous cultures of both *Daphnia magna*, which is native to western Canada, and a representative estuarine crustacean, the mysid shrimp, *Mysidopsis bahia*. At the present time we have reproducing colonies of *Daphnia*, however, our attempts at mysid culture initially were unsuccessful but are now showing established growth. We have performed an acute toxicity test utilizing *Dapnia* and *Mysidopsis* (Table 1). A 21-d, 3 generation lifecycle test was performed with *Daphnia* (Table 1). From our results, it appears that the toxicity of DDAC to these species of invertebrate is approximately 10-fold higher than in fish.

Table 1. Acute toxicity data for fish and invertebrates.

Organism	Test	Value
Rainbow trout	96-h LC50	0.420 mg/L
Coho salmon	96-h LC50	
	salinity 0ppt	0.989 mg/L
	salinity 15ppt	0.970 mg/L
	salinity 30ppt	0.725 mg/L
Fathead minnow	96-h LC50	0.172 mg/L
Daphnia magna	48-h LC50	0.052 mg/L
Mysidopsis bahia	48-h LC50	0.039 mg/L
Daphnia magna	21-d lifecycle	NOEC 0.037 mg/L

2. Sublethal Experiments

Our approach was to examine the effects of DDAC on several stress indicators including biochemical parameters, swimming performance, behavior and disease resistance or immunocompetence in rainbow trout. These indicators have practical application to field situations and have been shown to be "ecologically relevant," i.e., the results of our tests can be linked to the survival of the species being studied, a factor which classical biomonitoring has often failed to achieve.

In the biochemical tests, fish were exposed for 24 hours to four sublethal concentrations of DDAC and analyzed for several biochemical parameters which are indicators of stress and altered biochemistry. The results are given in Table 2. DDAC caused alterations in plasma glucose, plasma lactate, hemoglobin, plasma cortisol and liver glycogen. Alterations in these parameters are typical of a generalized response to stressors such as toxicants.

The effect of DDAC exposure on maximal swimming performance (U_{crit}) is seen in Table 3. These data show that DDAC has an effect on fish swimming ability at sublethal concentrations.

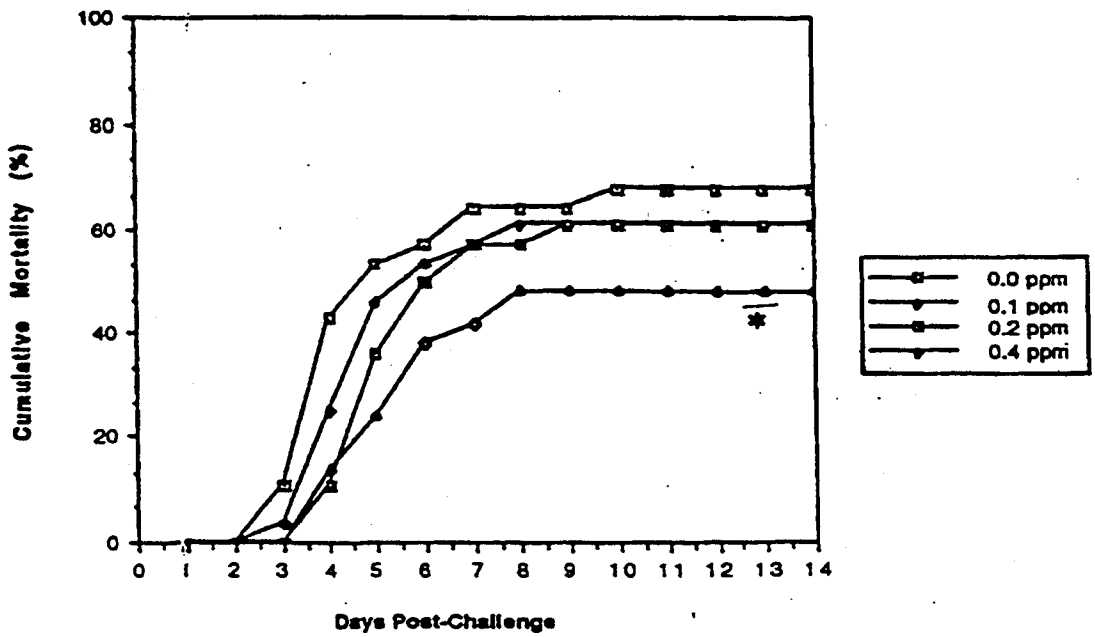
In the immunocompetence studies, fish were exposed for 24 urs to four sublethal concentrations of DDAC to exa ne effects on disease resistance. Fish were subsequently challenged to the pathogen *Aeromonas salmonicida*, which causes the fish disease furunculosis. Disease resistance was only affected in fish exposed to the high DDAC concentration (see figure).

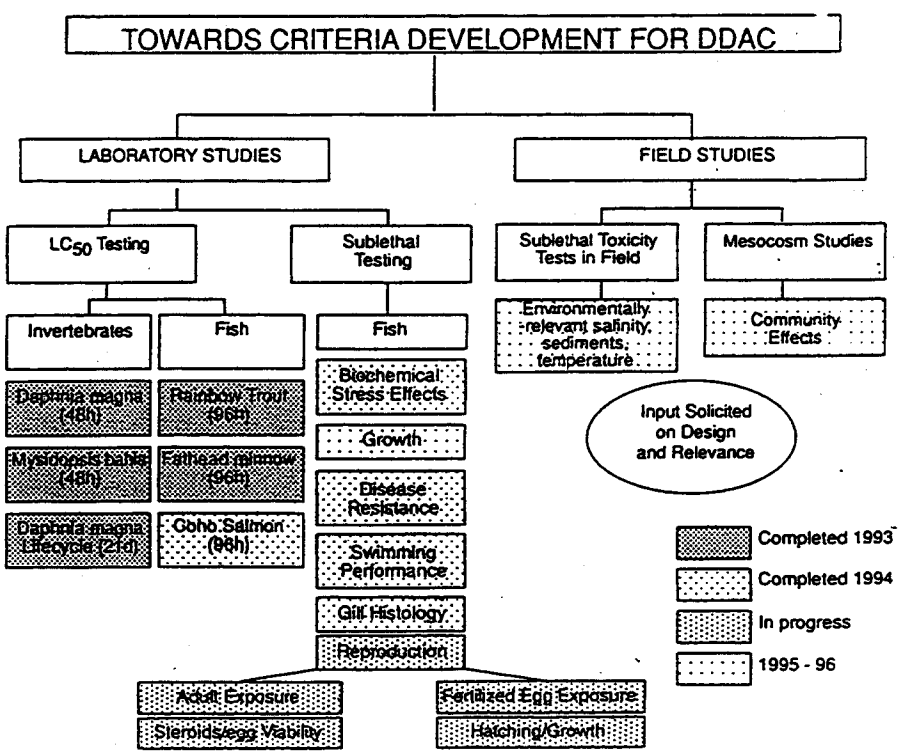
Table 2. Effects of an acute 24-h exposure on several parameters in rainbow trout at sublethal DDAC concentrations. LSI-liver somatic index, Hb-hemoglobin. Values are means ± standard errors, n=10 fish.
* denotes a significant difference from controls at $p<0.05$ level.

Parameter	DDAC concentration (mg/L)			
	0	0.1	0.2	0.4
LSI	0.011 ± 0.002	0.011 ± 0.004	0.012 ± 0.003	0.011 ± 0.002
Glucose (mg/dL)	65.48 ± 3.18	62.72 ± 2.72	63.12 ± 2.36	81.54 ± 4.92*
Lactate (mg/dL)	49.23 ± 4.79	42.51 ± 2.50	45.83 ± 4.55	61.58 ± 3.02*
Hb (g/dL)	7.48 ± 0.53	7.42 ± 0.016	7.39 ± 0.26	8.35 ± 0.23*
Hematocrit (%)	46.0 ± 1.29	46.3 ± 1.45	42.9 ± 1.82	48.9 ± 1.48
Leucocrit (%)	0.67 ± 0.07	1.02 ± 0.10	0.88 ± 0.10	0.78 ± 0.10
Cortisol (μg/dL)	1.88 ± 0.44	3.19 ± 0.92	0.81 ± 0.11	8.17 ± 2.16*
Liver glycogen (mg/g)	27.12 ± 4.53	23.78 ± 5.10	34.82 ± 2.92	27.98 ± 3.74

Table 3. Critical swimming speeds of juvenile rainbow trout following acute sublethal 12-, 24- or 48-h exposures to DDAC. Values are means ± SE of 10 fish.
* denotes a significant difference from controls at $p<0.05$.

Exposure time (h)	DDAC concentration (mg/L)			
	0	100	200	400
12	6.64 ± 0.14	6.73 ± 0.28	5.46 ± 0.28*	6.02 ± 0.15*
24	6.62 ± 0.24	7.32 ± 0.14*	5.04 ± 0.12*	5.15 ± 0.14*
48	6.54 ± 0.20	6.34 ± 0.32	5.99 ± 0.19	5.78 ± 0.11*


Cumulative Mortality (%)
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Days Post-Challenge
0.0 ppm
0.1 ppm
0.2 ppm
0.4 ppm
*


TOWARDS CRITERIA DEVELOPMENT FOR DDAC
LABORATORY STUDIES
FIELD STUDIES
LC50 Testing
Sublethal Testing
Sublethal Toxicity Tests in Field
Mesocosm Studies
Invertebrates
Fish
Fish
Environmentally relevant salinity, sediments, temperature
Community Effects
Daphnia magna (48h)
Rainbow Trout (96h)
Biochemical Stress Effects
Input Solicited on Design and Relevance
Mysidopsis bahia (48h)
Fathead minnow (96h)
Growth
Daphnia magna Lifecycle (21d)
Coho Salmon (96h)
Disease Resistance
Swimming Performance
Gill Histology
Reproduction
Adult Exposure
Sterioids/eggs Viability
Fertilized Egg Exposure
Hatching/Growth
Completed 1993
Completed 1994
In progress
1995 - 96

Reproductive Toxicity in White Sturgeon

B. Bennett and T. Farrell

Simon Fraser University

1. Objective

Examine the early life stage toxicity in white sturgeon to selected compounds released into the Fraser River by the wood industry, i.e., 4-chloro-1,2-benzenediol (catechol = CAT); 3,4,5,6-tetrachloro-2-methoxyphenol (tetrachloroguaiacol = TCG), 5-chloro-4 hydroxy-3-methoxybenzaldehyde (vanalin = VAN), and N,N didecyl-N,N dimethylammonium chloride (anti-sapstain = DDAC).

2. Approach

Performed static LC50 tests at various developmental stages up to and including the early feeding fry (42 days old).

Gametes and fertilized eggs were obtained from a Sacramento River Hatchery and transported to Malaspina College where the tests were performed.

The attached flow diagram summarizes the testing protocols.

3. Results

Toxicity tests performed on the eggs fertilized at Malaspina College were unsuccessful. All eggs died including controls. We suspect that unfertilized gametes do not transport well. The fertilized eggs did transport well and the successful toxicity tests are reported below.

a. TCG

Feeding fry exhibited no mortalities in the control, solvent control, and TCG concentrations of 0.1 and 1 ppm. Mortality was 100% in the TCG concentrations 5 ppm and 10 ppm. Mortalities were rapid, within the first 12 h for 5 ppm and within 4 h for the 10 ppm.

The 96-h LC50 for TCG lies between 1 and 5 ppm for the feeding fry stage.

Toxicity tests with pre-feeding fry were inconclusive. There were no mortalities with the control group. However, there was 100% mortality with the solvent control group, as well as variable mortality with TCG concentrations between 0.05 ppm and 10 ppm. At this time we cannot explain this sensitivity of pre-feeding white sturgeon to test chemicals.

b. VAN

Feeding fry exhibited no mortalities in the control, solvent control, and VAN concentrations of 0.01, 0.05 and 0.5 ppm. There was a 20% mortality after around 48-h in the 5.0 ppm VAN. Survivors of the VAN exposure were moribund for 24 h after the test was completed and remained alive until they were routinely stressed during aquarium cleaning.

The 96-h LC50 for VAN lies close to but above 5 ppm for the feeding fry stage.

With pre-feeding fry, responses were inconsistent, similar to the TCG exposure. No conclusions could be drawn. However, as with the feeding fry, many survivors of the VAN exposure, but not the controls, were moribund and eventually died.

c. DDAC

Feeding fry exhibited sporadic (less than 10%) mortalities in the control, solvent control, and DDAC concentrations of 0.1, 0.5 and 1.0 ppb. 100% mortality occurred with 10 ppb DDAC, mostly within the first 4 hours of exposure.

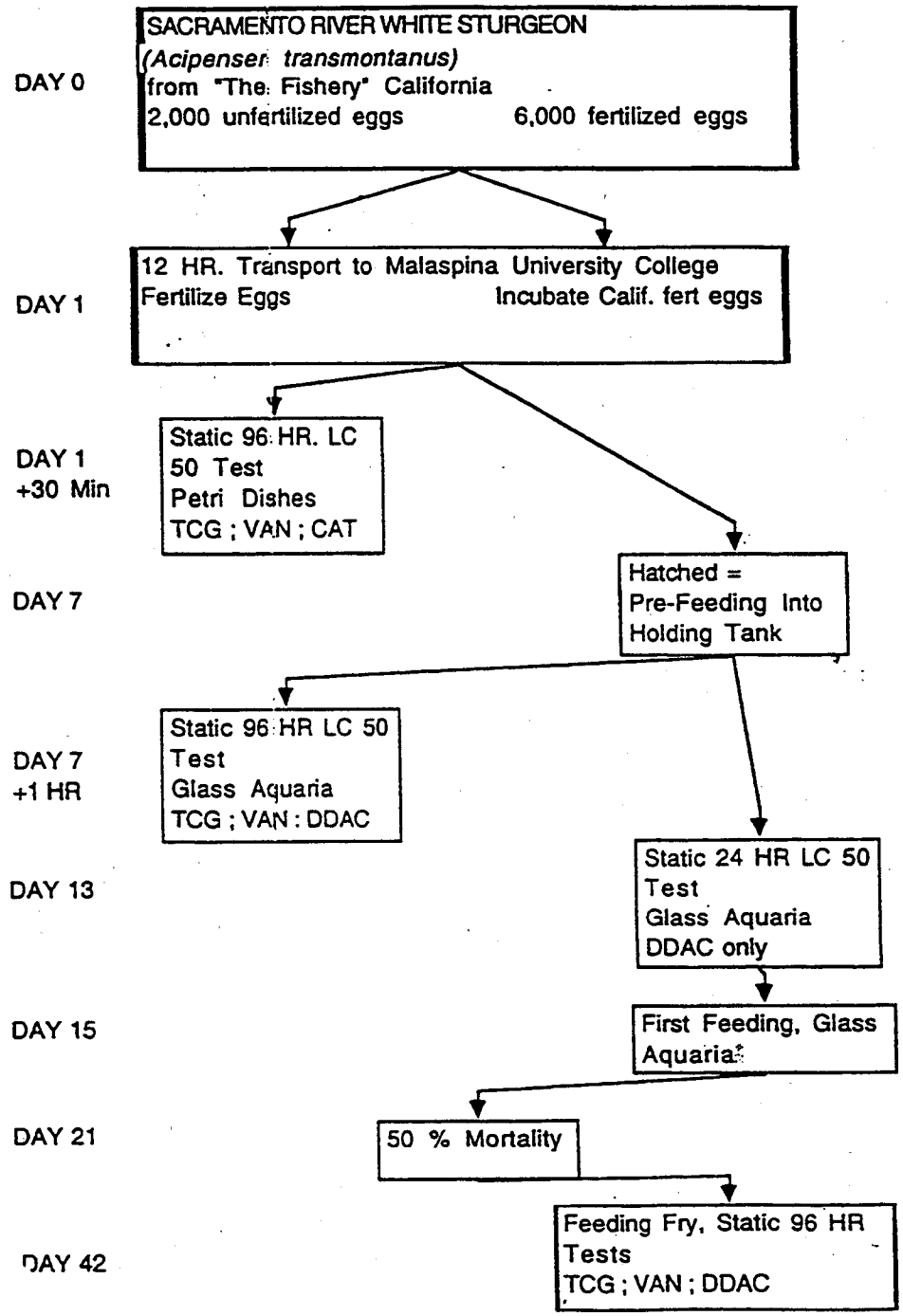
The 96-h LC50 for DDAC lies between 1 and 10 ppb for the feeding fry stage.

With pre-feeding fry, responses were inconsistent, as with the other two chemicals. However, immediate deaths occurred with DDAC concentrations as low at 0.05 ppb.

Because of the large and rapid mortality with DDAC, a 24-h LC50 test was performed 2 days later in the development. There were no pre-feeding fry mortalities in the control and solvent control. At concentrations equal to or above 0.5 ppb and up to 100 ppb there was always 100% mortality. There was 43% mortality at 0.1 ppb DDAC.

The 24-h LC50 for DDAC lies between 0.1 and 0.5 ppb for the pre-feeding fry stage.

In addition, we suspect that the unusual sensitivity of white sturgeon fry to DDAC is influenced to a very high degree by the developmental stage, with sensitivity decreasing as the fry age. White sturgeon undergo development very rapidly; they hatch in one week.


SACRAMENTO RIVER WHITE STURGEON
(Acipenser transmontanus)
from "The Fishery" California
2,000 unfertilized eggs
6,000 fertilized eggs
DAY 0
12 HR. Transport to Malaspina University College
Fertilize Eggs
Incubate Calif. fert eggs
DAY 1
Static 96 HR. LC 50 Test
Petri Dishes
TCG ; VAN ; CAT
DAY 1 +30 Min
Hatched = Pre-Feeding Into Holding Tank
DAY 7
Static 96 HR LC 50 Test
Glass Aquaria
TCG ; VAN : DDAC
DAY 7 +1 HR
Static 24 HR LC 50 Test
Glass Aquaria
DDAC only
DAY 13
First Feeding, Glass Aquaria
DAY 15
50 % Mortality
DAY 21
Feeding Fry, Static 96 HR Tests
TCG ; VAN ; DDAC
DAY 42

SESSION 4

ECOSYSTEM OBJECTIVES DEVELOPMENT

Combining Simulation Models with GIS as a Decision Support Tool

H. Schreier

University of British Columbia

The overall objectives of the project are to build a resource information system for the Salmon River Basin in Langley that is capable of supplying resource information to planners and managers in an integrated and rapid manner and in a form that is readily useful for management and decision support.

The specific aims are to:

1. Document current conditions and historic changes in stream and groundwater in the watershed.

2. Identify key non-point source pollutants in the system and relate them to current and past land use activities.

3. Evaluate current environmental conditions and ecosystem health.

4. Produce scenarios of land use options using a geo-referenced database.

5. Initiate innovative action programs to reduce inputs into the system, improve the water flow and quality within the system, and protect key habitat from further deterioration.

6. Use the GIS-based technology and geo-referenced information base as a tool for environmental education for managers, politicians and citizens.

An overview is provided of the nitrate and phosphorus conditions at 13 stations in the watershed over the 1993-94 annual hydrological cycle. The results are compared with comparable data collected in 1974 and key sites where contamination has increased are identified. The source of contamination is non-point source inputs from septic systems and agricultural land use. The land use dynamics over the past 10 years were analyzed using GIS overlay techniques and the results show rapid conversions of agricultural land into residential and speculative holdings. Evidence will be provided to show that the remaining agricultural land is being used more intensively and the animal numbers in the watershed have increased steadily as a result of greater intensity of hog production and increases in hobby farms. A comprehensive septic systems database was produced covering all houses built after 1950. The annual peak increase in septic systems occurred in 1973 and although the annual numbers have declined steadily since that time, the total number of systems in the watershed has now reached 4,245. This is a constant input source and since more than 50% of all systems are not functioning properly this has to be considered a major non-point source input. This problem is made worse since about one-half of all septic systems are located on a major groundwater aquifer, which is the main water source for the stream flow during the summer.

Having documented the major input and the current conditions in the stream, the issue to be addressed is the health of the groundwater aquifer. Available information proved to be incomplete and inadequate and a current survey is underway to address the groundwater dynamics and water quality issues. This is being done with the assistance of the Salmon River Watershed Partnership and is proving to be an innovative way of evaluating the groundwater.

The stream location with the highest nitrate levels is also the place with the greatest groundwater input and this is currently being documented with the assistance of DFO (FRAP) using automated temperature probes and flow measurements.

The watershed analysis has provided us with the tools to show the extent and location of water pollution and the likely sources of contamination. We can now initiate innovative management programs to reduce the inputs (initiating a septic system servicing program, reducing agricultural waste inputs, creating vegetated buffer zones alongside the stream, reducing further urbanization on the most sensitive portions of the aquifier).

In collaboration with the citizens and SRWPS scenarios will be developed over the next 4 months to demonstrate potential problems and options with different land use and development plans. This will be done in conjunction with modelling of nitrogen and

phosphorus in the watershed system. The established historic trends will be used to develop the scenarios.

The final product will be a computerized information system that enables all users to access the collected data and to examine different consequences based on a set of development scenarios.

SESSION 5

CONCLUSIONS

ISSUE COORDINATION AND PLANNING

GROUP A:	Ecology, Population Biology and Sentinel Species Development
GROUP B:	Transport and Sedimentation of Contaminants - Modelling; Chemical Uptake
GROUP C:	Environmental Impact of Specific Pollution Sources: Pulp Mill Effluent, STP & Urban Run-off -- Biomarkers and Toxic Effects

GEOGRAPHICAL COORDINATION AND PLANNING

GROUP D:	Mainstem Fraser and Thompson Rivers
GROUP E:	Urban and Agricultural Run-off in the Lower Fraser Valley
GROUP F:	Estuary

CONCLUSIONS

November 30, 1994

GROUP A:
Ecology, Population Biology and Sentinel Species Development

PARTICIPANTS:

Chair: L. Harding, Environment Canada

P. Whitehead	Environment Canada	R. Vadas	Simon Fraser University
D. McPhail	University of B.C.	T. Reynoldson	NWRI
T. Sullivan	University of B.C.	P. Harrison	University of B.C.
M. Sewell	Simon Fraser University	M. Healy	University of B.C.
K. Hutton	Fisheries and Oceans		

Focus Questions

1. Can the separately collected and interpreted information on population "structure" in benthos, fish and aquatic-based wildlife communities be used to construct food web descriptions which adequately demonstrate the role/importance of the candidate sentinel species?

2. What possible/potential indicators of structure, function or stress are there likely to be developed by the end of the program?

3. Are there protocols for undertaking ecosystem "context" research in each of the four major sub-systems of the Fraser?

Results of Discussion

1. We discussed what we want the Fraser Basin to "look like" and how we would characterize it.

   We agreed the basin does not, now, represent a "natural state," and to achieve this, remediation will have to be a component of our actions. However, some changes, such as introduction of exotic species and some kinds of land use, are irreversible. Human population is seen as the major challenge affecting the basin, and this effect has been pronounced from Hope down, and will get worse. Moreover, governance systems seem incapable of preventing "rapacious development." Preserving options for the future will be difficult; but success in reversing damage from stresses such as pulp mill effluent and overgrazing offer hope. Processes such as CORE have limited application in the river bottoms where much of the land is private, or committed to land uses not under the purview of CORE.

2. Some components of FRAP research are well integrated, but others are not. For example, the absence of fish community studies throughout the basin to complement NWRI's benthic community work was noted. An example of good integration is Westwater's work in the Lower Mainland.

3. We recommend a comprehensive conference, like the Georgia Basin conference. This conference was

organized by an independent science board that reported directly to senior politicians, thus directly linking science and policy.

4. Sentinel species: we feel we have good sentinel species for uptake of contaminants, but not for broader ecosystem effects. Moreover, selection of sentinel species for unknown or non-specific effects, or those of multiple stressors, was felt to be dangerous, because if you select one that is inapplicable for certain condition, or in certain places, you may miss serious changes. Also, you need to understand the ecosystem structure and function before choosing, and we're not at that stage yet. Finally, you would need too many indicators to capture specific stresses in specific situations. Better to concentrate on community structure.

5. We also discussed the role of endangered species and keystone species in ecosystem health assessment, and agreed that they have an important role.

GROUP B:
Transport and Sedimentation of Contaminants - Modelling; Chemical Uptake

PARTICIPANTS:

Chair: M. Church, University of B.C.

K. Krishnappan	NWRI	F. Mah	Environment Canada
F. Gobas	Simon Fraser University	P. Stecko	Simon Fraser University
L. Gomm	University of B.C.	C. Thomas	Simon Fraser University
R. MacDonald	Fisheries and Oceans	D. Millar	Environment Canada
M. Sekela	Environment Canada	B. Duncan	MOELP
J. Vine	University of B.C.	I. Moul	Foul Bay Ecological Research
W. Belzer	Environment Canada		

Focus Questions

1. For what contaminants do we have a complete story? Prepare a matrix?

Media	µg/L	flux (g/yr)	uptake
Water			
Sediment			
Benthos			
Fish			
Other			

2. Do we have sufficient concentration, flux and uptake data to verify the model being developed?

3. Are the identified sedimentation zones recognized in the model development?

4. Is there a strong linkage between near-field and far-field research projects?

Additional Questions Raised by Group

5. How well is sediment transport known?

6. Can we do hydraulic modelling in terms of sediment transport?

7. How well can we model the Fraser River?

Results of Discussion

1. Flow (Hydraulic) Modelling

- Quick's routing model of the length of the Fraser, including tributaries (UBC model)

- Krishnappen's unsteady flow model may work on the upper reaches of the river (NWRI model)
  - 1-D modelling requires upstream hydrograph plus downstream parameters
  - 2-D model requires channel geometry description, i.e., river survey
  - time of travel may be available from various sources including Quick and Derksen

- Gobas' Fraser model (SFU model)

2. Sediment Modelling

- excellent sediment transport information on the Fraser at the five measurement points, including size distribution, bed load/material at Mission station

- Church investigating transport of various sediment sizes

- leads to investigation of sediment sources and sinks, and seasonal variations/flux

- kilometre-by-kilometre knowledge of bed transport is available for the lower reaches of the river

- sediment transport through the estuary is not well known (some work is being done by U. Guelph, Geologic Survey of Canada, and UBC)

- dredging is a major factor in the sediment (sand) budget in the estuary

- Public Works Canada has estimated sediment flux in the estuary back to the turn of the century

- not enough information is available for reliable sediment modelling in the estuary

3. Contaminant Modelling

- are we aware of the extent of industrial loading?
  - yes...to some extent
  - less knowledge of seasonal variations and synoptic variations

- Gobas is finding reasonable data for some contaminants but not others (e.g., chlorophenolics input data does not support observed concentrations in the river -- by several orders of magnitude)

- is it possible for modellers to state input requirements (to industry, etc.) based on output quality desired?
  - good place to start managing data collection costs
  - may lead industry to only manage the output of the requested parameters, and ignore others

- we still require better end-of-pipe contaminant input data

- do contaminants-of-concern have a greater affinity for fibres and organics than for fine sediments?

- a knowledge gap exists in the understanding of contaminant desorption from sediment (as dilution increases downstream of contaminant sources)

4. Contaminants and Benthos

- there is reasonable information available on bioaccumulation to start developing a model

- researchers studying sediment-dwelling organisms might be persuaded to expand their research to include contaminants

- otherwise, there is limited knowledge of contaminant concentration levels/flux in benthos

5. Contaminants in Fish

- restricted by limited knowledge of fish migration (reports of up to 600 km migration of resident fish)

6. Do we have sufficient data to verify models?

- depends on the purpose of the model and output desired, e.g., other researchers may need output parameters from the model that require a different, unanticipated set of input data

- the intended extent/purpose of the model is also important, e.g., can any model relate pulp mill solids input to fish survivability, or only something less?

5. Sedimentation Zones and Model Development

- models have a limited ability to predict sedimentation zones

6. Near-field, Far-field

- models tend to be full-river, rather than site-specific
- again, modelling and research is restricted by a limited understanding of fish migration relative to contaminant sources
- could temperature (or some other parameter) modelling lead to a better tie between near-field and far-field research?
- near-field research can lead to better management by improving the application of environmental regulations
- definition of near-field and far-field varies with researcher

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Detailed Report of Working Group B

1. How well can we model the Fraser River?

This question is a key one for the FRAP program. It can be broken down in several ways. With respect to modelling strategy, models can be classified according to spatial dimensions preserved. 1-D models route runoff through a channel system, simulating hydrograph characteristics, but giving no details about within-channel dynamics. Information requirements include the upstream hydrograph and certain downstream parameters to determine channel performance in passing the flow. The latter information can be estimated by inverse solution of historical flows. Several such models are available for adaptation to Fraser River, including the UBC flow model, developed over many years by Professor M.C. Quick (UBC Civil Engineering), initially for the Fraser River, and the NWRI unsteady flow model (B.G. Krishnappen). 2-D models preserve some details of within-channel dynamics, particularly some index of dispersion and contaminant mixing in vertical or lateral dimensions. Contaminant time of travel and deposition zones can be predicted from such models. However, they require information of channel morphology, which can only be derived from detailed surveys.

Within the FRAP program, no single model will serve all of the river management objectives that it is intended to address. For basin-wide dispersion of contaminants along with the flow is the computationally feasible approach. The model of F. Gobas incorporates a 1-D hydraulic model. In such a model, specific sources and sinks of sediment must be identified, and the exchanges separately estimated. 2-D models may be required in the far-field (*sensu stricto*) region of a dispersing contaminant plume in order to study the potential effects of contamination upon the water column and benthic communities in the first few tens of kilometres downstream. They may also be used to study the effects of individual sediment sources in the basin-wide model. Even more specialized models of plume behaviour will be required in the near-field region (G. Lawrence) to study initial dispersion under the dominating influence of the inflowing contaminant stream.

Each of the model scales introduced above has scale correspondences in one or another of the sediment, contaminant and aquatic biology studies that are underway. Flow/contaminant models at the different scales introduced above can be integrated together by proper attention to outputs and to forcing and boundary conditions at each scale. But it appears as if relatively little thought has been given to integration of the various model scales. It is probable that 2-D models will be applied only in restricted reaches of the river downstream from significant contaminant sources. By extension, one may fear that relatively little thinking has been done about integrating the substantive studies that are underway in the project. This matter concerns the Transport/Modelling group.

2. How well is sediment transport known?

There is excellent sediment transport information on the Fraser River at five measurement stations which were maintained by the Water Survey of Canada from the mid-1960s until the late 1980s. These are Hansard, Marguerite, Hope, Agassiz and Mission (which continues). There are also observations at Port Mann. At Agassiz and Mission, bedload transport has been measured. These stations are very well situated in comparison with the reaches of the river that must be identified for study in the FRAP program.

Total suspended sediment flux has been published by the Water Survey. At present, re-analysis of the data from all stations is underway (Church) to permit the transport of individual size grades to be estimated. An analysis of sediment transport in the Hope-Port Mann reach was completed in 1986 (McLean and Church, 1986). There have been a number of measurement campaigns in the estuarine reach, but the transport here remains incompletely known. Dredging is a major factor in the sand budget of the estuary. Upstream, a study is underway to determine the effect of contaminant/ sediment interaction in the immediate vicinity of contaminant sources (Krishnappan). Flocculation is an important mechanism governing sediment behaviour.

In summary, clastic sediment transport is better known in this river than in any other major river of the world. The data are adequate for modelling in all reaches except the estuary.

3. Can we do hydraulic modelling in terms of sediment transport?

Yes, certainly. However, the nature of the sediment transport data archives will limit their use as a basis for modelling to development of a 1-D model along the mainstem of the Fraser River. This will be a major reach scale sediment budget model which takes account of major sources and sinks, and advects sediment downstream between them. This realization of sediment transfer processes is compatible with the contaminant transfer and fate model of F. Gobas.

Seasonal storage of fine sediment is an important question for modelling in the FRAP program. Studies by Krishnappan make clear that the open bed of the river -- as opposed to specifically identified traps such as side channels -- may be an important seasonal storage place for flocculated sediment. Studies currently underway should allow development of a model of this process. Our measurements will allow us to consider the process along the entire length of the river.

If models of sediment dispersion from specific sources are required, current theory is adequate to supply them. Of greater concern for additional study in this project is the identification of specific sources sufficiently important to warrant attention.

4. For what contaminants do we have a complete story?

None. But this matter is relative; we have tolerably good information for some contaminant species and media. Following is a summary abstracted from the matrix presented for consideration. Water, sediment, benthos and fish were considered with respect to ambient concentrations, fluxes and uptake of contaminants.

a. Water

Concentration is tolerably well known on a seasonal basis for some contaminants (e.g., major, naturally occurring ions, certain metals) but not for others. Knowledge of fluxes follows directly from knowledge of concentrations. Uptake of contaminants is, for water, equivalent to loading. Industrial inventories are reasonably known for come contaminants, but not for all, on an annual basis. Seasonal and synoptic variations are not well known. In sum, we still do not know what goes into the river. Yet once in the river, many contaminants are hard to measure, and it may be very difficult to prove the source. It was concluded that we still require better "end-of-pipe" contaminant input data.

As a test of adequacy of knowledge, Gobas has attempted to model the regime of some contaminants in comparison with data of concentrations or input. Results are reasonable for some chemical species, but not others. For example, chlorophenolics input data do not correspond with concentrations observed in the river by several orders of magnitude. The possibility to improve this situation led to discussion about the costs of acquiring data to provide a basis for modelling.

Because of the costs of data collection (largely associated with analytical costs), industry reasonably resists unspecific calls for more information, and agencies can afford only a limited number of observations. Some basis is required to decide what

information to require or to pay for. One possible starting point is for the modellers to specify what the data input requirements are to derive model outputs of a specified character and quality. This criterion, in turn, would require the water managers to specify the character and precision of model results required to manage the system effectively. There is some prospect to cost such a strategy. A stated shortcoming of the approach is that it may lead industry to manage only the output of chemicals specified by the strategy and to ignore others. A response might be that such targeted data requirements (the cost for acquisition of which might fairly be assumed or shared by industry) should be regarded as distinct from baseline monitoring, an important purpose of which would be to identify new parameters of potential concern. Rapid developments in industrial processes and potentially synergistic effects in the river appear to demand more than one data acquisition strategy.

Another issue that requires attention is the change in procedures of analysis for contaminants and sediments in water that have occurred over the years. Some significant historical data sources are not obviously compatible with current measurements. Within sediments, this arises in relation to changes in the methods for determining sediment size.

b. Sediment

Knowledge of sediment-contaminant interactions remains inadequate. Behaviour of metals is tolerably well known, but that of many organic species is not. Uptake of contaminants is a complex process in the Fraser River. Recent sampling efforts have notably failed to replicate sediment/contaminant associations that have previously been reported. It is not clear whether the problem lies with insufficiently frequent sampling, or with problems in sediment/contaminant chemistry that are not well understood.

It is not known whether contaminants of concern have a greater affinity for fine clastic sediments, or for fibres and organic materials, a substantial amount of which is introduced by the pulp mills. There is, further, insufficient evidence about whether the sedimentologically immature clastic materials characteristic of the Fraser River (much of the fine sediment derives from eroding glacial deposits, and is merely physically ground rock material) behave differently than more advanced weathering products (such as clay minerals). Finally, there is a gap in understanding of contaminant desorption from sediments downstream, as dilution of contaminants in the water column proceeds.

c. Benthos

Some of the mechanisms are known by which benthos take up contaminants, but application of this knowledge in Fraser River conditions is not well known. As a result, uptake and fluxes of contaminants in benthos are not well known. The group wondered whether FRAP researchers studying bottom and sediment-dwelling organisms might be persuaded to expand their research to include contaminant burdens. However, the proposal would face major problems of sampling and segregation of material for analysis. There appears to be a significant sampling problem here.

d. Fish

Considerable work has been done on body burden of certain fishes. However, all other issues here are overshadowed by lack of knowledge about the migrations of fish in the river. There are reports of resident fish migrating by up to 800 km in the adjacent Peace River system. Body burden information is uninterpretable in terms of uptake, storage and flux of contaminants unless fish movements are well known. This will become a major problem for modelling potential outcomes of contaminant inputs on fish populations -- which is, presumably, a significant objective of the entire FRAP exercise.

5. Do we have sufficient data to verify models?

This question was modified in light of discussion reported above. The answer, of course, depends upon the purpose of the model and the precision of the output desired. Furthermore, it should be recognized that a modelling exercise undertaken for broad management purposes -- such as the FRAP exercise appears to be -- may lead to certain research or management groups desiring output parameters from the model that require a different, unanticipated set of input data than those available. A key issue, then, is to guess what are the key data in terms of effects it is desired to study.

Data and modelling constraints jointly may limit the function of any model. For example, can any model relate pulp mill solids inputs to fish survivability? Or is some lesser relation the best that is achievable? The model is a diagnostic tool for management and, as management priorities evolve, the model must evolve as

well. For this reason, effective models are apt to have an architecture that remains 'open' to convenient modification as knowledge of contaminants, mechanisms and effects evolves.

6. Are the identified sedimentation zones recognized in the model development (can/does the model predict these zones)?

Models have a very limited ability to predict the location of sedimentation zones, unless they are of the 2-D variety, which will not be feasible for some time to develop for the entire river. However, sedimentation zones are more or less evident, and a survey has already been completed (Northwest Hydraulic Consultants, 1994). It would be reasonable to specify major sedimentation zones as specific boundary inputs to the river-length model.

7. Is there a strong linkage between the near-field and the far-field research projects?

The answer to this question must be predicted upon definitions, since "near-" and "far-field" have important differences in meaning for different research groups. To the hydrodynamic researchers concerned with contaminant plume dispersal, the "near-field" designates the region of initial dispersion governed by input stream characteristics. For example, for warm, point-injected contaminant streams, the "near-field" designates the region in which plume behaviour is as a thermally buoyant jet. It may extend for over 100 m from input. The "far-field" is the subsequent realm of turbulent mixing, until vertical and lateral dispersion are complete. It may extend for tens of kilometres, possibly as far as 100 km in the Fraser River for lateral mixing, but main attention would be given to the first 10 km. In comparison, many other researchers would regard the "near-field" as that first 10-km reach within which the exposure of an organism, or a sediment body, to contamination will vary with its position in the cross-section. The rest of the river (in which advective mixing along the river continues) is, then, the "far-field." There was some discussion whether temperature, an easily monitored parameter, might serve as a tie between the two concepts for modelling purposes.

Near-field research (in the hydrodynamic sense) can lead to better contaminant management by improving the application of environmental regulations about concentrations permissible in the river in the initial dispersion zone.

Full-river models would tend to take the second set of definitions because the mechanics of initial plume dispersal are below the resolution of the model. But the effectiveness of modelling even here is limited by the lack of knowledge of fish movements relative to contaminant sources.

GROUP C:
Environmental Impact of Specific Pollution Sources: Pulp Mill Effluent, STP & Urban Run-off -- Biomarkers and Toxic Effects

PARTICIPANTS:

Chair: J. Culp, NWRI

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K. Munkittrick	Fisheries and Oceans	G. Kan	Environment Canada
B. Raymond	Environment Canada	J. Nener	Fisheries and Oceans
G. Derksen	Environment Canada	B. Kooi	Environment Canada
K. Day	NWRI	S. Lum	Environment Canada
M. Dube	MOELP	K. Cash	NWRI
T. Tuominen	Environment Canada		

Focus Questions

1. How many biomarker techniques are likely to be developed by mid-95/96? For which contaminant classes and which species (tissues)?

2. Are the chosen biomarkers of exposure associated with quantifiable effects?

3. Are the toxicological results from single substance testing usable in the field?

4. Are the present (and future) body burdens of persistent\bioaccumulative chemicals in sentinel species leading to declines in these species which could have ecosystem-wide implications?

Additional Questions Raised by Group

5. How can mesocosm technology be further developed to aid biomarker development?

6. What information is needed to: a) link or validate mesocosm results with field observations; and b) estimate potential changes in the ecosystem as a result of changes in effluent loadings?

Results of Discussion

1. a) One new technique (P4501A1); we are assessing applicability of techniques to the Fraser System.

   b) Techniques aren't designed for specific contaminant classes/or species although some specific tests are being undertaken with laboratory.

2. a) This is the subject of ongoing research.

   b) Biomarkers should relate to ecological endpoints of reproduction, growth, disease resistance and performance (e.g., swimming).

c) Tiered Approach:
i) measurement of change in ecological endpoints
ii) identify underlying causal mechanisms

d) The ideal suite of biomarkers would assist in the identification of both effect and underlying cause.

3. a) Laboratory tests increase our understanding of effects in the field.

b) With appropriate modification, toxicological tests can be applied to field situations.

c) Mesocosms represent a powerful link between laboratory and the field.

4. Proposed that a working group be formed to develop criteria for mesocosm development.

OVERVIEW

1. Develop basic understanding of ecology of these systems (Structure and Function)

2. Measurement of impacts (Exposure and Performance)

3. Ecosystem consequences (e.g., risk assessment)

4. Management consequences (e.g., remediation/status quo)

Mesocosm Use in FRAP Research Programs

J.M. Culp

Artificial streams (i.e., mesocosms have been used as tools for investigating ecological interactions in running waters since the 1960s (see Lamberti and Steinman, 1994, for review). In the Fraser River Action Plan, mesocosms will be used to investigate dose-response relationships of complex food webs, including primary and secondary producers, to treated pulp mill effluents as well as specific chemical compounds. Thus, the objectives for this breakout group were the following:
1)provide an operational definition of mesocosms that will be useful for FRAP applications;
2)discuss the relevant temporal and spatial scales for mesocosm experiments;
3)indicate technical problems likely to be encountered when undertaking mesocosm experiments and identify any anticipated shortfall in resource allocations;
4)identify possibilities for collaboration among groups working on mesocosm research;
5)define the role of this experimental approach in FRAP research programs.

1. Stream Mesocosms

Mesocosms can be defined as outdoor facilities which simulate, rather than reproduce exactly, key aspects of the riverine environment. In FRAP research programs we will attempt to use ambient regimes of temperature and light. These partially recirculating systems will be supplied with water from the river and, therefore, will be located at specific research sites along the river.

2. Scales

a. Temporal

The group identified that the length of mesocosm experiments was linked to the level of biological organization and the type of biota being studied. For example, studies of fish reproduction would be difficult (or impossible) to complete successfully due to the length of time needed for egg development and spawning. However, it may be possible to undertake short-term experiments (i.e., days to a few weeks) on fish if correlates of reproductive success are examined. In contrast, studies of invertebrate communities and benthic food webs could extend for a period of 1-2 months. This will allow dose-response research at the community level to be undertaken using effluents and specific chemical compounds.

b. Spatial Scale

As with the discussion on temporal scale, the appropriate size of mesocosm will be dictated by the scientific question that is posed, the organisms under

study and practical considerations. Presently, the size of mesocosms (i.e., water volume and depth) to be developed and used for FRAP research programs will allow studies of the benthic food web. The members of this food web could include biofilm (algae, fungi and bacteria), invertebrates and small benthic fish. Larger systems will be needed for the investigation of endpoints targeted to fish populations.

3. Problems and Resource Shortfalls

Many of the technical difficulties associated with mesocosms increase in proportion with mesocosm size. Thus, to keep costs down and to increase treatment replication (i.e., statistical power), mesocosms for benthic food web research will be small (i.e., 200 L tanks with 30 cm wide channels). Since resource shortfalls limit the number of sites that can be studied, mesocosm research for the benthic program will focus on the Prince George, B.C., research node.

4. Collaboration

A number of exciting possibilities exist for collaborative research between researchers using biomarkers and mesocosms as research tools. Presently, it is too early to identify specific studies but discussions among workshop attendees clearly identified that mesocosm research provides the best potential for generating dose-response relationships for community and population endpoints.

5. Role of Approach in FRAP

The strength of mesocosm research lies in our ability to investigate complex benthic food webs in model systems that simulate specific riverine conditions. This tool will aid the development of community bioassays and has the potential to indicate new ecosystem indicators (see figure). Currently, mesocosms are research tools. However, the possibility exists that they could be used in monitoring programs (e.g., EEM) or to estimate potential changes in the ecosystem as a result to changes in effluent loading.

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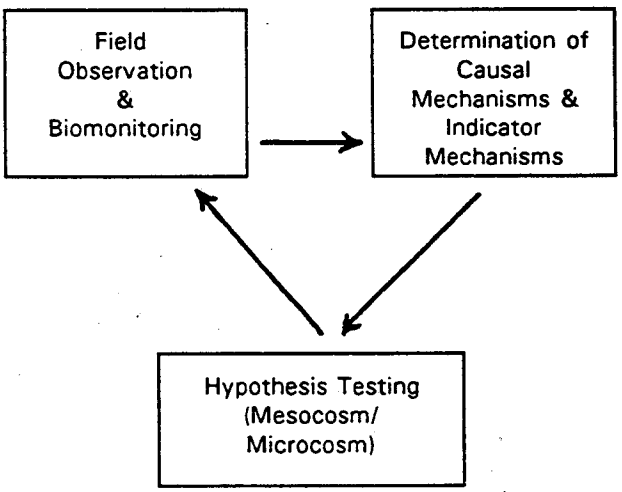

Flow diagram indicating the conceptual steps needed in order to use mesocosms as tools which aid biomonitoring assessments and the identification of new ecosystem indicators.

GROUP D:
Mainstem Fraser and Thompson Rivers

PARTICIPANTS:

Chair: B. Duncan, MOELP

M. Sullivan	Fisheries and Oceans	K. Hutton	Fisheries and Oceans
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T. Reynoldson	NWRI	M. Sekela	Environment Canada
K. Day	NWRI	M. Dube	MOELP
J. Vine	University of B.C.	T. Tuominen	Environment Canada
L. Gomm	University of B.C.	B. Vadas	Simon Fraser University
F. Gobas	Simon Fraser University	F. Mah	Environment Canada
K. Munkittrick	Fisheries and Oceans	M. Rosenau	BCE Fisheries
D. McPhail	University of B.C.		

Focus Questions

1. Are there ways to share costs on logistics?
2. Will the research products supplement a monitoring program already active in the area?
3. Would semi-annual meeting of this group be useful (in the pre-field season)?

Results of Discussion

1. Logistics

Fish

Coordinator - B. Raymond, DOE
Plan to have early spring meeting/set up teleconferencing

Benthos

Coordinator - T. Reynoldson, NWRI
Few linkages
CWS not present

Sediment
Coordinators - K. Krishnappan, NWRI and G. Lawrence, UBC

Air

Linkages to be explored?

2. Research Needs

a) Need loading of point sources
b) Need list of contacts/names/phone numbers
c) EEM
   - Linkages need further exploration
   - Difficult to harmonize regulated monitoring and research projects, but this should be addressed

GROUP E:
Urban and Agricultural Run-off in the Lower Fraser Valley

PARTICIPANTS:

Chair: M. Healey, University of B.C.

B. Kooi	Environment Canada	K. Hall	University of B.C.
G. Kan	Environment Canada	J. Nener	Fisheries and Oceans
G. Derksen	Environment Canada	H. Schreier	University of B.C.

Focus and Additional Questions

1. What are the key issues in urban and agriculture runoff and are we addressing them?

2. Can we share costs and logistics?

3. Will projects supplement monitoring already in action?

4. Would a semi-annual meeting of the group by useful?

Results of Discussion

1. Discussion on question 1 fell into five general categories:

a. Issues having to do with the sources and fates of contaminants and nutrients

Most of our research activity is directed to this issue. We are developing a picture of levels of contamination and nutrients, sources, movement and storage, and changes over time in the urban Brunette, agricultural Sumas, and rural Salmon rivers. There are our most intensive research locations, but some measurements are also being made elsewhere. Coverage of contaminant and nutrient sources and fates is not comprehensive; however, even in the intensively studied locations. Particularly important gaps in our work include:

- Analysis of pesticides. We are doing only a small amount of work with four pesticides used on berry crops, focussing on rates of dissipation in soil. Some work is also being conducted on corn cropping demonstrations in the valley. Costs of analysis have been the main impediment to doing more with pesticides.

- Management options for and impacts of domestic sewage in the GVRD. Domestic sewage is one of the largest sources of particulate organics, nutrients and contaminants in the lower river. We have no specific projects dealing with this important issue and getting information and cooperation from the GVRD has proven difficult. Estimates made a few years ago by Westwater suggest that installation of secondary treatment, if population growth continues at the present rate, would only "buy" 7-10 yrs before total loadings returned to present levels.

- The expansion of hobby farms and their contribution to non-point source rural pollution. The extent of the problems for small watercourses posed by hobby farmers is unknown. However, the number of farms and the density of animals on those farms, and the variable conditions of animal husbandry used suggests that the problem could be large.

- Atmospheric fallout. A particular issue in agricultural areas is nitrogen delivered to the atmosphere from animal wastes that falls out elsewhere in the rain. Studies in the Netherlands indicate that this can be a substantial source of nitrogen. The specific problem, however, highlights the fact that we have very little work underway or planned on atmospheric sources of contamination, nutrients, etc., yet we know that many of the contaminants we are studying are readily transported in the atmosphere.

b. Assessing the consequences of non-point pollution for organisms of greatest interest to the public (mainly fish and birds)

Work on the consequences of non-point contamination for organisms that the public values highly is in its initial stages. Some of the work on indicator species will contribute to our understanding. Research on pathological abnormalities in fish is part of the lower Fraser studies but at the moment this is concentrated in the main river. More needs to be done in the tributaries. Mesocosm studies to assess impacts of ambient pollution on aquatic organisms are planned for the coming year but these will probably focus on invertebrates. Getting a good appreciation of the link between aquatic pollution and the fish and birds is likely to be particularly important in raising public concern and stimulating change.

c. Evaluating the effects of guidelines and management practices on ecosystem integrity

Although we have considerable research underway designed to assess the present state of the lower Fraser ecosystem, little of this is directed at assessing the effectiveness of present development guidelines in maintaining ecosystem integrity. Recent work on replacement habitats is one example. At the moment there are a variety of guidelines (sometimes conflicting among levels of authority) governing construction to conserve watercourses. A project specifically to assess the effectiveness of these guidelines would be useful. Such a project is contemplated for a proposed residential development on Sumas Mountain. Another location where the effects could be studied is in the Kanaka catchment where considerable urban development is imminent.

d. Linking the results of research to policy and regulatory change

We perceived that there was a problem linking the results of the work being done with municipal planning. An example of the problem is the conflicting guidelines for leave strips along streams between federal and municipal agencies. This may be in part a problem of territoriality between levels of government. Several Westwater projects are directly linked to planning processes in municipalities (Langley Township, Abbotsford/Matsqui, Richmond).

A number of important community-based demonstration projects are underway in the Fraser Basin. We perceived a need to ensure that the important lessons from these projects are consolidated and made available to municipal decision makers.

Given the tenuous state of farming economics, it seems to be particularly difficult to get farmers to accept or try new ways of doing things. Specific demonstration projects that show, for example, that reduced use of fertilizers or manure does not reduce crop yield are a good way to convince farmers. Simply showing the excessive use of fertilizer damages soils and water is ineffective. Collaborative projects with farmers can also be effective, such as the use of lure crops for water fowl in the delta. Another way that the farm community is encouraged to try new practices is through having to respond to new regulations.

A similar issue can affect attitudes to urban streams. Simply showing that urban activities degrade the stream is ineffective. This is what everybody expects. There is a need to show that a productive and healthy stream ecosystem can be sustained in an urban setting to convince decision makers to adopt different practices.

e. Issues outside the lower Fraser

We were concerned about the extent to which results from the lower Fraser could be extrapolated to other urban and agriculture areas. Westwater has proposed that some of our studies could be repeated in another urban area in a different climatic and geologic setting (e.g., Kamloops) to test transportability of results.

It was also suggested that we should pay attention to the sensitivity of lakes outside the region to acid fallout.

2. Questions 2-5

We are taking advantage of opportunities to coordinate our research and save on logistics when we can. We did not identify any new opportunities.

We are doing most of the measurements on non-point pollution, so there are few "monitoring" programs to complement.

We felt that a pre-field season meeting would be useful. DFO had proposed arranging a meeting particularly on urban issues. Agricultural issues might be combined with this or held separately. The province and GVRD should be represented at any such meetings.

GROUP F:
Estuary

PARTICIPANTS:

Chair: P. Harrison, University of B.C.

M. Sewell	Simon Fraser University	C. Thomas	Simon Fraser University
W. Belzer	Environment Canada	L. Nikl	Fisheries and Oceans
Z. Arifin	Simon Fraser University	P. Stecko	Simon Fraser University
K. Hutton	Fisheries and Oceans		

Results of Discussion

1. Cost Sharing:

a) T. Farrell may use PBS barge for river work and DDAC studies.

b) R. Macdonald has information on anoxic sites.

c) P. Stecko - metal in suspended sediments and sampling problems. DFO agreed to help.

d) C. Thomas - will do metal part of Iona project?

e) P. Harrison
- SFU will do metals
- PAHs - C. Kennedy (SFU) will help with analysis
- R. Macdonald (IOS) will help

2. All thought their work (mostly baseline information work) could be useful for monitoring programs. It was noted that there are not really many monitoring programs at present.

3. Most thought semi-annual meeting would be beneficial, but timing for the meetings was not resolved. It was suggested that the mid-term meeting would address linkages, not formal presentations. Need E-mail addresses.