GREAT LAKES FISHERY COMMISSION

2001Project Completion Report[1]

Emerging Technologies Workshop

by:

J.C. Headwaters Canada, Ltd.

269 Lakeshore Road
East Oakville, ON L6J 1H9

September 2001

[1]Project completion reports of Commission-sponsored research are made available to the Commission's Cooperators in the interest of rapid dissemination of information that may be useful in Great Lakes fishery management, research, or administration. The reader should be aware that project completion reports have not been through a peer review process and that sponsorship of the project by the Commission does not necessarily imply that the findings or conclusions are endorsed by the Commission. Do not cite findings without permission of the author.

Emerging Technologies Workshop – GLFC – Sept 17-21, 2001

....

J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax
headwaters@sprint.ca

Preliminary List of Participants:

1. Marilee Chase marilee.chase@mnr.gov.on.ca
2. Katherine Mullet Katherine_Mullett@fws.gov
3. Lisa O'Connor OConnorL@DFO-MPO.GC.CA
4. Karen Smokorowskik Smokorowskik@DFO-MPO.GC.CA
5. Susan Greenwood susan.greenwood@mnr.gov.on.ca
6. Robert Elliott Robert_Elliott@fws.gov
7. Ronald Kinnunen kinnunen@msue.msu.edu
8. Mike Friday mike.friday@mnr.gov.on.ca
9. Tom Pratt PrattT@DFO-MPO.GC.CA
10. Rod McDonald mcdonald@DFO-MPO.gc.ca
11. Lloyd Mohr lloyd.mohr@mnr.gov.on.ca
12. Chuck Krueger ckrueger@glfc.org
13. Mike Steeves steevest@dfo-mpo.gc.ca
14. Brian Stephens stephensb@dfo-mpo.gc.ca
15. Fraser Neave NeaveF@DFO-MPO.GC.CA
16. Stephen Gile stephen.gile@mnr.gov.on.ca
17. Troy Pherson (?) in place of Harry Taylor
18. Arunis Liskauskas arunas.liskauskas@mnr.gov.on.ca
19. Roger A Bergstedt roger_bergstedt@usgs.gov
20. Dave Scruton dscruton@DFO-MPO.gc.ca

Emerging Technology Workshop - schedule

	Monday	Tuesday	Wednesday	Thursday
9-10:15	***Lecture*** *Intro* Scott McKinley (9-9:30) ***Lecture*** Gary Sprules (9:30-10:30)	***Lecture*** Wendy McFarlane	***Lecture*** Scott McKinley	***Lecture*** Ullrich Krull
10:15 – 10:45	**Break** (10:30-11)	**Break**	**Break**	**Break**
10:45-12	***Lecture*** Nigel Lester/Trevor Middel (11-12)	***Lecture*** Tom Singer	***Lecture*** Chad Gubala	**Visitor's Centre or Nature Hike**
12-1:30	**Lunch**	**Lunch**	**Lunch**	**Lunch**
1:30 – 4:30	***Workstation 1 – Group A*** ***Workstation 2 – Group B*** ***Workstation 3 – Group C*** ***Workstation 4 – Group D***	***Workstation 1 – Group B*** ***Workstation 2 – Group C*** ***Workstation 3 – Group D*** ***Workstation 4 – Group A***	***Workstation 1 – Group C*** ***Workstation 2 – Group D*** ***Workstation 3 – Group A*** ***Workstation 4 – Group B***	***Workstation 1 – Group D*** ***Workstation 2 – Group A*** ***Workstation 3 – Group B*** ***Workstation 4 – Group C***

Presentations:

W. Gary Sprules
Department of Zoology
University of Toronto

"Why fisheries biologists should worry about plankton, and how to measure it"

Nigel Lester
Resource and Community Assessment Unit
Ontario Ministry of Natural Resources

"Developing a sonar method for estimating lake trout abundance"

Wendy MacFarlane
Waterloo Biotelemetry Institute
University of Waterloo

"Applications for physiological telemetry"

Tom Singer
Waterloo DNA Microarray Laboratory
Waterloo Biotelemetry Institute
University of Waterloo

"DNA Micro-array: applications to aquatic research'

R. Scott McKinley
Waterloo Biotelemetry Institute
University of Waterloo

"Biotelemetry procedures and applications"

Chad Gubala
JC Headwaters Canada, Ltd

"Aquatic Asset Inventoring - Knowing What You Have"

Ulrich J. Krull
Chemistry Department
University of Toronto

"Towards the detection of pathogenic organisms in real-time"

Workstations

For accommodation to the workstations, participants will be separated into four groups. Each group will attend a different workstation over the four days.

Workstation 1 – Plankton/Water quality. Gary Sprules

Workstation 2 – Data analysis – hydroacoustics. Chad Gubala

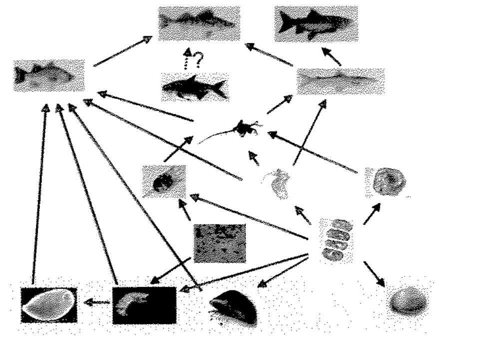
Workstation 3 – Data analysis – Telemetry; fish handling techniques; tracking. Lori Flavelle and Jennifer Wilson

Workstation 4 – Demonstrate remote sensing of plankton, water quality, bathyometric mapping (bottom profile, bottom type), integrated with geo-referencing, mapping techniques and biotelemetry. Scott Milne

Why fisheries biologists should worry about plankton, and how to measure it.

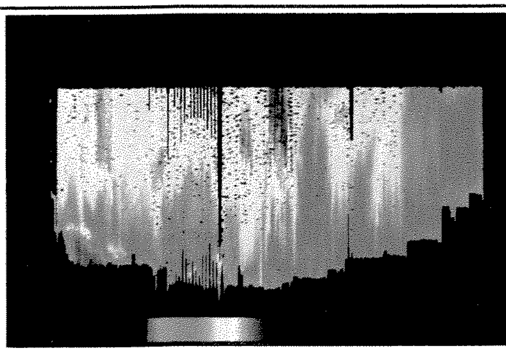
W. Gary Sprules
Department of Zoology
University of Toronto at Mississauga
Mississauga, ON L5L 1C6
905-828-3987
gsprules@cyclops.erin.utoronto.ca

1



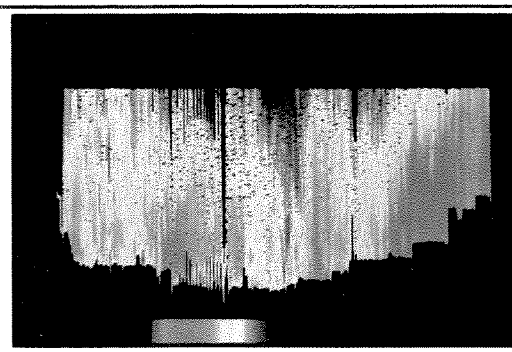
All energy entering a lake comes from the sun. Algae use this energy to fix carbon which is transferred to bacteria, a variety of invertebrates and ultimately to fish.

2



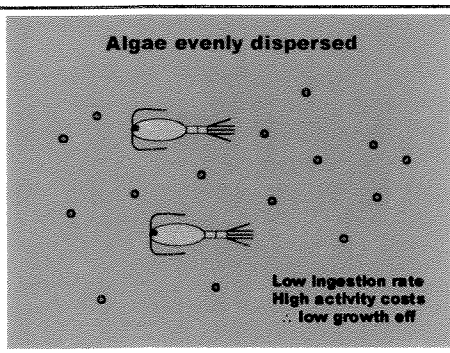
Algae (chlorophyll in this image across the central basin of Lake Erie) can be quite patchy in its distribution, indicating that the quality of aquatic habitat is not uniform [data collected by undulating a fluorometer from surface to depth as a ship traversed the 69 km north-south width of the basin].

3



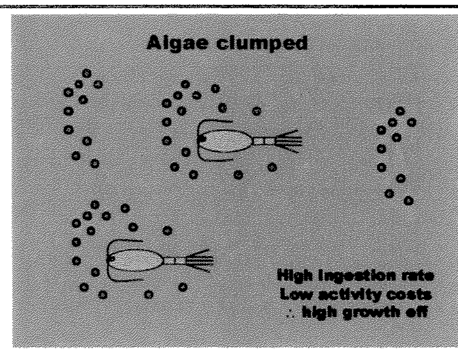
Zooplankton biomass can also be patchy, so the quality of habitat for larval or planktivorous fish growth is not uniform [data collected by undulating an Optical Plankton Counter in the same fashion as the fluorometer].

4



Furthermore, the efficiency with which energy moves through the food web can depend on spatial patterns of predators and their prey. Here a grazing zooplankter experiences high cost of searching for minimal food gain in a uniformly low prey density.

5



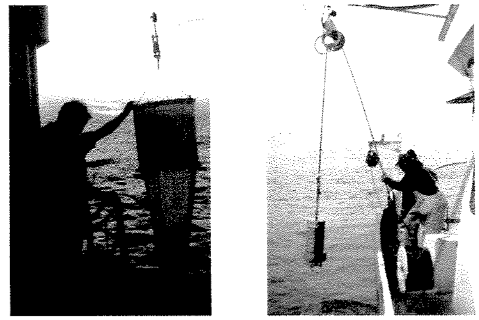
By contrast, grazing in a high concentration patch of prey tips the energy balance in favour of growth because searching costs are low while ingestion is high The same arguments apply at all trophic linkages in the food web.

6

It is thus important to be able to measure the spatial and temporal patterning of plankton biomass in lakes in order to:

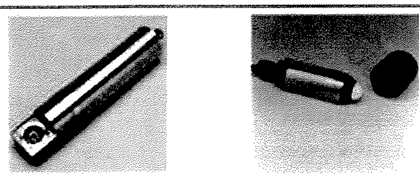
- quantify the volume of high quality fish habitat
- document seasonal changes in the location of this habitat
- assess the capacity of a lake to produce fish taking into account spatial and seasonal variations in the structure of the whole food web

7



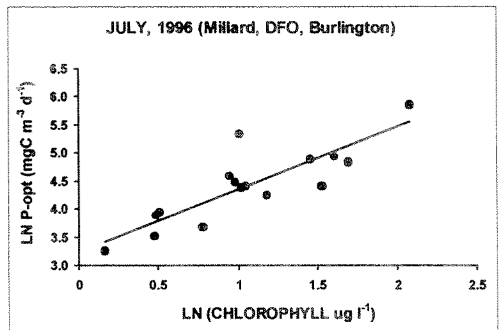
Traditional methods of net sampling for zooplankton (left) or integrated water sampling for algae (right) provide very low spatial resolution. Microscopic processing of such samples requires specialized training and enormous amounts of time. In future such techniques will be used only to provide periodic ground-truthing of more powerful technologies.

8



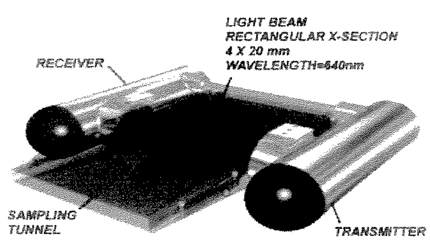
A powerful alternative to traditional point sampling techniques is the use of a variety of continuous electronic sensors, each sensor designed for a particular trophic group of organisms. These sensors provide continuous observations while towed behind a vessel with spatial resolution up to fractions of a meter horizontally and centimetres vertically. For algae the use of a fluorometer (on left above) for measuring chlorophyll concentration, in combination with a light sensor for measuring photosynthetically active radiation- PAR (right above) provide the basis for integrated, spatially explicit estimates of carbon fixation at the base of the food web.

9



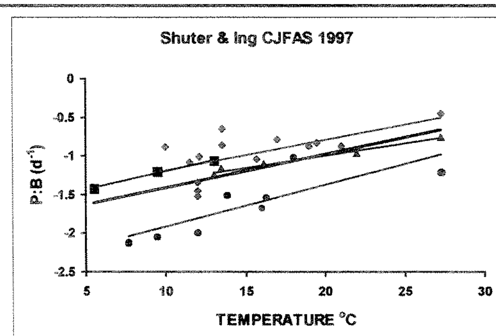
The chlorophyll concentrations can be scaled to primary production as long as a few direct experimental measures of carbon uptake are made (data courtesy S. Millard, DFO, Burlington).

10



Continuous measurements of zooplankton concentration and body size can be made with an Optical Plankton Counter (OPC). As the OPC is towed behind a vessel, zooplankton pass through the sampling tunnel and break a light beam that results in an organism being counted and sized. Such data form the basis for the image shown in Slide #4 - a whole water column profile of zooplankton biomass along a 69 km cross-lake transect.

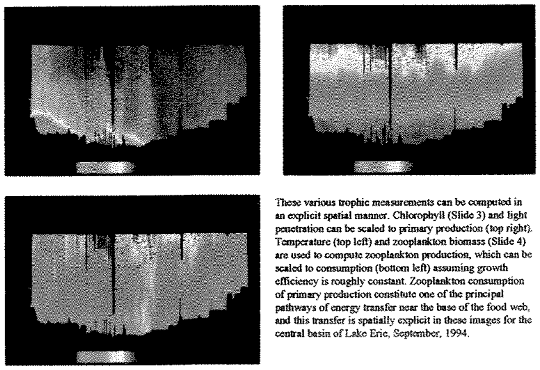
11



Zooplankton daily growth rate is strongly dependent on temperature. Many recorders are available for continuous temperature measurement.

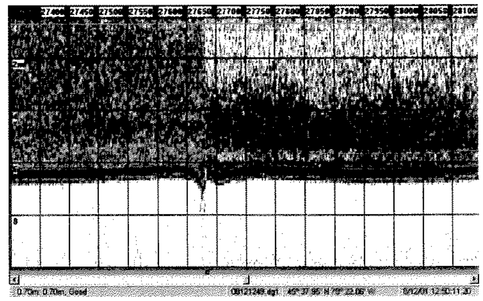
12

....
J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax



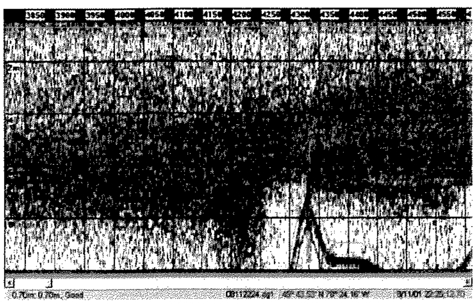
These various trophic measurements can be computed in an explicit spatial manner. Chlorophyll (Slide 3) and light penetration can be scaled to primary production (top right). Temperature (top left) and zooplankton biomass (Slide 4) are used to compute zooplankton production, which can be scaled to consumption (bottom left) assuming growth efficiency is roughly constant. Zooplankton consumption of primary production constitute one of the principal pathways of energy transfer near the base of the food web, and this transfer is spatially explicit in these images for the central basin of Lake Erie, September, 1994.

13



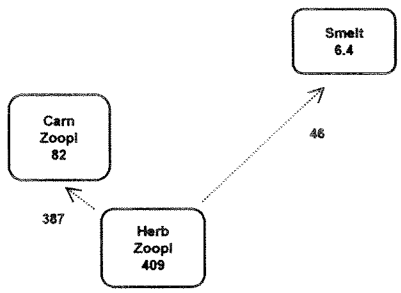
To profile the whole water column, the OPC has to be undulated from surface to depth thus leaving large areas of unsampled water. High frequency acoustics (710 kHz) provides a complementary technology that continuously profiles the water column from near surface to a depth of about 14 m. This acoustic image shows high night time zooplankton biomass (red colours to the left) just off the Harkness Lab site in Lake Opeongo on August 12, 2001 and much lower biomass at the same location during mid day.

14



Although it is more difficult to extract organism size and numerical density from the acoustic signal than the OPC, acoustic data provide more complete information on spatial patterns in biomass. In this image a sill in the south arm of Lake Opeongo (sharp brown bottom feature) clearly affects zooplankton distribution. Such bottom features may create local habitats of high quality for fish species or developmental stages dependent on zooplankton.

15



Combining the spatial biomass data for various trophic groups in the foodweb with temperature- or light-determined rates provides a spatially explicit summary of energy flow. Here for the east basin of Lake Erie the seasonal production (kt yr^{-1} within boxes) of smelt, herbivorous zooplankton, and carnivorous zooplankton are shown. Values on the arrows indicate consumption. Clearly carnivorous zooplankton strongly compete with smelt for the available herbivorous zooplankton production – in fact they consume most of it.

16

J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

"Developing a sonar method of estimating lake trout abundance"

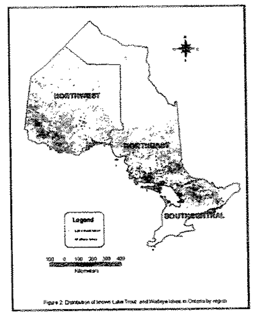
Nigel Lester, Trevor Middel

Developing a sonar method of estimating lake trout abundance

Nigel Lester
Trevor Middel

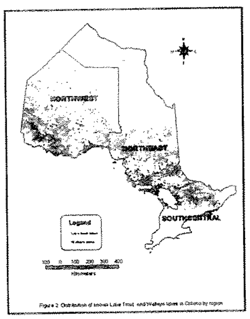
Emerging Technologies Workshop
Harkness Lab
Sept 17, 2001

The Resource



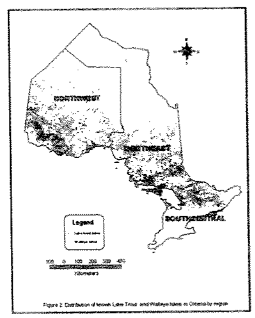
- Many lakes & species
  - > 2000 lake trout lakes
  - > 3000 walleye lakes
  - also pike, bass, perch, ...
- Large economic value

The Problem



- Lakes subject to stress
  - exploitation
  - habitat degradation
  - species introductions
- Don't know what's happening
  - Monitoring is expensive
  - Sampling is biased

The Solution



- Unbiased sampling
- Periodic reporting
- Adaptive management approach
- Operate at appropriate scale

Development of a program

- Design for selecting lakes
- Indicators and criteria for evaluating health
- Efficient sampling methods

Minimum sampling program

- Lake bathymetry (done for 10,000 lakes)
- Water quality
- Fish abundance
- Angling stress

"Developing a sonar method of estimating lake trout abundance"

Nigel Lester, Trevor Middel

Estimating fish abundance

- Need estimates for "valued" fish species
  - Lake trout, walleye, bass, pike
- Traditional methods
  - mark-recapture
  - index netting
- Can sonar be used?
  - Start simple - lake trout
  - What information needed to estimate adult lake trout abundance from sonar survey?
  - What is optimal design?
  - Other benefits (non-invasive, size spectrum)

Model-based approach

- Minimum size of adult lake trout (35-50 cm)
- Identify confusing targets (other species of similar size)
- Spatial distribution of lake trout and confusing targets
- Can we define rules to interpret sonar data?

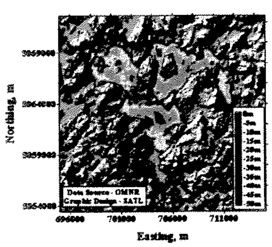
Methods

- Study "known" populations of lake trout
  - Opeongo, Smoke, Louisa, Drag, Whitepine, Squeers, ...
- Develop spatial distribution models of species
  - depth/time stratified index netting
  - telemetry
- Conduct acoustic surveys
  - Calibrate target strengths
  - Apply spatial models to estimate lake trout abundance
- Compare estimates with known abundance

Lake selection

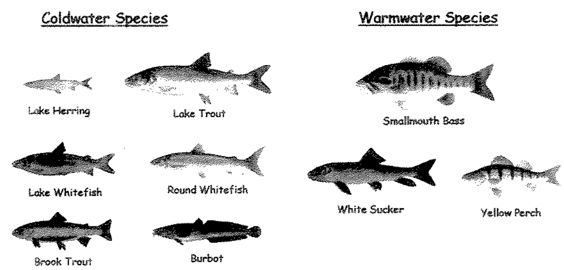
- Variation in
  - lake size
  - lake trout density
  - lake trout forage base
  - confusing targets (other species)
- Collaboration needs
  - mark-recapture
  - index netting
  - telemetry studies
  - sonar surveys

Lake Opeongo



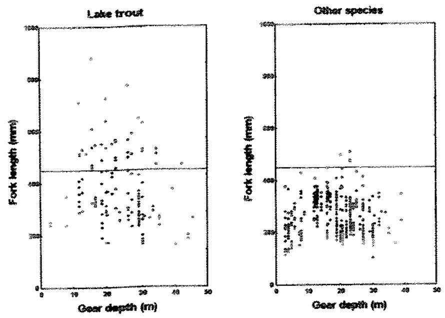
- Area = 5860 ha
- mark-recap studies (1994-1996)
- 7600 lake trout (> 450 mm)
- 1.3 fish/ha

Fish Community of Lake Opeongo

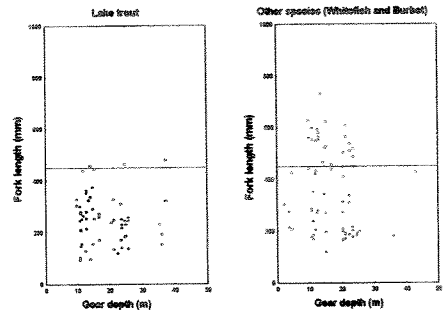


J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

Daytime Netting (summer) - Lake Opeongo



Overnight Netting (summer) - Lake Opeongo



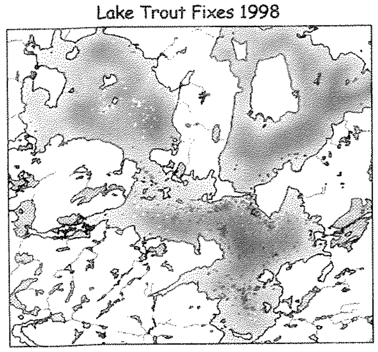
Tentative Spatial Model (Opeongo)

- Adult > 450 mm
- below thermocline
- daytime activity

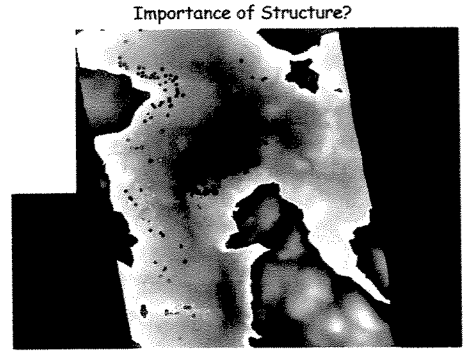
Lake Trout Telemetry

- Telemetry of lake trout conducted 1998-2000
- 8-10 lake trout tracked per year
- Temperature and depth sensing acoustic tags
- provide information on where lake trout "hang out"

Lake Trout Fixes 1998

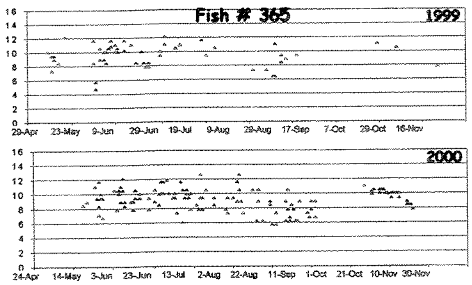


Importance of Structure?

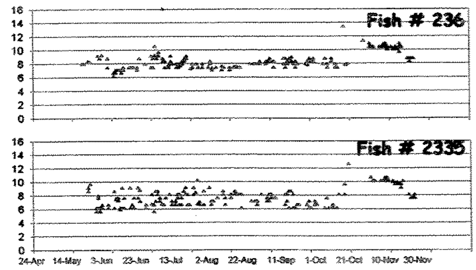


J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

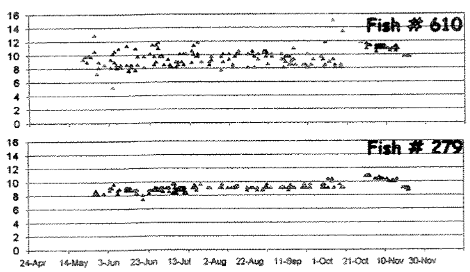
Temperature Sensor Data



Temperature Sensor Data



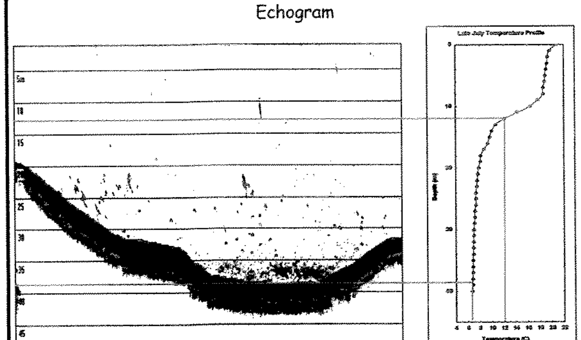
Temperature Sensor Data



Refinement of Spatial Model

- Orientation to structure and possibly specific substrate types
- Temperatures indicate fish are below thermocline as expected
- Netting suggest that in summer LT are suspended more than 2 m off bottom in Opeongo

Echogram



Target Strength

- Target strength (TS) is a measure of reflected sound energy
- Target strength is proportional to fish size
- Target strength varies with tilt, roll and depth of fish
- What is the maximum target strength of a 450 mm or larger lake trout?
- What is the variation in target strength of a 450 mm or larger lake trout

J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

"Developing a sonar method of estimating lake trout abundance"

Nigel Lester, Trevor Middel

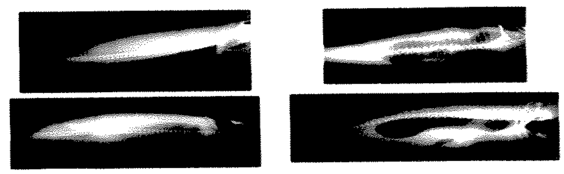
Calibration Proposal

- Develop target strength - fish size relationships for key species of coldwater fish and discover variation in TS due to factors such as aspect and roll and depth
- Combine this knowledge with spatial model and attempt to estimate lake trout abundance in lakes for which population estimates are available

Development of Theoretical TS Models

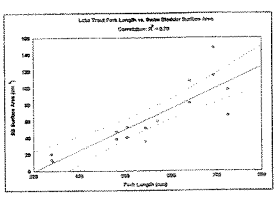
- Obtain dorsal and lateral radiographs for key species of fish in order to measure swim bladder volume and surface area

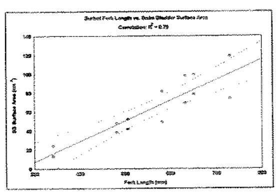
Lake Trout | Burbot



Theoretical Target Strength

- Develop swim-bladder - fish size relationships for key species



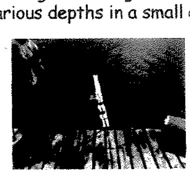


Theoretical Target Strength

- Following work of Horne and Clay (1994), develop theoretical TS - fish length relationships for key coldwater fish species

In Situ Target Strength Measurements

- Record target strengths of single fish of a known size "free swimming" in an enclosure
- Record target strengths of single fish of a known size suspended at various depths in a small enclosure



Comparison of Theoretical TS vs. Observed TS

- Examine relationship between predicted and observed maximum TS for key species
- Examine variability in TS observed from "free swimming" fish in enclosures

J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

Application of Spatial Model and TS Calibration

- Collection of sonar data through LLT project following multi lake design
- Estimation of lake trout densities from sonar surveys in lakes with population estimates available

Summary

- Need more cost-effective methods of assessing abundance
- Model-based approach
  - spatial ecology of lake trout and confusing targets
  - multi-lake design - spatial rules may vary
  - calibration of sonar data (target strength vs fish size)

Applications for physiological telemetry

Wendy McFarlane
Scott McKinley

The University of British Columbia
WBI
University of Waterloo

Overview

- Introduction to biotelemetry
- Physiological telemetry
- Evaluating animal welfare
- Developing intelligent systems

Biotelemetry

- the remote detection and measurement of a human or animal function, activity, or condition

Remote sensing

- Addresses problems associated with obtaining direct measures of activity from animals living in an aquatic environment
- View environmental change "from the perspective of the fish"

Physiological transmitters

- Wireless communication devices that enable remote monitoring of in freely swimming fish
- Biosensors

Value of physiological transmitters

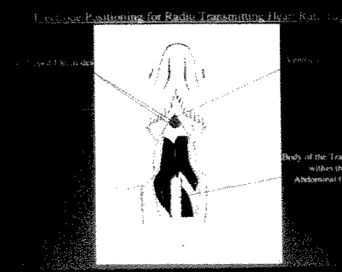
- tools for assessing fish response to environmental change
- monitor freely swimming fish in *real time*

J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

Physiological parameters

- Animal welfare correlates
  - heart rate
  - tailbeat/ventilation frequency
  - locomotory activity
- Increases in these parameters are energetically costly

Heart rate



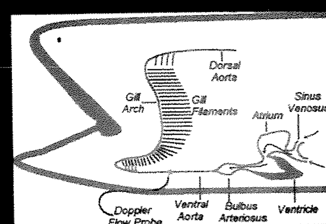
- Limited indicator of metabolic rate

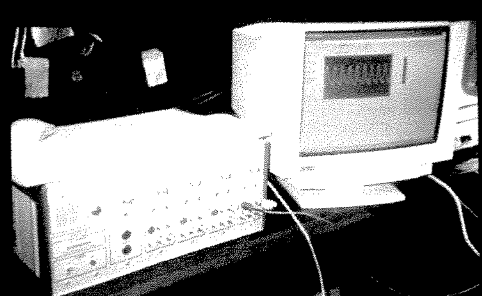
Limitations of heart rate telemetry

- Numerous cardiovascular adjustments contribute to metabolic rate
- VO_2 = CO x (a-v)O_2 difference
- CO = HR x SV

Cardiac output

- hard-wired, Doppler flow technique

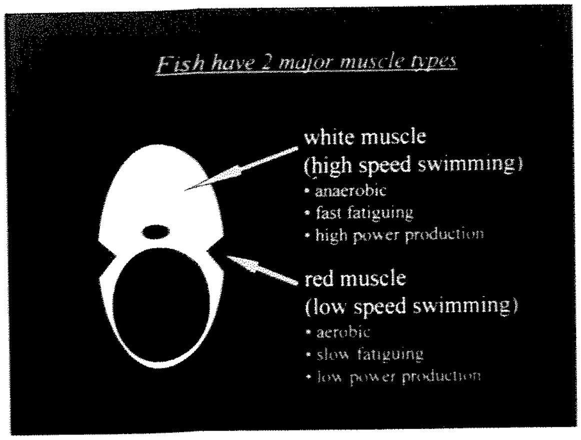


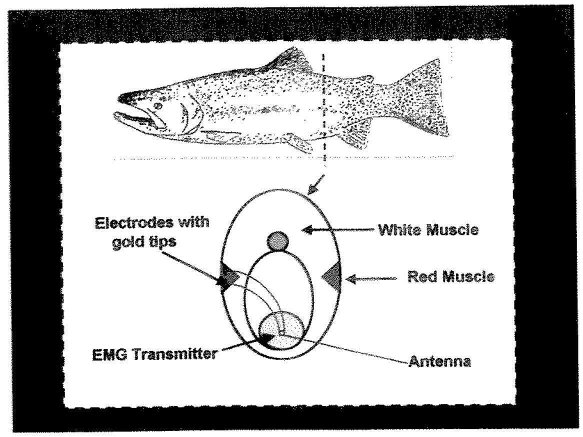


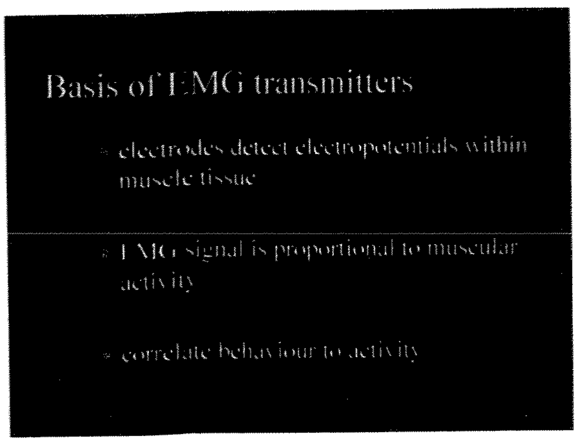
Locomotory activity

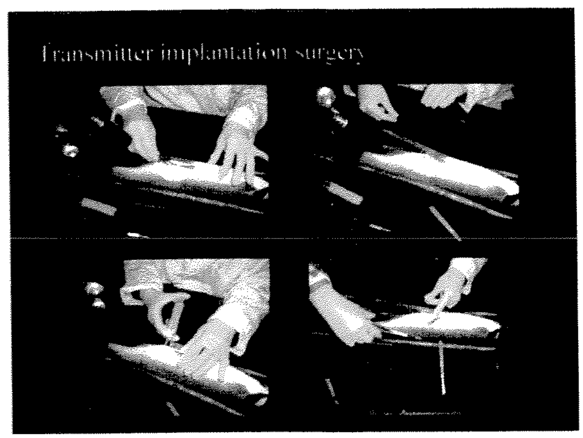
- integrated electromyogram transmitter (EMGi)
- internal (abdominal)
- electrodes implanted into aerobic swimming muscle
- remotely monitor axial muscle contraction

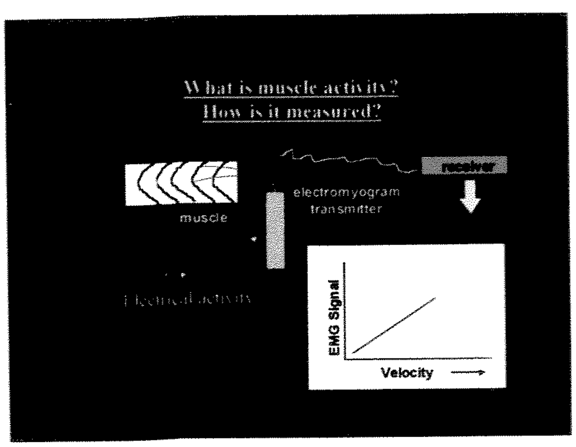
J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

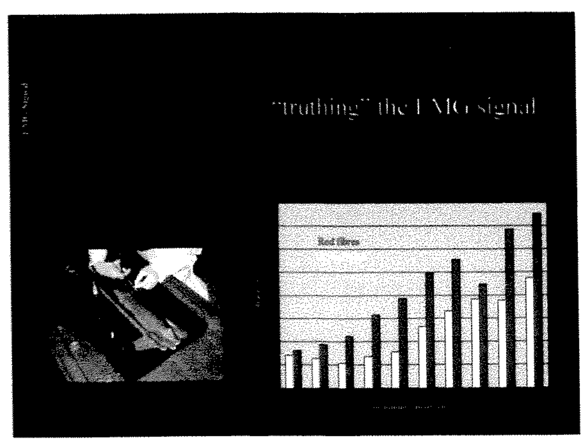




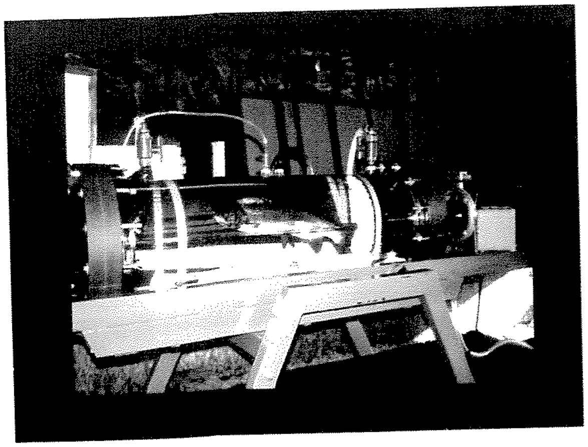


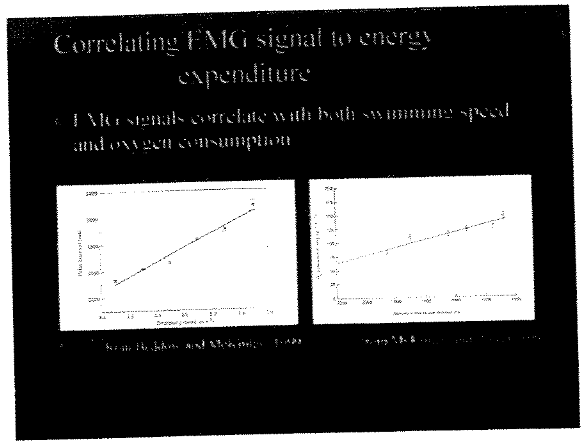


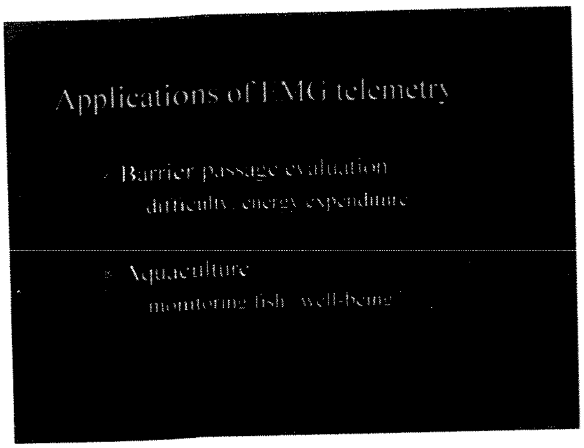


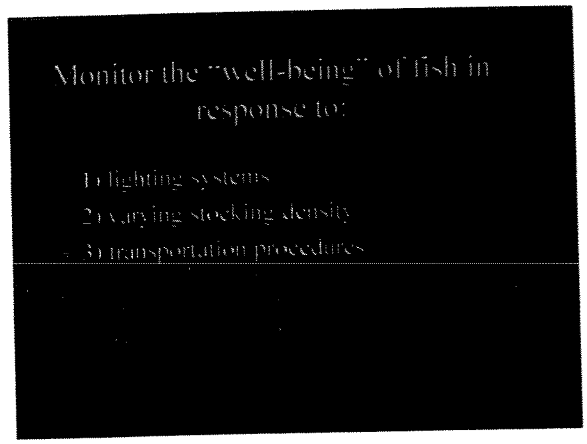


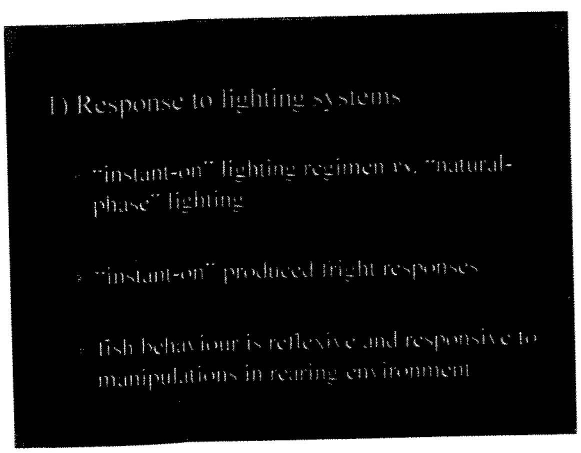
J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

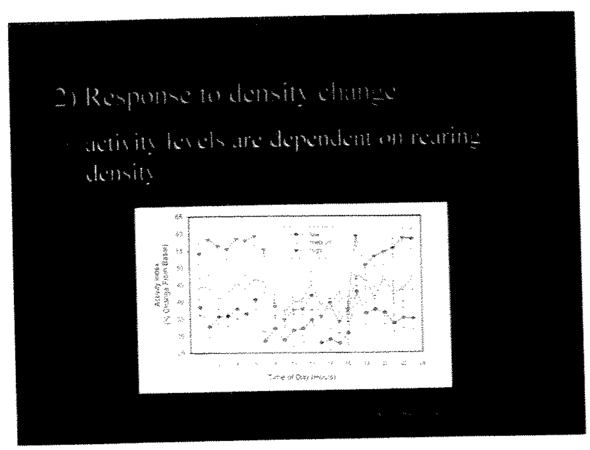




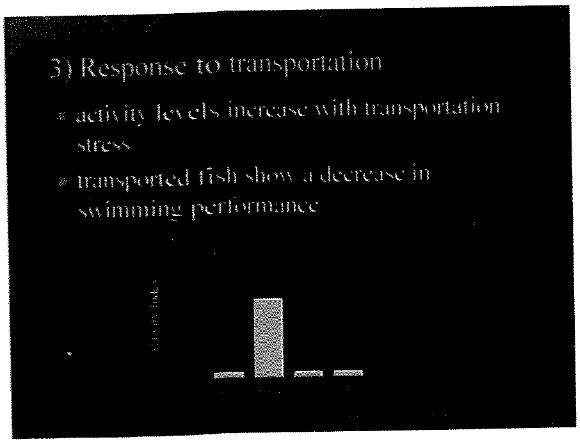


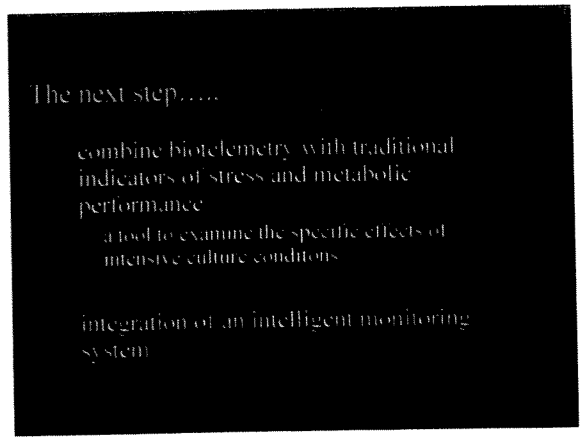






J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax





J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

DNA Microarray: Applications to Aquatic Research

Emerging Technologies Workshop
Harkness Research Laboratory
Sept 18, 2001

Thomas D. Singer

University of Waterloo DNA Microarray Laboratory
Department of Biology
Waterloo Biotelemetry Institute

OUTLINE

- What is DNA Microarray?
- How does it work?
- Applications of DNA Microarray to Aquatic research
- Web based resources

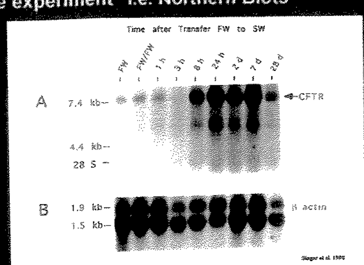
What is DNA Microarray?

- New enabling technology that represents a rapidly growing field
- Invented by Dr. Patrick Brown, Stanford University in 1995
- It allows the monitoring of the expression of thousands of genes simultaneously (gene expression profiles)

Why study gene expression ?

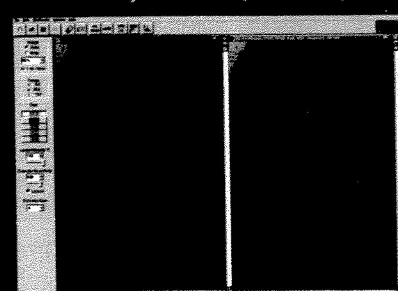
- Pattern of gene expression in a cell is characteristic of its current state
- Virtually all differences in cell state or type are correlated with changes in the mRNA levels of many genes
- Changes in gene expression are critical in the regulation of normal growth, development, disease resistance and stress response
- DNA Microarray allows monitoring of the expression of many genes simultaneously and identification of key genes based upon expression level

Traditional approaches have examined "one gene in one experiment" i.e. Northern Blots



Gill *kfCFTR* expression is upregulated during abrupt seawater transfer

DNA Microarray: Gene expression profile



Monitor many genes simultaneously in single experiment

DNA Microarray Applications

1. Large-scale gene discovery : identification of complex genetic diseases
2. Drug discovery and toxicology studies
3. Screening of disease-specific genes
4. Mutation/Polymorphism detection (SNPs)
5. Pathogen analysis

Main use in human and medical research.

How does it work? DNA Microarray : Basic Principal

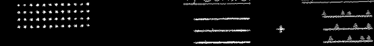
- Base-pairing or hybridization is underlying principal
  - i.e. A-T and G-C
- DNA Microarray requires 2 essential elements

1 complementary to genes of interest arranged on solid surface in defined position

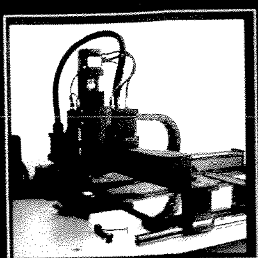
2 from samples eluted over the surface - complimentary DNA binds and is detected by fluorescent label

1. Array with Target DNA
2. Labeled probe DNA

1) Control + 2) Treatment



DNA Microarray : Equipment



DNA Chip•Writer

DNA Chip•Reader

How does DNA Microarray work ?

- Example 1
  - Gene Discovery experiment Gene expression profiles
- Example 2
  - Mutational analysis experiment Genotyping

DNA Microarray experiment

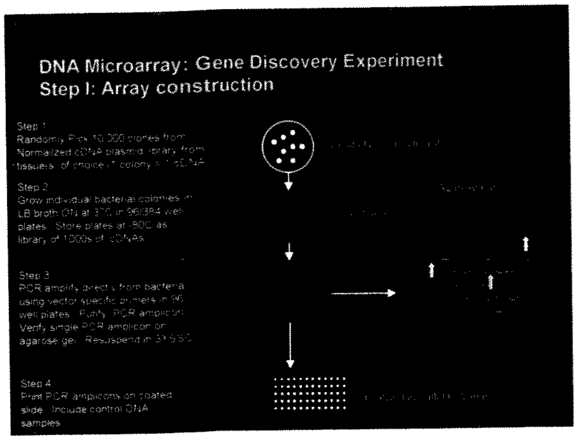
- Example 1
  - Gene Discovery experiment Gene expression profiles

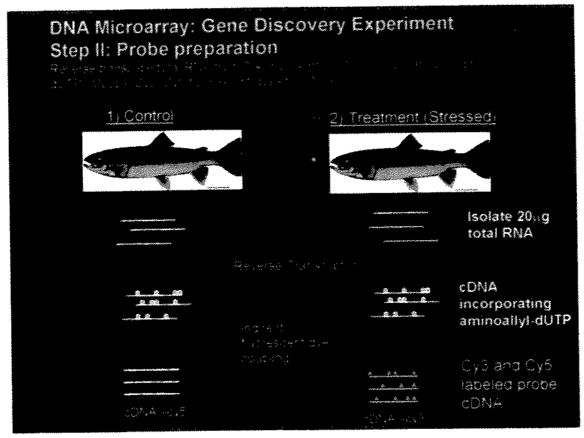
Experimental outline: Identify genes responsive to stressors in fish in order to develop a molecular probe for stress detection in aquaculture

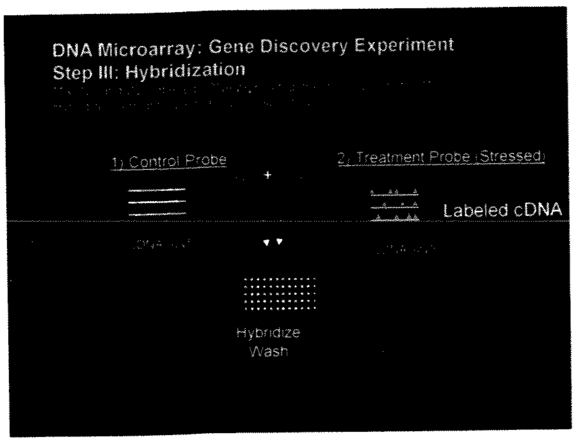
DNA Microarray: Gene Discovery Experiment
Step I: Array construction

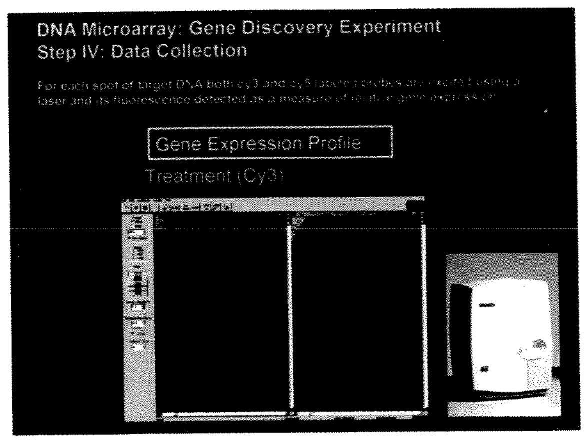
- Require individual cloned genes from organism of interest spotted on a glass microscope slide
  - (biochip, DNA chip, DNA Microarray, gene array, GeneChip)
- For several organisms these are available commercially (i.e. human, mouse, yeast, bacteria
- For most aquatic species must custom amplify and spot clones (this is costly approx $5.00 gene

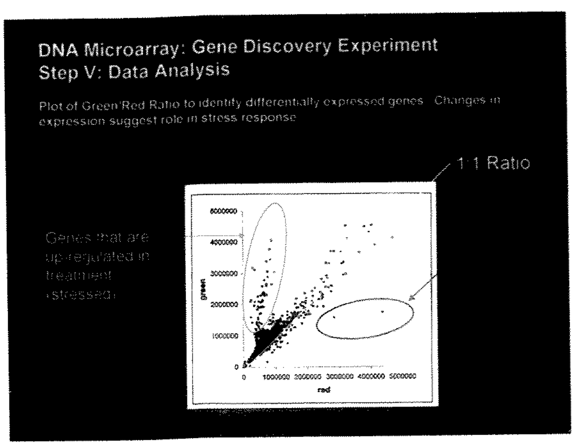
J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

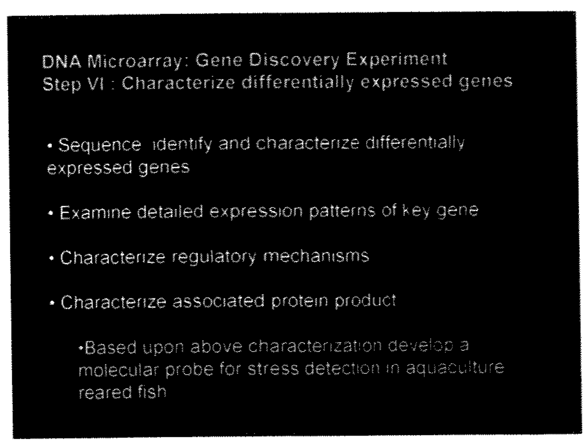




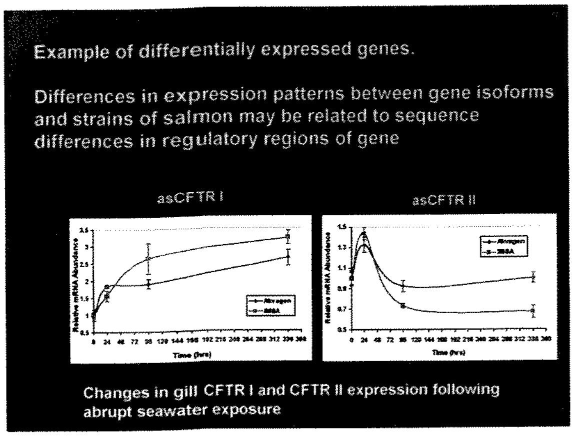


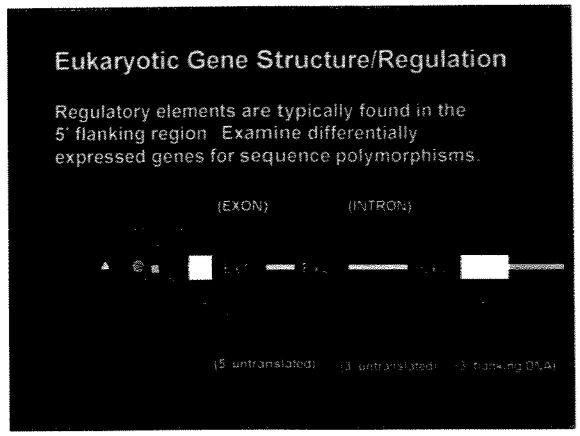


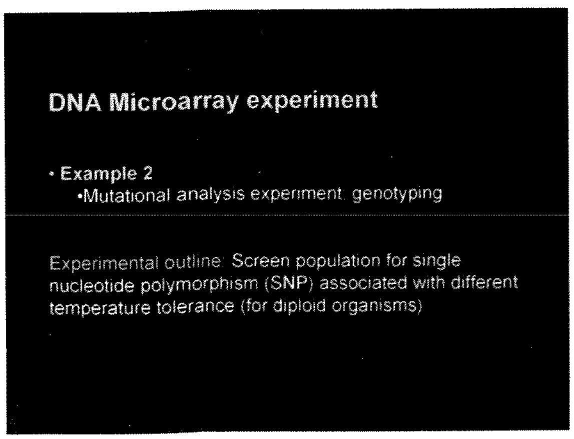


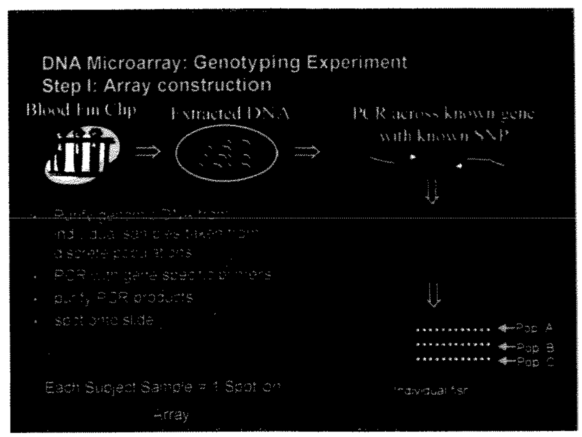


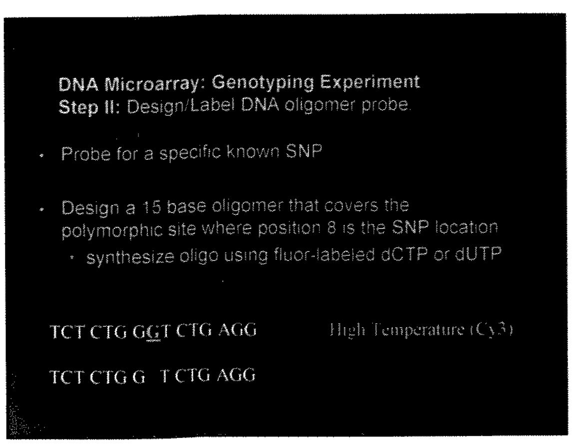
J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

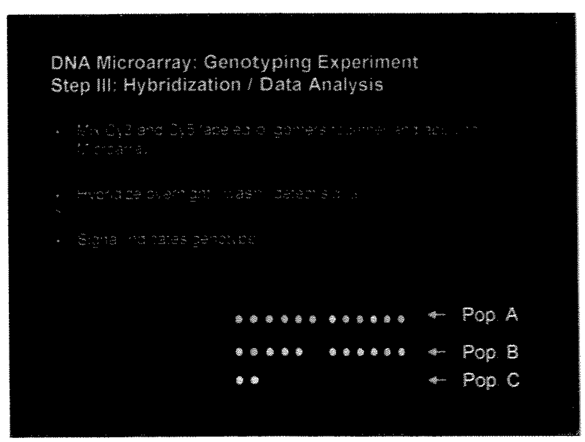




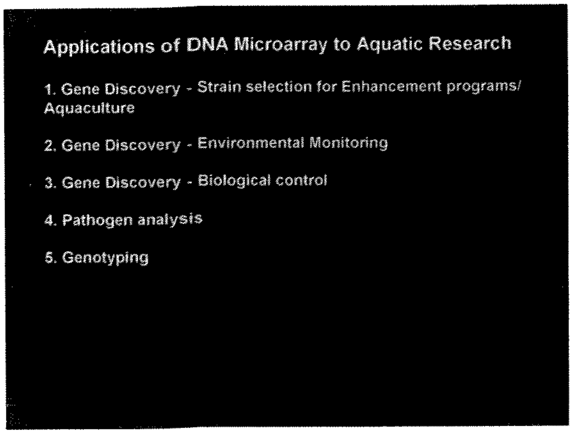


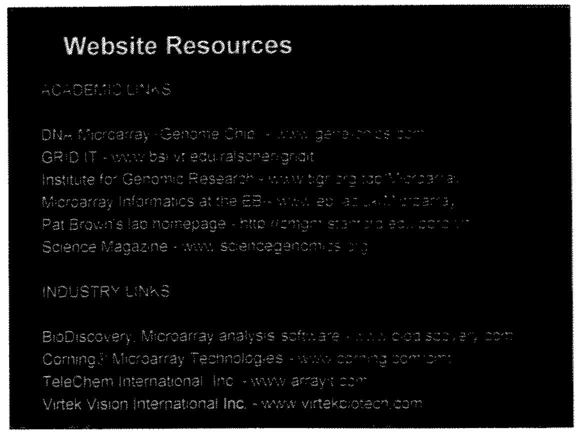




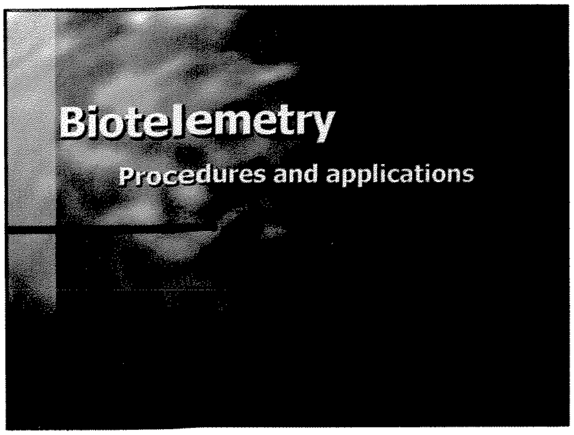


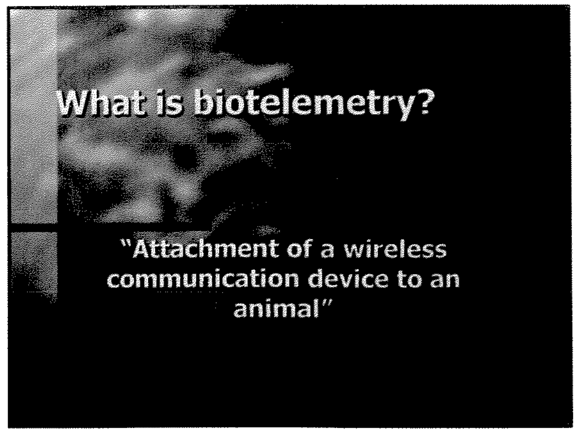
J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

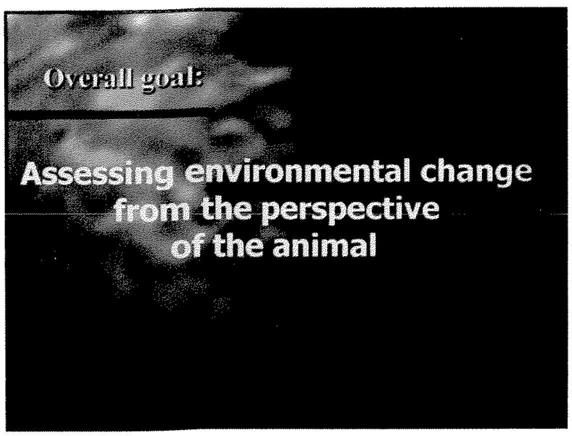


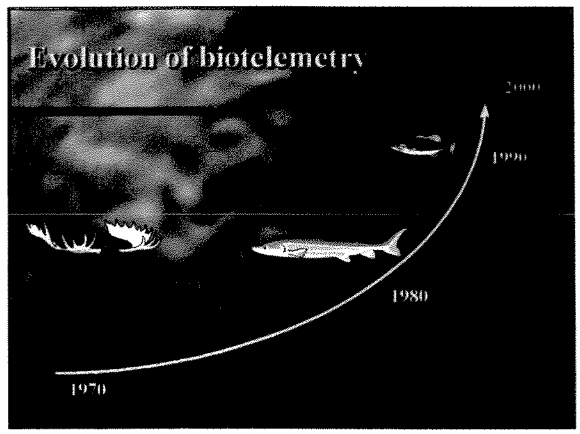


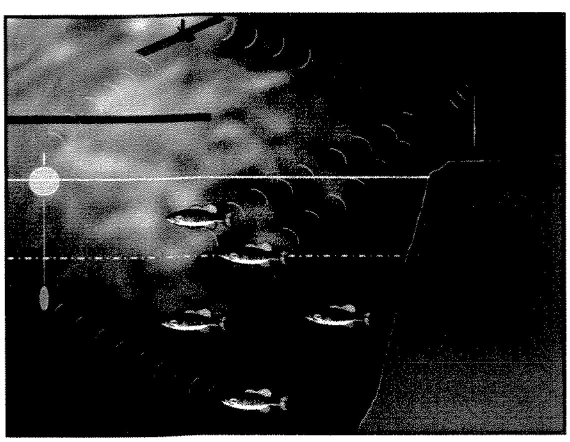
J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax











J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

Types of sensors

- water temperature
- conductivity
- water depth
- light intensity
- biosensor - emg (swimming musculature), heart rate

Types of attachment

- external
- internal
- gastric
- oviduct (salmonids, sturgeon)

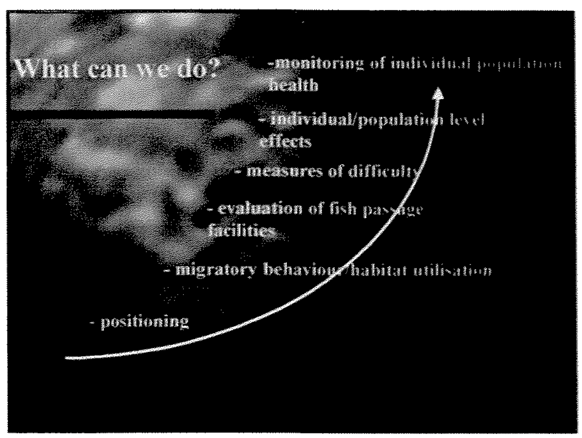
Tagging effects

Types of anaesthetics

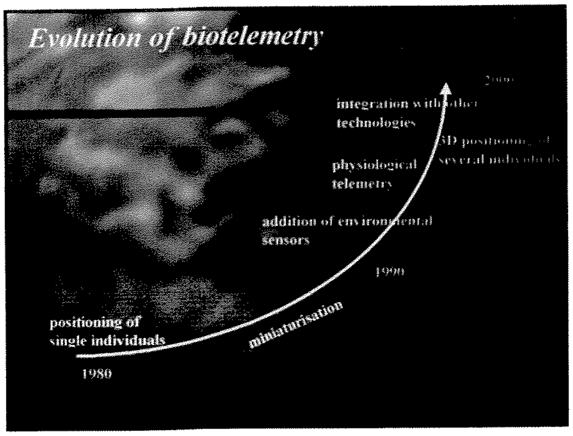
- MS-222
- benzocaine
- quinaldine
- clove oil
- carbon dioxide
- electroanaesthesia

Anesthetic Characteristics

- Induction time of less than 15 minutes
- Recovery time short, ie. Less than 5 minutes
- Non-toxic to fish -physiology
  -behaviour
- Ease of handling



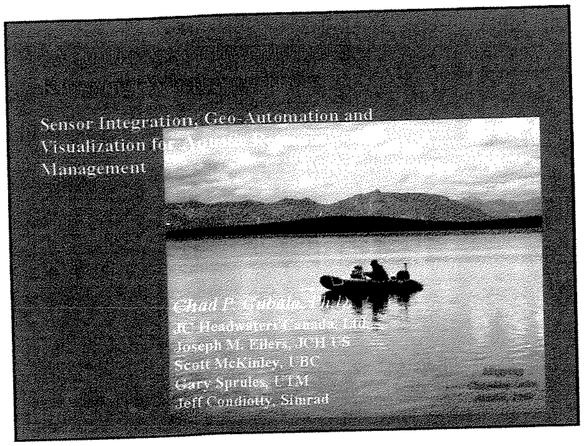
J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

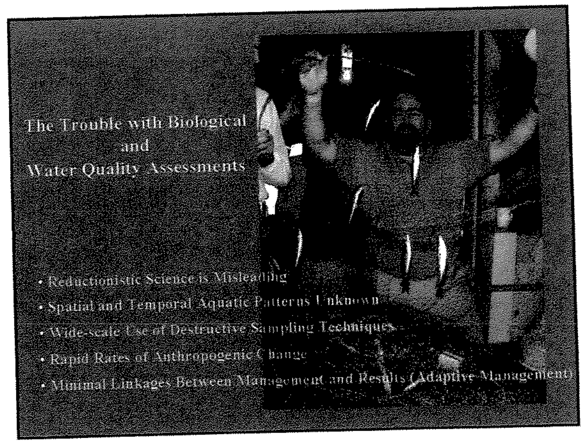


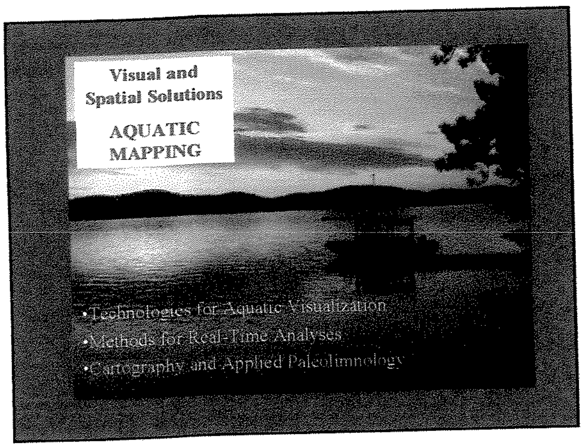
J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

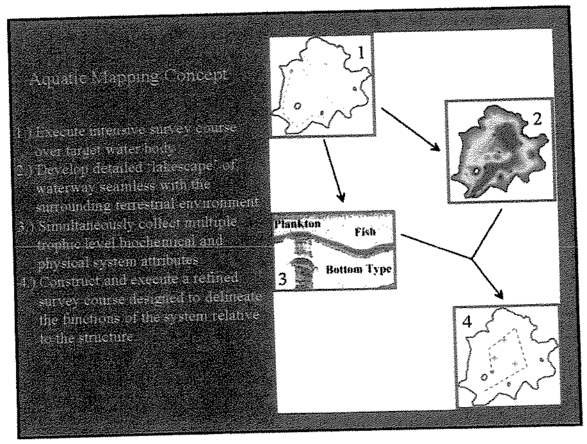
"Aquatic asset inventorying – knowing what you have"

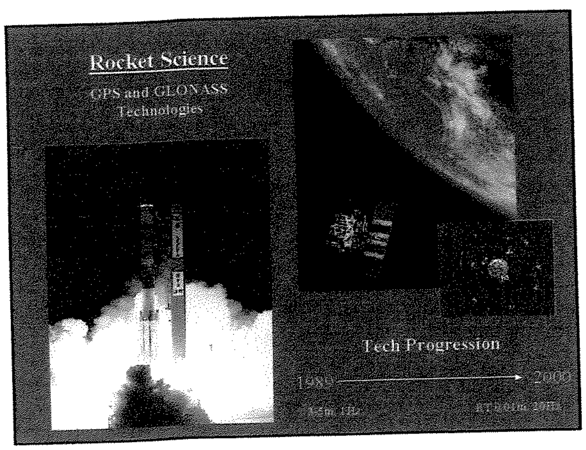
Chad P. Gubala

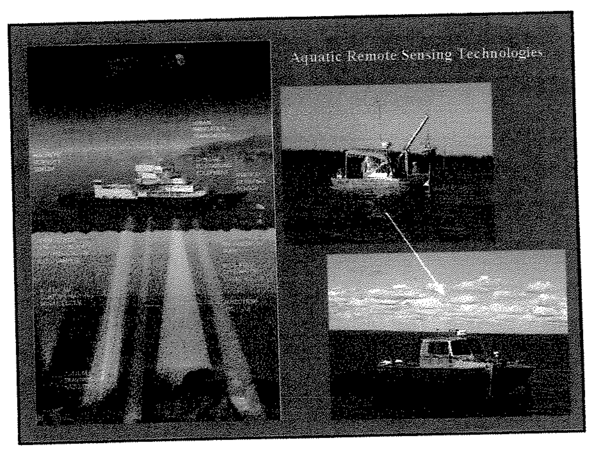






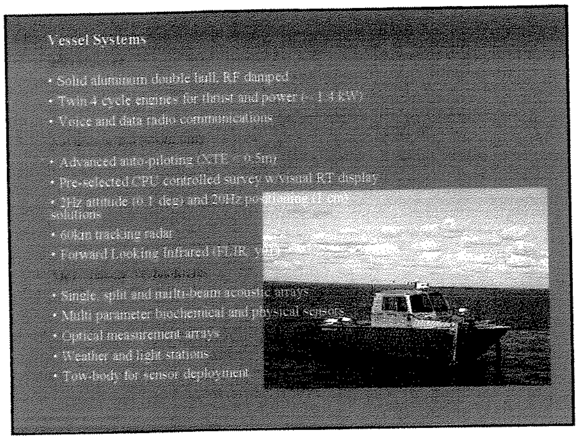


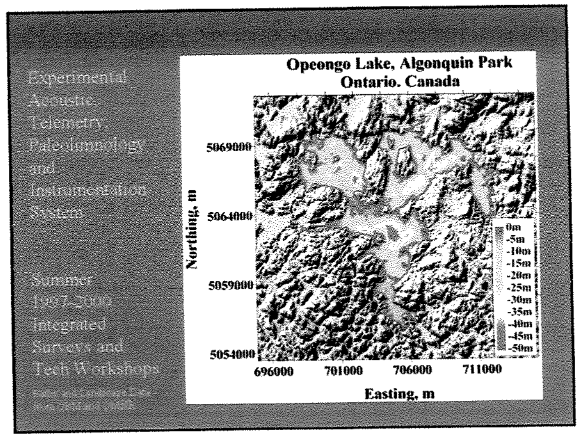


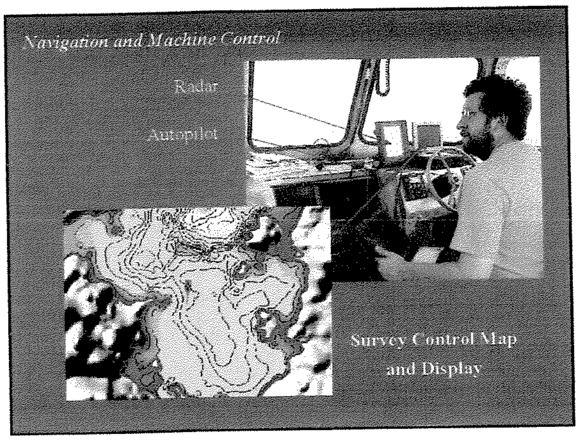


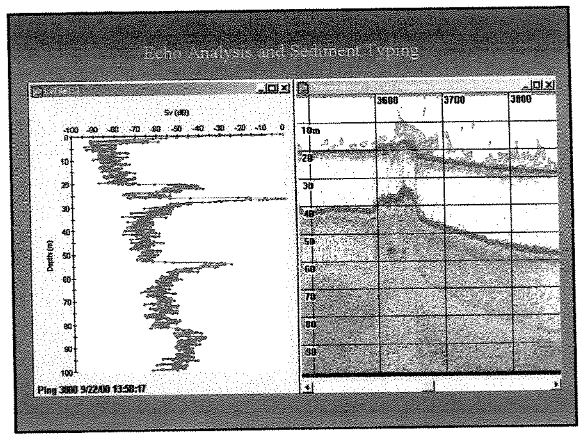
Emerging Technologies Workshop – GLFC – Sept 17-21, 2001

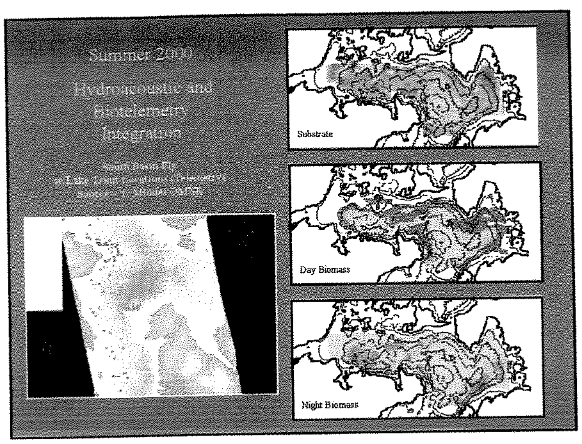
J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

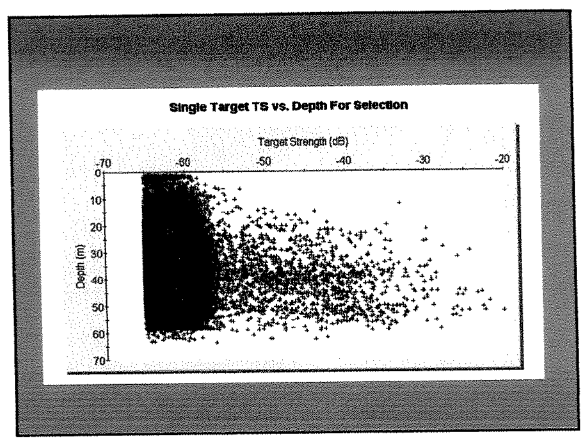




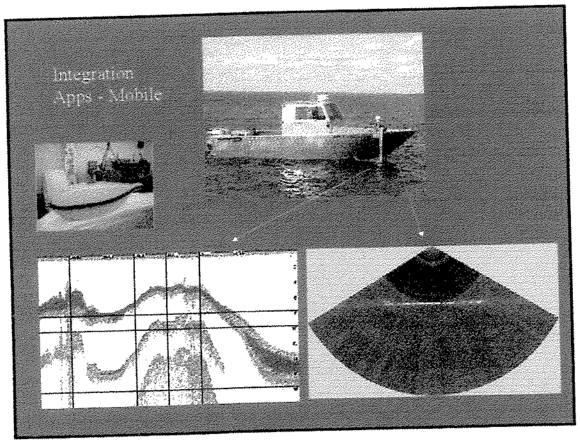


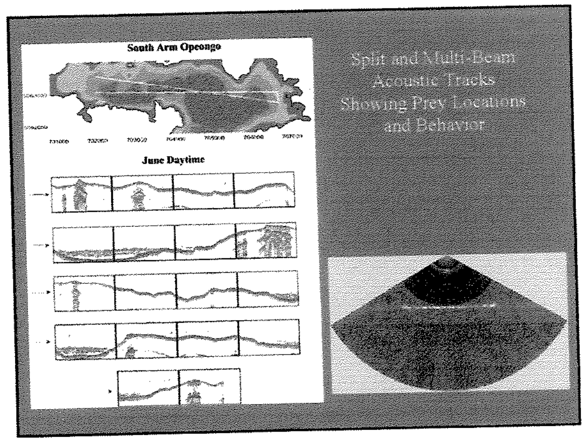


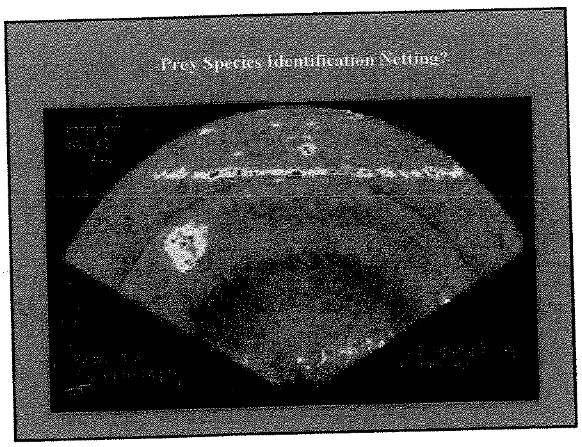


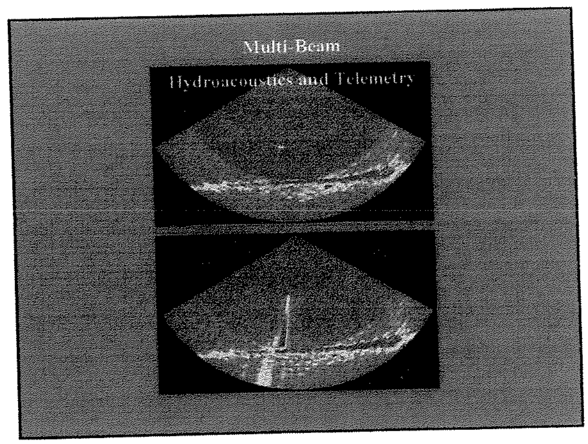


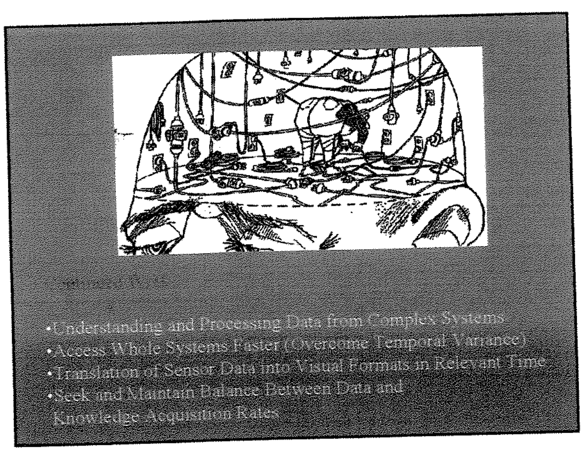
J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax



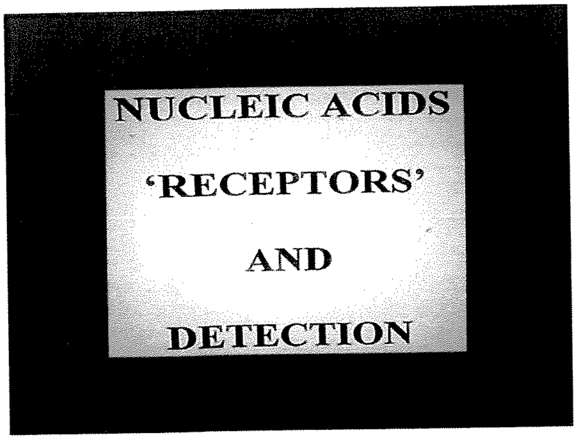


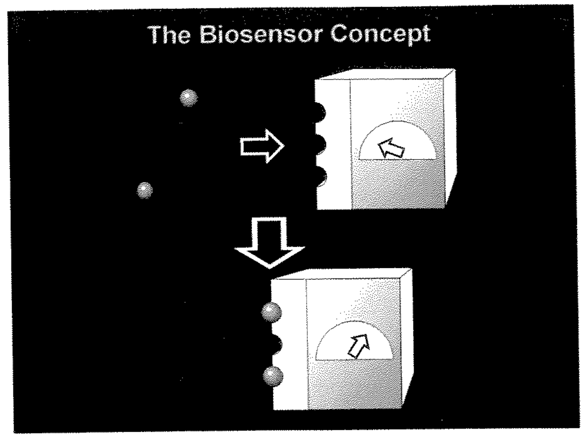


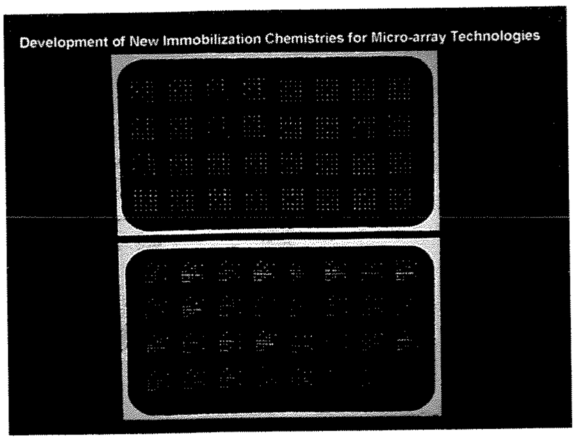


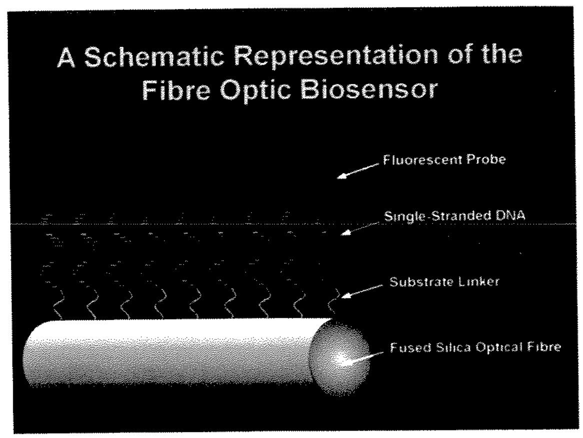


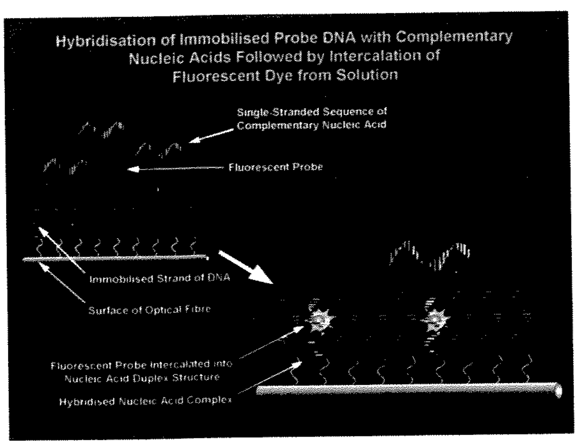
J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax

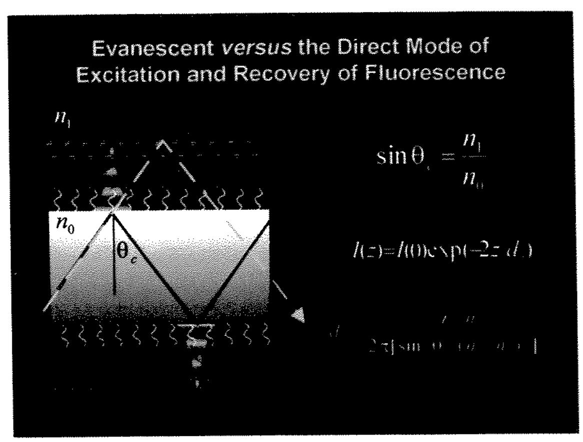




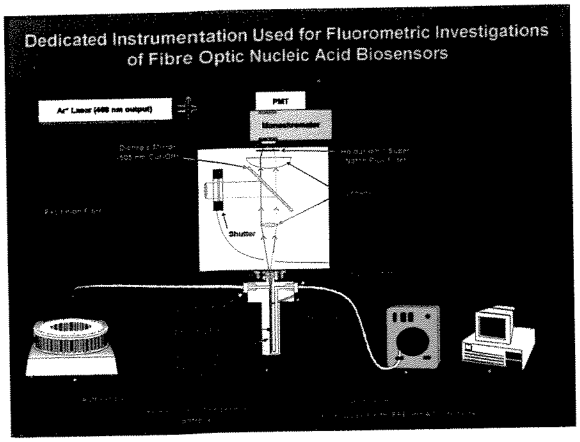


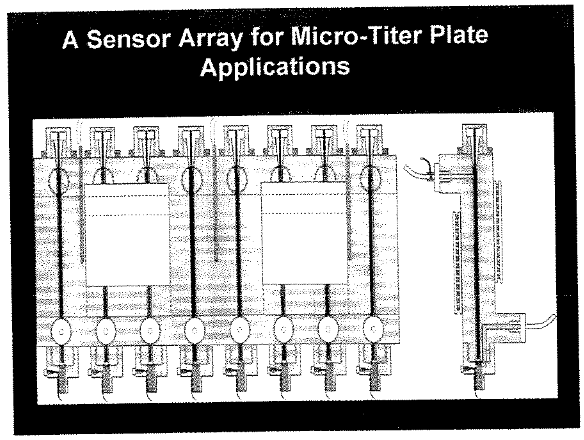


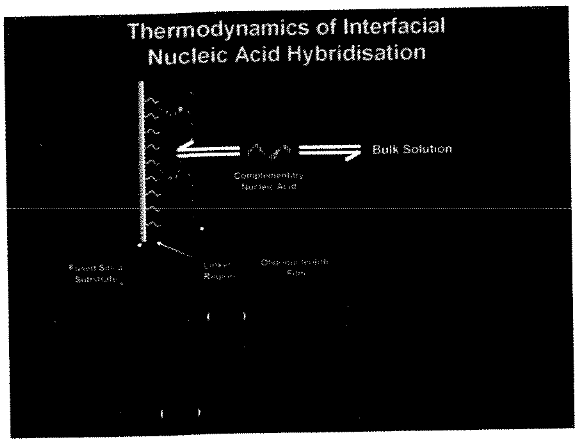


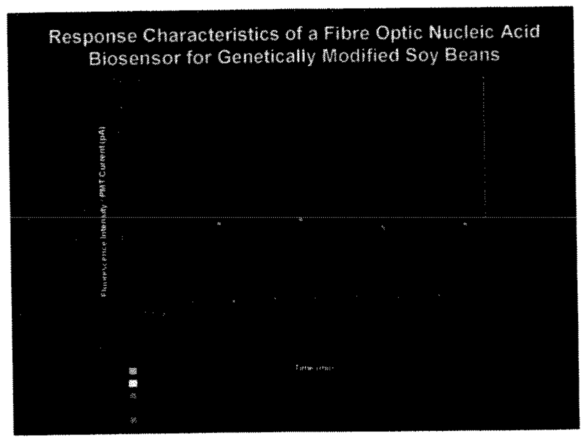


J.C. Headwaters Canada, Ltd.,
269 Lakeshore Road E. Oakville, Ontario L6J 1H9; 905-849-0210 voice; 905-849-0234 fax


Dedicated Instrumentation Used for Fluorometric Investigations of Fibre Optic Nucleic Acid Biosensors
PMT
Shutter


A Sensor Array for Micro-Titer Plate Applications


Thermodynamics of Interfacial Nucleic Acid Hybridisation
Bulk Solution


Response Characteristics of a Fibre Optic Nucleic Acid Biosensor for Genetically Modified Soy Beans