Genomics applied to conservation and management of aquatic resources: are the promises being filled?

Louis Bernatchez

Chaires de recherche du Canada | Canada Research Chairs

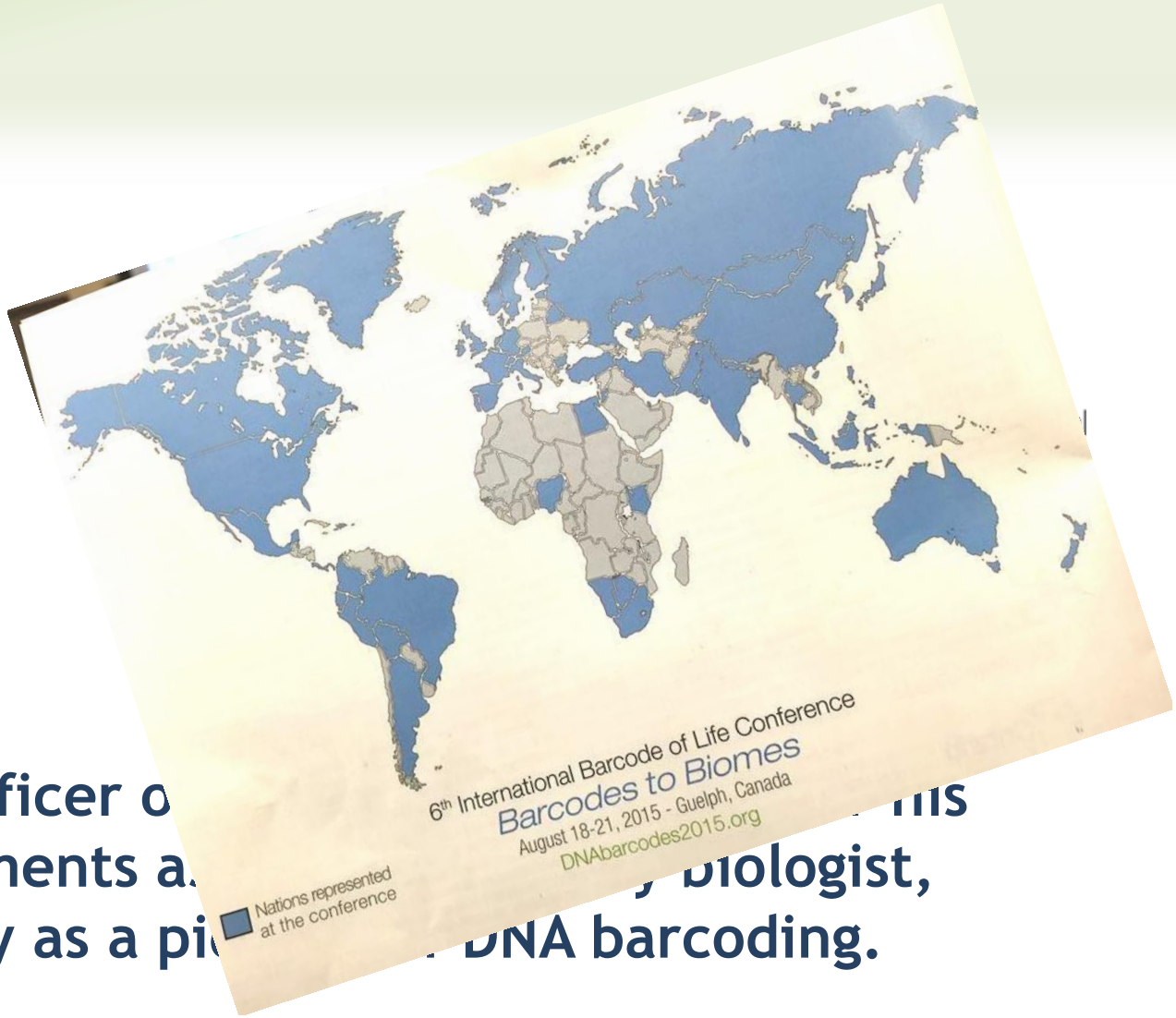
Génomique et Conservation des Ressources Aquatiques

UNIVERSITÉ LAVAL

INSTITUT DE BIOLOGIE INTÉGRATIVE ET DES SYSTÈMES IBIS

Ressources Aquatiques Québec RAQ

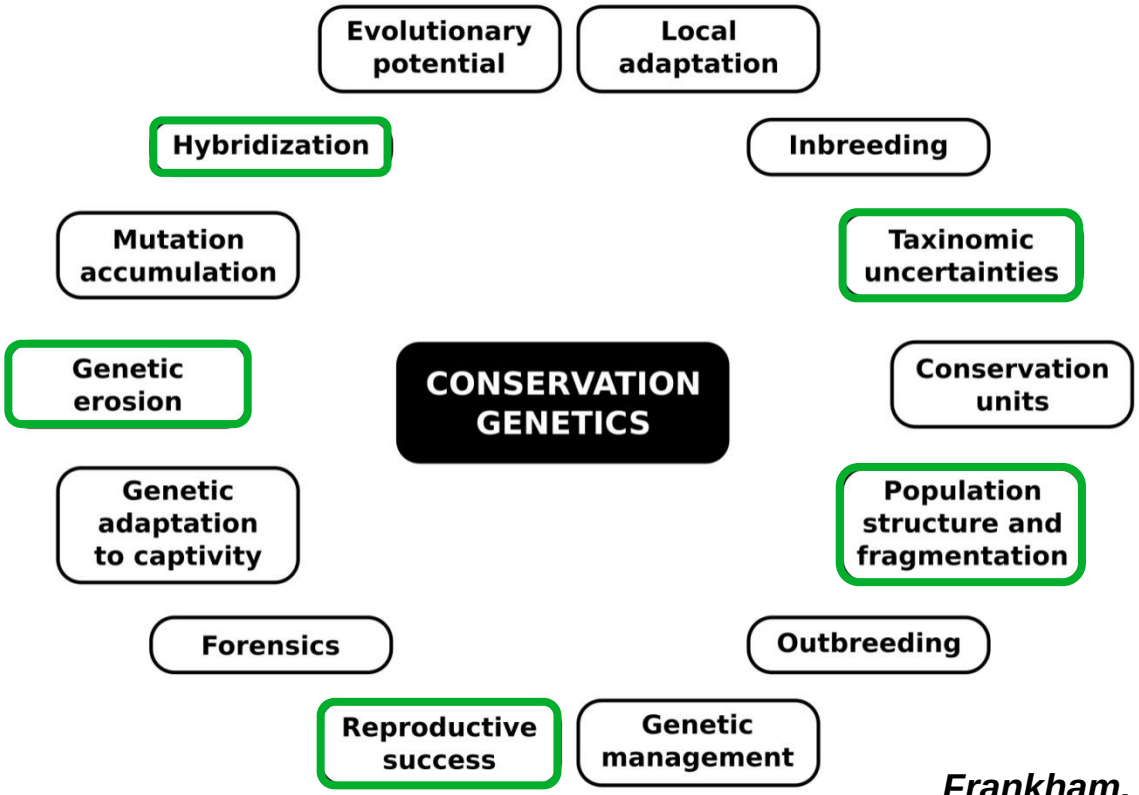
Congratulations & Thank you Paul !



Named Officer o… …his achievements a… …y biologist, notably as a pi… …DNA barcoding.

Two fundamental roles of molecular data in conservation genetics

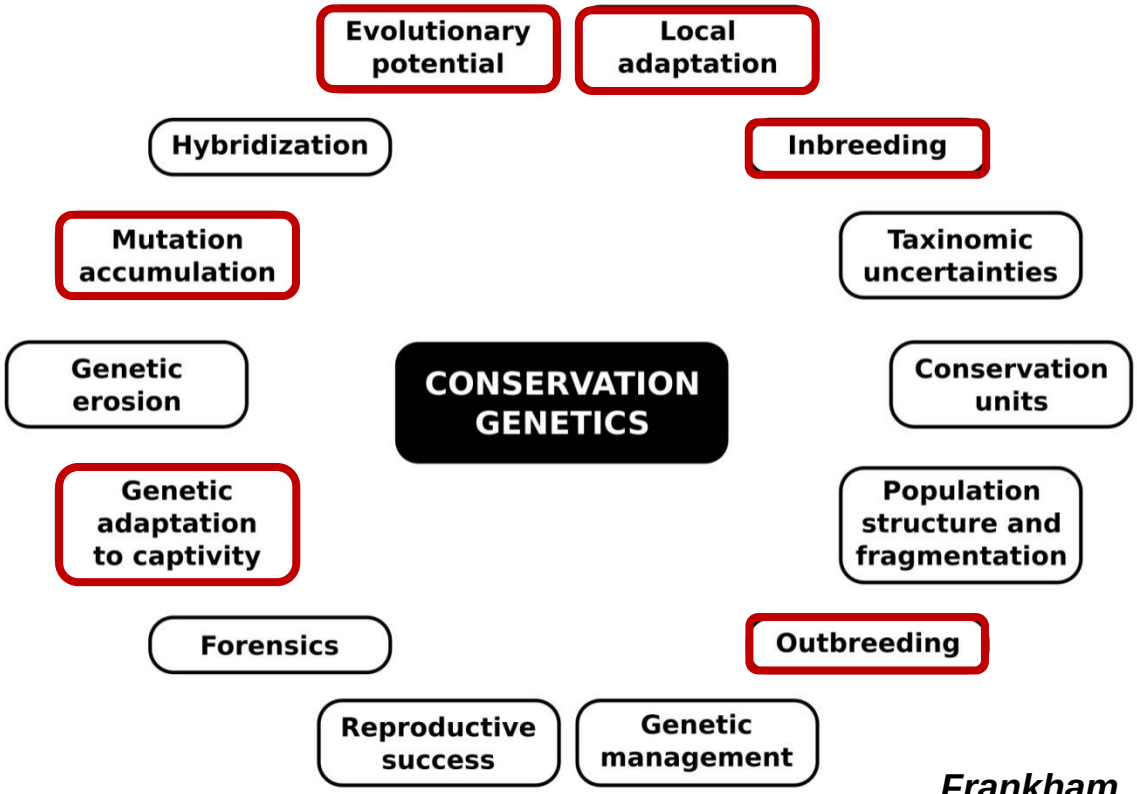
Inventorial : Documenting patterns



Frankham, Ballou & Briscoe 2010

Two fundamental roles of molecular data in conservation genetics

Mechanistic : Deciphering processes



Frankham, Ballou & Briscoe 2010

The Promises of Genomics for Conservation Biology

I. Scaling up genome coverage for any non-model species:
Improve estimates of population genetic and evolutionary parameters.

II. Markers « that counts » (SNP) and integrative approach (all the « …omics »):
Elucidate the functional and adaptive significance of molecular variation.

Allendorf et al. Nat.Rev.Gen. 2010

The Promises of Genomics for Conservation Biology

III. Get to the « real stuff » for conservation genetics :

Finding causal relationships between genetic variation, phenotypes and the environment to predict future dynamics of selectively important variation and potential for adaptation to new conditions.

Questioning the role and use of genomics in conservation genetics

Opinion

CellPress

Genomics and the challenging translation into conservation practice

Aaron B.A. Shafer[1], Jochen B.W. Wolf[1], Paulo C. Alves[2], Linnea Bergström[1], Michael W. Bruford[3], Ioana Brännström[1], Guy Colling[4], Love Dalén[5], Luc De Meester[6],

However, the generation of genomic data and subsequent analyses and interpretations remain challenging and largely confined to academic research in ecology and evolution. This generates a gap between basic research and applicable solutions for conservation managers faced with multifaceted problems. Before the

Evolutionary Applications

Open Access

How and why should we implement genomics into conservation?

Barry J. McMahon,[1] Emma C. Teeling[2] and Jacob Höglund[3]

With the advent of genomics, an important question emerges: should genomic tools and whole genomes be used in conservation studies? Genomics offer lots of promises, and the conservation genetics community have been enthusiastic about its prospects for some time

Yet, there are very few concrete examples of where genomics have made a major impact.

Guidelines for Recognizing Designatable Units

Approved by COSEWIC in November 2014

http://www.cosewic.gc.ca/eng/sct2/sct2_5_e.cfm

COSEWIC
Committee on the Status of Endangered Wildlife in Canada

Discrete and evolutionarily significant populations:

Discreteness

A population may be considered discrete based o
… and/or neutral genetic markers (e.g.
DNA microsatellites, DNA rest
polymorphisms (RFLPs)

Genetic distinctiveness by itself is not sufficient for DU designation; nor is it necessary for DUs to demonstrate genetic differences. (!!!)

Signifi

Evidence … in genetic
characteri … reflect relatively deep
intraspecif … genetic divergence.

Such differences would typically be manifested as qualitative genetic differences at relatively slow-evolving markers (fixed differences in mtDNA or in alleles at multiple nuclear loci).

Genomics applied to conservation and management of aquatic resources: are the promises being filled?

Outline:

Illustrate from a recent case study how genomics can successfully be used to address questions of applied relevance for management and conservation .

(and as such, bridging the gap between basic research and applicable solutions for conservation managers).

Conceptual framework: How do species cope with occupying heterogeneous environments ?

Local adaptation :

Adaptive genetic structure matching the environment.

Alternative solutions to local adaptations :

Phenotypic plasticity :

Different phenotypes expressed by a same genotype in different environmental conditions.

Spatially varying selection :

Local selection acting on polymorphism maintained by balancing selection (reshuffled every generation)

Understanding how species cope with occupying heterogeneous environments is key for management and conservation

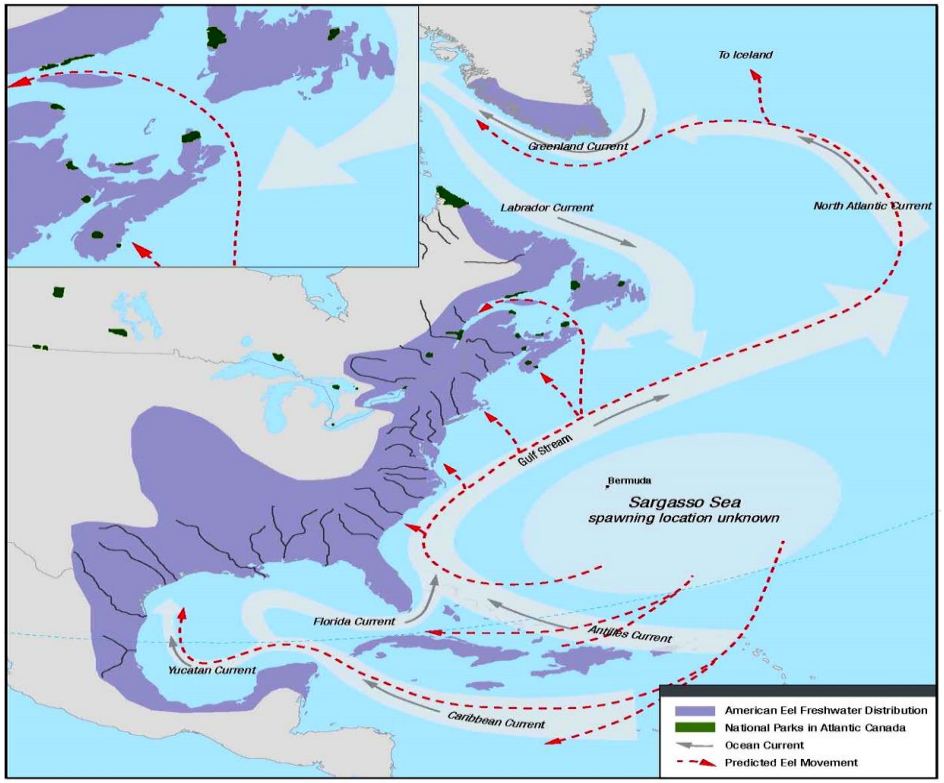
. For properly defining the number and geographic scales of management and-or evolutionary significant units.

. For predicting how species can respond to either natural or anthropogenic changes.

. For a better understanding of how to manage genetic diversity in conservation strategies (including translocation practices).

Population genomics and Conservation of the American Eel

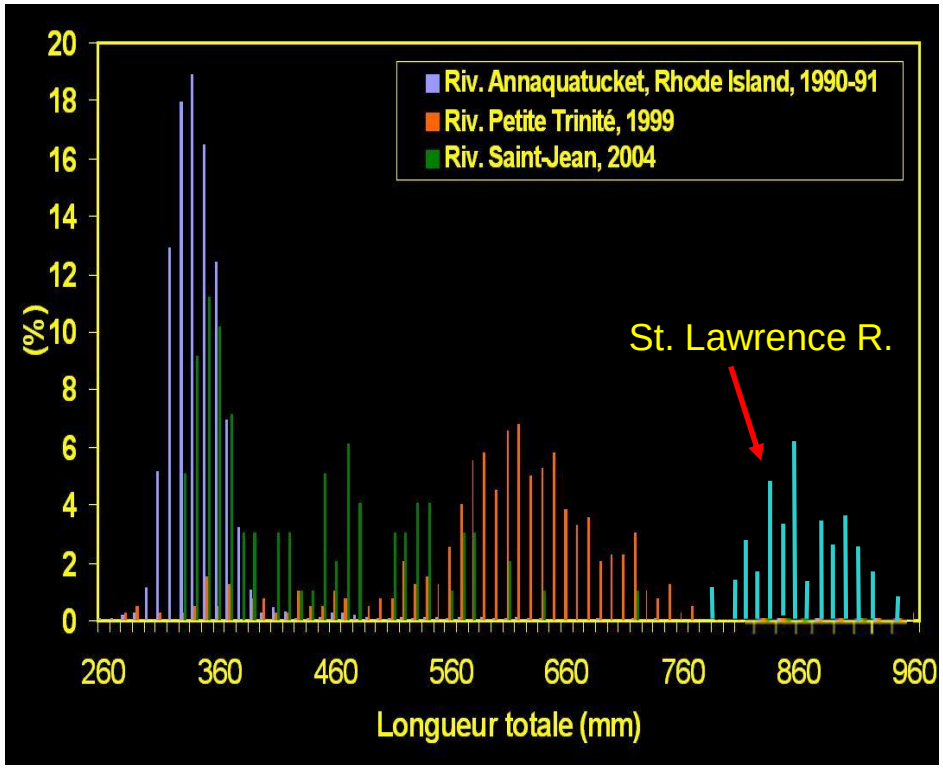
American eel distribution

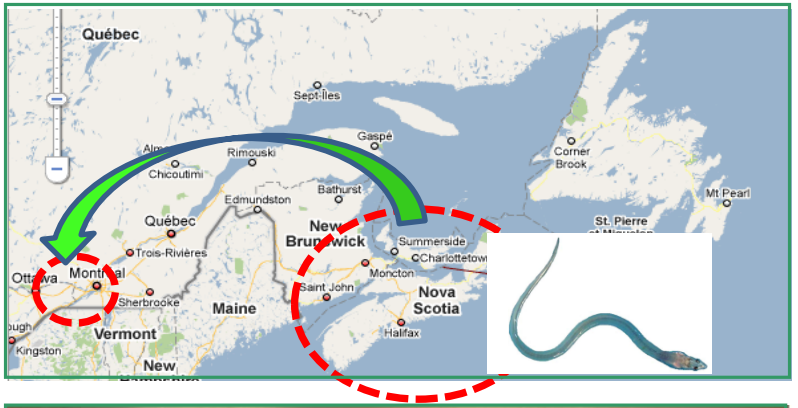


Population genomics and Conservation of the American Eel

. Pronounced regional differences in phenotypes:

Growth rate, mean adult size, sex-ratio





Population genomics and Conservation of the American Eel

Phenotypic & ecological variation in American eel:

. “Adaptive” population structure ?

. “Pure” phenotypic plasticity ?

. Genetic differences caused by spatially varying selection?

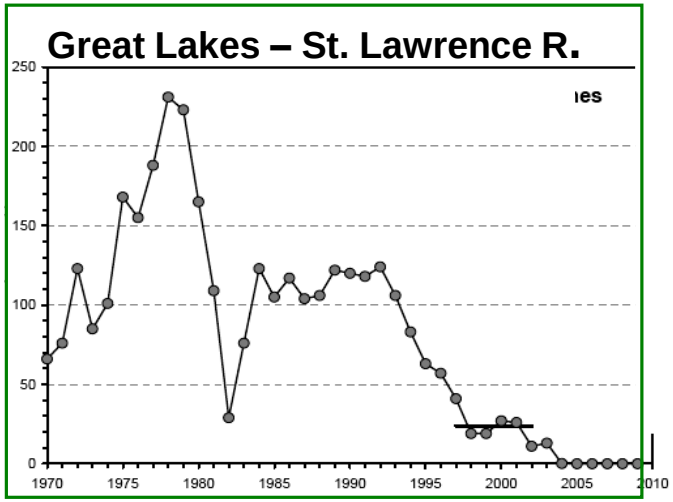
. …or ? …

Population genomics and Conservation of the American

"Freshwater eels" (*Anguilla* sp.) in decline worldwide.

Dramatic decline of American eel over the past 35 years.

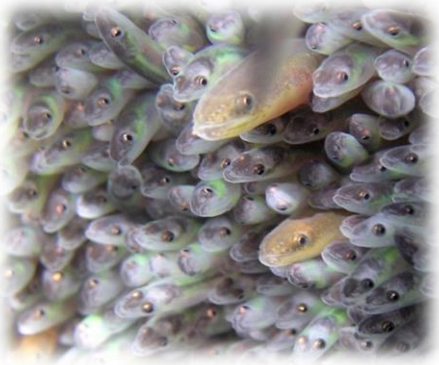
Local recruitment highly variable
Decline most pronounced in upper St. Lawrence River & Lake Ontario
(99% since 1980).



Population genomics and Conservation of the American Eel

Increasing demand in the face of
European & Japanese eel fishery collapse

- ✓ More than 1500 tons / year (Canada)
- ✓ Glass eel : The most pricy fish in the world: up to **3 000$ / kg**



Population genomics and Conservation of the American Eel

Need to better understand the causes of variable recruitment for improved management.

Need to elucidate the causes and consequences of phenotypic and genetic variation throughout the species range.

Pêches et Océans Canada | Fisheries and Oceans Canada

Great Lakes Fishery Commission

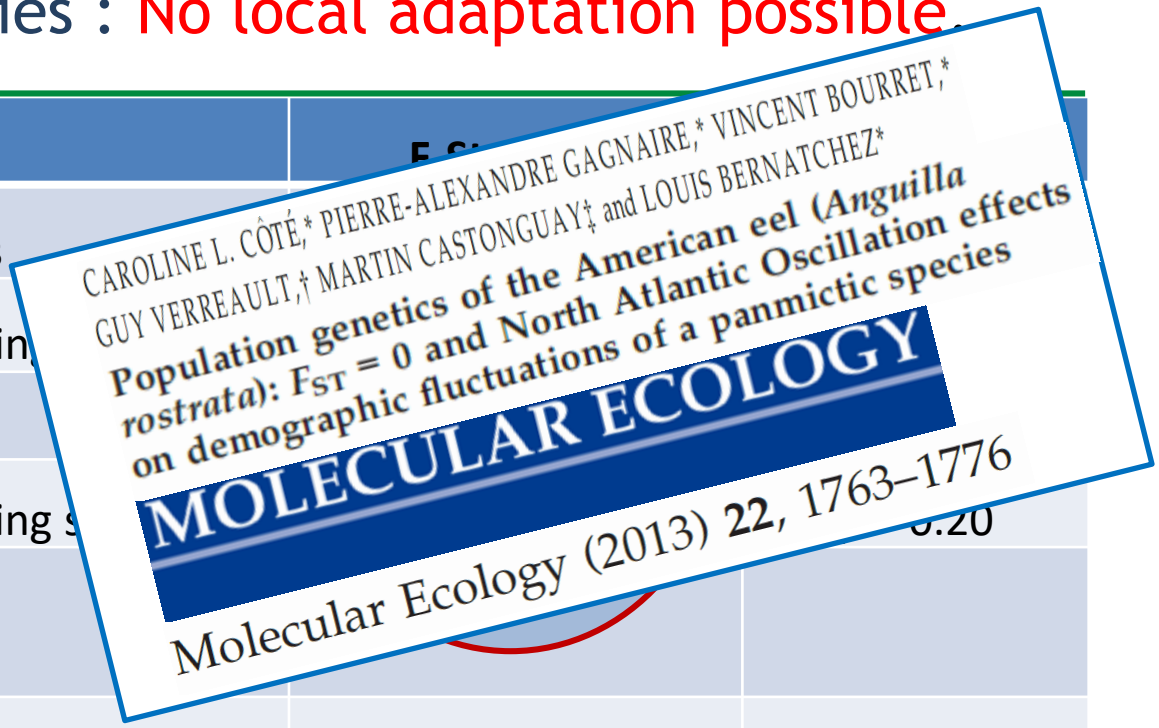
Forêts, Faune et Parcs Québec

NSERC CRSNG

Population genomics and Conservation of the American Eel

No genetic structure at the scale of the whole species : No local adaptation possible.

Factor	F S	
Life stages		
Samplin		
Cohorts		
Sampling s		0.20


CAROLINE L. CÔTÉ,* PIERRE-ALEXANDRE GAGNAIRE,* VINCENT BOURRET,* GUY VERREAULT,† MARTIN CASTONGUAY‡ and LOUIS BERNATCHEZ*

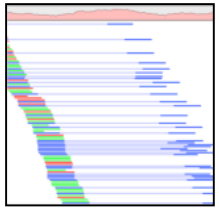
Population genetics of the American eel (*Anguilla rostrata*): $F_{ST} = 0$ and North Atlantic Oscillation effects on demographic fluctuations of a panmictic species

MOLECULAR ECOLOGY

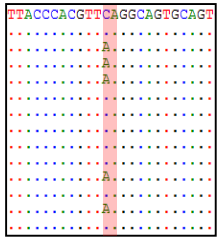
Molecular Ecology (2013) 22, 1763–1776

Population genomics and Conservation of the American Eel

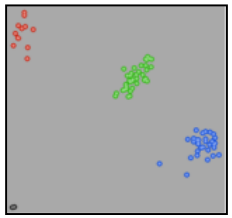
RNAseq: Sequencing the products of gene expression



22076 *cDNA* contigs



13293 SNPs



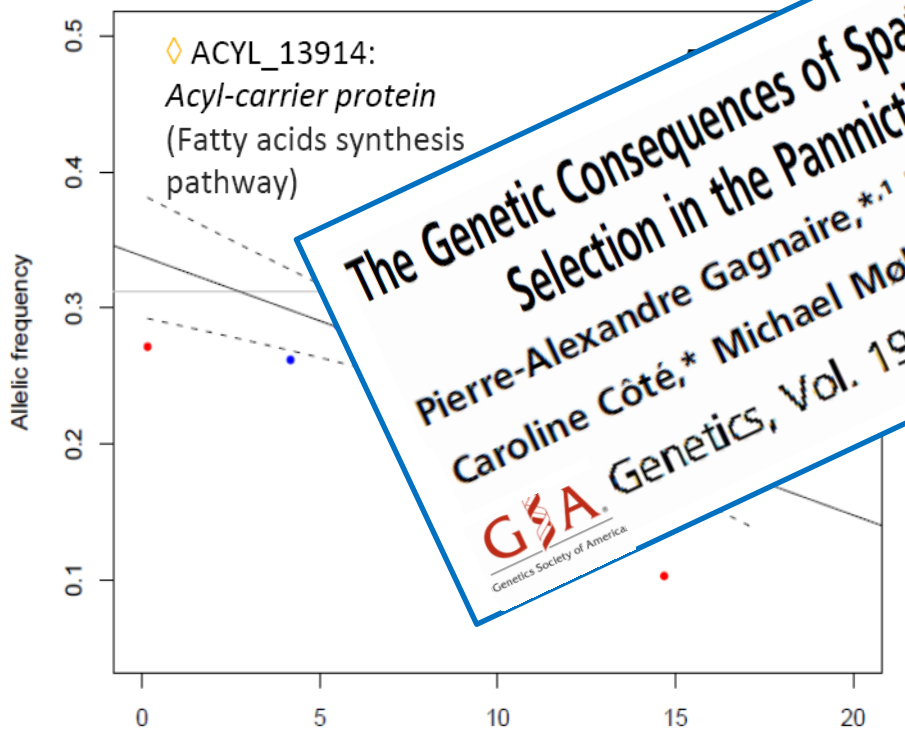
Genotyping of 75 “outlier” coding SNP on 1000 glass eels from 16 sites

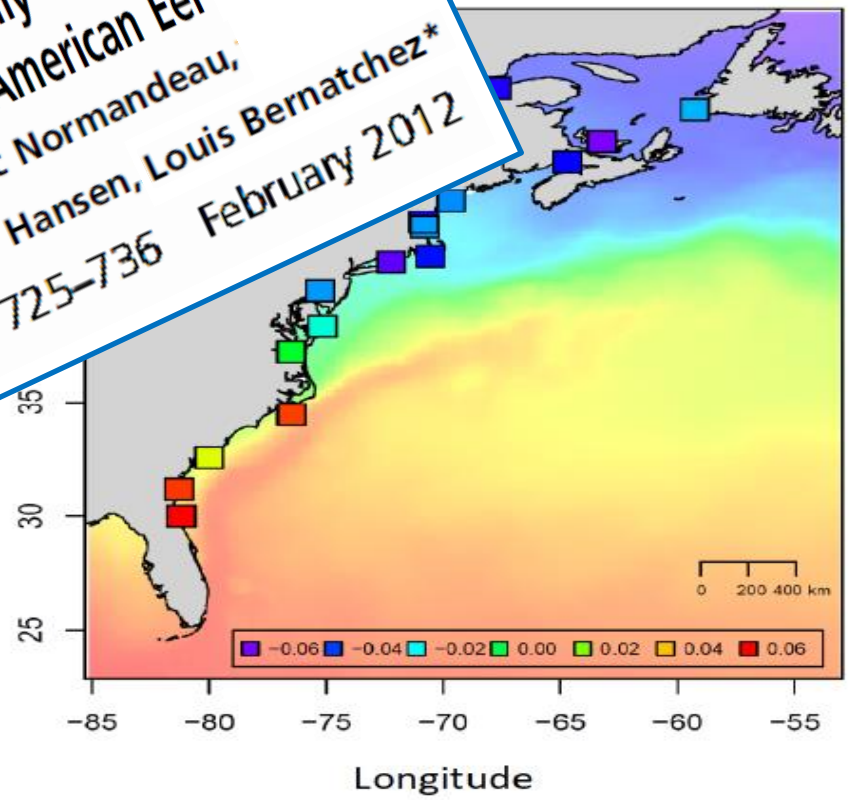
Florida vs. Québec

Population genomics and Conservation of the American Eel

Allele frequency of 12 genes varies with sea surface temperature

Spat… Component Analysis …cus cline (12 genes)





Population genomics and Conservation of the American Eel

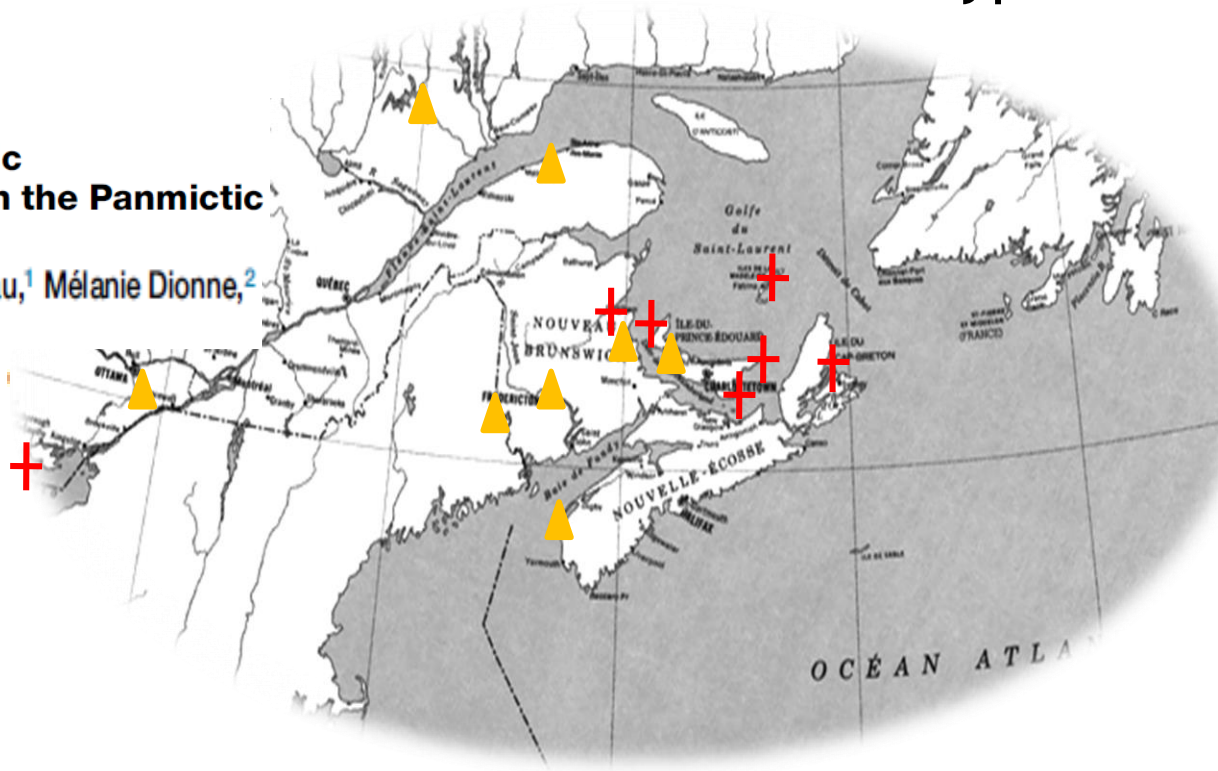
Does spatially varying selection also cause genomic differentiation between freshwater vs. saltwater “ecotypes” ?

Current Biology

RAD Sequencing Highlights Polygenic Discrimination of Habitat Ecotypes in the Panmictic American Eel

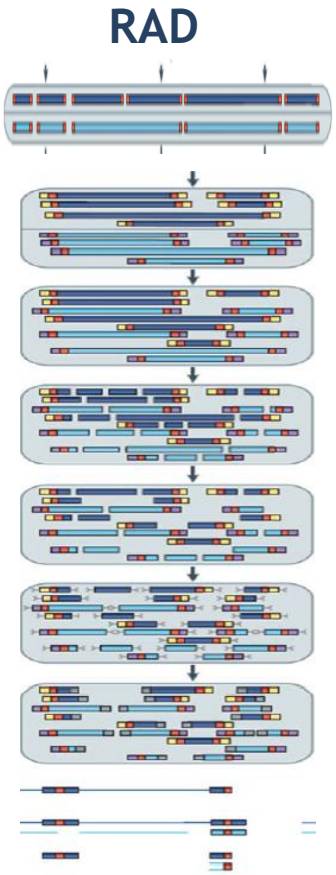
Scott A. Pavey,[1,*] Jérémy Gaudin,[1] Eric Normandeau,[1] Mélanie Dionne,[2] and Louis Bernatchez[1]

Current Biology 25, 1–6, June 15, 2015



384 eels from 16 sampling sites (8 fresh and 8 salt/brackish)

Population genomics and Conservation of the American Eel

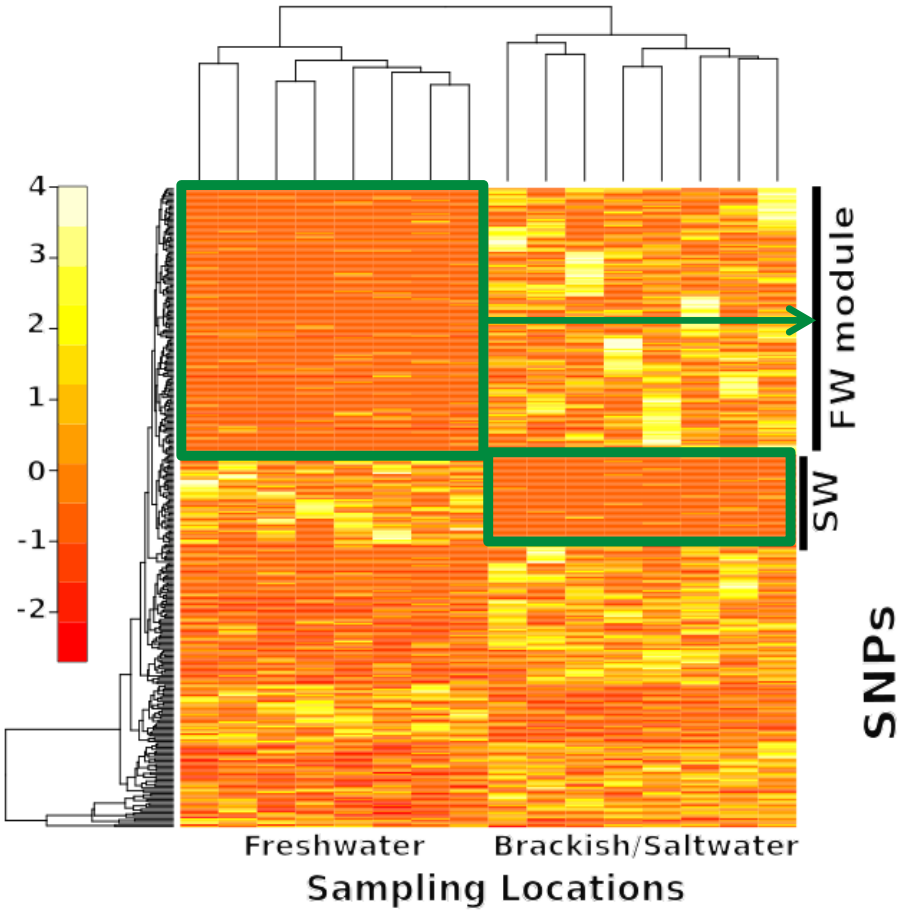


RAD sequencing
(Restriction site associated DNA markers)

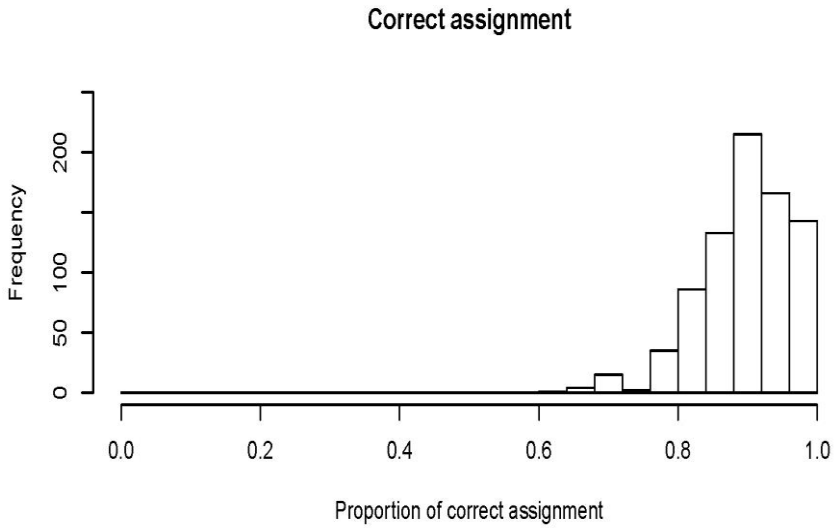
- 42,424 SNP ($F_{ST} = 0$).

- "Random Forests" statistical approach to search for markers that co-varied between ecotypes.

Population genomics and Conservation of the American Eel

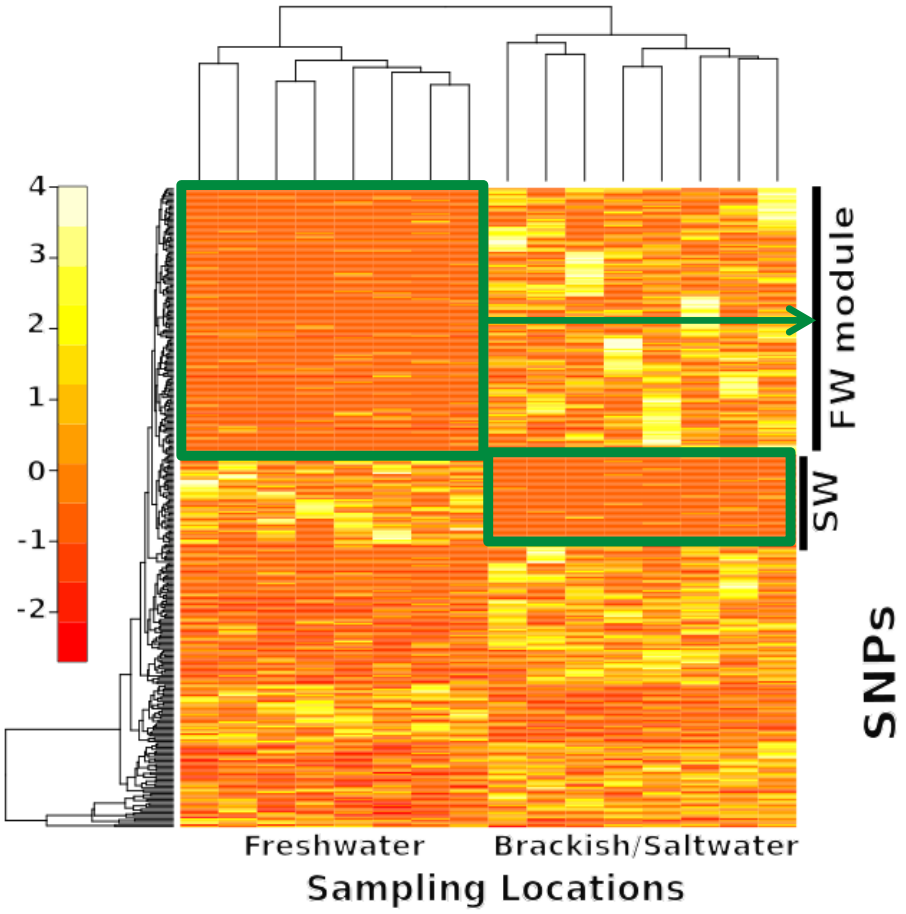


331 SNP were most important to discriminate ecotypes at a 90% success rate (random datasets = 50%)



- 137 fixed or nearly fixed in FW
- 45 fixed or nearly fixed in SW

Population genomics and Conservation of the American Eel



Over-representation of functions associated with early development:

. Respiratory system

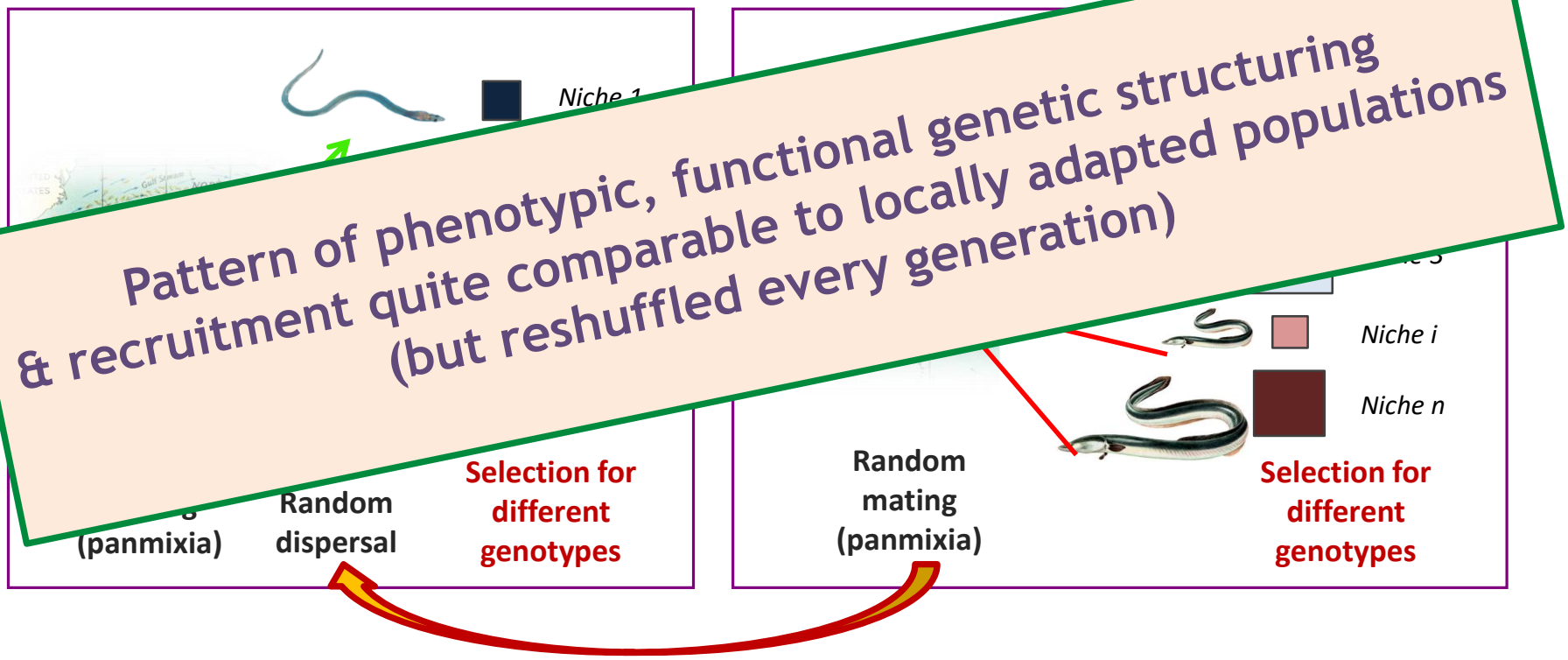
. Cardiac muscle tissue

. Limb bud formation

. Patterning of blood vessels

Population genomics and Conservation of the American Eel

Spatially varying selection imposed by temperature and salnity gradients produces local functional genetic differences despite panmixia



Population genomics and Conservation of the American Eel

Manage globally...

. **The persistence of the whole species depends on the demography and genetic diversity a single gene pool.**
Eel restoration in a given location could benefit from improved conservation measures applied elsewhere.

Think locally also...

. **Sound local management practice must take the existence of local genetic differences into account.**
If eels colonising different waters are not genetically homogeneous, stocking eels from different origins could have negative impacts, or failed to reach desired objectives for instance by impairing the association between life history characteristics and habitat preference.

Some concerns about today's place of (basic) science in Canada

Stand Up for Science rallies target federal government

CBC news | Technology & Science

nature International weekly journal of science

Death of evidence

Nature **487**, 271–272 (19 July 2012)

Some concerns about today's place of (basic) science in Canada

David Schindler : "It's like they don't want to hear about science anymore. They want politics to reflect economics 100 per cent - economics being only what you can sell, not what you can save."

Jeff Hutchings (former President, CSEE):

« Freedom of expression is no longer a right enjoyed by Canadian government scientists. When you inhibit the communication of science, you inhibit science. When you inhibit science, you inhibit the acquisition of knowledge. »

Drastic changes to science in Canada in recent years, which have happened in 3 distinct ways:

1) Reducing ts to comm ic.

THE GLO

Ottawa 'muzzli
tells global resea

"It's pretty clear that
researchers can talk, it."

CBCnews | Nova Scotia

LIVE Halifax
CBC Radio One
Listen Live

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Canada | NS | Photo Galleries

Steve Campana, Canadian biologist, 'disgusted' with government muzzling

Some concerns about today's place of (basic) science in Canada

Evidence for Democracy

Can Scientists Speak

Can Scie

Grading communica
federal government

Results

Safeguards Against Political Interference (25)	Protects Scientific Free Speech (30)	Dispute Resolution and Whistleblower Protection	Total Score (Out of 95)	Total Score (%)	Letter Grade
23	10	5	71	75	B
12	17	5	66	69	C+
7	15	5	59	62	C
	17	5	55	58	C-
	10	5	55	58*	C-
	10	5	55	58*	C-
	10	5	55	58*	C-
	15	5	53	56	C-
	5	5	52	55	C-
	10	5	49	52	D
	10	4	45	47	F
		3	44	46	F
		5	37	39	F
		5	36	38	F
	-	-	-	Inc.	Inc.

...olicies were used to assess Agriculture and Agri-Food Canada, Canadian Nuclear Safety ...e to the absence of media policies for these departments. Inc. = Incomplete.

85% of ministries: < C

Drastic changes to science in Canada in recent years, which have happened in 3 distinct ways:

2) Eroding of Canada's (basic) science capacity.

Dismantling of the world-famous Experimental Lakes Area (ELA).

- Crucial evidence on the effects of acid rain.
- Phosphates from detergents cause algal blooms
- Elucidated the impacts on fish of mercury.
- Some of the longest running data on climate change's impact.

The ELA cost $2 million a year to maintain, but its research saved governments around the world billions of $$$ by preventing water contamination.

Some concerns about today's place of (basic) science in Canada

2) Eroding of Canada's (basic) science capacity.

. Shutting down PEARL:
Polar Environment Atmospheric Research Lab (PEARL).

. Closing DFO ecotoxicology labs and contaminants monitoring capacity.

. Disapearance of 7 out of 11 DFO libraries

Some concerns about today's place of (basic) science in Canada

2) Eroding of Canada's (basic) science capacity.

More than 2,000 scientists lost their jobs,
100s of research programs & facilities lost their funding.

From the

Enlightment years…

…to the

Great Darkness

Drastic changes to science in Canada in recent years, which have happened in 3 distinct ways:

3) Reducing the role of evidence in policy decisions.

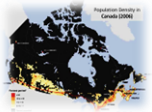
Fisheries
American Fisheries Society • www.fisheries.org
VOL 38 NO 11 NOV 2013
Vol 38 No 11 • November 2013

Jeffrey A. Hutchings John R. Post

Gutting Canada's Fisheries Act: No Fishery, No Fish Habitat Protection

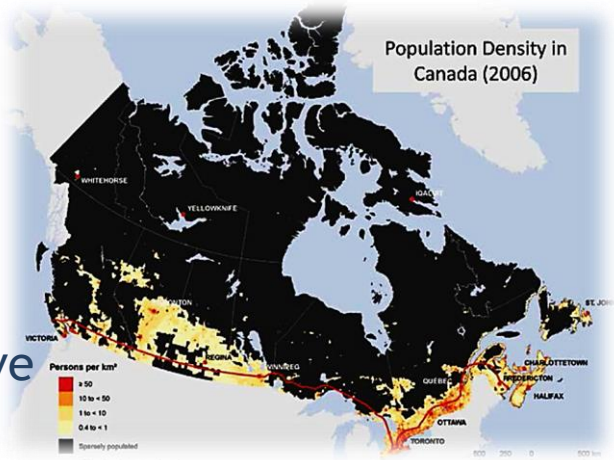
. Habitat protected only for fish that are considered part of a fishery or that support a fishery.

. 80% or species at risk of extinction lose protection.



. Fish inhabiting waters not regularly visited by humans no longer warrant protection.

. Prioritizes habitat protection for some nonnative species & even hatchery-produced hybrids.



Drastic changes to science in Canada in recent years, which have happened in 3 distinct ways:

3) Reducing the ence in poli .

- Canadi

- Species

- Navigable
  for **3,000,**

- **National En** lead agency in determining
  issues that re the Species at Risk Act or the Fisheries Act.


LE DEVOIR
LIBRE DE PENSER

Harper place un ex-lobbyiste des pipelines à l'ONE

11 août 2015 | Marco Bélair-Cirino - Correspondant parlementaire à Québec | Canada

Changes not supported by scientific advice.
Inconsistent with an ecosystem-based approach to management.
(Who gets benefits out of this?)

CEPA
Canadian Energy Pipeline Association
Association canadienne de pipelines d'énergie

Canadian Gas Association
Association canadienne du gaz

December 12, 2011

Honorable Peter Kent
Minister
Environment Canada
Les Terrasses de la Chaudière
10 Wellington Street, 28th Floor
Gatineau, Quebec K1A 0H3

Honorable Joe Oliver
Minister
Natural Resources Canada
580 Booth Street, 21st Floor, Room C7-1
Ottawa, Ontario K1A 0E4

Dear Ministers Kent and Oliver:

We are writing to you today on behalf of the Energy Framework Initiative (EFI) which represents Canada's energy sector value chain. The purpose of our letter is to express our shared views on the near-term opportunities before the Government to address regulatory reform for major energy industries in Canada.

In addition to process issues, we believe that the basic approach embodied in existing legislation is out-dated.

This approach we advocate is based on a whole-of-government consideration of several pieces of legislation that are currently planned for review in the coming months

[1] *National Energy Board Act* (NEB Act), *Canadian Environmental Assessment Act* (CEAA), *Species at Risk Act* (SARA), *Fisheries Act*, *Migratory Birds Convention Act* (MBCA), *Navigable Water Protection Act* (NWPA), and others.

In closing, we wish you and your staff a safe and happy holiday season.

Brenda Kenny
President
CEPA

Timothy M. Egan
President
CGA

Peter Boag
President
CPPI

David Collyer
President
CAPP

Gro Harlem Brundtland

**“Politics that disregard scientific knowledge will not stand the test of time…
If we compromise on scientific facts and evidence, repairing nature will be enormously costly – if possible at all.”**