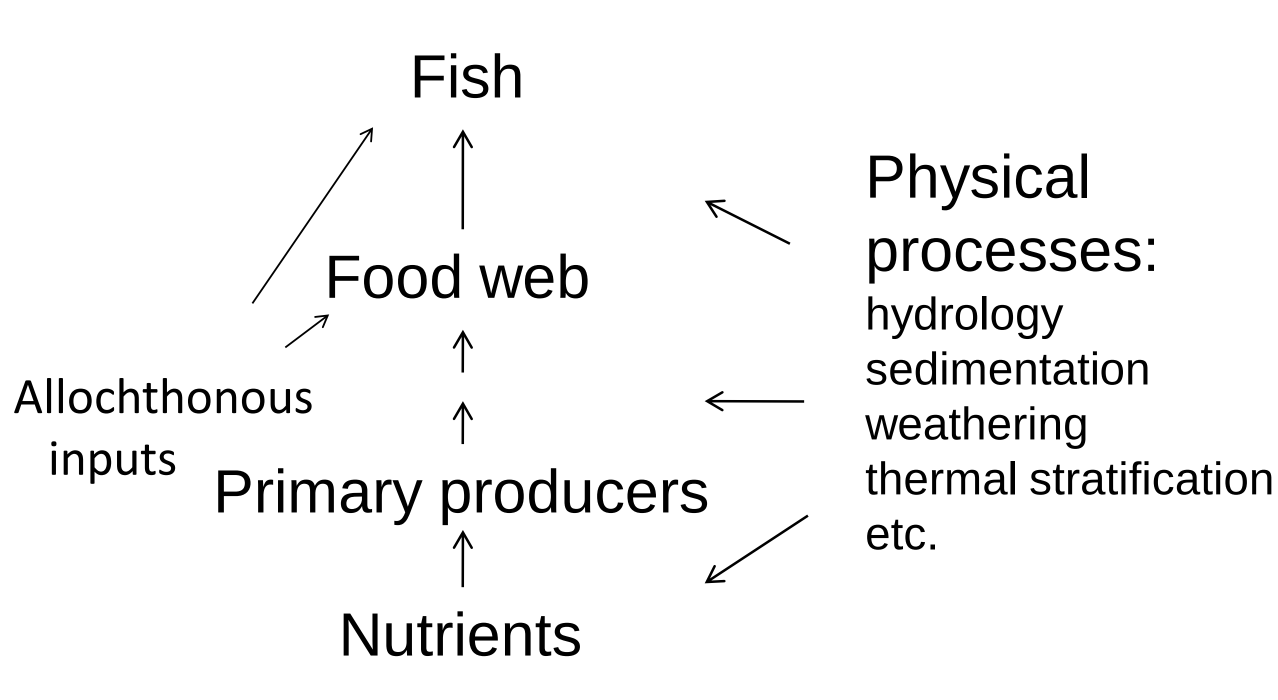
Chemical and biological drivers of fish productive capacity:SNG 2:1

NSERC HydroNet CRSNG



•Premise:

fish productive capacity can be viewed as the product of the ecosystem's "food base" which can be expressed in terms of "**energy flow**" (primary & secondary productivity) or at the level of its **nutrient** regime.

Chemical Drivers of Fish production:

(Leader: Joseph Rasmussen, U of Lethbridge)

Objective: to establish a relationship between productive capacity for fish and the nutrient regime: TP (total phosphorus concentration in water), and TN (total Nitrogen concentration).

Nutrient richness will depend on underlying geographic/geologic factors, land-use factors, and point source loadings, and nutrient-based fish models should thus allow us to integrate effects of a wide range of factors.

To provide a benchmark estimate of the potential fish productivity scaled to the level of system productivity.

Hypothesis:
total phosphorus concentration in the water (TP) will be the best overall predictor of fish productive capacity (Downing and Plante, 1993; Dillon and Rigler, 1974),

Regional differences in relationships of fish Productive Capacity to Nutrients:

Objective: recognize regional differences in relationships between fish productivity and nutrients, allowing regional scaling of benchmark expectations for fish productivity.

How river regulation will affect concentrations of available nutrients, and consequently fish biomass and production, downstream of impoundments

Hypothesis:

We expect nutrient models to differ among regions as a function of

(a) Geographic/edaphic factors that affect nutrient cycling and bioavailability
(b) Zoogeographical differences in the makeup of fish communities among regions (Links to 4.2 Effects of fish biodiversity on productive capacity).

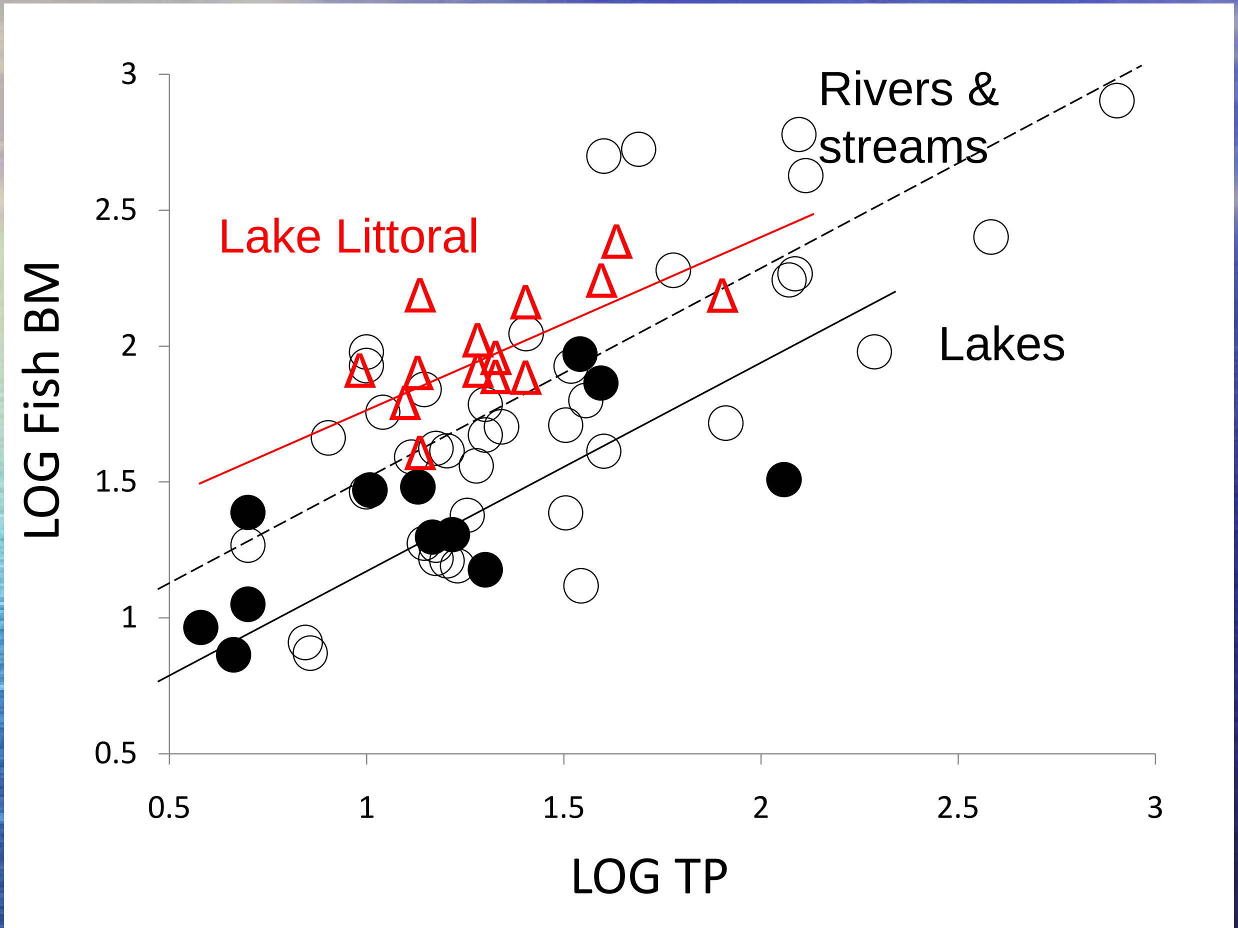
Collaborations between the chemical drivers project and other HydroNet projects

•co-ordinate nutrient analysis (Biogeochemical Analytical Laboratory, Dept. Biol. Sci. Univ. Alberta) from the Productive Capacity of Fish Habitats Project (1.1) and other HydroNet projects and analyze for relationships to fish biomass and production in all HydroNet study regions.
--Collaborators Daniel Boisclair and his team, Keith Clarke

•collecting and collating published and unpublished data on fish biomass and production, and nutrients (N and P) from sources throughout Canada, on lakes, reservoirs, and regulated and unregulated rivers and streams throughout Canada and other temporal zone locations throughout the world.

Statistical analysis using regression and other approaches to produce general and regional model relating fish biomass and production to nutrient data and other co-variables.
Collaborators—Bob Randall, Keith Clarke, Daniel Boisclair, Paul Higgins, Alf Leake, Mike Bradford

Relationships of fish biomass to nutrient levels differ among different types of systems but all increase with trophic status



•Rivers are more productive than lakes for the same level of nutrient richness,

•However, lake littoral fish communities 2-fold richer than rivers and streams?

Chemical Drivers of Fish production:

Fundamental/Scientific relevance:

•Nutrient richness will depend on underlying geographic/geologic factors, land-use factors, and point source loadings, and nutrient-based fish models should thus allow us to integrate effects of a wide range of factors.

Benefits to Industry and Government:

•Models relating fish production to nutrients will provide important benchmarks for management

•Such benchmarks/baselines will differ regionally as a result of differences in nutrient export regimes and fish zoogeographic factors.

•More comparisons between the productive capacity of reservoirs, rivers (regulated and unregulated) and natural lakes are needed and we need to understand the different role of nutrients in these systems.

4.2 Effect of differences in fish biodiversity on fish production

Objectives:

How productivity is influenced by the number of fish species, and how this biodiversity factor differs regionally and affects trophic relationships and habitat use.

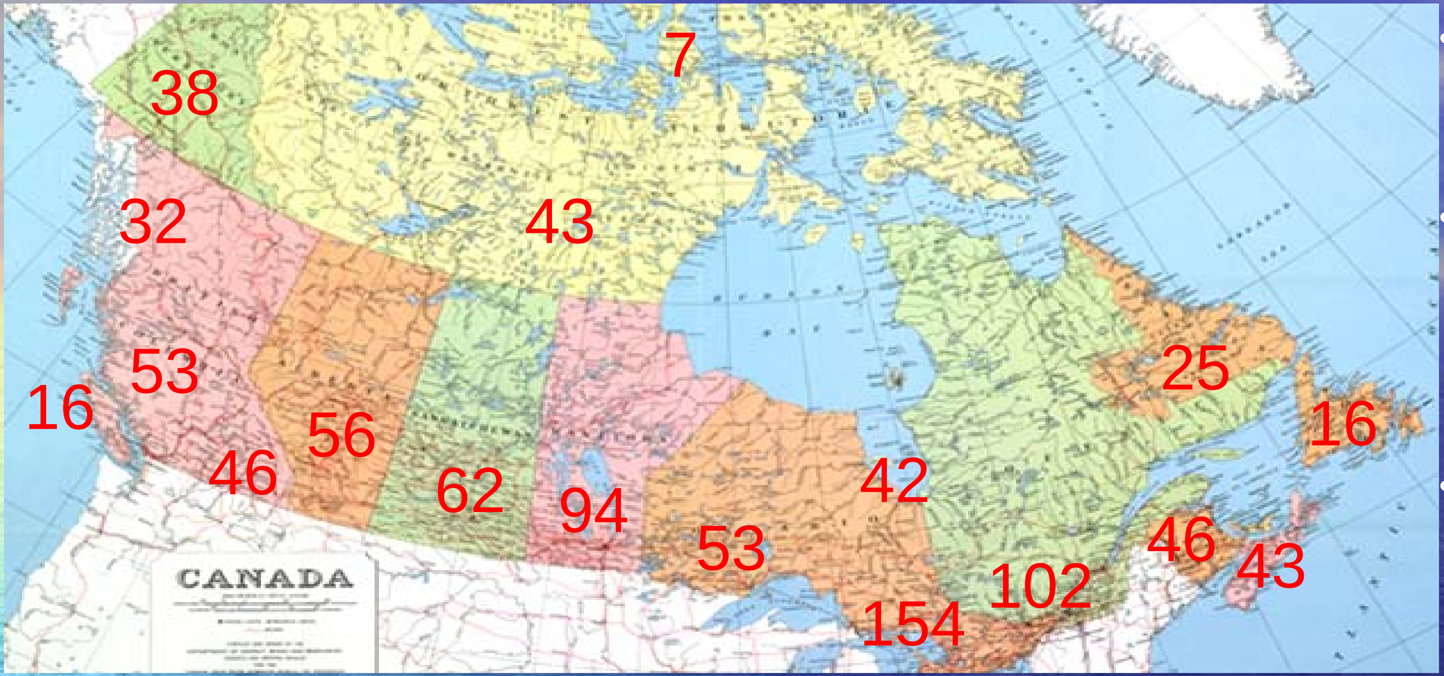
Hypotheses:

•Species poor communities lack specialists (e.g. Benthivores) --dominated by generalist feeders (*e.g.* brook trout); productive capacity should be low.

•Diet breadth, morphological diversity, life-history diversity, habitat range of individual species of fish will decrease with increasing fish species richness.

•Collaborators, --Boisclair, Clarke, Randall—Links to project 1.1 PCFH

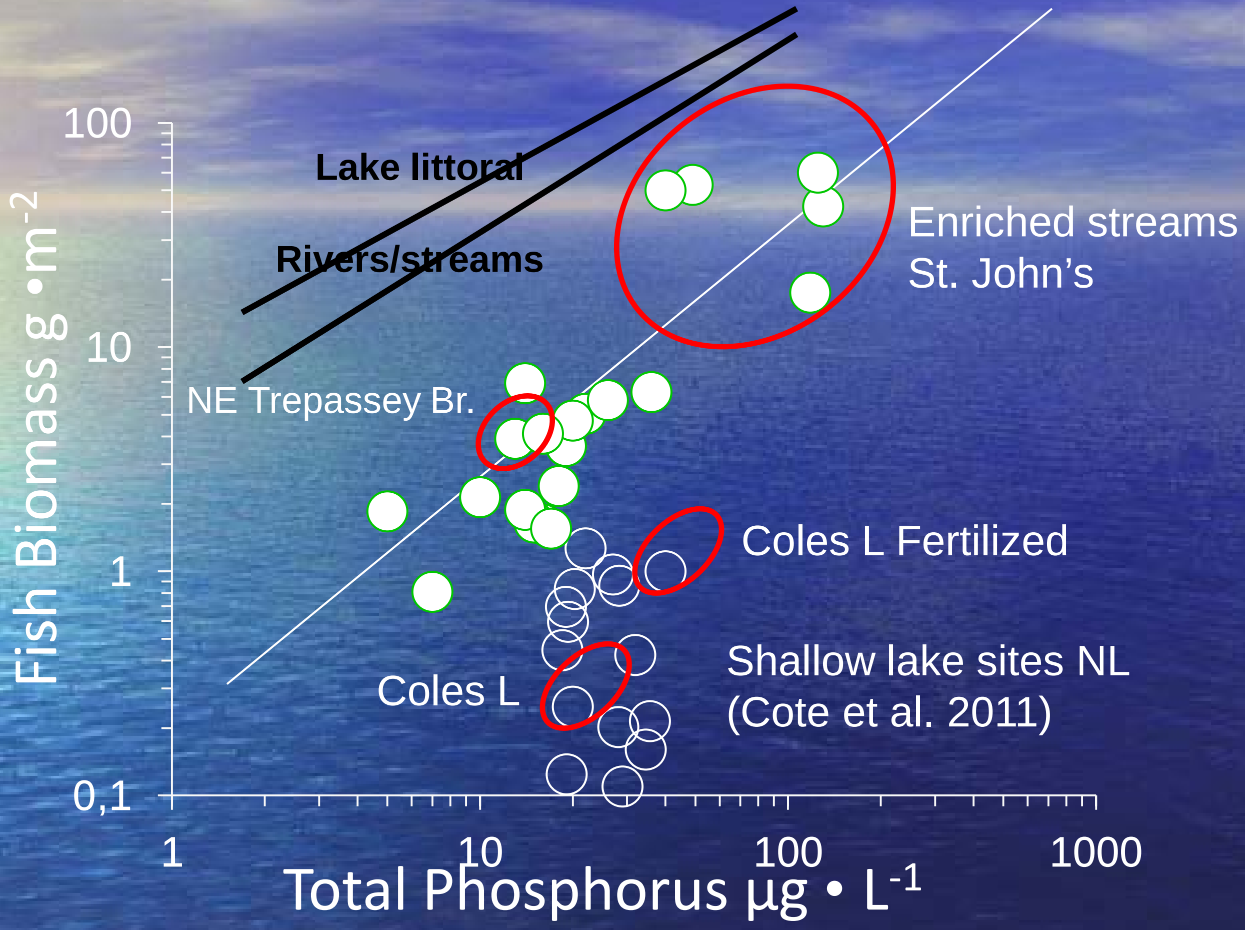
Freshwater fish species richness across Canada



- Coastal regions dominated by species from marine refugia
- Central regions acquired species from many continental refugia through large proglacial lakes
- Cordillera barrier to fish from interior refugia

- Coastal islands lack many families:
  cyprinids, catostomids, esocids, coregonids, percids, centrarchids, gadids
- Lack many significant functional groups—many resources unutilized
  No true pelagic zooplanktivores or specialized benthivores, algivores, mud feeders
  few efficient piscivores
- Most of these families/functional groups decline with latitude
- Fisheries based mostly on generalists cannot be expected to be as productive as those dominated by specialists

In NL lake littorals are much less productive for fish than streams and both have fish biomass far below the continental benchmark



- NL lake systems likely unsaturated communities, little salmonid spawning habitat in lakes, fish migrate to lakes from rivers.

Analysis of Literature values from Canada and other Temperate zone sites provides emprical support for a biodiversity effect

$$\text{Log BM} = -0.63 + 0.79\,\text{Log}\,TP + \begin{bmatrix} 0.140 \;\; \text{Lake Littoral} \\ 0.070 \;\; \text{Rivers/stream} \\ -0.208 \;\text{Lakes} \end{bmatrix} + 0.45\,\text{Log\#spp.}$$

$$\text{R}^2 = 0.80, SE = 0.30, n = 110$$

Cryptic biodiversity

•In regions where species richness is low, species can diversify to form distinct morphs or ecotypes that occupy different habitats and functional roles within the foodweb.

•This is best known in arctic charr in Iceland, Greenland and the British Isles—15 charr morphs described for the British Isles

•In Canada this is known in lake trout, brook trout, whitefish, lampreys and sticklebacks, but may be much more common than presently recognized in the north and in coastal regions where species richness is low.

Charr 'morphs' in Iceland : impact on productivity

Lake Thingvallavatn, TP = 10 mg/m³
Fish production 4.6 g/m²/yr
Fish biomass 9.7 g/m²
Arctic charr 4.2; 8.8;

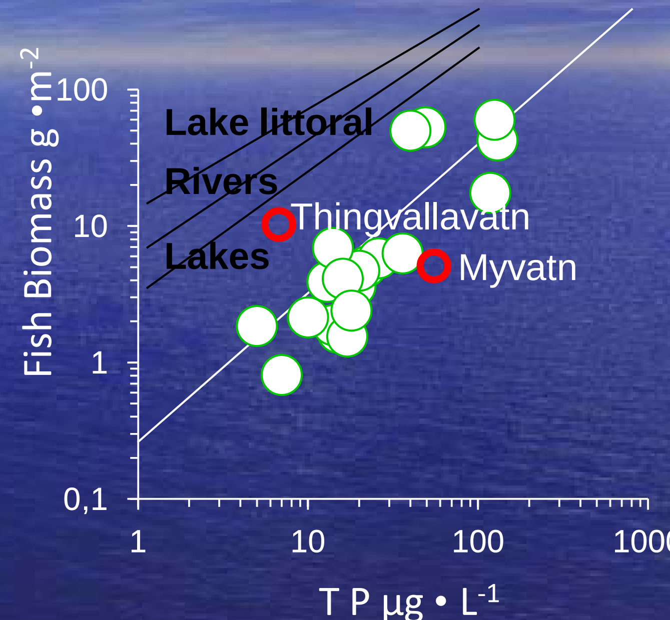
planktivore **3.9; 7.2**
piscivore 0.18; 0.41
small benth 0.04; 0.10
large benth 0.12; 0.25

Snorrason et al. 1992

Lake Myvatn, TP= 50 mg/m³
Fish production 3.0 g/m²/yr
Fish biomass 5.3 g/m²

Arctic charr 1.1; 2.7

Species present;
Arctic char, stickleback, brown trout



- Arctic charr are usually not very successful in large deep lakes, their generalist feeding mode allow them to feed on zooplankton but not efficiently
- The high biomass of in Thingvallavatn is attributable to the presence of specialized pelagic zooplanktivore

Fish Biodiversity and its contribution to productivity

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Fundamental/Scientific relevance:

•Functional biodiversity depends on zoogeographic factors, as well as the history of species introduction to the system

Benefits to Industry and Government:

•Models relating fish production to the presence of key functional groups will provide important benchmarks for management

•Such benchmarks/baselines will differ regionally

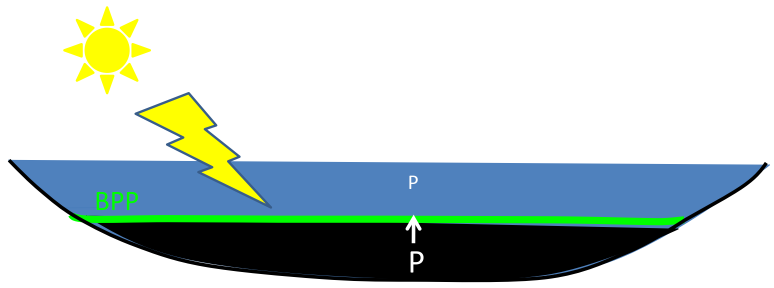
•**Final thought**:

•More study of resource exploitation by different groups of fish will provide a better understanding of the ecosystem processes that contribute to fisheries productivity.

•While high biodiversity communities may be more productive, they may be more difficult to manage when flow regimes are altered. Optimizing flow regimes for a multi-species community may be more daunting than for a single species.

Why do rivers and streams produce more fish than lakes?

- Flow?
- Allochthonous organic input?
- Benthic primary productivity (BPP)?



- Where light reaches the bottom →BPP
- Interstitial water in hyporheic zones, and sediments are much more nutrient rich than the overlying water
- BPP has access to more nutrients than phytoplankton
- Thus littoral zones in lakes should be as least as rich as rivers.

Chemical Drivers of Fish production:

Methods:

•sampling sites and schedule used will be the same as those used to estimate the productive capacity of fish habitats (PCFH).

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•Total nitrogen (TN) = DIN (minus N2 gas) + DON + PON

•analyzed as an aggregate with an in-line digestion and oxidization method using ultraviolet light and heated alkaline persulfate.

•$NO_3^- \rightarrow NO_2^-$ by Cd column.

•nitrite measured colorimetrically as a diazonium ion (APHA 2004-4500-N).

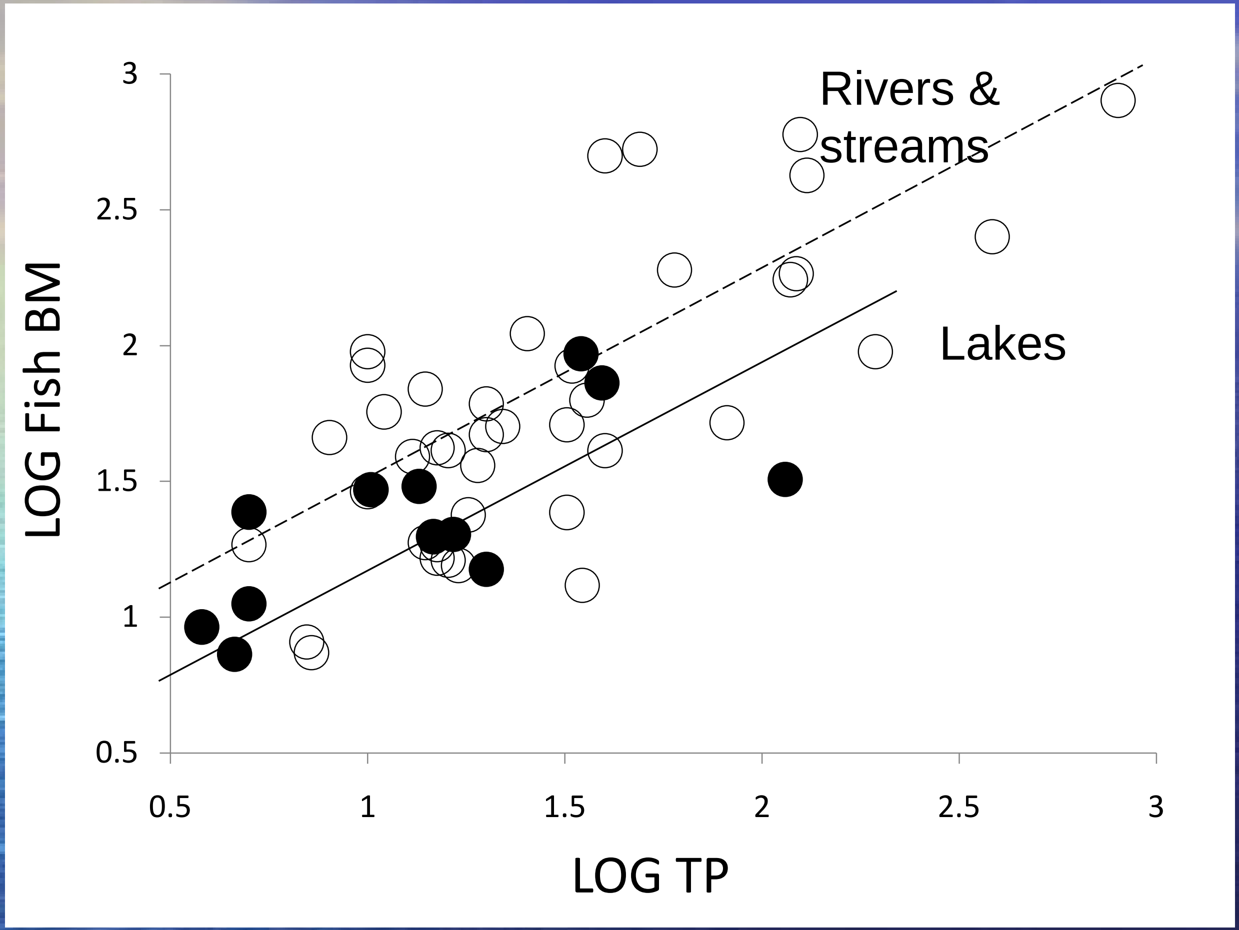
Total phosphorus (TP) = ortho, poly, + organic PO_4 (diss + part).

Org- $PO_4 \rightarrow$ in-line to ortho- PO_4 (heat, ultraviolet and persulfate digestion) measured colorimetrically, ascorbic acid reduction (APHA 2004-4500-P).

Dissolved inorganic carbon (DIC) analyzed as an aggregate using a Shimadzu Model TOC-5000A carbon analyzer.

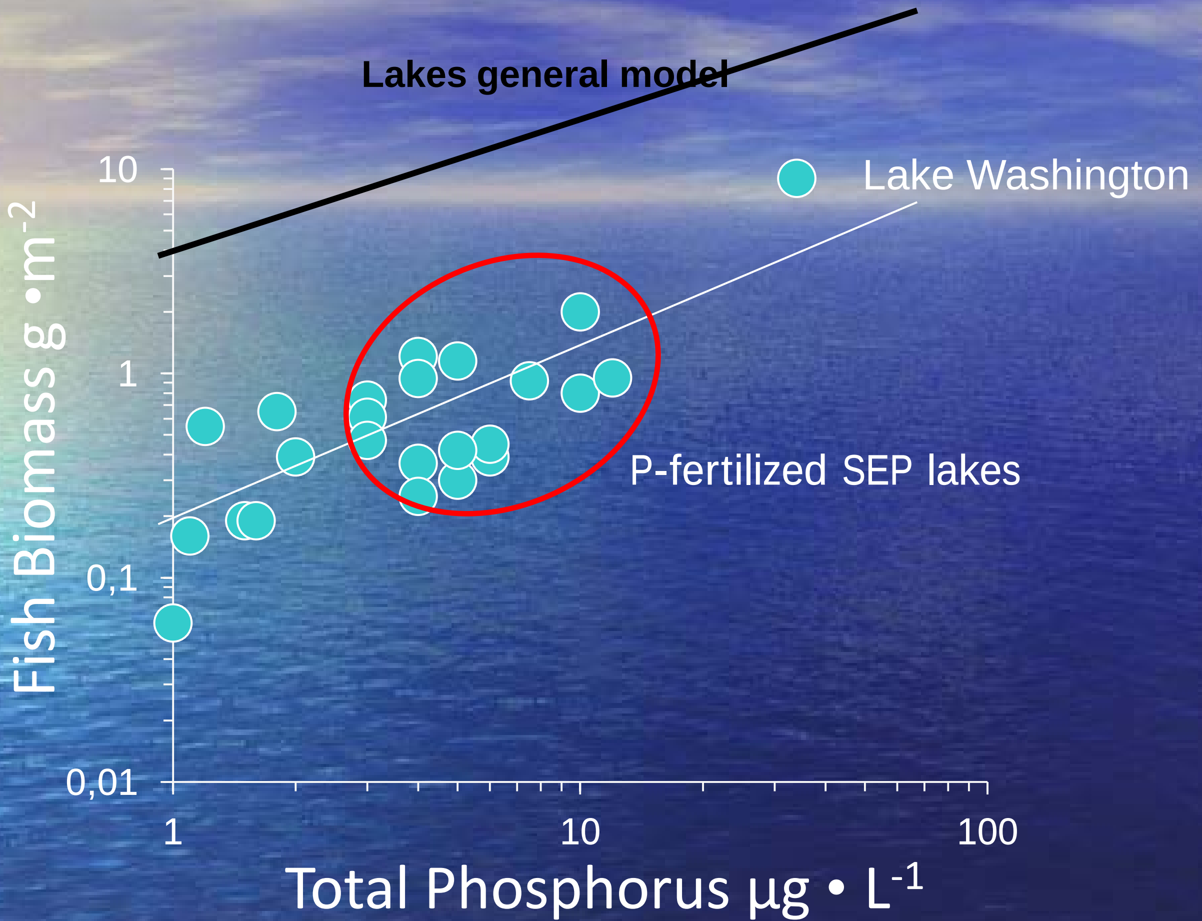
Analyses (TN, TP, DIC) by Biogeochemical Analytical Laboratory in the Department of Biological Sciences at the University of Alberta

Chemical drivers of fish productive capacity:

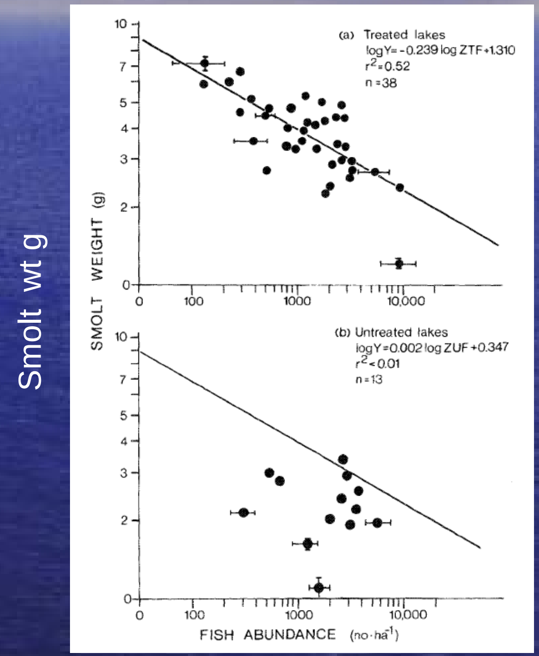


While we expect that the relationship between fish community production and nutrient concentrations in water will differ between lakes, reservoirs, rivers etc. , it is possible that the nutrient regime will provide a unifying estimate of the potential fish productive capacity of an aquatic ecosystem.

BC Sockeye nursery lakes also unproductive

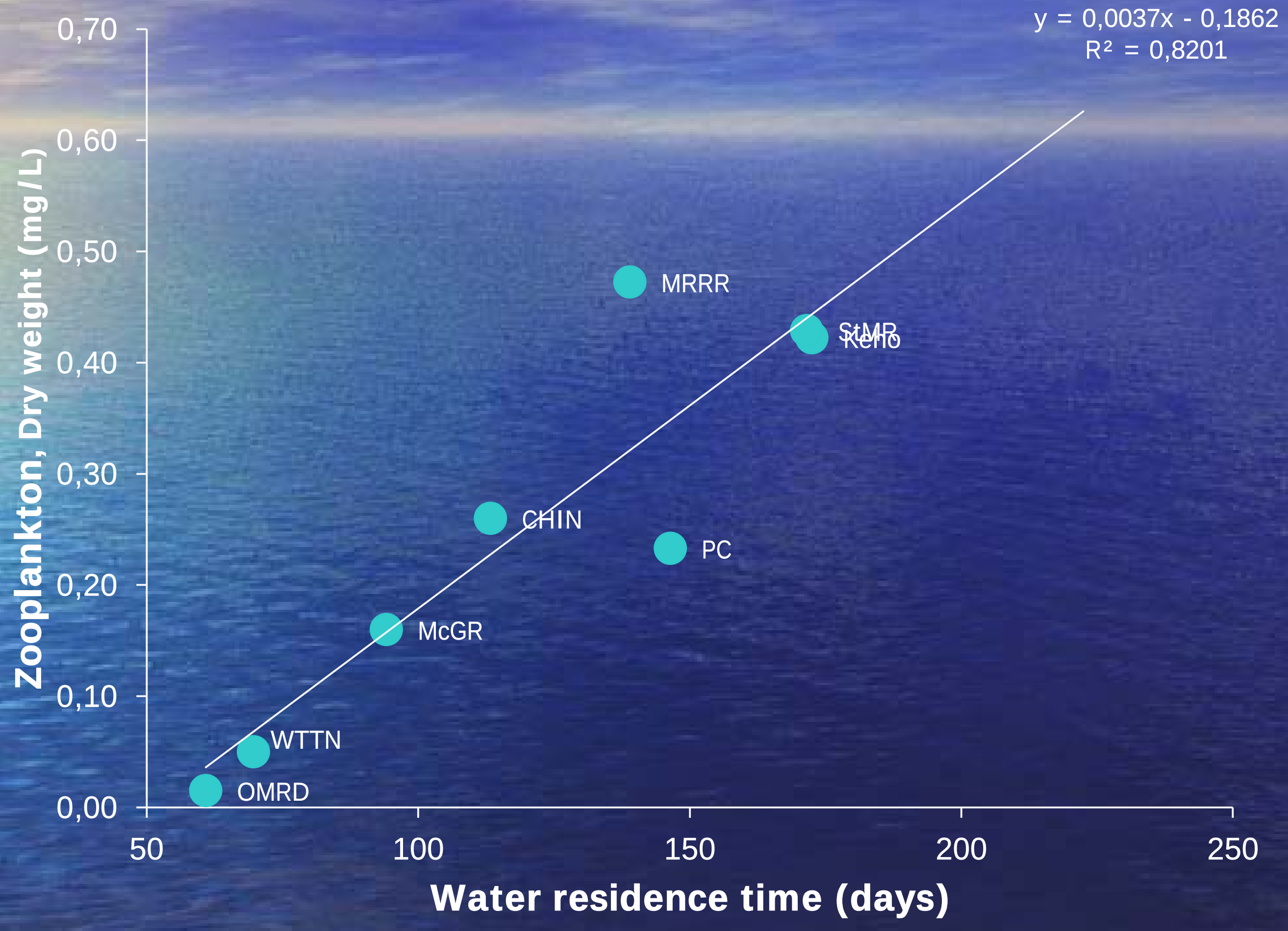


Sockeye growth is density dependent in treated lakes

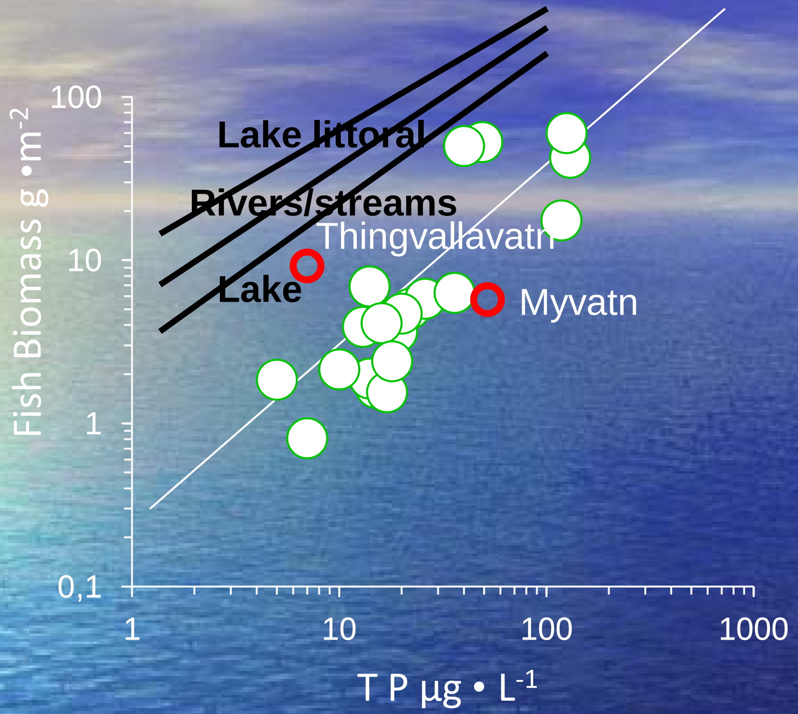


Smolt density #/ha

From Hyatt & Stockner 1985, CJFAS



y = 0,0037x - 0,1862
R² = 0,8201
Zooplankton, Dry weight (mg/L)
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,00
MRRR
StMR
Kello
CHIN
PC
McGR
WTTN
OMRD
50
100
150
200
250
Water residence time (days)



Lake littoral
Rivers/streams
Thingvallavatn
Lake
Myvatn
100
10
1
0,1
1
10
100
1000
Fish Biomass g •m-2
T P µg • L-1