A Bioenergetic-based Food Web Evaluation of Factors Affecting Bull Trout and Kokanee Production in Kachess and Keechelus Reservoirs

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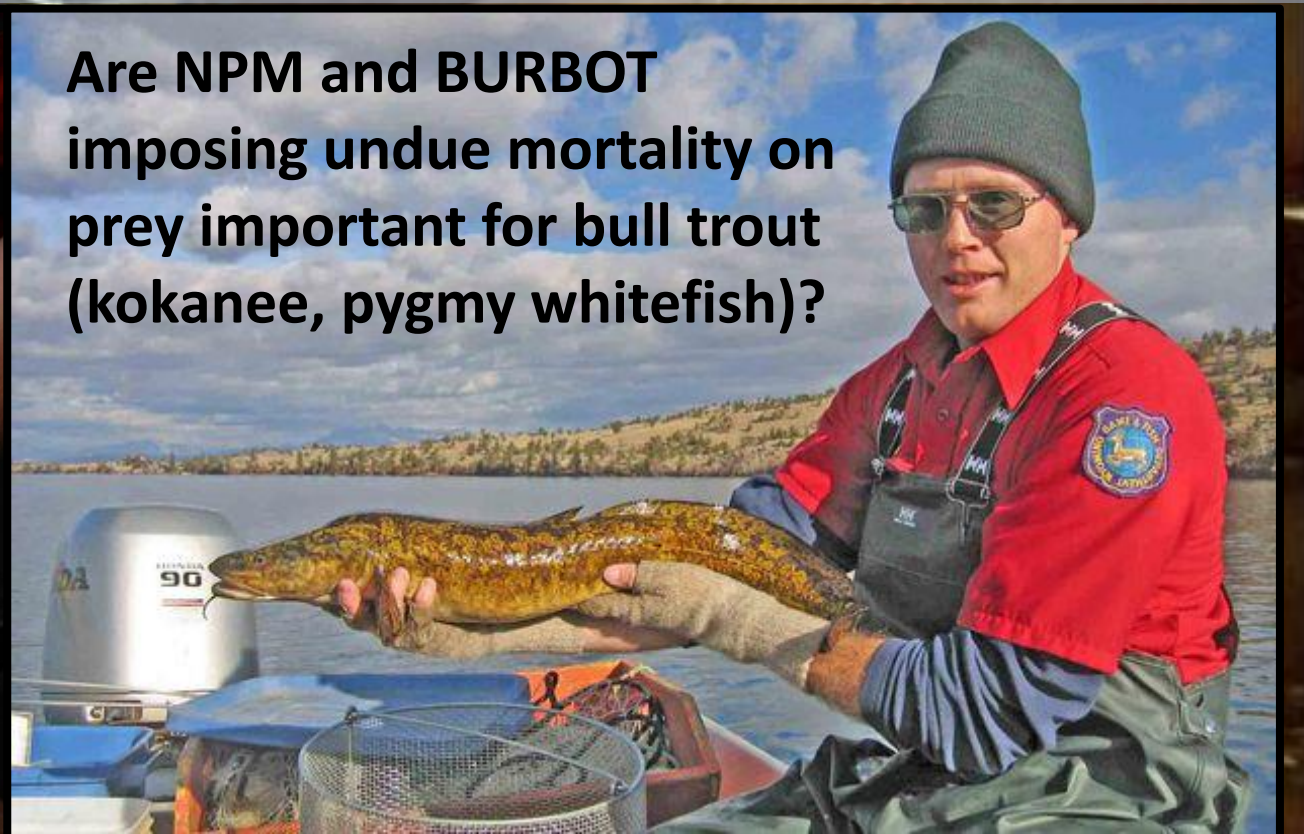
U.S. Department of the Interior Bureau of Reclamation

USGS science for a changing world

How will K-K Conveyance & pumping affect food web interactions and bull trout in Lake Kachess?

Is Kokanee production limited by thermal regime or seasonal food supply?

Are NPM and BURBOT imposing undue mortality on prey important for bull trout (kokanee, pygmy whitefish)?



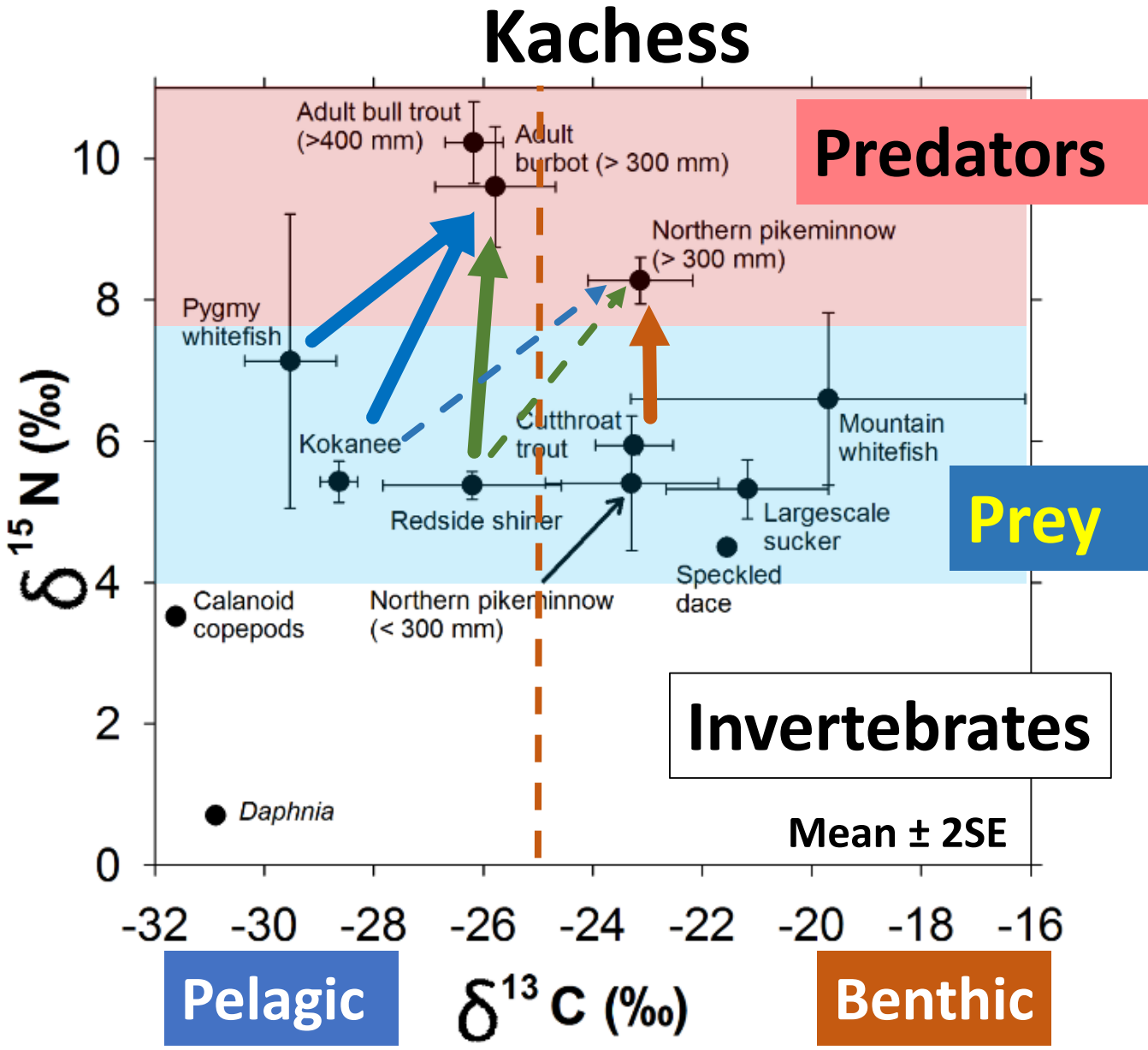
Objectives of Baseline Food Web Analysis

- Characterize Food Web Structure of Reservoirs & Processes affecting Bull Trout & Kokanee
  - Identify trophic position (prey, competitors, predators)
  - Identify & quantify primary energy pathways (Pelagic or Benthic)
- Evaluate how current food web structure and environmental conditions affect foraging, growth, and survival of salmonids
  - Seasonal Effects of Thermal Stratification & Prey Availability
  - Quantify consumption Demand v Food Supply Piscivores & Planktivores
- Consider how future water operations might affect Bull trout and Kokanee via environmentally-mediated food web processes

Food Web Structure From Stable Isotopes

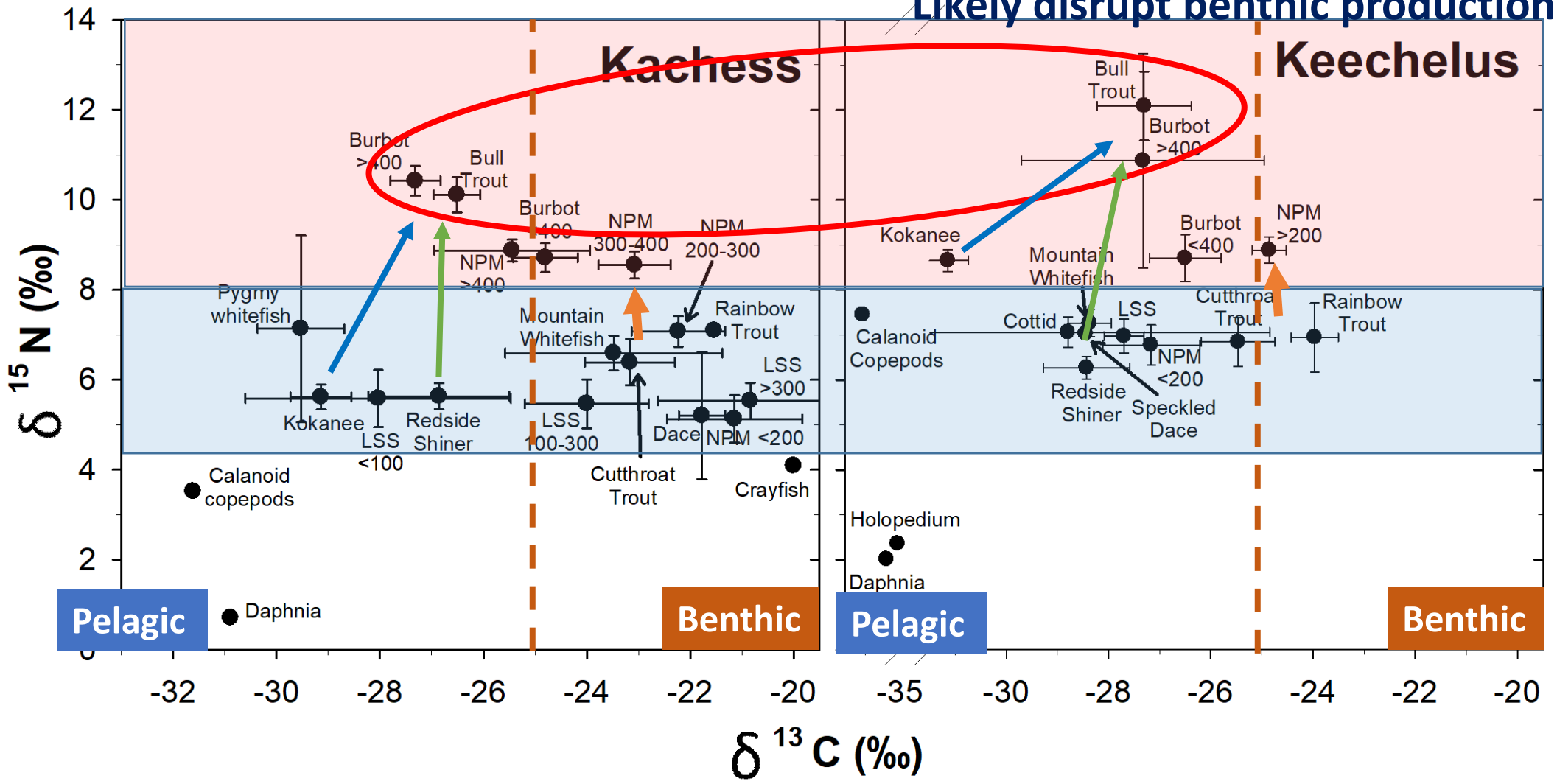
Feeding history and position in food web (fish fin or muscle)

- Top predators: large bull trout, burbot, northern pikeminnow
- Kokanee and other pelagic prey important for bull trout and burbot
- Northern pikeminnow eat mix of fish Benthic & Pelagic prey, but more reliant on Benthic fishes

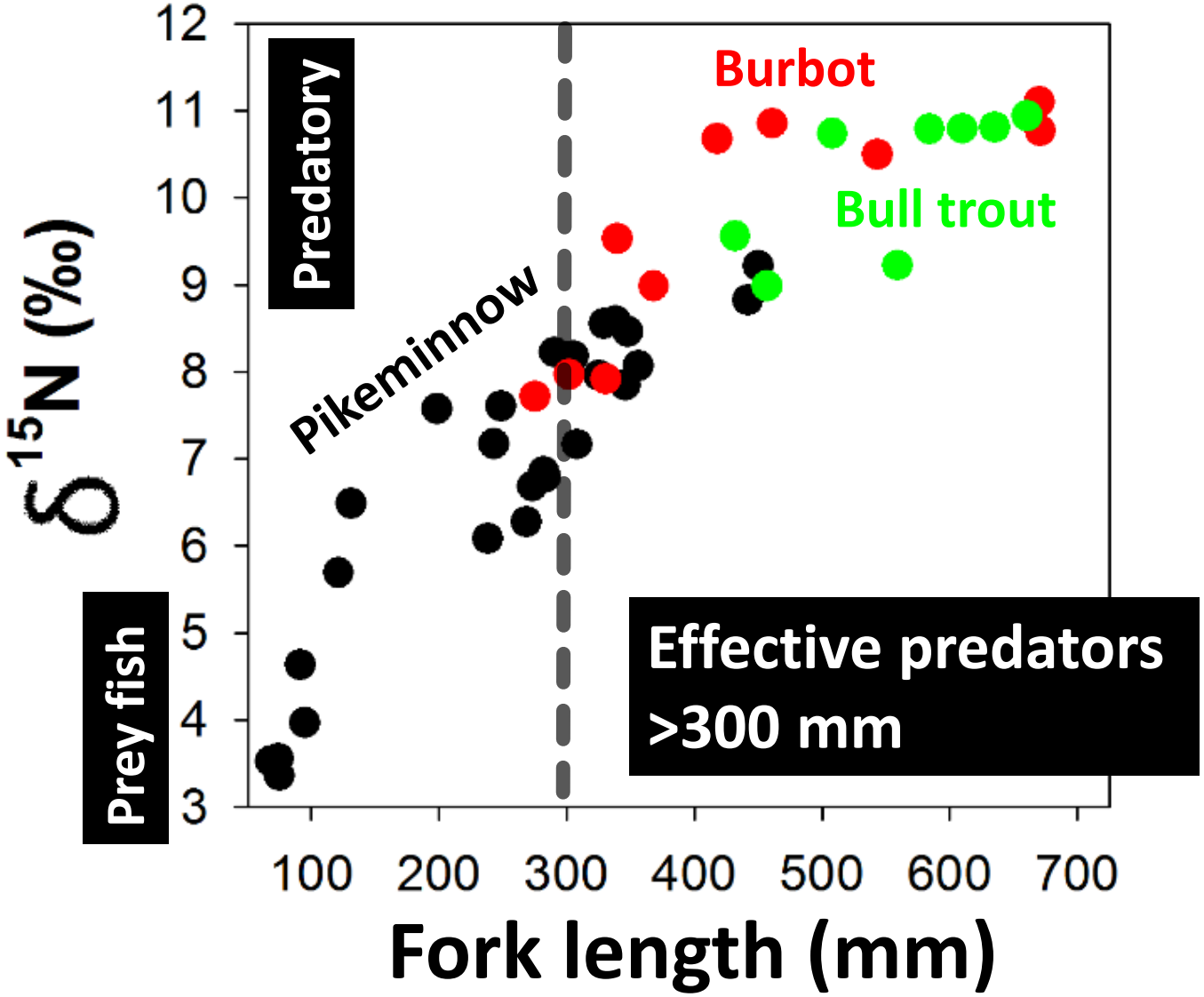


Food Web Structure

-Benthic pathways more truncated in Keechelus;
-Earlier, more extreme drawdown
Likely disrupt benthic production



Predatory Threat Dependent on Size



Relative number of small individuals vs. large predatory individuals?

Why Quantify Food Web Interactions?

- Identify processes (**predation**, **competition**, **food supply**, **temperature**, **distribution**) that **LIMIT** or **PROMOTE** the growth and survival of key species (e.g., bull trout)

- Foundation for evaluating how different species respond to change
  - Temperature regime
  - Water level fluctuations
  - Predator-prey abundance

Affected by reservoir operations

Bioenergetics Approach

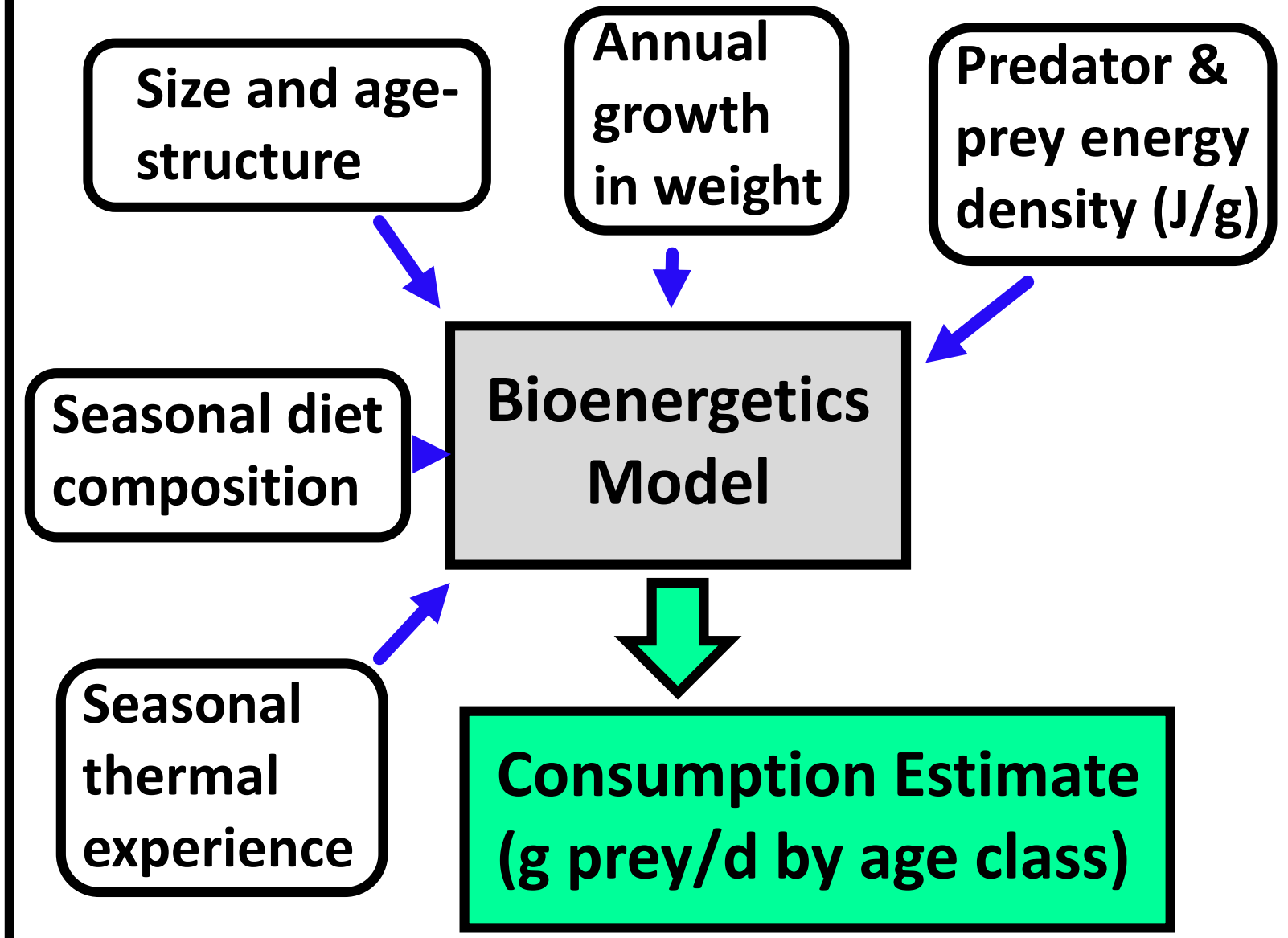
- ❑ Inputs for a bioenergetics model of consumption from directed Field sampling
- ❑ Sample fish within **seasonal**, **depth**, and **size-structured** framework
- ❑ Fish sampling informs:
  - ❖ Abundance, distribution, size-structure
  - ❖ Age, growth, survival
  - ❖ Diet composition
  - ❖ Thermal experience
  - ❖ Food web structure

Matt Polacek, LLRT

Washington Department of FISH and WILDLIFE

Bioenergetics Approach

- Species-specific **thermal responses:** accessible food & habitat, Climate, water mgt.
- Examine the relative importance of thermal regime, food availability & energetic content to **growth of consumers**
- Estimate **Carrying Capacity** for planktivores (kokanee, juvenile & resident salmonids)
- Quantify **Predatory Impacts** on kokanee & other salmonids



Thermal effects on Bioenergetic performance of Species

Differing thermal responses influence Strength of Interactions among species:

-Spatial-temporal overlap

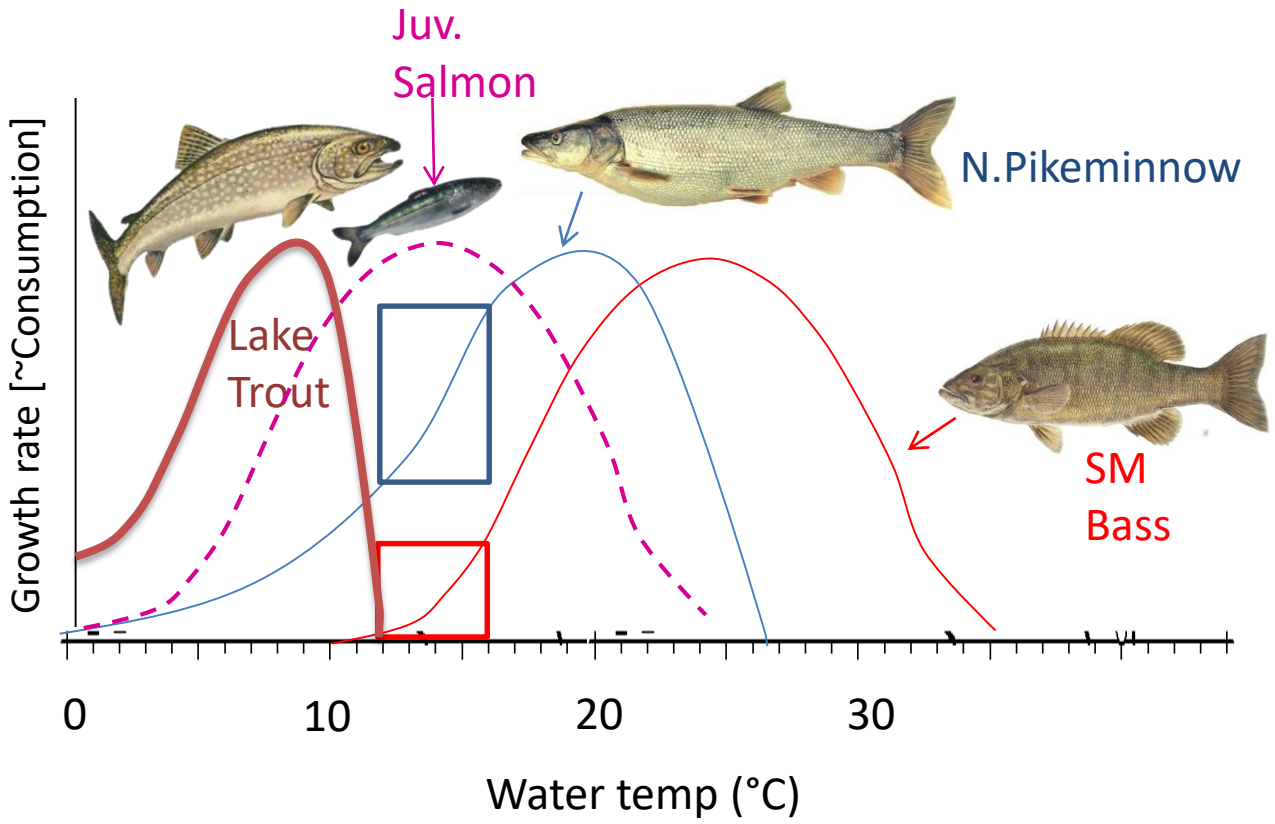
-Production potential/carrying capacity

-Predation potential

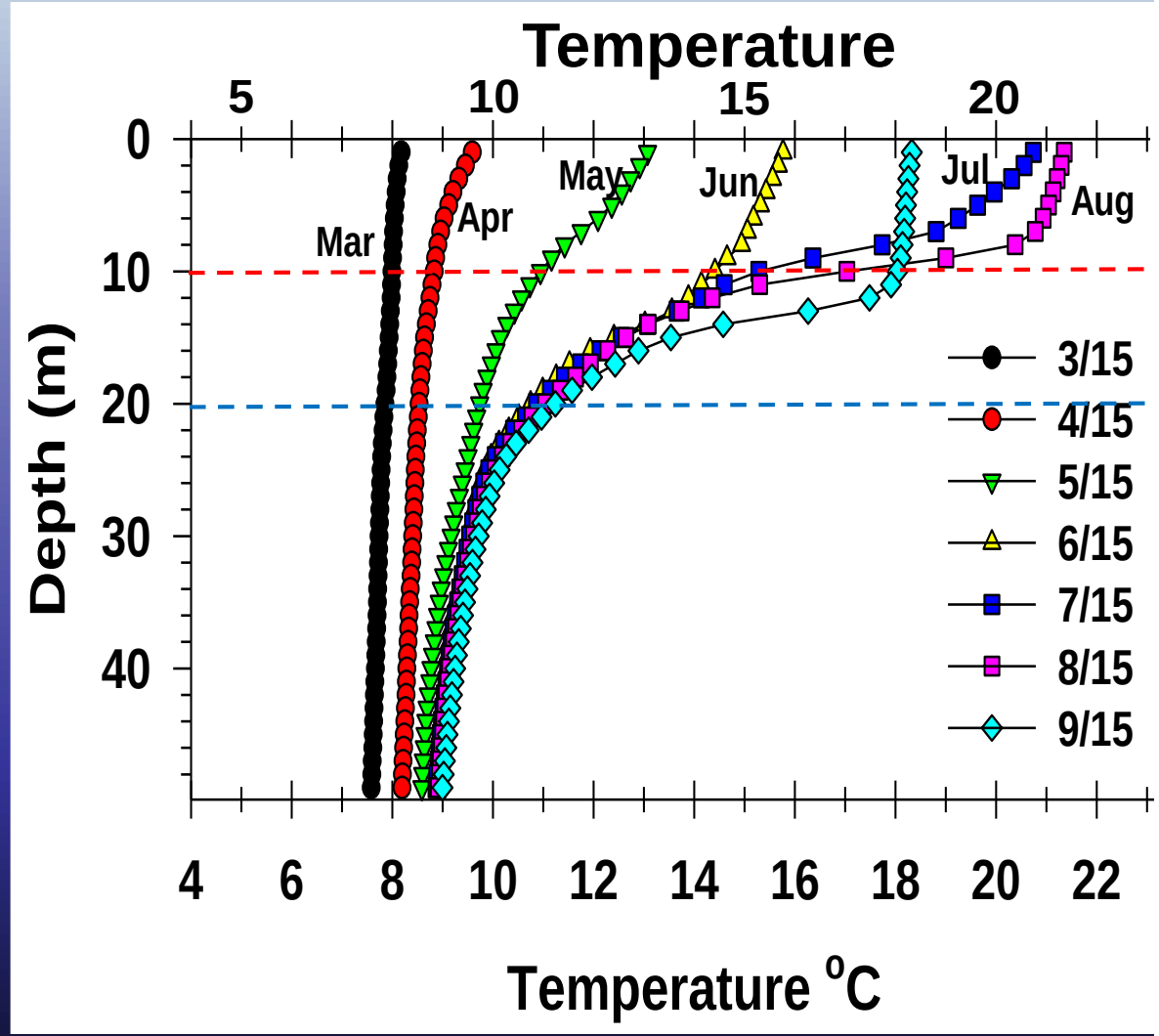
Effects of:

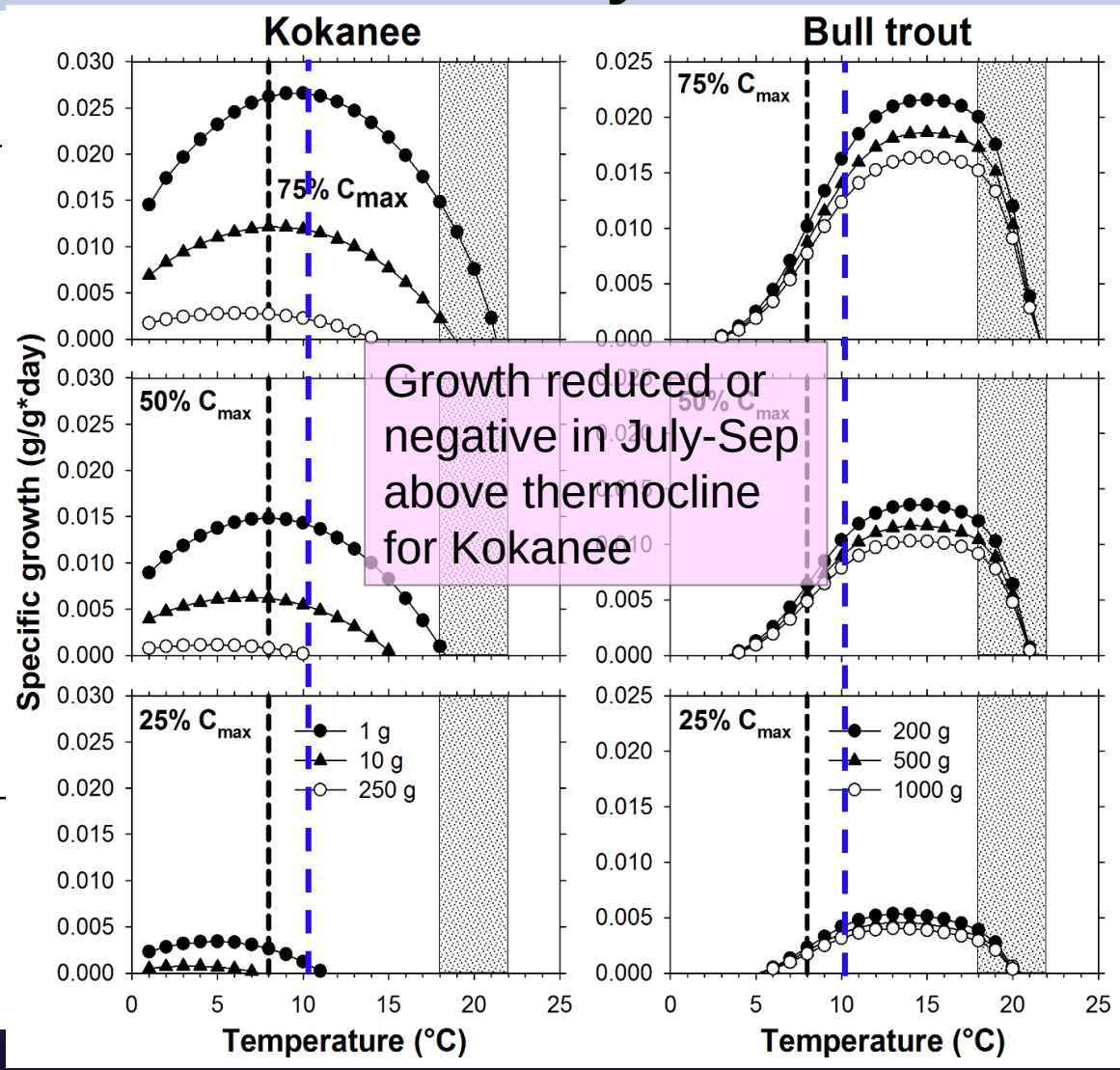
-Seasonal Hydrology

-Thermal Stratification



Thermal Stratification & Food Availability





Trade-off between Thermal Stress & Food Availability

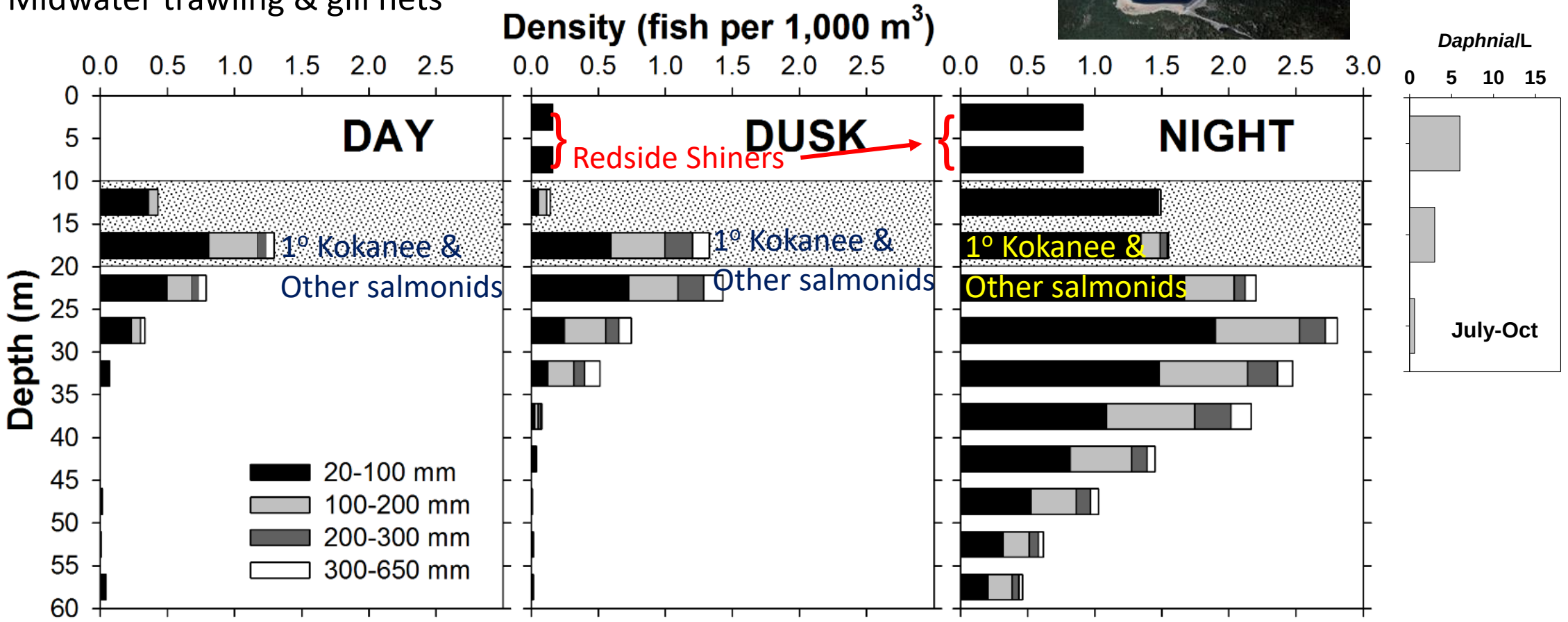
Diel Depth Distribution

Hydroacoustics

Midwater trawling & gill nets

Kachess Lake

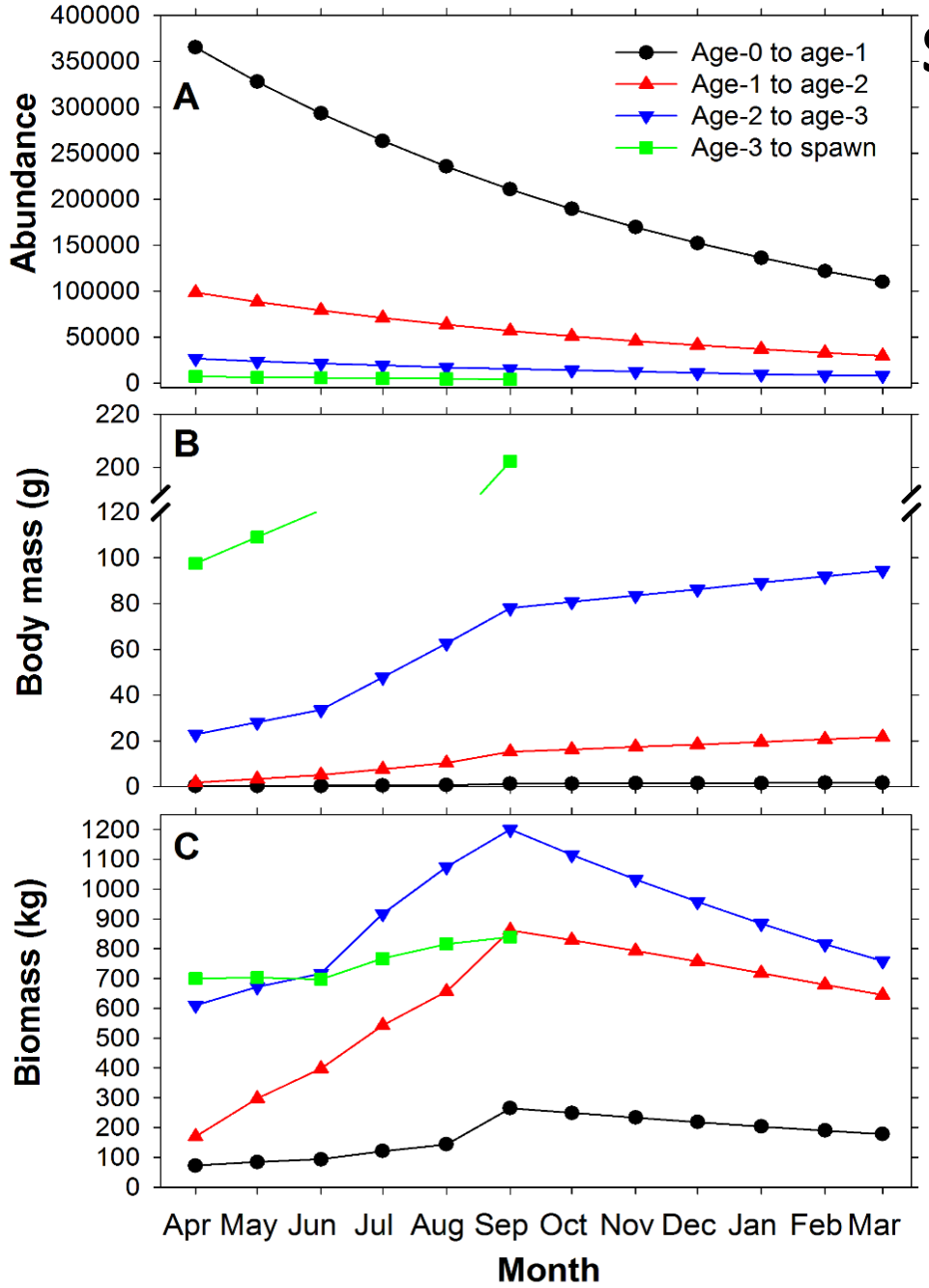
August 2014



Hansen et al. 2015

Kokanee:
Seasonal Dynamics

Abundance, Growth & Biomass



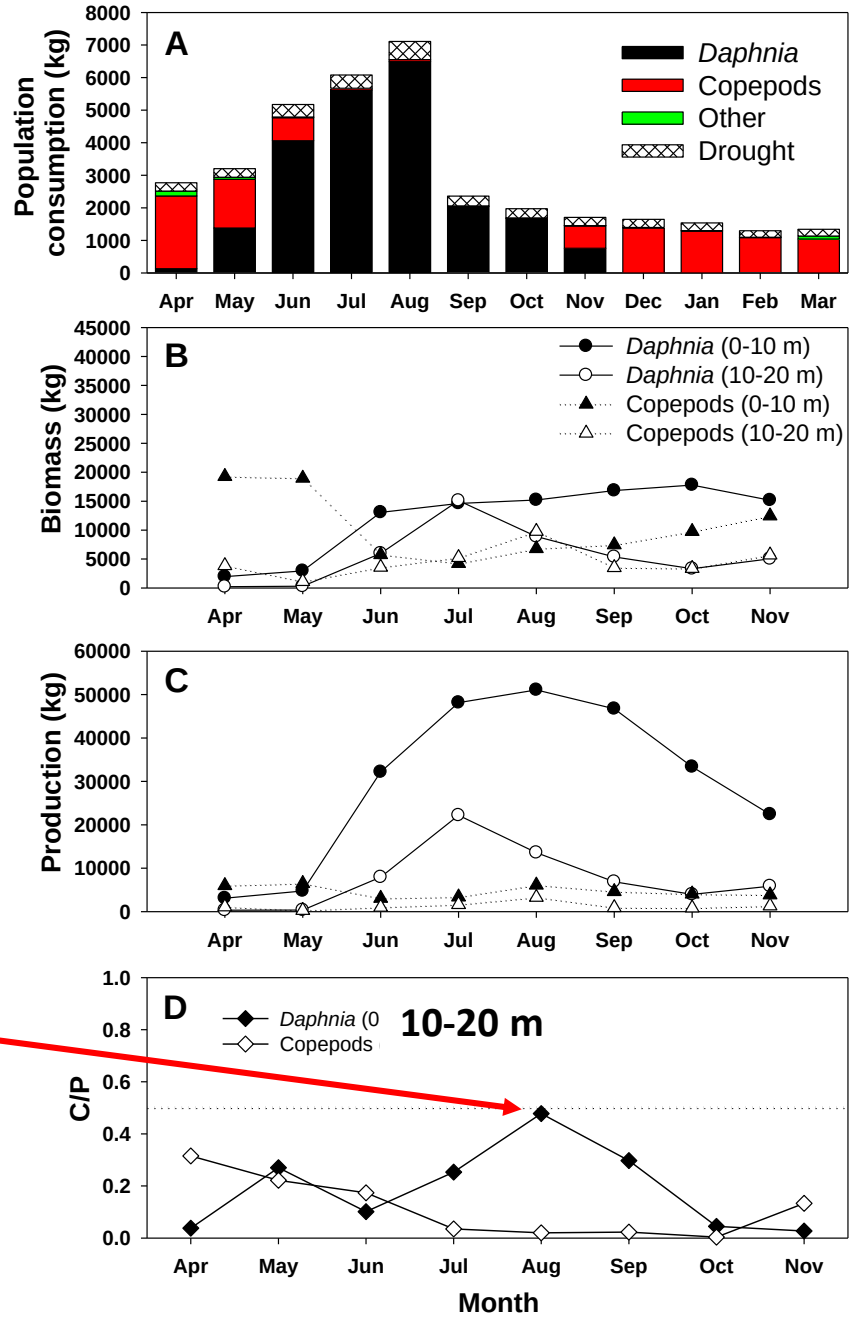
Kokanee Feeding Rates During Summer Growth

>67% Cmax Ages 2-3

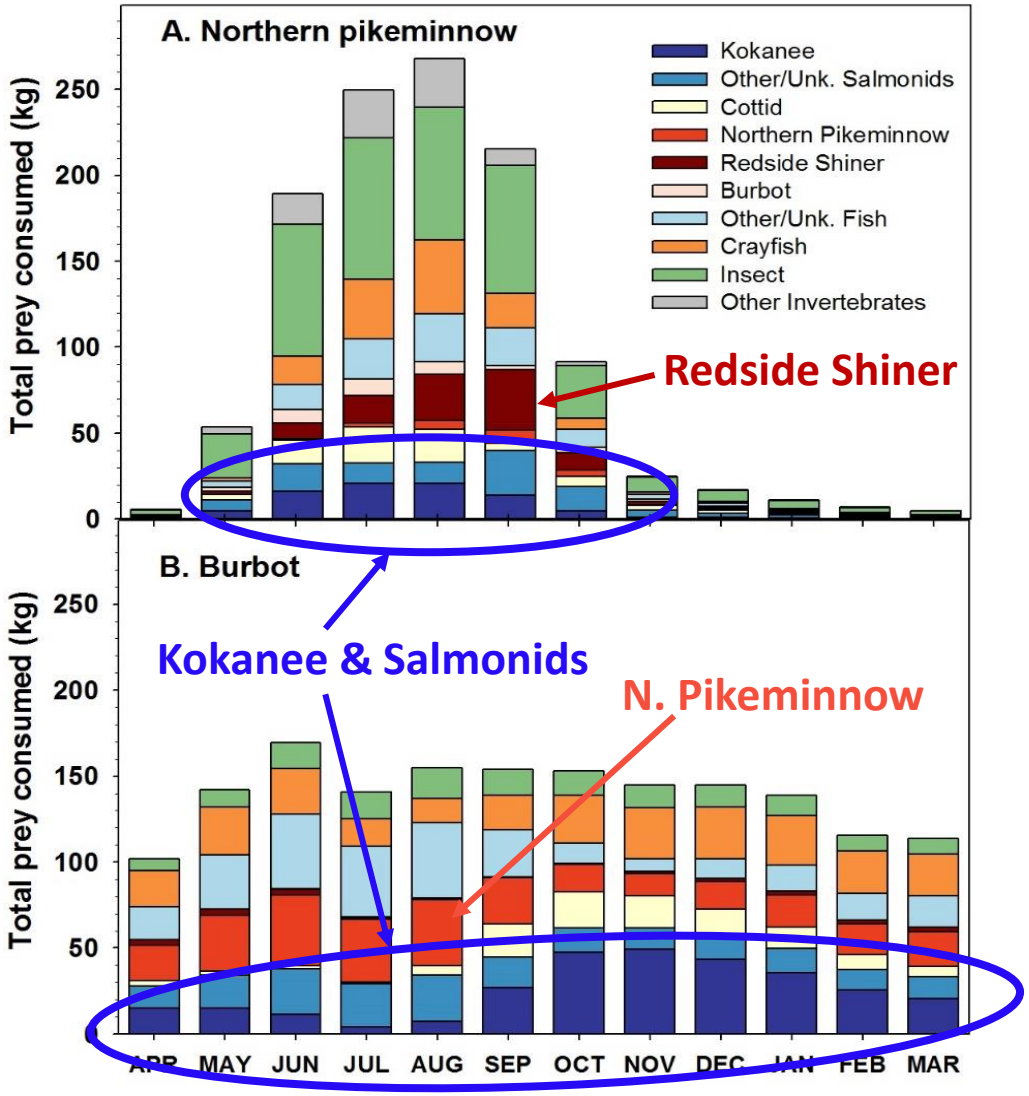
34-66% Cmax Ages 0-1

Food most "Limited" during August ~50% P

Monthly Food Demand and Supply



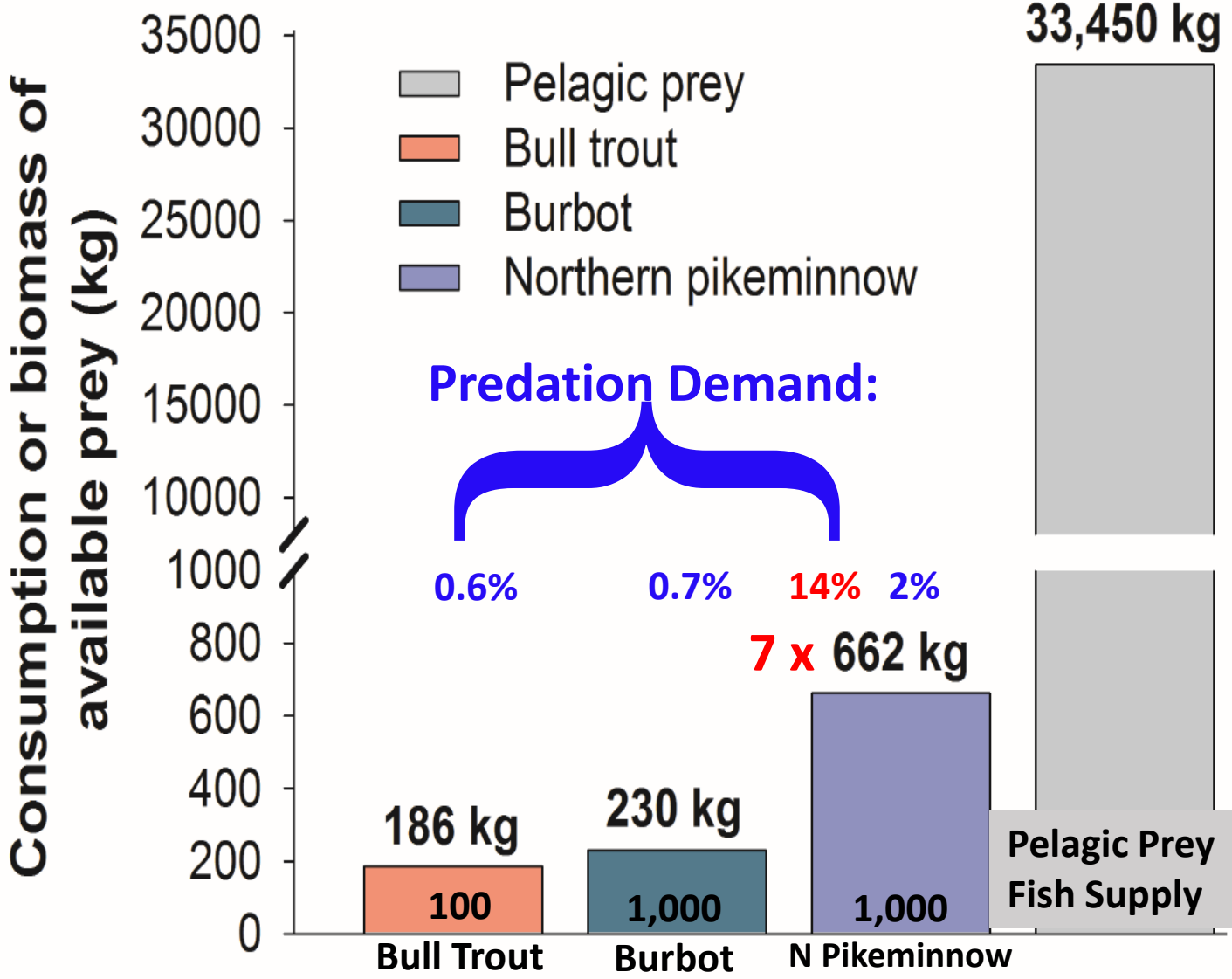
Seasonal predation demand by size-structured populations of 1,000 predators > 200 mm



Predator Abundance remains uncertain:

-This "Standardized Predator Population"

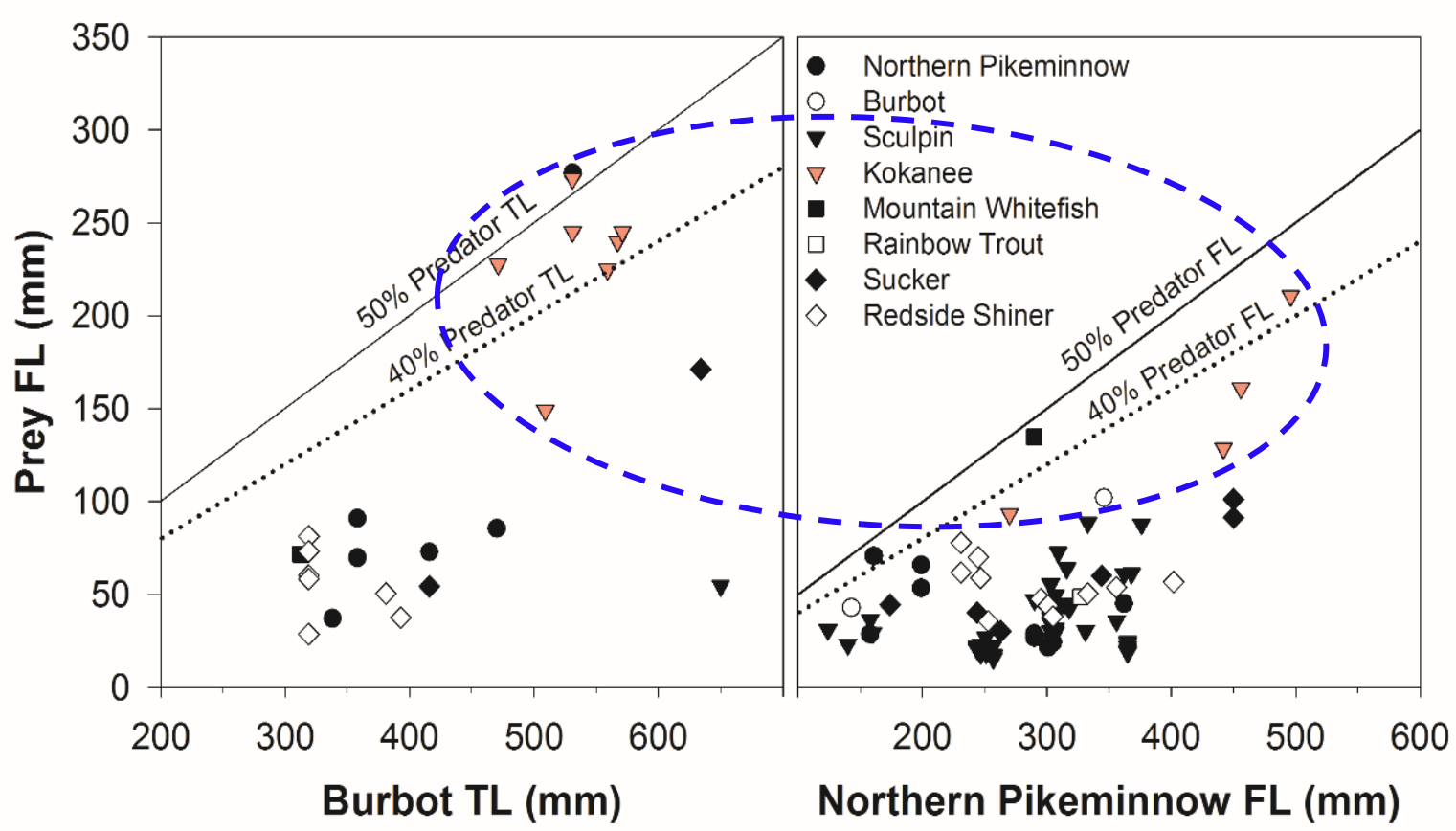
Consumed ~15% of pelagic prey fish community



Summary

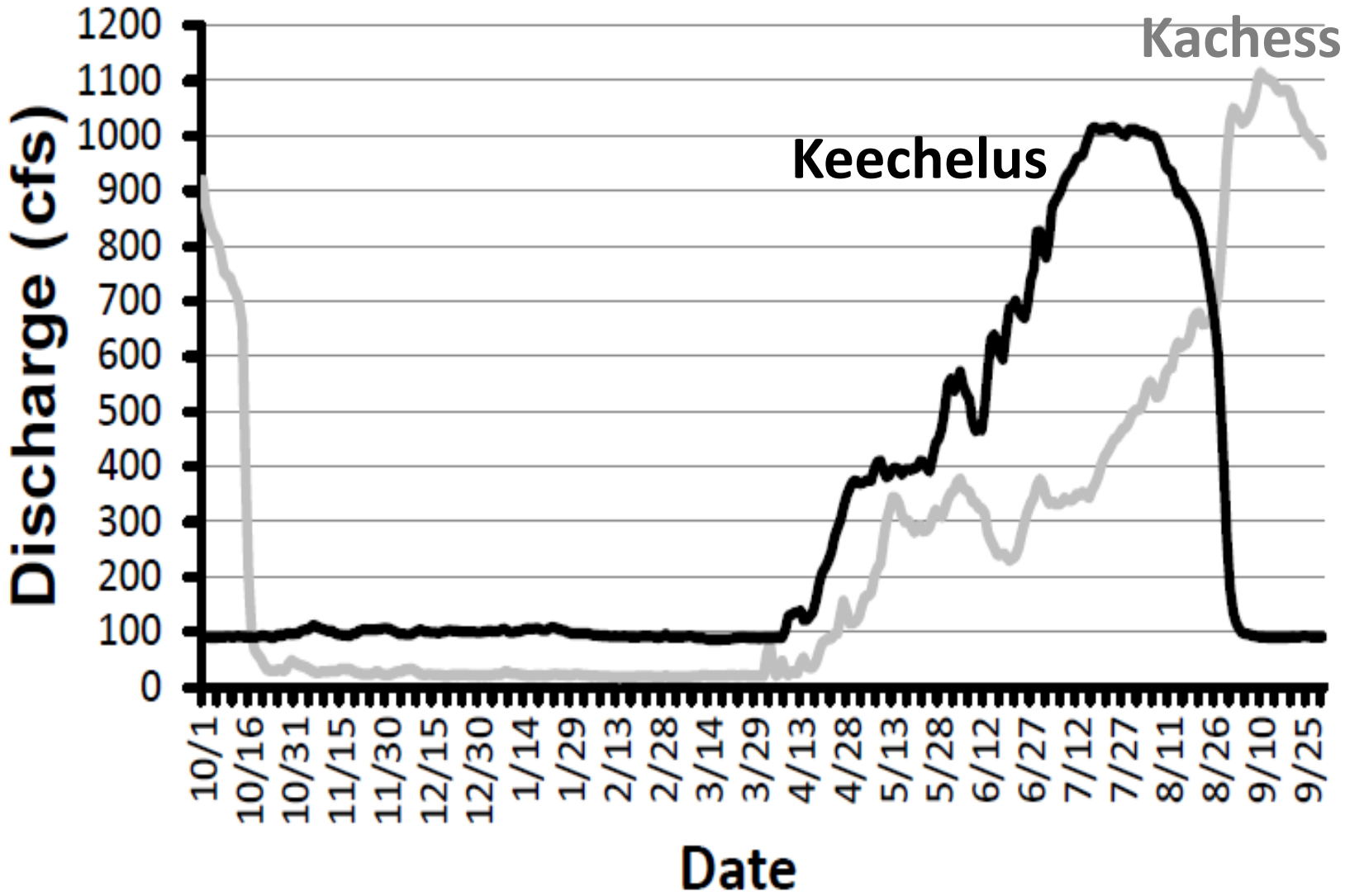
- **Bull Trout abundance very low; Kokanee & other pelagic fishes are their 1º forage base in these reservoirs**
- **Kokanee production limited by low *Daphnia* production [& predation?]**
  - **Hi Temperature prevents access to higher *Daphnia* densities above thermocline**
  - **Feeding bottleneck in August**
  - **Thermal stratification does not segregate kokanee from piscivores**
- **N. Pikeminnow [NPM] & Burbot are more abundant piscivores & compete with Bull trout for prey.**
  - **NPM more abundant & consume the most kokanee, mostly June-Oct**
  - **NPM progressively more piscivorous with increasing size**
  - **NPM also feed heavily on bentho-pelagic fishes (prey buffers for kokanee?)**
    - **Benthic truncation in Keechelus has implications for food web shift in Kachess**
  - **Burbot feed on kokanee throughout the year (heaviest during Fall/Winter)**
  - **Burbot important predators on N. Pikeminnow**

Predator-Prey Size Relationships in Diet Samples

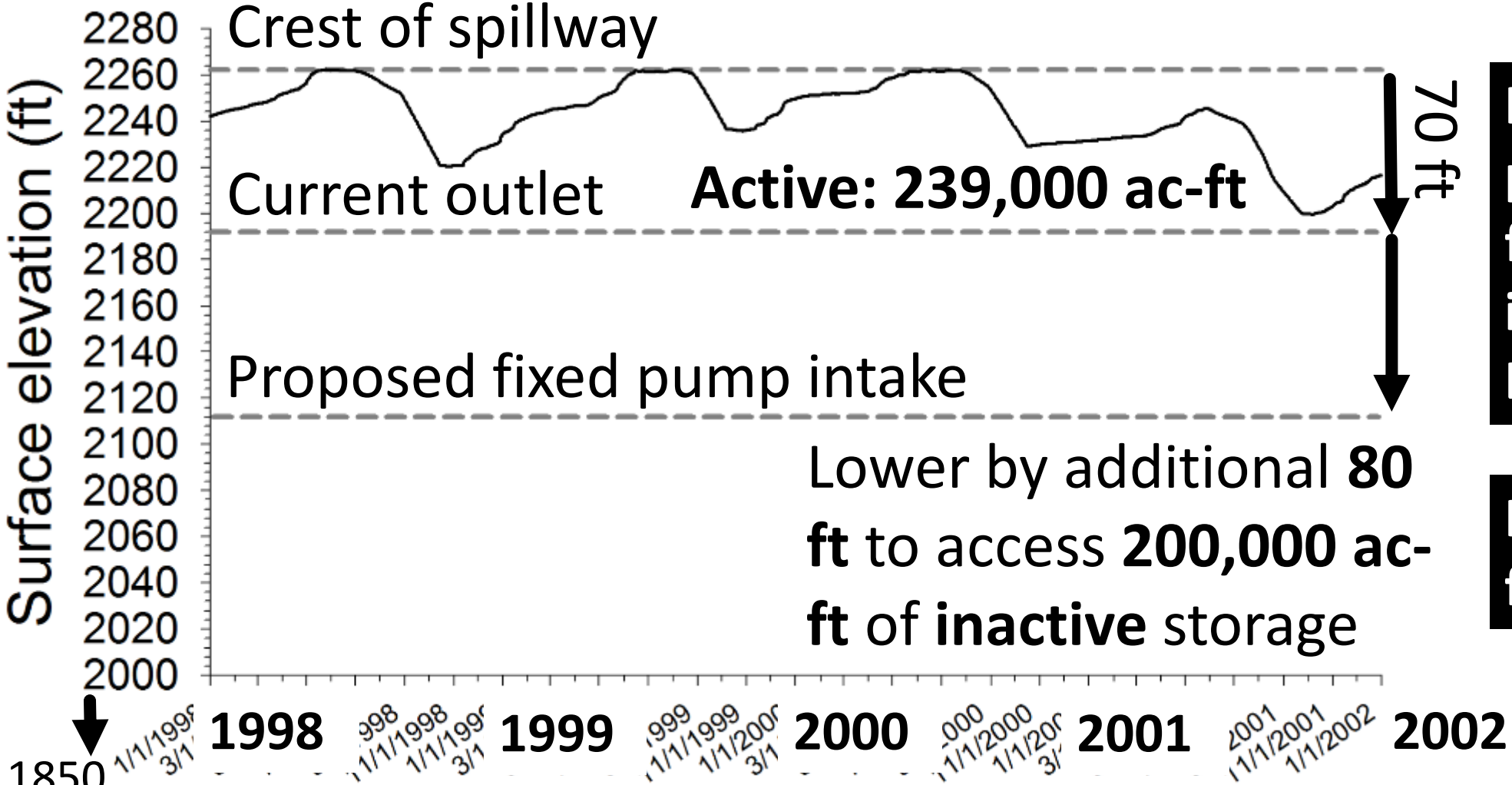


Kokanee Predation:
Mostly age 1-3 kokanee eaten rather than age-0 kokanee
FL > 100 mm

Seasonal Differences in Discharge from Reservoirs



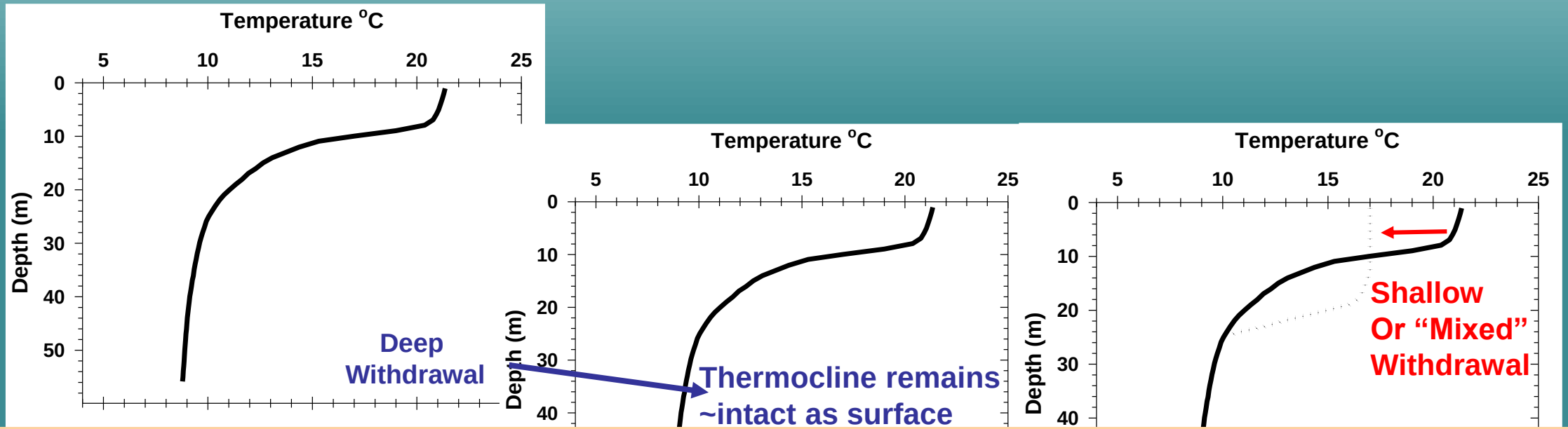
Kachess Drought Relief Pumping Plant (Fixed or Floating Barge)



How will pumping affect food web interactions in Lake Kachess?

Implications for bull trout?

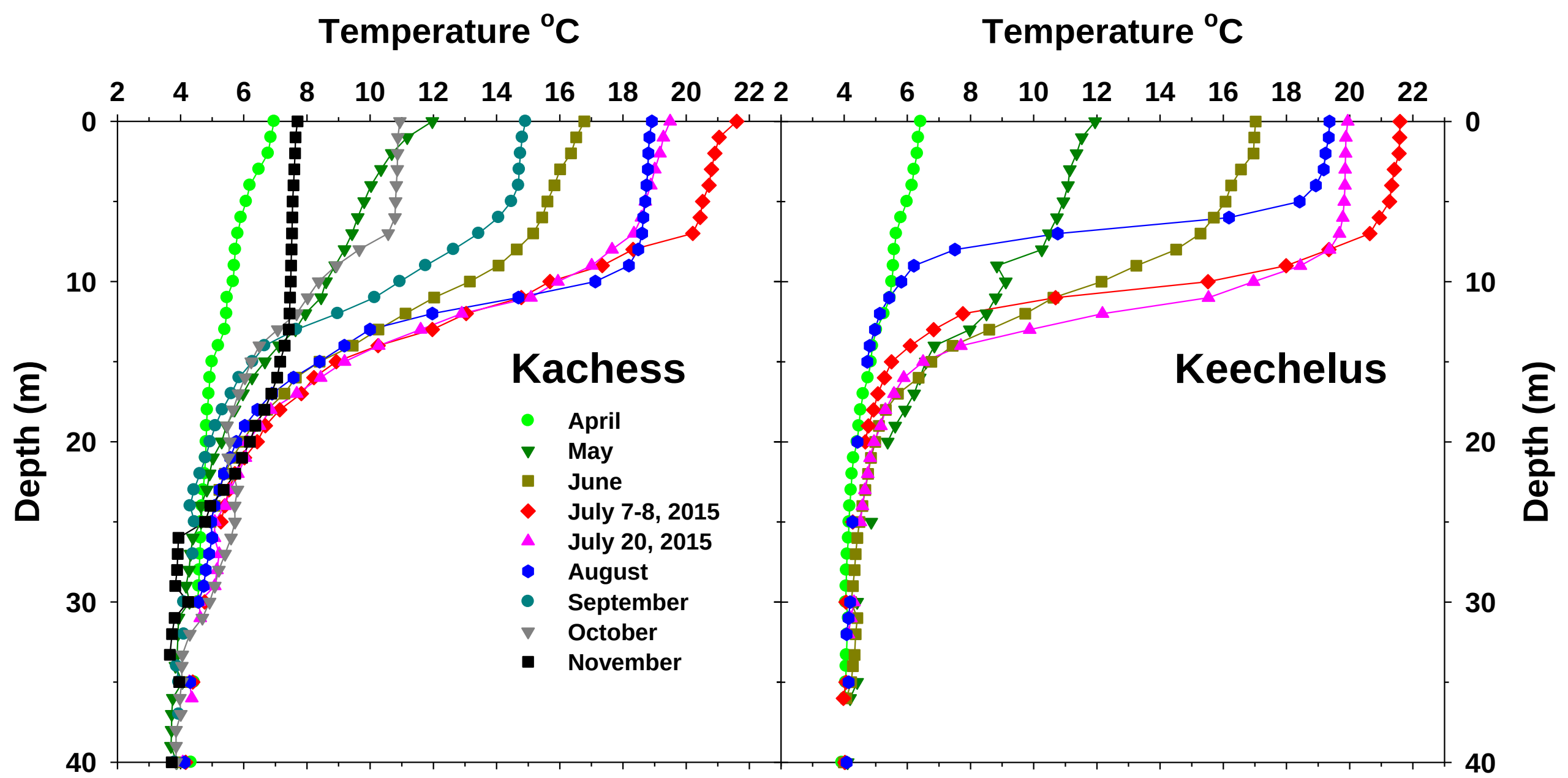
Water Withdrawal Depth & Stratification



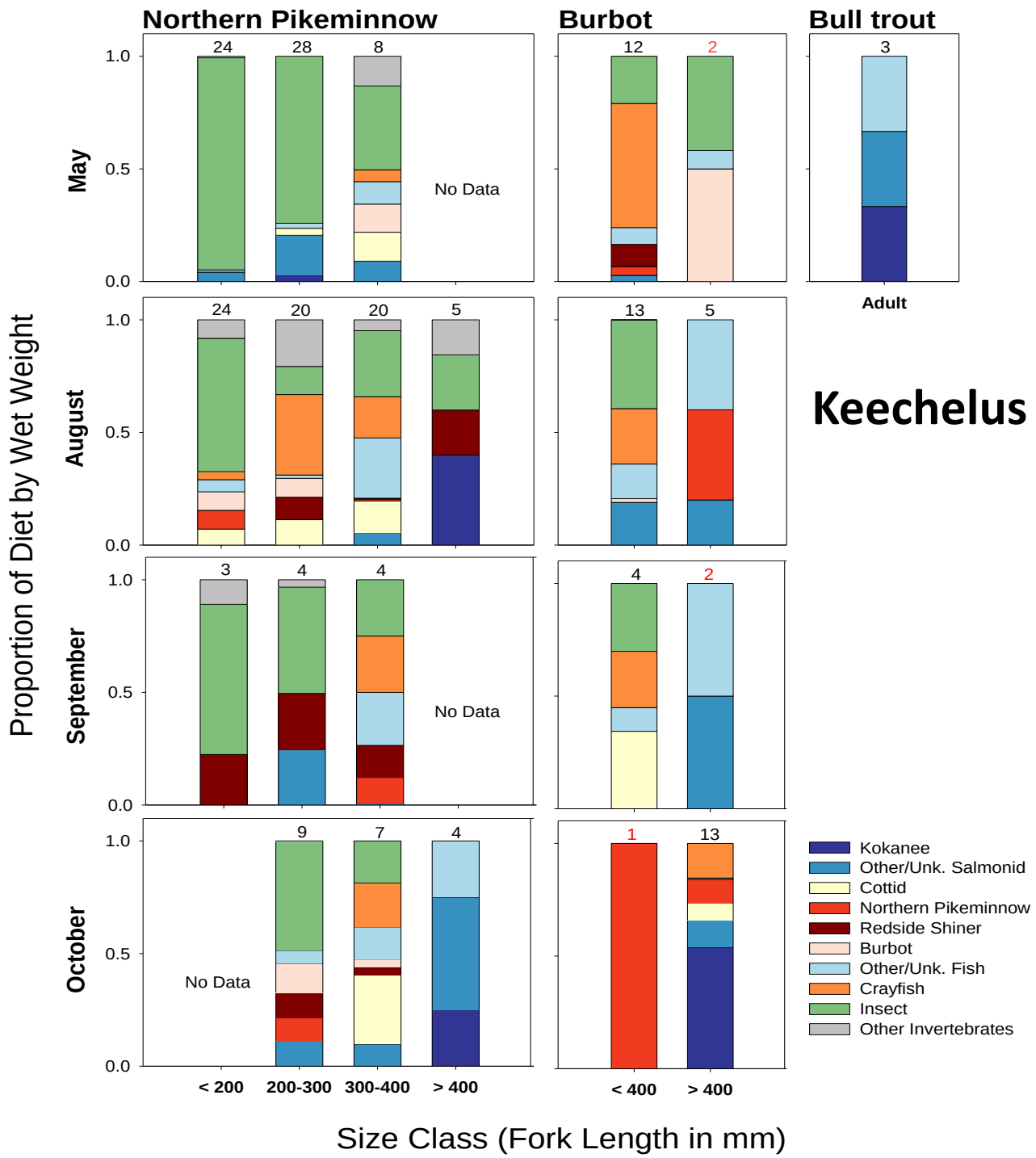
Reservoir bottom

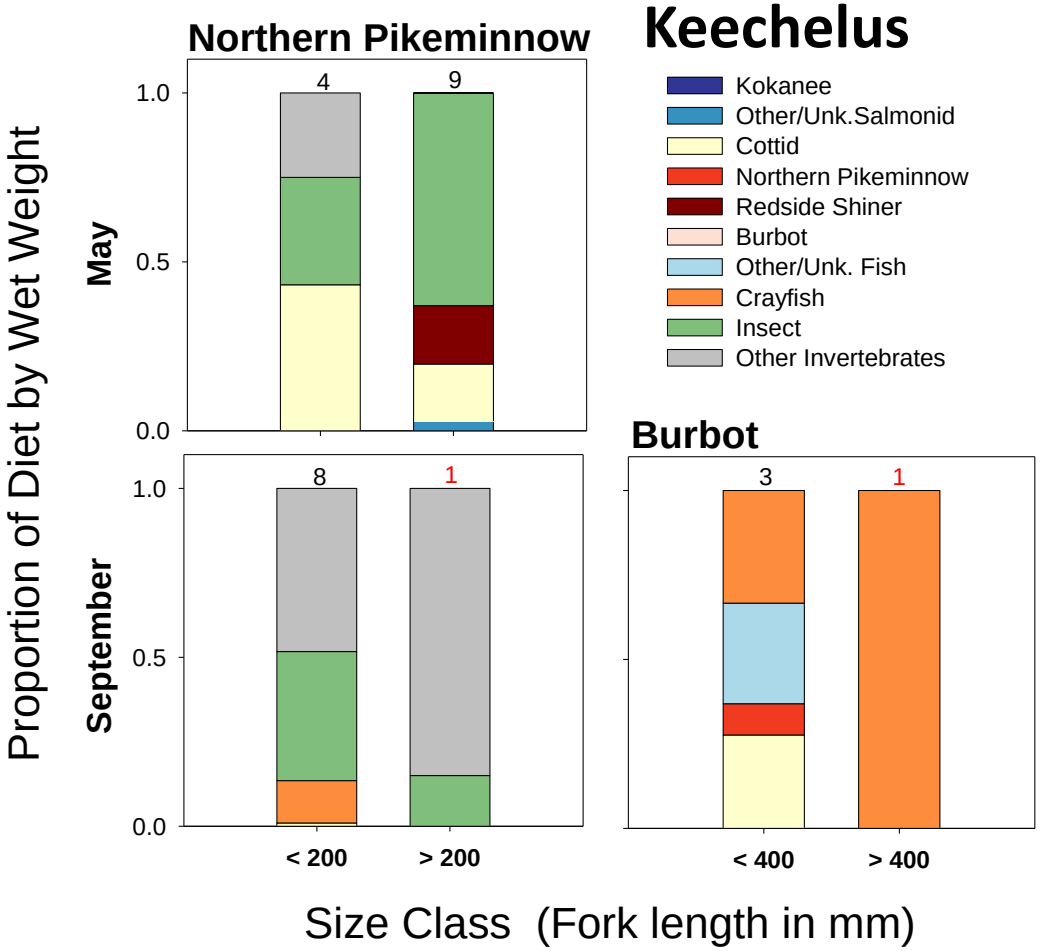
Epilimnion becomes cooler & Deeper
Potentially allowing salmonids access
To epilimnion
But-could also increase overlap with Predators

Link hydrodynamic & ecological models


Temperature °C
Temperature °C
2
4
6
8
10
12
14
16
18
20
22
0
10
20
30
40
Depth (m)
Depth (m)
Kachess
Keechelus
April
May
June
July 7-8, 2015
July 20, 2015
August
September
October
November

Predator Seasonal Size-based Diet Composition





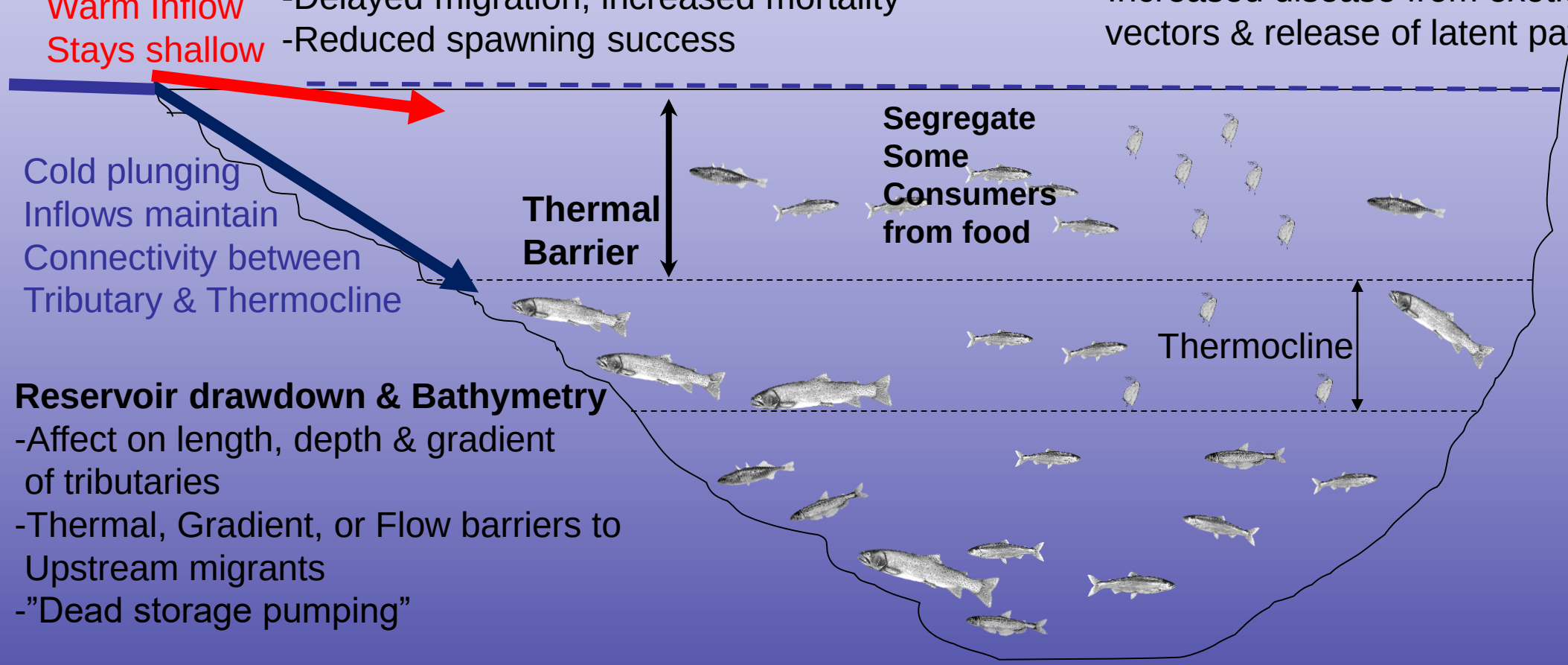
Lakes & Reservoirs as Coldwater Refuges

- **Thermal Stratification influences depth distribution & metabolism of Plankton, Planktivores & Piscivores**
  - **Creates trade-offs: Thermal growth responses vs Food supply**
  - **Food availability influences thermal tolerance & spatial distributions of species and life stages within species**
  - **Stratification can concentrate or segregate predators & prey**
  - **Magnitude & duration of stratification can affect food web interactions & community structure**
  - **Seasonal accessibility to essential habitats & Life history connectivity (food, spawning, juvenile rearing & migration)**
- **Climate Change & Reservoir operations matter:**
  - **Withdrawal timing, location & magnitude could be managed to maintain or disrupt trophic interactions among species and growth performance**

Climate Warming

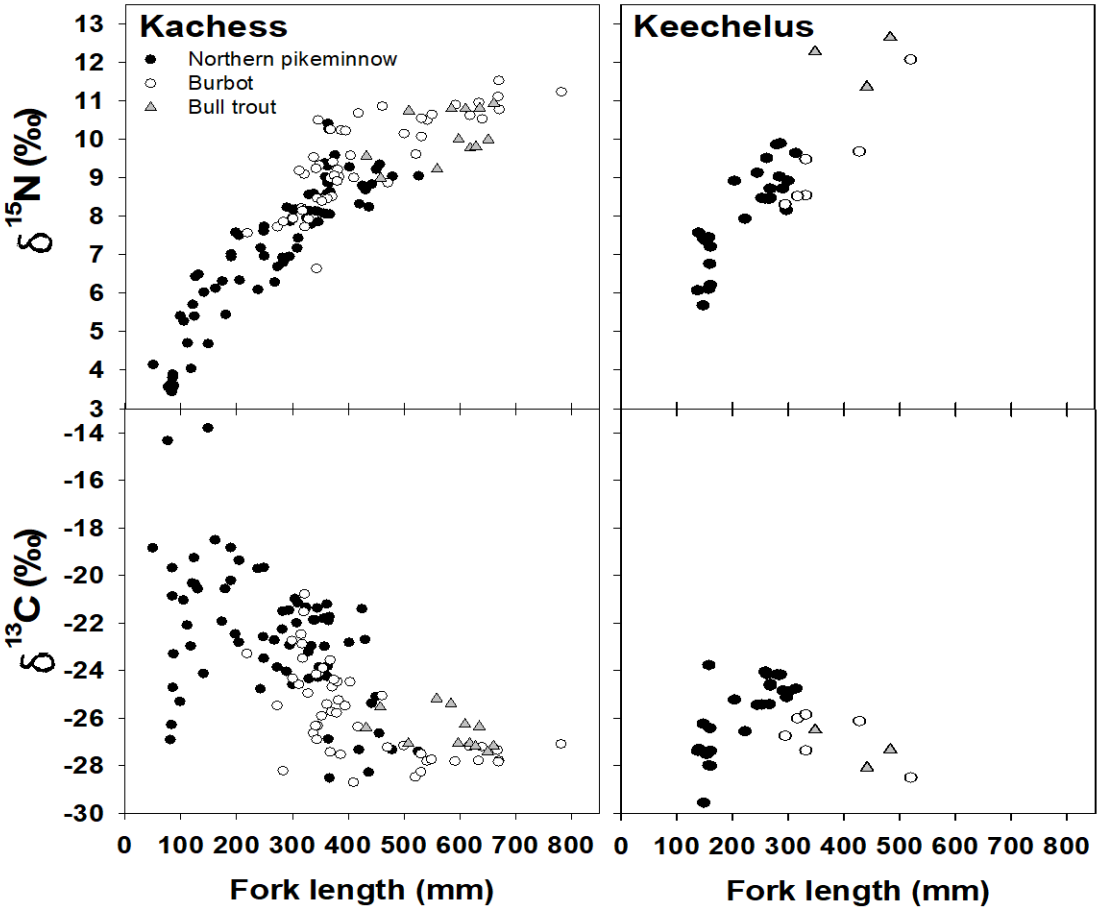
-Thermal stratification intensifies
-Surface layer warms
-**Thermal barrier to juvenile or adult migration**
-Delayed migration, increased mortality
-Reduced spawning success

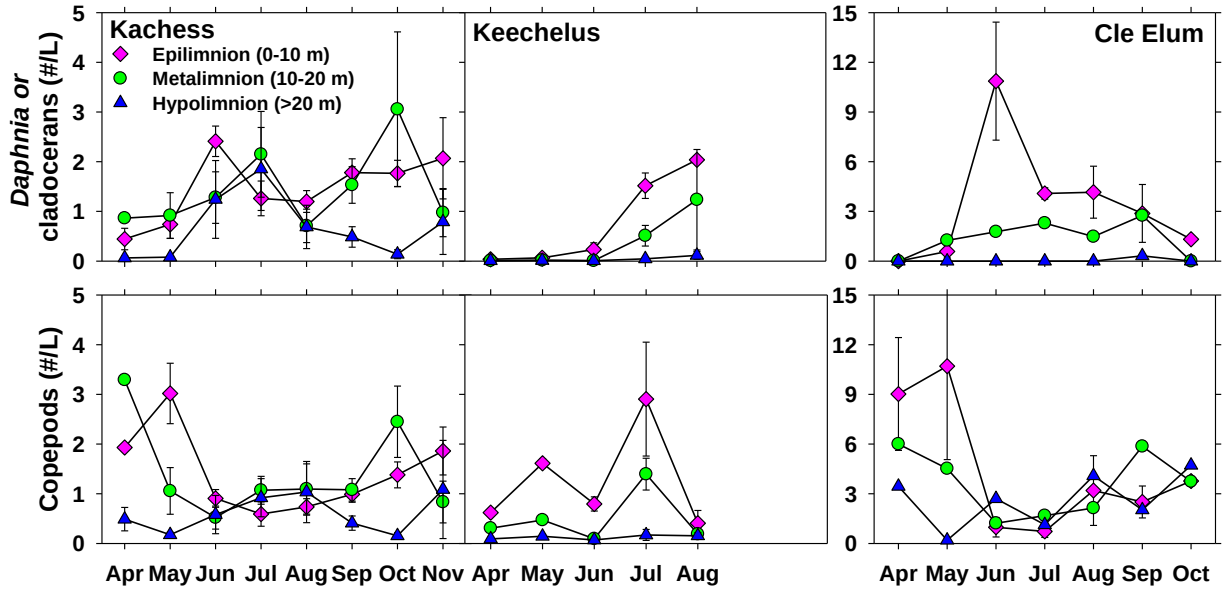
-Extended Growing season for some species
-Non-native warmwater fish & inverts become more productive
-Increased disease from exotic vectors & release of latent pathogens

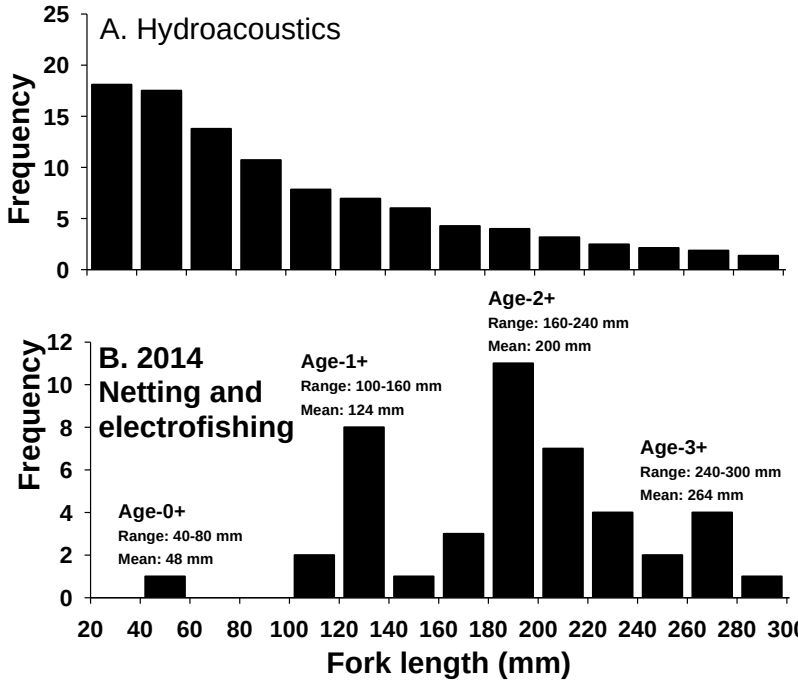


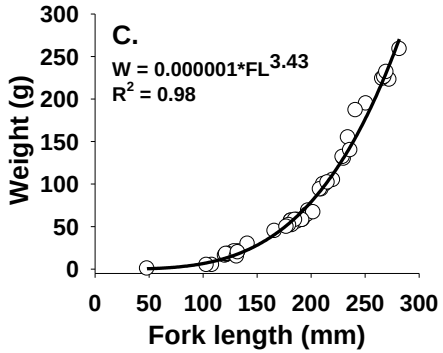
Reservoir drawdown & Bathymetry

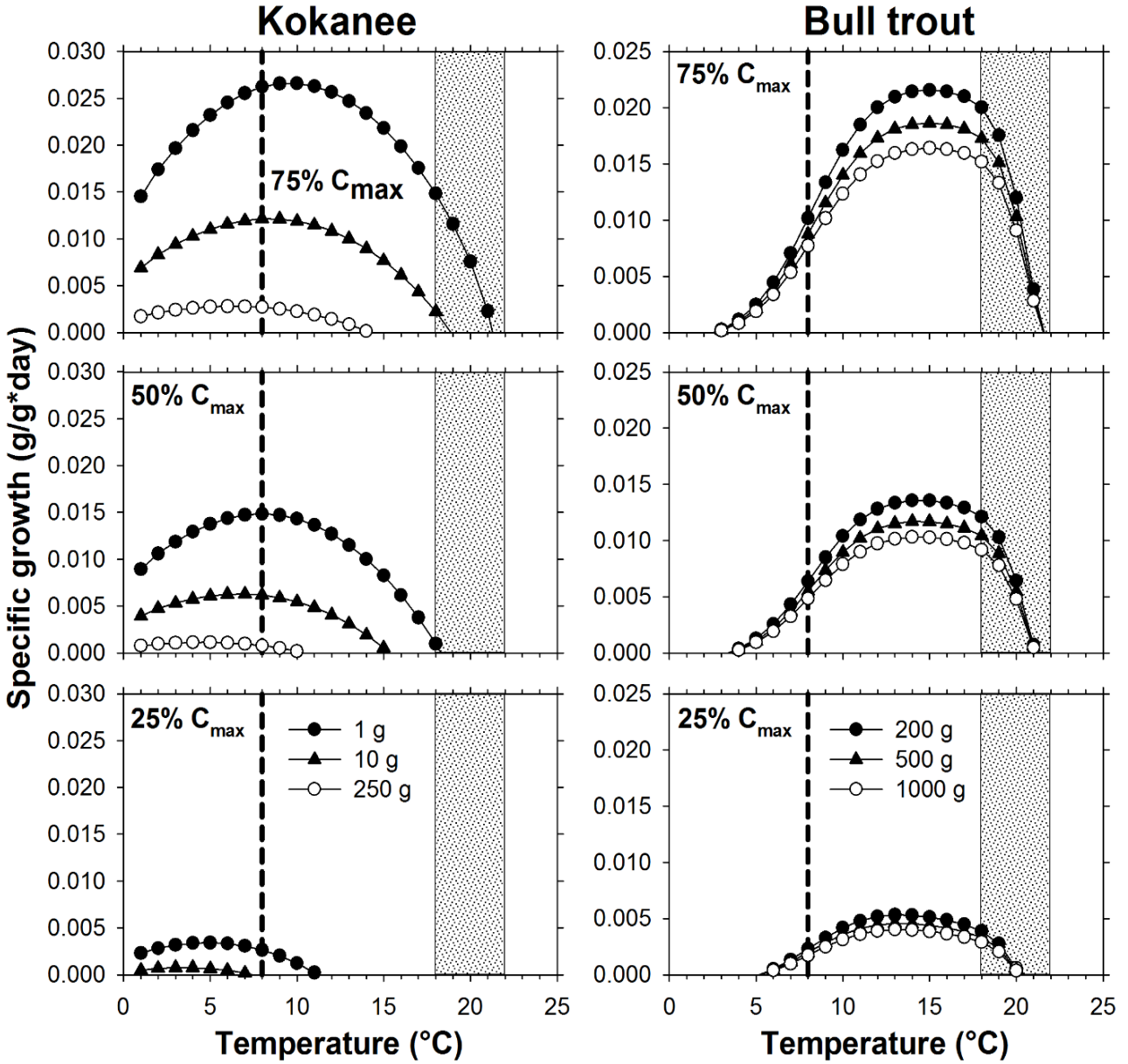
-Affect on length, depth & gradient of tributaries
-Thermal, Gradient, or Flow barriers to Upstream migrants
-"Dead storage pumping"

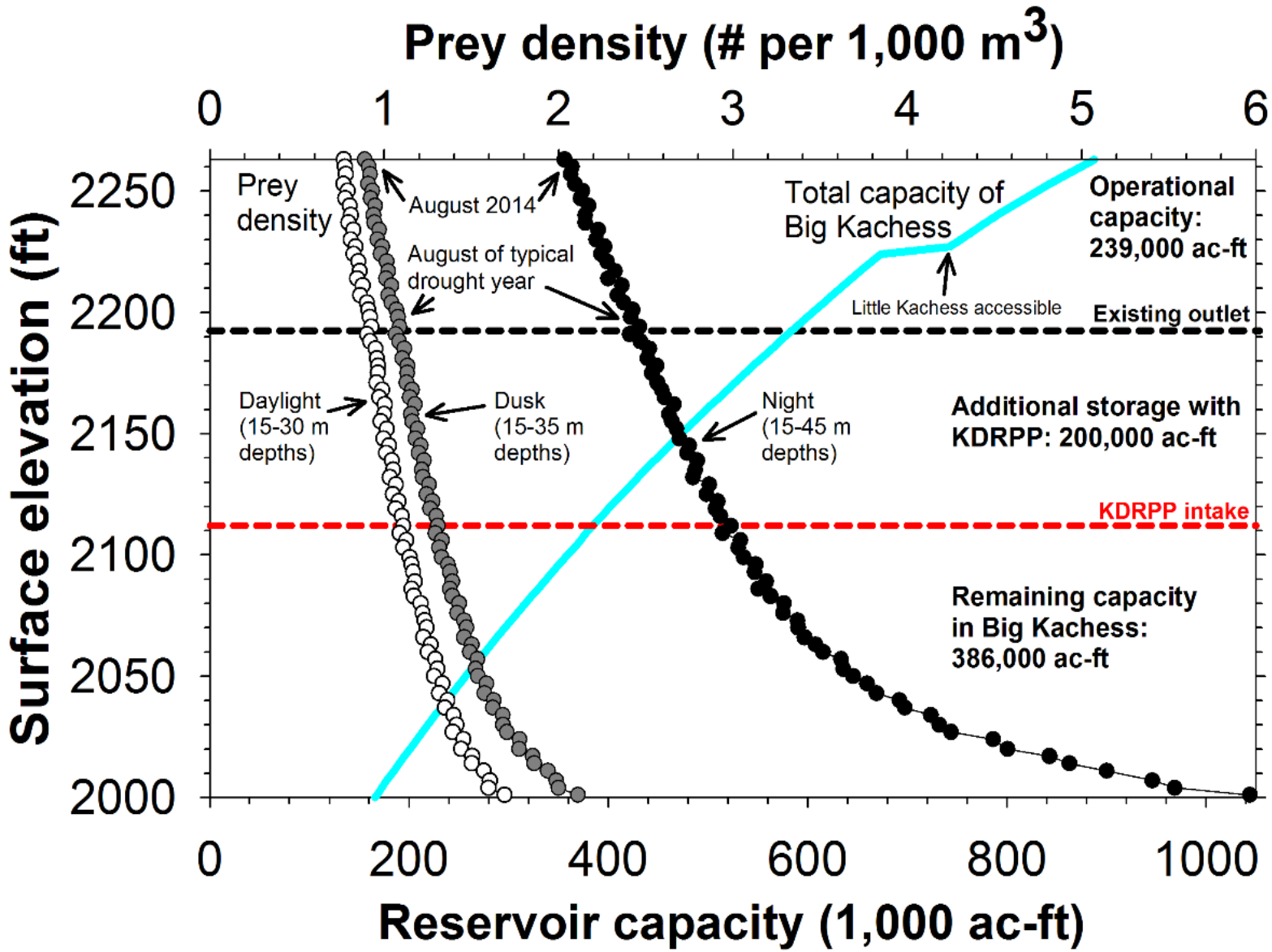

Kachess
Keechelus
Northern pikeminnow
Burbot
Bull trout
δ15N (‰)
δ13C (‰)
Fork length (mm)
Fork length (mm)


Kachess
Epilimnion (0-10 m)
Metalimnion (10-20 m)
Hypolimnion (>20 m)
Keechelus
Cle Elum
Daphnia or cladocerans (#/L)
Copepods (#/L)
Apr May Jun Jul Aug Sep Oct Nov
Apr May Jun Jul Aug
Apr May Jun Jul Aug Sep Oct


A. Hydroacoustics
Frequency
B. 2014 Netting and electrofishing
Age-0+
Range: 40-80 mm
Mean: 48 mm
Age-1+
Range: 100-160 mm
Mean: 124 mm
Age-2+
Range: 160-240 mm
Mean: 200 mm
Age-3+
Range: 240-300 mm
Mean: 264 mm
Fork length (mm)


C.
W = 0.000001*FL3.43
R2 = 0.98
Weight (g)
Fork length (mm)

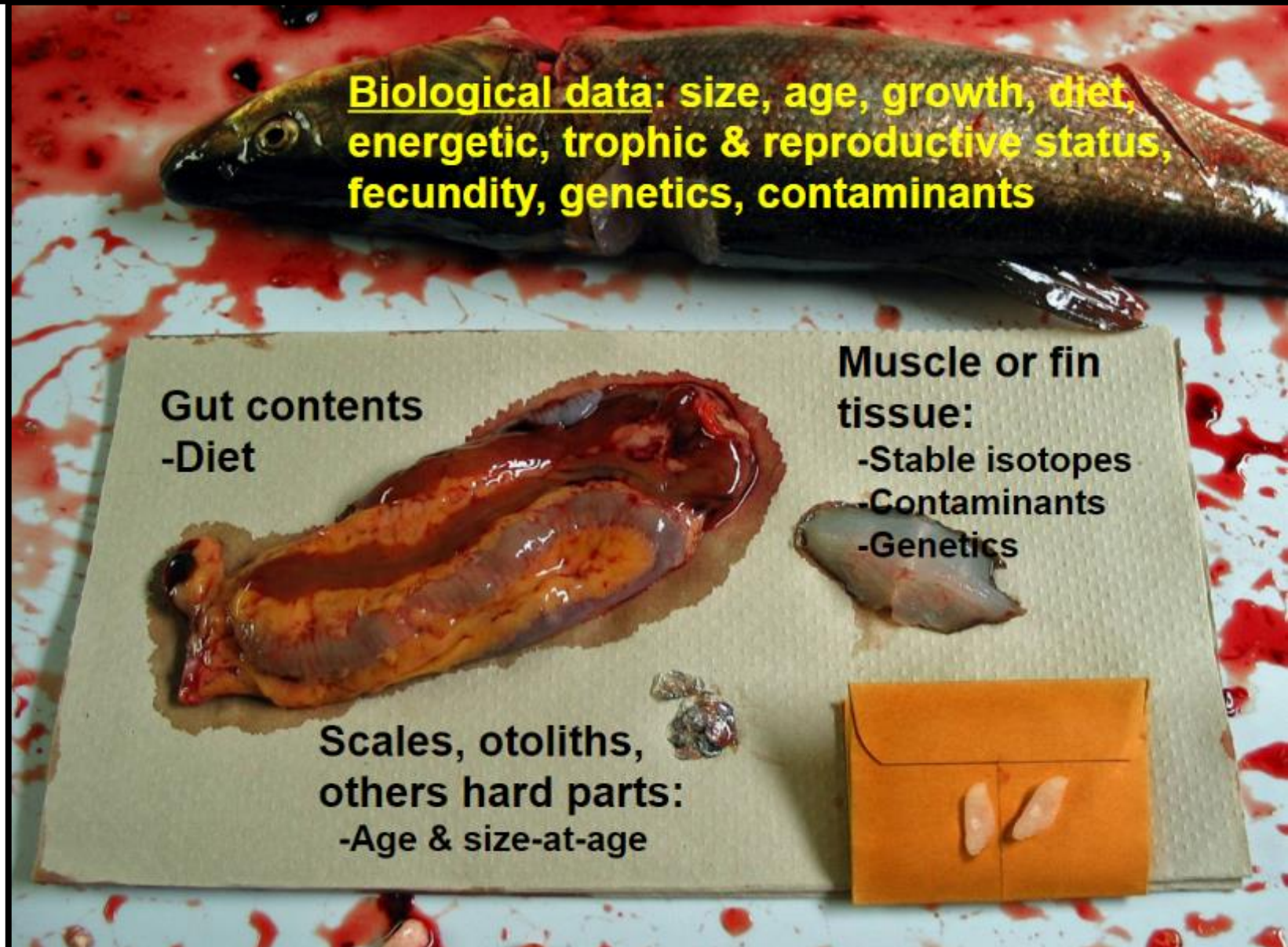

Kokanee
Bull trout
75% Cmax
50% Cmax
25% Cmax
1 g
10 g
250 g
200 g
500 g
1000 g
Specific growth (g/g*day)
Temperature (°C)


Prey density (# per 1,000 m3)
0
1
2
3
4
5
6
Surface elevation (ft)
2250
2200
2150
2100
2050
2000
Prey density
August 2014
August of typical drought year
Total capacity of Big Kachess
Operational capacity: 239,000 ac-ft
Little Kachess accessible
Existing outlet
Daylight (15-30 m depths)
Dusk (15-35 m depths)
Night (15-45 m depths)
Additional storage with KDRPP: 200,000 ac-ft
KDRPP intake
Remaining capacity in Big Kachess: 386,000 ac-ft
0
200
400
600
800
1000
Reservoir capacity (1,000 ac-ft)

Bioenergetics Approach

- Collect fish samples within a **seasonal**, **depth**, and **size-structured** framework

- Fish sampling informs:
  - Abundance, distribution, size-structure
  - Age, growth, survival
  - Diet composition
  - Thermal experience
  - Food web structure



Bioenergetics Approach

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- Fish samples inform:
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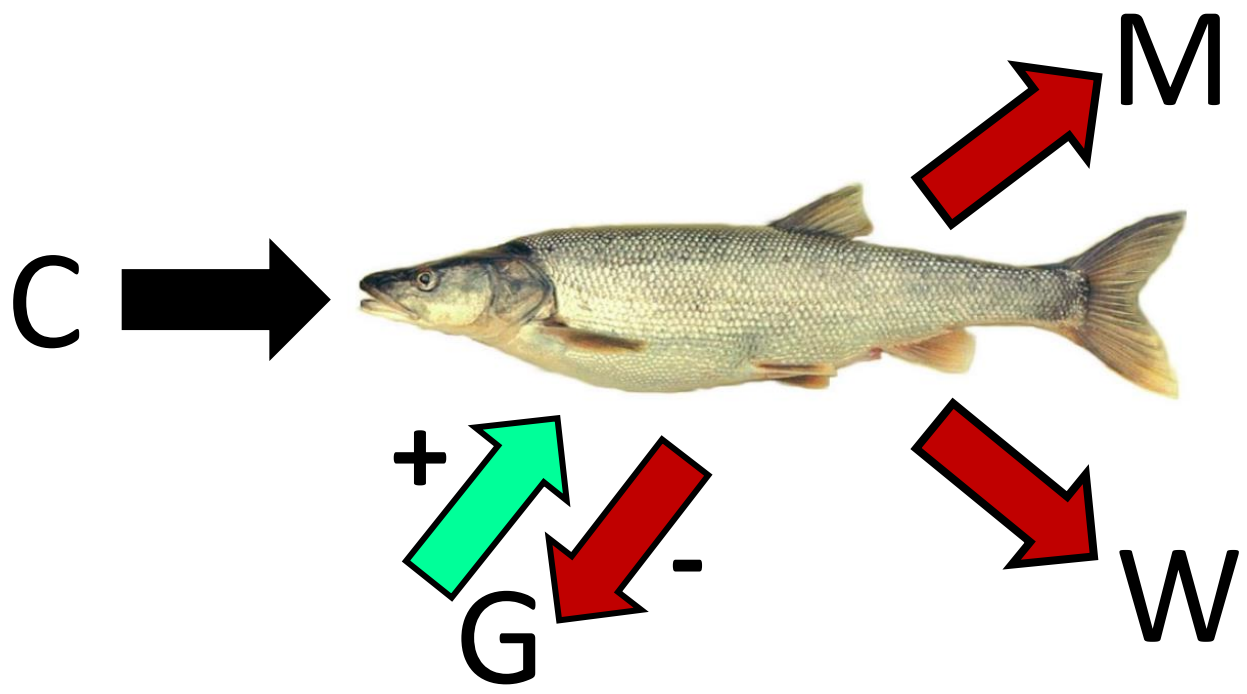
  - Food web structure

- Inputs for a bioenergetics model of consumption

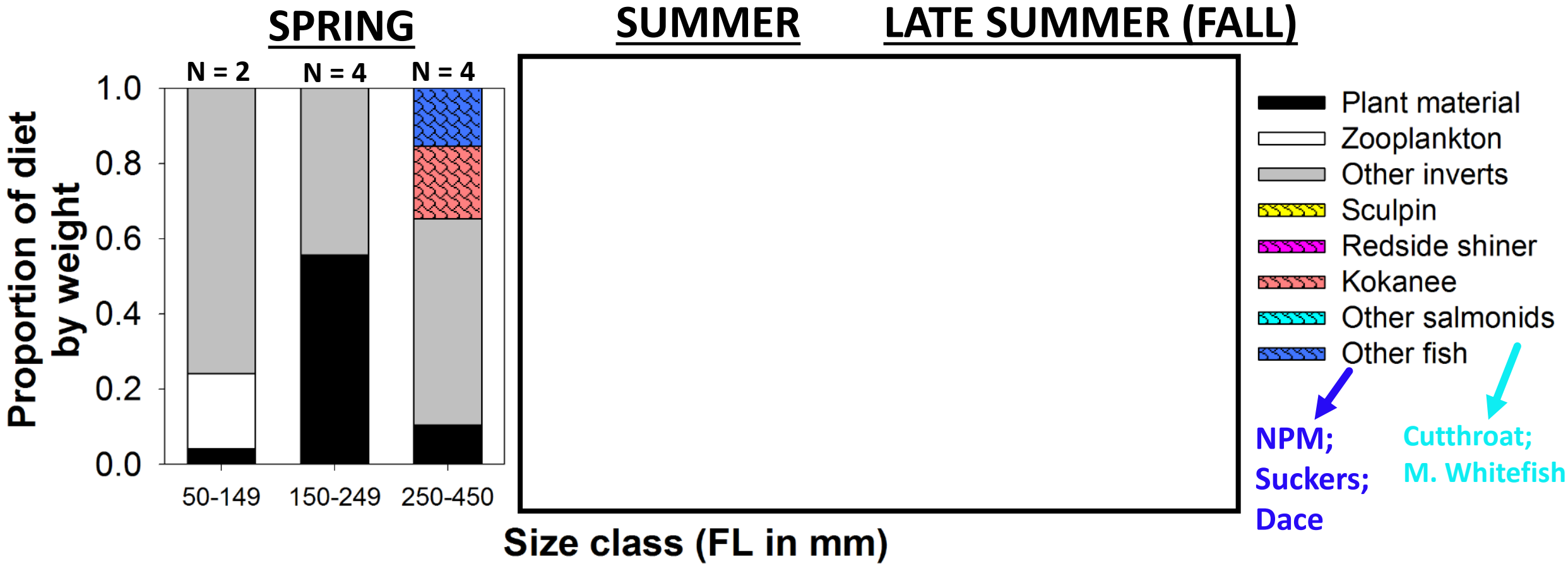
Consumption = **M**etabolism + **W**aste + **G**rowth (in weight)



Dependent on temperature and body size

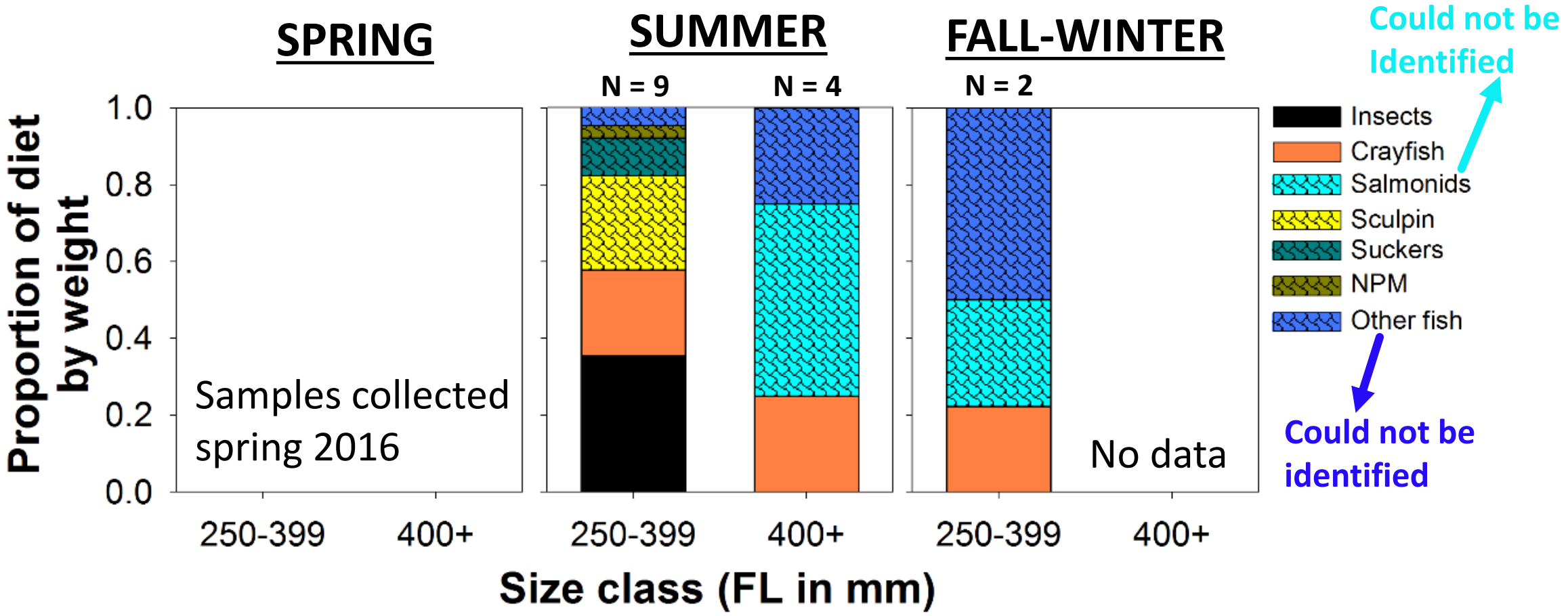
Seasonal Diet Composition: **NPM**

- ❑ Diet varied by size and season (fish: 22-75% of diet)
- ❑ Predation on kokanee by large NPM: spring & summer (8-19%)
- ❑ No pygmy whitefish detected

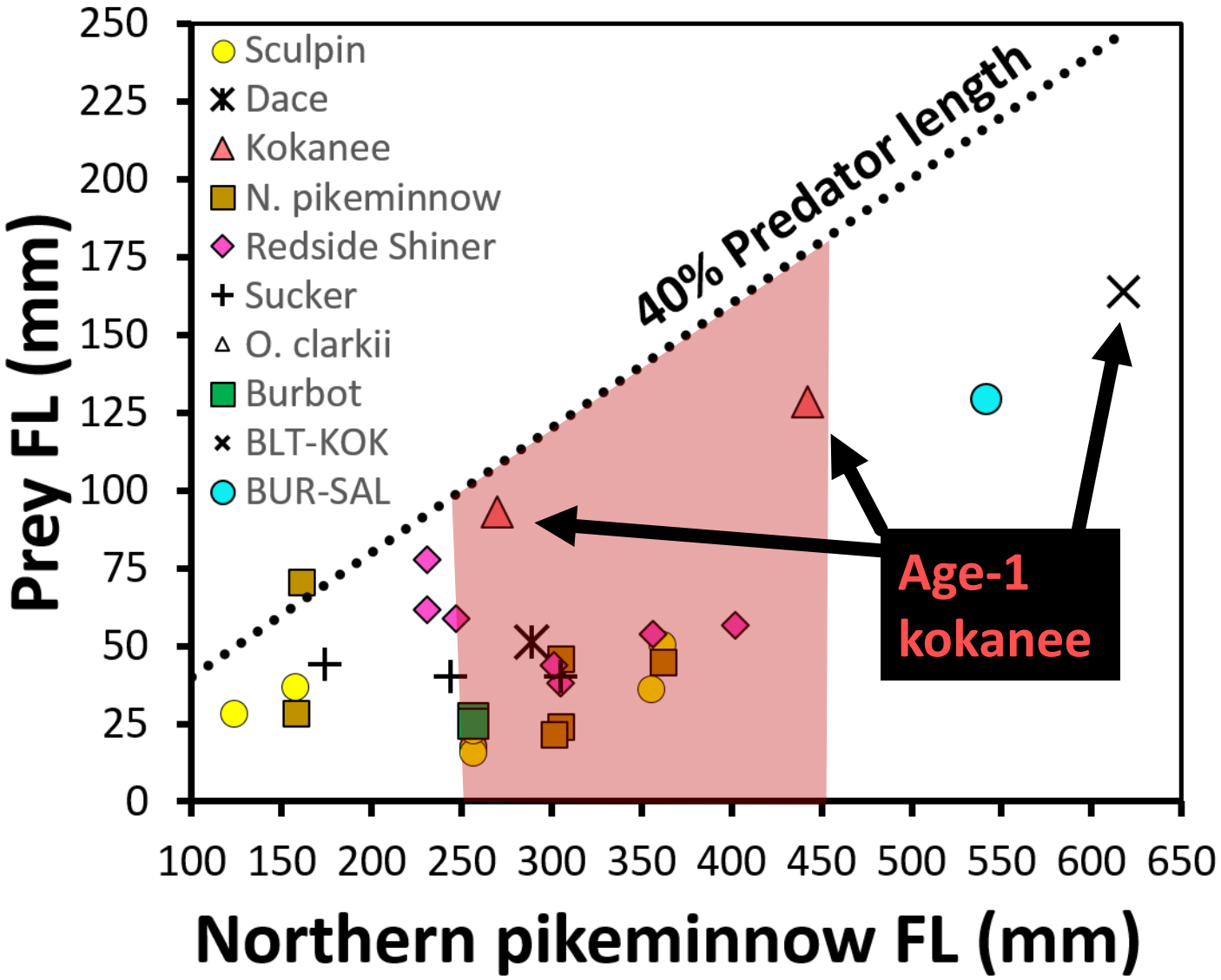


Seasonal Diet Composition: **BURB**

- Diet composed largely of fish, including salmonids (fish: 42-78%)



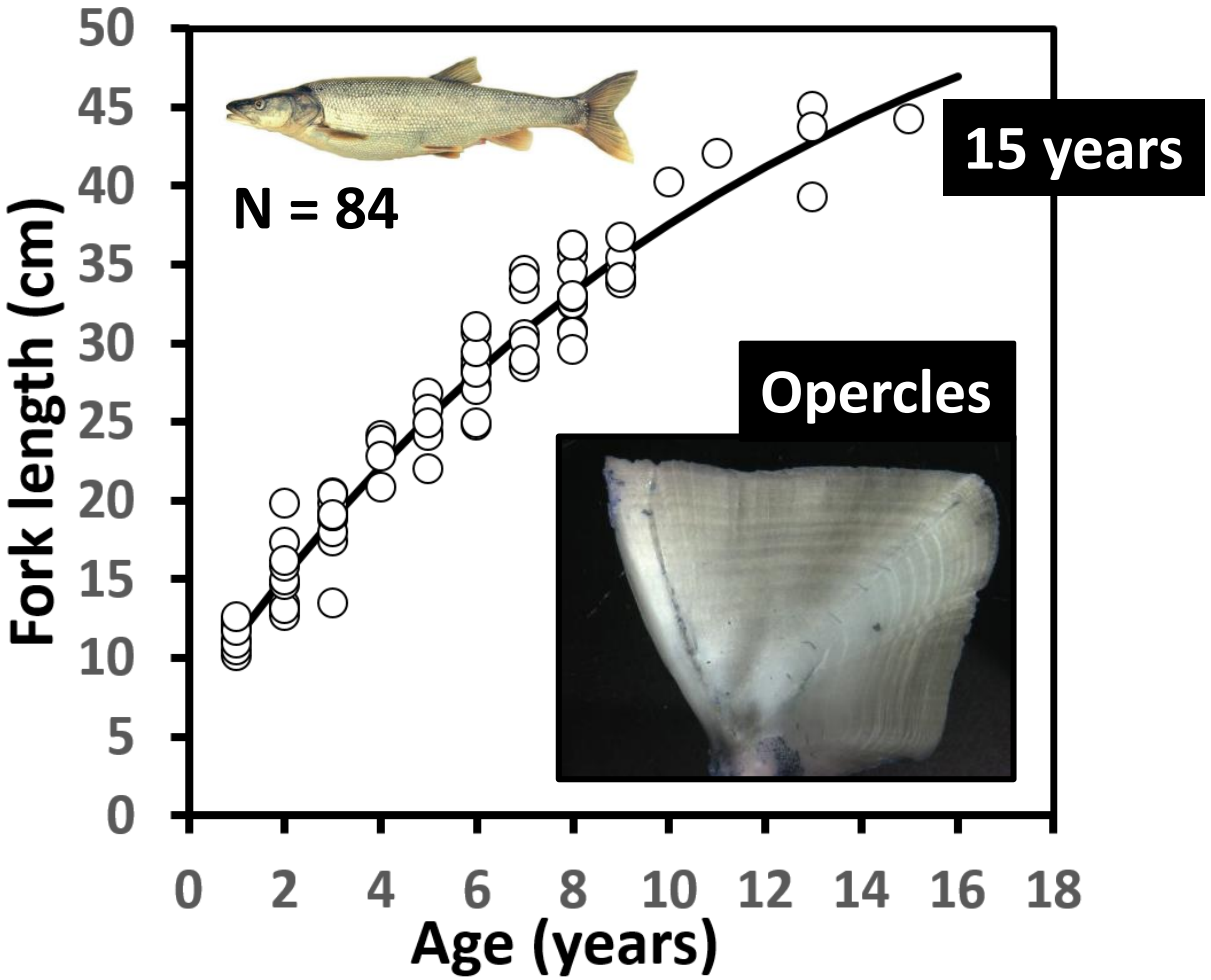
Predator-Prey Size Relationship

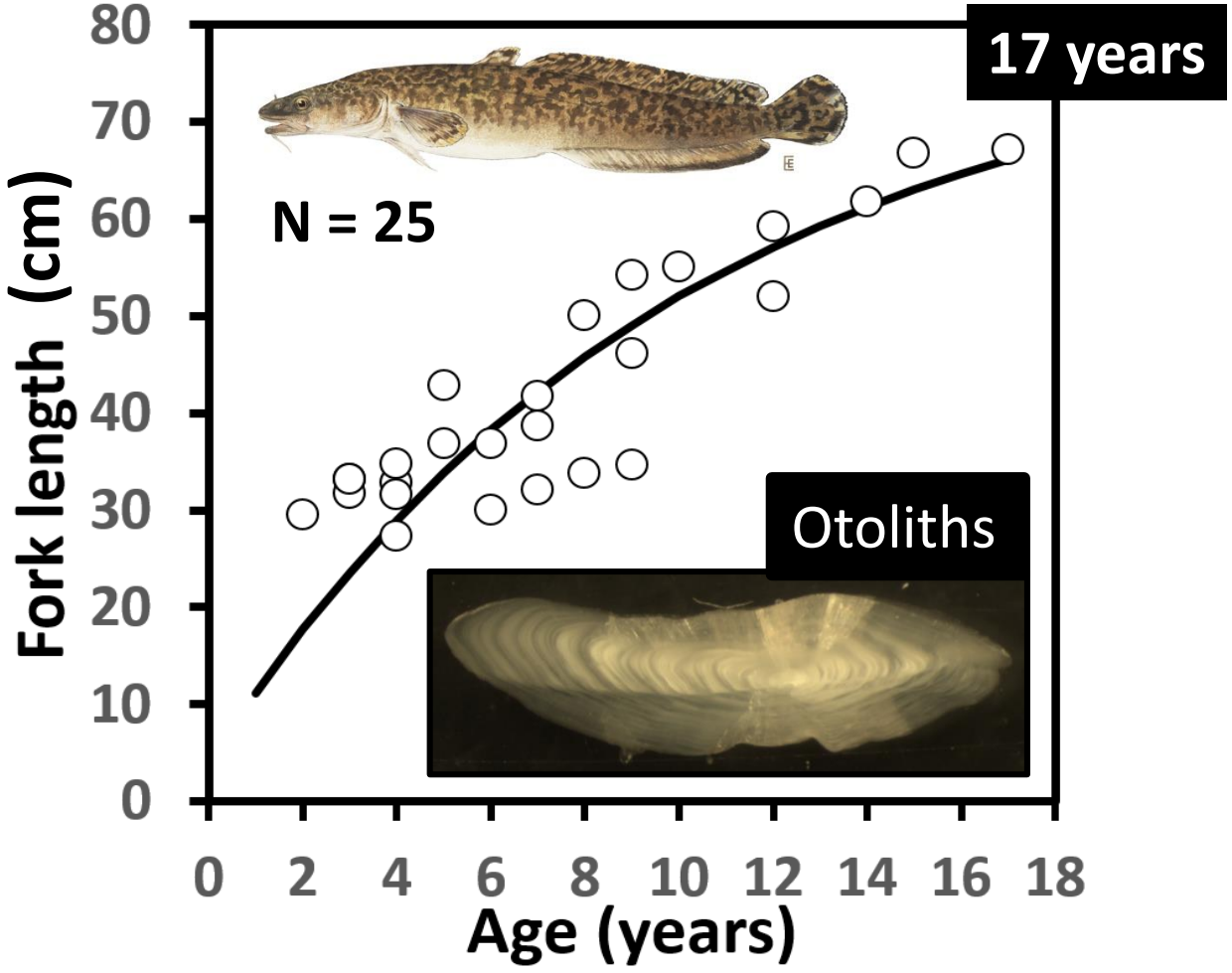


- Which size or age-classes of prey are most vulnerable to different size or age-classes of predator?
- Numerical predation rates
- Age-2 and older kokanee not vulnerable to NPM
- Assuming majority of predation on kokanee by NPM focused on age-1

Age & Growth: **NPM** and **BURBOT**

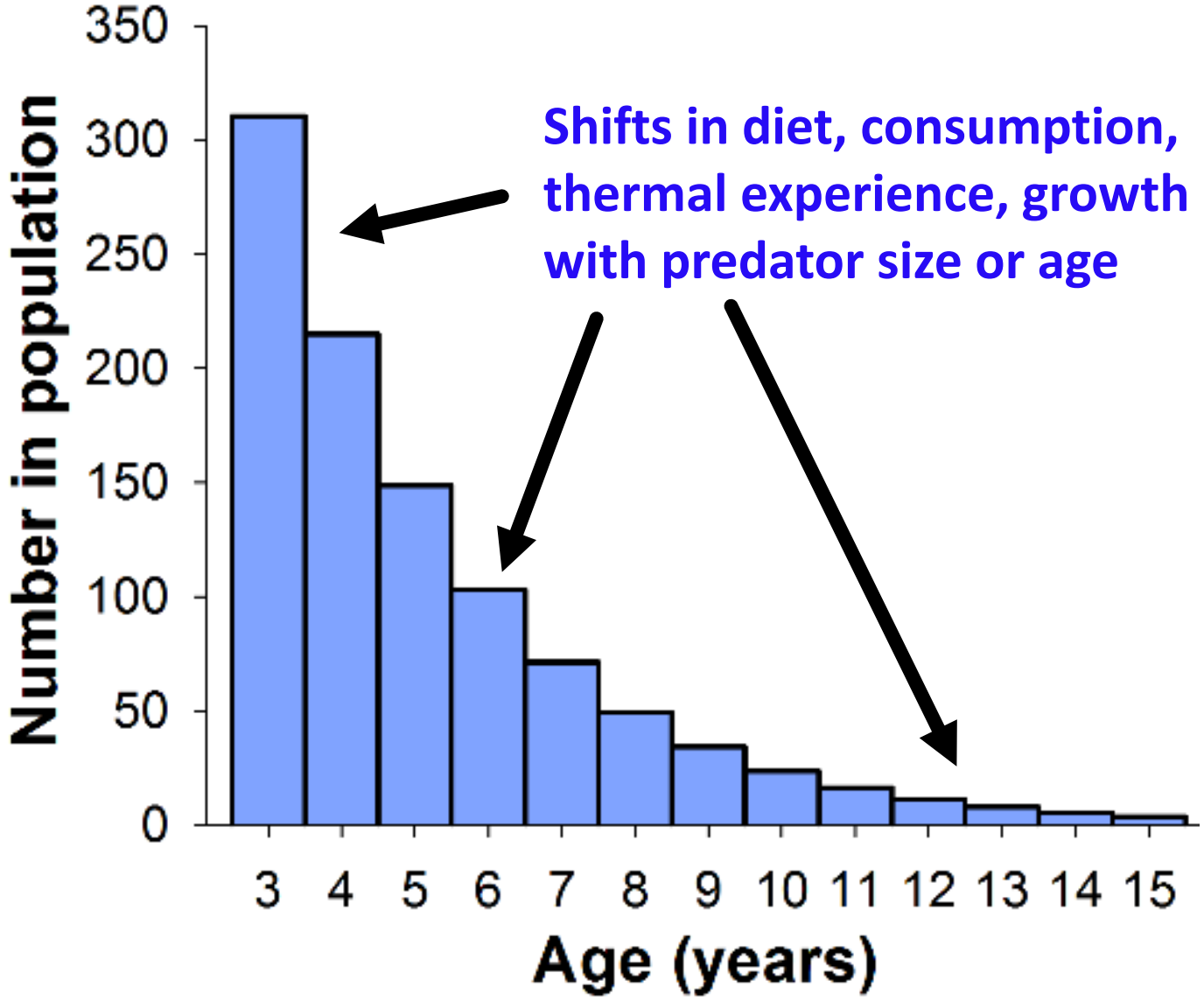
- Annual growth in length estimated from model that describes length as a *f*(age)



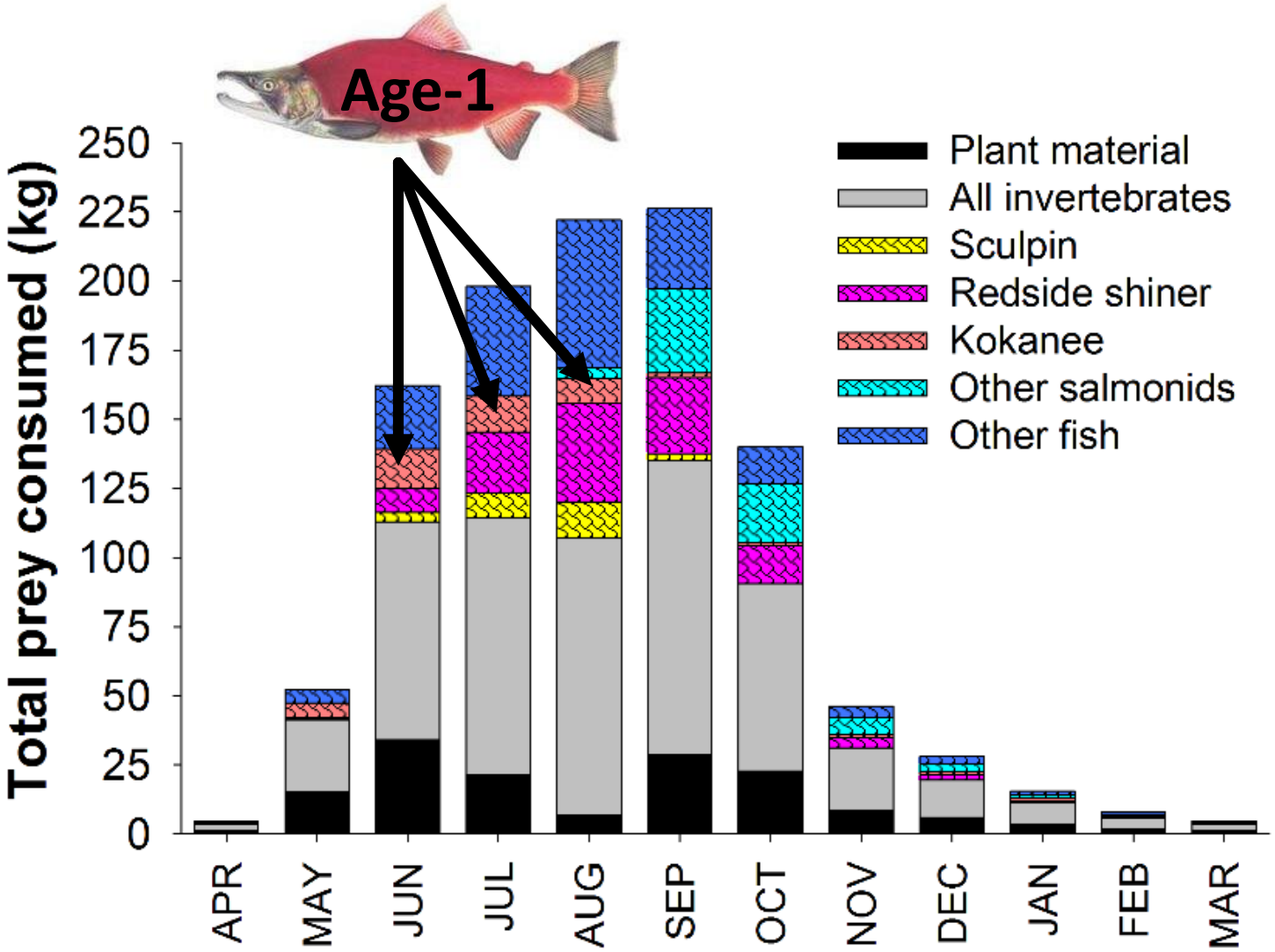


Survival and Age-Structure: **NPM**

- **Total abundance unknown**: estimate predation on key prey by age-structured population unit of 1,000 NPM **≥150 mm or ≥age-3**
- Useful metric for gauging extent of predation mortality and quantifying baseline food web interactions
- Need estimate of annual survival to develop age-frequency distribution



Annual Consumption by **NPM**



- ❑ Unit population of 1,000 NPM ≥ age-3
- ❑ Total consumption of kokanee: **48 kg**
- ❑ **~6,200 age-1 kokanee**
- ❑ **~3.0% of age-1 kokanee at large August 2014 (206,000)**
- ❑ **Age-structured unit of 100 bull trout: 22,000; 10.7%**

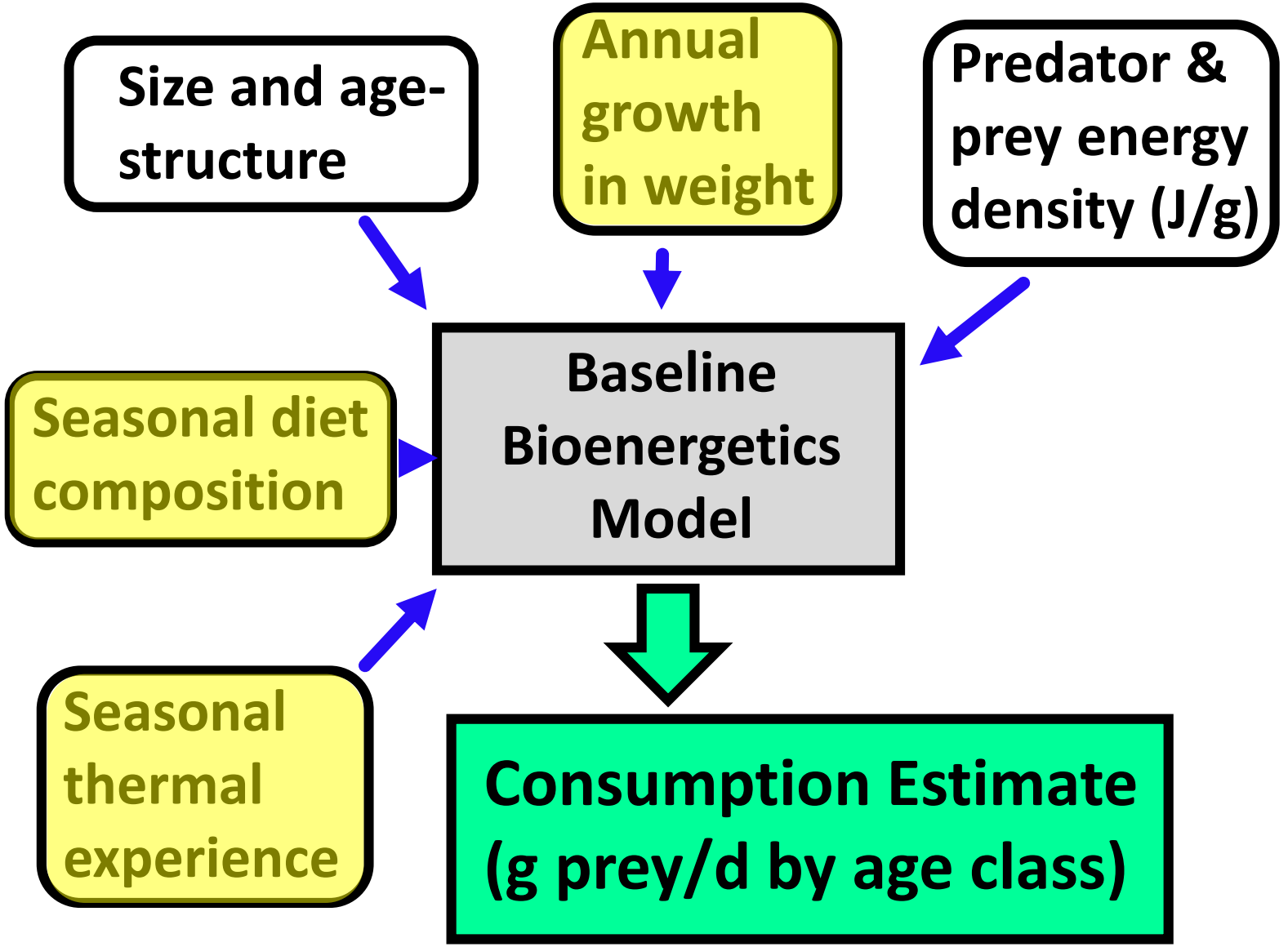
Summary

- Modest predation on kokanee by NPM
- Numerically, sufficient kokanee to support age-structured unit of 100 bull trout and population expansion
- Sufficient numbers ≠ sufficient access
- Refinements to baseline food web interactions still needed
  - Seasonal diet for NPM and Burbot (**FALL**)
  - Distribution
  - Age & growth

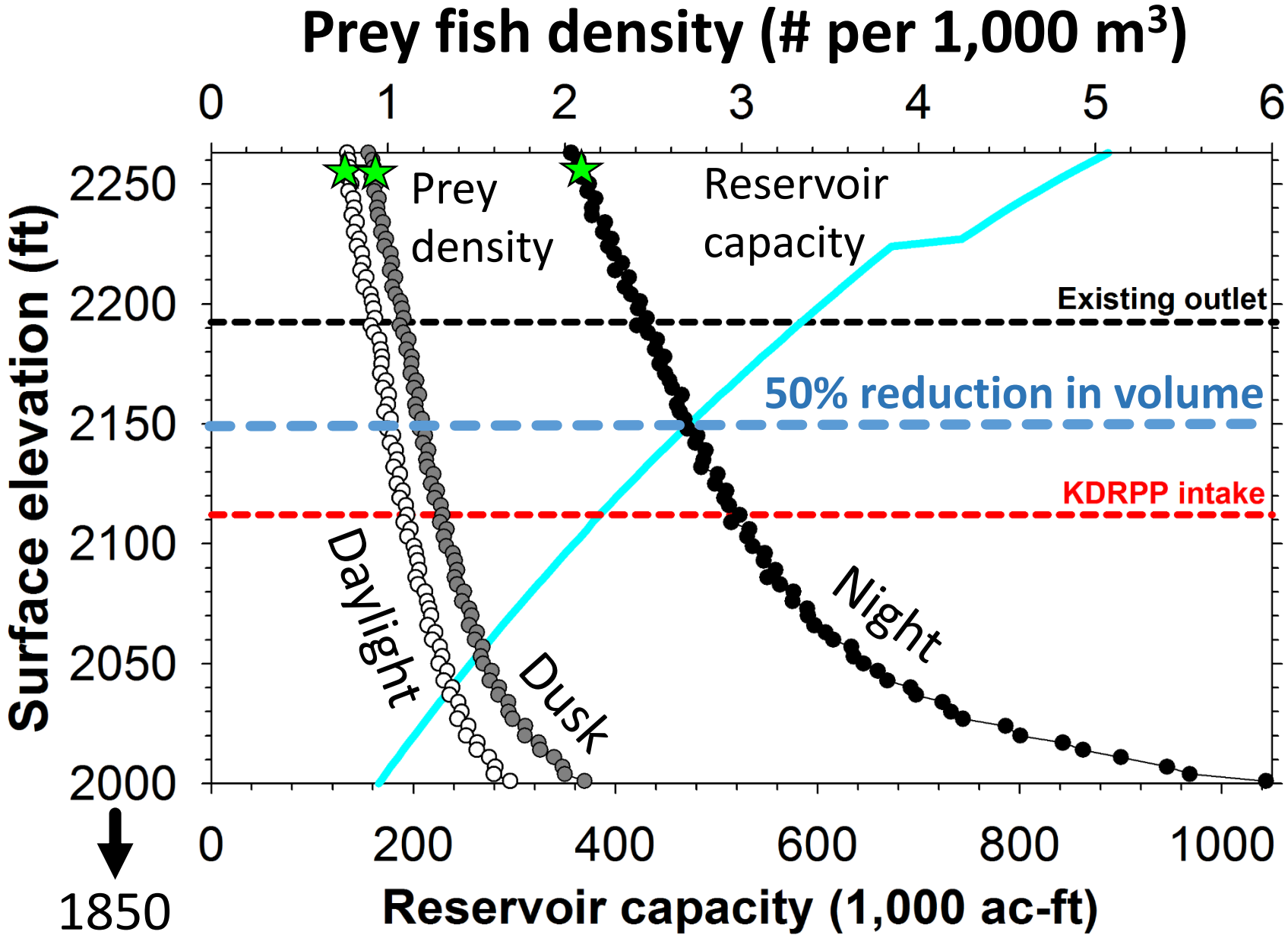
Next Steps

- Modeling effects of alternative pumping strategies on thermal structure (Scott Wells, Portland State)

Questions?



Simulated effect of drawdown on prey density



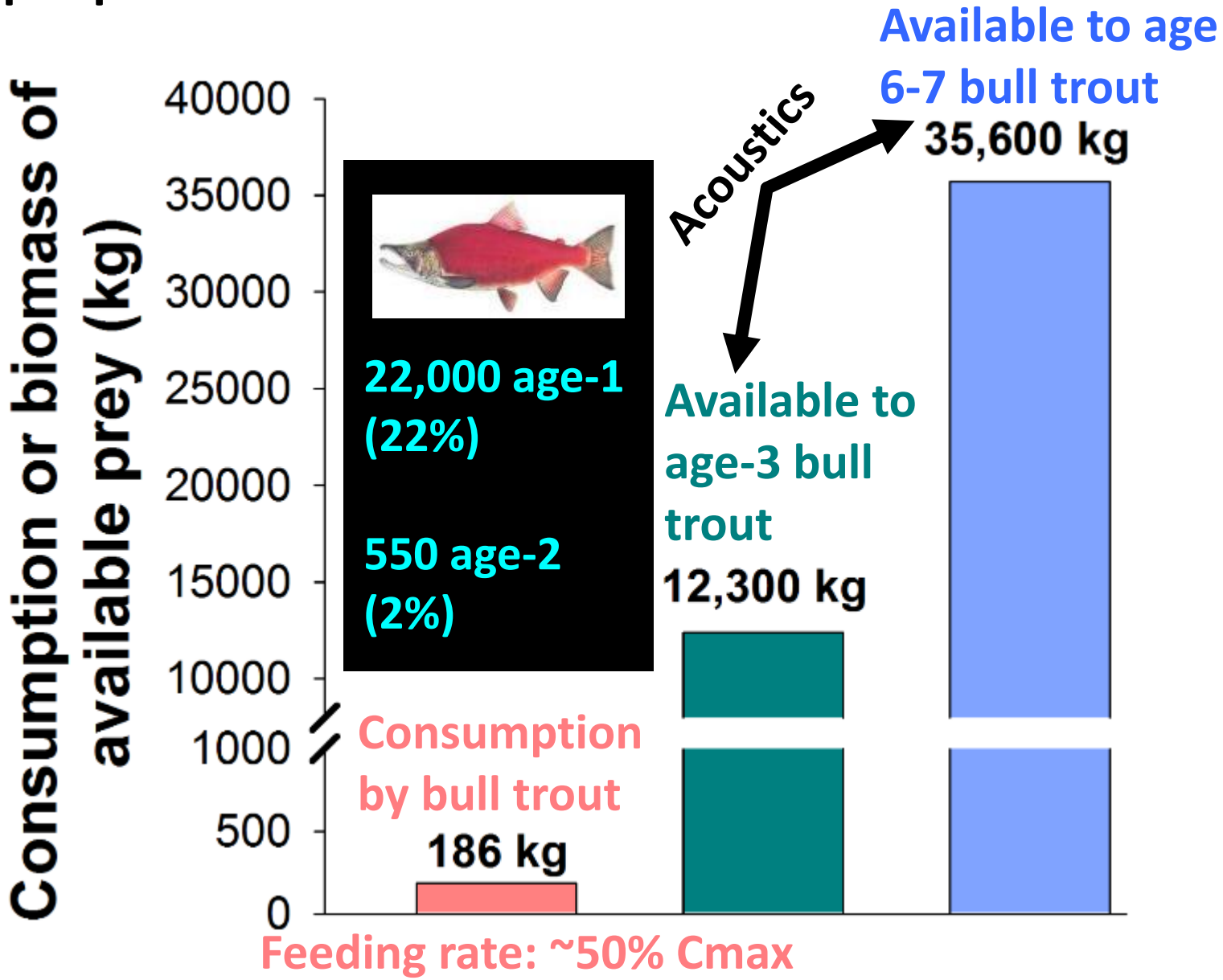
Little change w/n region of operation

Buffered by steep bathymetry & depth

Not really changing the game

Access to spawning tribs, thermal structure, downstream impacts

Annual consumption of fish by size-structured population unit of **100** bull trout



Assumptions:

Annual growth: averages for 400-700 mm bull trout from Bumping & Rimrock

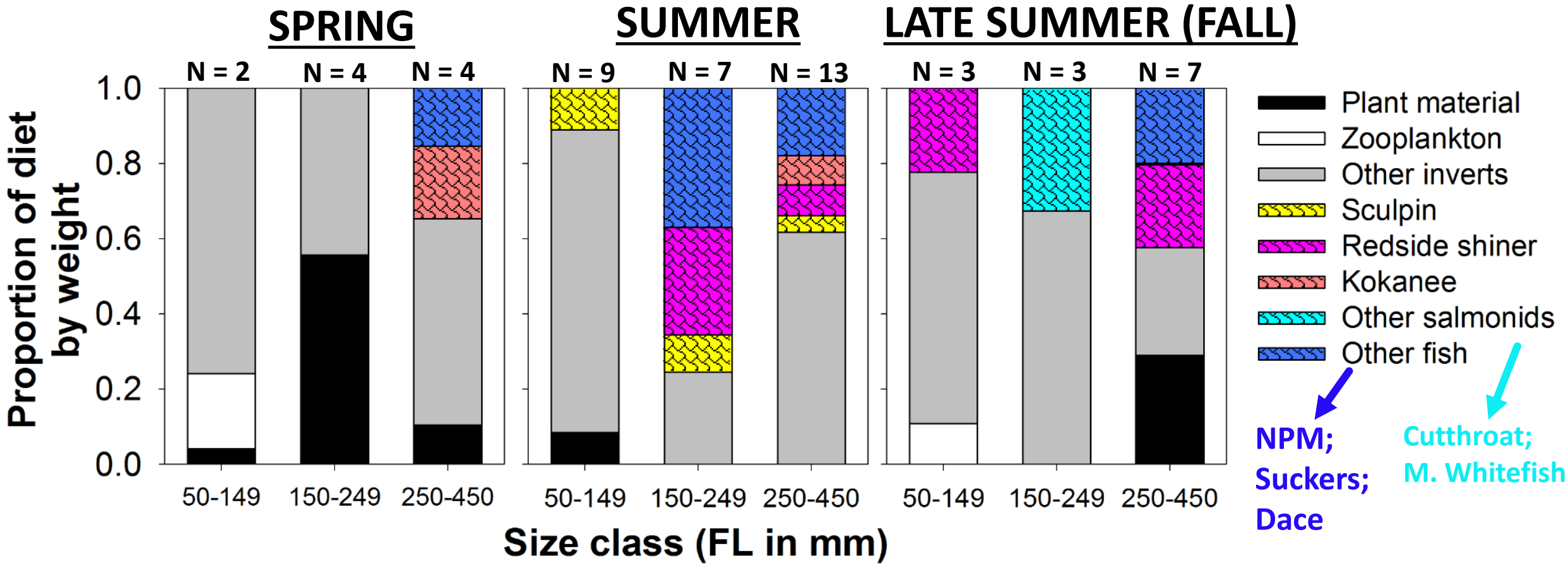
Annual survival and size-age structure: Lake Billy Chinook

Ages 3-7 dominate reservoir population

Diet 100% fish (kokanee)

Seasonal Diet Composition: **NPM**

- ❑ Diet varied by size and season (fish: 22-75% of diet)
- ❑ Predation on kokanee by large NPM: spring & summer (8-19%)
- ❑ No pygmy whitefish detected



River Systems Offer a Range of habitats and Thermal Regimes that can Influence Seasonal Segregation of Species

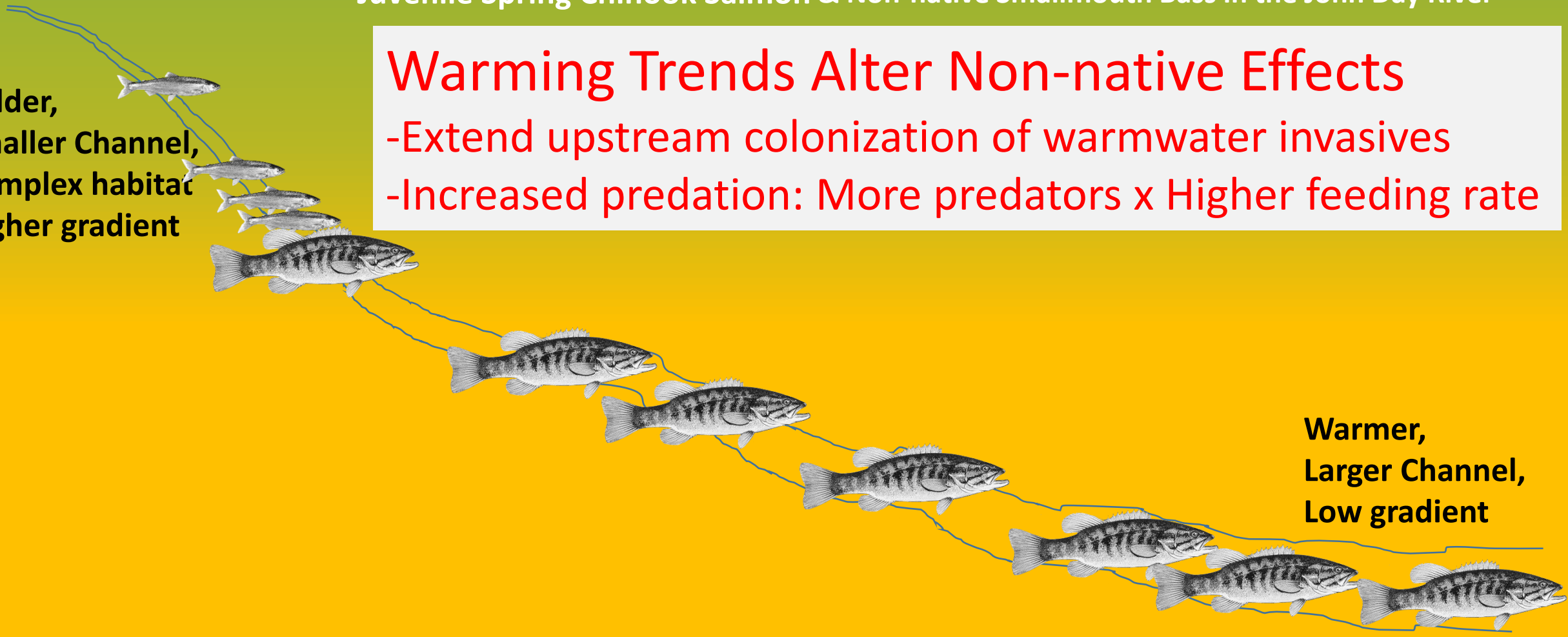
Juvenile Spring Chinook Salmon & Non-native Smallmouth Bass in the John Day River

Warming Trends Alter Non-native Effects

-Extend upstream colonization of warmwater invasives

-Increased predation: More predators x Higher feeding rate

Colder,
Smaller Channel,
Complex habitat
Higher gradient



Warmer,
Larger Channel,
Low gradient

Lawrence et al. 2014 Ecol. Apps.; 2015 J. Animal Ecol.