Quantifying aquatic food web interactions in Lake Chelan: Results to date and future directions

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Lake Chelan
9th deepest lake in the world (453 m)
Over 80 km long
Ultraoligotrophic
Composed of two basins
Lucerne Basin
Wapato Basin
N
W
E
S
Image © 2006 MDA EarthSat
Image © 2006 DigitalGlobe
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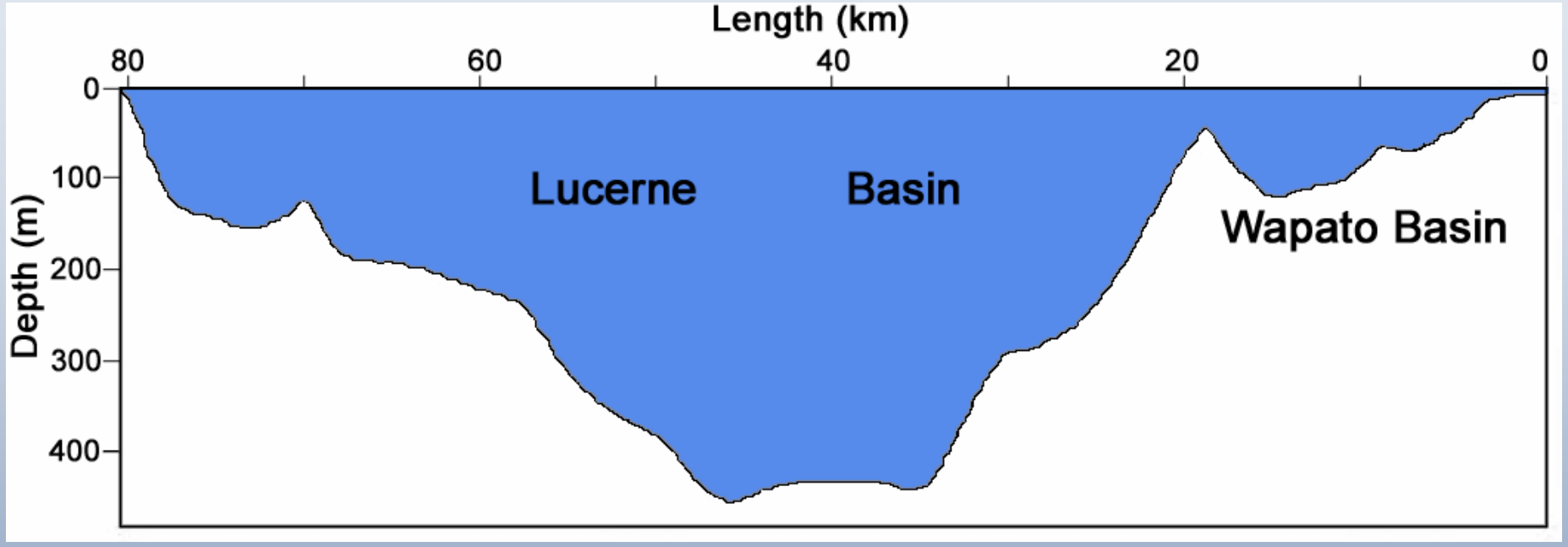
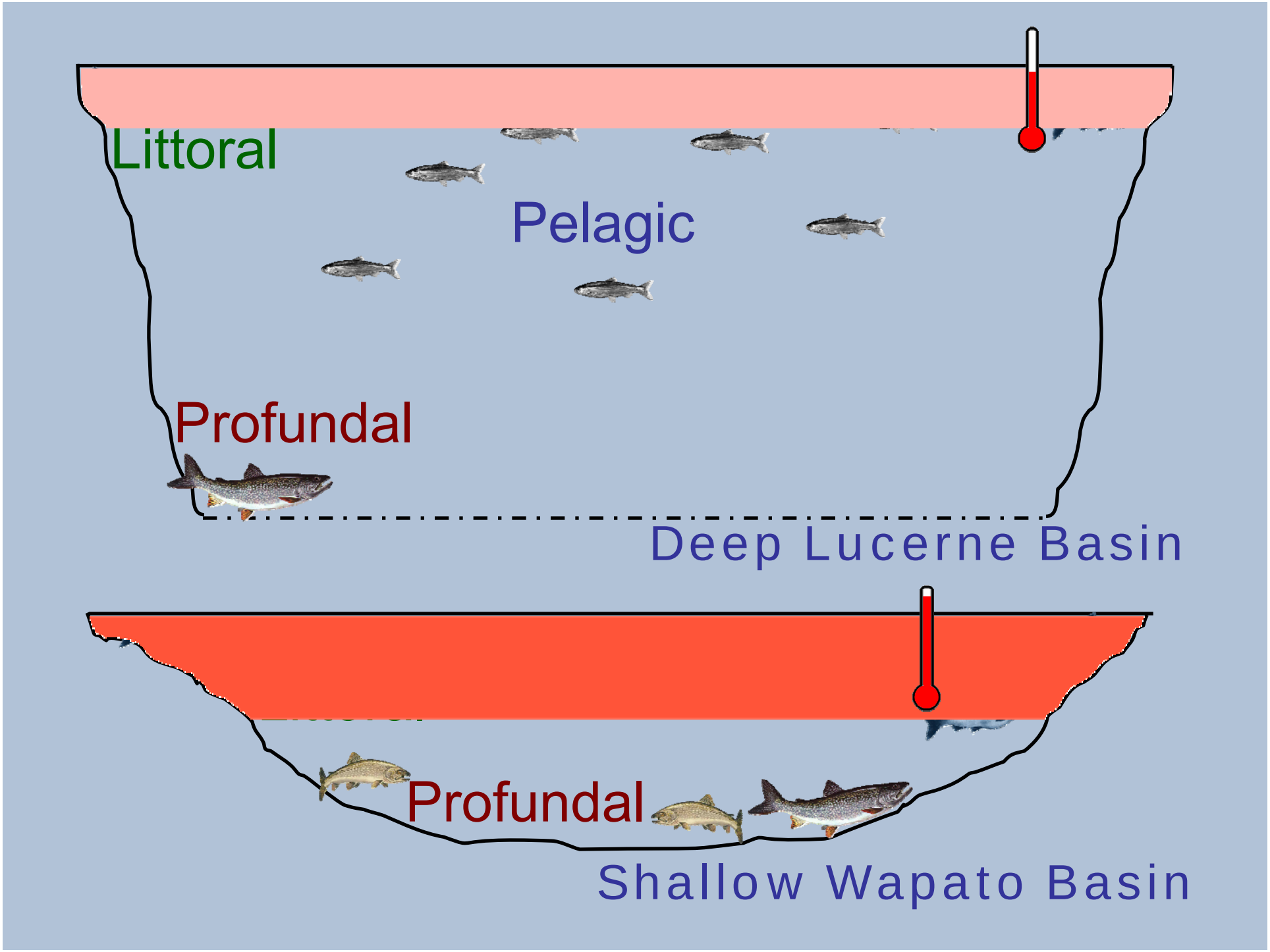
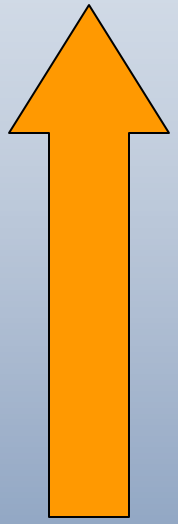

Length (km)
80
60
40
20
0
0
100
200
300
400
Depth (m)
Lucerne
Basin
Wapato Basin


Littoral
Pelagic
Profundal
Deep Lucerne Basin
Profundal
Shallow Wapato Basin

Top Predators



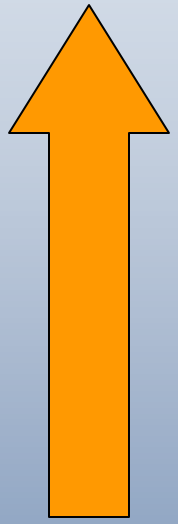
Planktivores & Primary Consumers

Native	**Introduced**
Bull trout (extirpated)	Lake trout
	Chinook salmon (collapsed)
	Smallmouth bass
Burbot	
Westslope cutthroat trout (collapsed)	
	Rainbow trout (no longer stocked)
Northern pikeminnow	
Sculpins	Kokanee
Three-spine stickleback	*Mysis relicta* shrimp
Suckers	

Native

Introduced

Top Predators



Lake trout

Chinook salmon (collapsed)

Smallmouth bass

Burbot

Westslope cutthroat trout (collapsed)

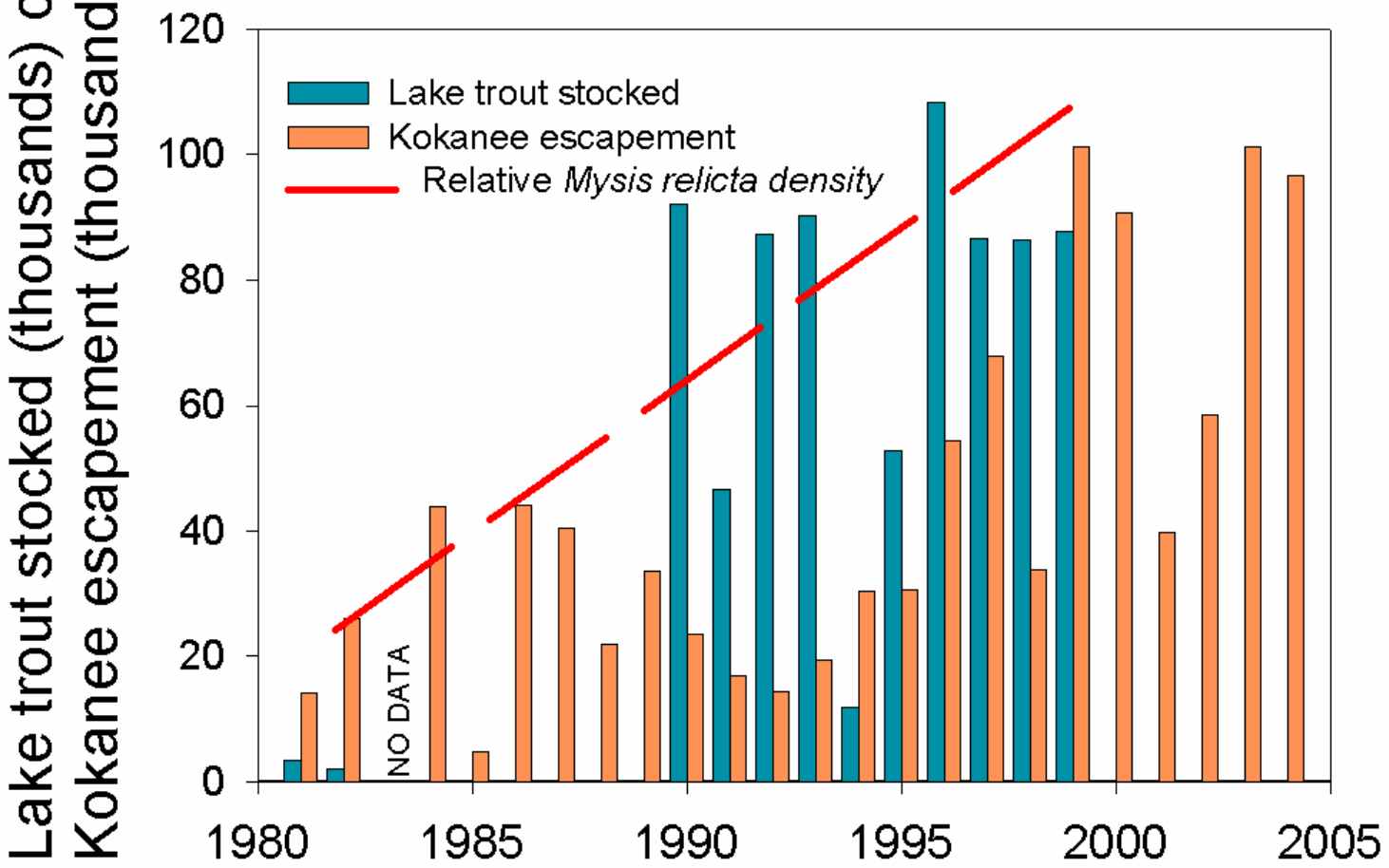
Northern pikeminnow

Planktivores & Primary Consumers

Kokanee

Mysis relicta shrimp

Lake Chelan kokanee thrive after lake trout and *Mysis* become established



Sources: WDFW stocking records, Chelan PUD 2005, Brown 1984, DES 2000

Predation on salmonids

What are the major predators of salmonids in the lake?

Especially

Kokanee

Cutthroat trout

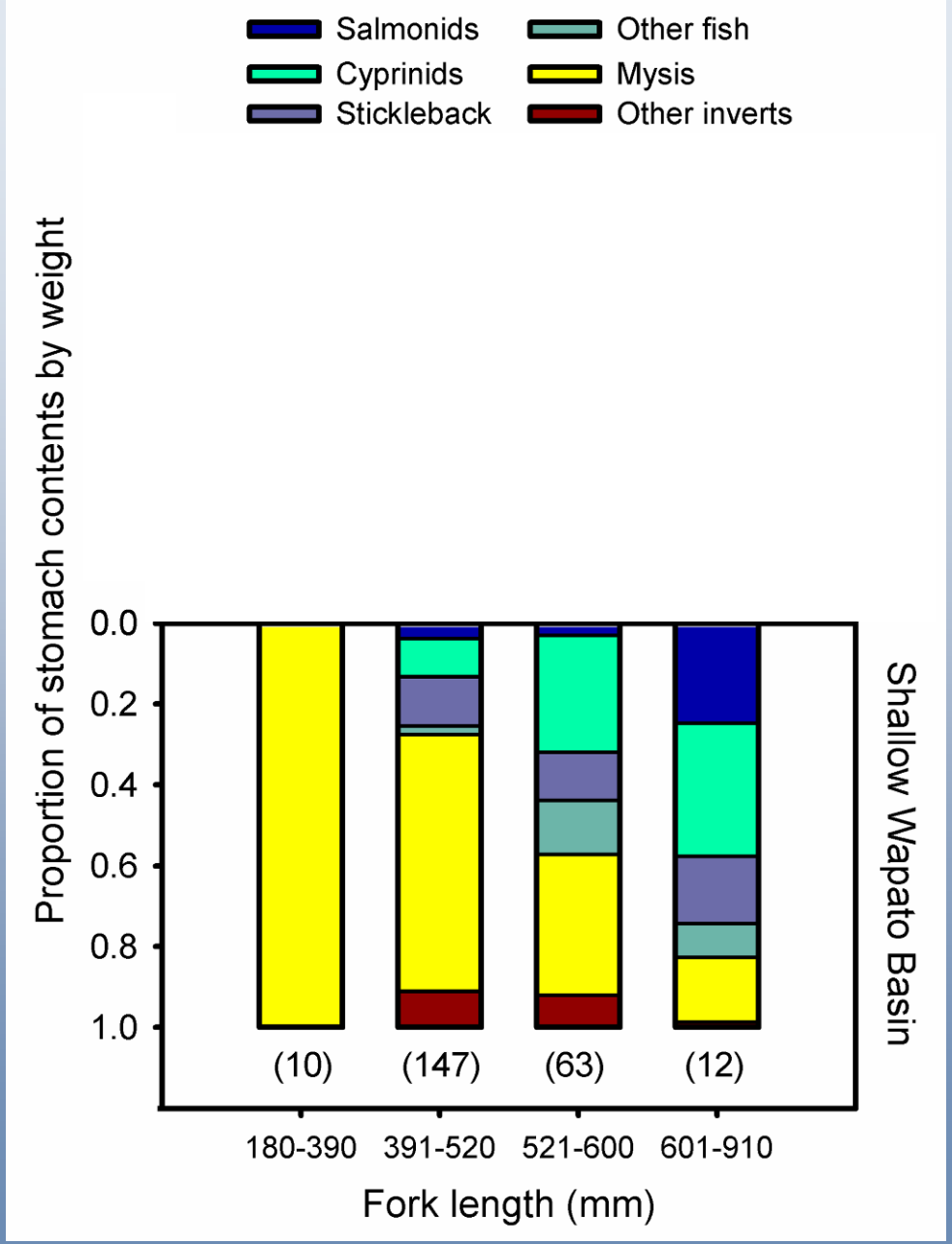
Chinook

Is predation currently a major limiting factor for kokanee?

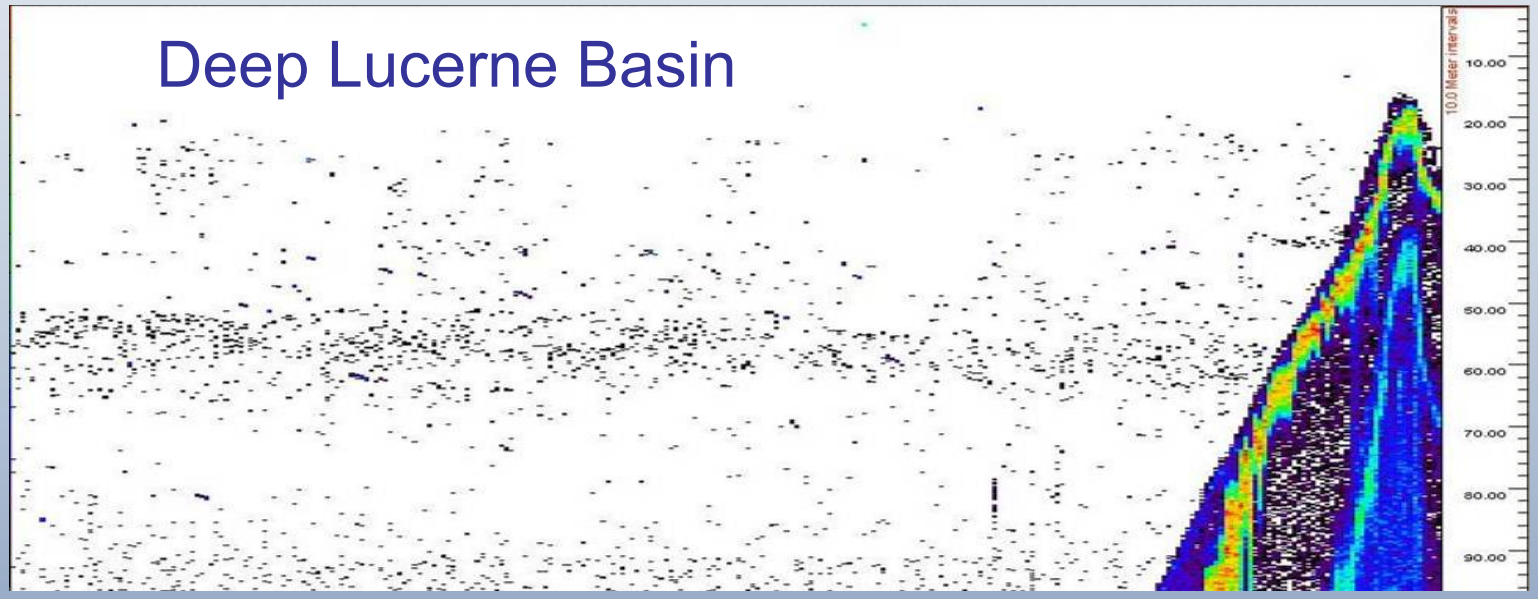
Photo: Martin Grassley

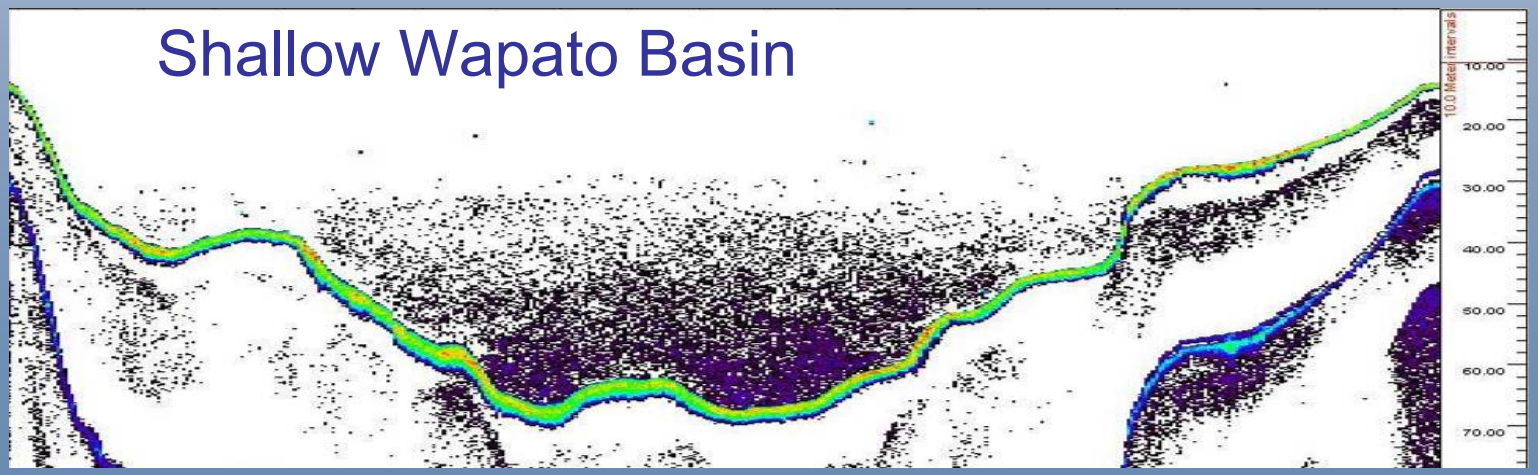
Lake trout diet

- All size classes of lake trout ate large proportions of *Mysis* in shallow Wapato Basin
- Only the smallest lake trout ate substantial amounts of *Mysis* in deep Lucerne Basin
- Preliminary stable isotope results show same pattern



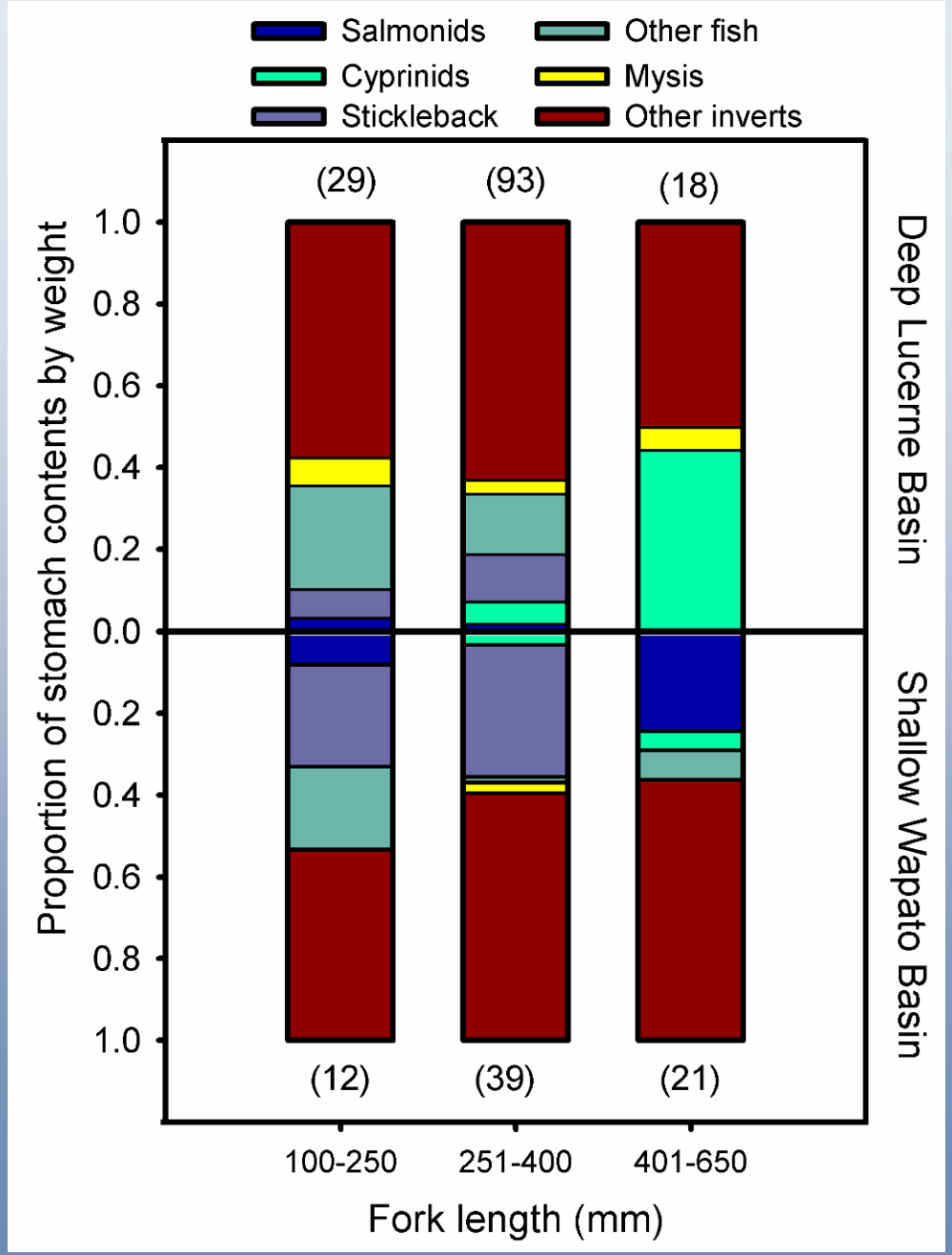
Lake depth may control vulnerability of *Mysis* to lake trout





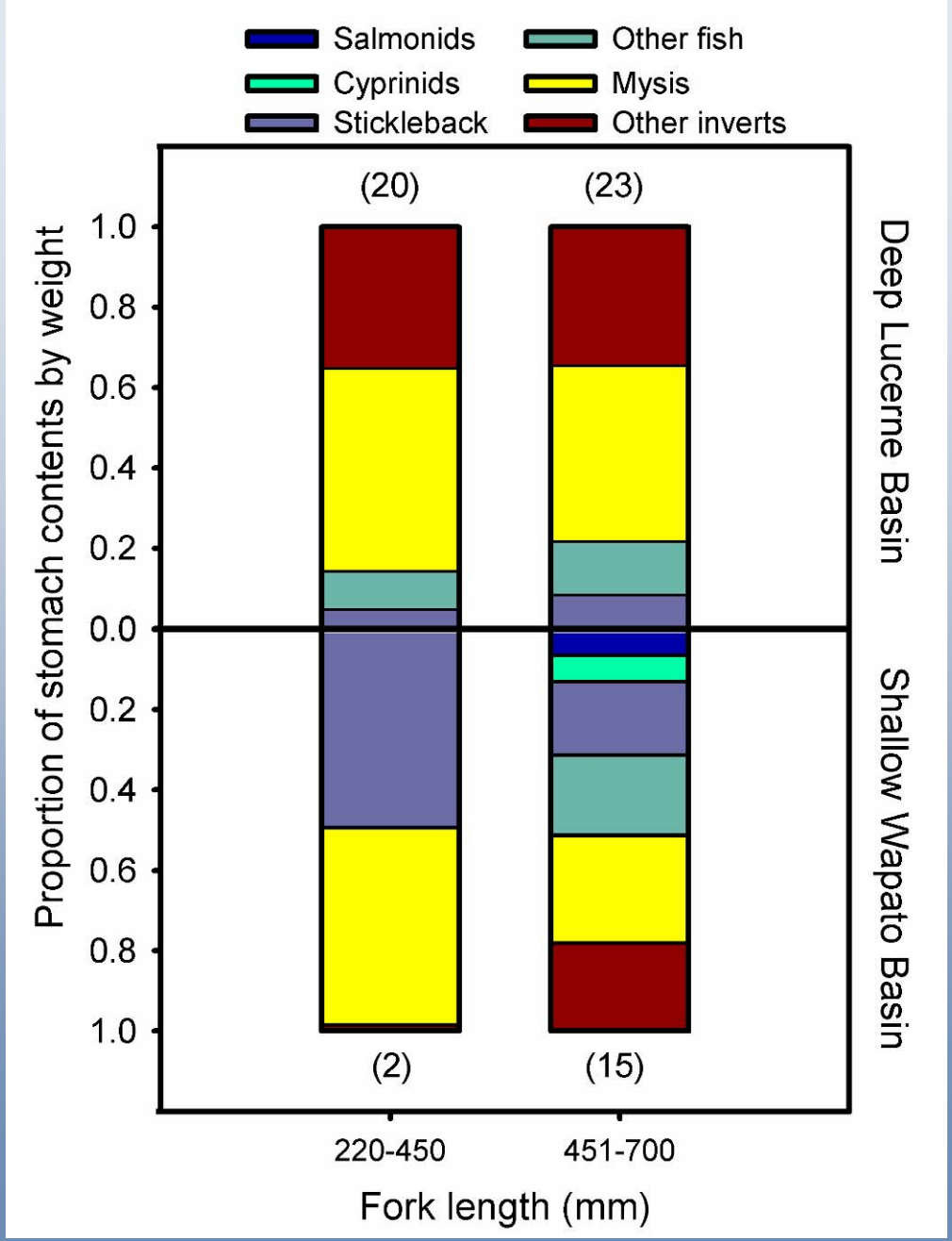
Northern pikeminnow diet

- All size classes ate mostly invertebrates
- The largest pikeminnow ate significant numbers of salmonids in Wapato Basin
- Good news for salmonids: Pikeminnow ate almost no salmonids in Lucerne Basin



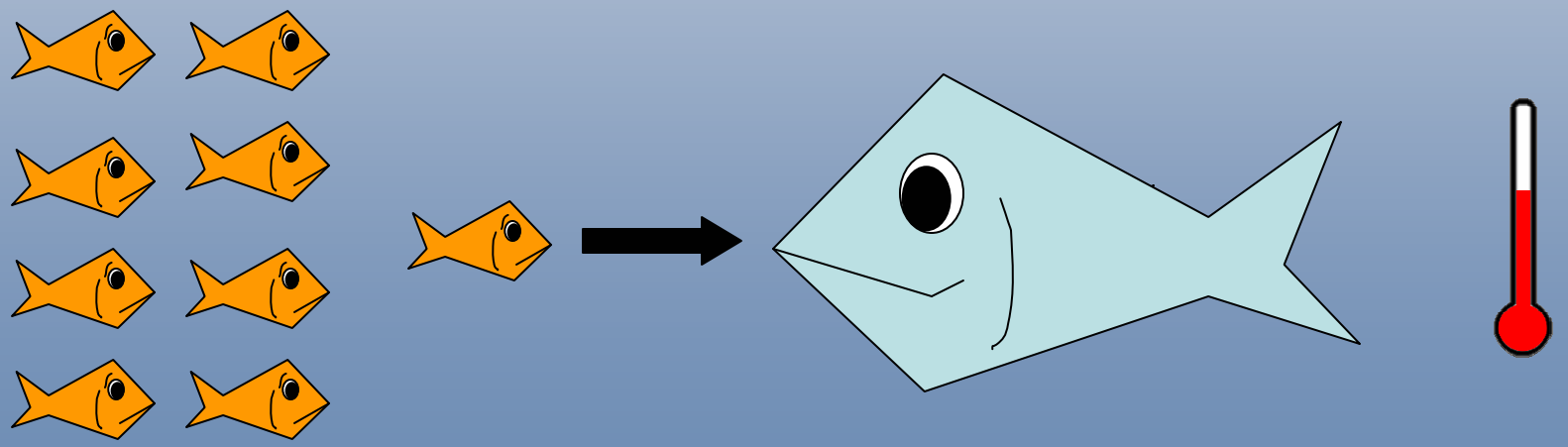
Burbot diet

- Burbot are not a major salmonid predator
- Burbot may be a significant predator of *Mysis*



Consumption = Growth + Metabolism + Waste

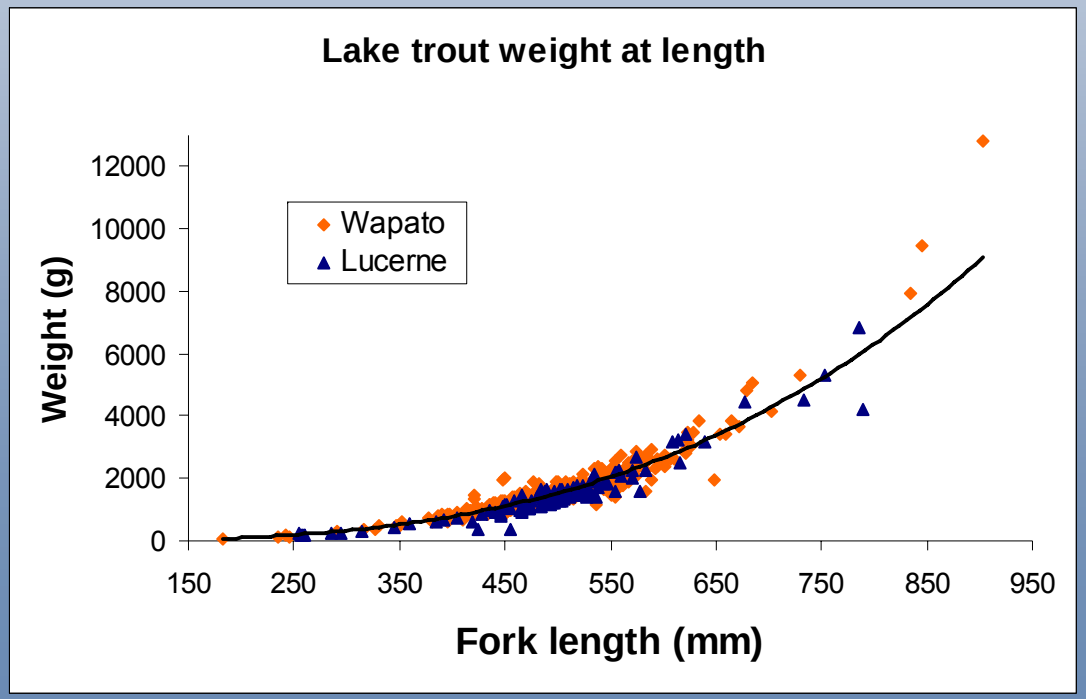
Bioenergetics Model



Lake trout age and growth

- Ages determined from opercles
  (Sharp and Bernard 1988)

- Growth rate calculated from length-at-age and weight-at-length curves



Lake trout survival and population size

- Survival rate determined from age frequency of catch ($Z \approx 0.55$, annual survival ≈ 58%)
- Estimated annual harvest in Wapato Basin = 2000 to 3000 (A. Jones, pers. comm.)
- Estimated minimum age vulnerable to harvest at 3.5 years (fork length = 372 mm or 14 1/2”)
- Population size estimated using Baranof catch equation (Shuter et al. 1998)

$$Catch_t = \frac{Z - M}{Z}(1 - e^{-(Z)})N_t$$

where

Z is the total mortality rate

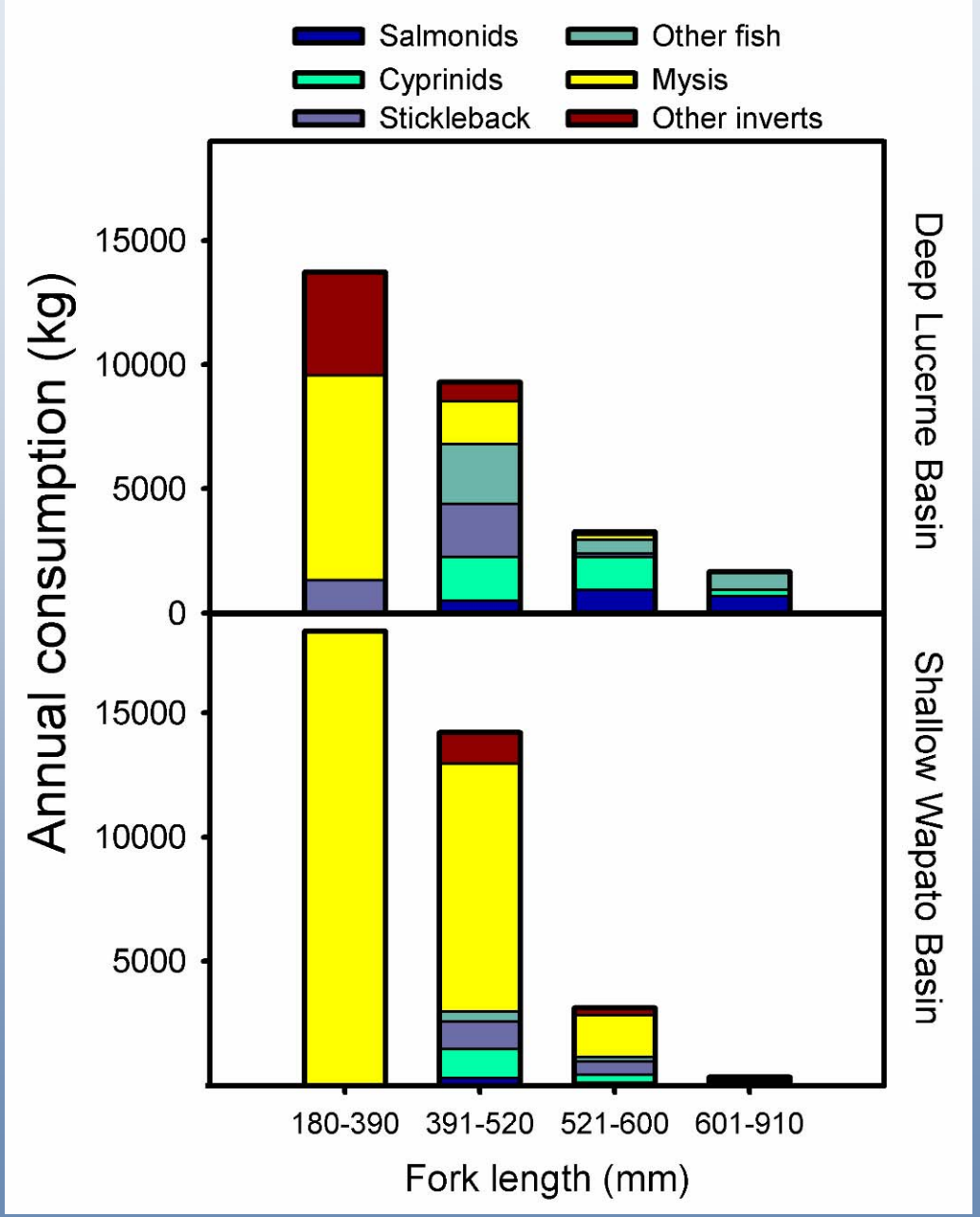
M is the natural mortality rate

N_t is the population at time *t*

Preliminary estimated size of Wapato Basin population

= 13,959 to 20,939 lake trout (excluding age 0)

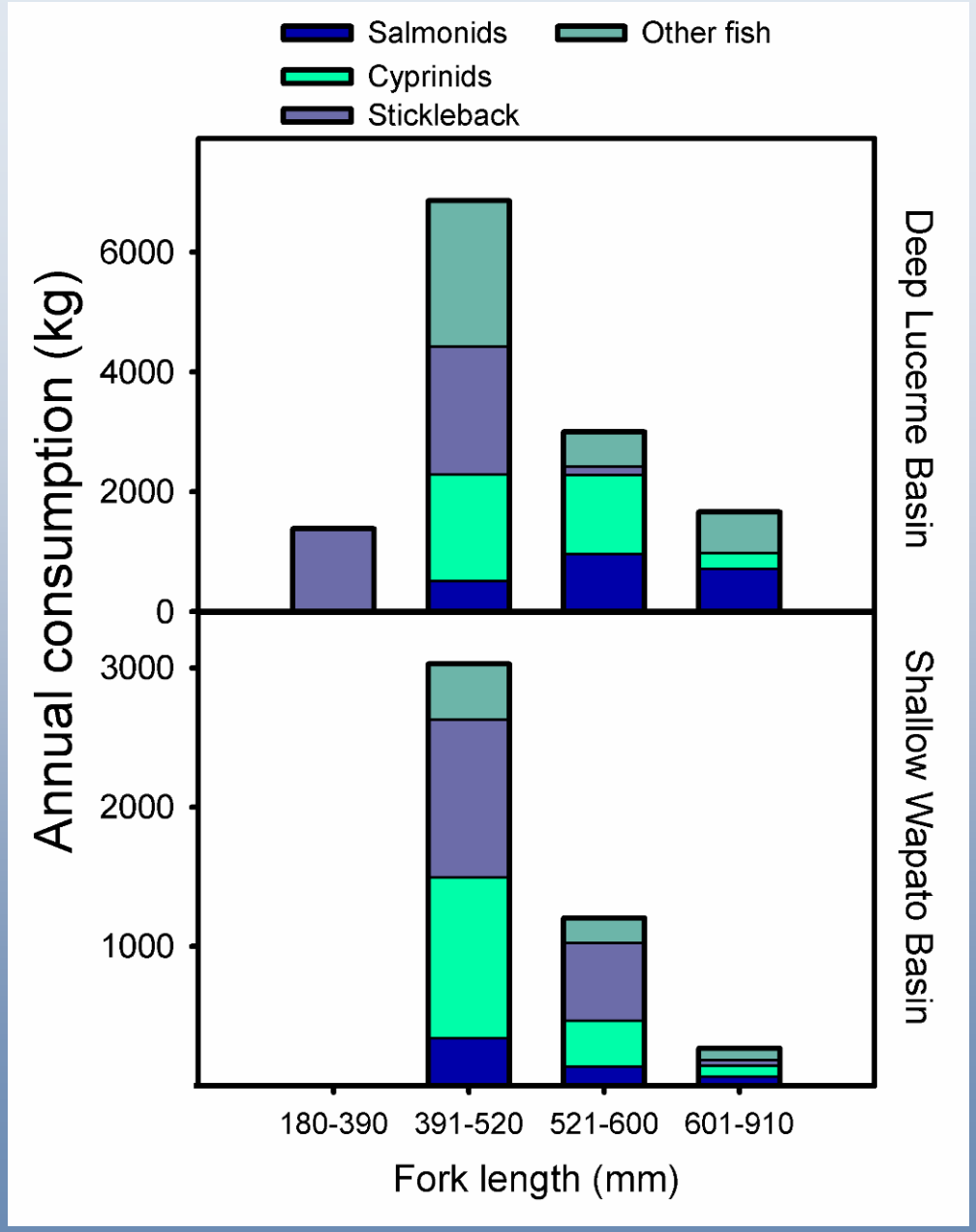
Lake trout population-level consumption



Lake trout population-level consumption: fish only

Salmonid prey difficult to identify by bones: about half are kokanee, rest are mostly unidentified

Under this scenario, annual lake trout consumption
= 3,400 kg salmonids
= 92,000 age 1 kokanee



Predation on salmonids: Conclusions

Lake trout are a major predator on salmonids in both lake basins. We have the tools to quantify their current predation impact on kokanee.

Northern pikeminnow may also be an important predator, in the Wapato Basin only. No other species currently eats many salmonids

Competition for zooplankton

Do *Mysis* compete with kokanee for food?

1. How many *Mysis* and kokanee are in each lake basin?
2. How many zooplankton does each individual eat?
3. How many zooplankton are produced in the lake and available to planktivores?

Kokanee abundance and zooplankton consumption

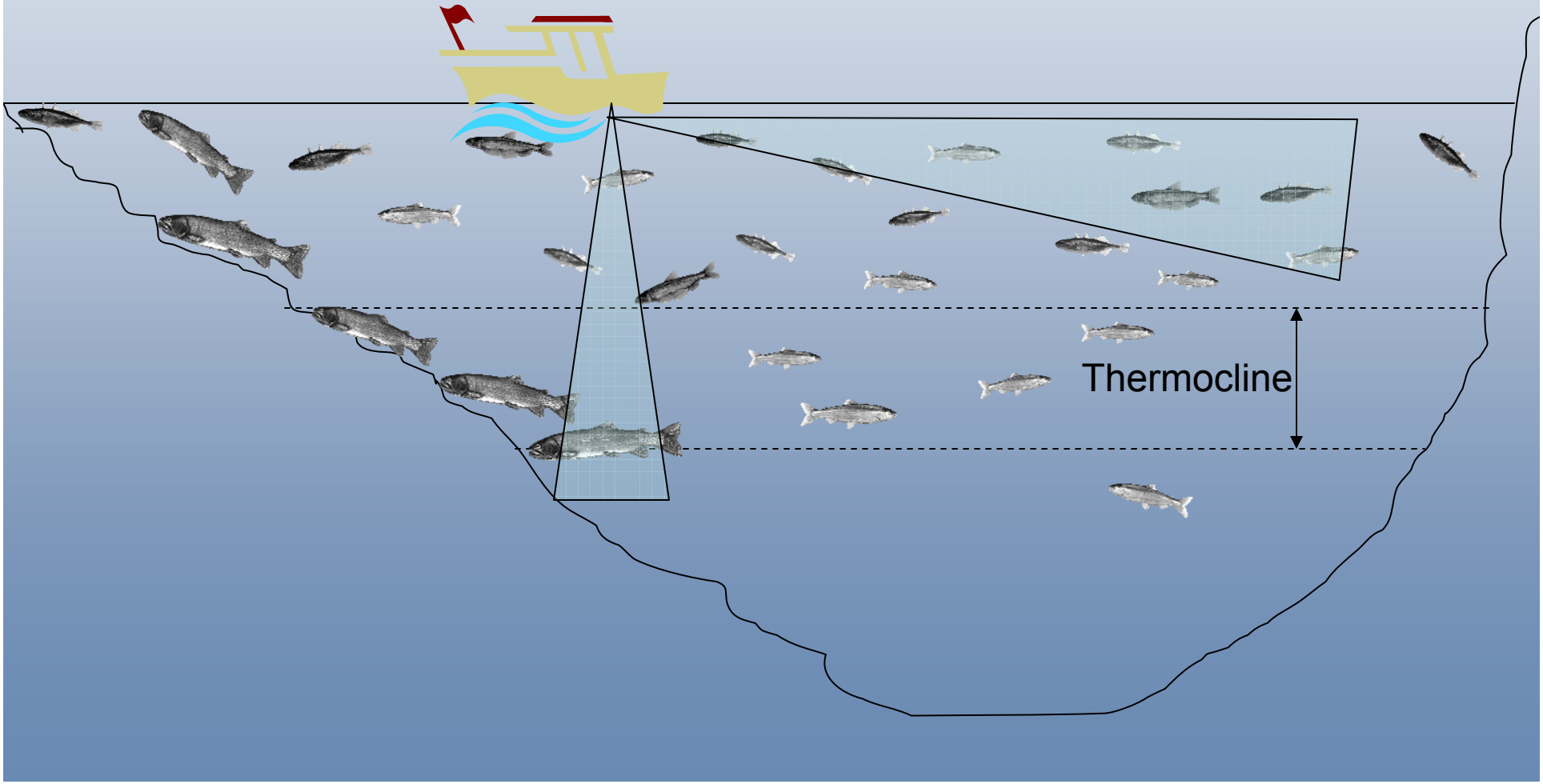
Estimate abundance by two methods:

- Hydroacoustic surveys
- Age-structured population model based on the number of kokanee surviving to spawn

For kokanee and *Mysis*: Estimate consumption demand with bioenergetics models

(Beauchamp et al. 1989, Chipps and Bennett 2002)

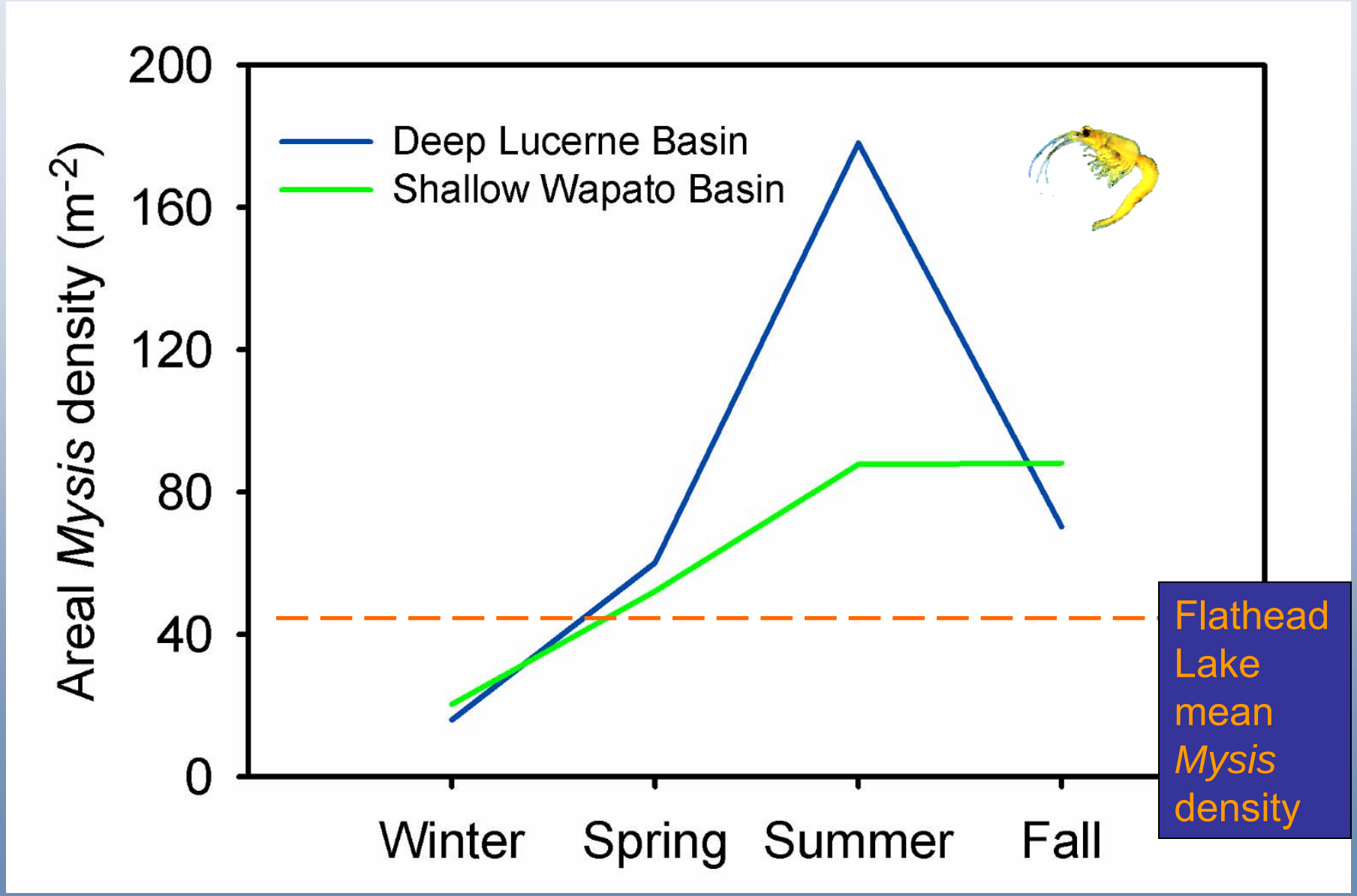
Estimating abundance, distribution, and migration patterns of kokanee and *Mysis*



Mysis sampling

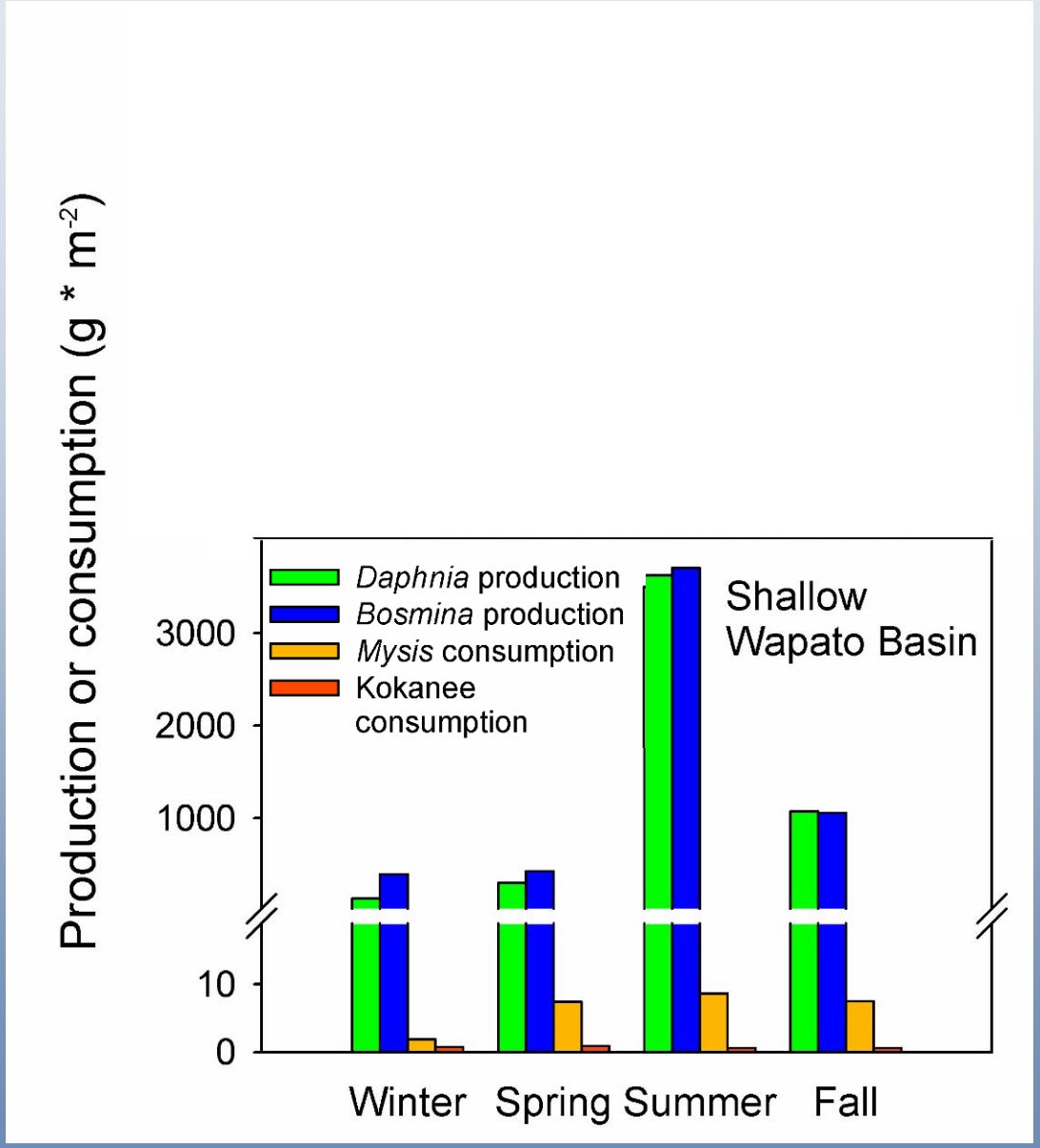
Zooplankton sampling

Mysis abundance and distribution

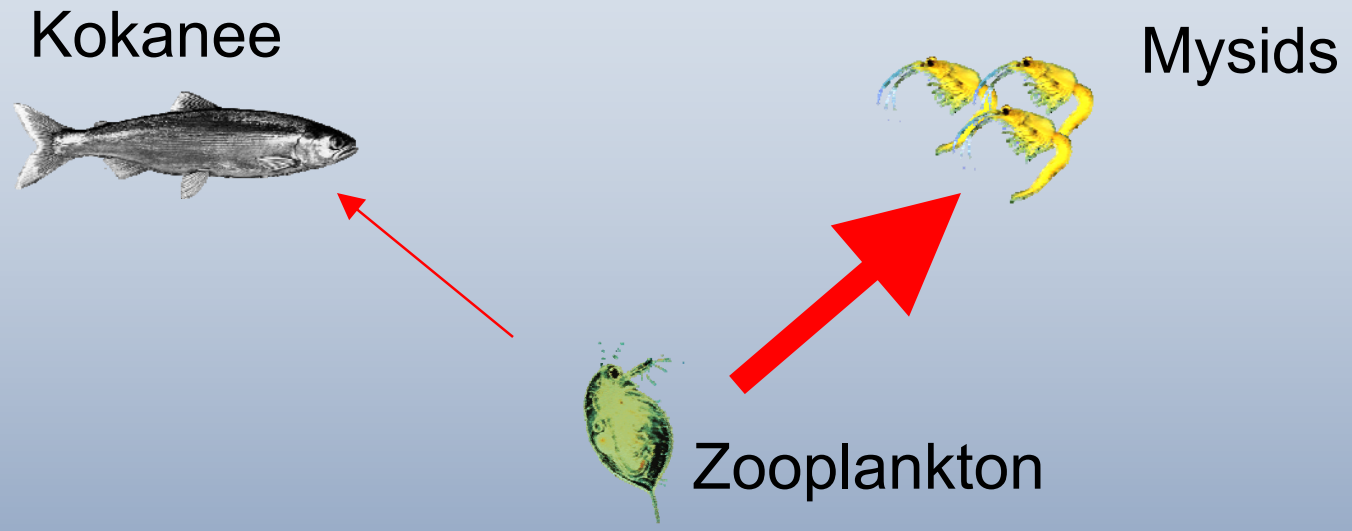


Competition for zooplankton?

- Zooplankton production dominated *Mysis* and kokanee consumption during most periods
- Lucerne Basin had near-zero production during winter



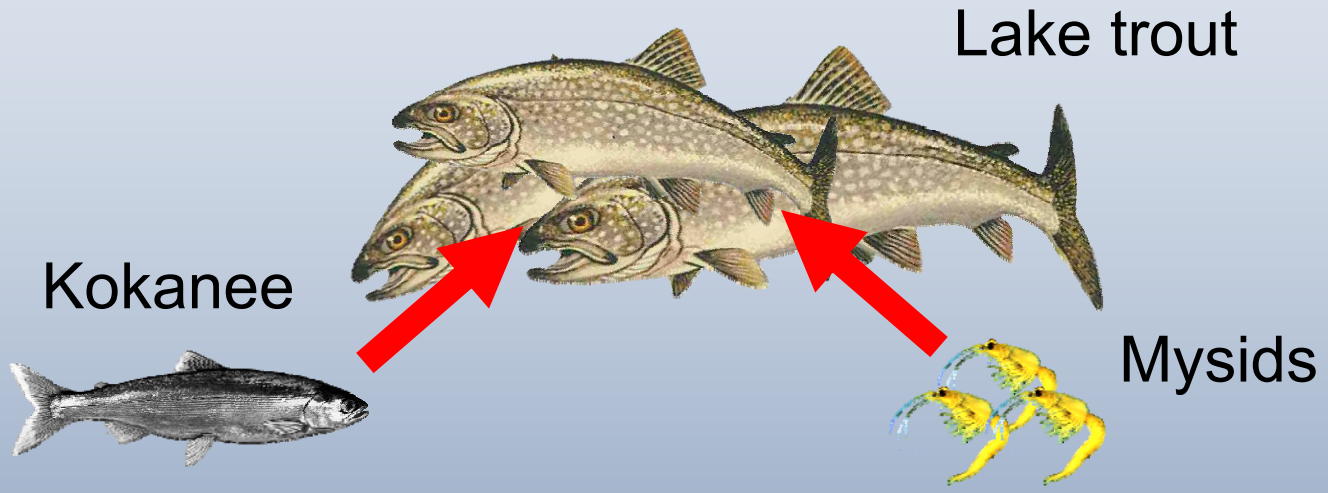
Do *Mysis* and kokanee compete for food? Possibly, but only in Lucerne Basin



In deep Lucerne Basin, zooplankton productivity is low enough during winter that kokanee may be food limited

Next step: compare vertical distribution of zooplankton and consumers

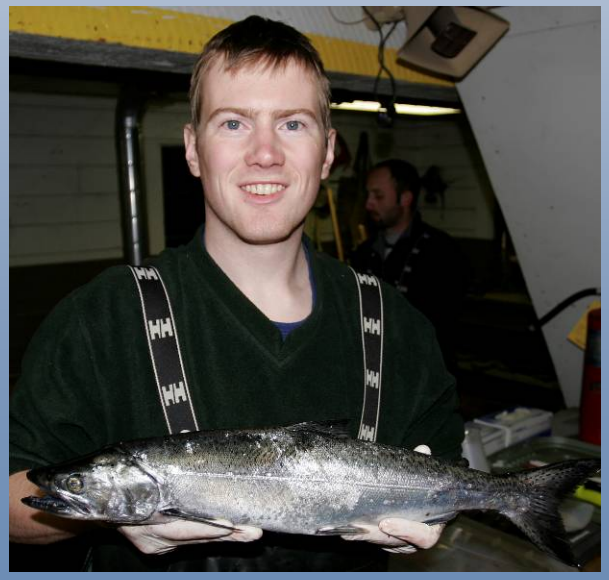
Do *Mysis* enhance predation impact of lake trout? Likely in Wapato Basin



- Lake trout CPUE is 10x higher in shallow Wapato Basin where mysids are the major prey
- Lake trout have higher relative weight ("plumpness") in Wapato Basin
- When kokanee are available during the spring, lake trout switch prey and eat them

Cutthroat trout and Chinook

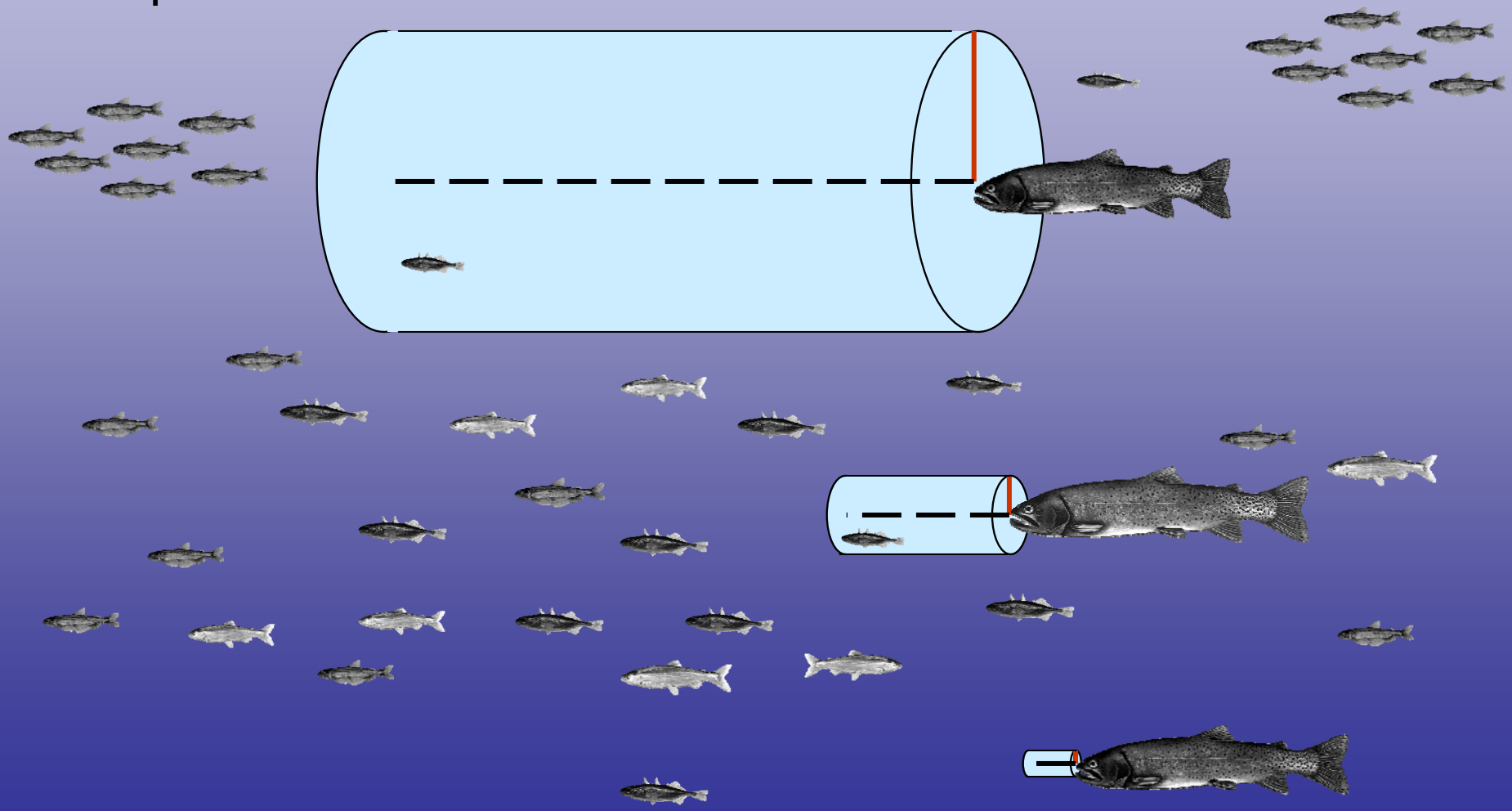
- No cutthroat or Chinook were positively identified in predator stomachs, but could be unidentified salmonid prey
- Only 6 wild cutthroat trout and 5 Chinook caught during the study, all in Lucerne Basin
- Pending stable isotope analysis will give general indication of diet–anglers contributed additional samples
- Can address predator-prey consequences of about future management actions using visual foraging framework



FUTURE RESEARCH OPPORTUNITIES

Visual foraging framework: based on behavior of pelagic fish

Search Volume & Prey Density interact to determine predation rates



FUTURE RESEARCH OPPORTUNITIES

Visual foraging applications for Lake Chelan management:

Cutthroat trout recovery

Do current lake trout densities preclude recovery of cutthroat trout?

How much enhancement by stocking is necessary to overcome predation losses?

How would predation pressure change under different densities of lake trout or Chinook?

Chinook salmon rebuilding

Do current lake trout densities preclude rebuilding a Chinook population?

Are recent kokanee densities high enough to support Chinook? At what Chinook density?

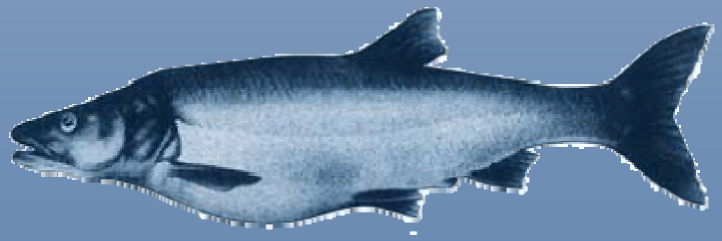
FUTURE RESEARCH OPPORTUNITIES

Refining existing diet data

Genetic ID of unidentified salmonid prey: 40 stomachs contained salmonids. Of these, 20 contained unidentified salmonids, 19 contained kokanee, and 2 contained lake trout.

Analysis of littoral diet samples collected in Wapato Basin by electroshocking and gill netting by WDFW (n = 197)

Bioenergetics modeling for pikeminnow (or bass)



FUTURE RESEARCH OPPORTUNITIES

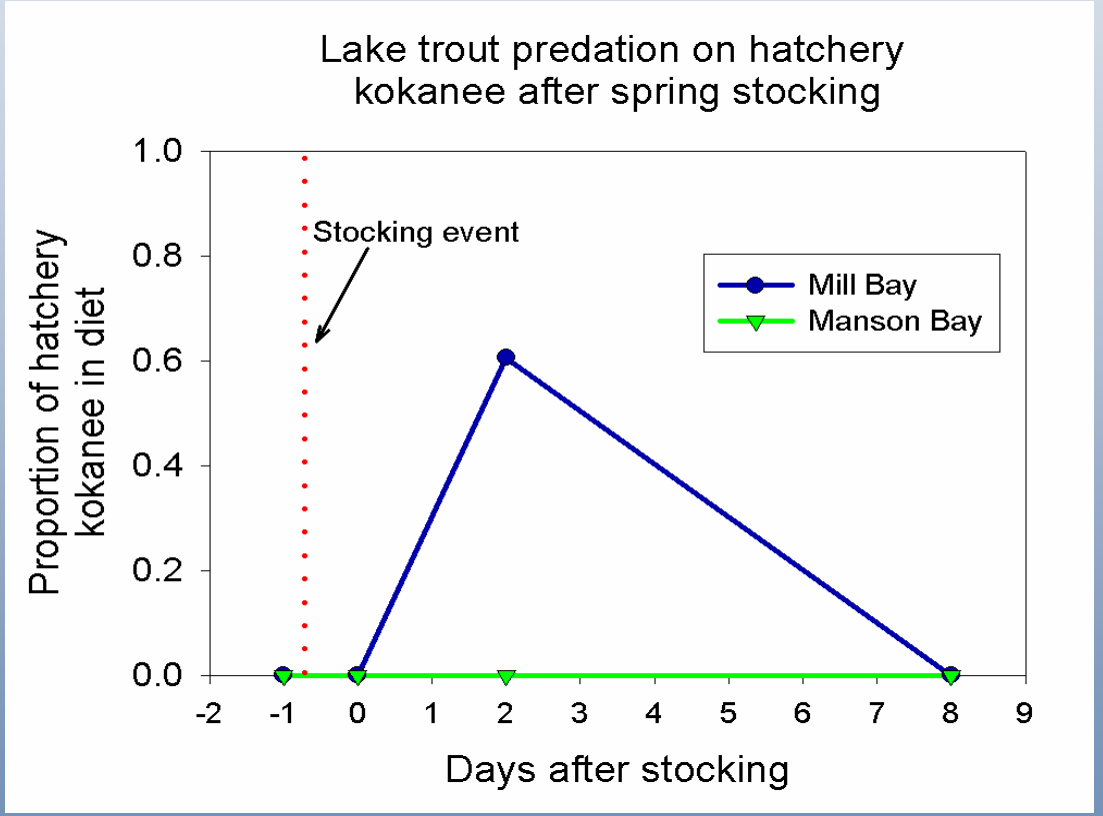
Evaluating alternative stocking strategies

How many stocked fish are consumed immediately after stocking?

Pilot study in 2005 found major lake trout predation response to kokanee stocking

Can alternative stocking strategies reduce this loss?

Stocking at night? In Lucerne Basin? Other ideas?



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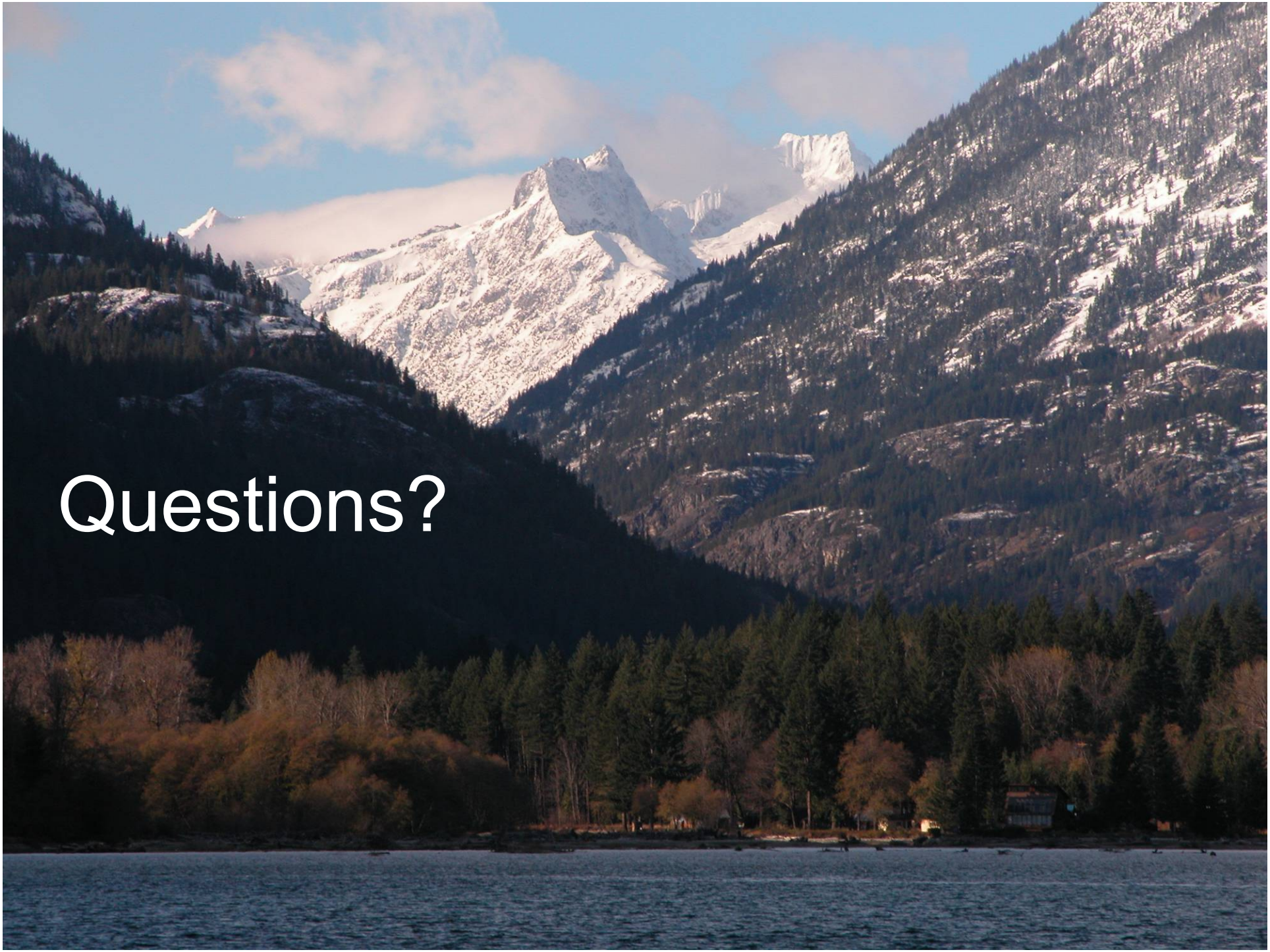
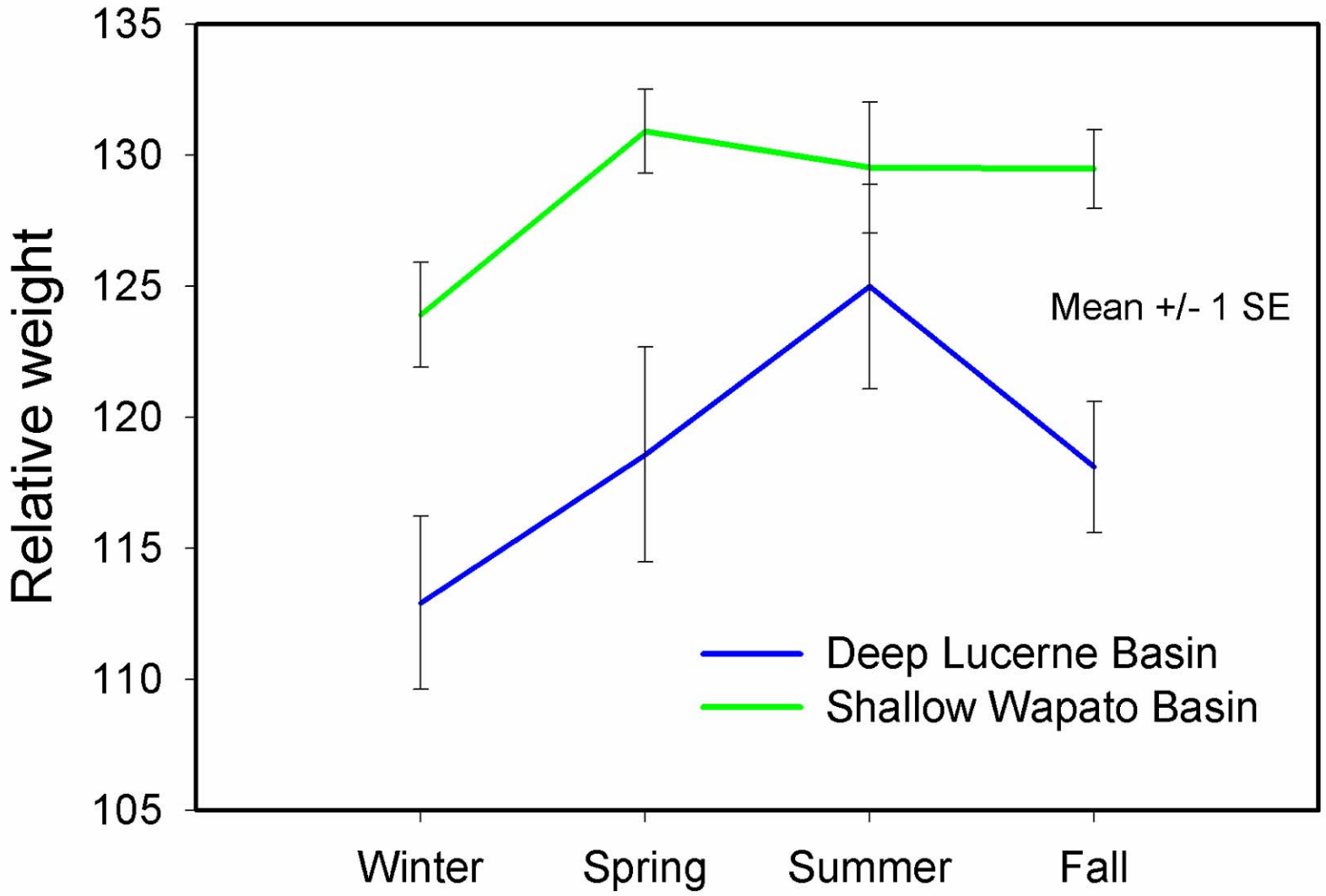
Jeff Osborn and Chelan PUD

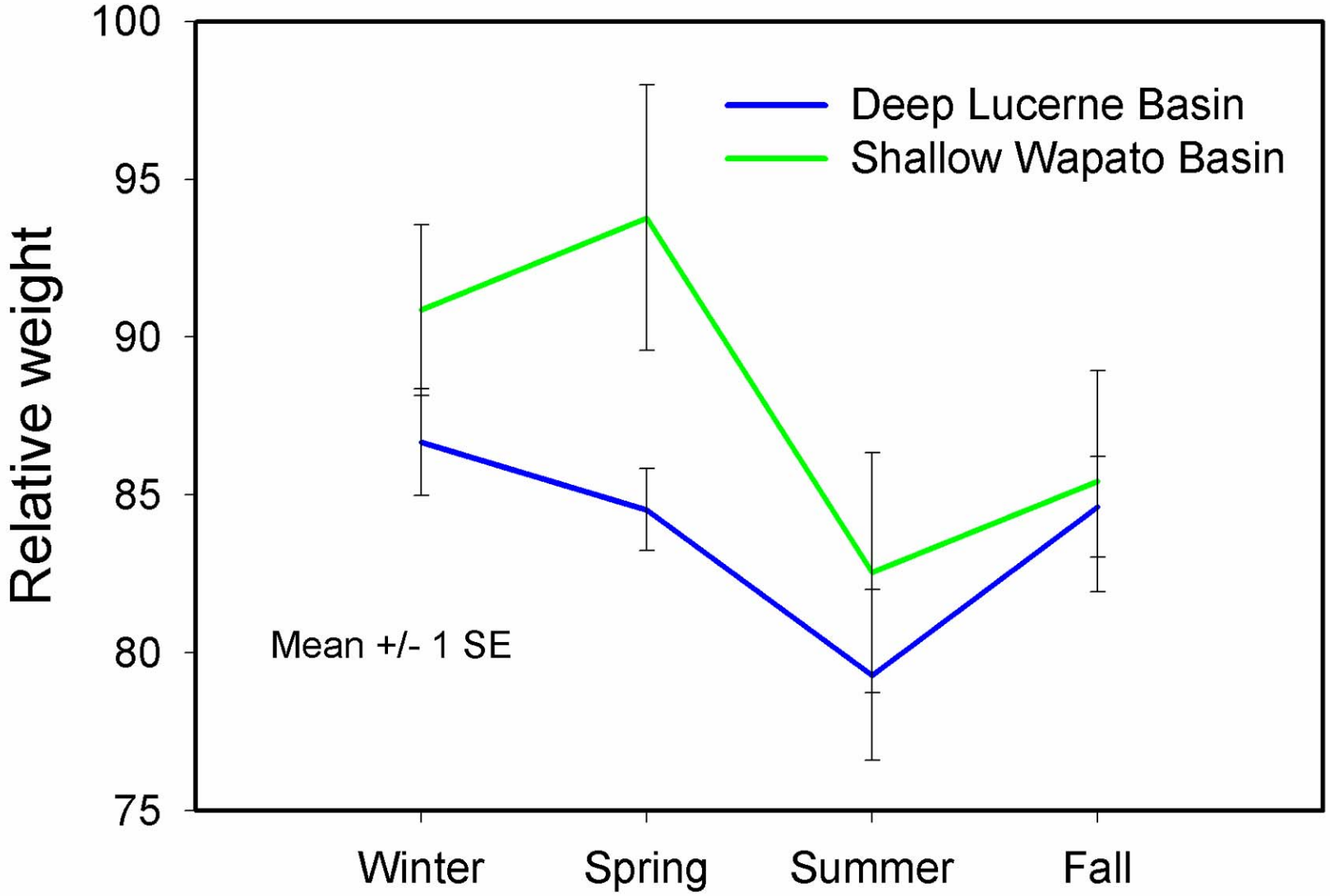
Lake Chelan Fish Hatchery

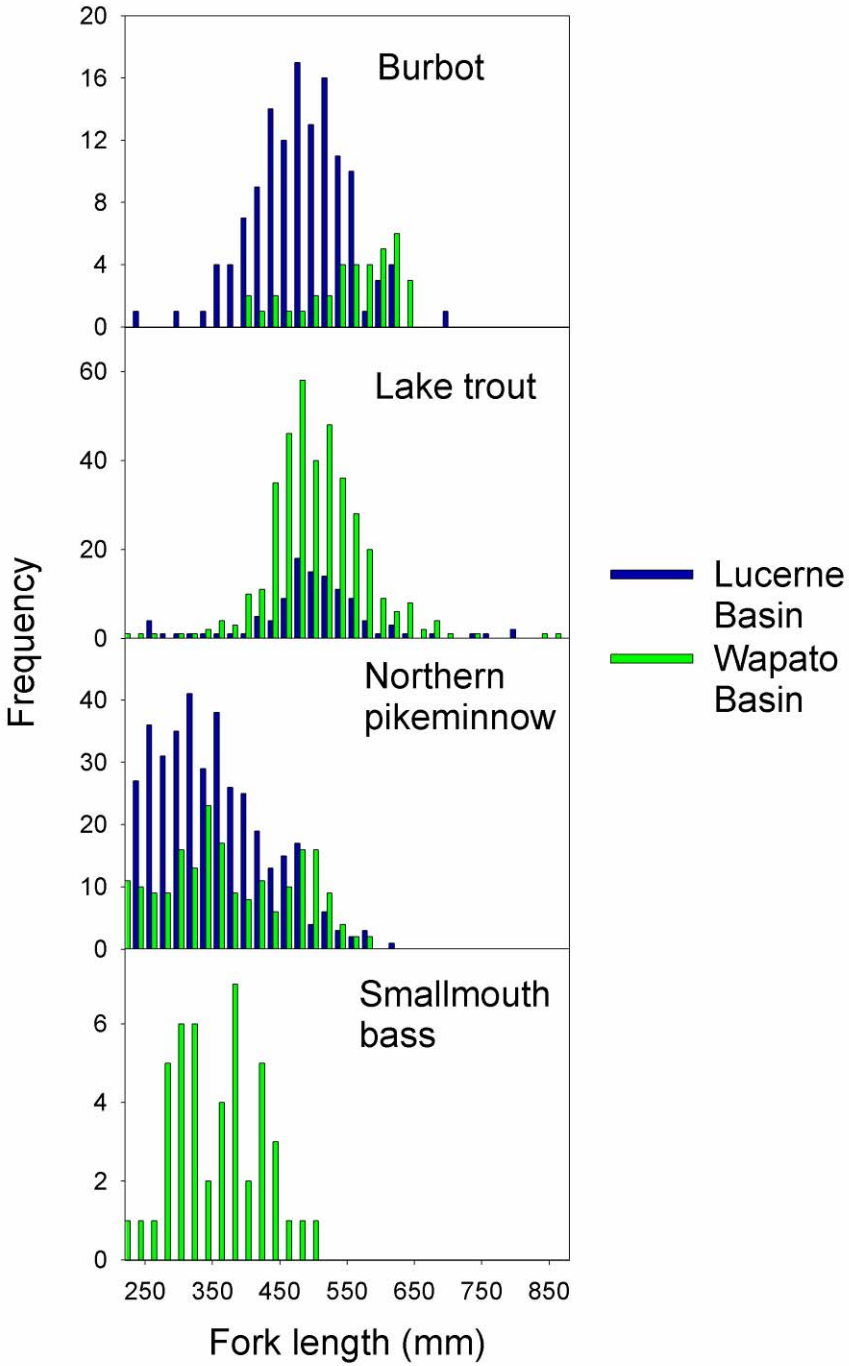

Questions?

Lake trout relative weight

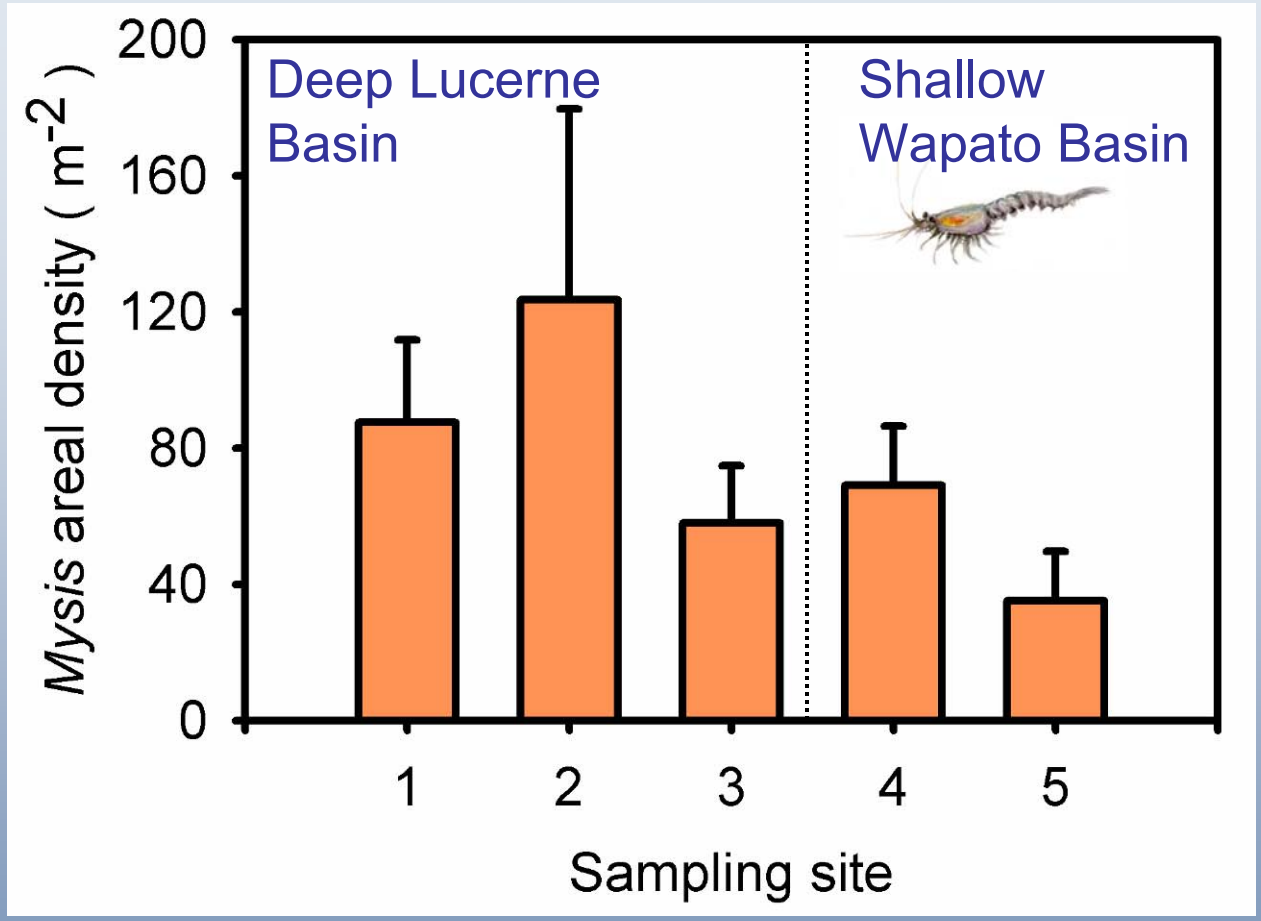


Burbot relative weight



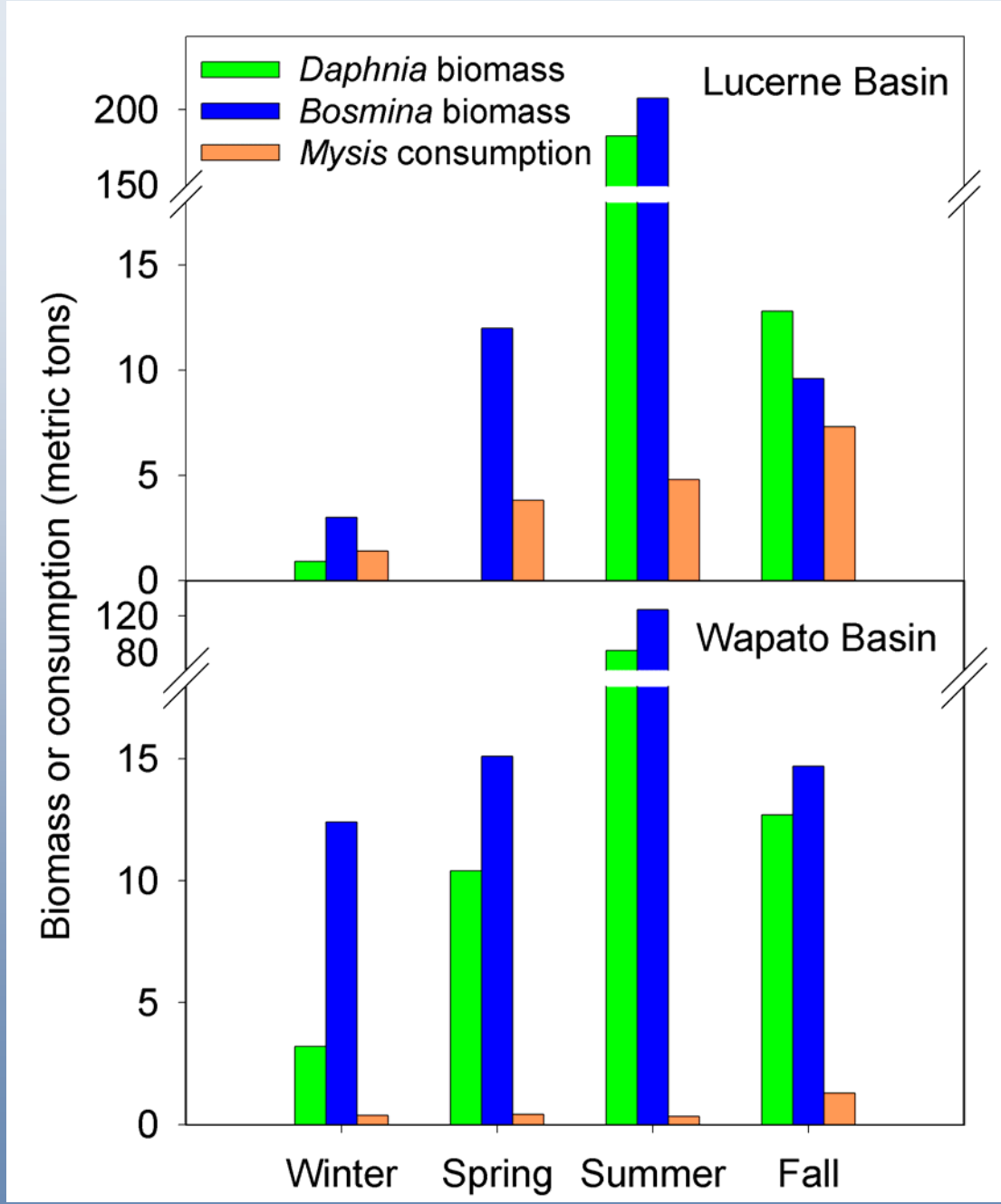

Burbot
Lake trout
Northern pikeminnow
Smallmouth bass
Frequency
Fork length (mm)
250 350 450 550 650 750 850
Lucerne Basin
Wapato Basin

Annual mean *Mysis* densities

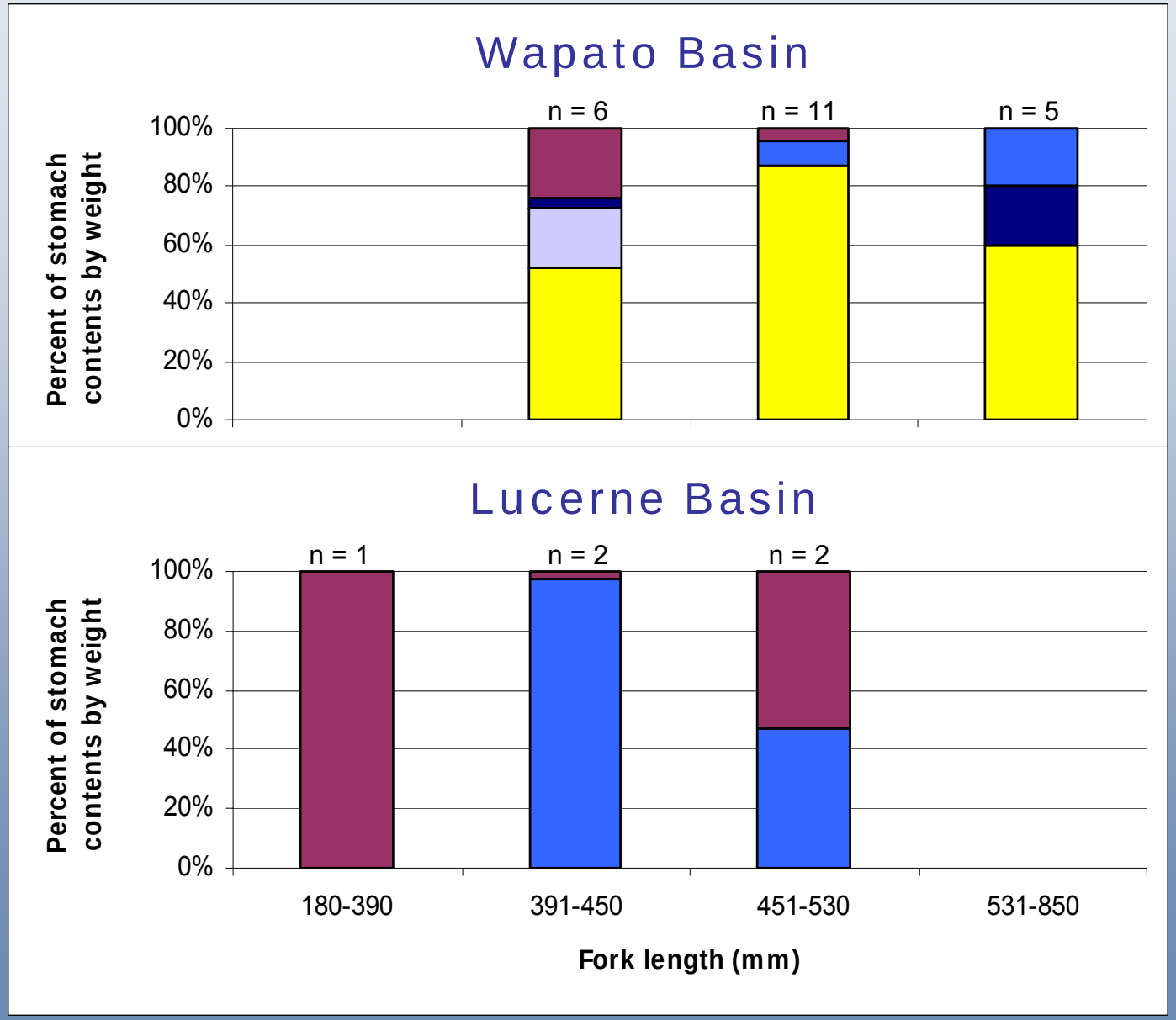


Mysis planktivory

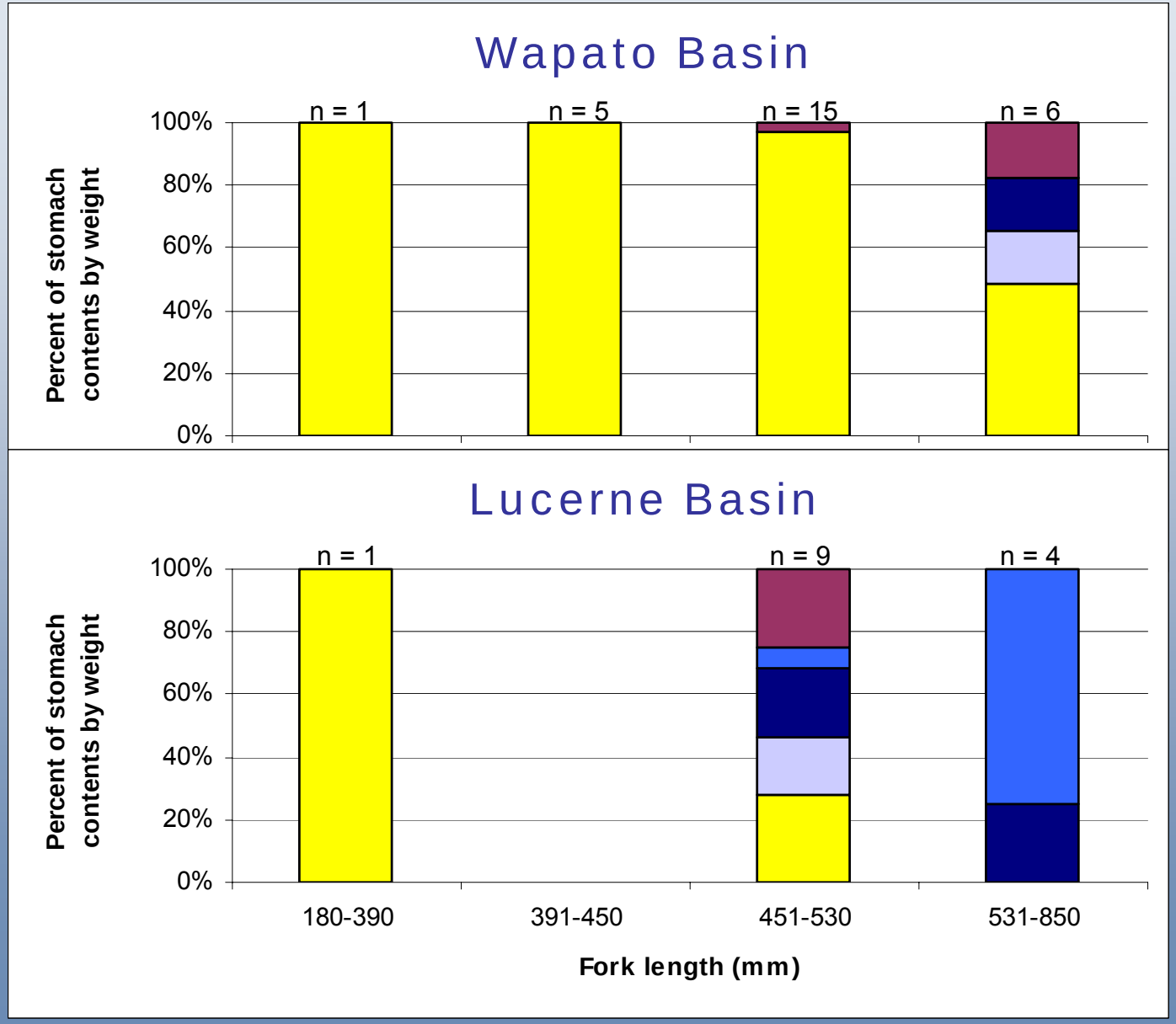
- Cladoceran standing stock biomass was far greater than seasonal *Mysis* consumption during most periods
- *Mysis* consumption may limit *Daphnia* densities in deep Lucerne Basin during cold months (caveats)

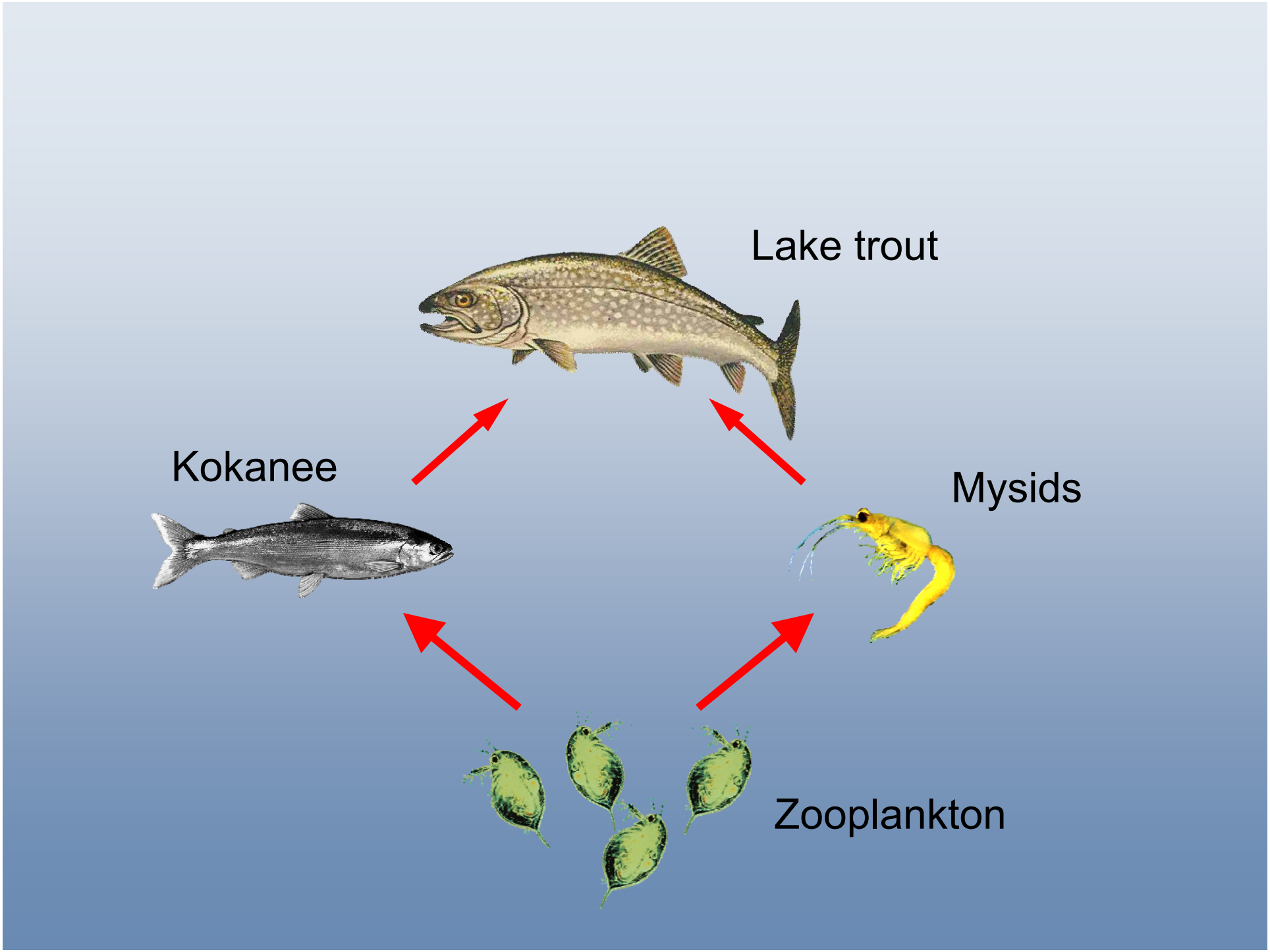


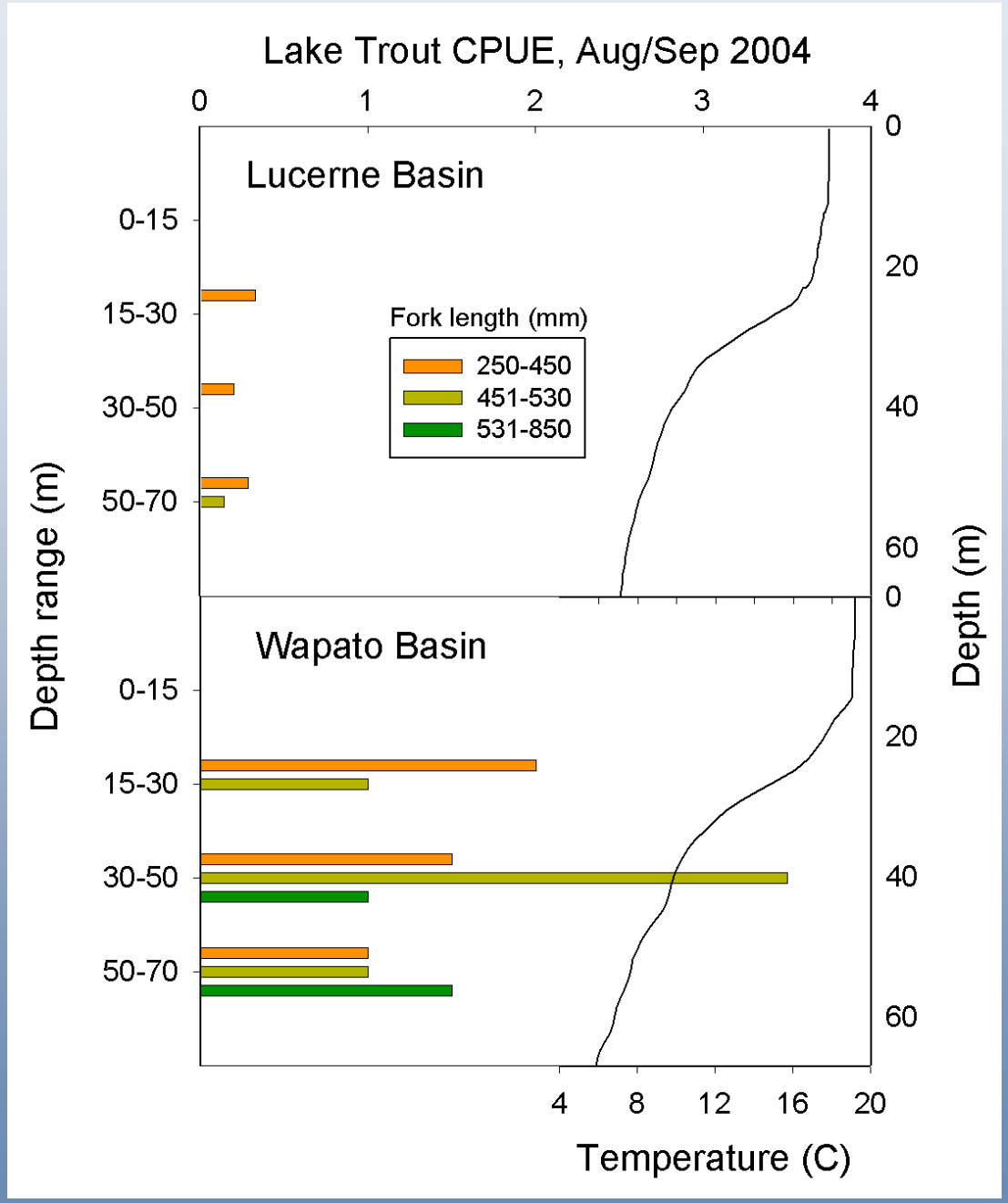
Lake trout diet: August



Lake trout diet: February




Lake trout
Kokanee
Mysids
Zooplankton


Lake Trout CPUE, Aug/Sep 2004
0
1
2
3
4
Lucerne Basin
0-15
15-30
30-50
50-70
Fork length (mm)
250-450
451-530
531-850
Wapato Basin
0-15
15-30
30-50
50-70
Depth range (m)
0
20
40
60
Depth (m)
4
8
12
16
20
Temperature (C)