Food web structure of Kachess and Keechelus Reservoirs: identifying and quantifying important interactions for bull trout

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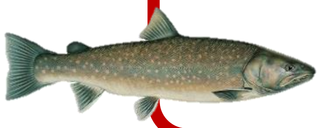
U.S. DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

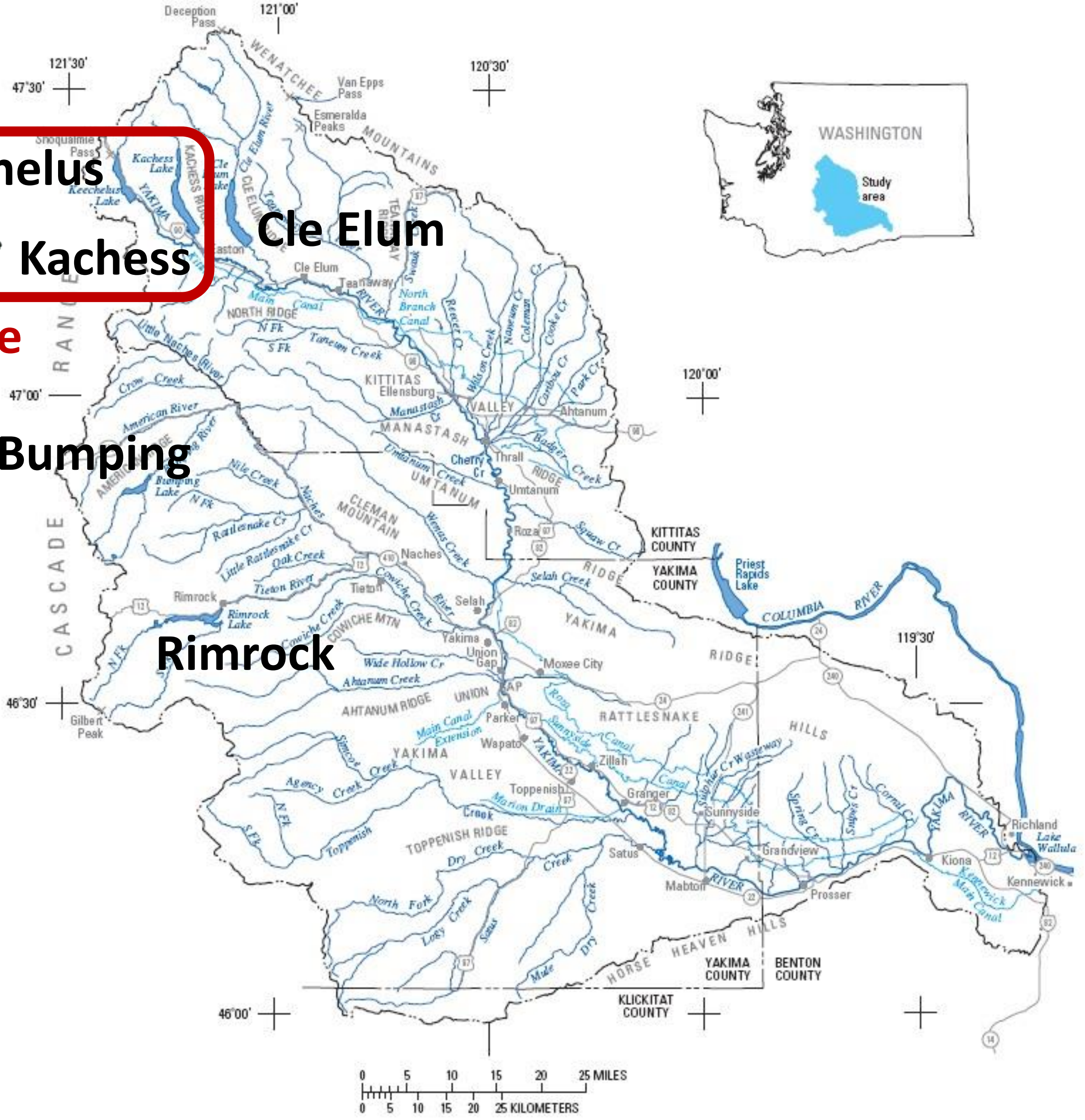
DEPARTMENT OF ECOLOGY State of Washington

Primary use: irrigation demand



Low abundance

Reiss et al. (2012)

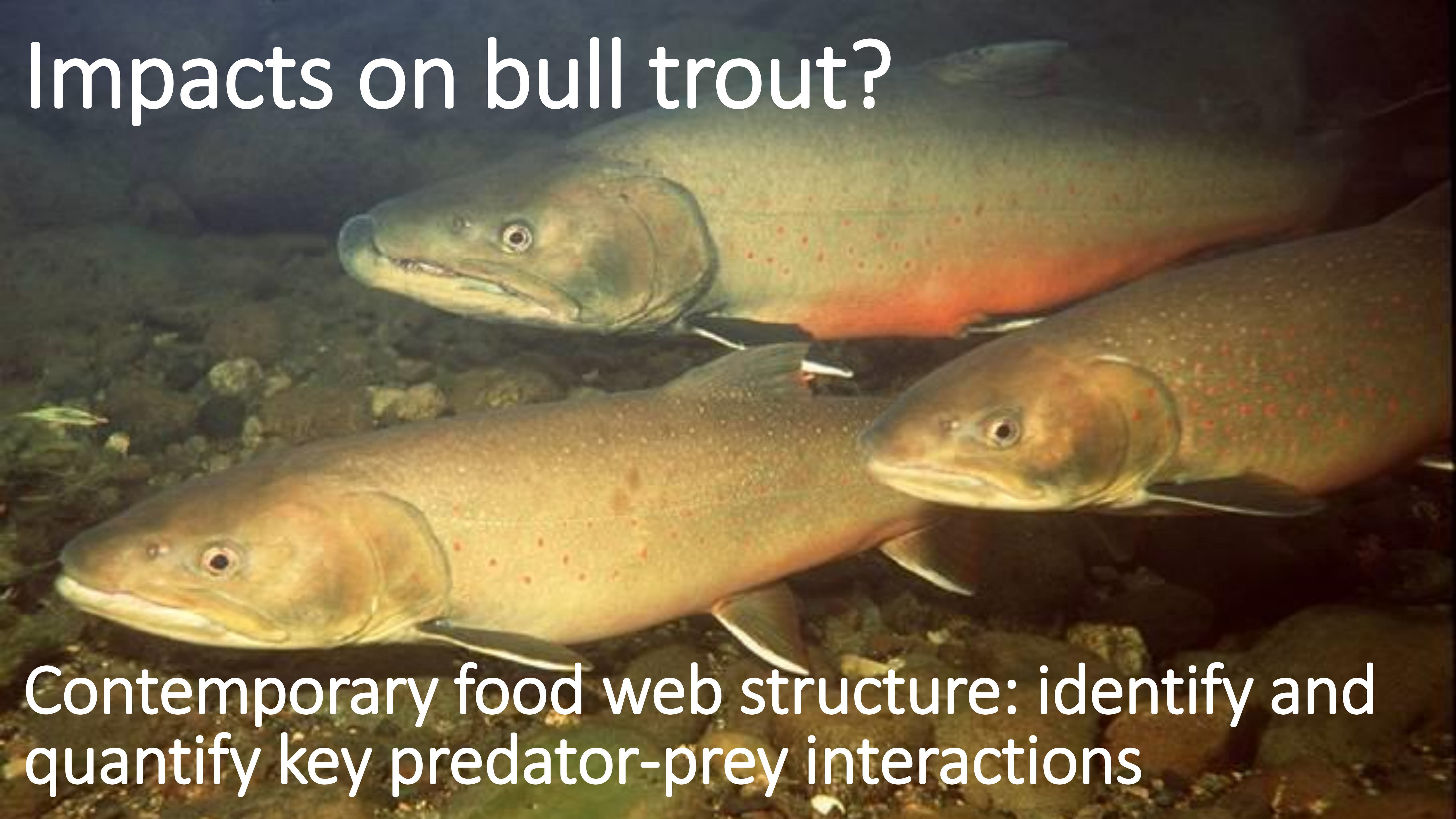


Projects proposed:

(1) Keechelus-to-Kachess conveyance to capture excess water from Keechelus drainage

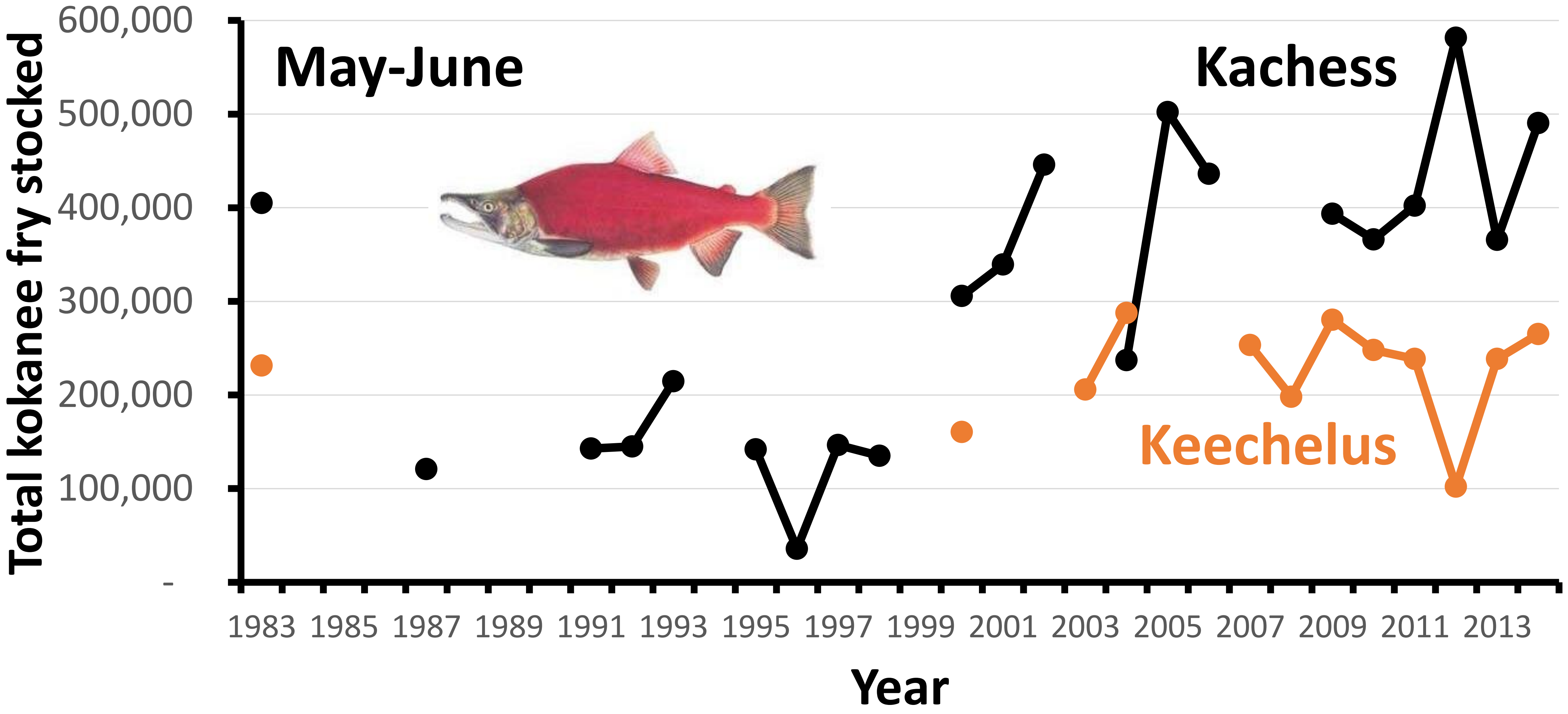
(2) Pumping plant to access **200,000 ac-ft** of currently inactive storage in Kachess during periods of drought

Impacts on bull trout?



Contemporary food web structure: identify and quantify key predator-prey interactions

Stocking records: kokanee fry



Objectives and Approach

(1) Characterize food web structure with stable isotopes

- Identify key interactions as they relate to bull trout (BLT) and kokanee (KOK)

(2) Evaluate foraging and growth environment for BLT & KOK

- Thermal structure, food supply, density/distribution
- Drives predation mortality, food availability, growth, survival

(3) Relative importance of food supply, temperature, predation as limits to production of key species

- Bioenergetics modeling to quantify key interactions and carrying capacity: consumption demand vs. food supply for BLT, KOK, other predators

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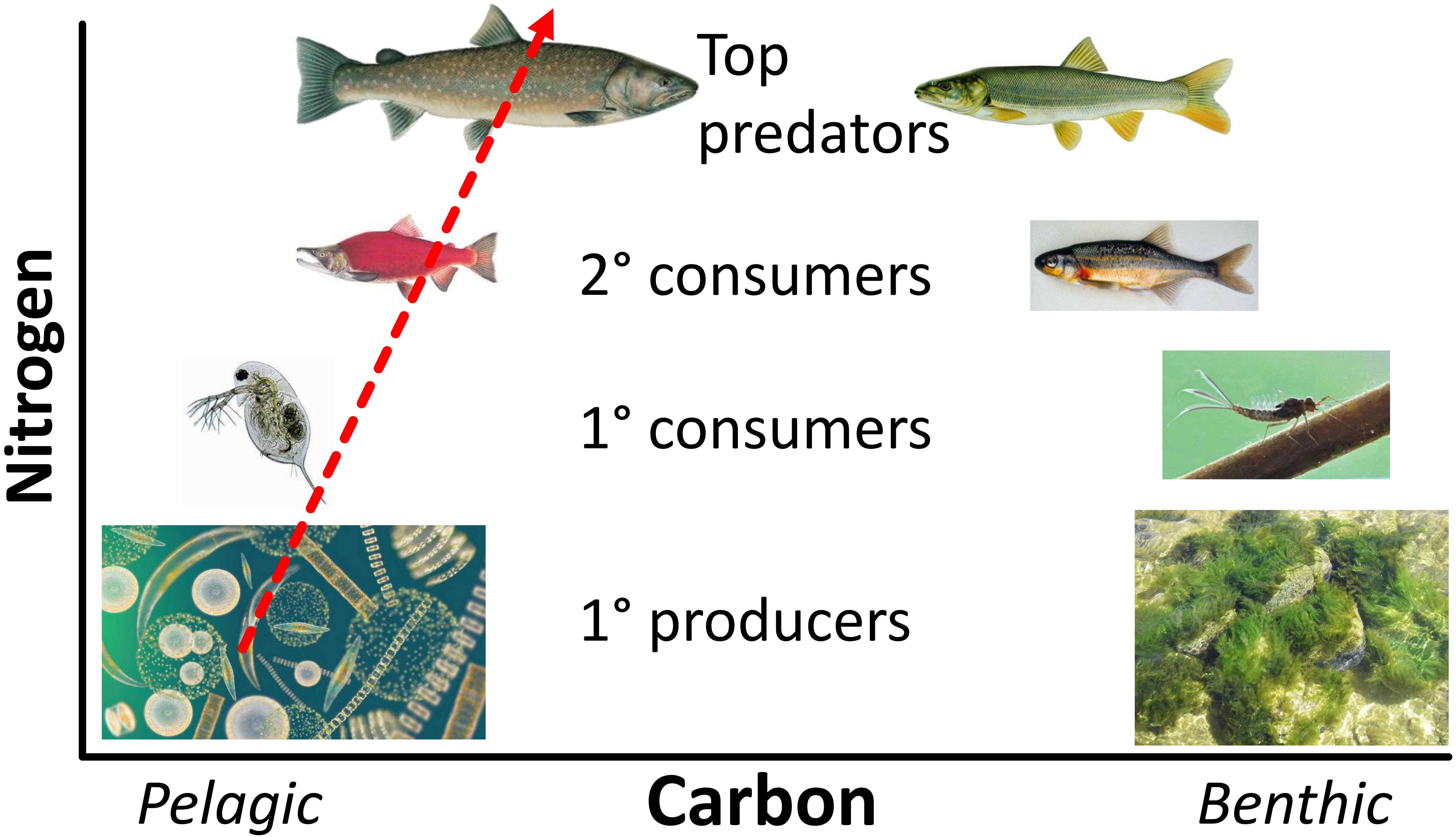
Stable Isotope Analysis

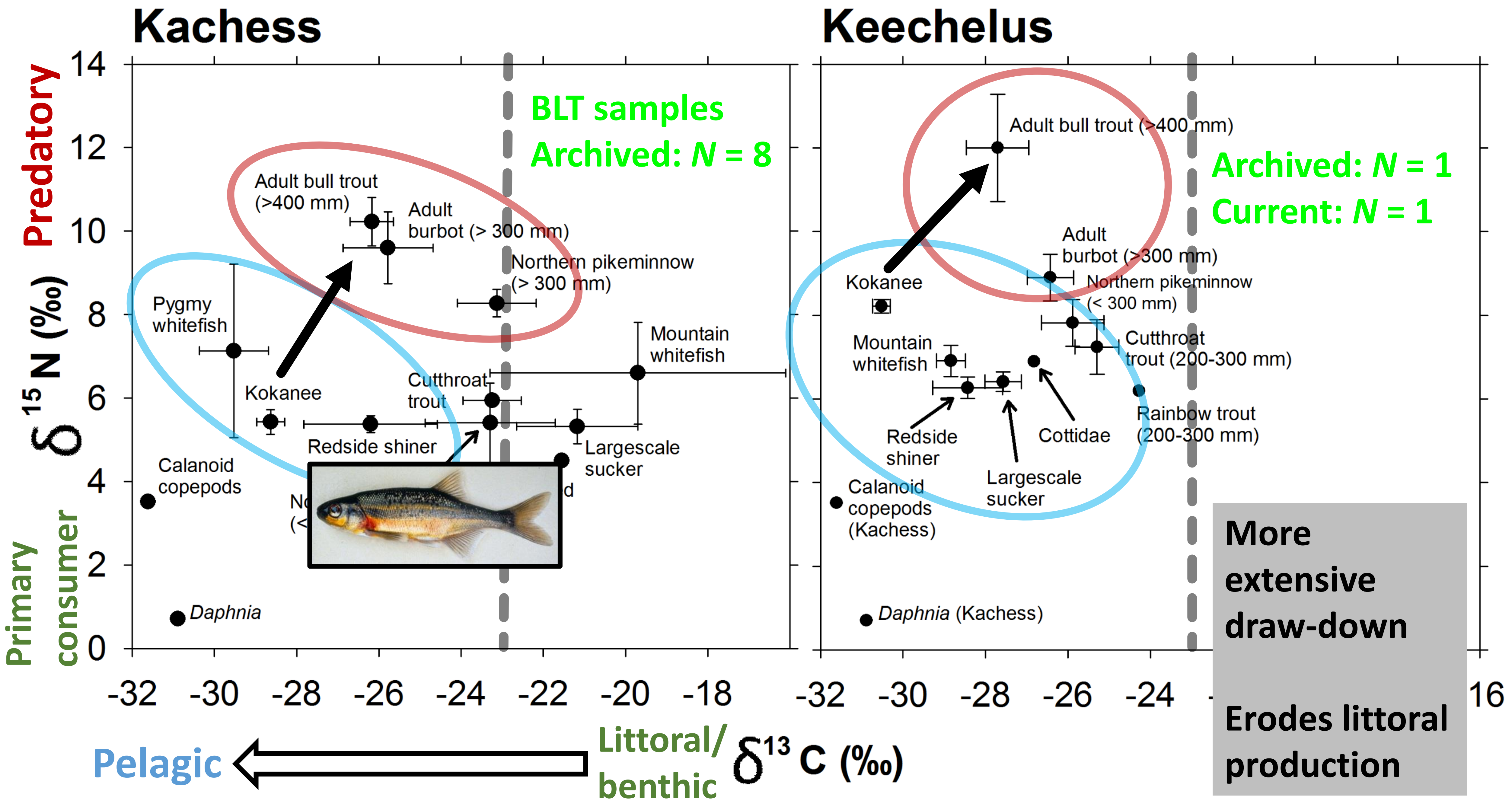
(1) Using chemical signatures of fish and invertebrates (ratio of **carbon** [^{13}C and ^{14}C] and **nitrogen** [^{14}N and ^{15}N] isotopes) to understand food web linkages → ***<u>you are what you eat</u>***

(2) **Nitrogen** → position in food web (1° producer to top predator)

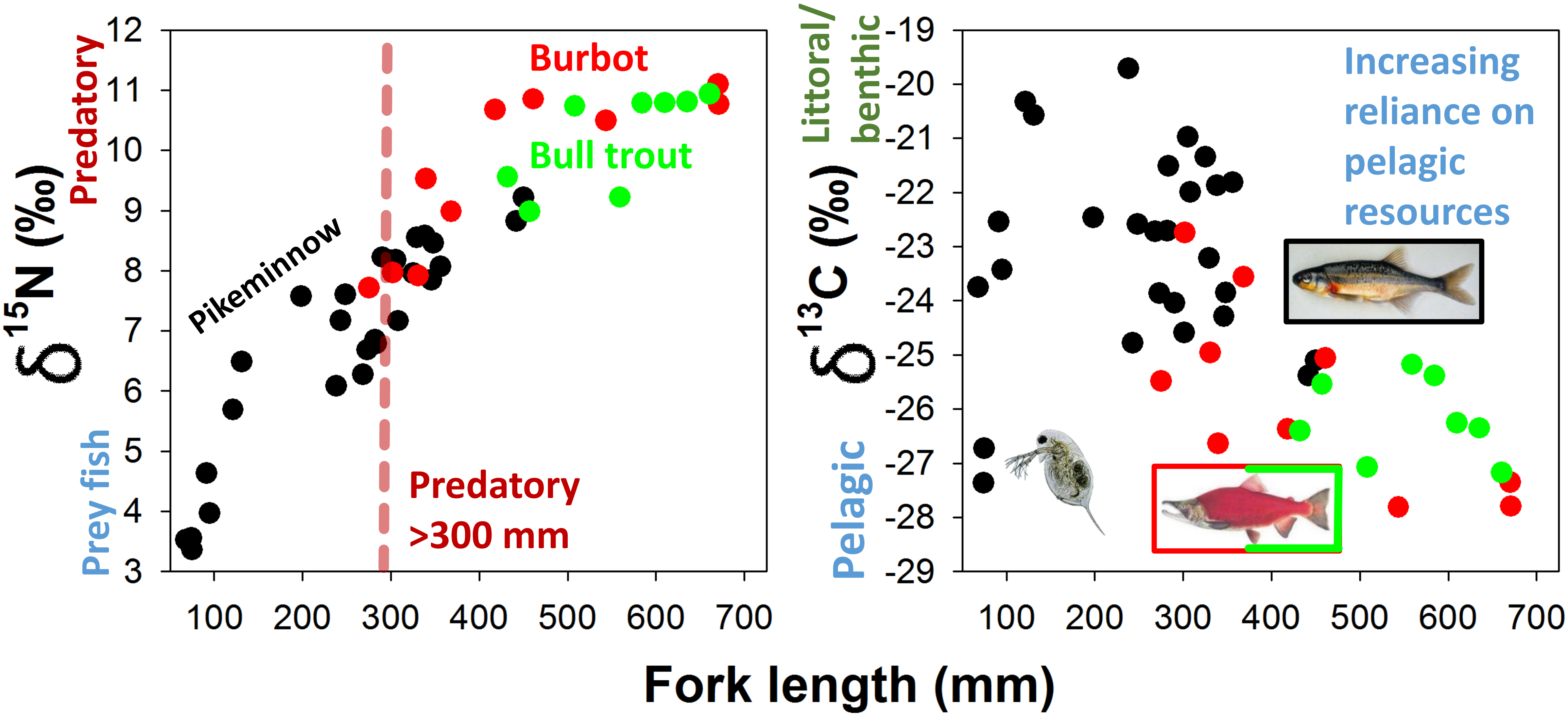
(3) **Carbon** → primary energy source (offshore vs. littoral)



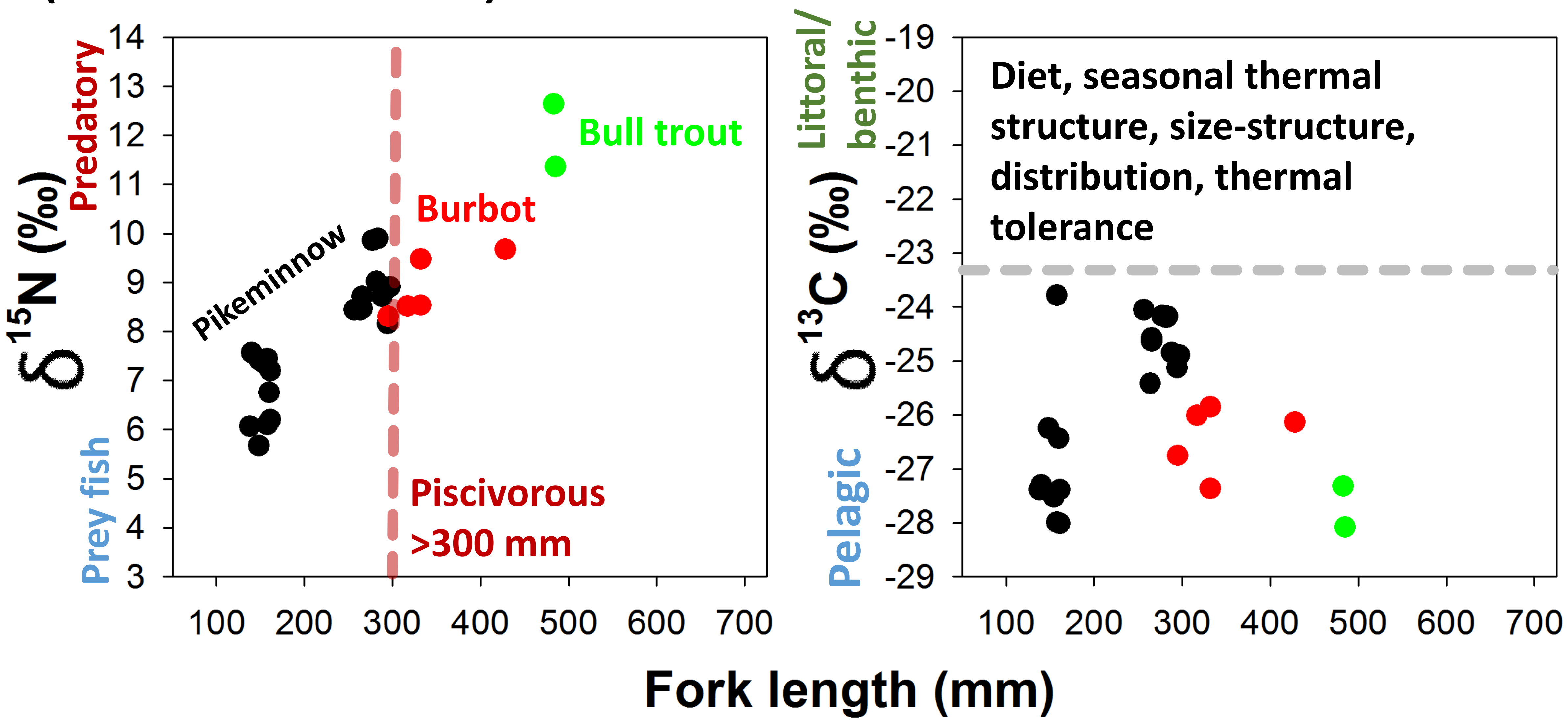
Nitrogen
Top predators
2° consumers
1° consumers
1° producers
Pelagic
Carbon
Benthic


Kachess
Keechelus
Predatory
Primary consumer
δ15N (‰)
BLT samples
Archived: N = 8
Archived: N = 1
Current: N = 1
Adult bull trout (>400 mm)
Adult burbot (> 300 mm)
Northern pikeminnow (> 300 mm)
Pygmy whitefish
Kokanee
Redside shiner
Cutthroat trout
Mountain whitefish
Largescale sucker
Calanoid copepods
Daphnia
Adult bull trout (>400 mm)
Kokanee
Adult burbot (>300 mm)
Northern pikeminnow (< 300 mm)
Mountain whitefish
Cutthroat trout (200-300 mm)
Rainbow trout (200-300 mm)
Redside shiner
Cottidae
Largescale sucker
Calanoid copepods (Kachess)
Daphnia (Kachess)
14
12
10
8
6
4
2
0
-32
-30
-28
-26
-24
-22
-20
-18
-16
Pelagic
Littoral/ benthic
δ13C (‰)
More extensive draw-down
Erodes littoral production

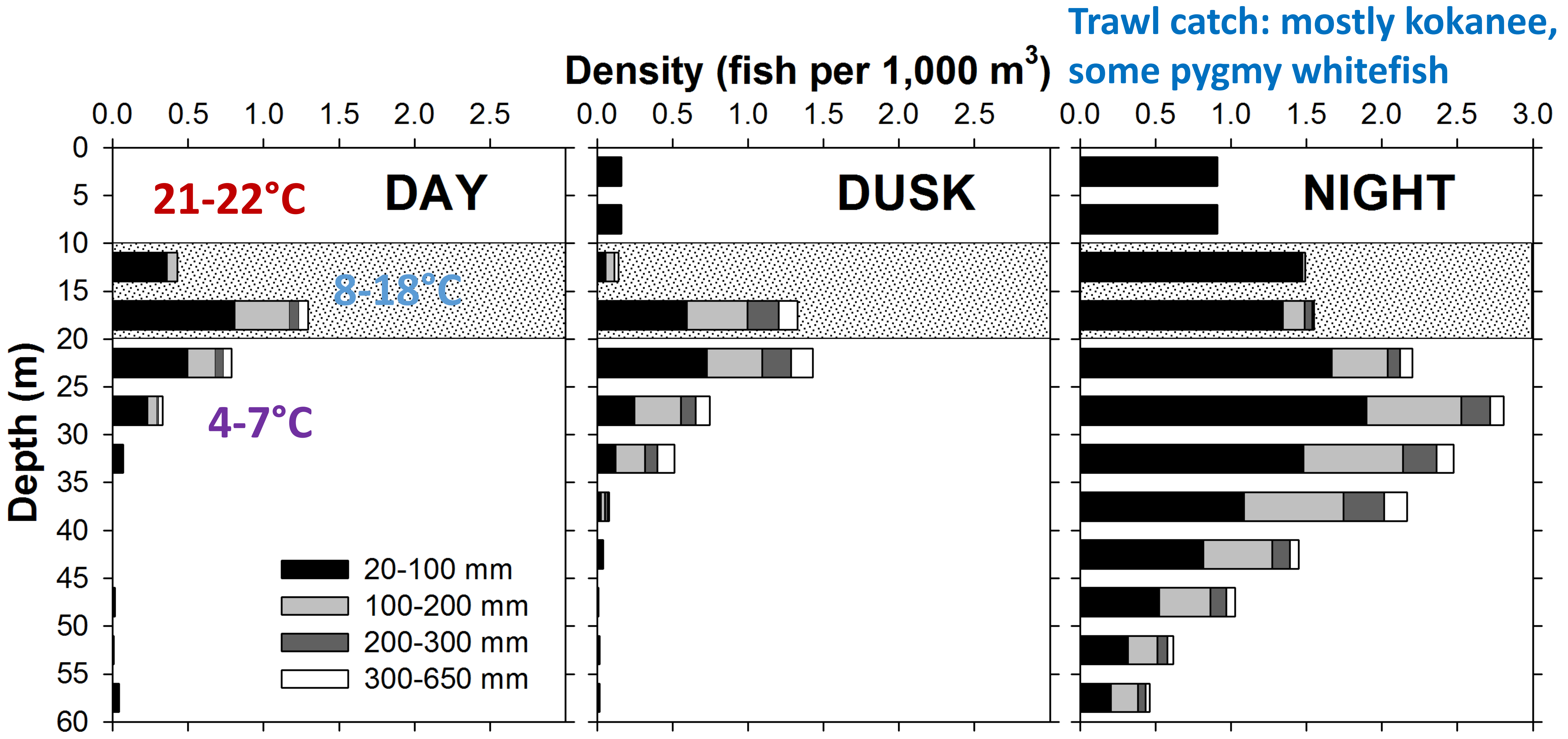
Predatory threat dependent on size (Kachess):



Predatory threat dependent on size (Keechelus):



Offshore fish distribution: August 2014 (Kachess)



Summary: stable isotopes

- Keechelus driven heavily by pelagic production (eroded benthic production from extensive draw-down over growing season)
- ***Implication***: more burden on pelagic energy pathways important for BLT in Kachess with KDRPP
- Top predators: adult BLT, large burbot, large NPM
- Kokanee and other pelagic prey important for adult BLT
- *Daphnia*/other ZOOP important for kokanee
- Large burbot could be important predator on KOK & juv. BLT

Going forward:

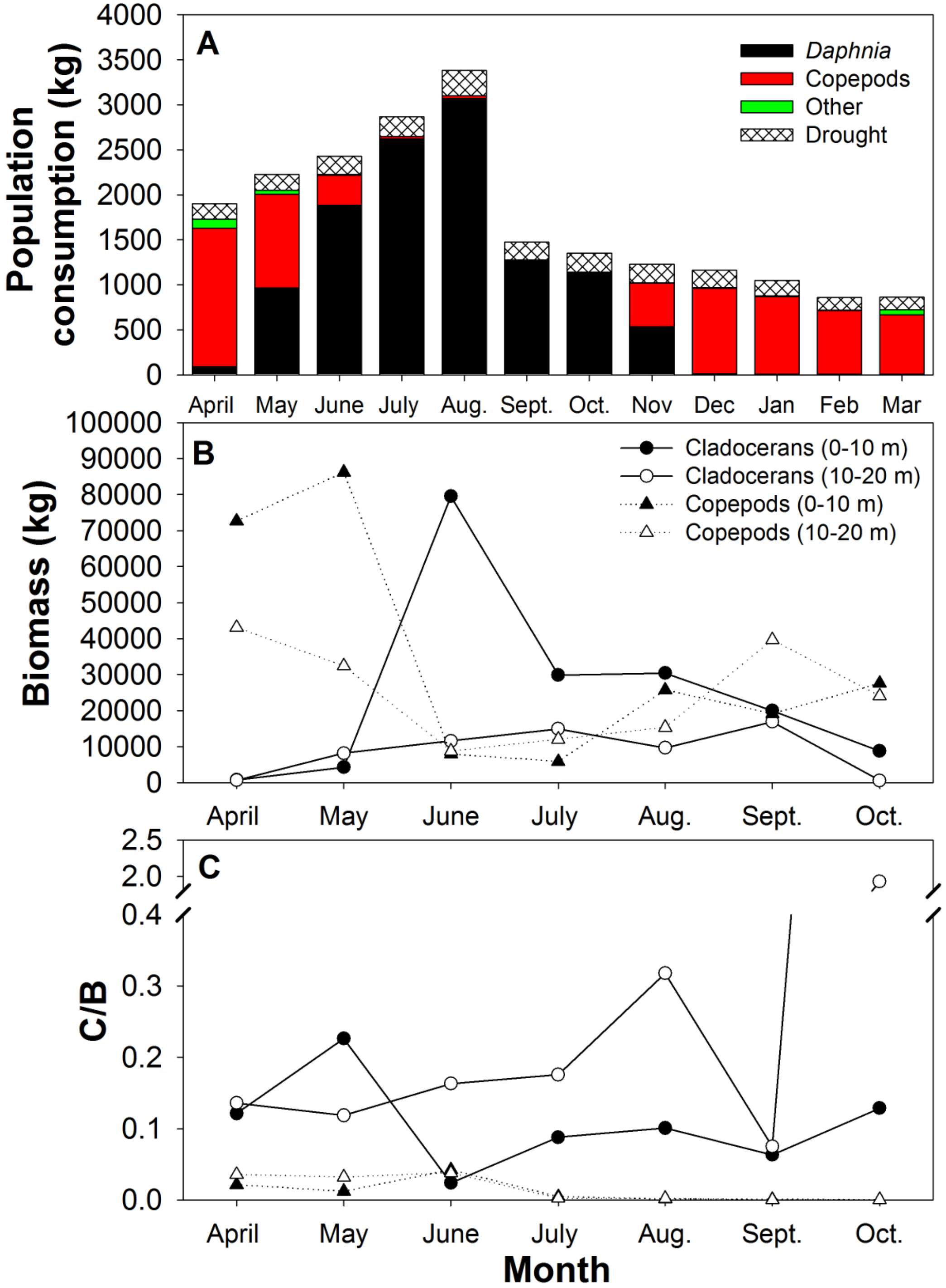
(1) What is the seasonal predation impact of burbot and pikeminnow on KOK/other prey versus bull trout?

(2) How will new water management influence limnology (e.g., thermal structure, food supply), and in turn, baseline food web interactions?

(3) Important data gap: Size/age at reservoir entry, habitat use, predation risk for juv. & sub-adult bull trout.

Questions?

Reintroduction of sockeye salmon net benefit for bull trout?



(1) Consumption from "natural cohort" of KOK << available biomass in metalimnion over growing season

(2) Within physical/ecological constraints could support (stock) 2-3x more KOK

~1.0 million 40-300 mm pelagic fish in August

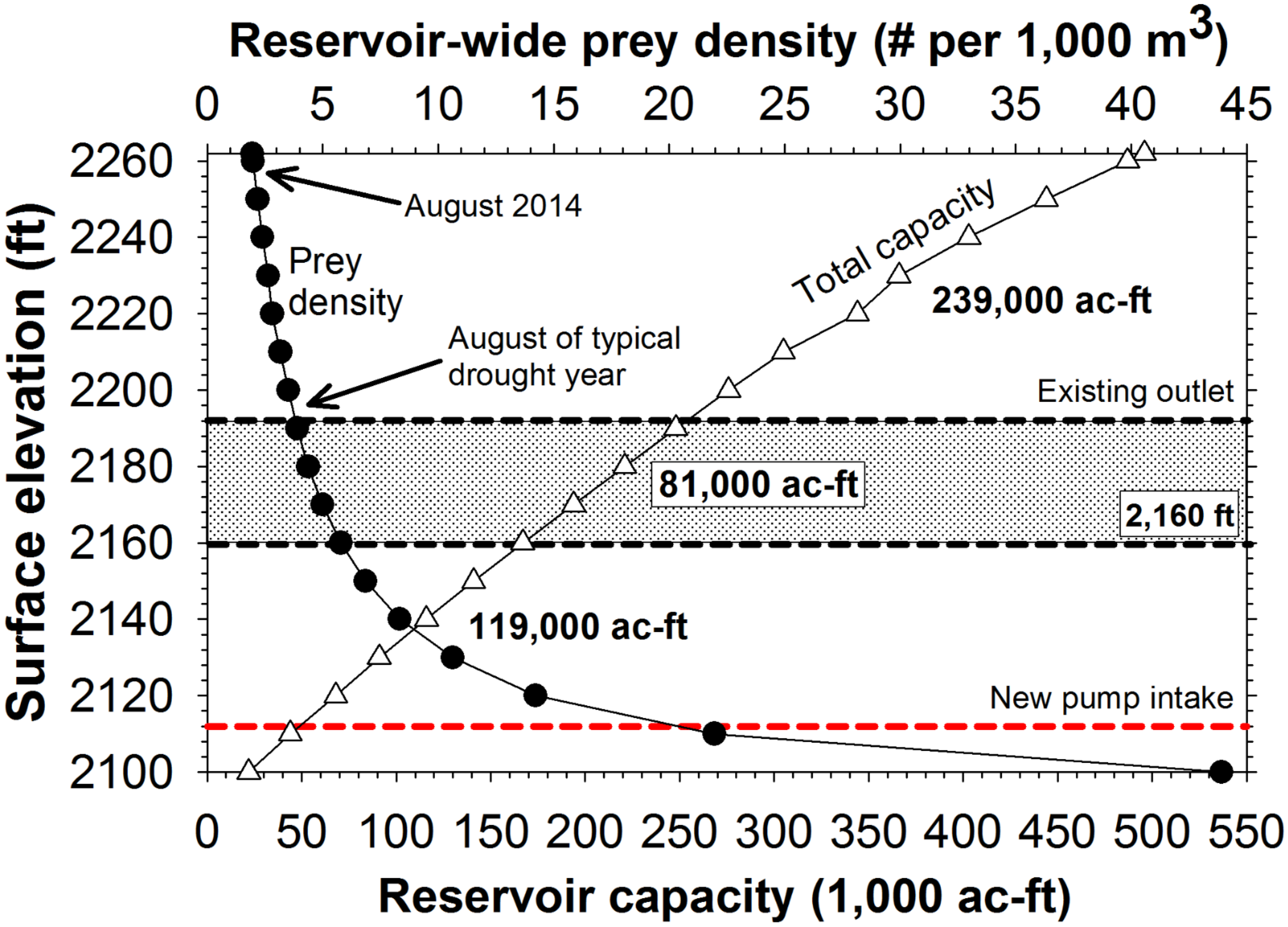
(3) Low to intermediate feeding rates (19-55% Cmax): food limitation or limited feeding near surface?

(4) Limited by temp and predator avoidance


HONDA
90

Relate ecology to water management

Identify management targets that attempt to avoid adverse impacts



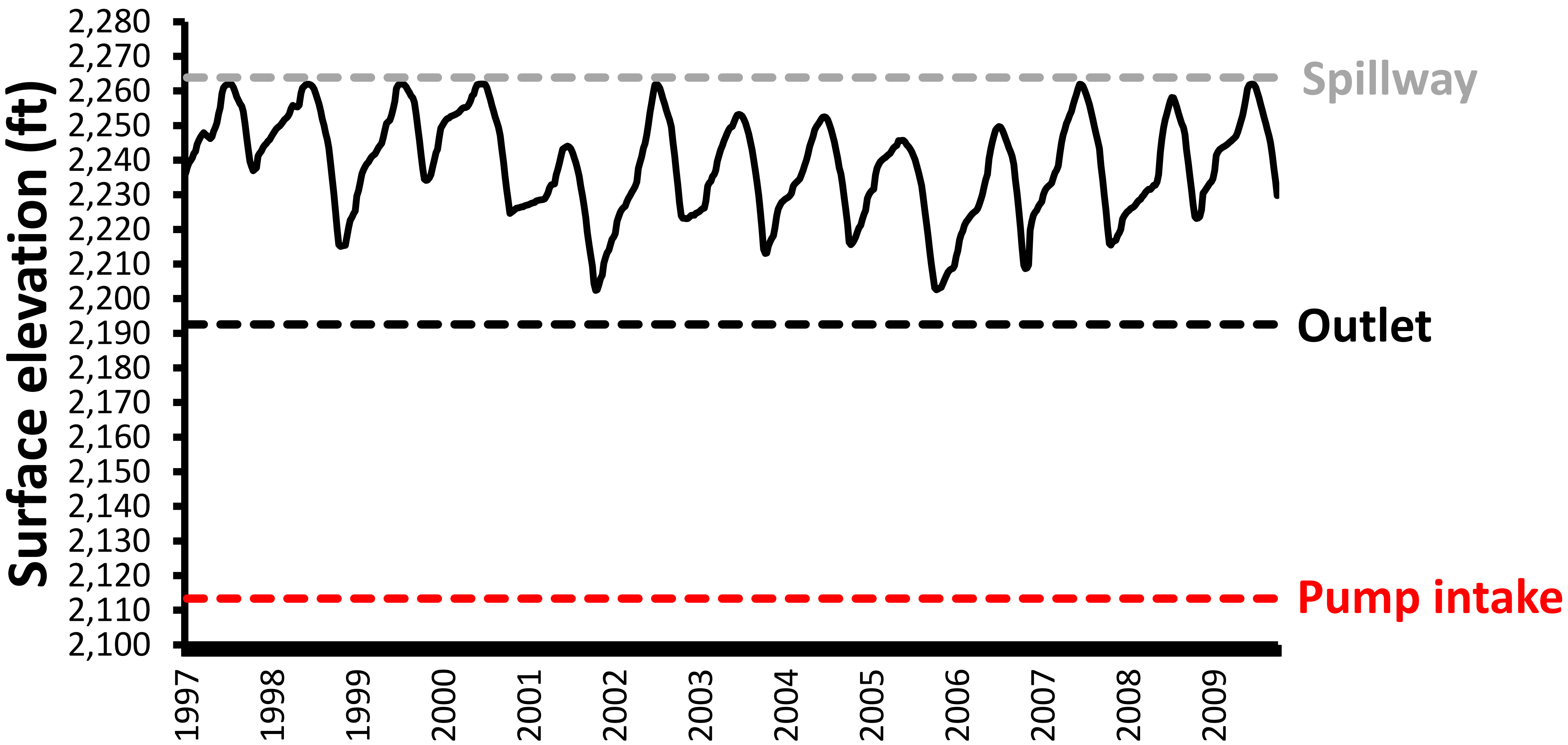
Reduce volume by ~90%

High compression of cold water habitat

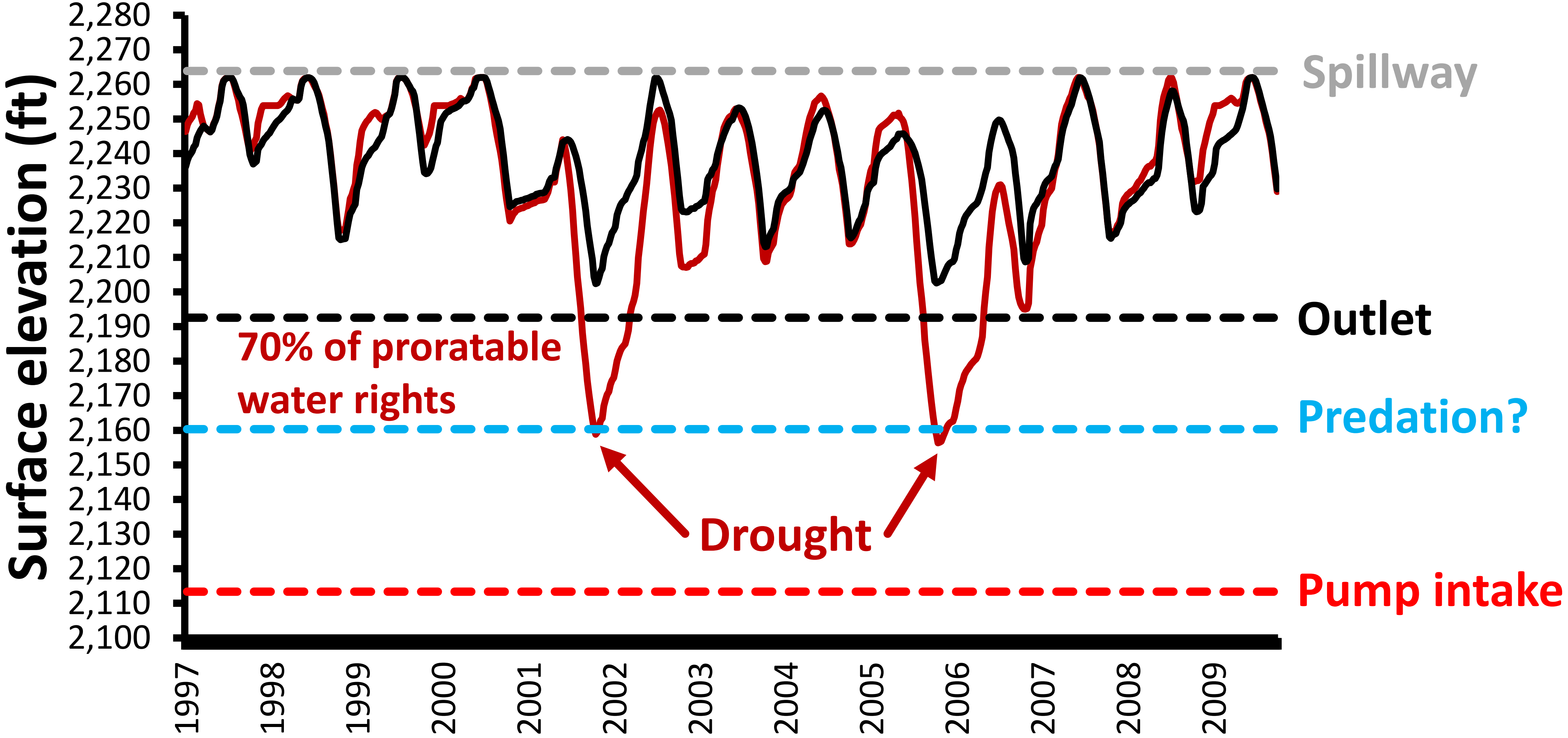
Potential for high predation mortality

Suspension of sediments, access to spawning tribs, downstream impacts

Baseline (1997-2009)



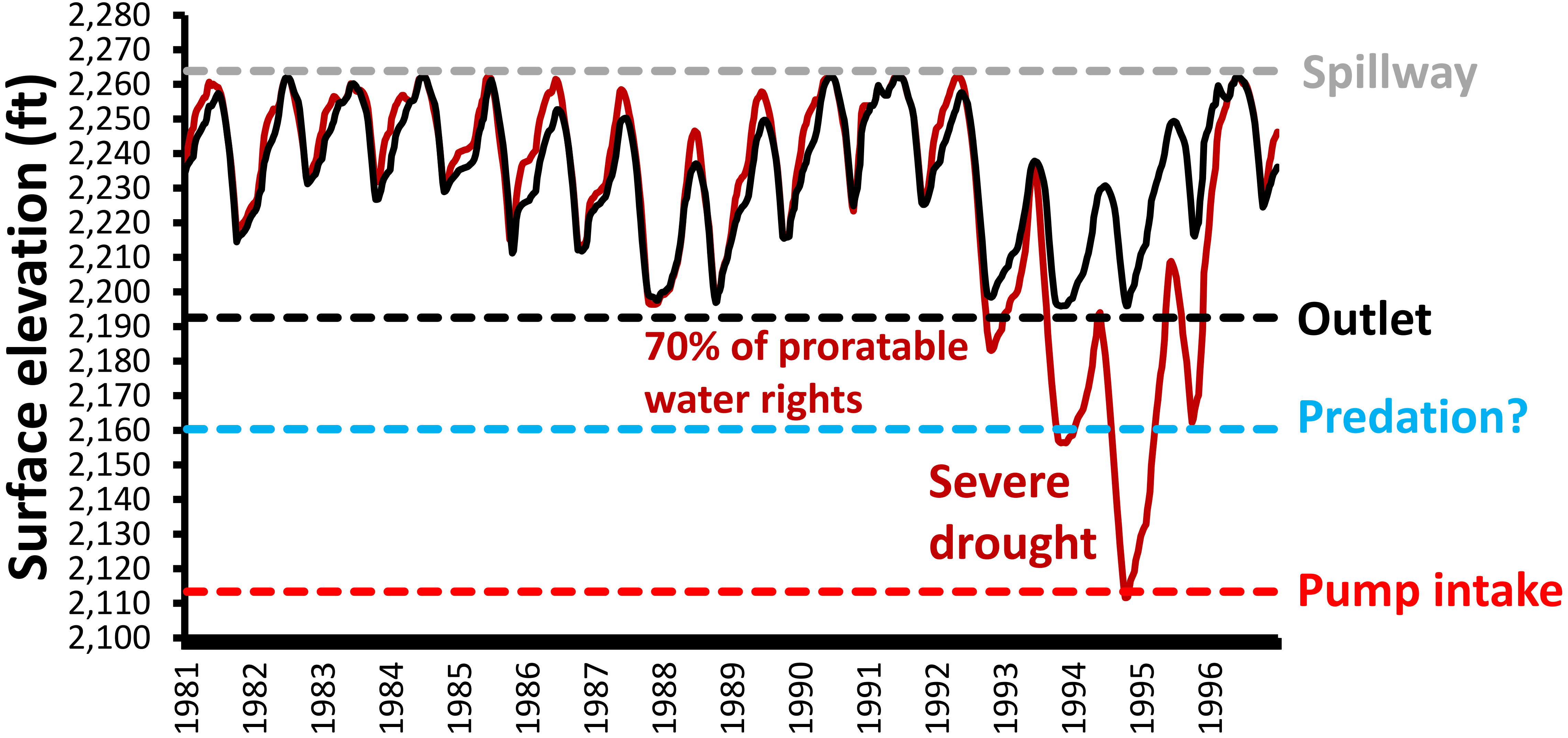
Baseline vs. KDRPP + KKC (1997-2009)



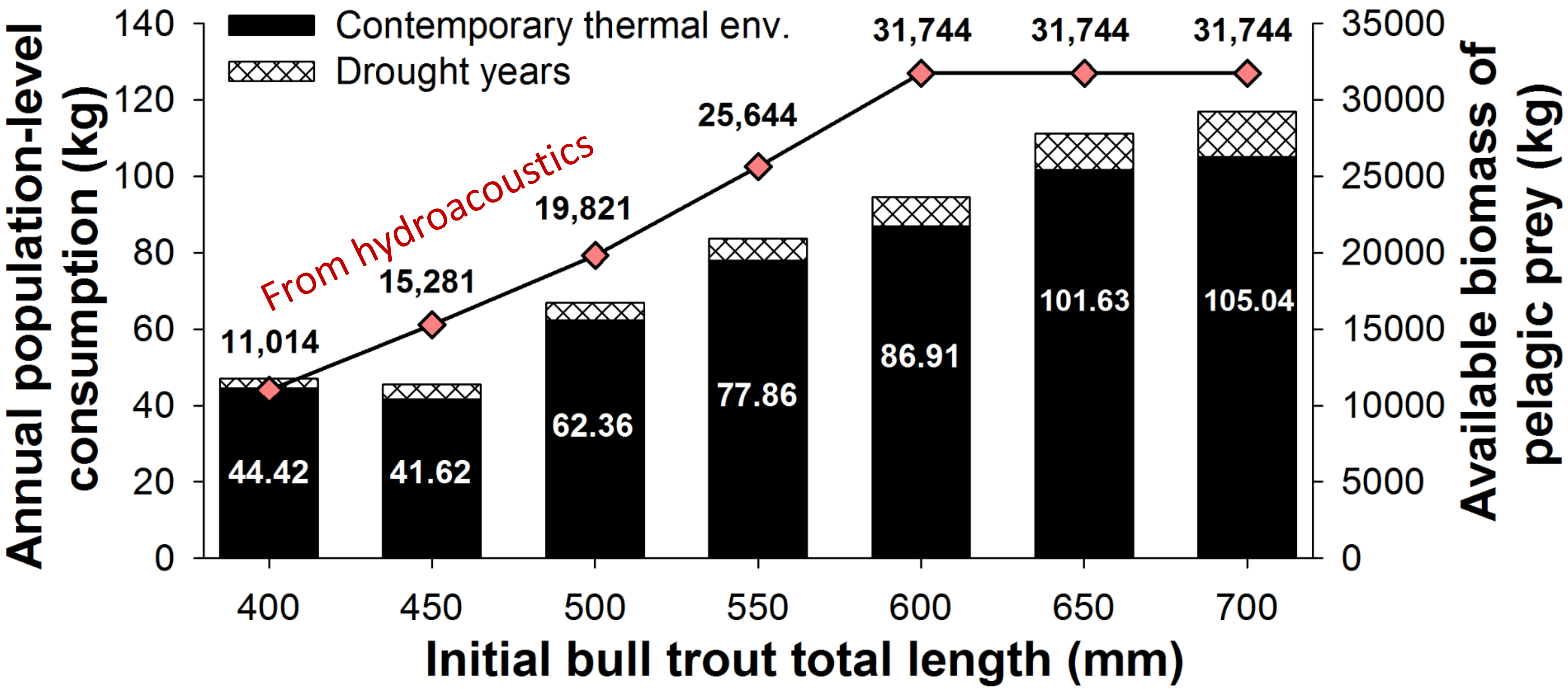
Project Background

- Agricultural economy valued at **$3.4 billion**
- Heavy irrigation demand (1,000 mi^2; hops, wine grapes, field crops, cherries, apples, beef)
- Demand not met in drought years – *uncertain climate future*

Baseline vs. KDRPP + KKC (1981-1996)

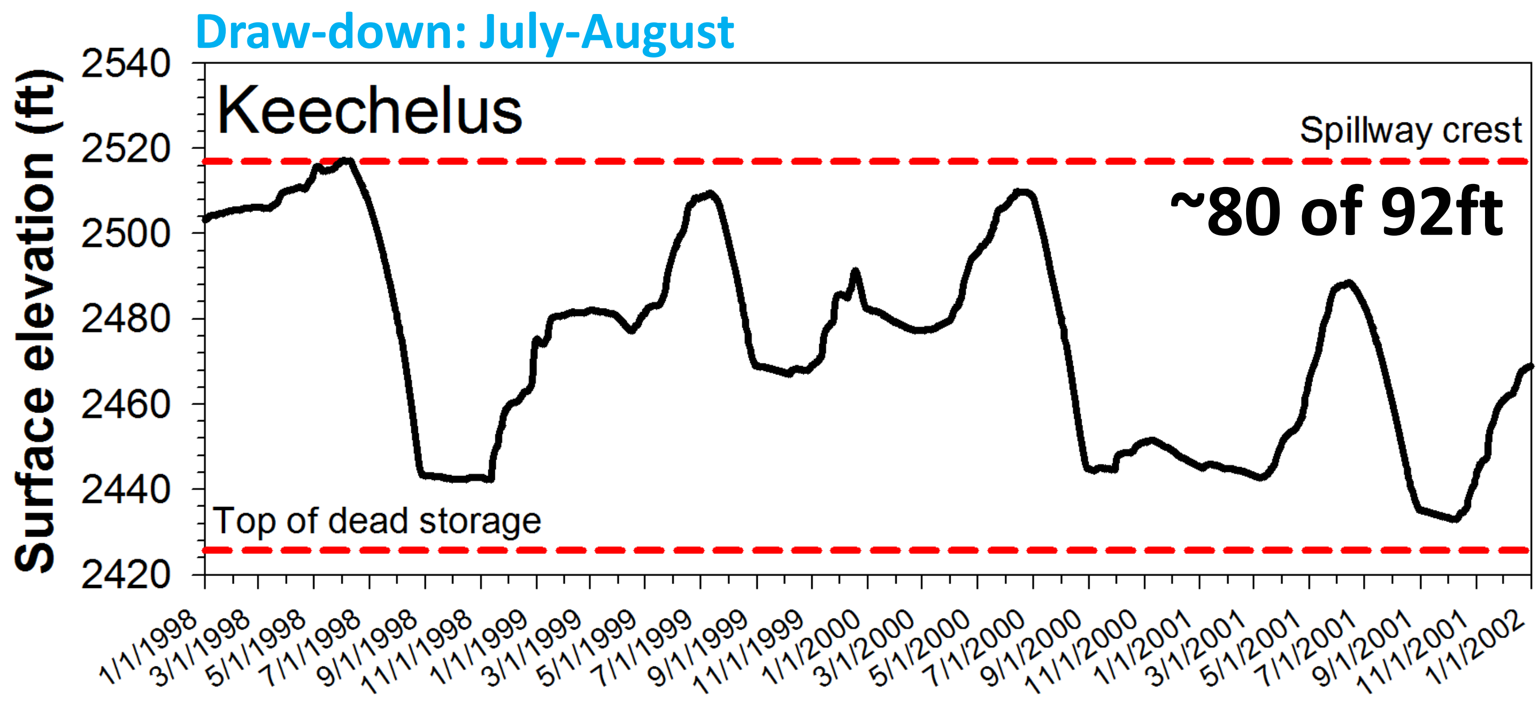


Annual consumption of KOK by 25 bull trout in each size-class

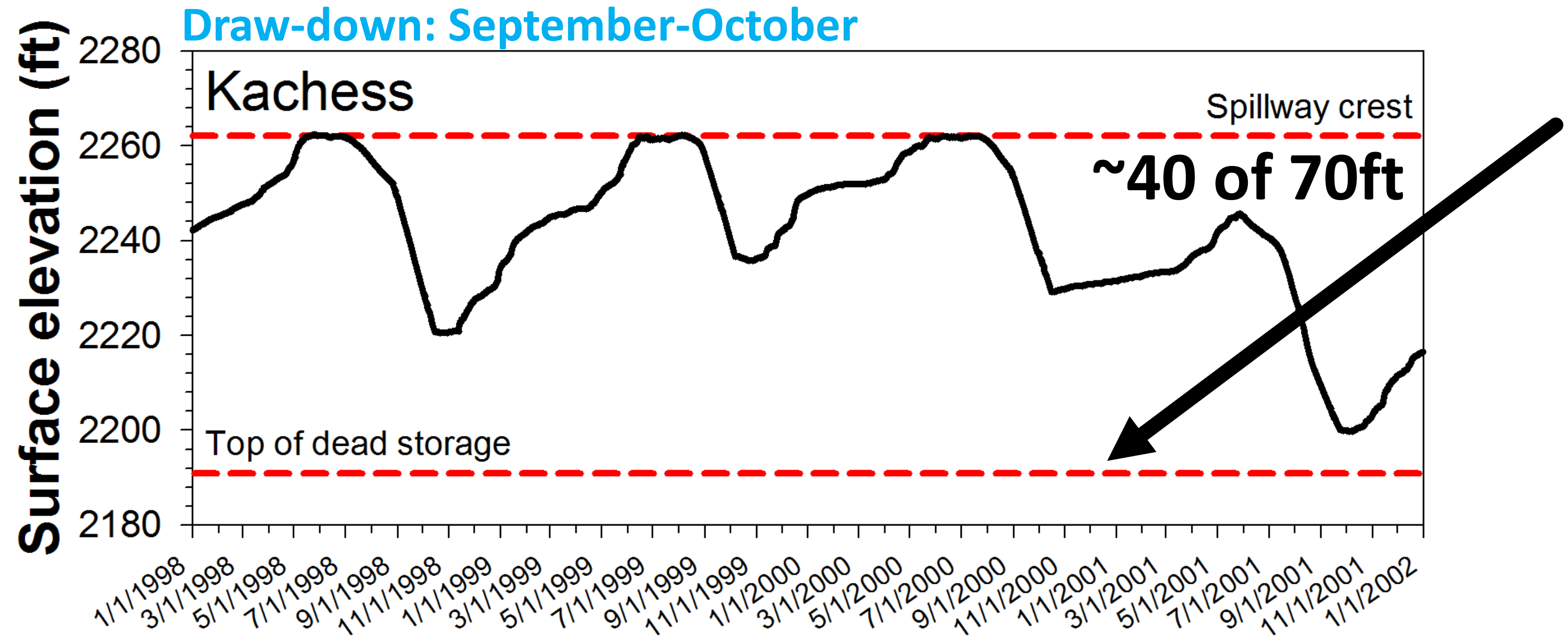


Kachess vs. Keechelus

Parameter	Kachess	Keechelus
Surface area (ha)	1,837	1,039
Flushing rate (days)	227	68
Max. depth (ft)	430	310
Mean depth (ft)	-	96
Surface elevation at full pool (ft)	2,262	2,517
Elevation of outlet (ft)	2,192	2,425
Active capacity (ac-ft)	**239,000**	**157,800**
Drainage area (ha)	16,472	14,167
Average annual runoff (ac-ft)	**213,398**	**244,764**



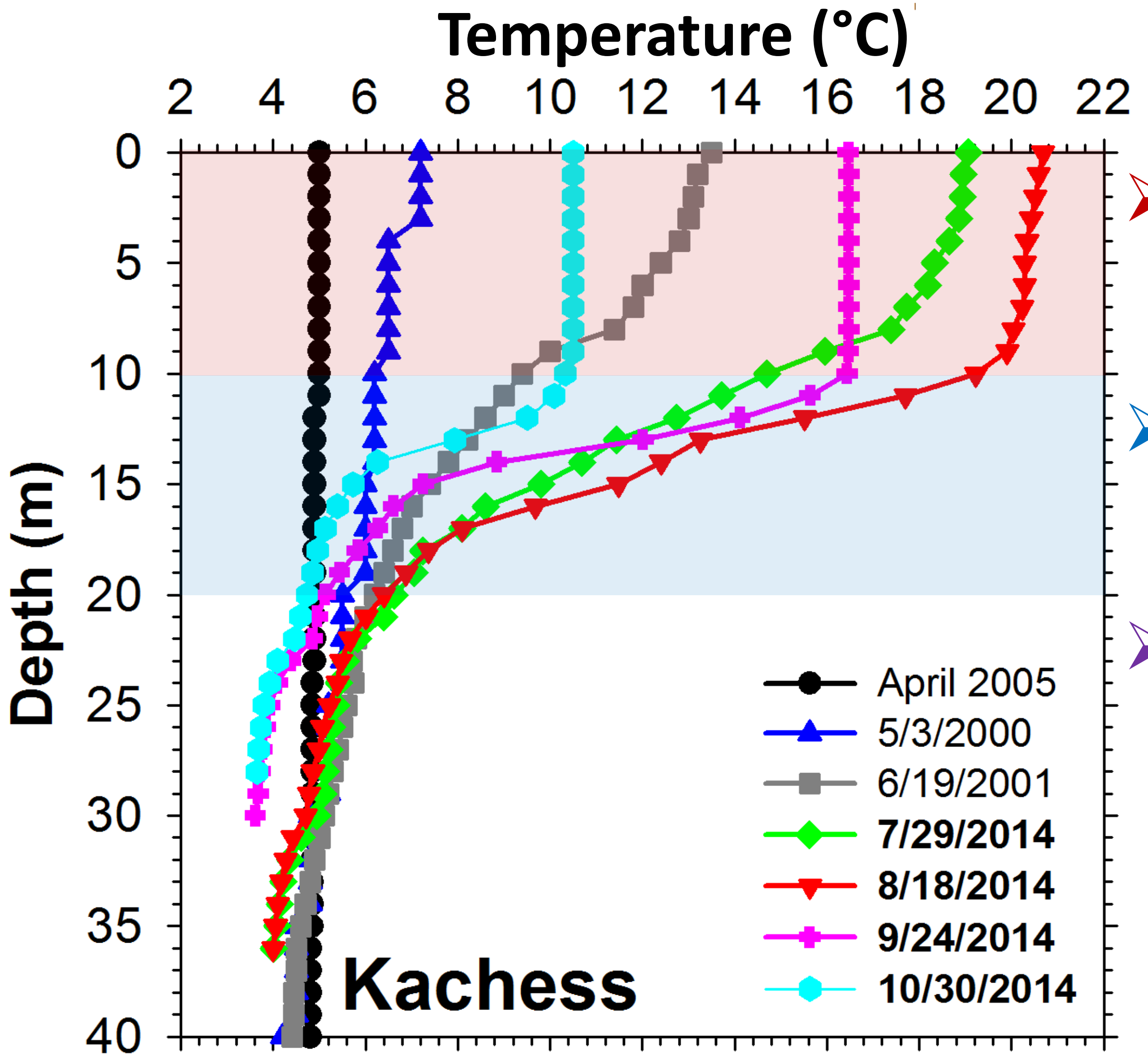
Draw-down more extensive in Keechelus



Pumping water from below here

Potential to reduce elevation by additional 80ft (2,112 ft elev.)

Seasonal thermal environment

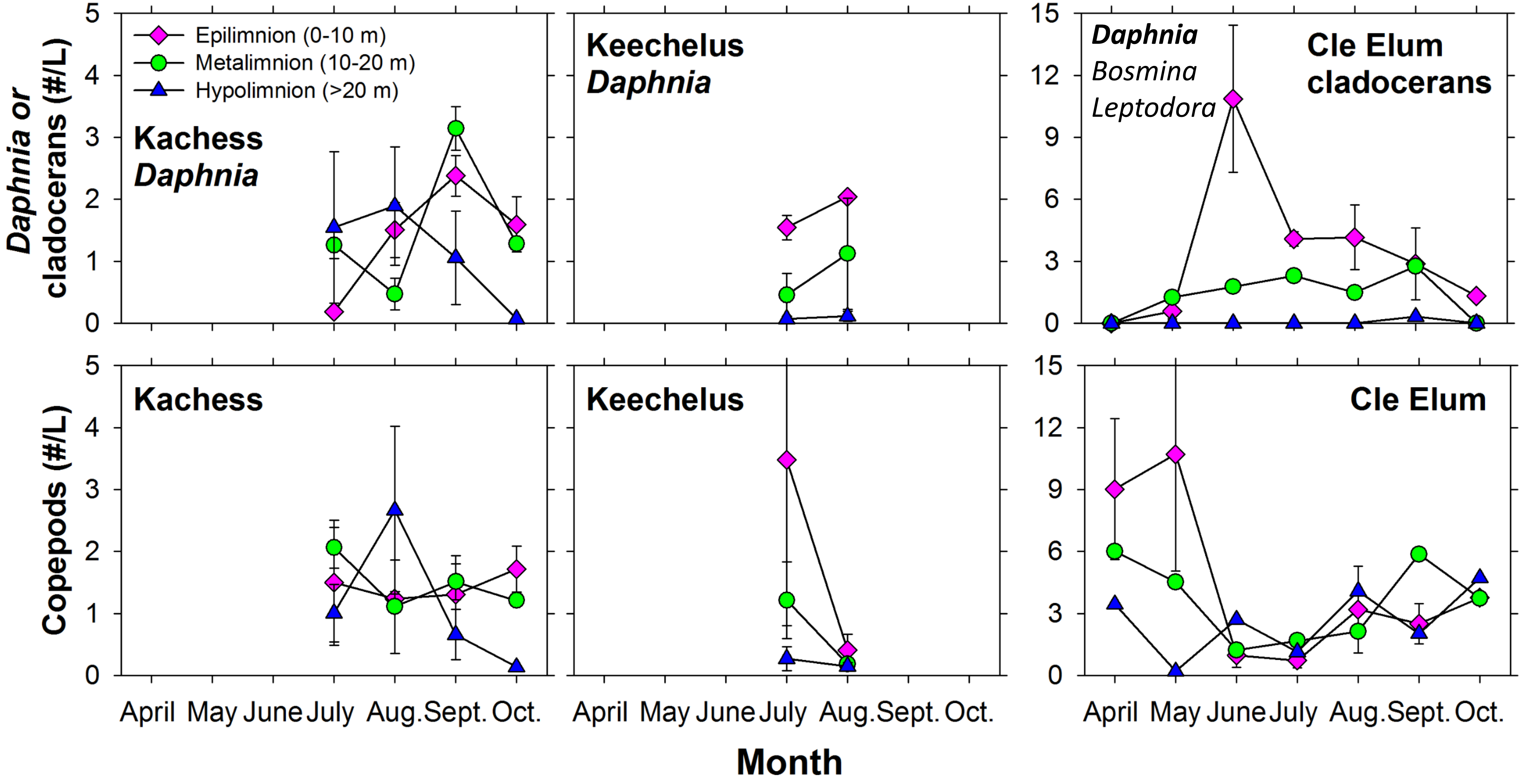


Peak thermal stratification: August

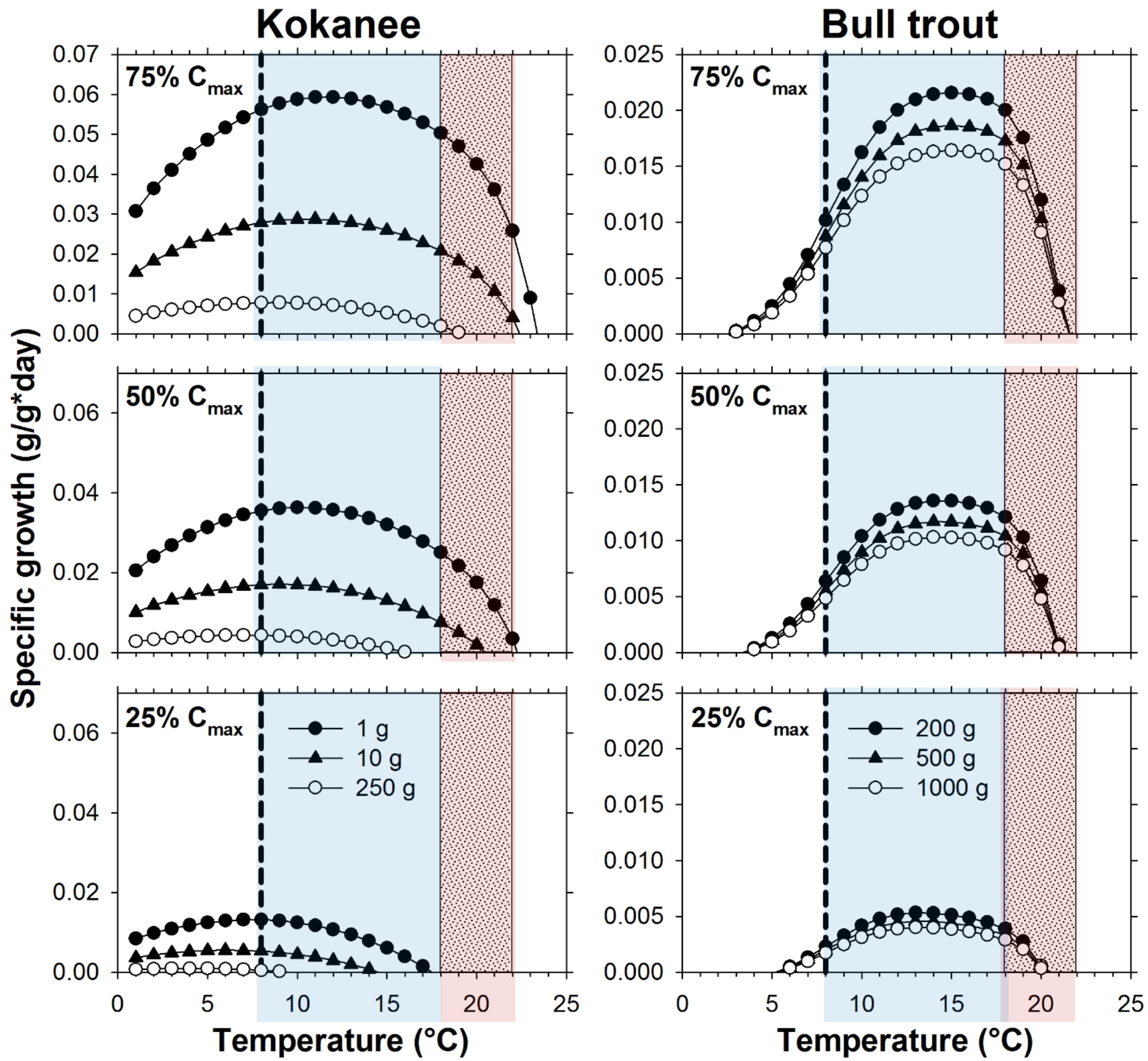
- **Epilimnion**: **0-10 m**, 21-22°C
- **Gradual thermocline**: **10-20 m**, 8-18°C
- **Cold hypolimnion** **>20 m**, 4-7°C

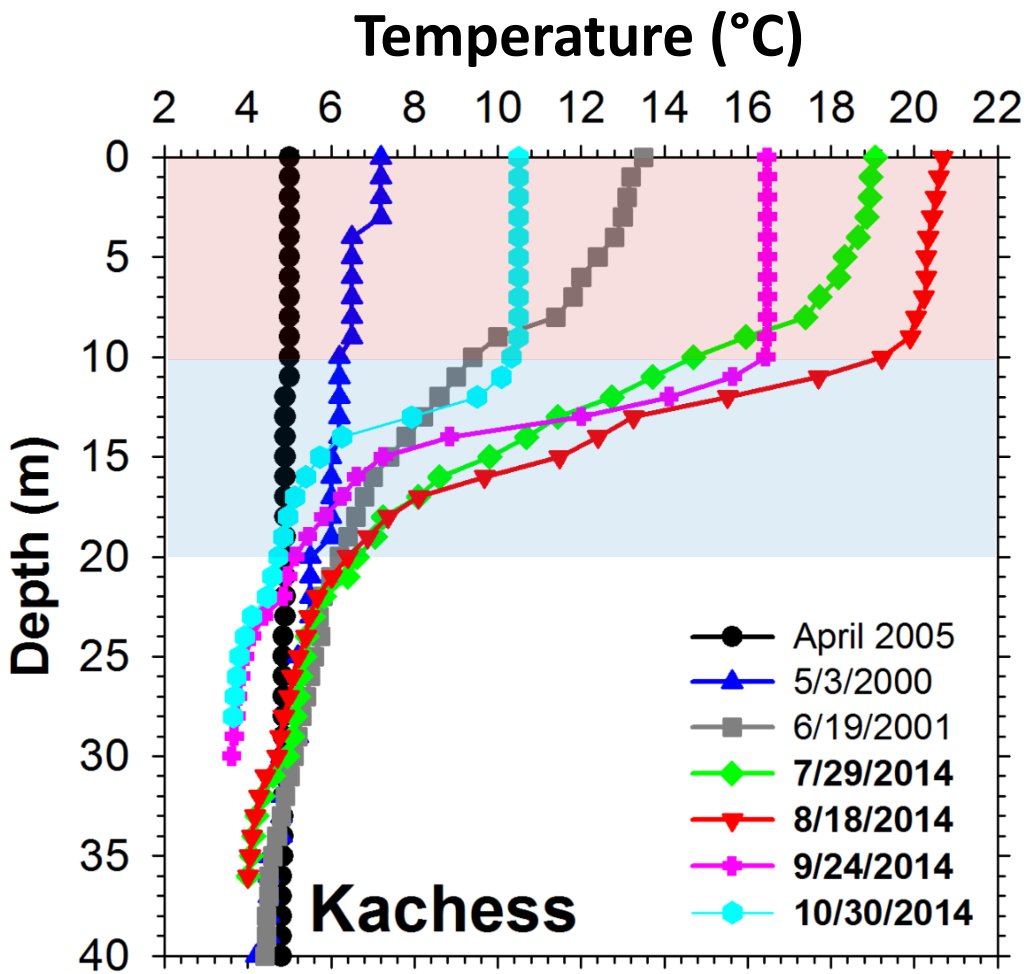
Food supply for kokanee

Expectation for Kachess and Keechelus year-to-year



Bioenergetic growth responses





Kokanee: 19-55 % Cmax

Bull trout: 35-54 % Cmax

Summary: foraging-growth env.

- *Daphnia* density highest in warm epilimnion (peaks in June)
- Warm epilimnion avoided by kokanee. Likely reliant on lower food supply in metalimnion July-September
- Kokanee, bull trout, and burbot should respond similarly to shifts in thermal environment
- Average monthly thermal experience: **COLD**
- Northern pikeminnow unlikely to significantly impact kokanee
- Key data gap: seasonal diet of burbot and NPM

What's limiting kokanee production in Kachess and Keechelus?

- Temperature, food supply, predation?

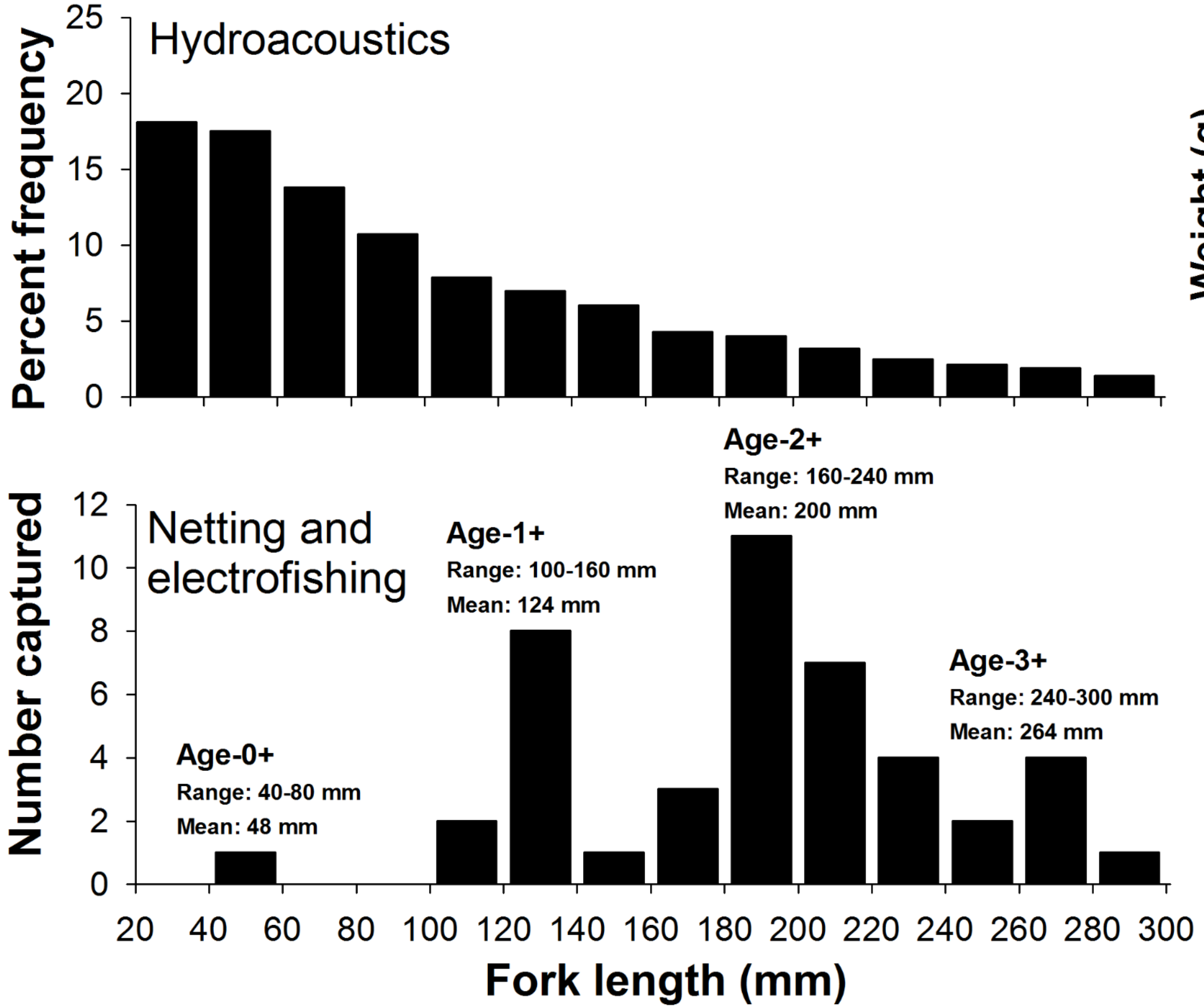
  (1) Seasonal carrying capacity of kokanee

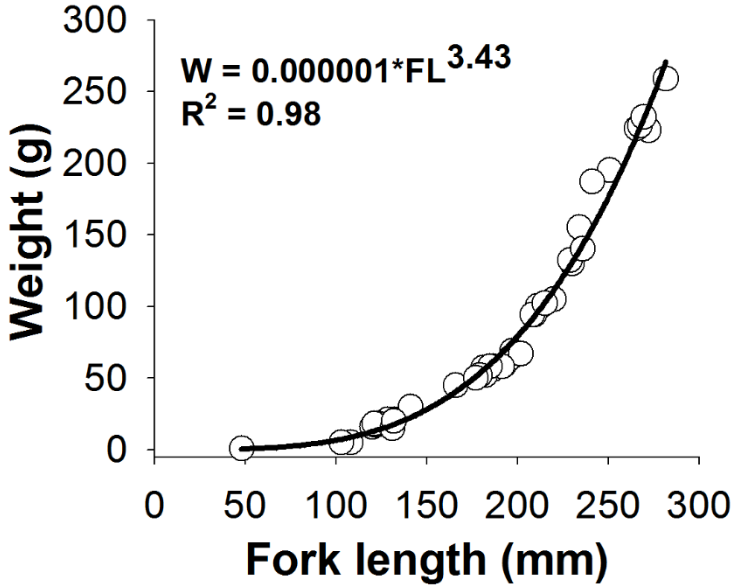
  (2) Predation by bull trout

- Bioenergetics modeling: feeding rate & population-level consumption demand vs. biomass and production of key prey

Ray Cox shows mature kokanee - redrockadventure.com

Growth of kokanee

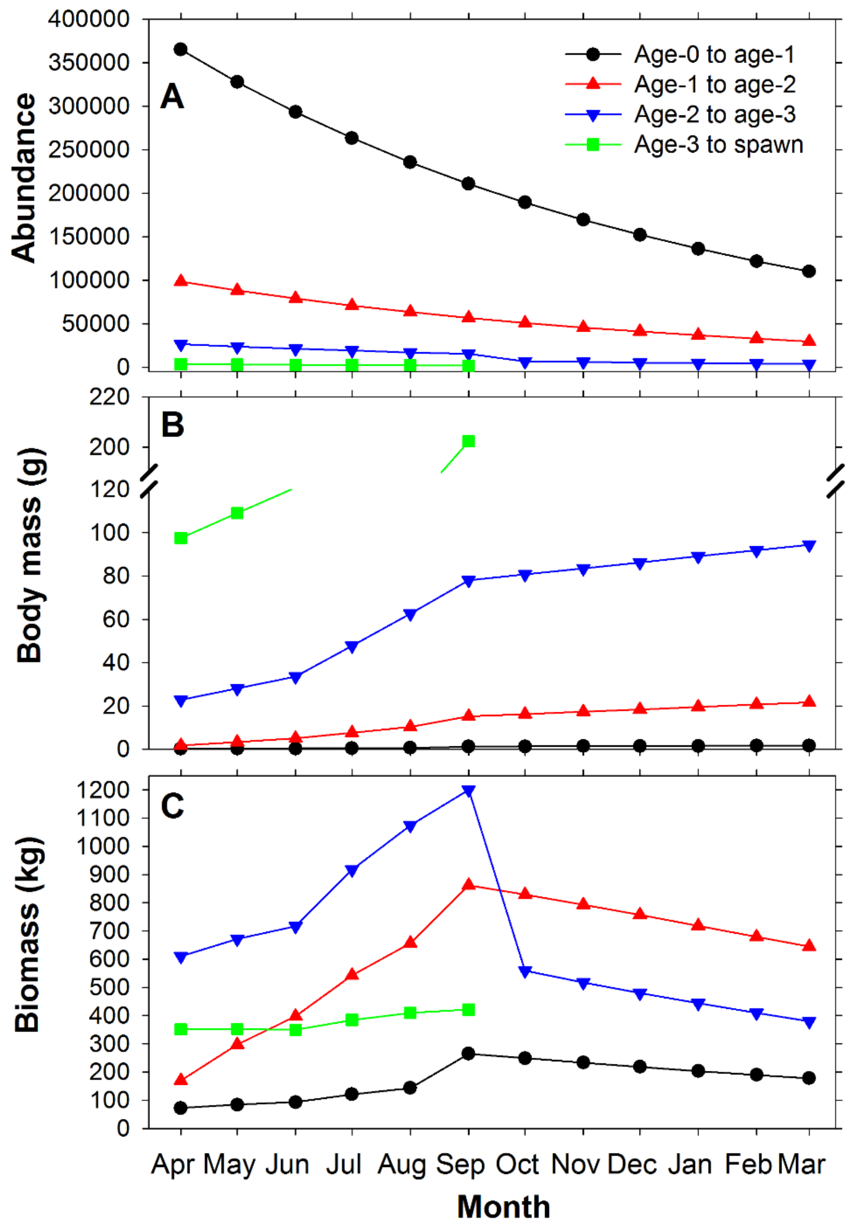




KOK captured Aug-Sept. in Kachess and Keechelus 2014

Size & age designations from Mongillo and Faulconer (1982)

Population dynamics of kokanee



(1) 365,801 KOK fry stocked into Kachess June 2014

(2) "Natural cohort" with annual recruitment: 365,000 fry (35 mm FL) April 1st

(3) Annual survival rate (S): 27%

$$N_t = N_0 \cdot e^{-Zt}$$

$$Z = -\log_e(S)$$

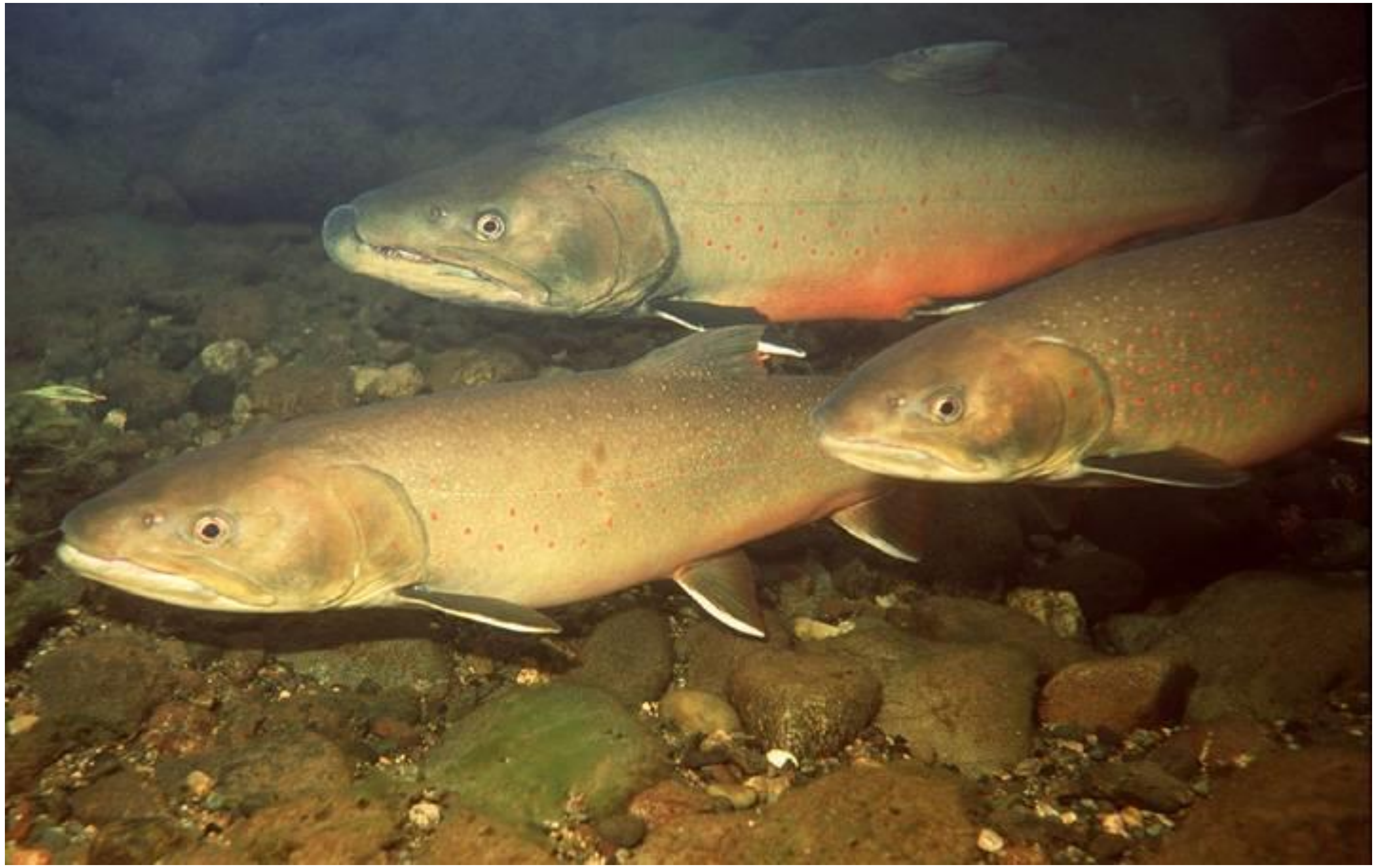
(4) Spawning Sep. 1st at age-2 (50% of cohort) and age-3

Diet and thermal experience

Calendar day	Simulation day	Thermal experience (°C)	Daphnia	Copepods	Other
April 1st	1	4.9 (6.9)	0.010	0.919	0.071
May 1st	31	5.5 (7.5)	0.226	0.733	0.041
June 1st	62	5.9 (7.9)	0.672	0.316	0.012
July 1st	92	6.4 (8.4)	0.990	0.010	0.000
August 1st	123	6.9 (8.9)	0.990	0.010	0.000
September 1st	154	6.7 (8.7)	0.990	0.010	0.000
October 1st	184	5.7 (7.7)	0.990	0.010	0.000
November 1st	215	4.7 (6.7)	0.990	0.010	0.000
December 1st	245	4.7 (6.7)	0.010	0.980	0.010
January 1st	276	4.7 (6.7)	0.010	0.980	0.010
February 1st	307	4.7 (6.7)	0.010	0.980	0.010
March 1st	335	4.7 (6.7)	0.010	0.900	0.090
March 31st	365	4.7 (6.7)	0.010	0.918	0.072

Bull trout

- Very little is know about bull trout in Kachess and Keechelus
- Low abundance (25-50 spawning adults), based on redd counts



Annual growth of 400-700 mm BLT tagged during spawning migrations in tribs of Rimrock and Bumping (James 2002)

Per-captia consumption of average individual in each size class?

Assumpitons: 100% diet of KOK, same thermal experience as KOK

Lake Kachess Capacity Curve

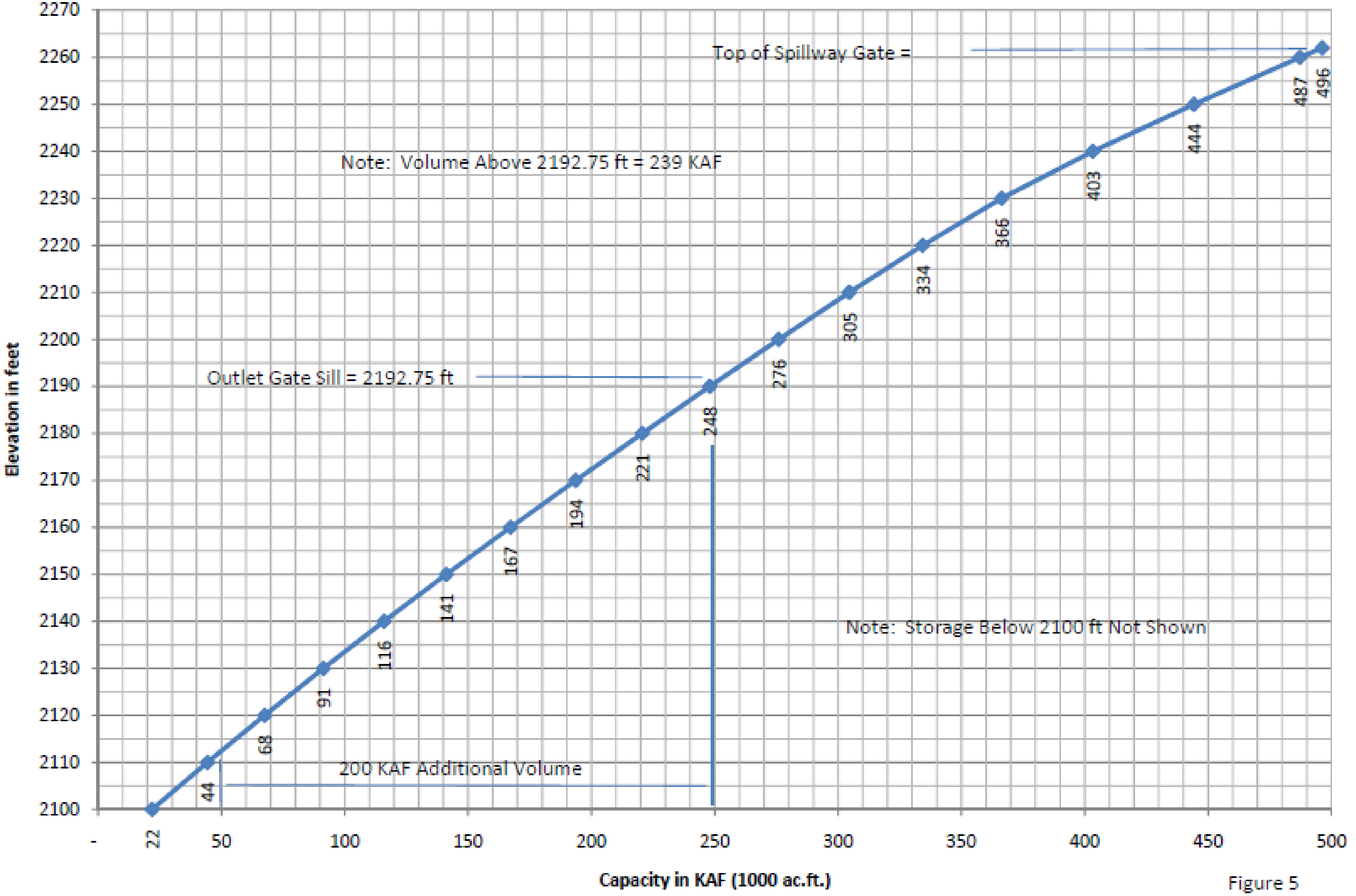
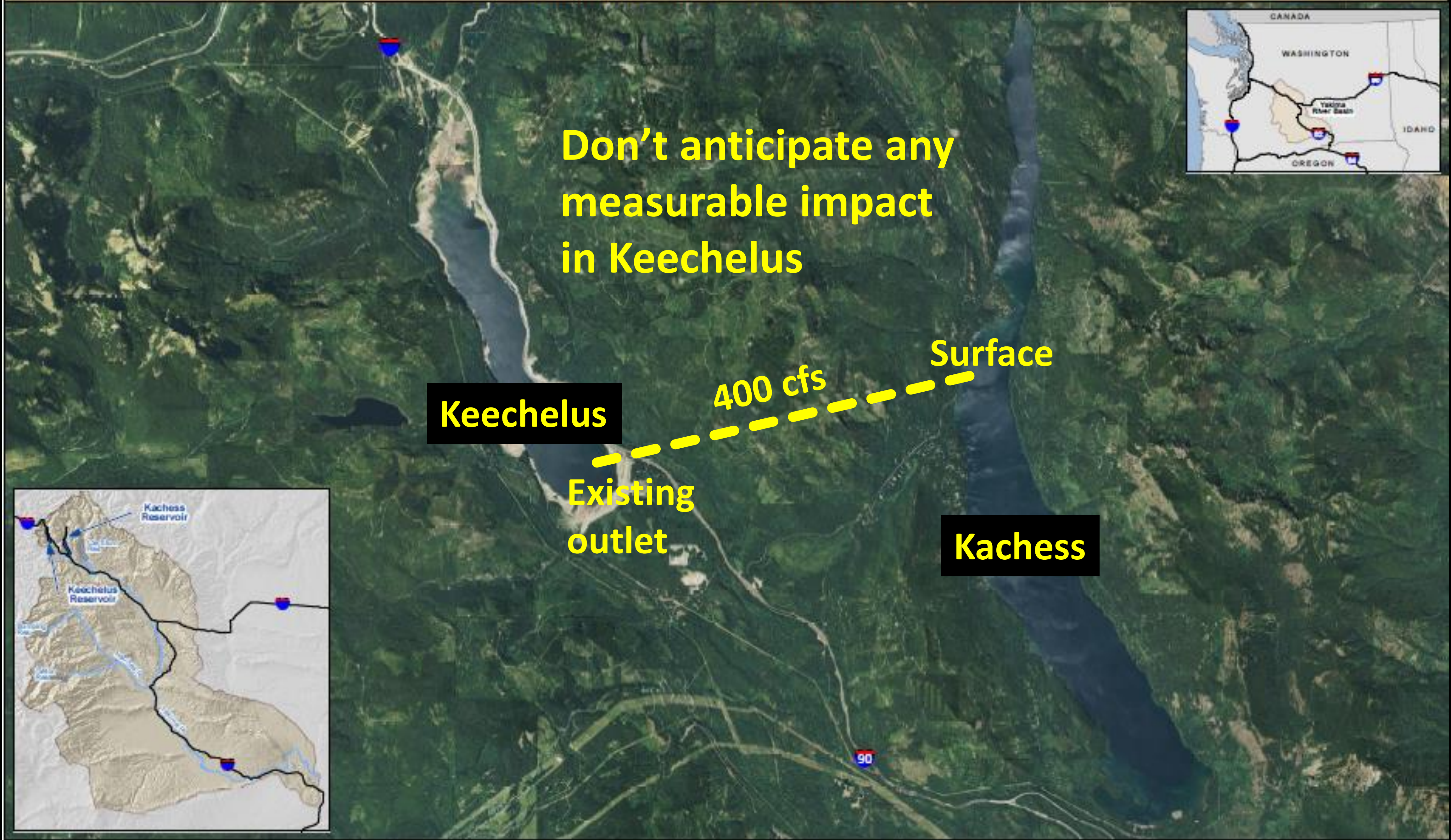


Figure 5

RECLAMATION
Managing Water in the West

Kachess Drought Relief Pumping Plant and Keechelus-to-Kachess Conveyance Projects

DEPARTMENT OF ECOLOGY
State of Washington



Kachess pumping plant (KDRPP)