Predicting effects of climate change on aquatic biota: developing a decision support system for the Yakima River Basin.

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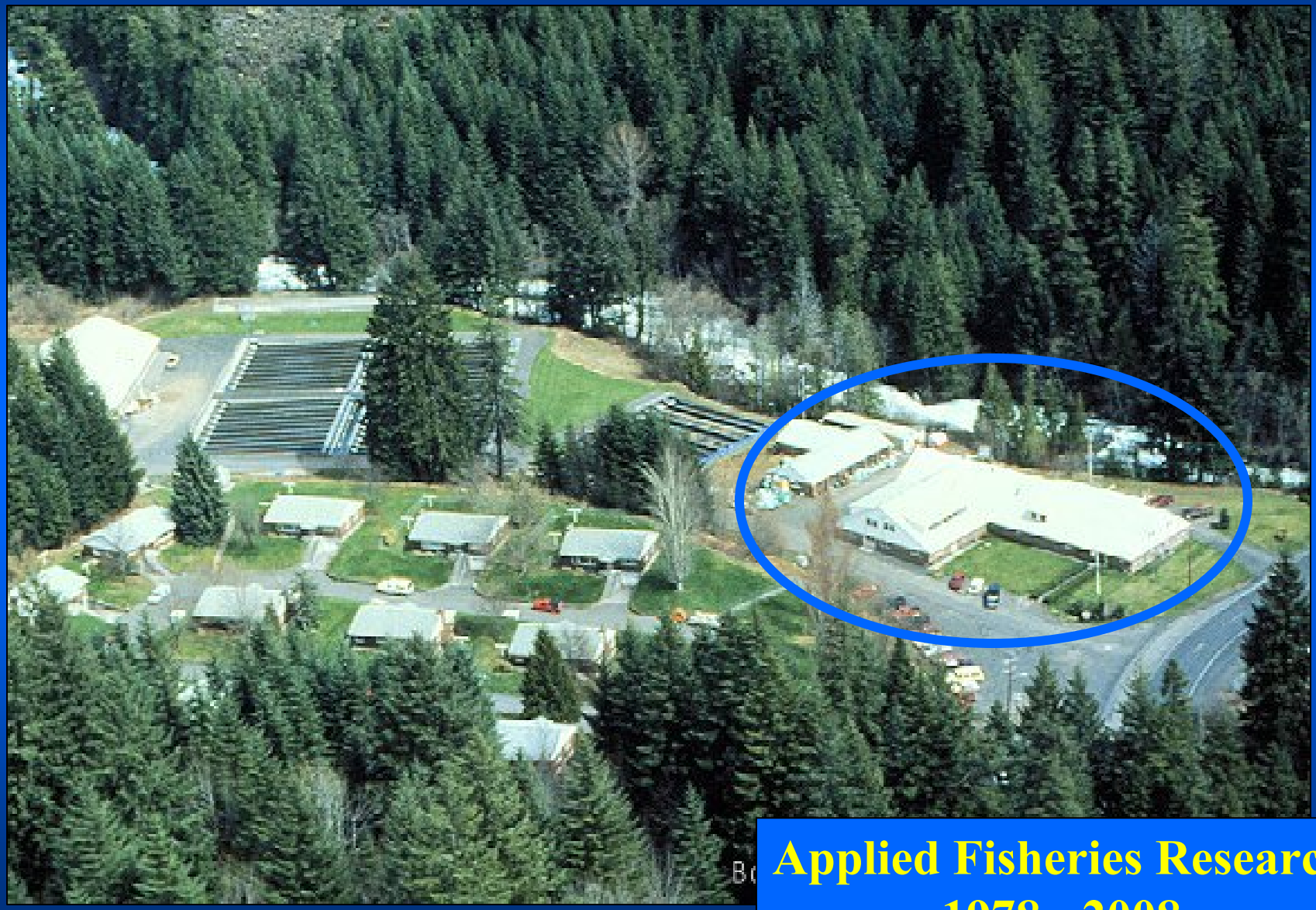
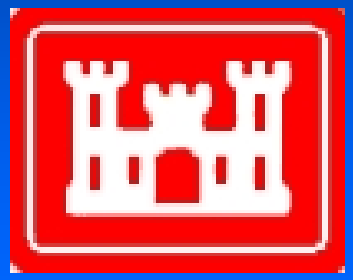
science for a changing world

Columbia River Research Laboratory



Applied Fisheries Research
1978 - 2008

Some of Our Collaborators & Funding Sources



ESA-listings drive research

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Effects of climate change on the hydrology & aquatic ecosystem of the CRB and social & economic coats to mitigate those impacts.

Maule, Mastin, Bovee, Montag, Koontz,
Mesa, Hatten & Counihan

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Development & Application of a Decision Support System for Water Management Investigations in the Upper Yakima River DSS

Bovee[1], Waddle[1], Talbert[1], Hatten[2] & Batt[2]

USGS Open-File Report (in review)

[1] Fort Collins Science Center; [2] Columbia River Research Lab

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Yakima River DSS

Objectives – to develop:

1) **Habitat response models – species- & life-stage-specific**
   Chinook, Coho, STHD & resident RBT, Bull trout

2) **DSS re: water management effects**

State variables: **1° - habitat characteristics** **(ESA)**
(decision points) **2° - effects on water users**

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Yakima River DSS

Physical models:

1) **RiverWare (BOR)**
2) **SNTEMP (max daily temp)**
3) **Sediment transport models**

Habitat model (Delphi-type—expert opinion) :

1) **Redd scour**
2) **Habitat time series – suitable area x life stage**
3) **Max. temperature**
4) **Fish passage - flow**

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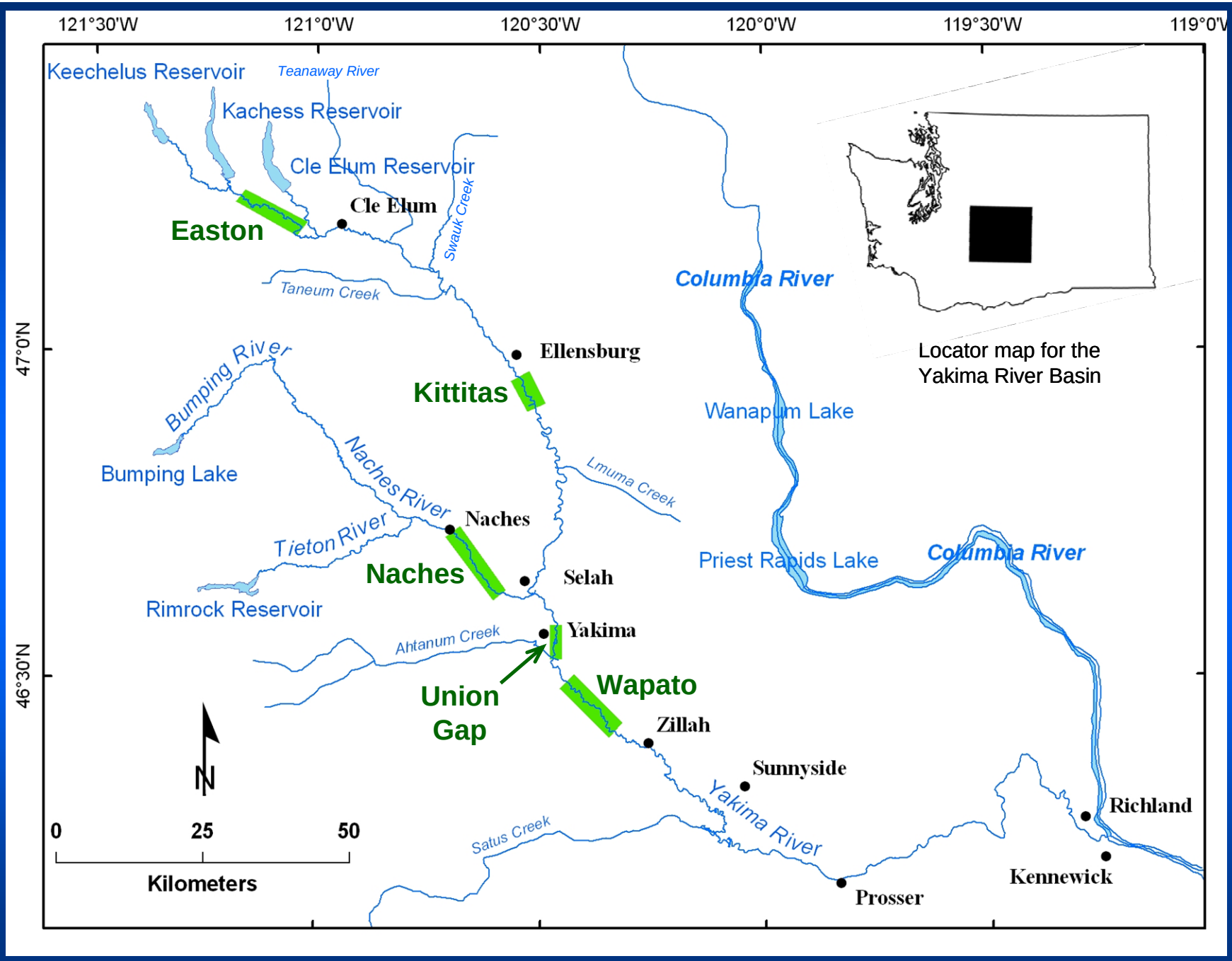

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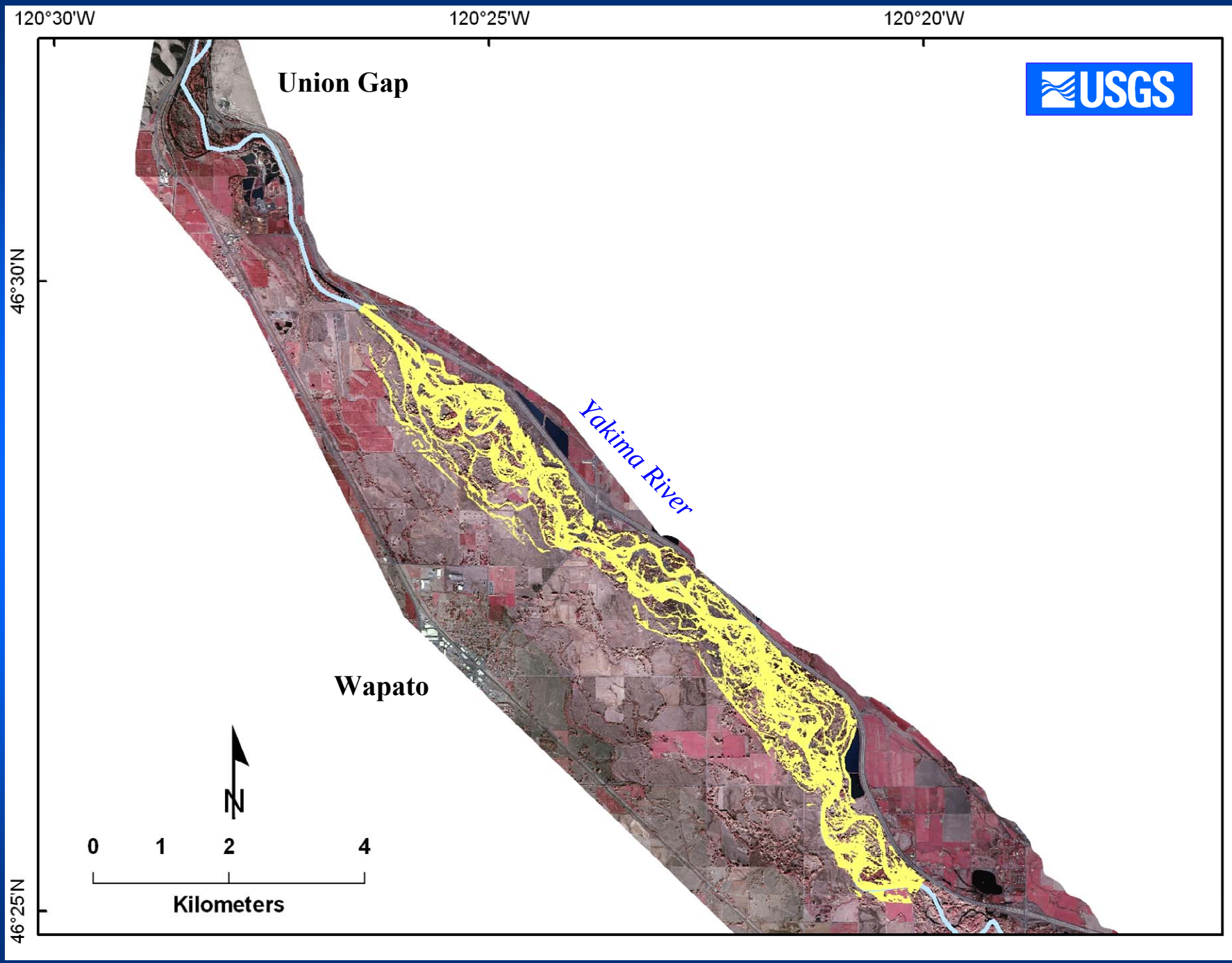
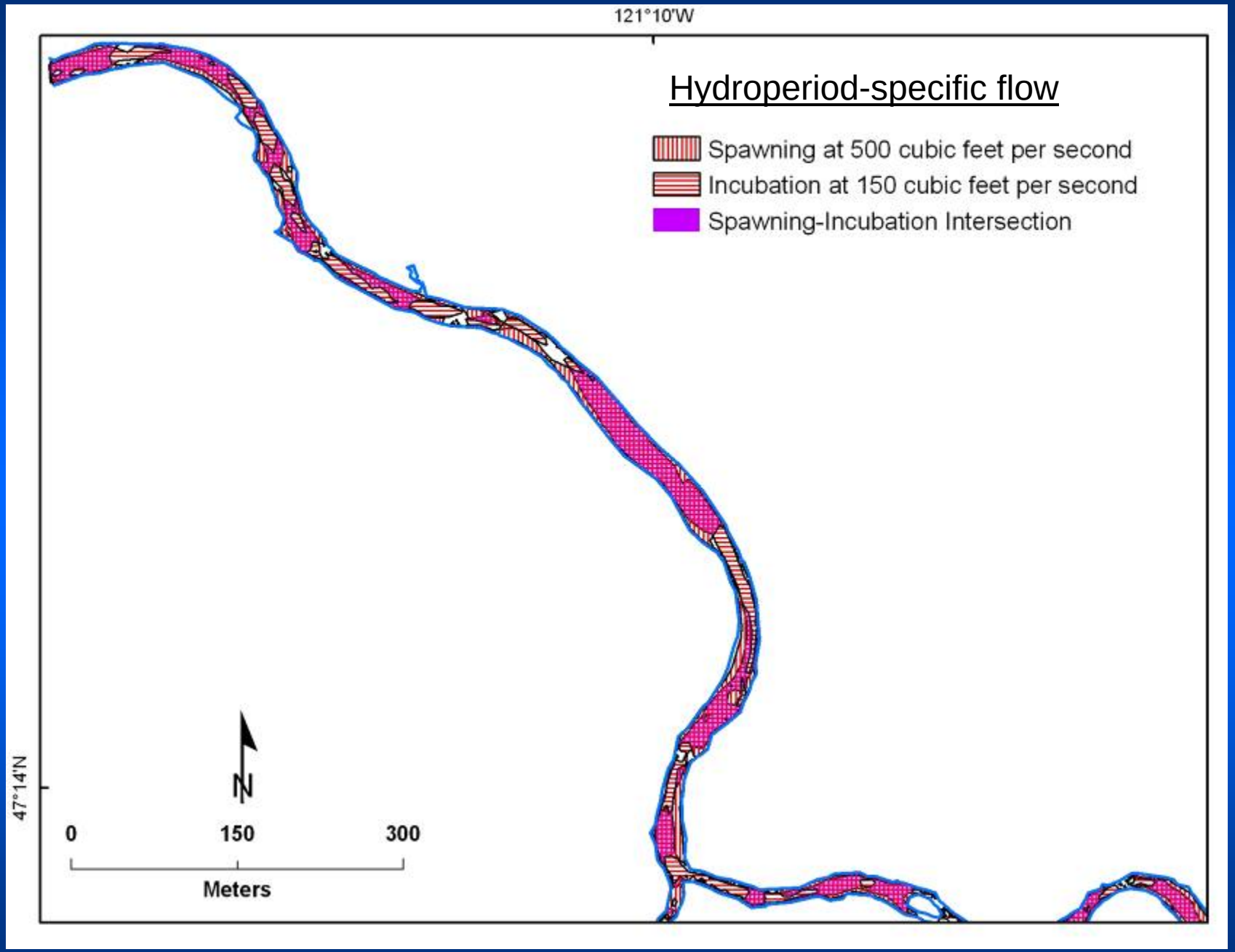
> 6,000 mi²


120°30'W
120°25'W
120°20'W
46°30'N
46°25'N
Union Gap
Wapato
Yakima River
USGS
N
0
1
2
4
Kilometers


121°10'W
Hydroperiod-specific flow
Spawning at 500 cubic feet per second
Incubation at 150 cubic feet per second
Spawning-Incubation Intersection
47°14'N
N
0
150
300
Meters

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NEW Yakima River DSS

1. Use existing DSS to assess climate change
   Four scenarios – temp & flow
2. Use existing Bioenergetics Models to determine effects of temp & flow on fish
3. Determine if restoration, flow management, & mitigation are likely to be cost-effective

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NEW Yakima River DSS

Habitat model (Delphi-type—expert opinion) :

1) **Redd scour**
2) **Habitat time series – area x life stage**
3) **Max. temperature**
4) **Passage**

Bioenergetics Models to determine effects of temp & flow (input from Physical Models) on:

a) **growth of salmonids–development & migration**

a) **growth & consumption of native predator northern pikeminnow**

b) **growth & consumption of invasive predators smallmouth bass, walleye**

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Bioenergetics models

- Conservation of energy
- Balanced equation:
- Growth = Consumption – Respiration – Egestion – Excretion
- $G = C - R - Eg - Ex$
- Temp, activity, diet & fish size dependent
- Models developed for ~48 species

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Bioenergetics models can:

- Predict food (i.e., prey) needed to grow *x* amount
- Predict growth given food & temperature
- Project from individuals to populations
- Hindcast or forecast growth w/ time series
- Provide "bounds" to answers
  - (e.g., min – max growth for temp scenario)

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Bioenergetics Models

Input data	Input parameters
Growth increment	*Cmax*
Period of growth	Respiration
Diet composition	Activity
Energy density	SDA (std. dyn. action)
Temperature	Excretion
Activity (flow)	Egestion
	Growth
	Reproductive loss

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Blazka-type Respirometer

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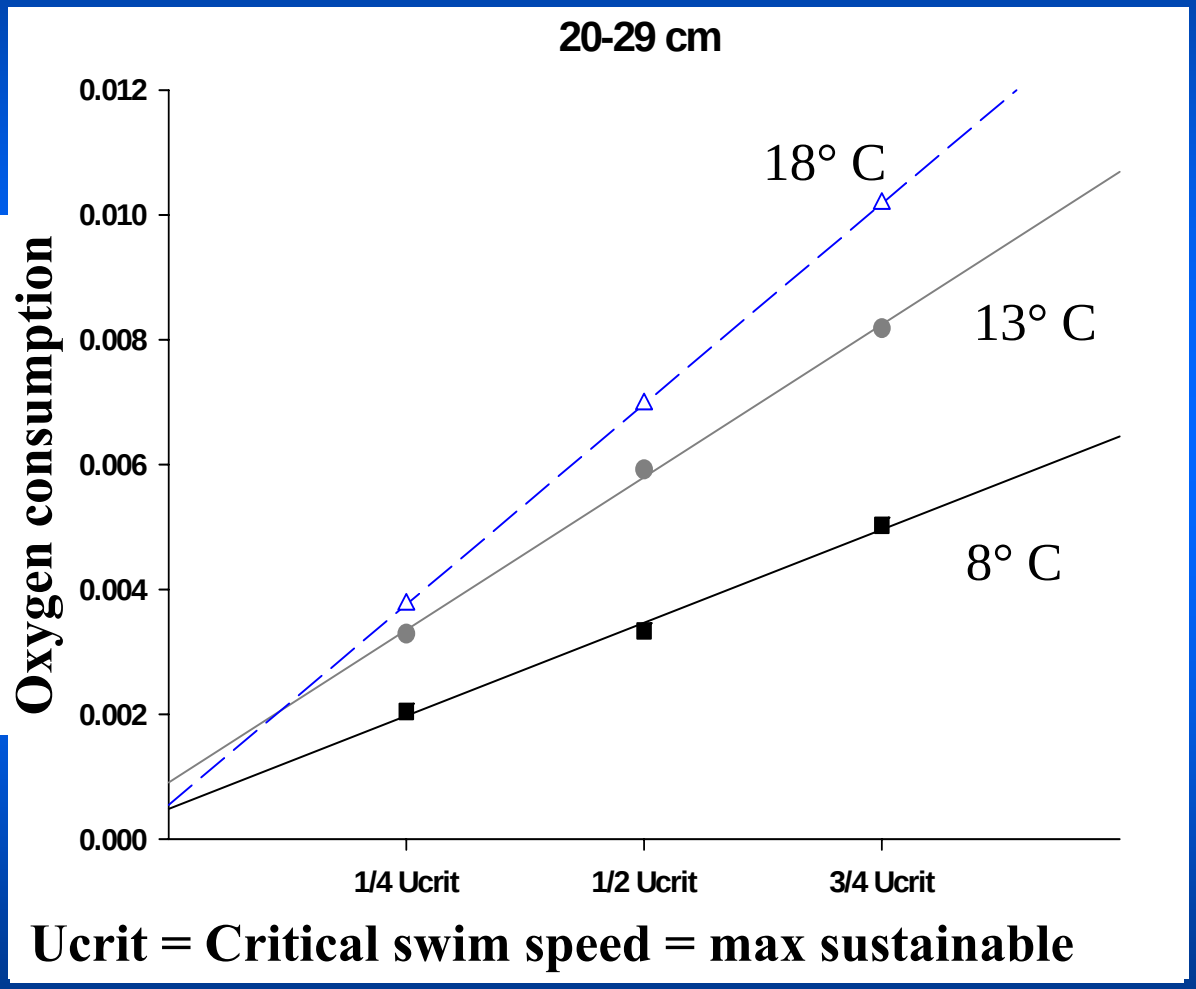
Oxygen consumption ↑ w/ swim speed & temp

$$G = C - \underline{R} - Ex - Eg$$



Ucrit = Critical swim speed = max sustainable

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Climate regimes and water temperature changes in the Columbia River: bioenergetic implications for predators of juvenile salmon

- Petersen & Kitchell 2001

Has variation in climate & water temp (1933-1996) influenced predation on juvenile salmon?

PDO, PNI, CBI – 19 gages, independent of dams, irrigation etc

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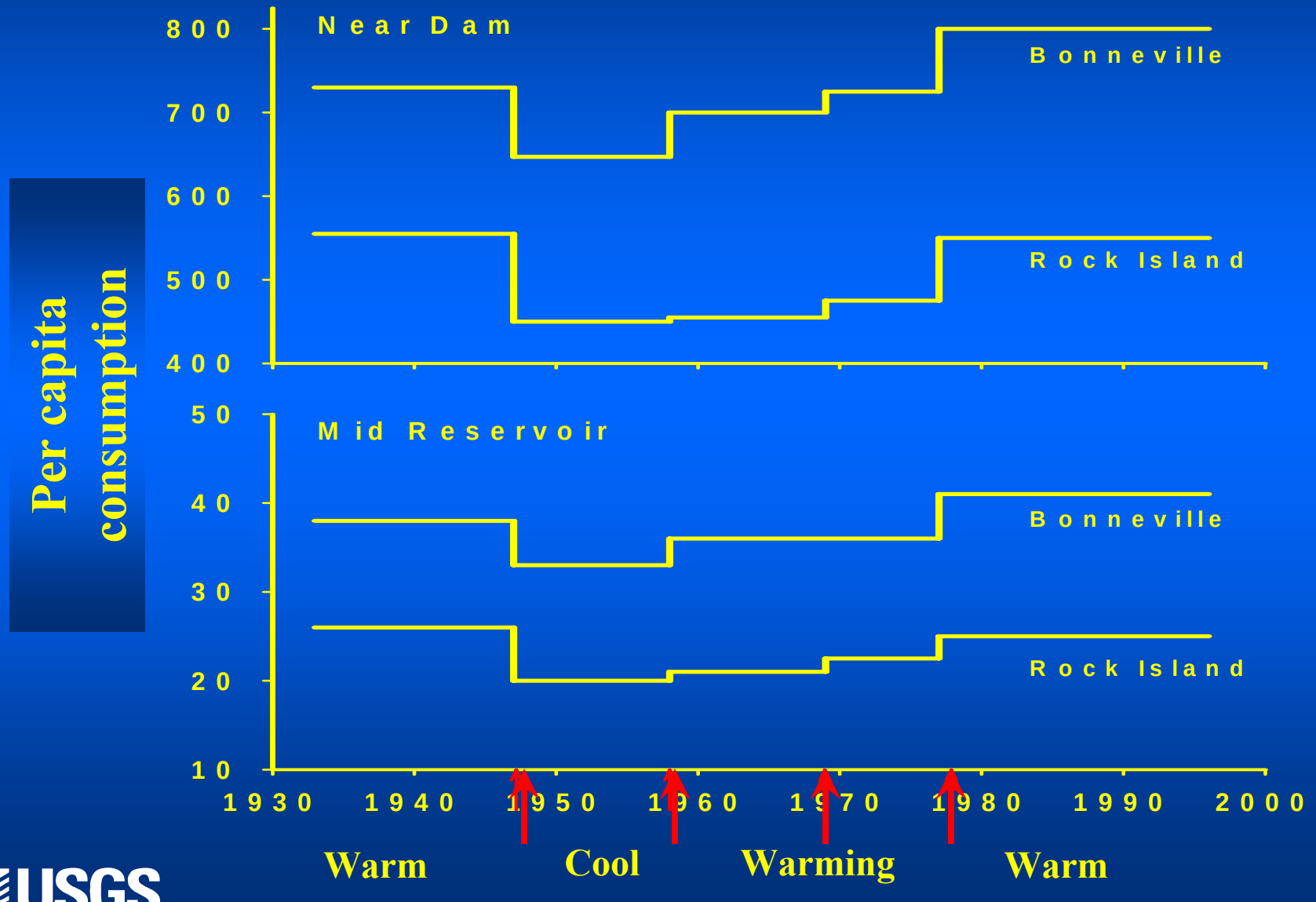
Temporal changes – salmon consumption by native predator (Northern pikeminnow)



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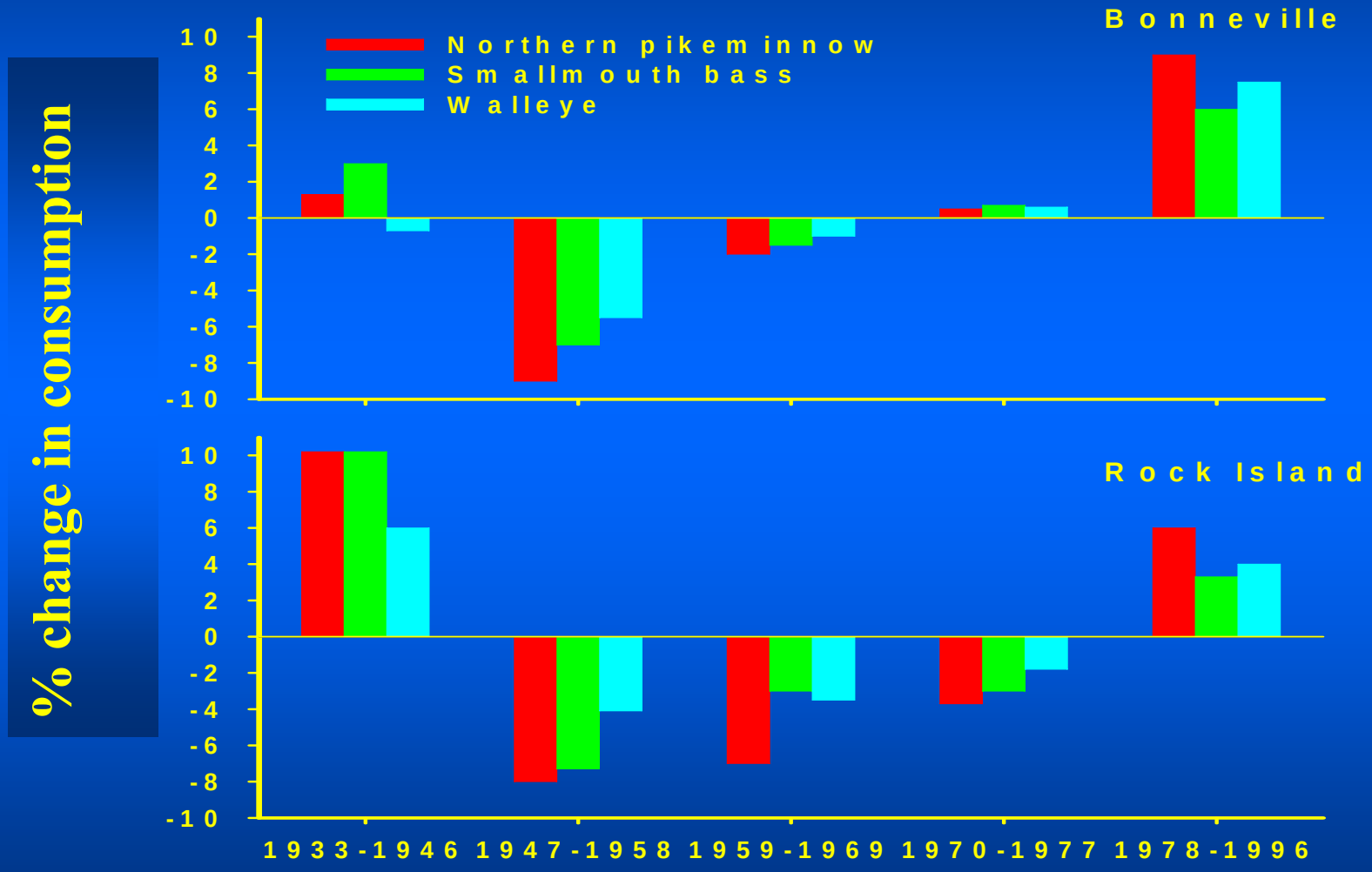
Cumulative consumption of salmonids - native & non-native predators



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Warm Cool Warm

Assessment of Smolt Condition: Biological & Environ. Interaction

Impacts of prey & predators on juvenile salmonids

Sauter, Schrock, Petersen & Maule, 2004

Has variation in water temp & non-native prey fish influenced predation on juvenile salmon?

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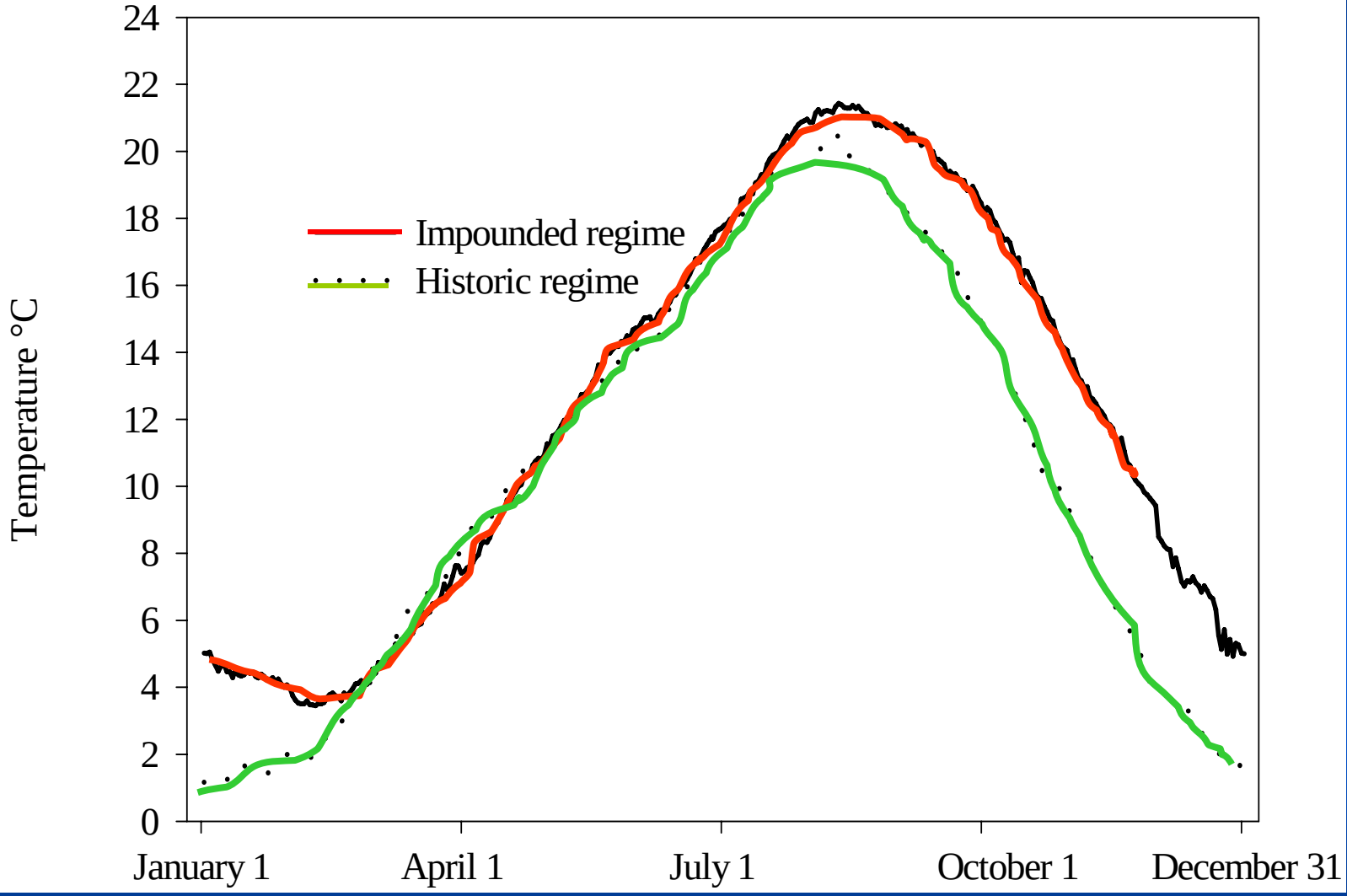
Columbia River Water Temperatures



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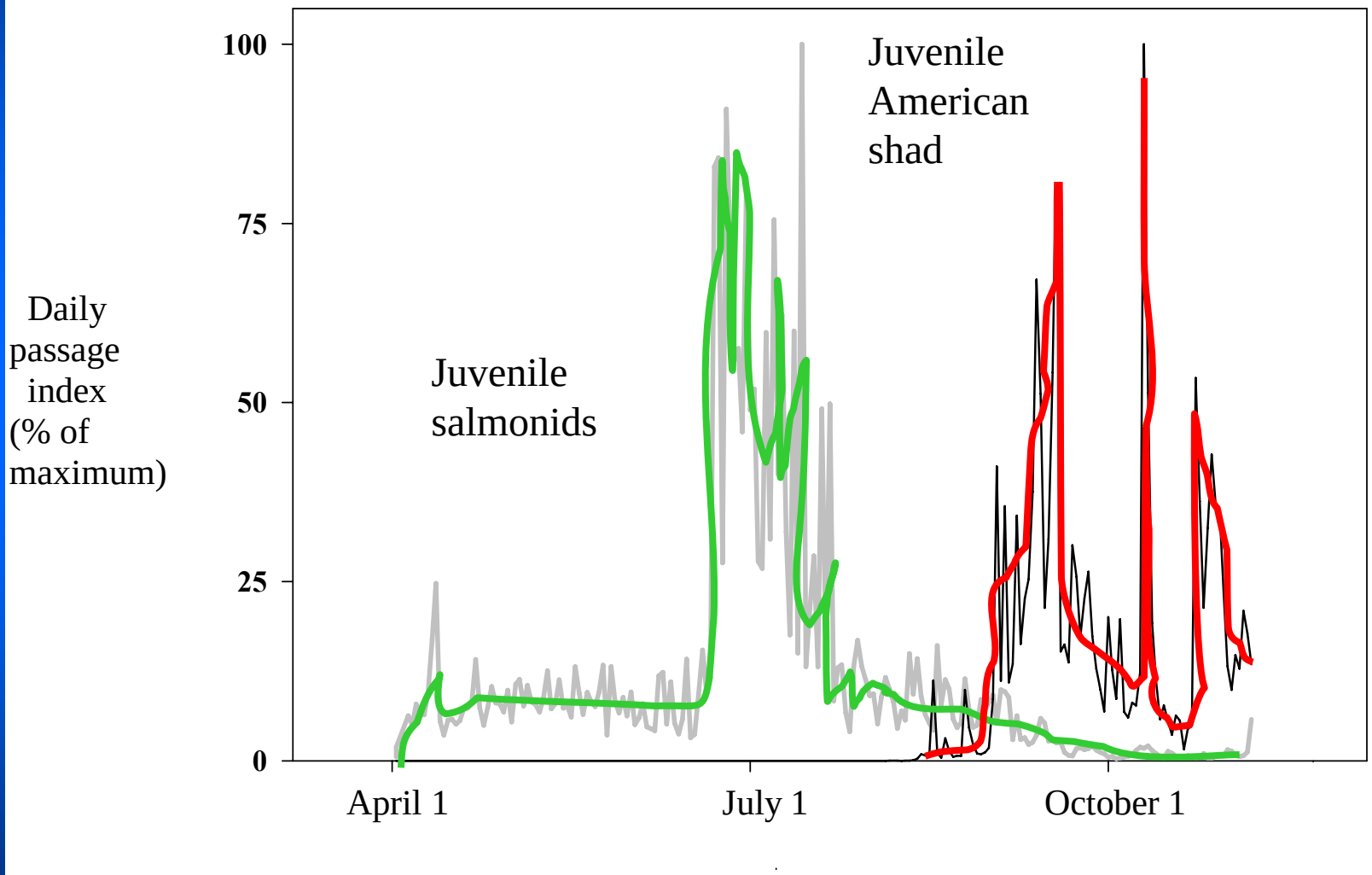
Seasonal passage of juvenile anadromous fishes
John Day Dam, 2000



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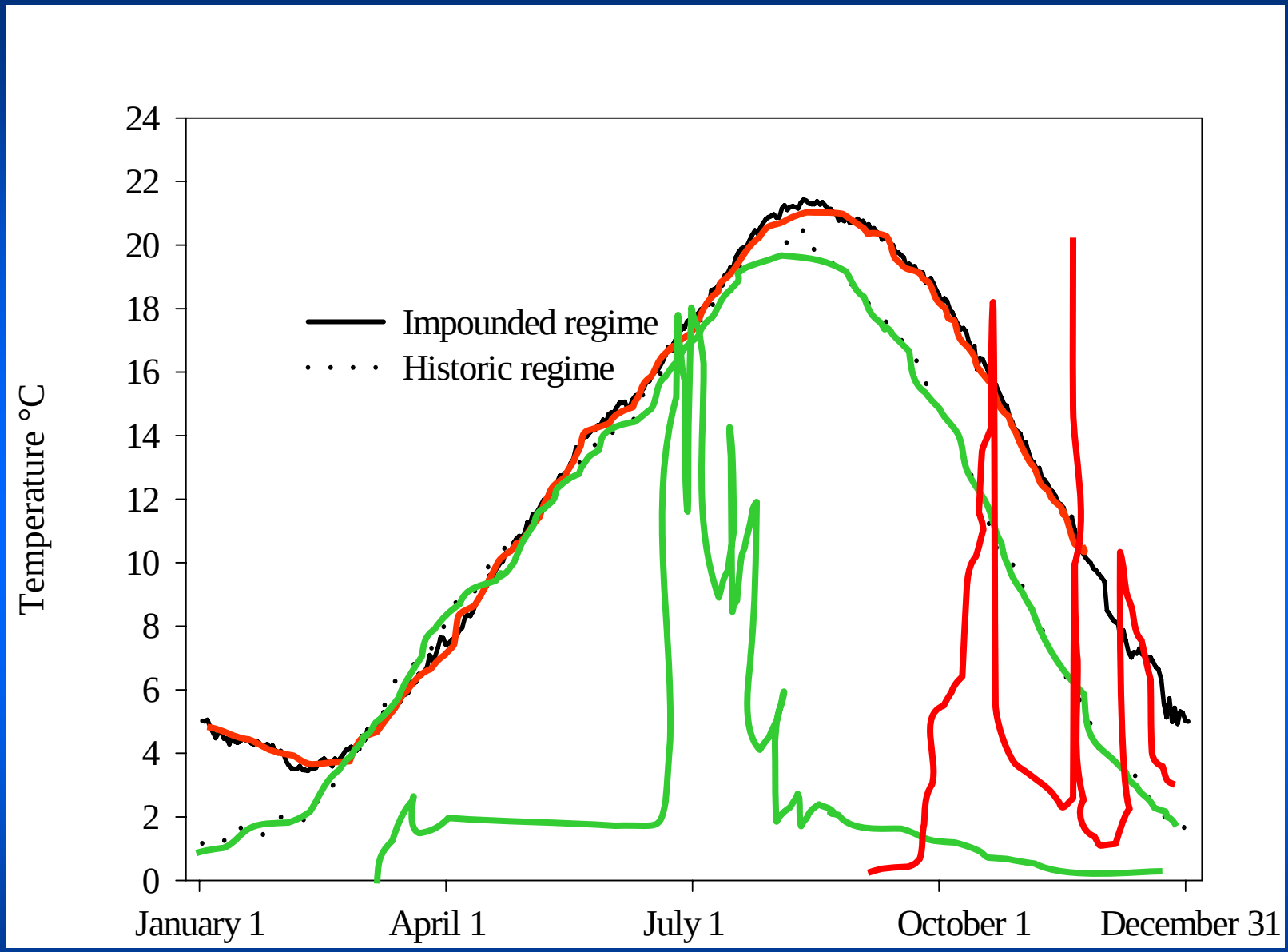
Temperature °C
24
22
20
18
16
14
12
10
8
6
4
2
0
Impounded regime
Historic regime
January 1
April 1
July 1
October 1
December 31

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Do these higher temperatures & the presence of juvenile Am. shad allow native & non-native predators an extended growing season?

Significance: bigger predators eat more & are more fecund

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Did these changes alter predator consumption?

Bioenergetics modeling compared scenarios:

1. **Current temps with American shad**
2. **Current temps with out shad**
3. **Historic temps with shad**
4. **Historic temps without shad**

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Models predicted increased growth & predation

PREDATOR	TEMP	TEMP SHADE	Opt. Temp. Growth
Northern pikeminnow	7.0%	10.8%	20 - 23° C
Smallmouth bass	16.1%	43.4%	26 - 29° C
Walleye	4.4%	21.4%	20 - 28° C

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Overall: 27.5 % salmonids consumed were result of increased growth of predators

NOAA-Fisheries (2000) - 10% reduction in 1st yr mortality = 41.5% increase in population growth rate (λ)

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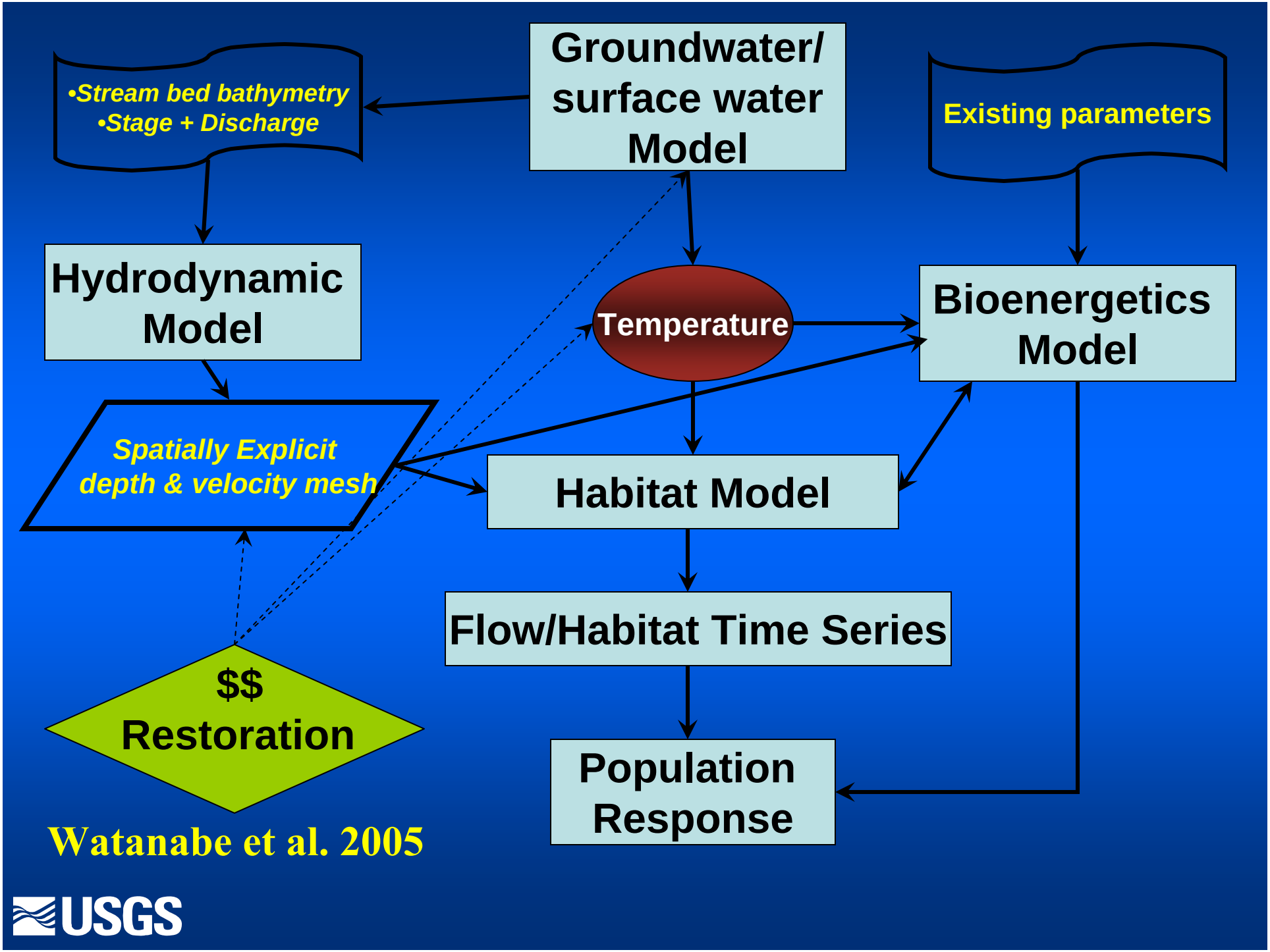
•Stream bed bathymetry
•Stage + Discharge
Groundwater/ surface water Model
Existing parameters
Hydrodynamic Model
Temperature
Bioenergetics Model
Spatially Explicit depth & velocity mesh
Habitat Model
Flow/Habitat Time Series
$$ Restoration
Population Response
Watanabe et al. 2005
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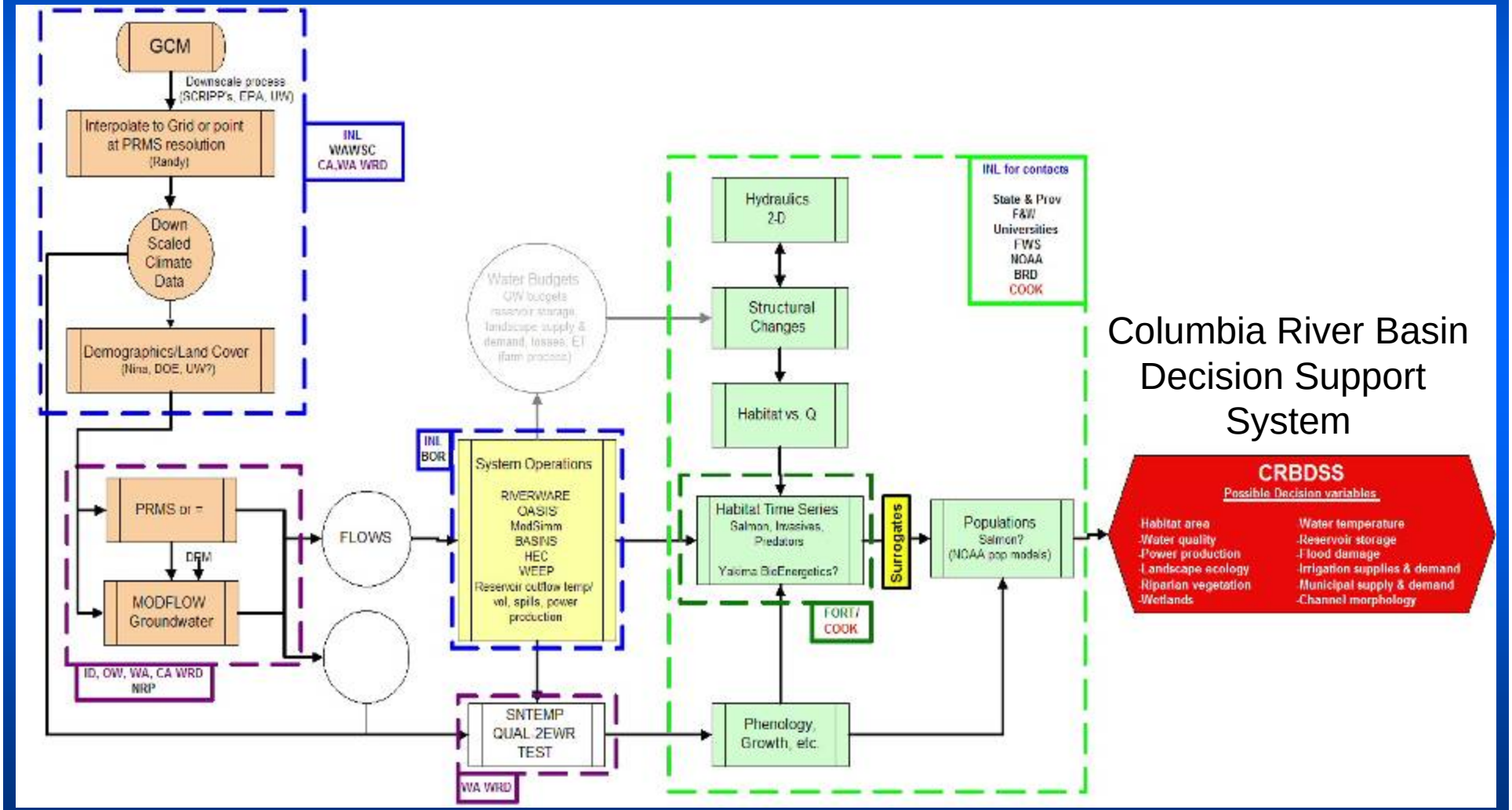
Predicting effects of climate change on aquatic biota: developing a decision support system for the Yakima River Basin.

Funded: DeWayne Cecil, Chief for Science Applications
USGS Global Change Science Program

"Development of a Forecasting Decision Support Tool for Water and Natural Resources Management in the Columbia River" - Ken Bovee, PI (and a cast of thousands)



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