Empirical evidence for the importance of zooplankton to juvenile salmon in the southern Salish Sea

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The Salish Sea

Decline in Salish Sea Marine Survival

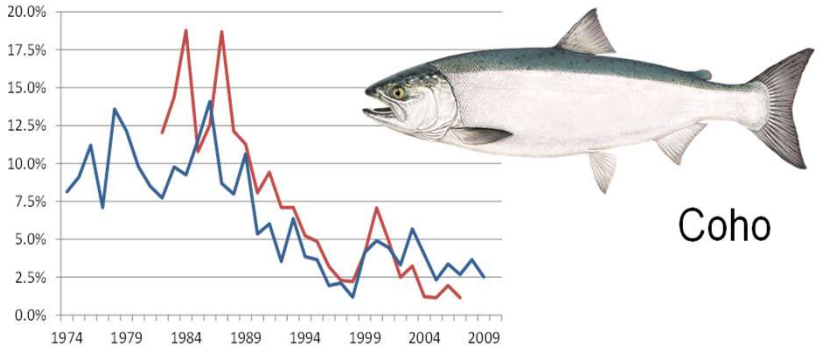
Puget Sound

Strait of Georgia

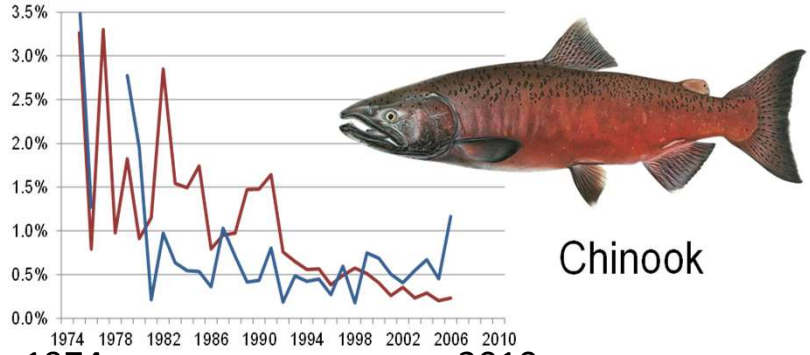
Versus :

Washington / B.C. Coast

Strait of Georgia and Puget Sound



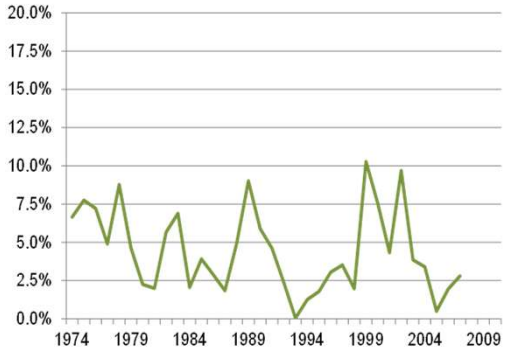
Coho

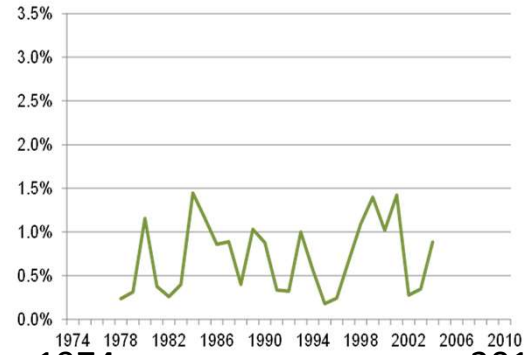


Chinook

1974 2010

Washington / B.C. Coast



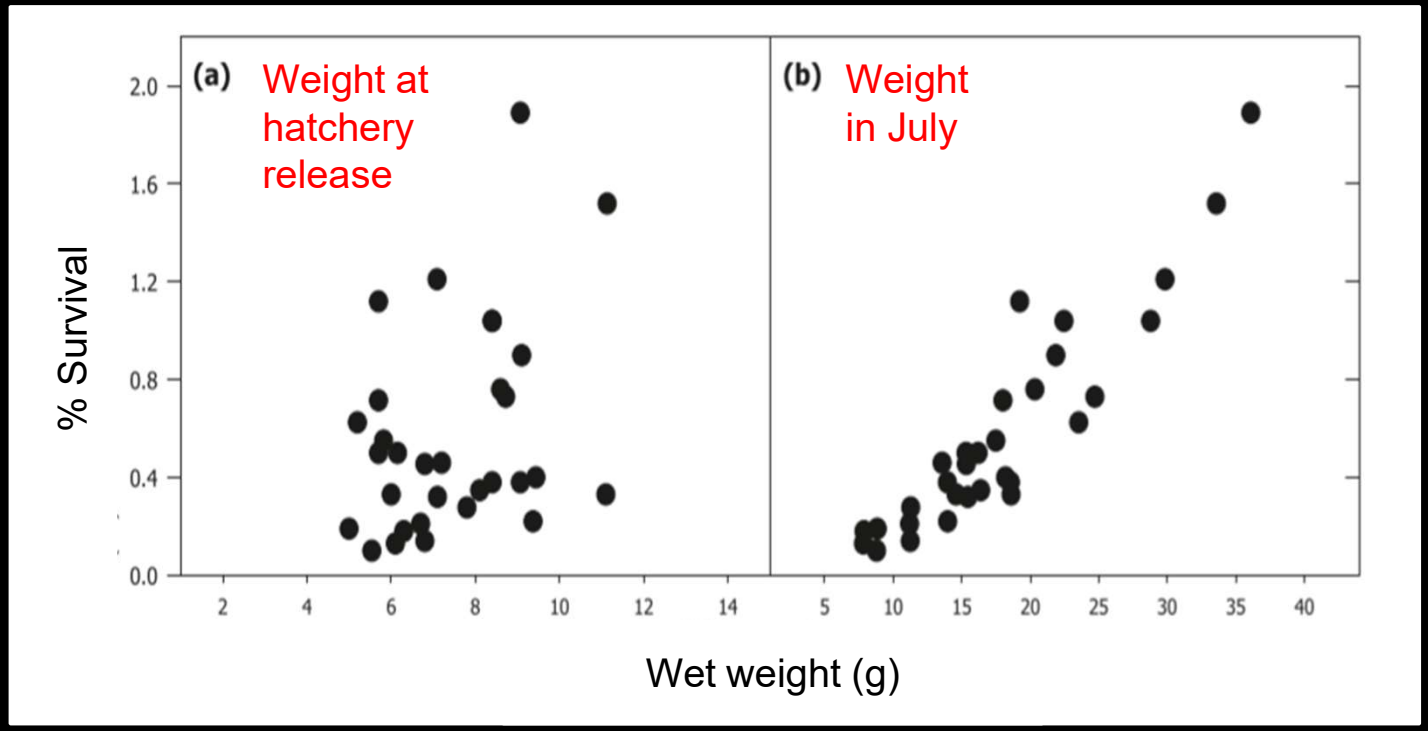


1974 2010

Survival of Chinook salmon is predicted by their weight in July, but not at hatchery release.

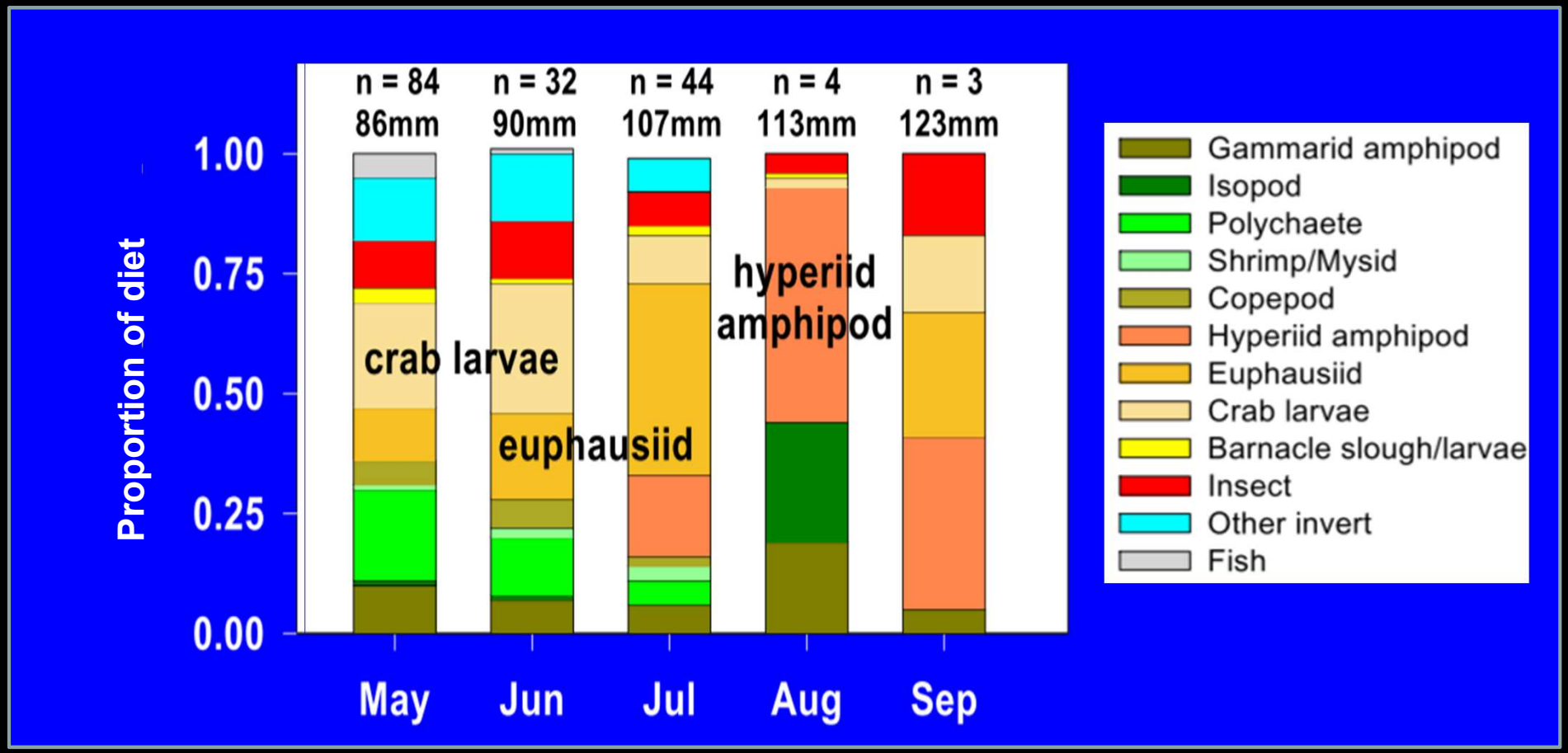
--Indicates that growth by July is critically important.

http://www.fpc.org



Plots courtesy of D. Beauchamp

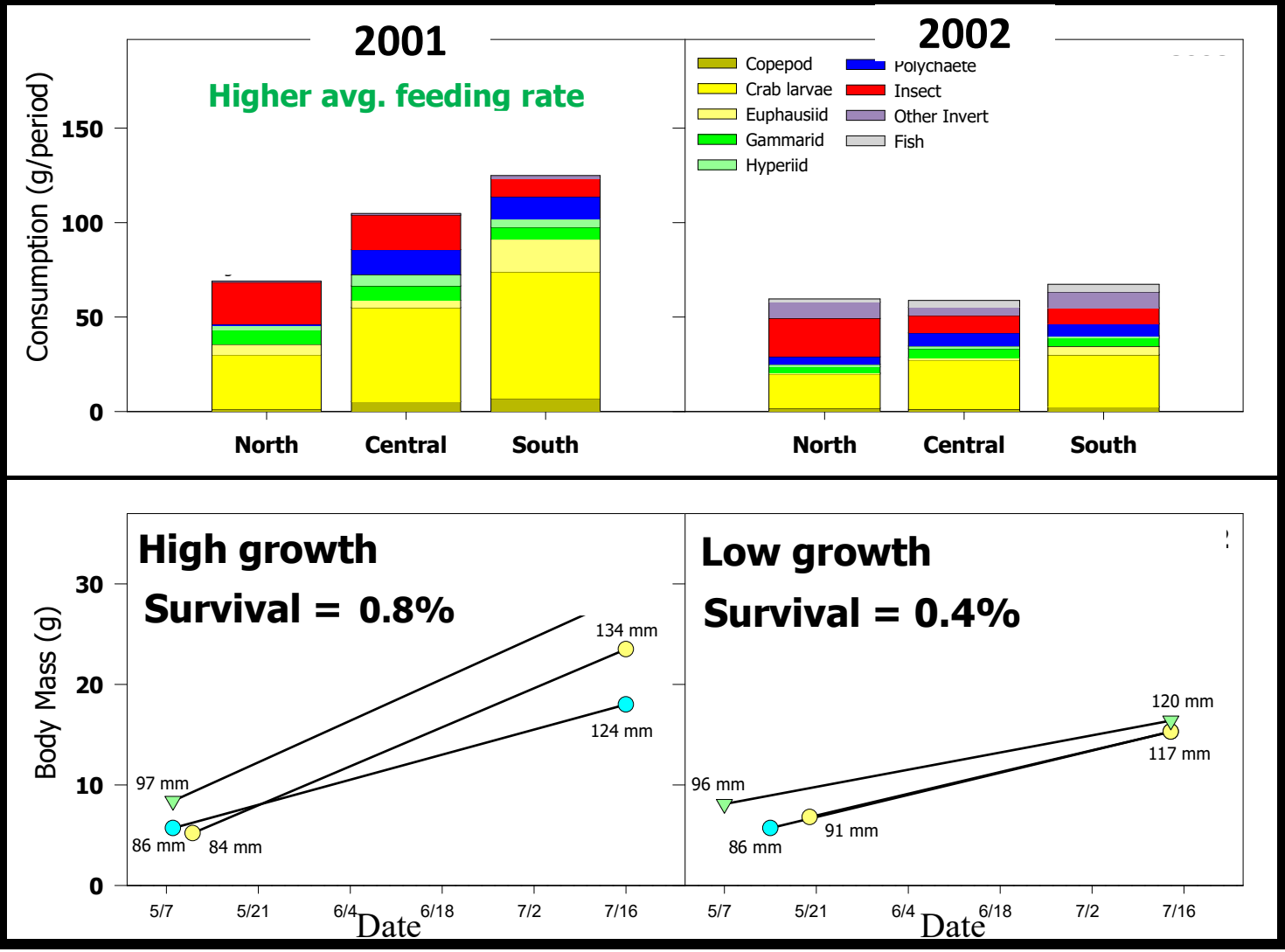
Zooplankton are known to make up most of juvenile Chinook and Coho salmon diets:



Duffy 2009 Dissertation

Higher Feeding Rate = Higher Growth & Survival

Hatchery Puget Sound Chinook

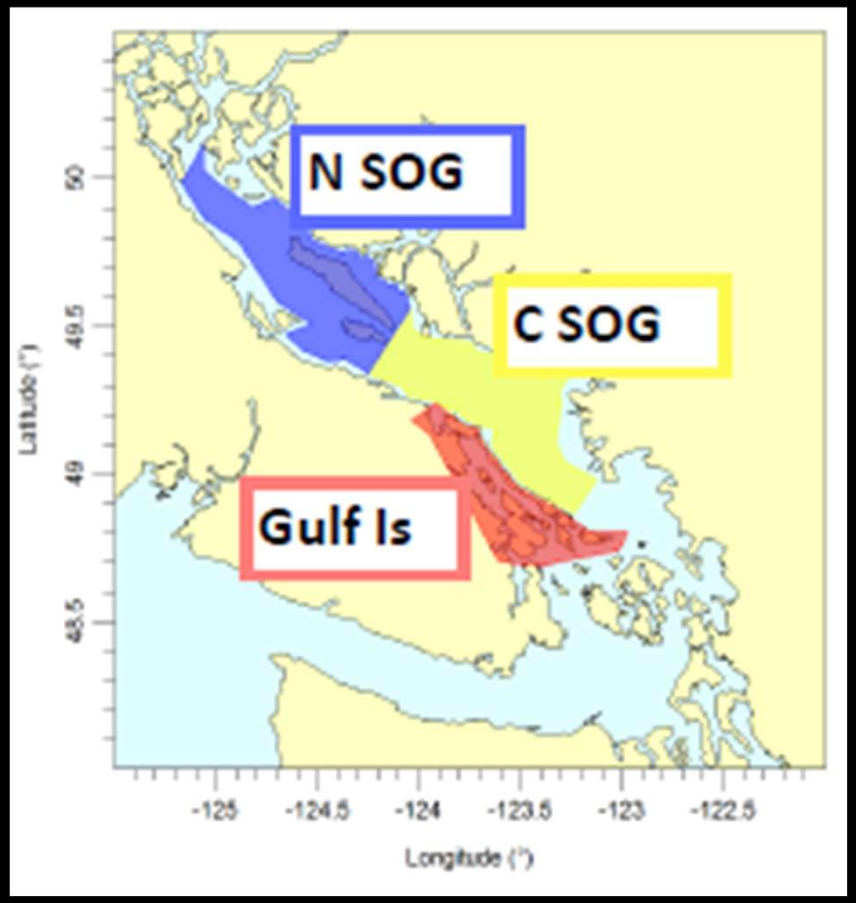


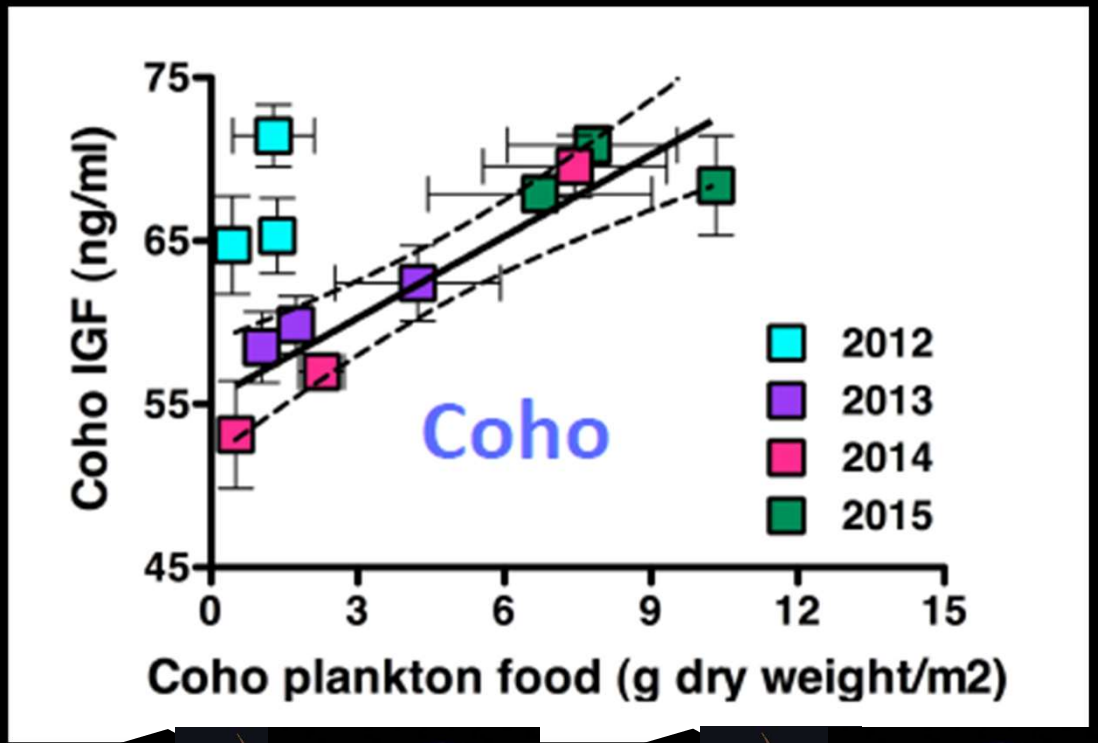
Low & variable feeding rates suggest food limitation

Duffy 2009 Dissertation

Juvenile salmon growth is correlated to plankton biomass

Insulin-like growth factor-I



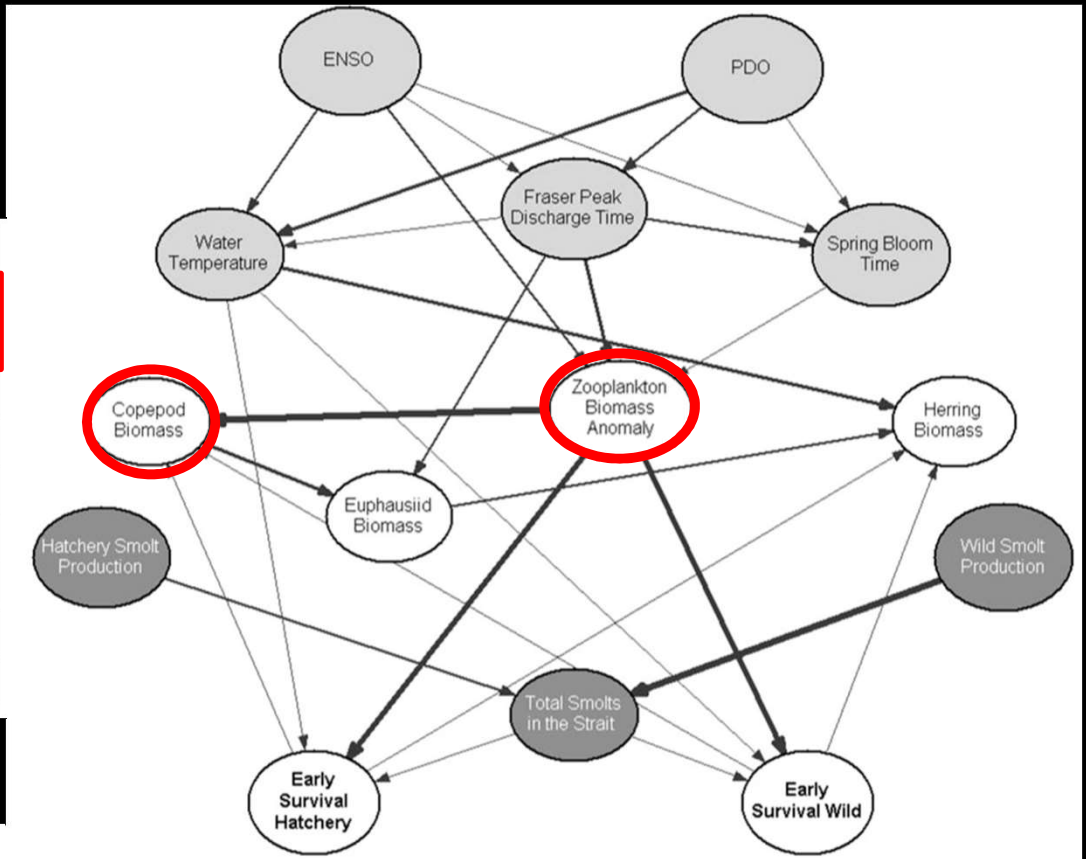


Beckman (NOAA), Trudel, Journey, Perry, Young, and Galbraith (DFO Canada)

In the Strait of Georgia, Zooplankton metrics (Total biomass; Calanoid copepod biomass) were the top two indicators of early marine survival of coho salmon

Bayesian network model

Indicator	Diagnostic Value
Zooplankton biomass anomaly	0.212
Calanoid copepod biomass	0.083
Herring biomass (pre-fishery)	0.073
Water temperature	0.056
Fraser peak discharge time	0.043
Euphausiid biomass	0.032
ENSO	0.029
PDO	0.021
Log spring bloom time	0.006



Araujo et al. 2013

Critical missing information for the Southern Salish Sea

Concurrent time series of the fish and zooplankton from which to assess relationships

Historical zooplankton data to address interannual and long-term changes

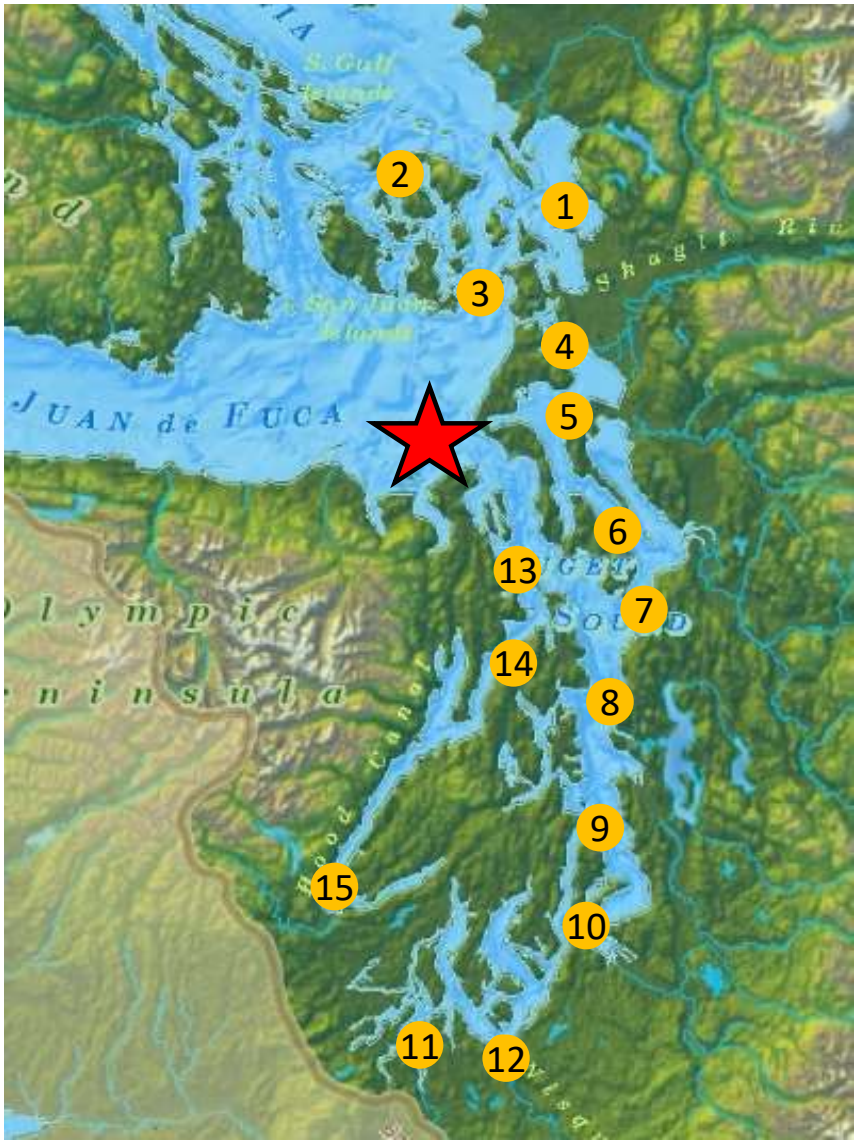
Strait of Juan de Fuca time series

- Monthly monitoring at a single station
- Upper 40 m vertical tows
- Began in 2003

Puget Sound Zooplankton Monitoring Program

- Bi-weekly March-October, monthly in winter at some stations
- Whole water column (to max. 200 m) vertical tows
- Began in 2014

Salmon survival time series
Juvenile salmon trawls – ended in 2017



Zooplankton composition relationship to salmon survival

Monthly zooplankton time series: 2003-present

- Zooplankton net tows
  - 75-cm diameter, 150-µm mesh
  - Surface (0-40 m) vertical net tows

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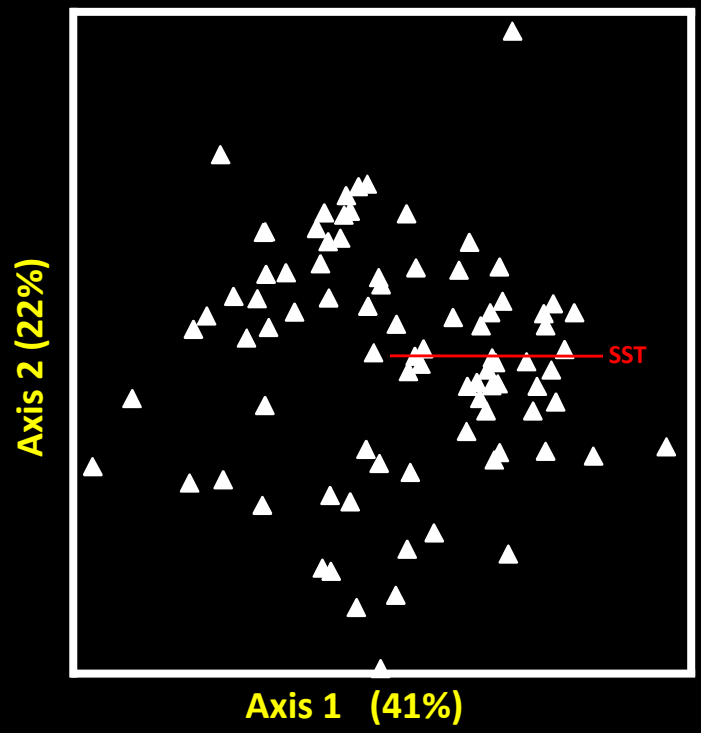
State of Washington

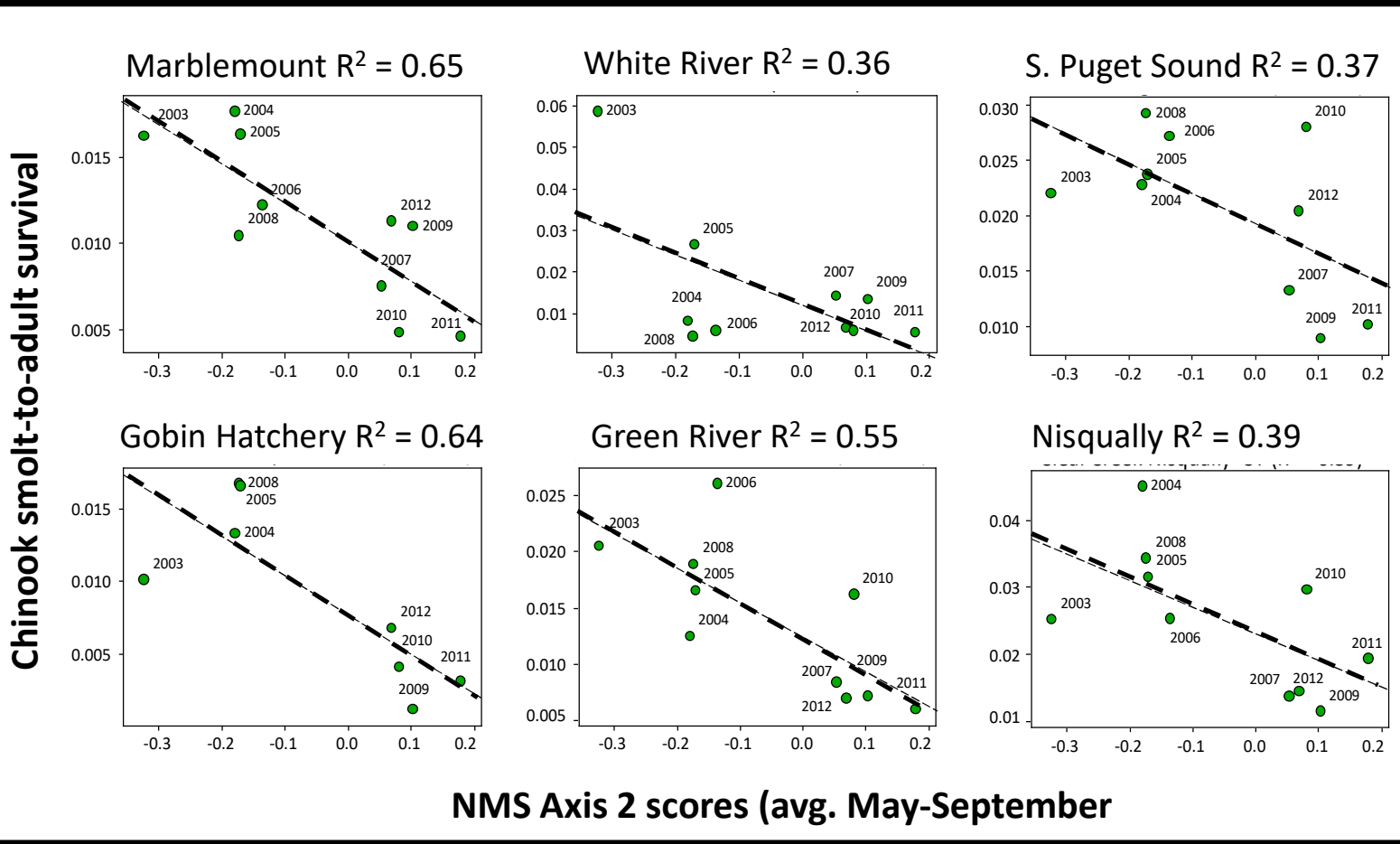
Data Analysis: Non-Metric Multidimensional Scaling (NMS) Ordination of copepod species composition

- **Relativized to species proportion in each sample**
- **Axis 2 = best indicator of salmon survival**
- **Average scores over May-Sept annually to compare to salmon survival**



Keister et al. L&O 2022

Relationships between zooplankton composition and Chinook survival



Keister et al. L&O 2022

Huge differences among copepods: body size, lipid content, behavior

Puget Sound Zooplankton Monitoring Program

- Bi-weekly March-October, monthly in winter at some stations
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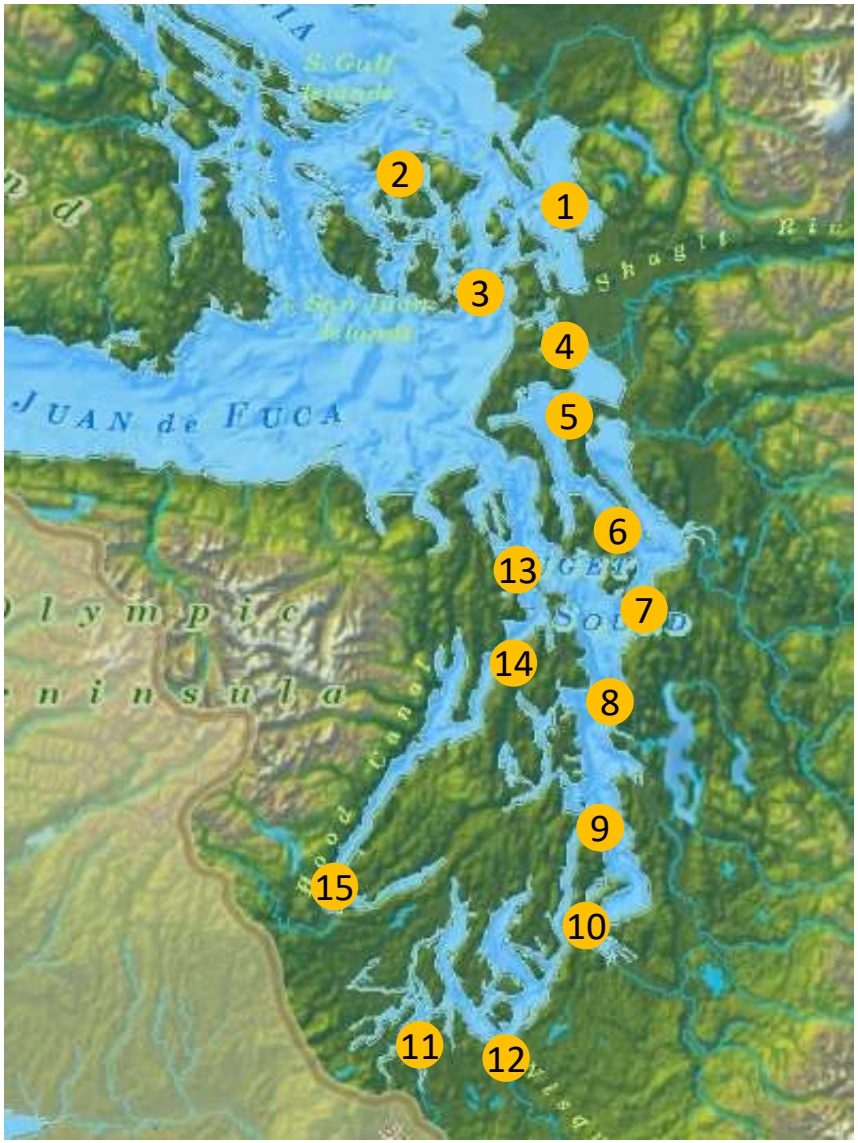
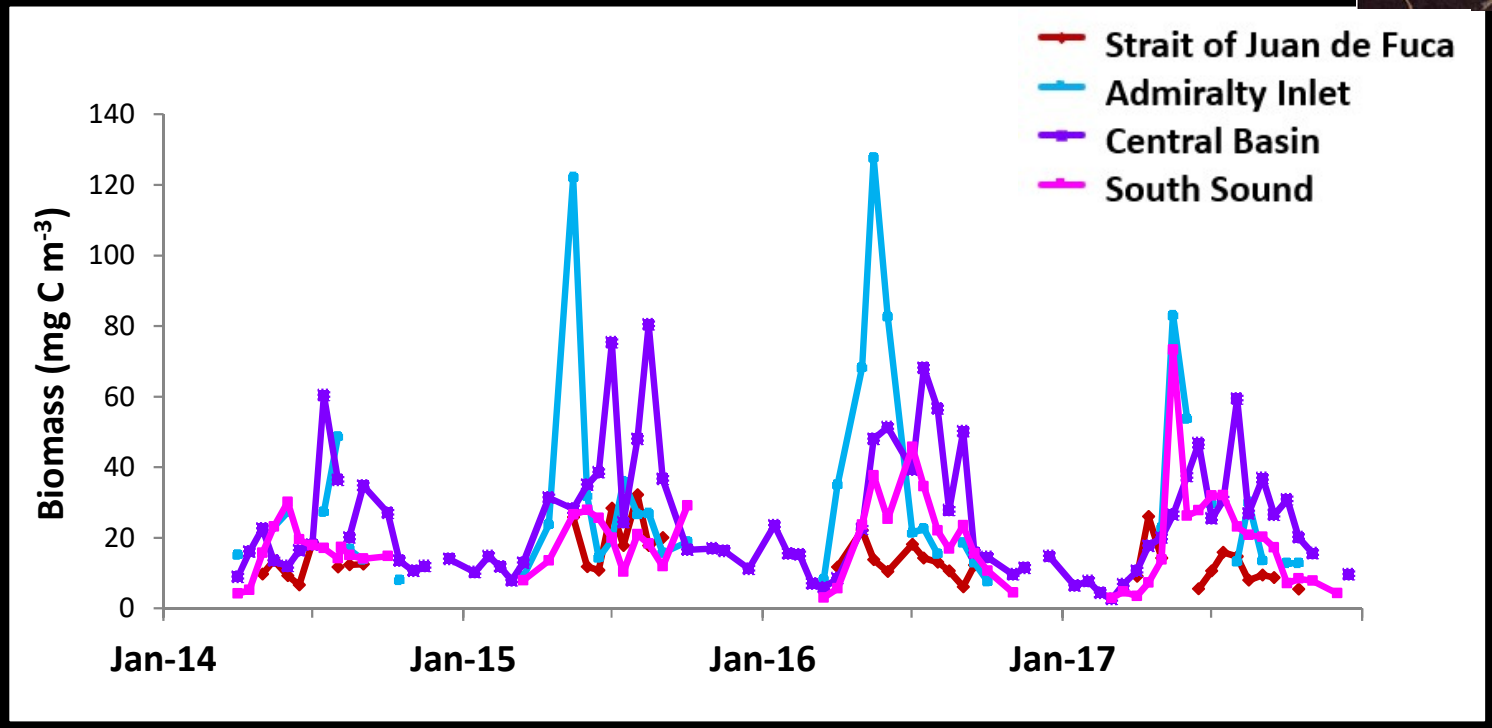
- Began in 2014



Total zooplankton biomass:

Higher in most regions in 2015 and 2016



Winans, Herrmann, and Keister (submitted)

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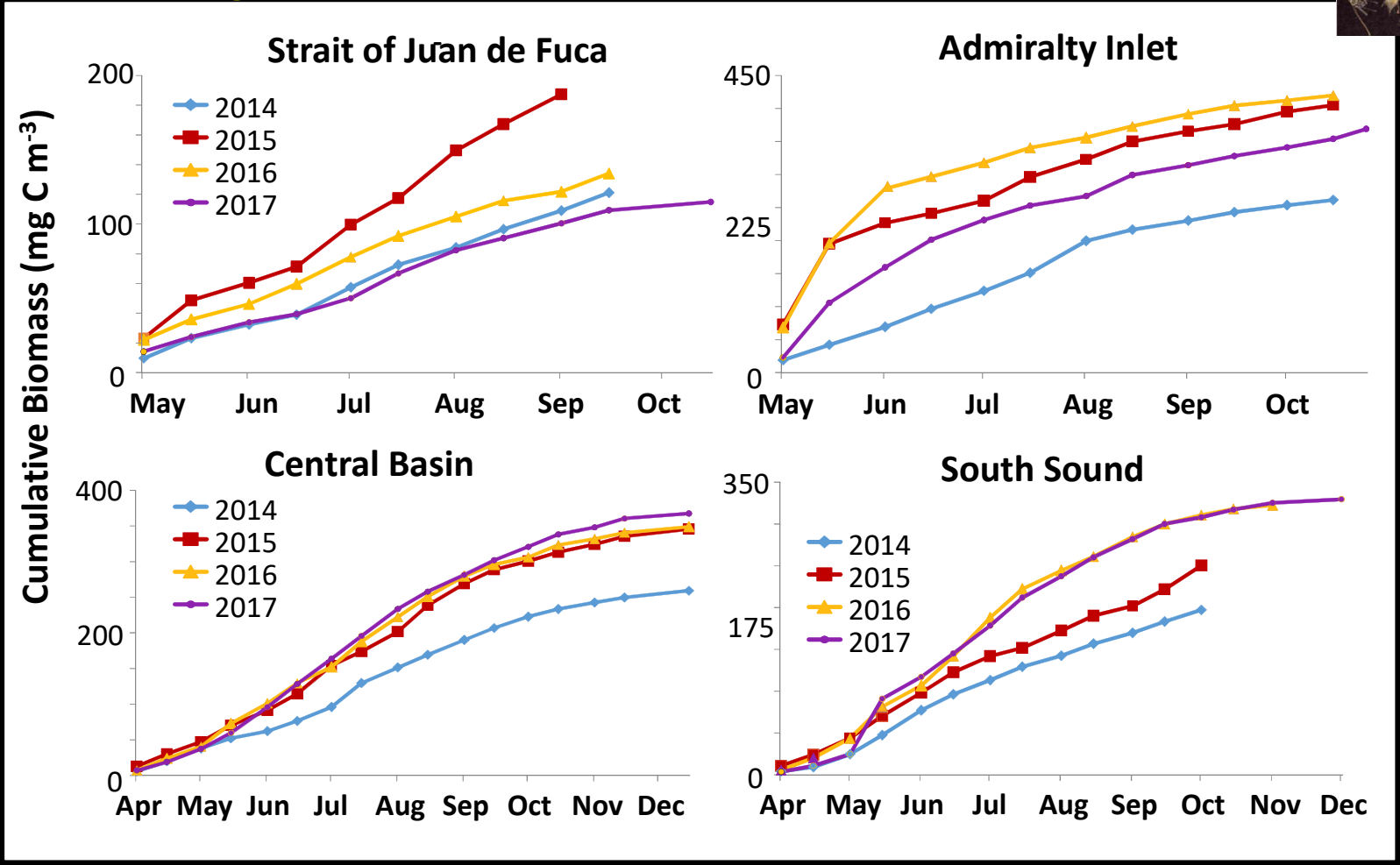
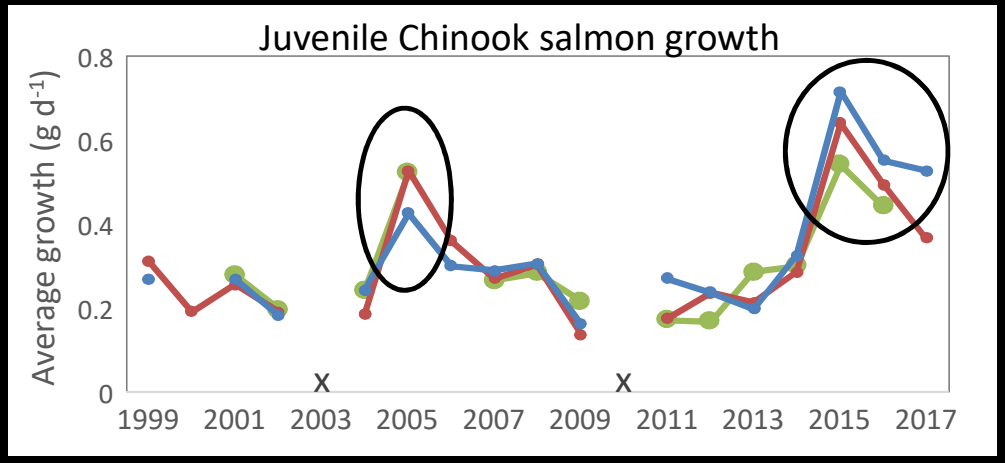


Juvenile salmon growth (hatchery Chinook)

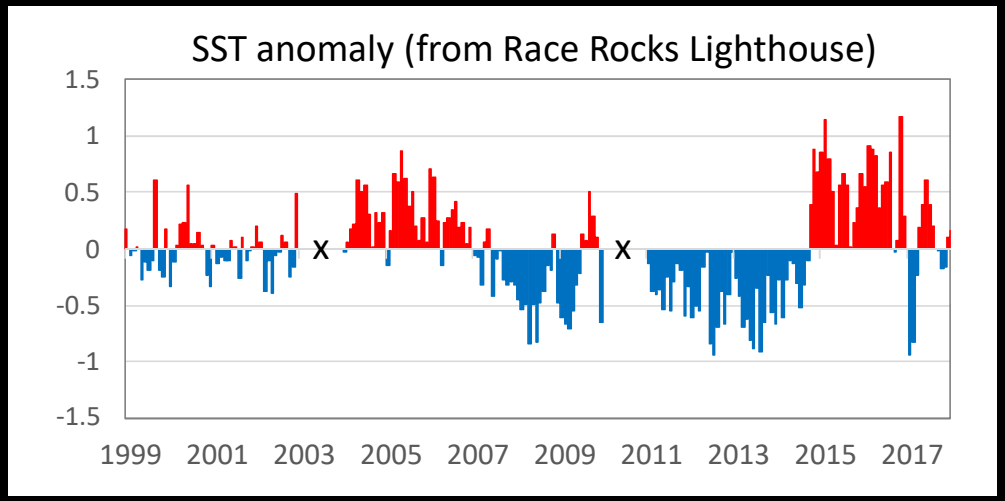
Average weight gain per day from hatchery release to recapture

http://www.fpc.org



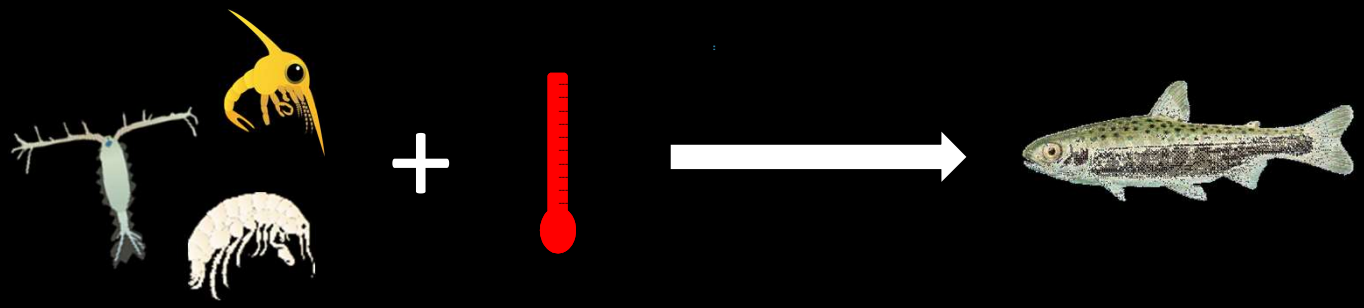
Hatchery region

- North Puget Sound
- Central Puget Sound
- South Puget Sound

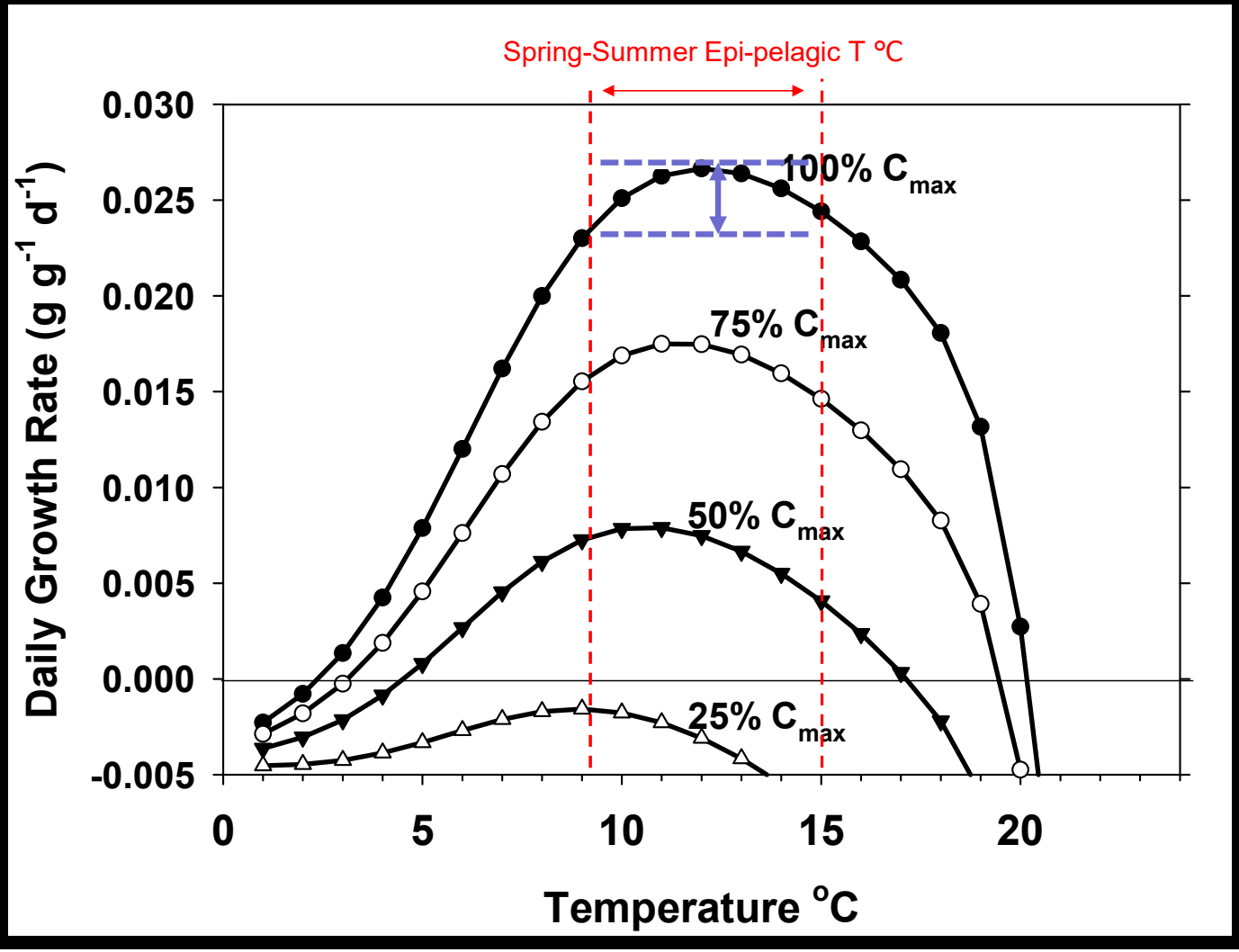


Data courtesy DFO Canada,
Growth calculations by I. Kemp

Indication is that higher temperature *combined* with high food availability led to higher growth



Chinook: Feeding is more important than temperature for growth



Consumption (feeding rate) has a much bigger influence on juvenile Chinook salmon growth than temperature during summer in Puget Sound.

Beauchamp & Duffy 2011

Conclusions

- Very little historical zooplankton data
- Relationships to salmon survival largely assumed from diet and consumption
- Empirical evidence suggests higher growth and survival with higher prey availability
- Composition seems as important as total biomass
- Short time series = need for continued monitoring of both zooplankton and salmon survival

Partnerships & Funding