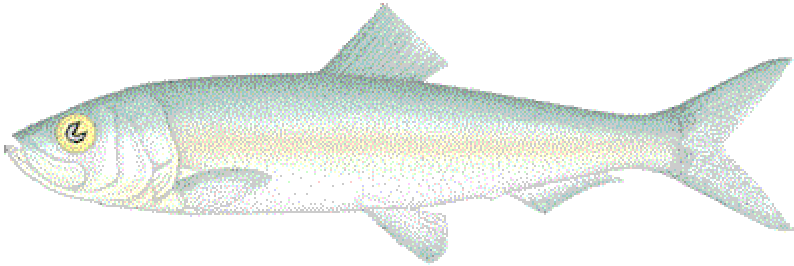
Fisheries and Oceans Canada / Pêches et Océans Canada

Juvenile Pacific Herring (*Clupea pallasi*) trophic linkages in the Strait of Georgia, British Columbia



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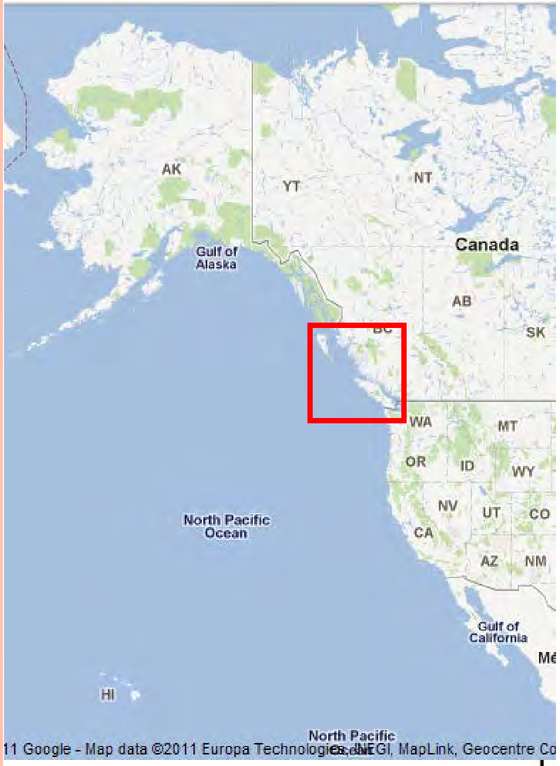
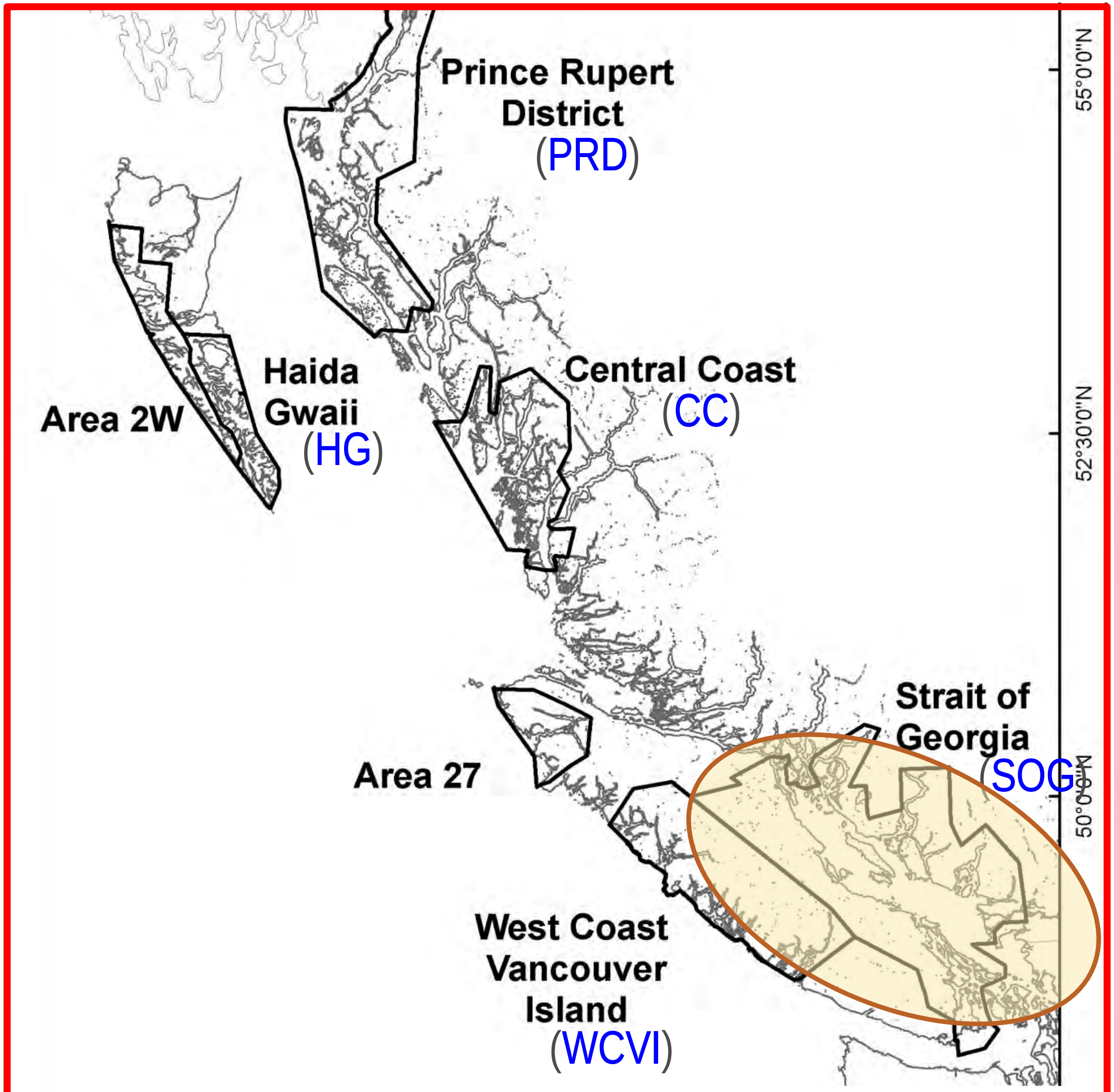
PICES 2016, San Diego, USA

Canada

British Columbia Pacific Herring

5 major & 2 minor fishing stocks

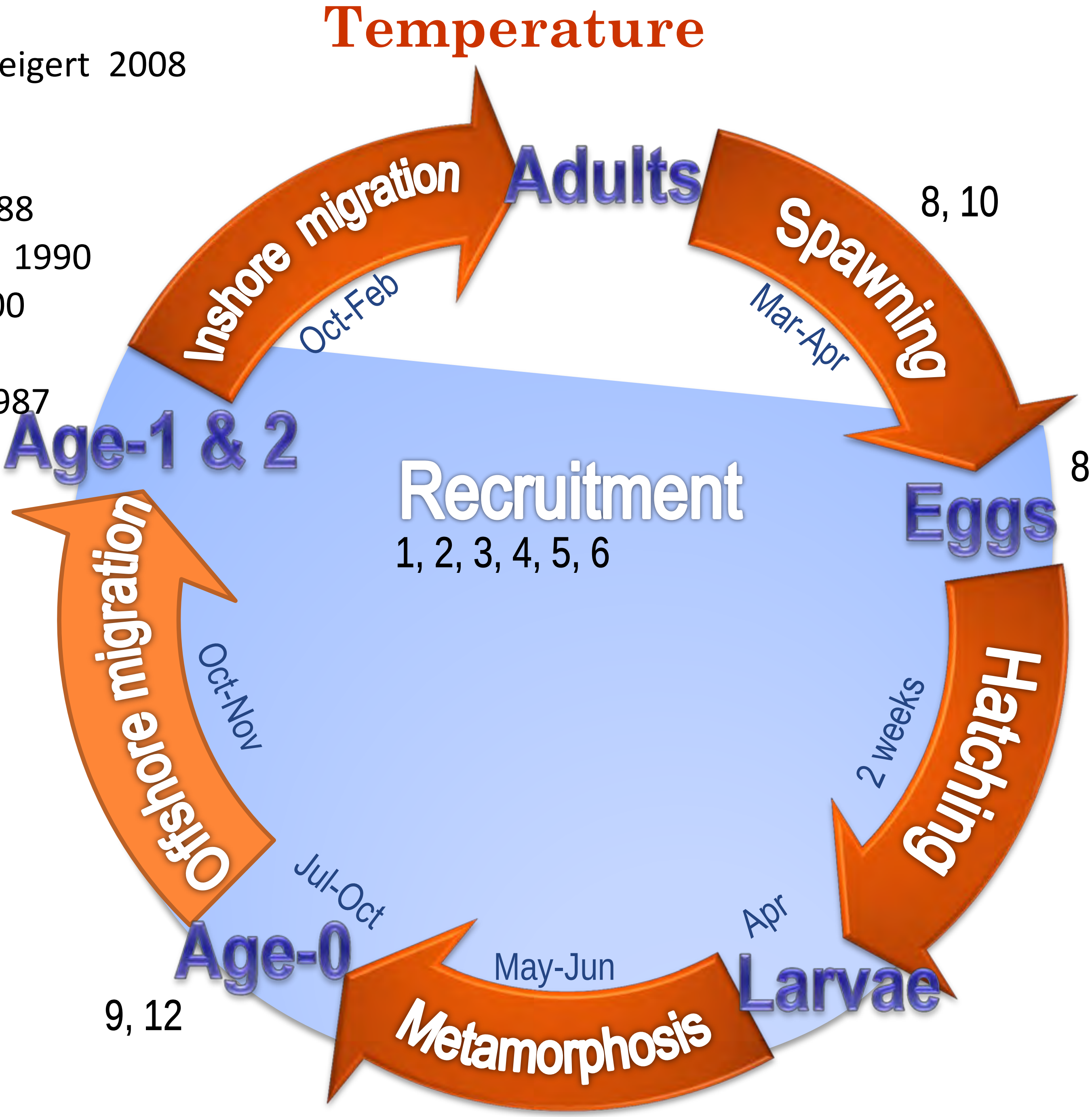




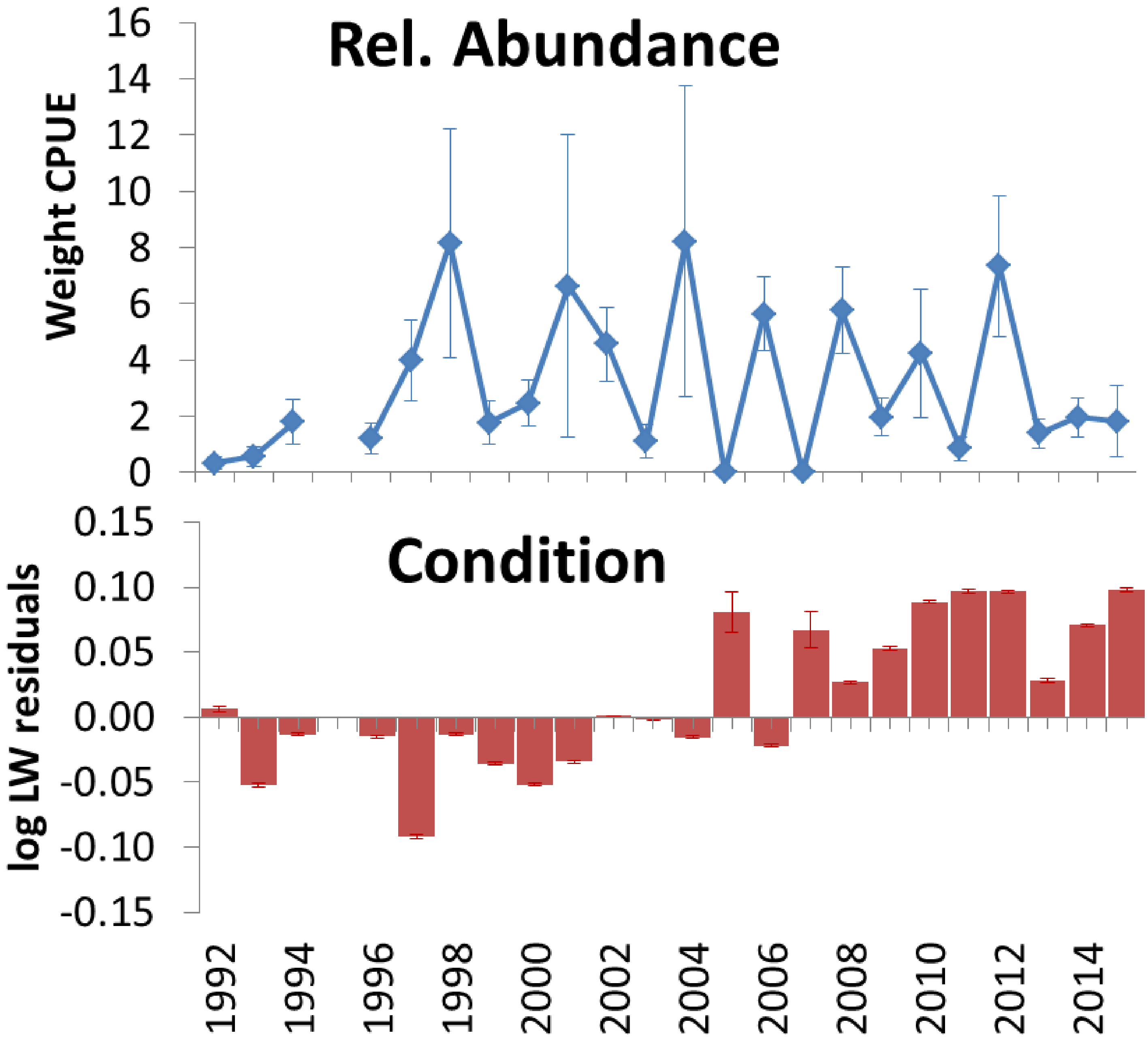
Map courtesy of Kristen Daniel, DFO

DFO 2010

	Publication
1	Dreyfus-Leon and Schweigert 2008
2	Zebdi and Collie 1995
3	Stocker et al. 1985
4	Stocker and Noakes 1988
5	Schweigert and Noakes 1990
6	Williams and Quinn 2000
7	Schweigert et al. 2013
8	Tanasichuk and Ware 1987
9	Tanasichuk 1997
10	Hay and Kronlund 1987
12	Reum et al. 2011



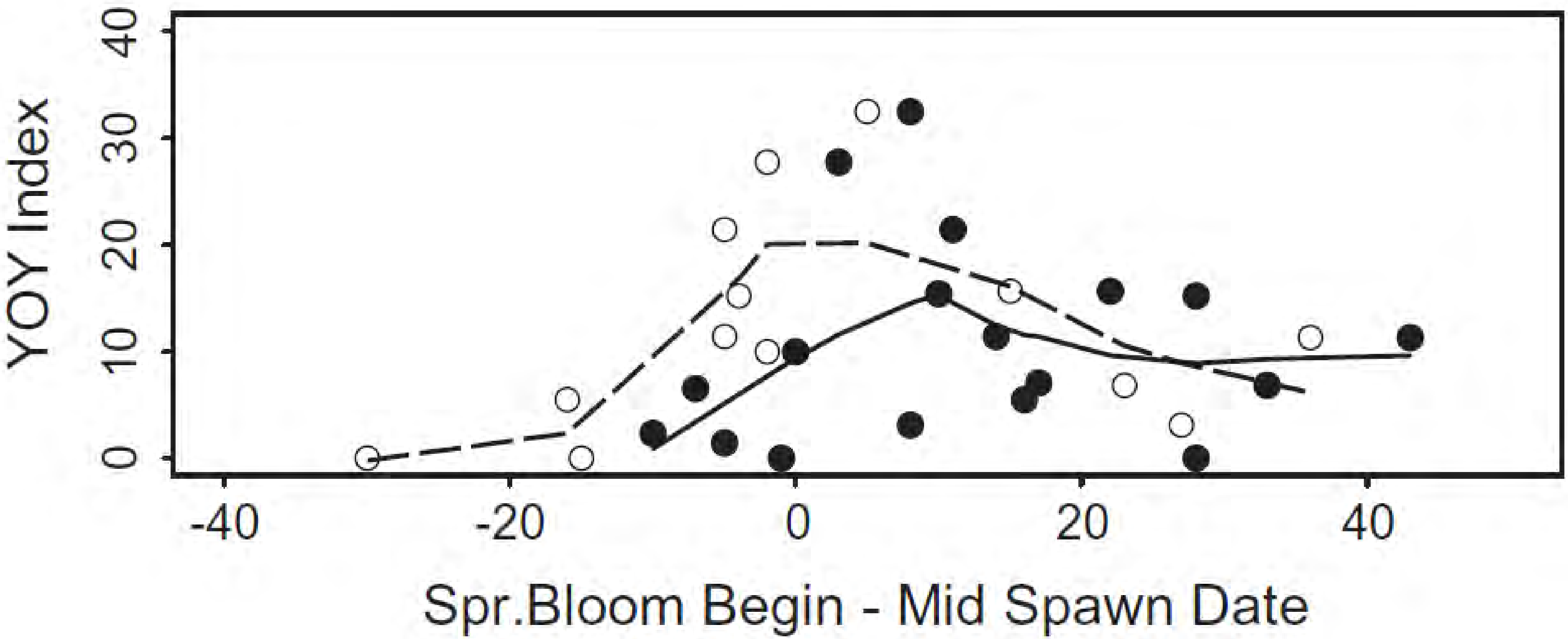
Strait of Georgia Juvenile (age-0) Herring Survey



Question:

- What drives observed patterns in juvenile herring abundance and condition?
  - Temperature
  - Bottom-up factors
  - Competition
  - Predation
  - Buffering

Bottom-up Factors Affecting Age-0 Herring Abundance

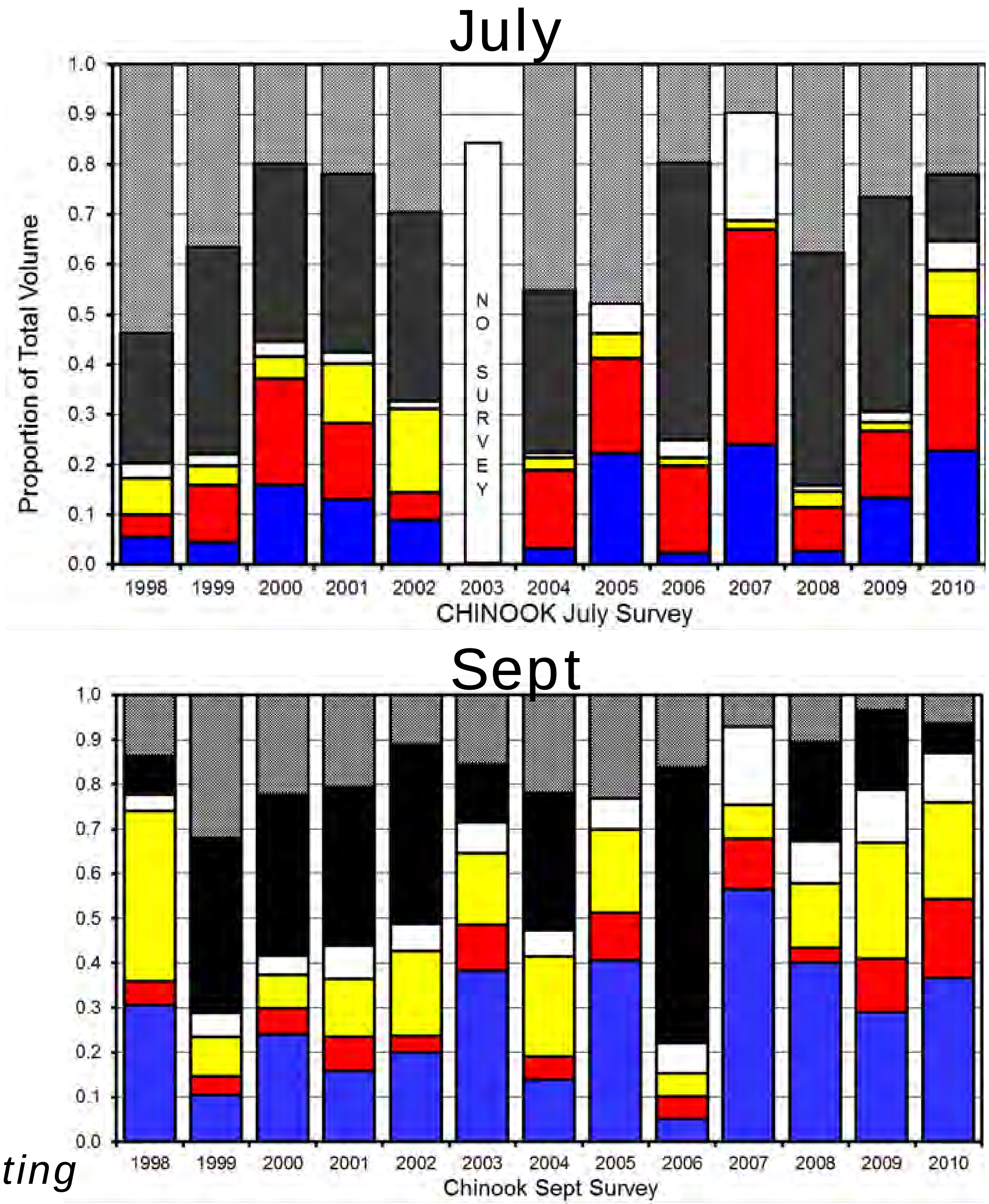


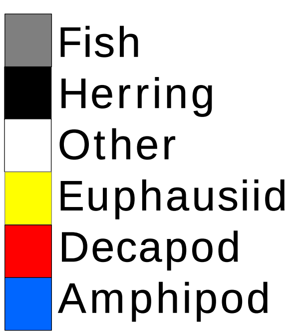
Timing of spawning relative to primary production (Schweigert et al. 2013)

open and closed circles and solid and dashed lines are different sources of spring bloom timing data

Juvenile Chinook Salmon Diets

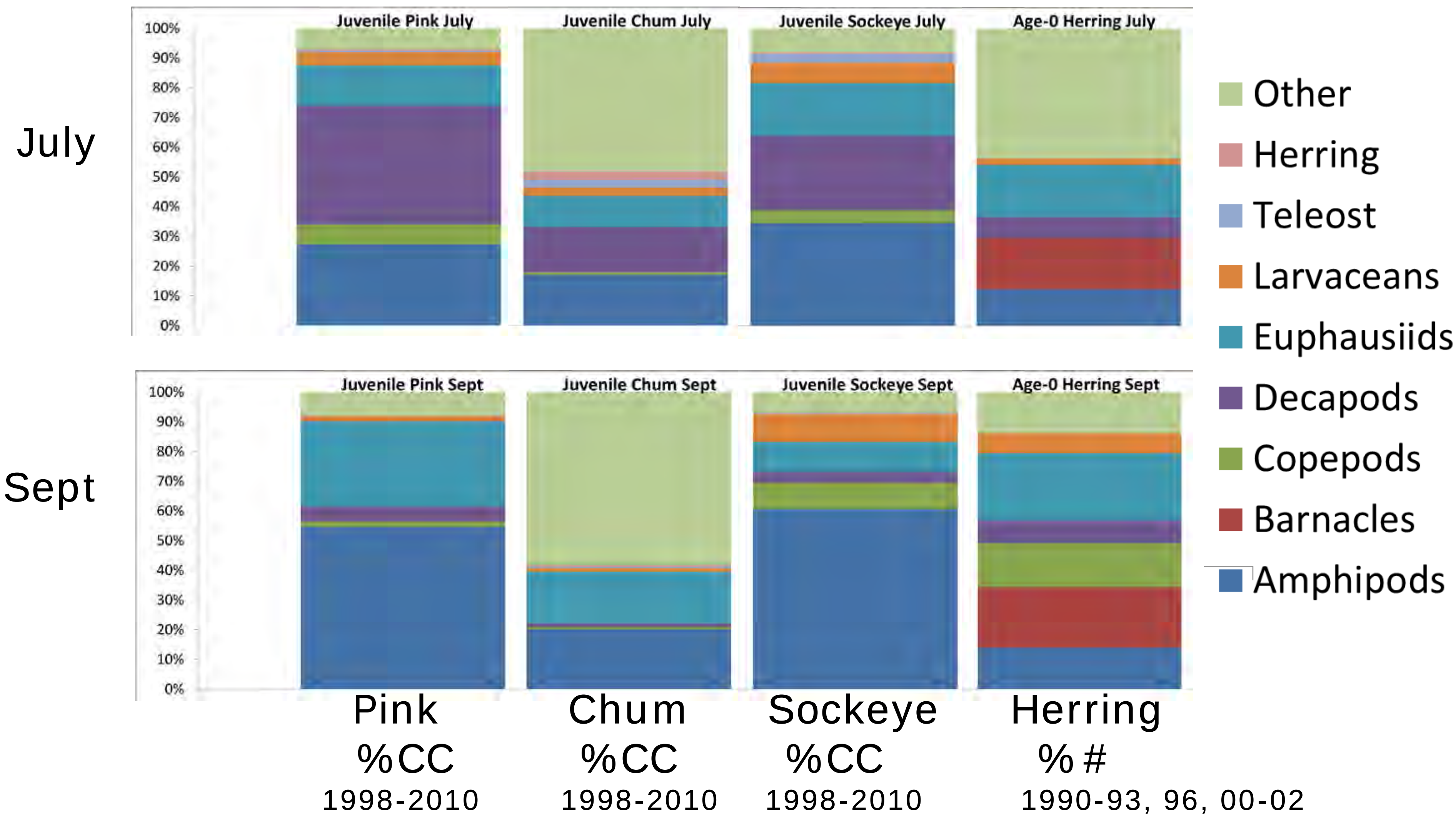
Juvenile Chinook eat juvenile herring





Courtesy of Rusty Sweeting

Potential Competitors
Juvenile Salmon and Age-0 Herring Diets



Salmon data courtesy of Rusty Sweeting

Fish Size and Condition

- Density-dependent habitat selection in Puget Sound, resulted in
  - Summer: herring size positively related to temperature
  - Fall: herring size negatively associated with abundance (Reum et al. 2013)

- In BC, avian predators select juvenile salmon prey of small size and poor condition relative to those available (Tucker et al. 2016)

Hypotheses

- juvenile herring **abundance** is higher when there are
  - fewer predators (Chinook, Coho),
  - fewer competitors (pink, chum, sockeye),
  - more prey (zooplankton),
  - more herring spawn, and
  - when date of most herring spawn aligns hatched larvae with spring bloom.

- juvenile herring **condition** is better when there are
  - more predators,
  - fewer competitors; both salmon (pink, chum, sockeye) and herring (herring spawn),
  - more prey (zooplankton),
  - warmer temperatures (metabolism; food conditions),
  - when the date of most herring spawn aligns hatched larvae with spring bloom

Data

Juvenile herring surveys (1992-2015):

- Abundance index
- Condition (length-weight residuals)
- Zooplankton density (#/m^3); herring prey

Spawn survey (1992-2015):

- Spawn biomass (mt), calculated from egg surveys
- Spawn date

Juvenile salmon surveys (1998-2015):

- Sum July and Sept CPUE Chinook and Coho (predators)
- Sum July and Sept CPUE Pink, Sockeye, Chum (competitors)
- Average values used for July 2003 (no survey)

Physical data (1992-2015):

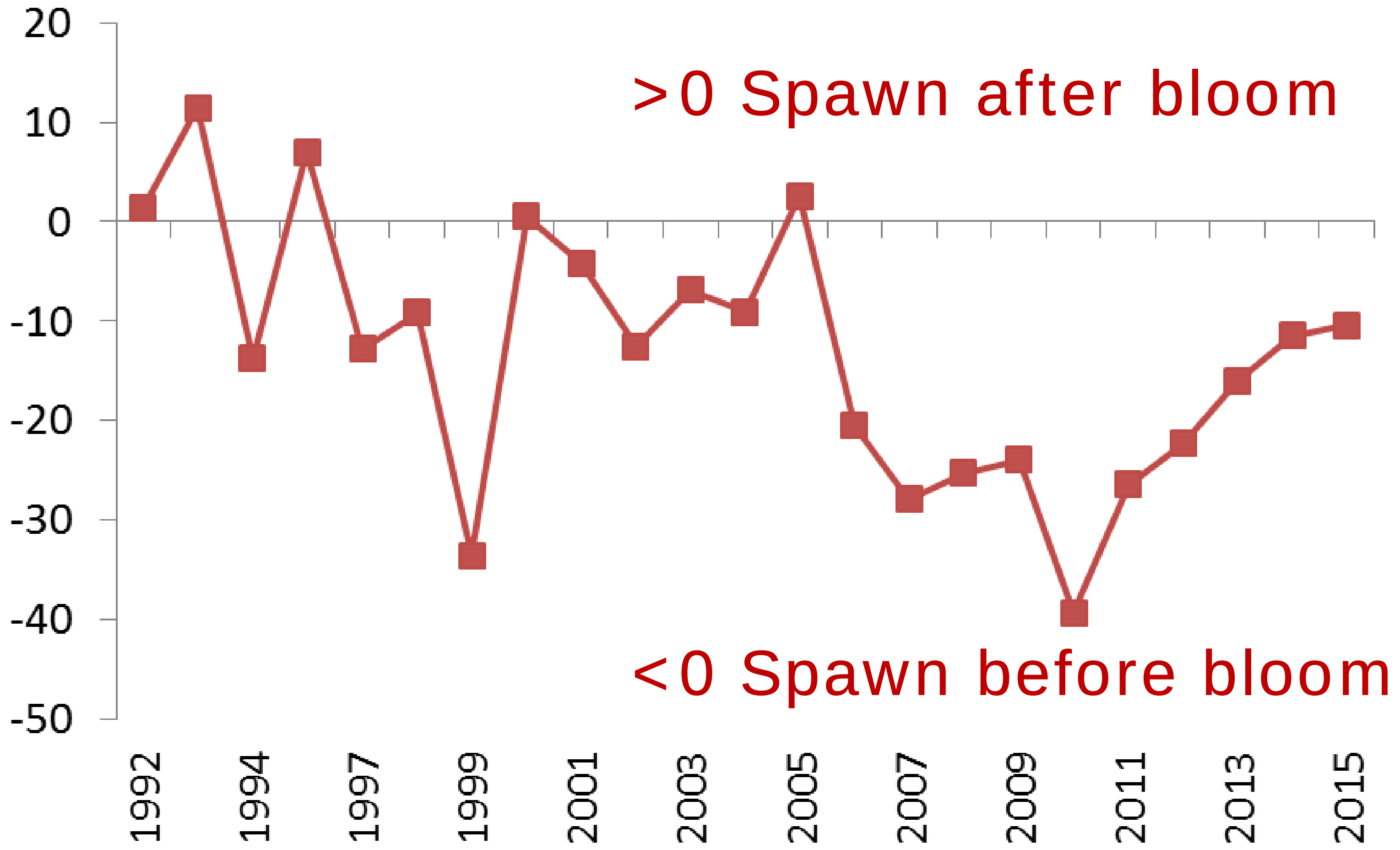
- Sea Surface Temperature (Chrome Island lighthouse, DJFM)
- Spring bloom timing –Allen et al. 2016, model output

Spawn Date Relative to Spring Bloom Date

Mid-spawn date weighted by spawn biomass

minus

Spring bloom date



Methods

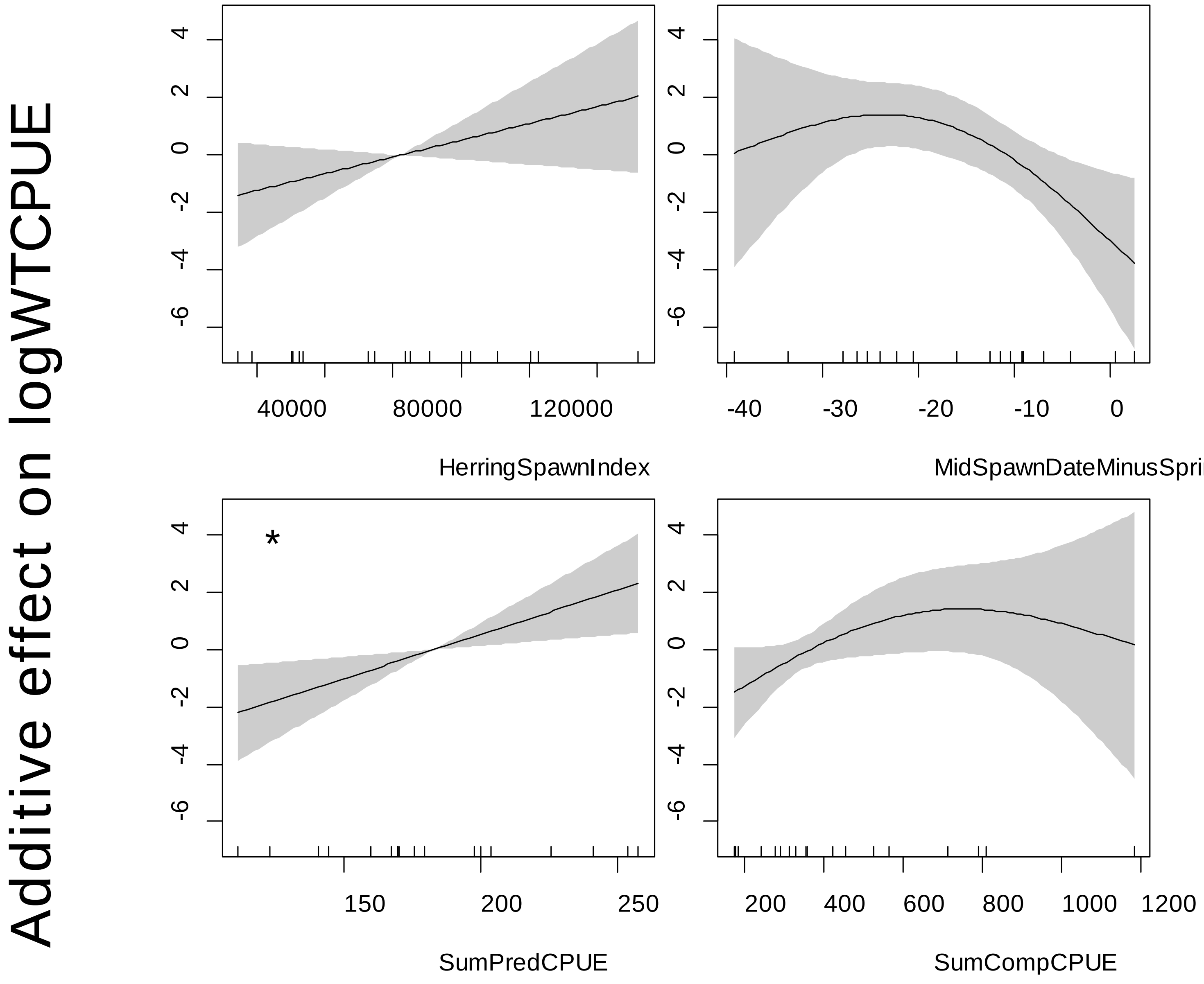
- Test biotic and abiotic variables as predictors of herring abundance and condition
- Examined correlations among variables
- Examined variance inflation factors
- General additive models (GAM, k=3)
- Hypothesized variables included in initial model
- Non-significant variables removed one at a time, starting with highest P-value, if two of three conditions met (Wood and Augustin 2002; Weinberg and Kotwicki 2008):
  - P-value >0.05
  - GCV score is reduced when variable is eliminated
  - effective degrees of freedom are close to 1.0

Models

- Juvenile herring abundance (log-transformed) as smooth spline function of:
  - herring spawn biomass
  - difference between:
    - Mid-spawn date weighted by spawn biomass and
    - Spring bloom timing
  - prey zooplankton density
  - predator CPUE
  - competitor CPUE

- Juvenile herring condition as a function of:
  - Same factors as above and
  - SST

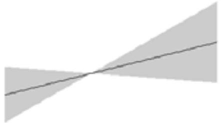
Juvenile Herring Abundance



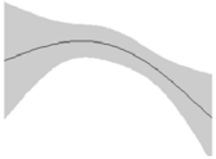
Deviance explained = 54.2%

Age-0 Herring Abundance

- increased with increasing herring spawning biomass



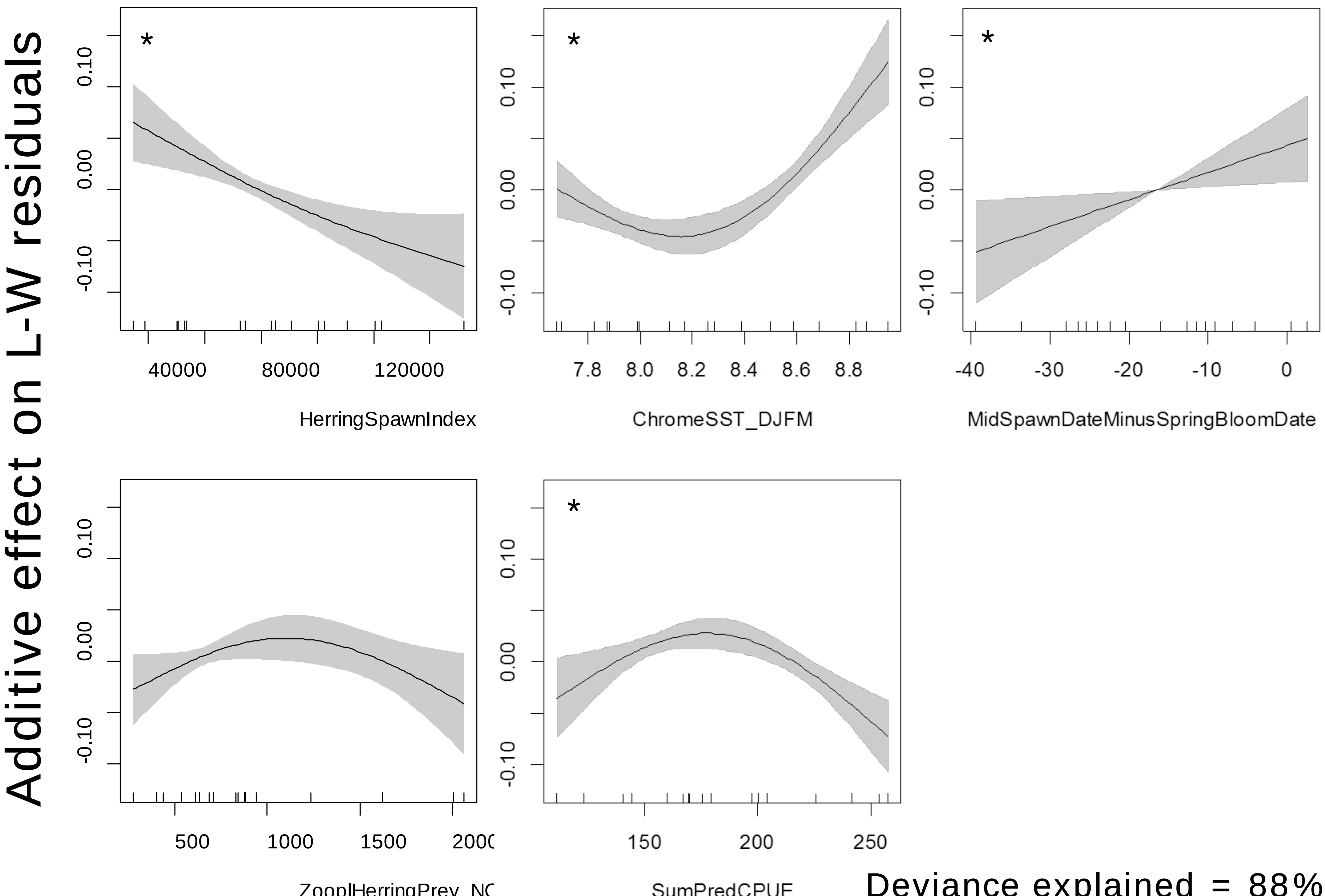
- peaked when the most herring spawn ~20 days prior to the spring bloom
  - Consistent with Cushing (1990) Match Mismatch hypothesis and Schweigert et al. 2013



- increased with increasing predator abundance*
  - Does not support hypothesis that predators are limiting herring abundance
  - Conditions are good for predators and herring?

- increased with increasing competitors and then leveled off (high variability)

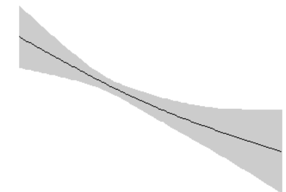
Juvenile Herring Condition



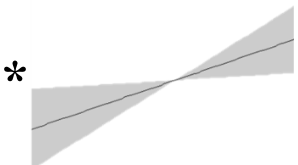
Deviance explained = 88%

Age-0 Herring Condition

- decreased with increasing spawn biomass*
  - Consistent with density dependence?



- increased when most herring spawn closer to the spring bloom*
  - Inconsistent with hypothesis to spawn before bloom date



- increased with increasing temperature*
  - Consistent with hypothesis that temperature, as a proxy for prey productivity

- increased with increasing predator abundance to a point and then decreased*
  - Inconsistent with hypothesis predators select prey in poor condition
  - At higher predator abundance, predator avoidance behaviour may affect ability to forage

- increased with increasing prey zooplankton density and then decreases/levels off.

Conclusions

- Bottom-up factors appear to affect age-0 herring
- There may be some indications of density dependence
- The date of most herring spawn relative to spring bloom affects both abundance and condition of age-0 herring.
  - After 2005, most spawning to occur prior to spring bloom
- Salmon predators may not affect abundance but may influence condition of age-0 herring; may have implications for survival
- Salmon competitors may not negatively affect age-0 herring

Next Steps

- Include/improve time series of:
  - prey:
    - zooplankton time series
    - spring bloom timing
  - other predators?
- Examine age-0 herring as drivers of Chinook survival
- Test age-0 herring as auxiliary time series (recruit prediction) in Herring stock assessment

ACKNOWLEDGEMENTS

- Pacific Salmon Foundation
- Herring Conservation and Research Society
- Doug Henderson
- Kristen Daniel
- Bob Armstrong
- Dennis Chalmers
- Carol Cooper
- Linnea Flostrand
- Mary Thiess
- Chuck Parken
- Lynda Ritchie
- Moira Galbraith
- Susan Allen
- Carl Haegele
- Vanessa Hodes
- Christa Hrabok
- Doug Miller
- Dan Ware
- Co-op students and volunteers