Apr 6th, 9:45 AM - 10:00 AM

Bottom-up and top-down processes affecting marine survival of salmon in the Salish Sea

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Top-Down and Bottom-up Processes Affecting Marine Survival of Salmon in the Salish Sea

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Washington Sea Grant
Pacific Salmon Commission
Salmon Recovery Fund Board
Puget Sound Partnership
Nisqually, Tulalip, Skagit Coop. & Lummi Tribes
NOAA, WDFW, Kwiaht, DFO-Canada, Pac. Salmon Foundation

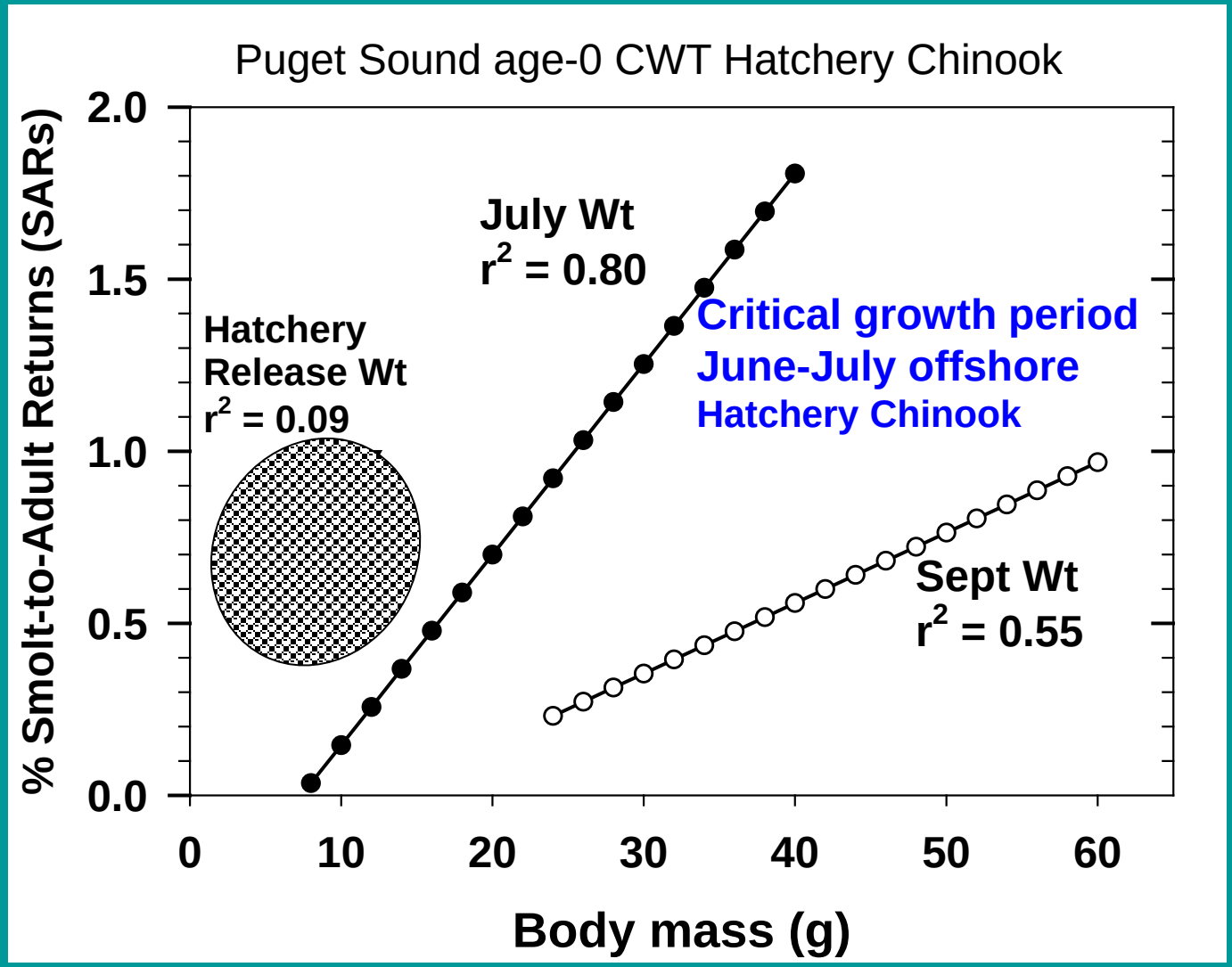
Survival Linked to Size & Growth at Specific Life Stages

Size at release & Marine entry NOT Correlated to Surv.

Marine survival Strongly linked to Wt after 1 month Epi-pelagic feeding In Puget Sound through July

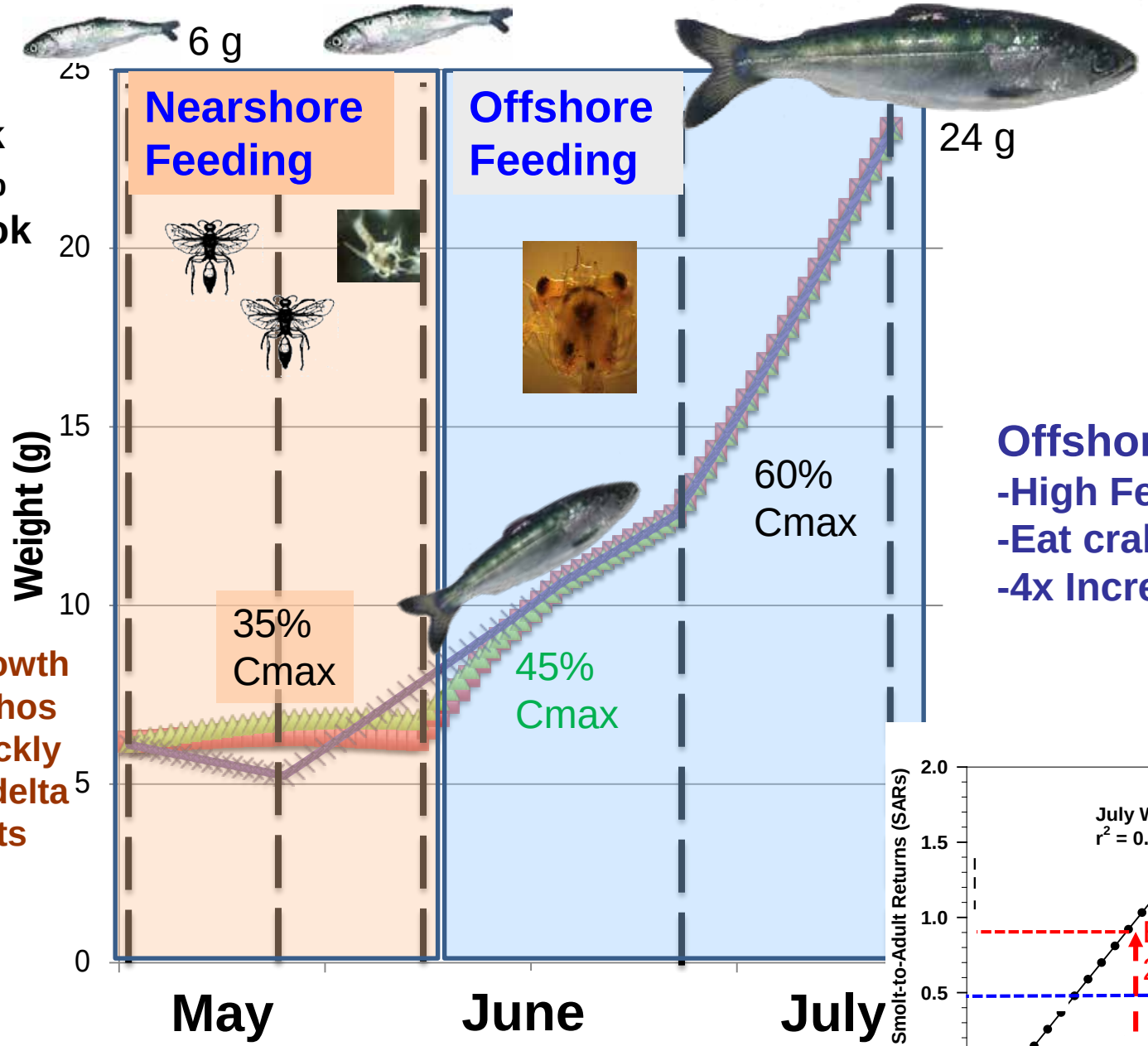
2-4 fold Wt gain during 1º pelagic feeding

Weaker pattern In Sept.



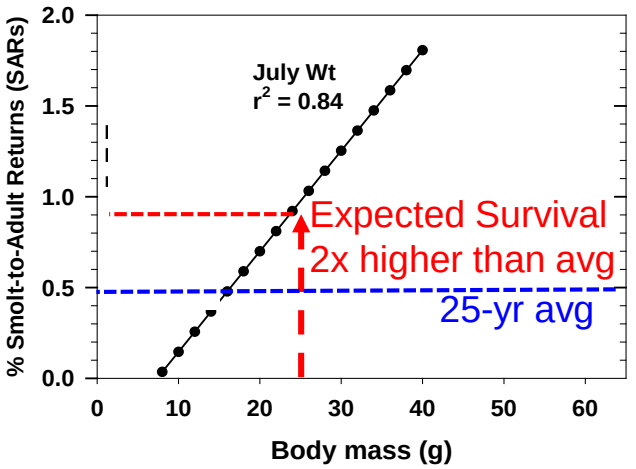
Duffy & Beauchamp 2011 CJFAS 68:232-240

Hatchery Chinook Represent 80-90% of juvenile Chinook in Puget Sound



Nearshore:
-Low Feeding & Growth
-Eat Insects & Benthos
-Pass relatively quickly through Estuarine delta & Nearshore habitats

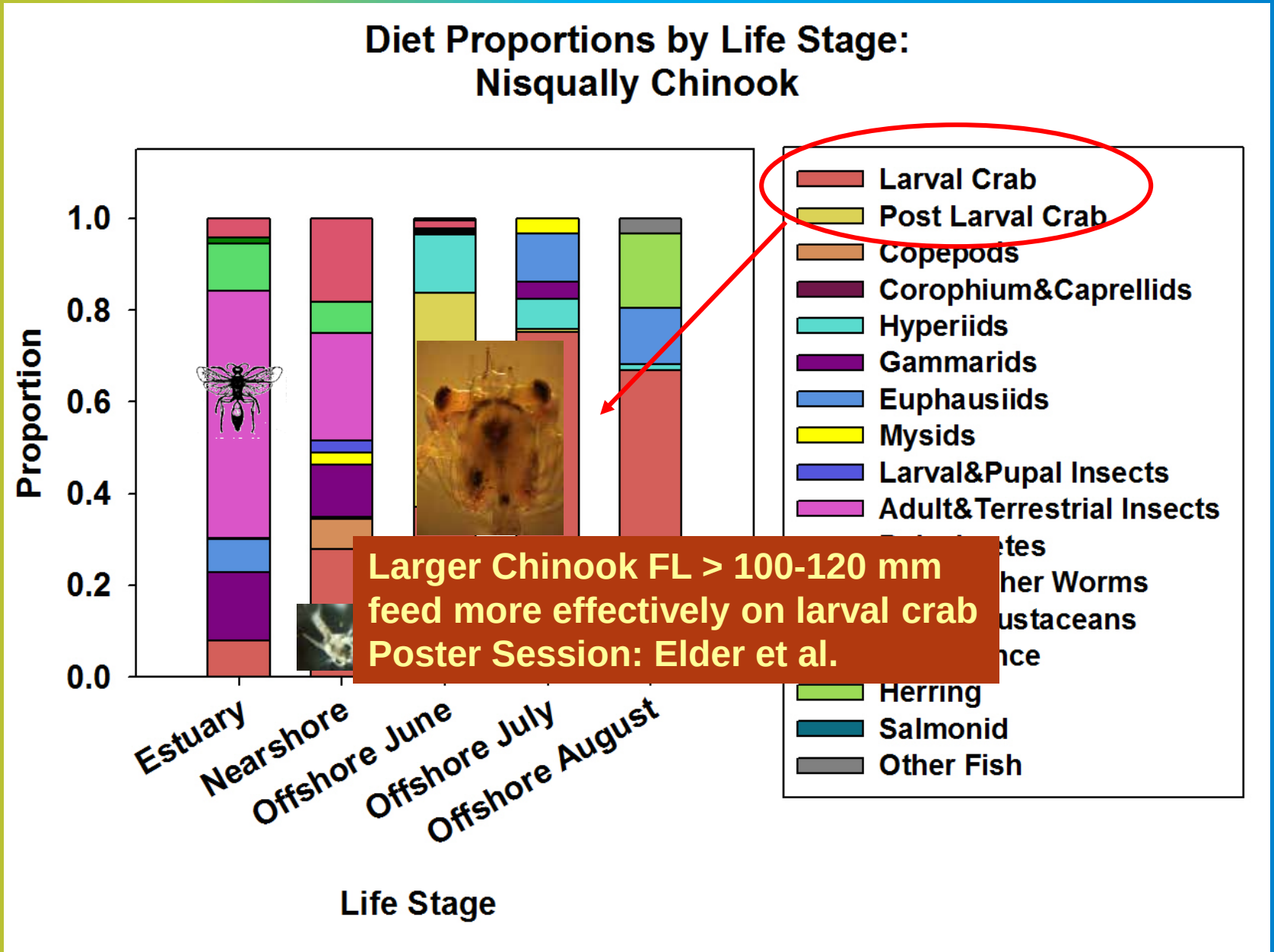
Offshore (epi-pelagic):
-High Feeding & Growth
-Eat crab larvae
-4x Increase in Mass



Diet Shift from Insects to Larval Crabs

Insects important in estuarine delta feeding

Larval crab more Important Offshore Feeding



Temperature Impacts on Growth
More extreme Nearshore than in Openwater habitats

Nearshore

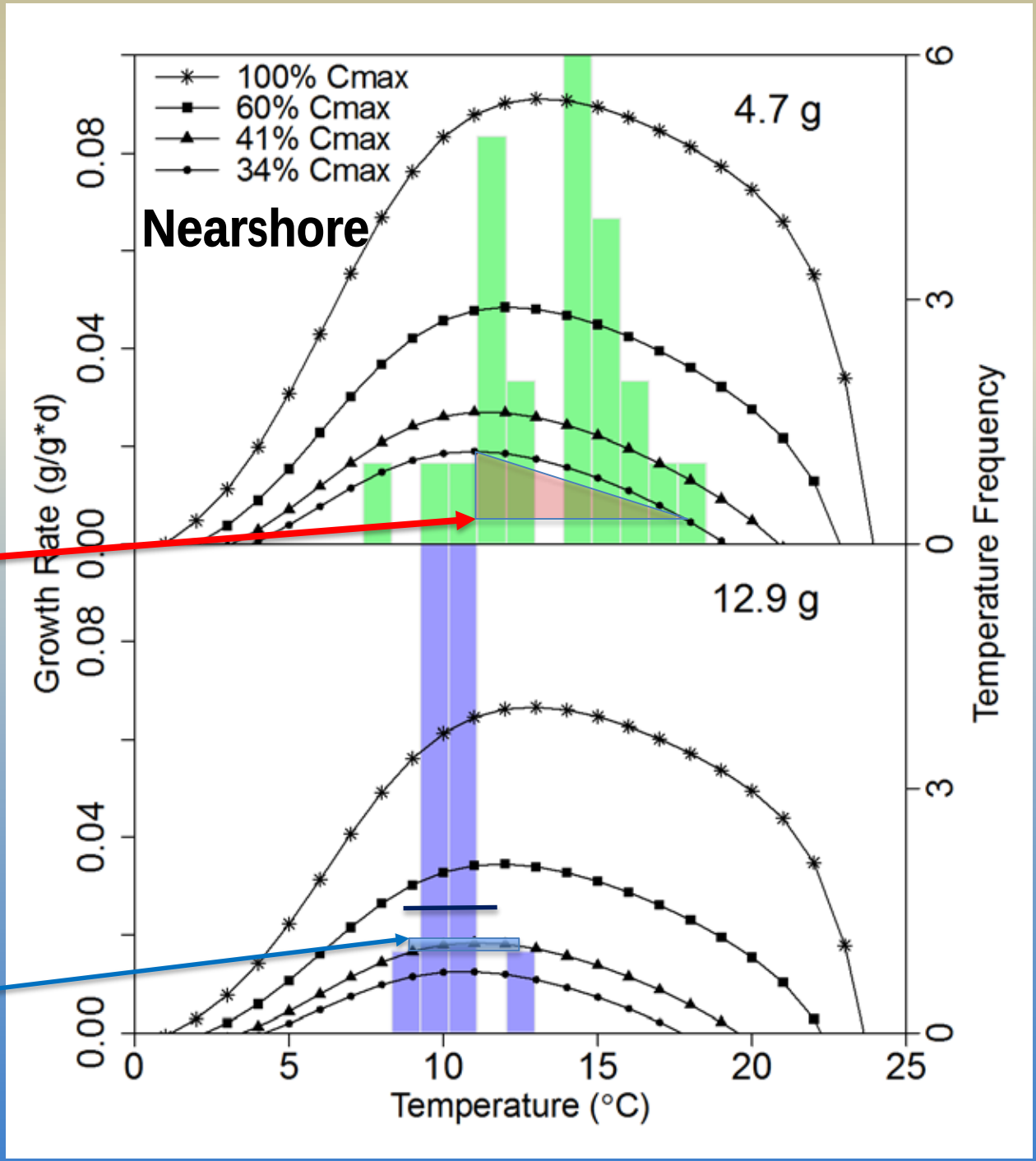
-Low feeding rate ~35% Cmax

-Warmer temperatures can Reduce growth rates by 60%

Offshore (w/in Puget Sound)

-Higher feeding rate ~50% Cmax

-Openwater temperatures are near Optimum for growth. Minimal effect of Temperature on growth: <10%



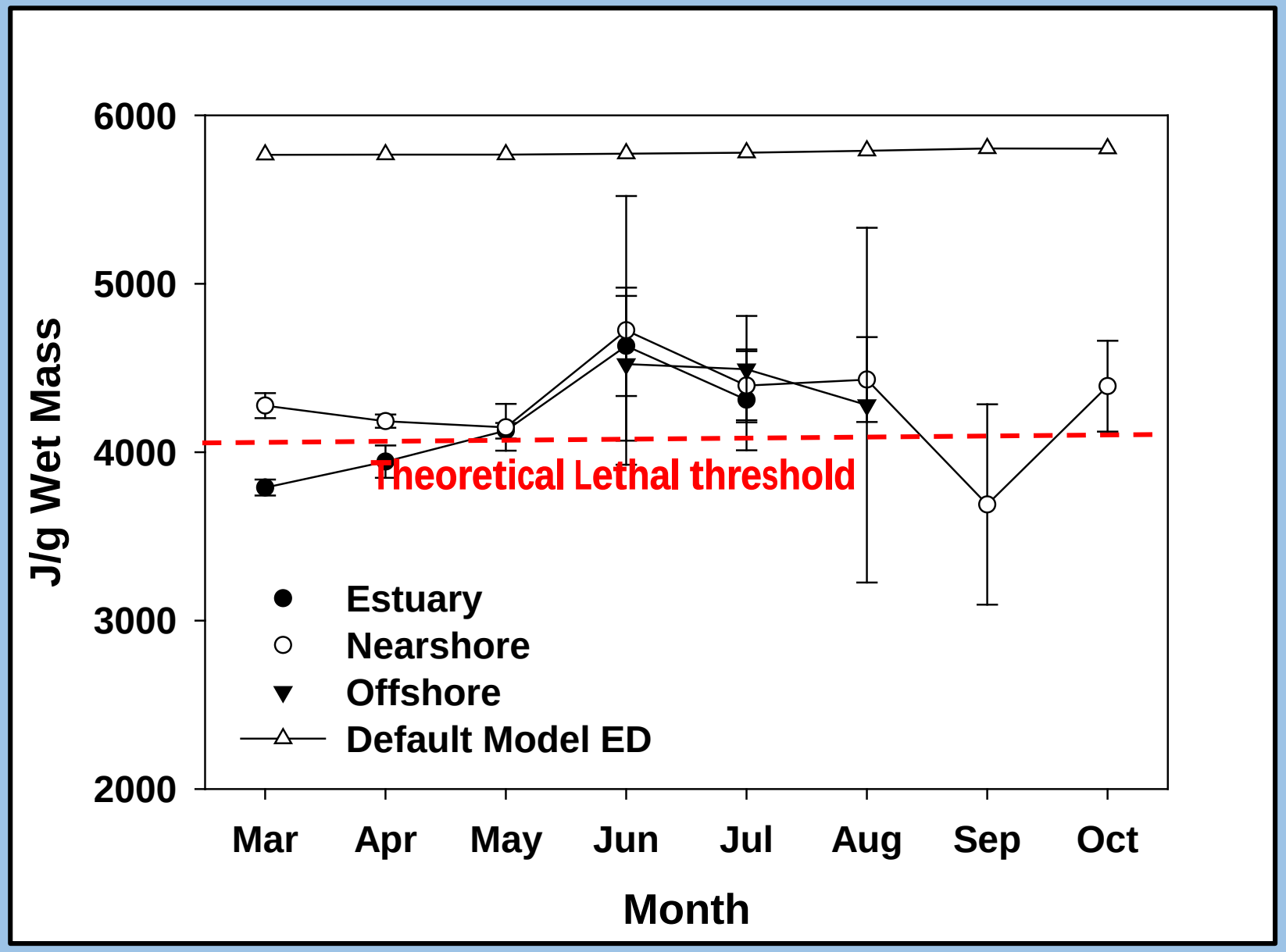
Madi Gamble 2016 MS Thesis

Energy Allocation Strategy by Juvenile Chinook during early Marine Growth

Juvenile Chinook allocate energy into rapid somatic growth rather than lipid stores throughout the growing season

-Reduce Size-selective predation

-More vulnerable to energy deficiency over winter

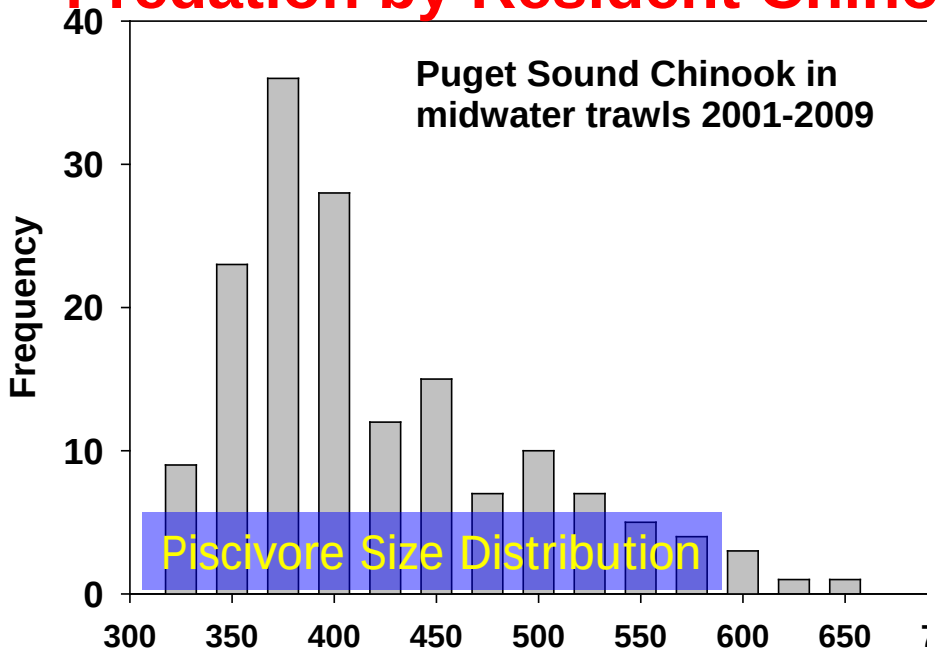


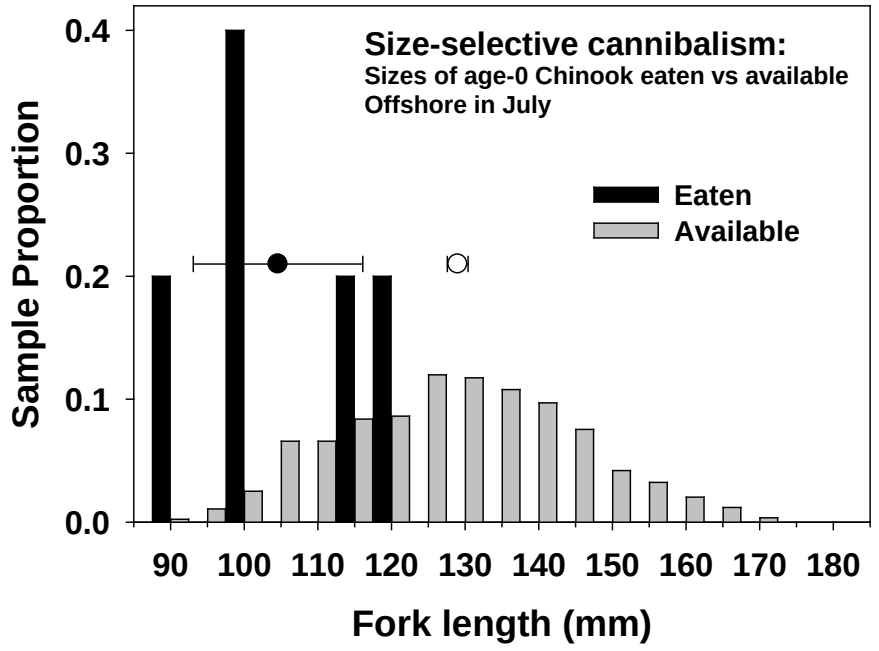
Bottom-up effects: Marine Survival & Critical growth periods

- **Marine survival is strongly size-selective after Critical Growth Period**
  - Related to size and growth performance during a critical period of initial epi-pelagic feeding within Puget Sound (June-July)
- **Thermal conditions in nearshore habitats can reduce growth significantly whereas offshore temperatures are near optimal**
  - Thermal conditions and food alter growth potential
  - This can create a “Push-Pull” scenario: pushed out by degraded conditions, Pulled toward better growth and/or survival prospects
- **Growth in estuarine delta and nearshore is moderate, but accelerates dramatically offshore during the critical growth period.**
- **Growth potential influenced by the energetic contribution of crab larvae (Z5 & megalops) during the critical growth period**
  - Prey availability varies thru spr-sum & among regions
  - Chinook size influences feeding efficiency on Crab larvae

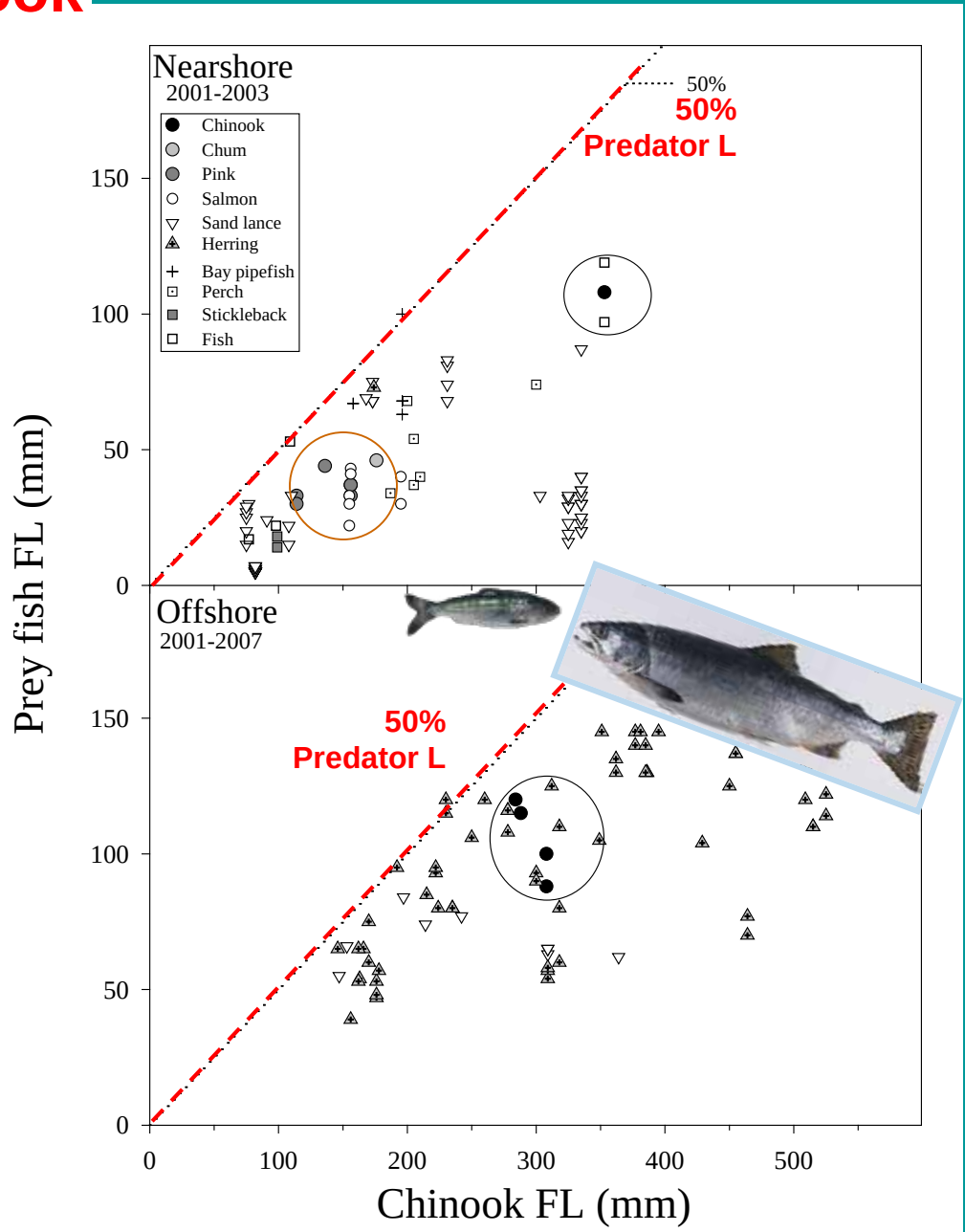
Top-Down

Predation by Resident Chinook





Prey Size : Predator Size



Beauchamp & Duffy 2011. Pacific Salmon Commission Rept.

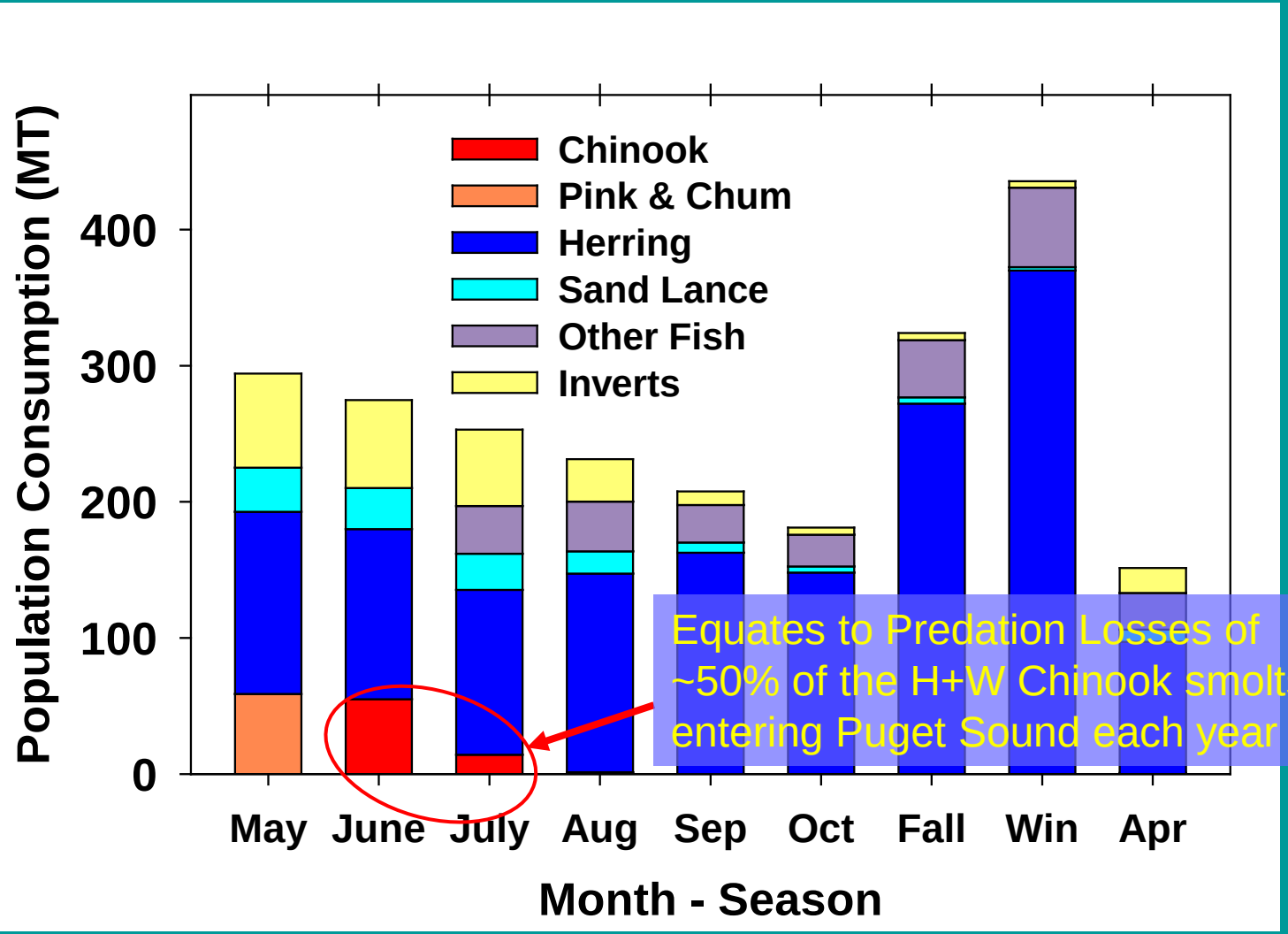
Simulated Predation Demand by Resident Chinook in Puget Sound

FL > 300 mm after 1st year of marine growth

Resident Chinook feed on Herring most of the year

Juvenile salmon become vulnerable during spring & summer

Higher resolution diet data will be collected during spring-summer 2018 & 2019



Beauchamp & Duffy 2011. Pacific Salmon Commission Rept.

Summary: Top-Down Processes

- Cannibalism by Resident Chinook potentially is potentially as severe as predation by marine mammals
- Piscivorous Fish exhibit size-selective predation
  - Bottom-up effects on juvenile Chinook growth reduces predation
  - Size-selectivity likely more variable for mammals & birds
- Visual foraging conditions have shifted in favor of predators
  - All major salmon predators primarily use vision to feed
  - Artificial lighting & skyglow have significantly increased nocturnal threat environment throughout Puget Sound
  - Increasing subsurface transparency increases efficiency of visual predators (shifting plankton dynamics, timing and duration of turbidity plumes: dams, erosion)
  - More on this at “Large Infrastructure” session Friday 1:30-3:00, room 613)

Mechanistic Integration Needed

Important to recognize mechanistic interplay among water quality-quantity with bottom-up and top-down processes as they affect salmon productivity & ecosystem health

Mechanistic Guide for Restoration

-Identify & target critical life stages & habitats

-Prioritize restoration of habitat **function** to enhance Growth & Survival

-Calibrate expectations to goals and actions targeting short- versus long-term restoration

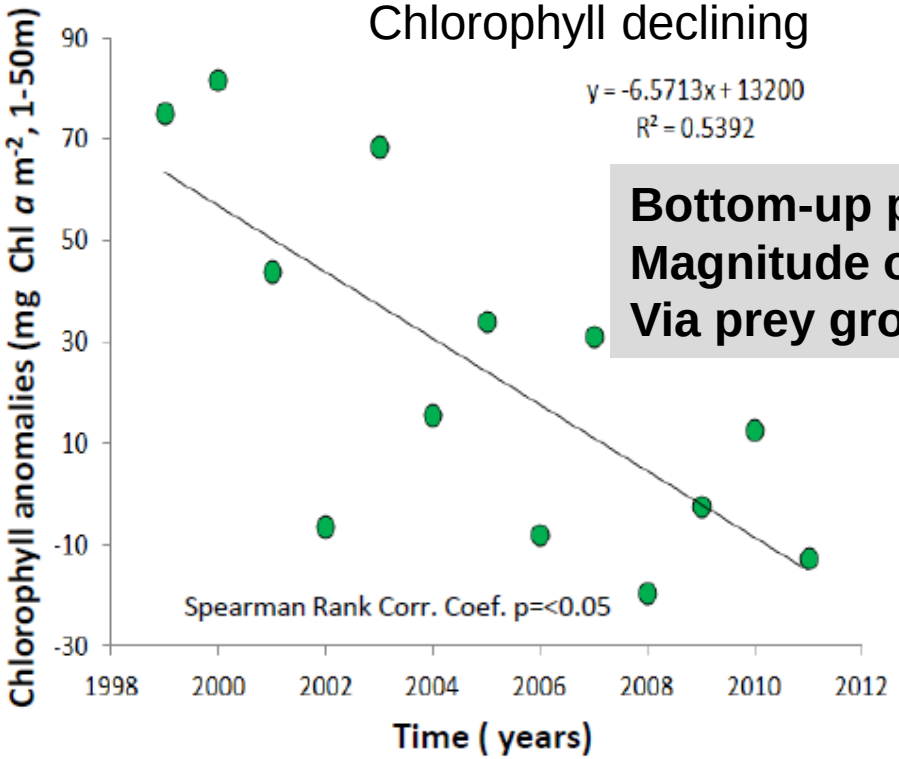
Efficacy of Predators Influenced by Many Factors

- Rate of Predator-Prey Encounters:
  - Predator-prey overlap in time or space
- Prey Detection and vulnerability to capture
  - Most salmon predators feed visually (Fish, Seals, Birds)
  - Light & Turbidity Affect Visual Feeding
    - Sediment Plumes, Algal Blooms & Artificial Light Pollution
    - (Large Infrastructure session Friday 1:30-3:00, room 613)

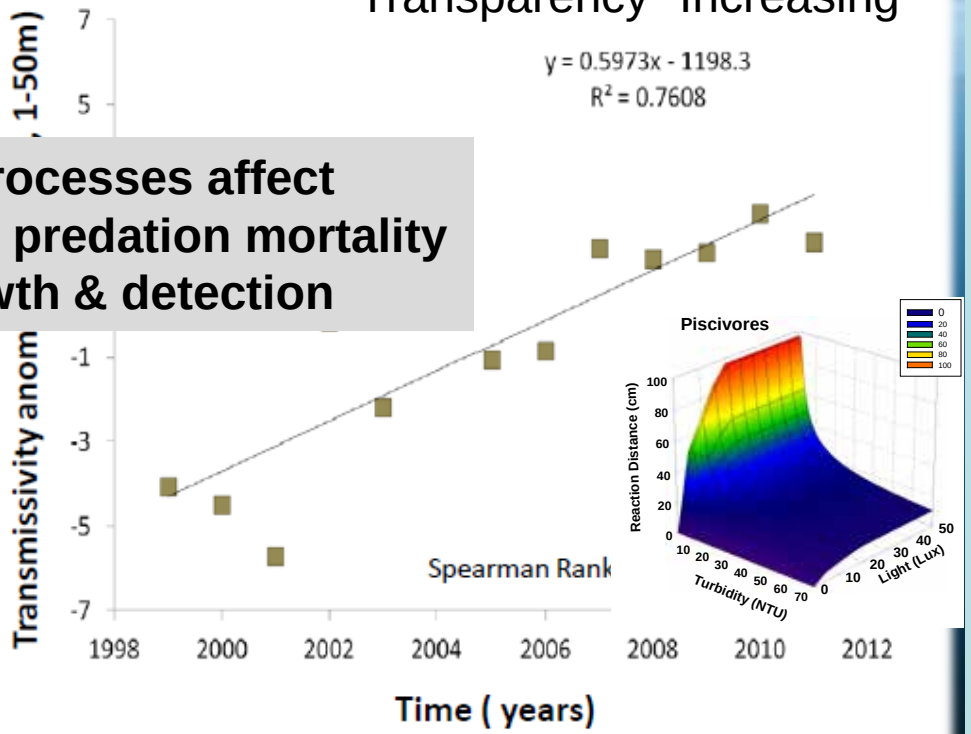
Depth integrated chlorophyll, a proxy for sub-surface phytoplankton biomass has been declining.

Puget Sound Water Quality Trends

Chlorophyll declining

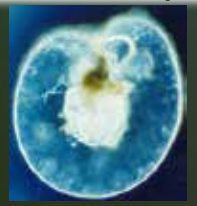


"Transparency" Increasing



Bottom-up processes affect
Magnitude of predation mortality
Via prey growth & detection

Christopher Krembs, WA Dept. Ecology



Increasing *Noctoluca:*
Gelatinous dinoflagellate
Feeds on Diatoms

Decline in edible phytoplankton (Diatoms)
Increased transparency & Predation risk

Hatchery: pre-release size structure & scales
release date & abundance

Outmigrant Trap
Timing, Abundance
Size, Scales, (~Diet & Otoliths from morts)
Weekly Feb/Mar to ~July

Estuarine Channels (trap or B Seine)
& Nearshore Beach Seine
Timing, Abundance
Size, Scales, Otoliths, Diet
2x per month

Offshore Purse seining
Timing, Abundance
Size, Scales, Otoliths, Diet
~2x per month
Including predatory fish
May to August

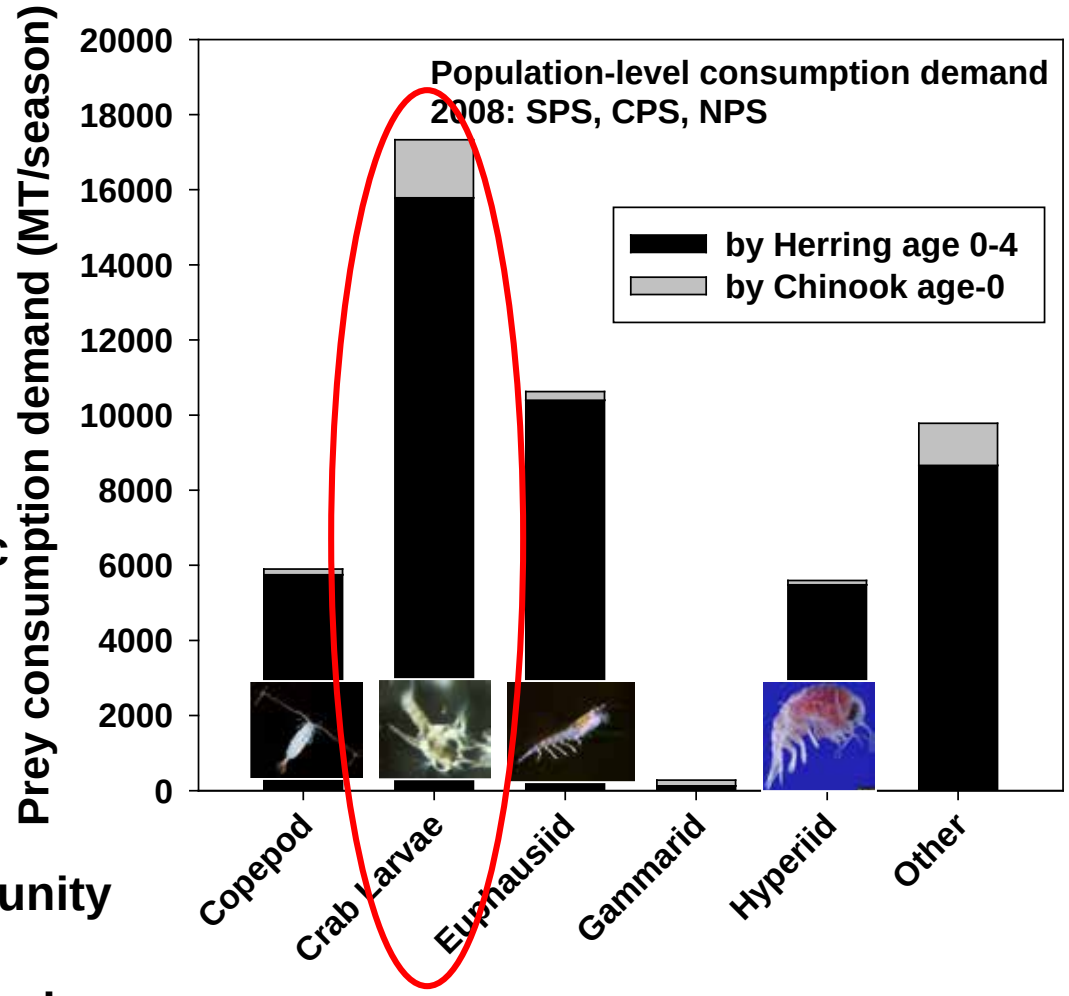
Offshore Midwater Trawl
Depth-stratified:
0-15,15-30,30-45m depths
Timing, Abundance
Size, Scales, Diet, Predators
July & Sept

Returning Adults: Scales & Otoliths
& Resident forms of salmon


Elwha River Plume
Piscivores
Effective
X
Juvenile salmon:
Feeding on
Zooplankton
& Surface Insect
w/out impediment
Piscivores:
Foraging on prey fish Ineffective for:
-Pelagic Fish (e.g.,Blackmouth)
-Some Birds & Mammals
Photo Credit: Tom Roorda
Roorda Aerial

Potential Inter-specific Competition for Food

Herring remove 10-47x more Biomass of key shared prey than H+W Chinook during Critical May-July period



CONCLUSION:

On average, <u>Competition</u> driven 1º by Herring in pelagic Habitats of Puget Sound.

Competition should be Considered across the entire Epi-pelagic planktivore community

Intensity of competition will likely Vary among regions & months, based on relative abundance & diet of each species

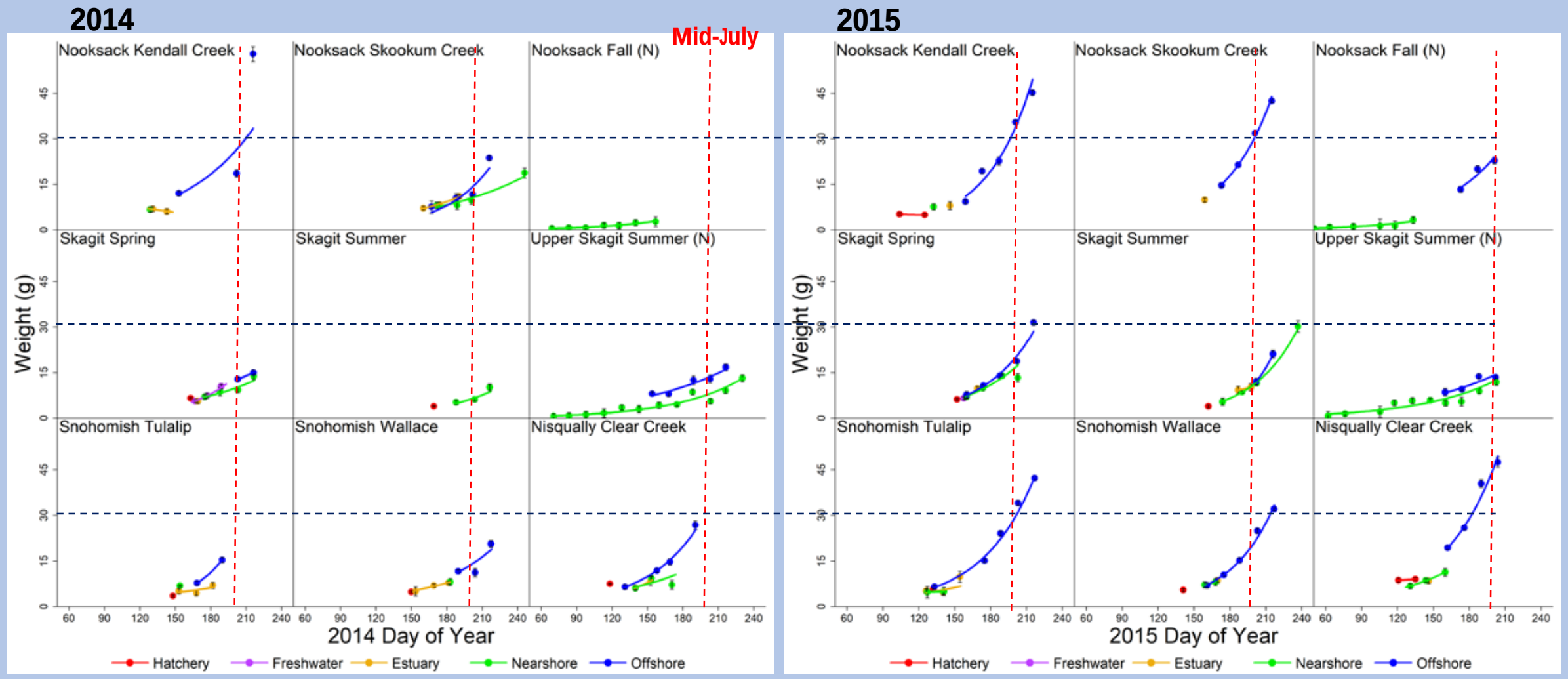
Top-Down Effects:
Factors Affecting Predation Mortality

- **Predator Abundance & Size structure**
  - Defines the pool of effective predators
  - Large increase in harbor seals & predation on Chinook since 1980s (Chasco et al. 2017) ~50% mort
  - Resident Chinook also significant predators on juvenile Chinook (up to 50% mortality?), other salmon & Herring (Beauchamp & Duffy 2011)
- **Fast prey growth (bottom-up) reduces predation vulnerability (Top-down)**
- **Foraging efficiency of predators:**
  - spatial-temporal overlap, prey detection capability

Summary: Bottom-up Processes

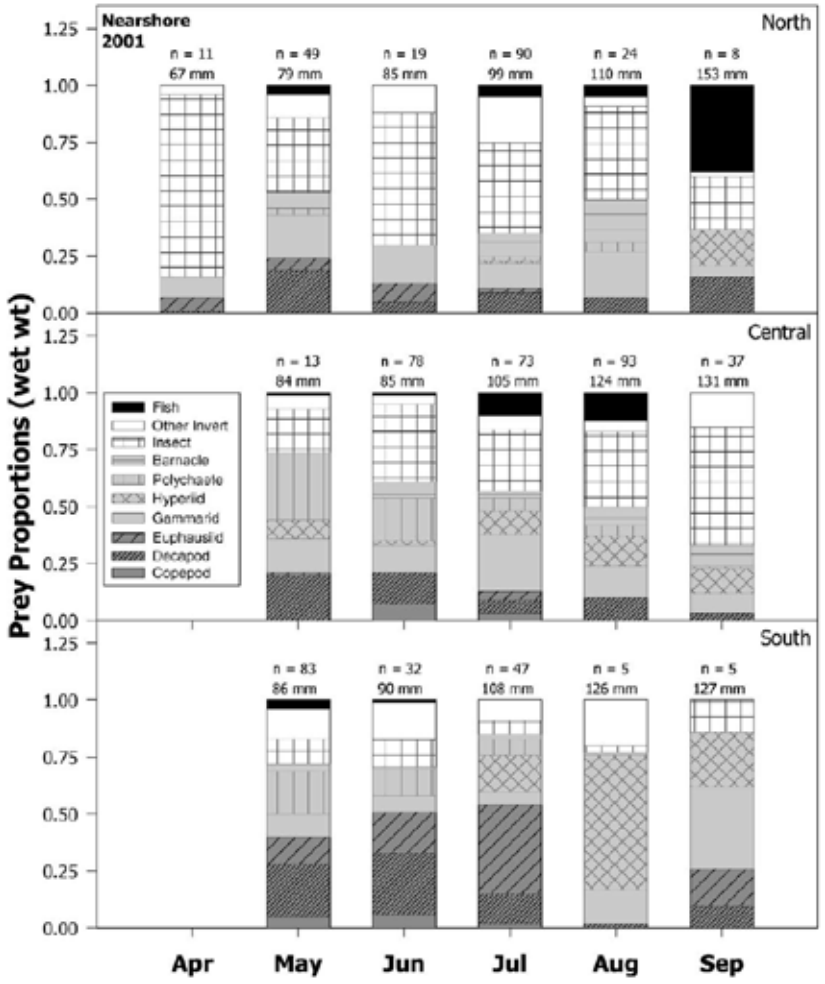
- **Delayed SSM** strongly associated with size achieved by **offshore feeding through July**
  - Feeding & growth increase dramatically (2-4x) within 1st month offshore: **Critical Growth Period**
  - **Larval crab** fuel growth during this **Critical Period**
- Variable offshore feeding & growth suggest **food limitation**
  - Competition with **herring** likely more important than competition within & among salmon species in Puget Sound
  - Gape-limitation might limit availability of larval crab to larger juvenile Chinook salmon

Growth Trajectories for Known Stocks of Hatchery and Natural (N) Subyearling Chinook in 2014 & 2015

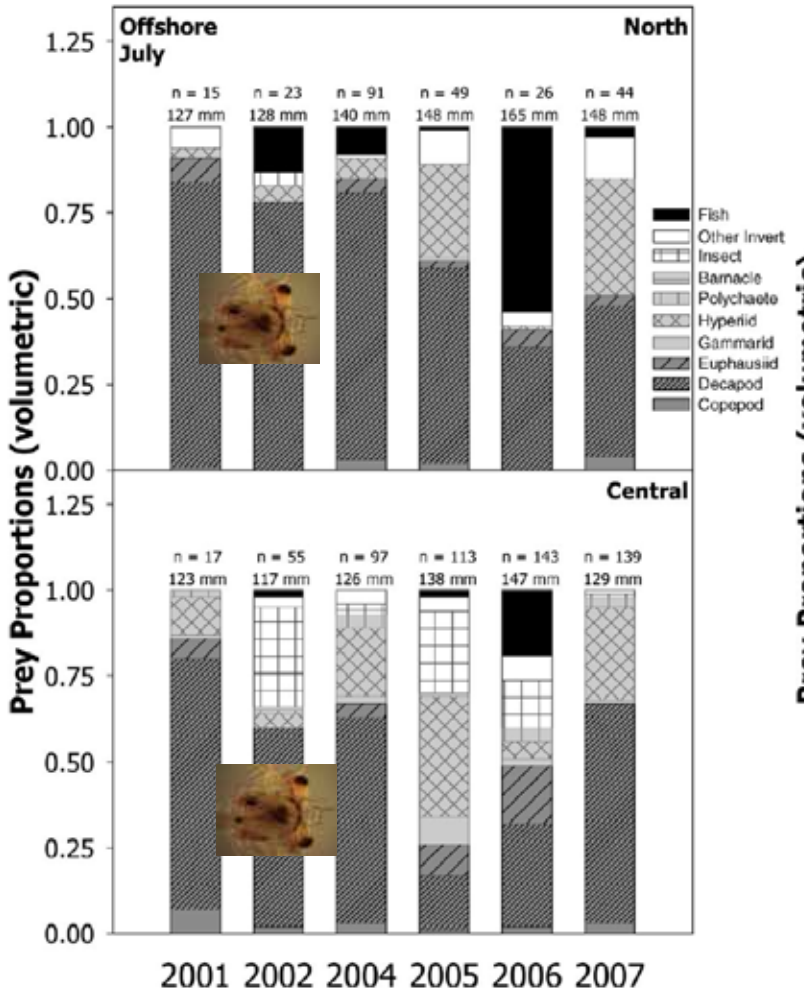


Why the fuss about Crab Larvae?

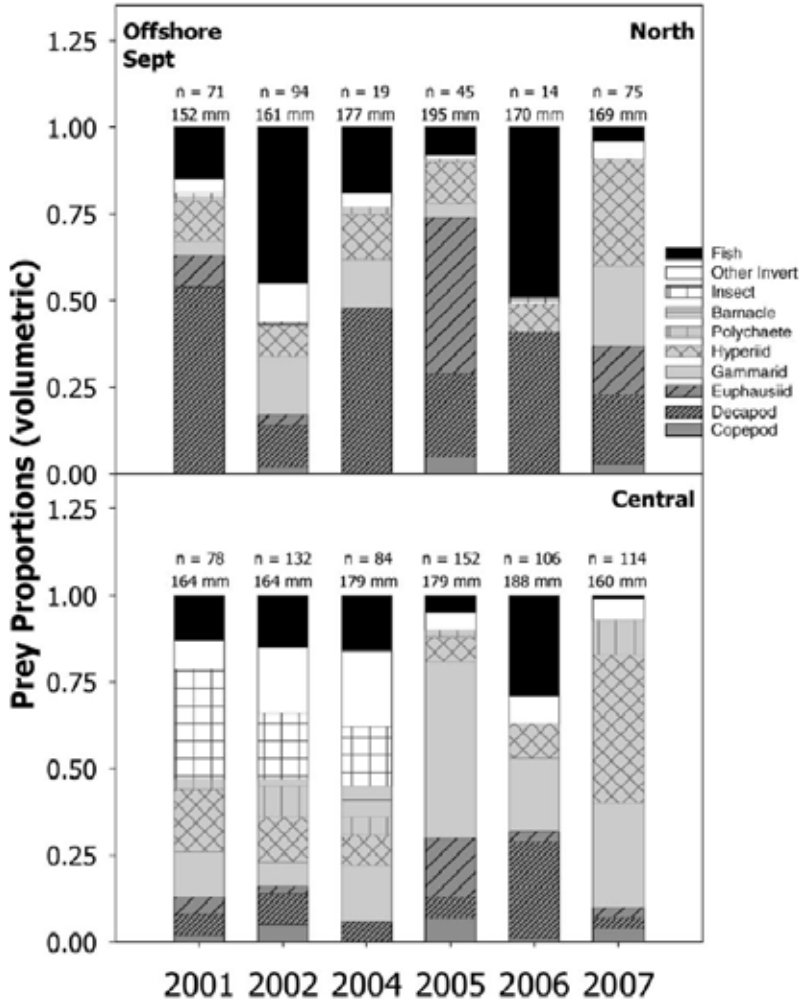
Nearshore, all months: Slower growth, low %Crab



July Offshore (Critical Growth Period): Fast growth, High %Crab

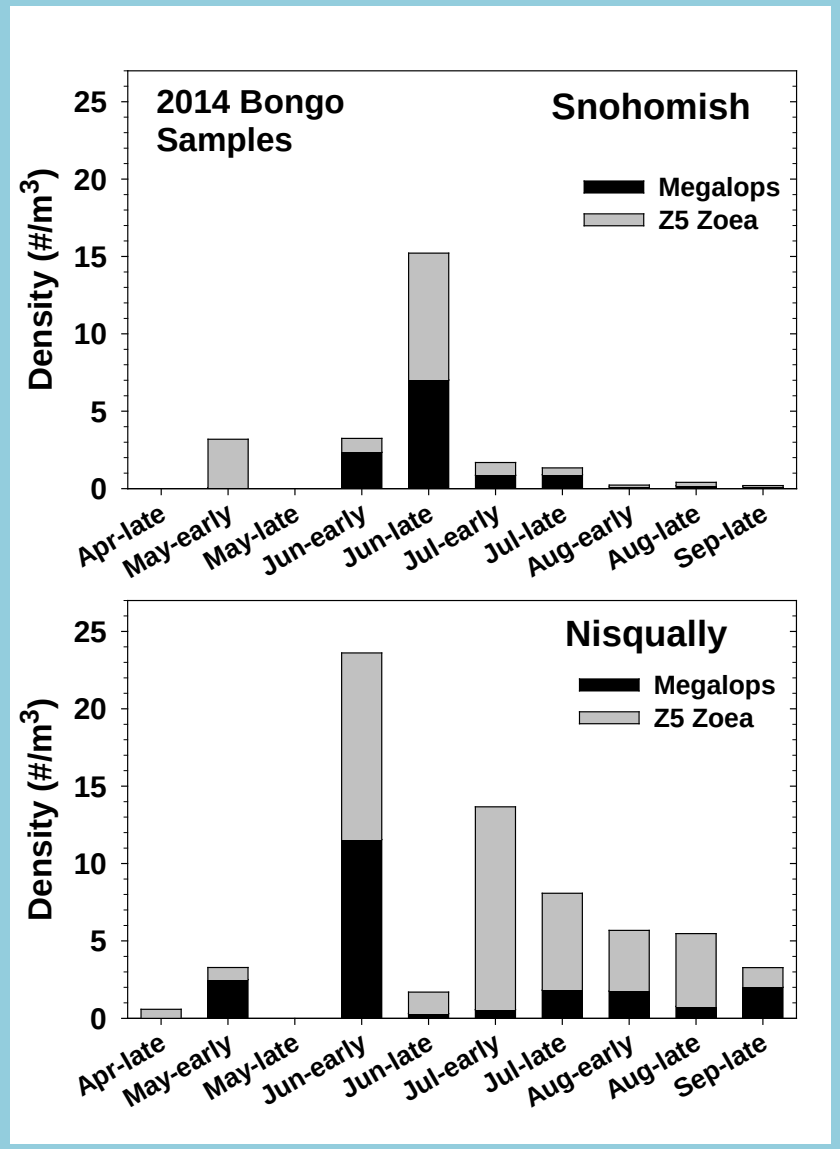


Sept Offshore (Ocean Emigration): Lower %Crab

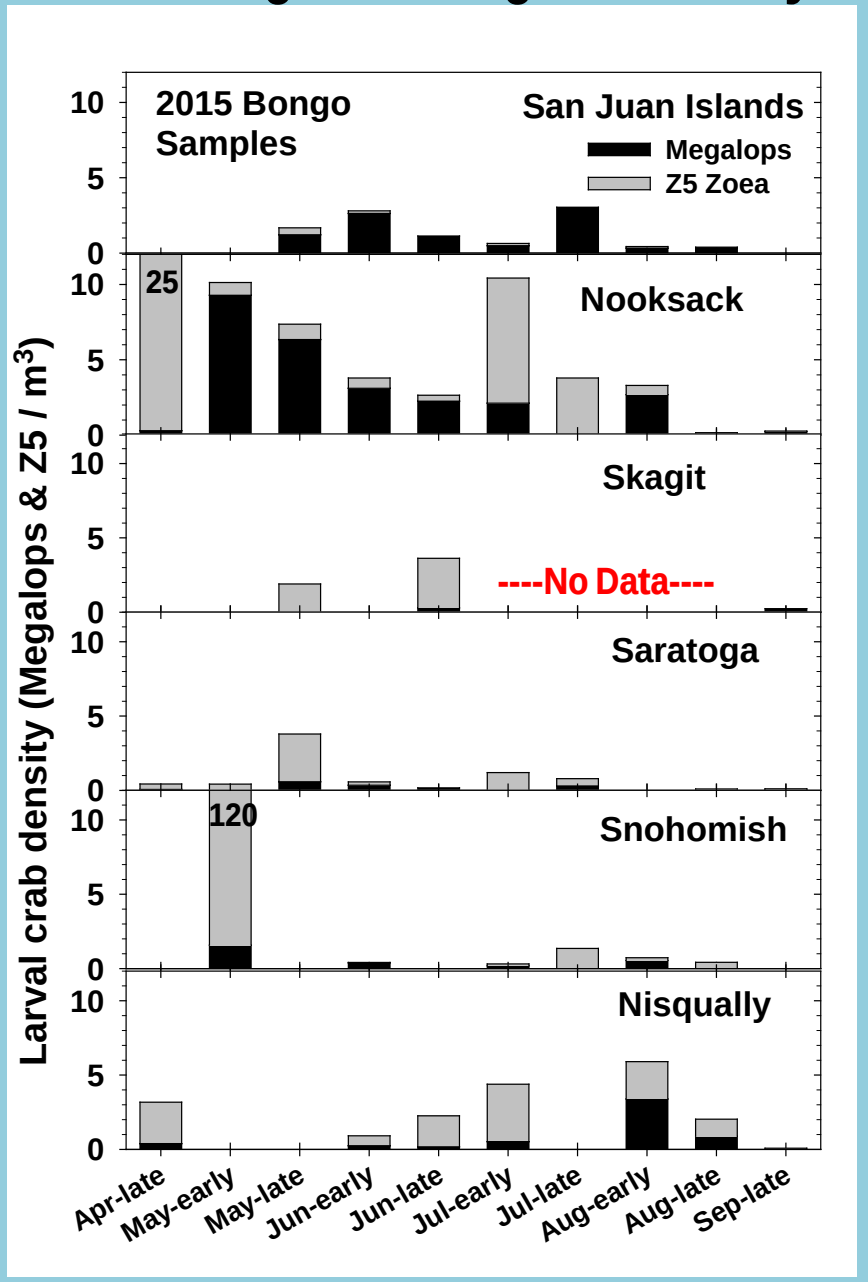


Duffy et al. 2010 Trans. Amer. Fish. Soc. 139:803-823.

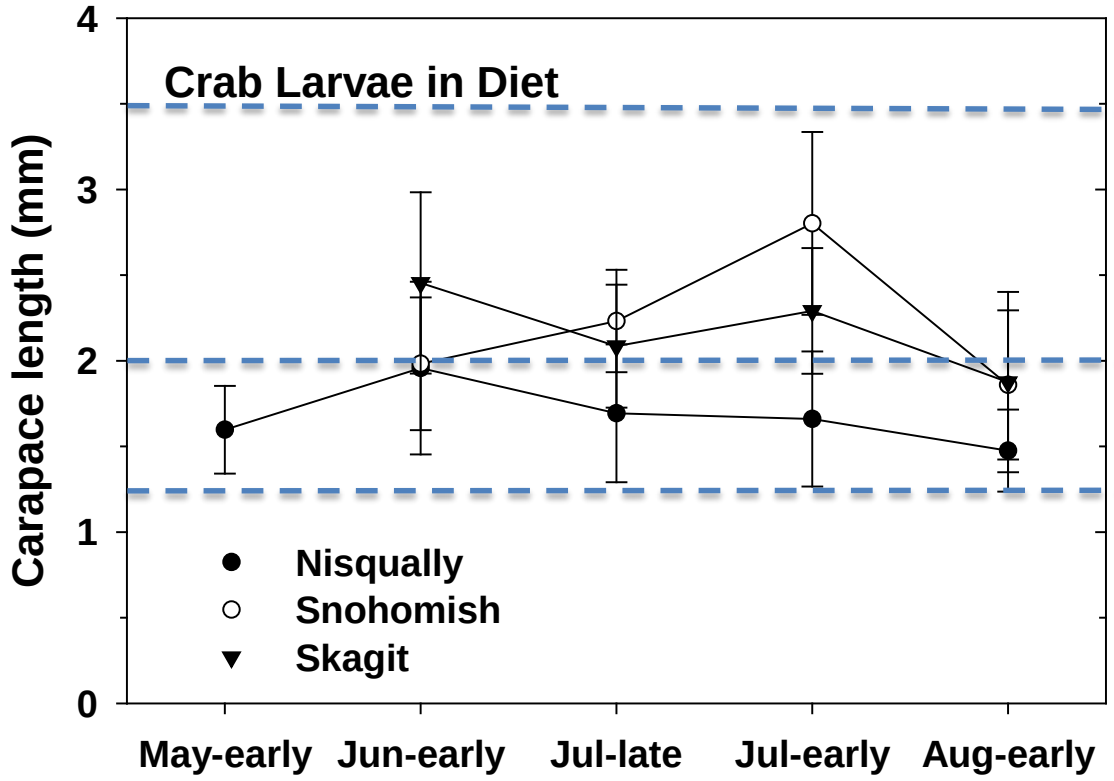
Larval Crab Availability: Edible Taxa & Sizes during Growing Season by Region

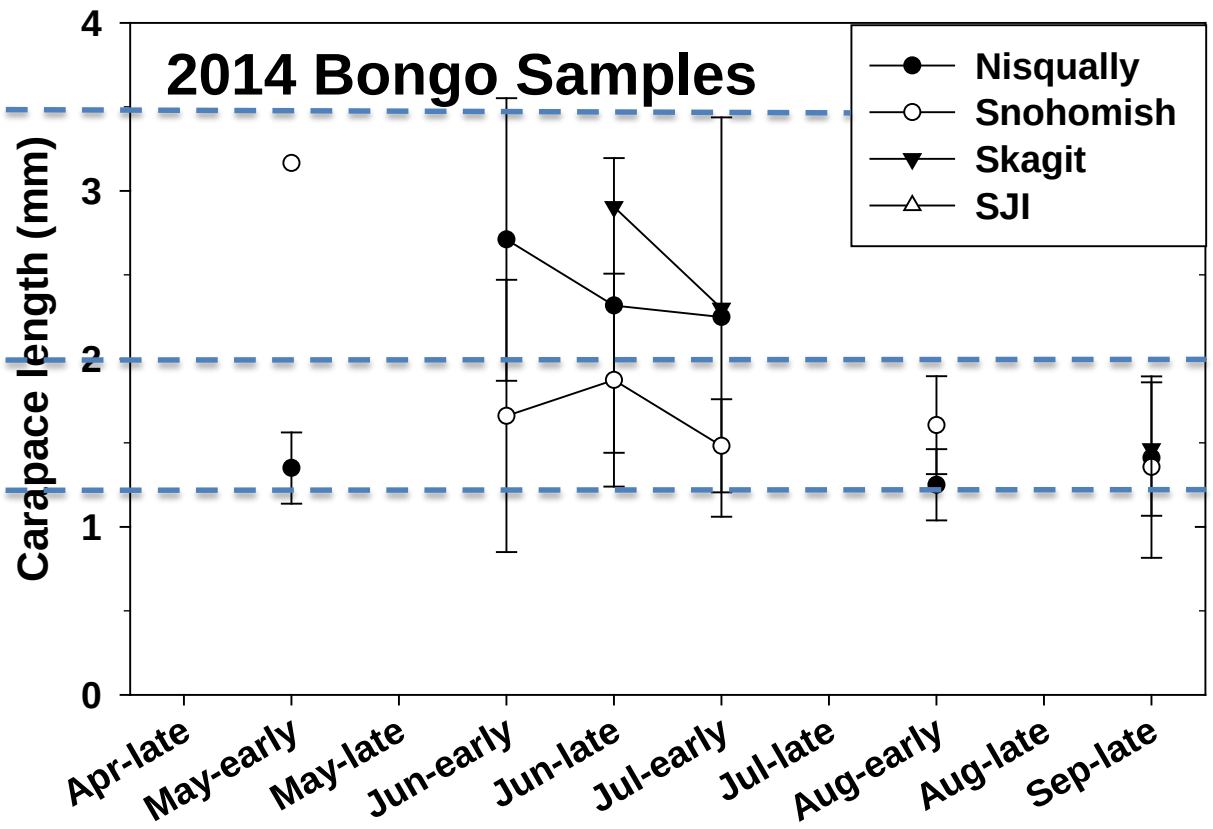


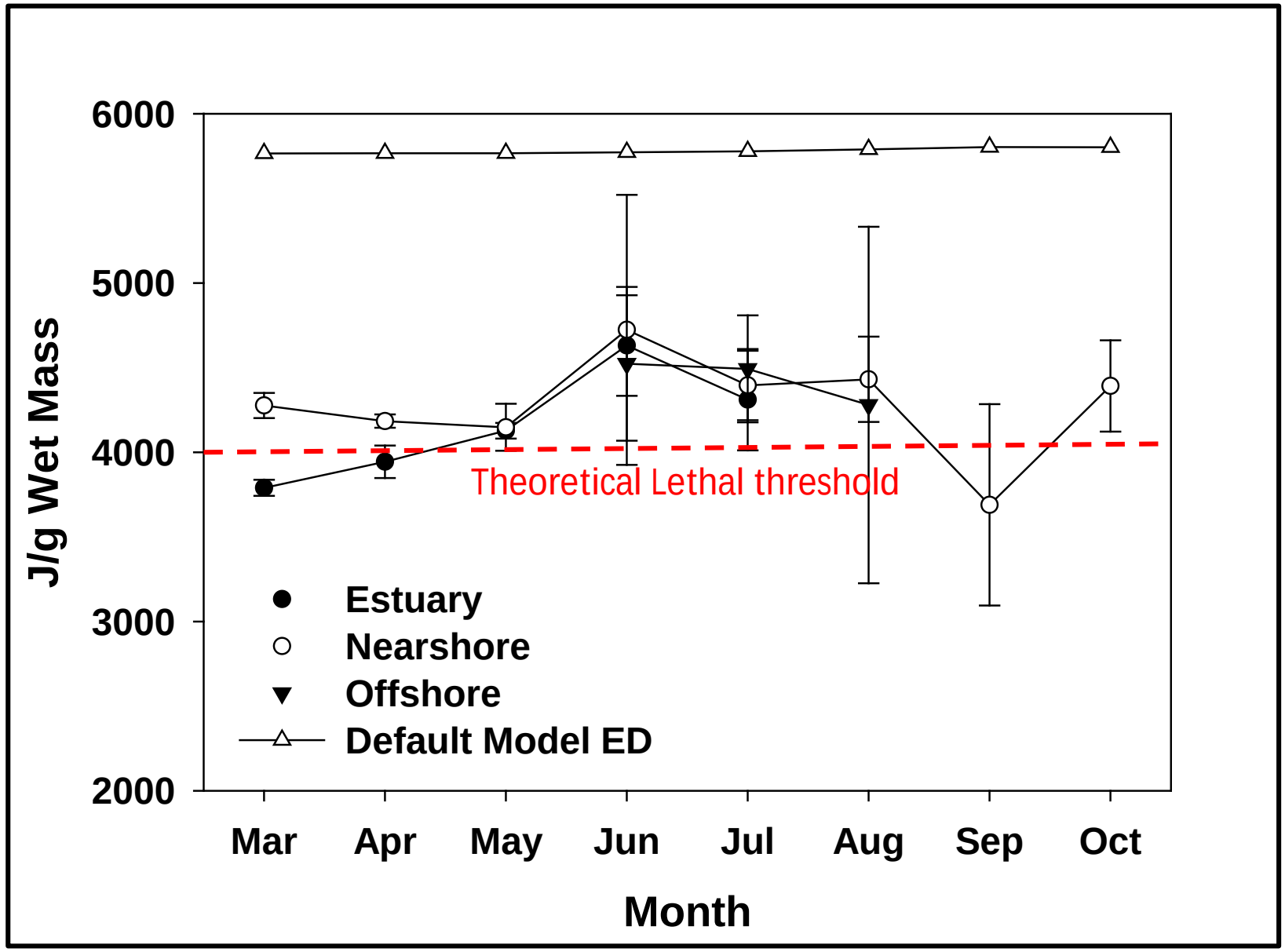
Predominantly Cancrid Z5 & Megalops



Size of Crab Larvae in the diet and available in situ



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J/g Wet Mass
Theoretical Lethal threshold
Estuary
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