

# RESEARCH/PD ANNUAL REPORT - PROGRESS REPORT

2015 annual report - progress

David Beauchamp

Marine Survival of Puget Sound Chinook Salmon: Size-selective Mortality, Critical Periods, and Growth Limitation

R/HCE-1

Submitted On: 04/15/2016 04:03:06 PM

## METRICS & MEASURES

Metric/Measure	Value	Note
Acres of coastal habitat	0	
Fishermen and seafood industry personnel	0	
Communities - economic and environmental development	0	
Stakeholders - sustainable approaches	0	
Informal education programs	0	
Stakeholders who receive information	730	presentations
Volunteer hours	0	
P-12 students reached	0	
P-12 educators	0	

## REQUESTED INFORMATION

### Publications

No **Publications** information reported

### Students Supported

**Madilyn Gamble** (Continuing Student)  
**mgamble@u.washington.edu**  
**University of Washington, School of Aquatic & Fisheries Science**

**Field of Study:** Juvenile salmon survival, feeding ecology and bioenergetics

**Advisor:** Dave Beauchamp

**Degree Type:** MS

**Degree Year:** 2016

**Student Project Title:** Marine survival of Puget Sound Chinook salmon: size-selective mortality, critical periods, and growth limitations

**Involvement With Sea Grant This Period (capstone, fellow, intern, etc.):** Thesis research represents the core of our Size-selective mortality and critical growth period study

**Post-Graduation Plans (employer, grad school, etc.):** enter Ph.D. program at Dartmouth to investigate factors limiting restoration of Atlantic Salmon populations in the Lake Champlain

basin.

**Was this thesis/dissertation supported by Sea Grant?:** Yes

**Thesis / Dissertation:** Marine survival of Puget Sound Chinook salmon: size-selective mortality, critical periods, and growth limitations

**New or Continuing?:** continuing

**Degree awarded this reporting period?:** No

**Financially supported?:** Yes

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**Angeline Blattenbauer** (New Student)  
**bitsyblatt@yahoo.com**  
**UW, SAFS**

**Field of Study:** Fisheries and Aquatic Sciences

**Advisor:** Dave Beauchamp

**Degree Type:** BS

**Degree Year:** 2015

**Student Project Title:** Size Selective Mortality in Offshore Juvenile Coho salmon

**Involvement With Sea Grant This Period (capstone, fellow, intern, etc.):** capstone

**Post-Graduation Plans (employer, grad school, etc.):**

**Was this thesis/dissertation supported by Sea Grant?:** No

**Thesis / Dissertation:**

**New or Continuing?:** New

**Degree awarded this reporting period?:** Yes

**Financially supported?:** No

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**Haila Schultz** (New Student)  
**hschultz@pugetsound.edu**  
**University of Puget Sound, No department**

**Field of Study:** Marine Biology

**Advisor:** Dave Beauchamp

**Degree Type:** BS

**Degree Year:** 2017

**Student Project Title:** Temporal variability in offshore diets of juvenile Chinook salmon and availability of key zooplankton prey

**Involvement With Sea Grant This Period (capstone, fellow, intern, etc.):** JISAO summer intern

**Post-Graduation Plans (employer, grad school, etc.):** grad school

**Was this thesis/dissertation supported by Sea Grant?:** No

**Thesis / Dissertation:**

**New or Continuing?:** New

**Degree awarded this reporting period?:** No

**Financially supported?:** No

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**Maggie O'Neil** (New Student)  
**maggio1217@gmail.com**  
**Loyola Marymount College, No department**

**Field of Study:** Biology  
**Advisor:** Dave Beauchamp  
**Degree Type:** BS  
**Degree Year:** 2017

**Student Project Title:** Diet comparisons between hatchery and wild Chinook salmon in Puget Sound

**Involvement With Sea Grant This Period (capstone, fellow, intern, etc.):** Summer intern paid by Loyola Marymount College to support undergraduate research experience for their students

**Post-Graduation Plans (employer, grad school, etc.):** grad school or med school

**Was this thesis/dissertation supported by Sea Grant?:** No

**Thesis / Dissertation:**

**New or Continuing?:** New

**Degree awarded this reporting period?:** No

**Financially supported?:** No

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## Narratives

**Marine survival of Puget Sound Chinook**  
**Uploaded File:** [SeaGrant\\_Annual\\_Rept\\_Apr2016-Beauchamp\\_&\\_Keister.pdf](#)

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## Partners This Period

**NOAA Northwest Fishery Sciences Center**  
**Types:** Government  
**Scale:** REGIONAL  
**Notes:** Collaborator for adding 2 northern watersheds and marine regions over 2 years to expand the scale of this project

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**Long Live the Kings**  
**Types:** NGO  
**Scale:** REGIONAL  
**Notes:** Coordinate the broader Salish Sea Marine Survival Project activities among agencies in US and Canadian counterparts

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**Nisqually Indian Tribe**  
**Types:** Other  
**Scale:** Tribal  
**Notes:** Perform estuarine and nearshore sample collections over 2 years in Nisqually Watershed

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**Tulalip Tribe****Types:** Other**Scale:** Tribal**Notes:** Perform estuarine and nearshore sample collections over 2 years in Snohomish Watershed**Skagit Cooperative Tribes****Types:** Other**Scale:** Tribal**Notes:** Perform estuarine and nearshore sample collections over 2 years in Skagit and Nooksack Watersheds**Washington Department of Fish and Wildlife****Types:** Government**Scale:** STATE**Notes:** Perform smolt trapping and pre-hatchery release voucher collections, genetic stock identification for unmarked Chinook, otolith microchem analysis, scale samples**Canada Department of Fisheries and Oceans****Types:** Government**Scale:** INTERNATIONAL**Notes:** midwater trawling with Ricker**Kwaiht****Types:** NGO**Scale:** LOCAL**Notes:** Collaborative Beach seining data and samples from the San Juan Islands during spring and summer.**STANDARD QUESTIONS****Impacts and Accomplishments****(1)**

Type	accomplishment
<b>Title</b>	Washington Sea Grant research finds critical mismatch between growth demands for young Chinook salmon and seasonal food availability in Puget Sound
<b>Relevance</b>	Dramatic declines over the past 30 years in the survival of young salmon have thwarted efforts to restore endangered Chinook salmon, restricted tribal and recreational fishing, and complicated land and water management. Identifying which part of the early life history is most susceptible to mortality could help direct protection efforts to the most critical stages, time periods and habitats.
<b>Response</b>	Washington Sea Grant-supported researchers examined feeding, diet, growth and size-selective mortality in nine distinct stocks of juvenile Chinook salmon from four watersheds as these fish migrated through delta, nearshore and open-water habitats. They measured growth against time, habitat-specific

	<p>diet, distribution and thermal exposure. Bioenergetics model simulations estimated feeding rates and how much key prey contribute to the growth observed during different life stages and within specific habitats.</p>
<b>Results</b>	<p>Little size-selective Chinook mortality appeared prior to the critical offshore growth period in late June and July. Preliminary 2015 results confirmed the importance of this period, when feeding and growth accelerate and body mass increases two to four times in a month, strongly influencing survival to adulthood. Larval crab fuel most of this growth, but their availability plummets just as the young salmon's demand peaks. Owing to the lack of an adequate time series for zooplankton prey, researchers could not determine if this critical mismatch has widened over time.</p>
<b>Recap</b>	<p>Washington Sea Grant researchers investigated high marine mortality in juvenile Puget Sound Chinook salmon and found a dangerous mismatch between a critical growth period and peak availability of their primary seasonal food source.</p>
<b>Comments</b>	
<b>Primary Focus Area</b>	Healthy Coastal Ecosystems
<b>Secondary Focus Areas</b>	Sustainable Fisheries and Aquaculture
<b>Goals</b>	<p>Ocean and coastal resources are managed using ecosystem-based approaches. Fisheries are safe, responsibly managed and economically and culturally vibrant.</p>
<b>Partners</b>	<p>Fisheries and Oceans Canada (DFO) Kwaiht Long Live the Kings Nisqually Tribe NOAA National Marine Fisheries Service Skagit River System Cooperative Tulalip Tribes Washington Department of Fish and Wildlife</p>
	<p>* Type accomplishment * Title Life stages and factors affecting marine survival of Puget Sound Chinook * Relevance Dramatic declines in marine survival of ESA-listed Chinook salmon over the past 30 years has restricted tribal and recreational fishing opportunities, complicated management and influenced land and water use in the region. Since early marine life stages of salmon are prone to excessive mortality and because larger body size improves chances of survival, if we can identify which life stages are most strongly affected by size-related mortality, we can focus restoration efforts on the appropriate life stages, habitats and time frames where and when the greatest impacts occur. * Response We examined feeding, diet, growth, and size-selective mortality associated with juvenile Chinook salmon during their downstream migration</p>

PI Draft

and feeding periods through estuarine delta, nearshore marine shorelines, and open-water habitats within Puget Sound. We tracked growth performance and evidence for size selective mortality for 9 identifiable stocks originating from 4 watersheds in spring-summer of 2014 and 2015. We measured observed and scale-based growth through time, time-varying habitat specific diet, distribution, thermal exposure. Bioenergetics model simulations estimated feeding rates and energetic contributions of key prey to growth observed during different life stages and within specific habitats. Feeding and growth performance will then be related to size-selective marine mortality relationships to identify the critical periods of growth that influence overall marine survival of Puget Sound Chinook. \* Results Little size-selective mortality is apparent during periods leading to the critical offshore growth period during late June-July identified in previous research. Results from 2014 and preliminary results from 2015 reiterate the importance of this critical offshore growth period, because growth and feeding accelerate after fish transition to foraging offshore, increasing body mass by 2-4 X within the first month. The body mass achieved over this offshore feeding period through July strongly influences survival to adulthood. Larval crab are the primary prey fueling most of the growth during this critical period; however, the seasonal availability of crab larvae declines rapidly just as the demand for this resource by juvenile Chinook is increasing. A mismatch in peak availability of an essential prey resource and feeding demand by juvenile Chinook currently exists, but has increased over time cannot be determined due to the lack of an adequate time series for key zooplankton prey. \* Recap Feeding on crab larvae in openwater habitats of Puget Sound during late June and July represents a critical growth period that strongly influences overall marine survival of Puget Sound Chinook Salmon, but there is a mismatch between the timing of peak larval crab availability and peak feeding demand by juvenile Chinook. Comments Primary Focus Area Healthy Coastal Ecosystems Secondary Focus Areas Sustainable Fisheries and Aquaculture, Ocean Literacy and Workforce Development Goals Ocean and coastal resources are managed using ecosystem-based approaches., Ocean and coastal habitats are protected, enhanced and restored., Fisheries are safe, responsibly managed and economically and culturally vibrant., Coastal water resources sustain human and ecosystem health., The future workforce is skilled in disciplines critical to coastal and ocean economies and ecosystem health. Partners Nisqually, Tulalip, Skagit Cooperative, and Lummi tribes, NOAA, WDFW, USGS, Long Live the Kings, Kwaiht, Canada DFO

## Tools, Technologies, Information Services / Sea Grant Products

(1)

<b>Description</b>	Salish Sea Marine Survival Project zooplankton sampling protocol.
<b>Developed (in the reporting period)?</b>	Yes
<b>Used (in the reporting period)?</b>	Yes
<b>Used for EBM?</b>	Yes
<b>ELWD product?</b>	No
<b>Number of managers</b>	2
<b>Description/Names of managers</b>	estimate
<b>Reported in previous year?</b>	

### Economic Impacts

No **Economic Impacts** information reported

### Community Hazard Resilience

No **Community Hazard Resilience** information reported

### Meetings, Workshops, Presentations

(1)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	Beauchamp, D.A., M. Gamble, J. Chamberlin, and E.J. Duffy. 2015. Identifying critical periods of growth and mortality in Pacific salmon-Then deciphering underlying mechanisms. 16th Annual Salmon Ocean Ecology Meeting. Victoria, BC.
<b>Event Date</b>	03-25-2015
<b>Number of Attendees</b>	95

(2)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	Madilyn M. Gamble, Joshua Chamberlin, Elisabeth J. Duffy, David A. Beauchamp. Identifying Critical Periods of Growth and Mortality in Pacific Salmon and Deciphering Underlying Mechanisms. American Fisheries Society. Annual Meeting. Portland, OR. August 20, 2016

<b>Event Date</b>	08-20-2015
<b>Number of Attendees</b>	300

(3)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	Beauchamp, D.A. 2015. Size-selective mortality, critical growth periods, bioenergetics, and marine survival of salmon. IX Jornadas Nacionales de Ciencias del Mar. Ushuaia, Argentina. Plenary speaker.
<b>Event Date</b>	09-24-2015
<b>Number of Attendees</b>	250

(4)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	Gamble, M., and J. Chamberlin. 2015. Identifying Critical Periods of Growth and Mortality in Pacific Salmon and Deciphering Underlying Mechanisms. Salish Sea marine Survival Project. 2015 US-Canada Science Retreat
<b>Event Date</b>	12-08-2015
<b>Number of Attendees</b>	85

(5)

<b>Type of Event</b>	Public or professional presentation
<b>Description</b>	Keister, J. 2015. Puget Sound-wide zooplankton assessment update. Salish Sea Marine Survival Project. 2015 US-Canada Science Retreat
<b>Event Date</b>	12-08-2015
<b>Number of Attendees</b>	0

### Leveraged Funds

(1)

<b>Purpose</b>	Marine Survival of Puget Sound Chinook Salmon: Size-selective Mortality, Critical Periods, and Growth Limitation
<b>Source</b>	Skagit River System Cooperative
<b>Amount</b>	166667
<b>Start Date</b>	02-01-2015



<b>End Date</b>	01-31-2016
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(2)

<b>Purpose</b>	Marine Survival of Puget Sound Chinook Salmon: Size-selective Mortality, Critical Periods, and Growth Limitation
<b>Source</b>	Tulalip Tribes
<b>Amount</b>	166667
<b>Start Date</b>	02-01-2015
<b>End Date</b>	01-31-2016

(3)

<b>Purpose</b>	Marine Survival of Puget Sound Chinook Salmon: Size-selective Mortality, Critical Periods, and Growth Limitation
<b>Source</b>	Nisqually Tribe
<b>Amount</b>	166667
<b>Start Date</b>	02-01-2015
<b>End Date</b>	01-31-2016

(4)

<b>Purpose</b>	Marine Survival of Puget Sound Chinook Salmon: Size-selective Mortality, Critical Periods, and Growth Limitation - undergraduate student support
<b>Source</b>	JISAO
<b>Amount</b>	3750
<b>Start Date</b>	02-01-2015
<b>End Date</b>	01-31-2016

(5)

<b>Purpose</b>	Marine Survival of Puget Sound Chinook Salmon: Size-selective Mortality, Critical Periods, and Growth Limitation - undergraduate student support
<b>Source</b>	Loyola Marymount
<b>Amount</b>	6300
<b>Start Date</b>	02-01-2015
<b>End Date</b>	01-31-2016



## **UPDATE (PROGRESS) REPORT (April 2016)- Marine survival of Puget Sound Chinook salmon: size-selective mortality, critical periods, and growth limitations (R/HCE-1)**

David A. Beauchamp (PI), Julie Keister (co-PI), Madilyn Gamble (Graduate Student)

The UW-NOAA-Tribal team successfully completed estuarine, nearshore marine, and offshore sampling for juvenile salmon and offshore zooplankton sampling during all targeted periods in 2015 (**Figure 1**). The scheduled purse seining cruises occurred in early May, early/late June, early/late July, and early August to sample offshore habitats associated with all four watersheds (Nisqually, Snohomish, Skagit, and Nooksack plus San Juan Islands).

Lab processing and analysis of key zooplankton prey availability, and of scales and diet composition for Chinook was completed for samples collected during 2014. A streamlined sample acquisition and processing plan was developed and adopted for the 2015 fish and zooplankton collections in the four watersheds to expedite in-season sample processing.

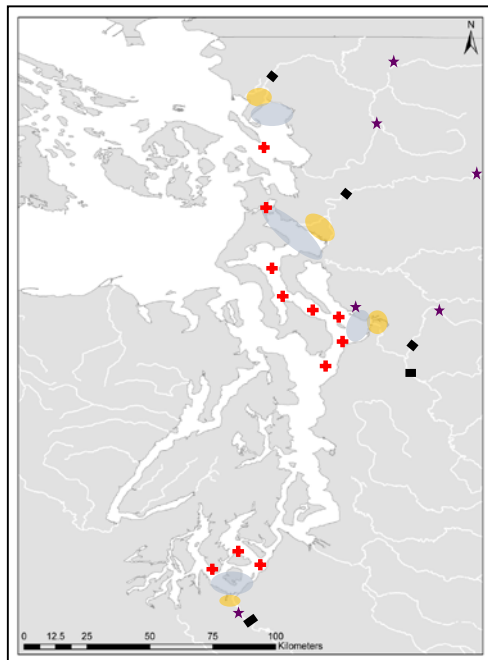
Scale samples were processed and analyzed for subyearling Chinook during peak periods in each habitat for all 4 watersheds and the San Juan Islands. Stomach content analysis was completed for juvenile Chinook from the Nisqually, and most of the samples from the Snohomish, Skagit and Nooksack watersheds. Selected tissue for genetics and plasma samples from the Skagit, Nooksack, and San Juan Island regions have been transferred to labs at Washington Department of Fish and Wildlife and NOAA/NWFSC, respectively, for processing. Bioenergetics simulations are underway to diagnose the underlying factors limiting growth during critical growth periods and will be completed by July 2016.

**Results:** Sample sizes were sufficient to track seven hatchery and two wild stocks of subyearling Chinook salmon through the sequential life stages leading to the critical size in July that strongly influences overall marine survival (smolt-to-adult returns, SARs) described by Duffy and Beauchamp (2011). Seven of these nine stocks showed little evidence for size-selective mortality (SSM) prior to achieving the critical size in July (**Figure 2**). The two stocks exhibiting SSM were the wild sub-yearling Upper Skagit River summer-run Chinook and the Skookum Creek hatchery stock from the Nooksack River. In both cases, juveniles captured in nearshore habitats were significantly smaller at the same circulus number (a surrogate for age) than juveniles captured in offshore habitats.

Bioenergetic simulations of habitat-specific feeding and growth examined the energetic consequences of various habitat use or migration strategies employed during early marine life stages of Chinook salmon. The Nisqually River Clear Creek Hatchery release group is shown as an example (**Figure 3**). In general, juvenile Chinook started feeding at modest rates on higher proportions of high-energy adult insects in estuarine or nearshore marine habitats, then transitioned offshore and shifted to diets predominantly composed of decapods (crab larvae). Feeding rates and net energy gain increased dramatically when feeding offshore on crab larvae during late June and July.

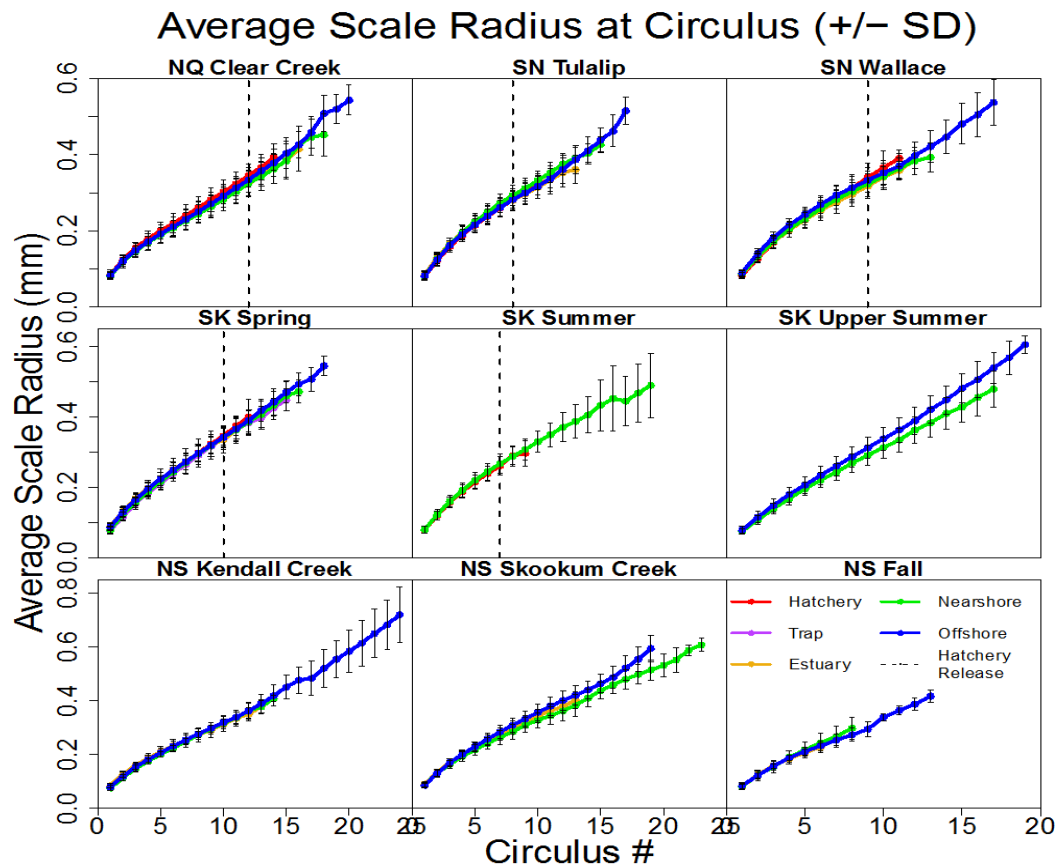
However, bongo net sampling of prey availability offshore in the 0-30 m surface layer of Puget Sound indicated that the availability of crab larvae was declining rapidly just as feeding demand by juvenile Chinook salmon was increasing (**Figure 4**). This apparent mismatch between peak prey supply and feeding demand during the critical growth period could influence inter-annual and regional variability in feeding, growth and SSM for juvenile Chinook salmon in Puget Sound. Unfortunately, there is not an adequate time-series for inter-annual and seasonal cycles of availability or production of crab larvae or other key prey that fuel early marine growth of salmon or forage fishes. Given the lack of adequate historic zooplankton data, we cannot determine whether this mismatch has persisted across many decades or whether the period between peak prey availability and peak feeding demand by juvenile Chinook is widening over time. The 2014 and 2015 zooplankton data and the concurrent data on feeding and growth of juvenile salmon offers a valuable baseline for monitoring temporal patterns in prey supply and feeding demand by different species and stocks of salmon and forage fishes.

The ongoing challenge for this project has been the time and resources required to process large numbers of diet and scale samples from key life stages and stocks of juvenile Chinook salmon.



- ★ Hatchery
- ◆ Smolt trap
- Estuary/tidal delta (beach seine)
- Nearshore marine (beach seine)
- ✚ Offshore (purse seine)

**Figure 1.** Locations of hatchery, smolt trapping, estuarine, nearshore marine, and set sites for 5 purse seine sampling cruises repeated during 2014 and 2015: Cruise 1-Early May; Cruise 2-Early June; Cruise 3-Late June; Cruise 4-Early July; Cruise 5-Late July; Cruise 6-Early August.



**Figure 2:** Mean ( $\pm 2$  SE) growth trajectories of specific CWT groups, all marked, and all unmarked juvenile Chinook sampled during peak periods of use for each habitat in each watershed. Dashed lines represent the median circulus # (age) at release for hatchery cohorts.

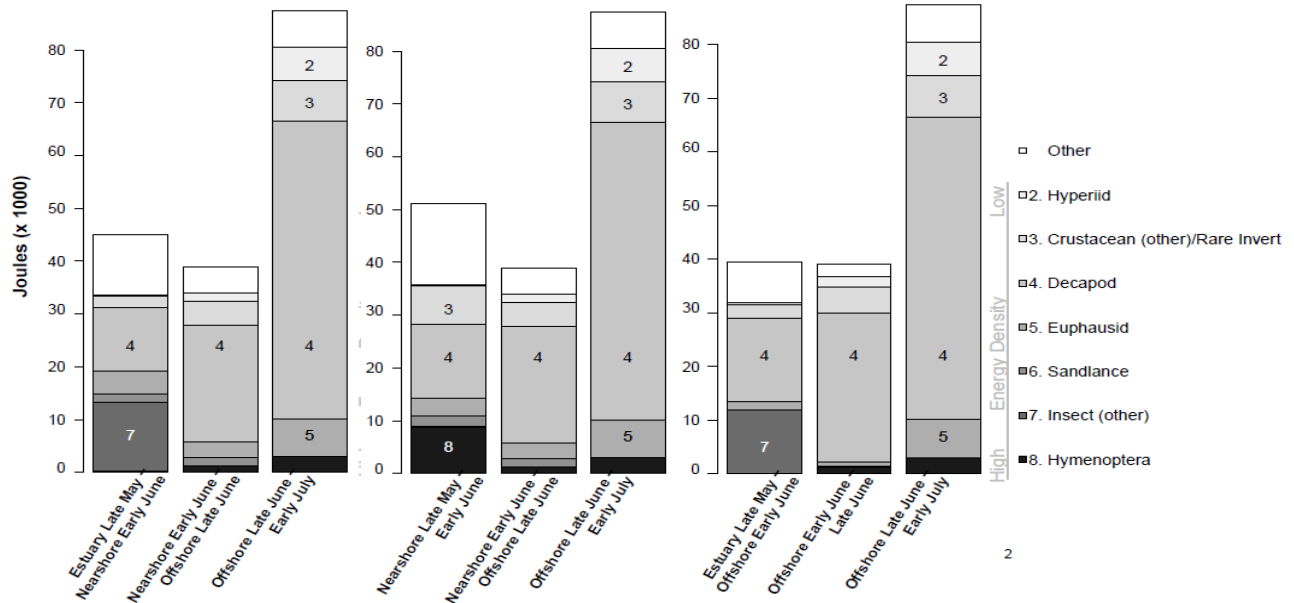


Figure 3. Estimates of energetic contributions of major prey categories (numbered groups ranked by increasing energy density [J/g wet mass] during ~2-week growth periods within habitats or transitioning between habitats. The three bioenergetic simulations represent the range of feeding and growth strategies exhibited by juvenile Chinook from the Nisqually River Clear Creek hatchery release in 2014.

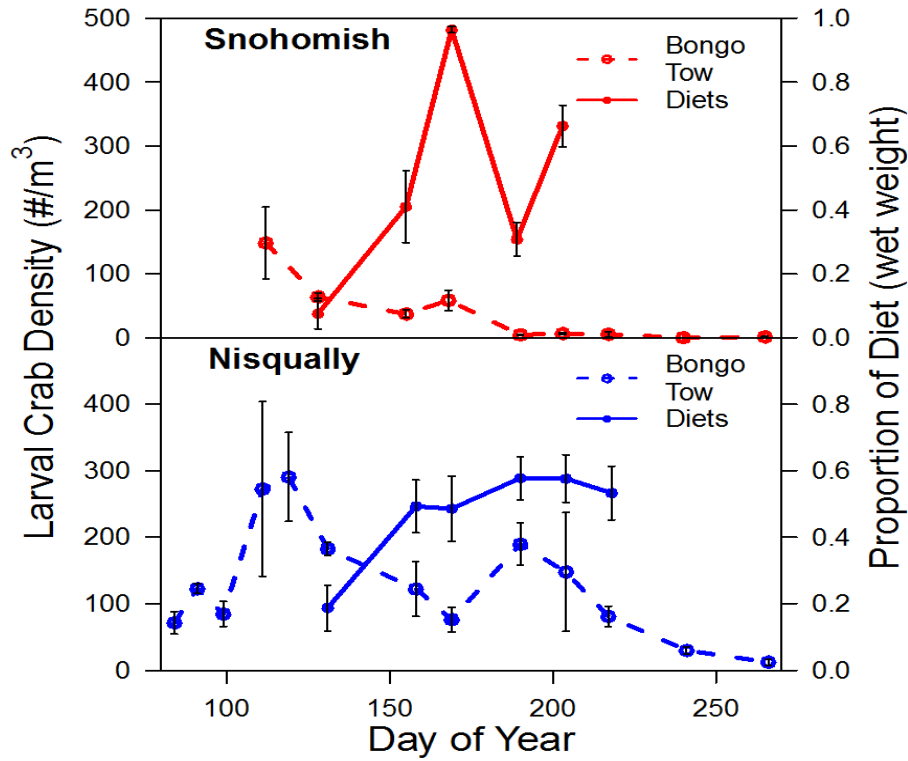


Figure 4. The availability of crab larvae (dashed lines) declined rapidly just as feeding demand by juvenile Chinook salmon increase (solid lines) as they shift to feeding in the epipelagic habitats of Puget Sound during their critical growth period.