Many stocks of anadromous Pacific salmon (*Oncorhynchus* spp.) have declined on the west coast of the USA (Nehlsen et al. 1991)

Recent recoveries on the Pacific coast, while some Salish Sea stocks have not recovered (Zimmerman et al. 2015)
- Declines in Chinook, and coho survival in the Salish Sea

- Puget Sound Chinook salmon marine survival currently <1%
Early marine growth of salmon juveniles is thought to determine their overall survival (Beamish & Mahnken 2001).

Marine survival in Puget Sound Chinook was strongly related to offshore July weight of juveniles (Duffy & Beauchamp 2011).
Over 150 participating scientists from 60 organizations

To better understand how salmon and steelhead survival are affected by bottom-up and top-down processes, climate, diseases, contaminants, etc.
Does the quality of salmon prey items vary?

Are there spatial and temporal differences in the quality and quantity of prey in Puget Sound?
Chinook salmon (*Oncorhynchus tshawytscha*)

Coho salmon (*Oncorhynchus kisutch*)

Juvenile diet consist mostly of euphausiids, crab larvae, hyperiid and gammarid amphipods, and large copepods, with an increasing proportion of small fish as they grow
Dietary essential fatty acids (EFAs) are important for juvenile fish:
- EPA (Eicosapentaenoic acid, 20:5ω3)
- DHA (Docosahexaenoic acid, 22:6ω3)
- ARA (Arachidonic acid, 20:4ω6)

They affect growth, reproduction, immune responses, and osmoregulation of fish.

Likely in high demand in rapidly growing juvenile salmonids that have recently entered the marine environment.
METHODS: FIELD SAMPLING

- Zooplankton was collected in March-October 2017 with Bongo Net tows
  - ~20 offshore stations
  - Fatty acid composition
  - Biomass estimation
- Few additional samples taken for fatty acids in 2018
METHODS: FATTY ACID ANALYSIS

- Zooplankton sorted and identified to species/family (~60 taxa)
  - 13 broad taxonomic groups
- Freeze-dried samples were weighed and extracted for lipids
- Fatty acids derivatized to fatty acid methyl esters and ran with GC-FID
- Results expressed as \( \mu g \) FA / mg C

Here, I am showing only the results on EPA+DHA and ARA
Technical Report

Fatty acid composition of zooplankton prey for juvenile salmonids in Puget Sound

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https://marinesurvivalproject.com/resources/
RESULTS: EPA+DHA CONTENT OF PREY ITEMS

- Significant differences between taxa (Kruskal-Wallis, $H = 80.419, p < 0.001, n = 279$)
CRAB LARVAE EPA+DHA CONTENT BY STAGE

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>EPA+DHA (µg mg C⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinnotheridae</td>
<td>Rhinolithodes</td>
<td></td>
</tr>
<tr>
<td>Pinnixidae</td>
<td>Oregonia gracilis</td>
<td></td>
</tr>
<tr>
<td>Paguridae</td>
<td>Hemigrapsis oregonensis</td>
<td></td>
</tr>
<tr>
<td>Lophopanopeus</td>
<td>Metacarcinus gracilii</td>
<td></td>
</tr>
<tr>
<td>Oregonia</td>
<td>Metacarcinus magister</td>
<td></td>
</tr>
<tr>
<td>Grapsidae</td>
<td>Paguridae</td>
<td></td>
</tr>
<tr>
<td>Emerita</td>
<td>Emerita analoga</td>
<td></td>
</tr>
<tr>
<td>Cancridae</td>
<td>Cancer productus</td>
<td></td>
</tr>
<tr>
<td>Emerita</td>
<td>Emerita analoga</td>
<td></td>
</tr>
<tr>
<td>Fabia subquatrata</td>
<td>Fabia subquatrata</td>
<td></td>
</tr>
<tr>
<td>Galatheidae</td>
<td>Galatheidae</td>
<td></td>
</tr>
<tr>
<td>Fabia subquatrata</td>
<td>Fabia subquatrata</td>
<td></td>
</tr>
</tbody>
</table>

Note: zoeae and megalopae stages are indicated on the graph.
EPA+DHA CONTENT OF AMPHIPODS BY MONTH

Month
- October
- September
- August
- July
- June
- May
- April
- March

EPA + DHA (µg/mgC)
- 200
- 150
- 100
- 50
- 0

Themisto pacifica
Cyphocaris challengeri

Cyphocaris challengeri

Themisto pacifica
Results: EPA+DHA content of prey items

- Significant differences between taxa (Kruskal-Wallis, $H = 80.419, p < 0.001, n = 279$)
RESULTS: EPA+DHA CONTENT OF PREY ITEMS

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RESULTS: EPA+DHA CONTENT OF PREY ITEMS

- Significant differences between taxa (Kruskal-Wallis, $H = 80.419, p < 0.001, n = 279$)
RESULTS: ARA CONTENT OF PREY ITEMS

- Significant differences between taxa (Kruskal-Wallis, $H = 125.499$, $p < 0.001$, $n = 279$)
RESULTS: ARA CONTENT OF PREY ITEMS

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RESULTS: ARA CONTENT OF PREY ITEMS

- Significant differences between taxa (Kruskal-Wallis, $H = 125.499$, $p < 0.001$, $n = 279$)
DISCUSSION: EFA CONTENT OF PREY

- Coho and Chinook salmon juveniles select large and pigmented prey items (Schabetsberger et al. 2003)
  - Also high in EFA
RESULTS: ESSENTIAL FATTY ACID AVAILABILITY IN PUGET SOUND

- We combined the taxon-specific EPA+DHA and ARA content with estimates of biomass to produce an integrated measure of food quantity and quality.

- We were interested in EPA+DHA and ARA availability in spring (April-May) and early summer (June-July) corresponding to the critical early marine period for juvenile salmon.
RESULTS: EPA+DHA AVAILABILITY

- High EPA+DHA availability in Bellingham Bay
  - Good feeding conditions
- In spring, very low availability in southern Puget Sound
  - Potential trophic mismatch
RESULTS: ARA AVAILABILITY

- Similar patterns to EPA+DHA
BIOMASS VS. EFA AVAILABILITY

Carbon biomass (mg C m⁻³)
EPA+DHA (µg m⁻³)
ARA (µg m⁻³)
DISCUSSION: EFA AVAILABILITY

- Low EFA availability in southern Puget Sound when salmon juveniles enter in the spring → potential trophic mismatch
  - Chinook salmon had lower 1st year ocean growth in south compared to northern part during 1992-2008 (Clairborne et al. 2017)
  - South Sound had lower survival of coho salmon than other basins during 1992-2010 (Zimmerman et al. 2015)
CONCLUSIONS

- Clear differences in the quality of juvenile salmon prey
  - Salmon seem to target high quality prey
- Spatial and temporal differences in EFA availability in Puget Sound
  - Can these be linked to juvenile salmon fitness?
- Future studies will reveal the potential value of EFA availability as an integrated measure of food quantity and quality