Juvenile Chinook Diet & Macroinvertebrate Prey Availability

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What are juvenile Chinook eating?
Does prey consumption change as fish grow larger?
Does prey consumption change over the out-migration season?
Are fish feeding differently among sites?
What can feeding patterns tell us about the quality of a habitat?

DIET

Does prey availability differ among sites?
Does prey availability change over the out-migration season?
Are the macroinvertebrates sampled representative of prey consumed?
What can prey availability tell us about the quality of a habitat?

PREY AVAILABILITY

What are juvenile Chinook eating?
Does prey consumption change as fish grow larger?
Does prey consumption change over the out-migration season?
Are fish feeding differently among sites?
What can feeding patterns tell us about the quality of a habitat?

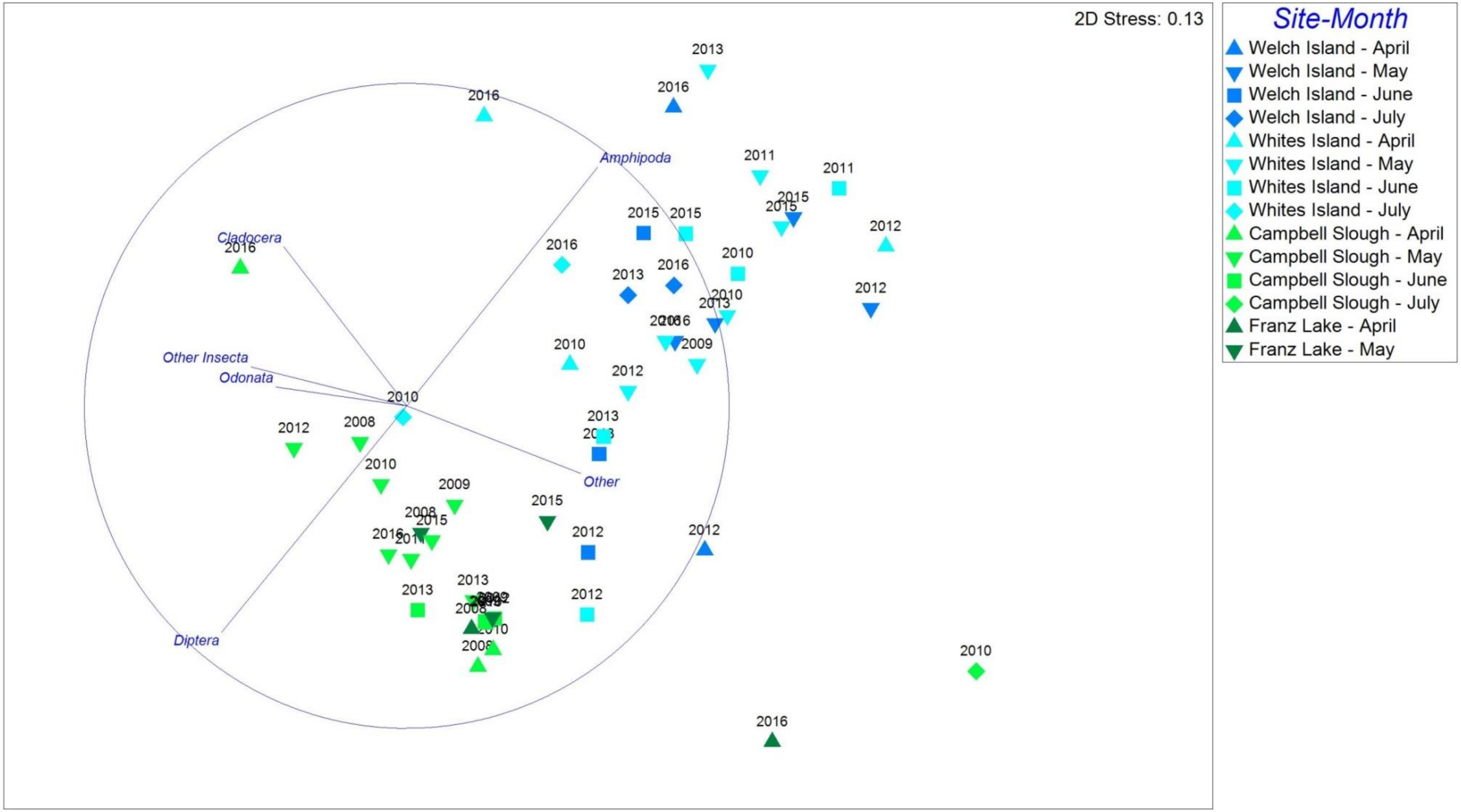
DIET

Index of Relative Importance (IRI)

Combines 3 variables into a composite index: accounts for prey weight and numbers, as well as the likelihood of taxa appearing in the diet of individuals (frequency of occurrence)

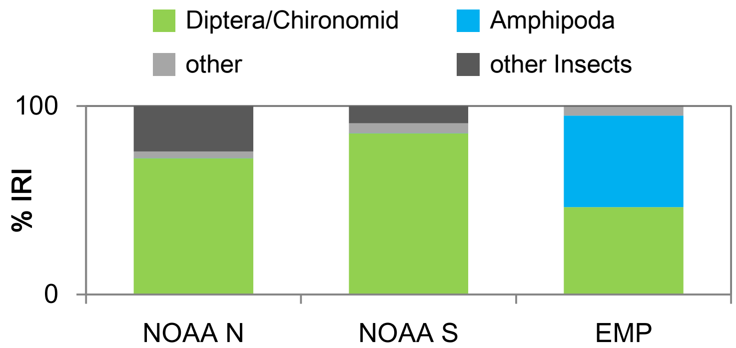

Amphipoda
Diptera
Copepoda
Cladocera
Hemiptera
Other taxa
Other Insecta
Total Percent IRI Compiled over 2008-2013, 2015-2016
Welch Island
Whites Island
Campbell Slough
Franz Lake
100
50
0
30-59
60-79
80-99
fish
(# years)
April
May
June
July
27 (2)
28 (4)
36 (4)
26 (4)
20 (3)
23 (3)
13 (1)
14 (2)
37 (3)
48 (5)
30 (6)
16 (4)
25 (5)
39 (5)
19 (3)
15 (2)
11 (2)
14 (3)
8 (2)
3 (2)
18 (4)
68 (8)
65 (8)
24 (3)
27 (4)
5 (2)
8 (1)
12 (1)
3 (1)
12 (1)
3 (1)
12 (3)
4 (2)
All but 1 of these fish were collected in 2010; diets predominantly comprised of other fish.
Fish collected in 2016; both neuston and diets had a large number of copepods (other April fish from 2008)

Are fish feeding differently among sites?

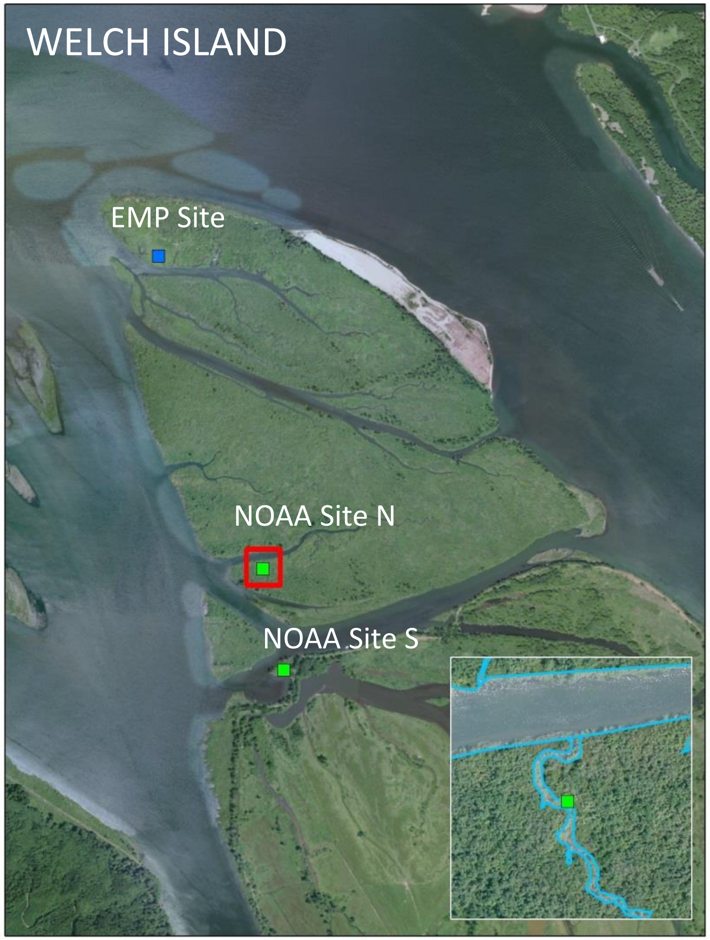


- Two-dimensional NMDS plot based on Bray-Curtis similarities between transformed %IRI of major prey groups in diets sampled between 2008 and 2016.
- Significant difference in prey consumption between upriver and downriver sites (ANOSIM R=0.416, p<0.001) of the more downriver sites (Welch Island and Whites Island, blue symbols) and the more upriver sites (Campbell Slough and Franz Lake, green symbols).
- The % contribution of Dipterans is greater on average from Campbell Slough and Franz Lake, while Amphipods are strongly associated with Welch Island and Whites Island.

What fish are eating is closely associated with where they are feeding.



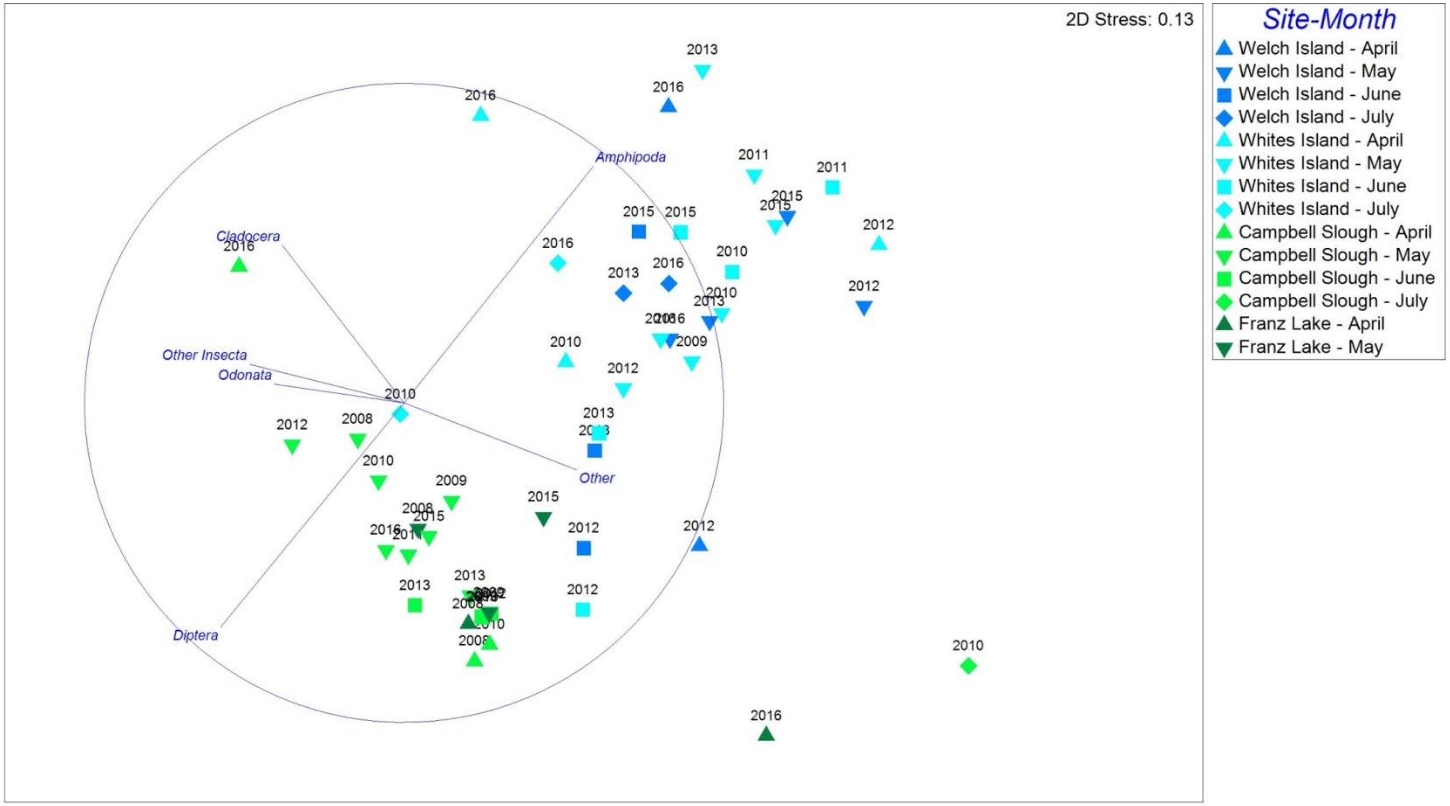
	NOAA N	NOAA S	EMP
n	**63**	**62**	**160**
FL mm	40-90	40-87	32-88
Mean FL	50.86	50.77	61.74



- Many small subyearling Chinook migrants rear in shallow wetland channels (secondary interior channels of emergent marsh islands).
- In general, dipteran insects, and specifically emerging chironomids, dominate the diet of juvenile Chinook, regardless of the shallow-water habitat type they occupy (emergent marsh, scrub-shrub, and forested wetlands).
- Amphipods rarely occurred in benthic samples from shallow interior channels, but dense colonies were observed in the larger adjacent tidal channels.

Bottom et al. 2011. Estuarine Habitat and Juvenile Salmon: Current and Historical Linkages in the Lower Columbia River and Estuary

Are fish feeding differently among sites?



Yes. A shift from diets dominated by dipterans and other insects at the upriver sites to primarily amphipods and dipterans at the downriver sites has been consistently shown over study years.

However, it is likely that there is much more behind this than simply position in the estuarine gradient…

- Sediment grain size
- Organic content
- Water depth
- Channel morhpology

How does availability of dominant prey taxa differ among sites?

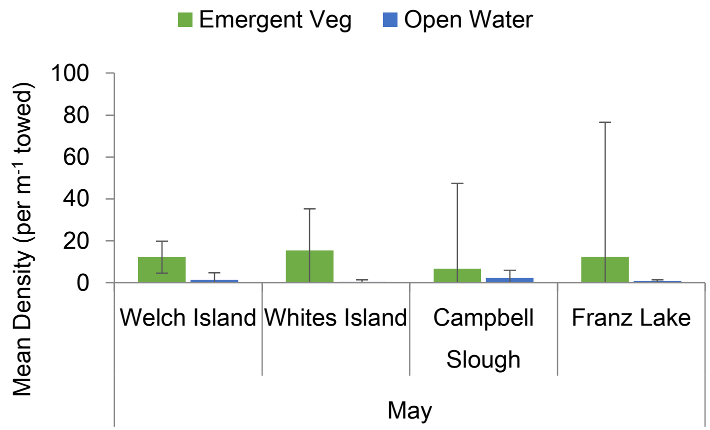
Neuston

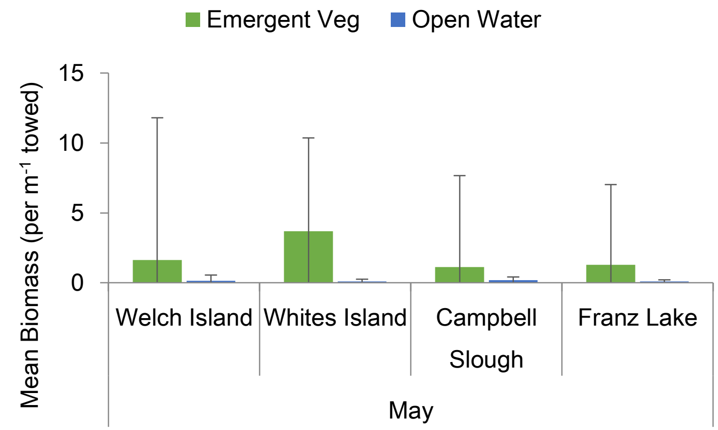
May 2015-2016

Density

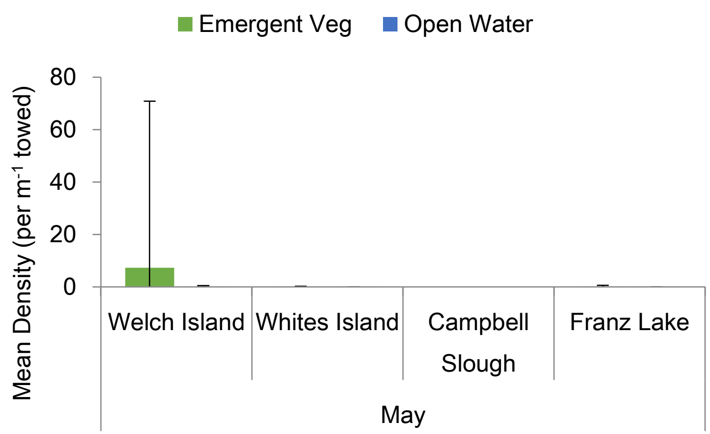
Biomass

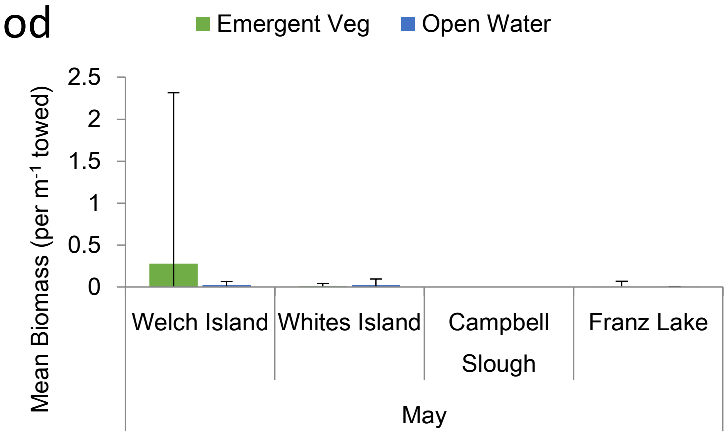
Diptera





Amphipod





Error bars: 95% confidence interval

How does availability of dominant prey taxa change over the season?

Neuston

Neuston sample collected	April								May								June								July								August							
	2008	2009	2010	2011	2012	2013	2015	2016	2008	2009	2010	2011	2012	2013	2015	2016	2008	2009	2010	2011	2012	2013	2015	2016	2008	2009	2010	2011	2012	2013	2015	2016	2008	2009	2010	2011	2012	2013	2015	2016
Ilwaco Slough				X			X					X								X																				
Welch Island					X			X					X	X	X	X					X	X	X	X						X		X								X
Whites Island			X		X			X		X	X	X	X	X	X	X			X	X	X	X	X	X			X			X		X								
Campbell Slough	X		X				X	X	X	X	X	X	X	X	X	X		X	X		X	X		X			X													
Franz Lake	X						X	X	X	X		X			X																									

There has been consistent sampling from Welch, Whites, Campbell in May and June; other sites and months have been too inconsistent to infer temporal trends.

Neuston data is useful for comparing prey availability to diet data collected at the same time.

- Less so for examining dynamics of prey availability in these habitats.

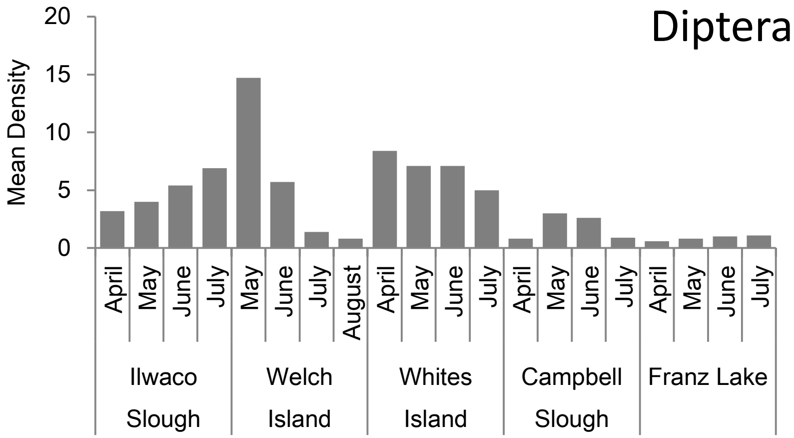
How does availability of dominant prey taxa differ among sites?

Benthic Cores
2015-2016

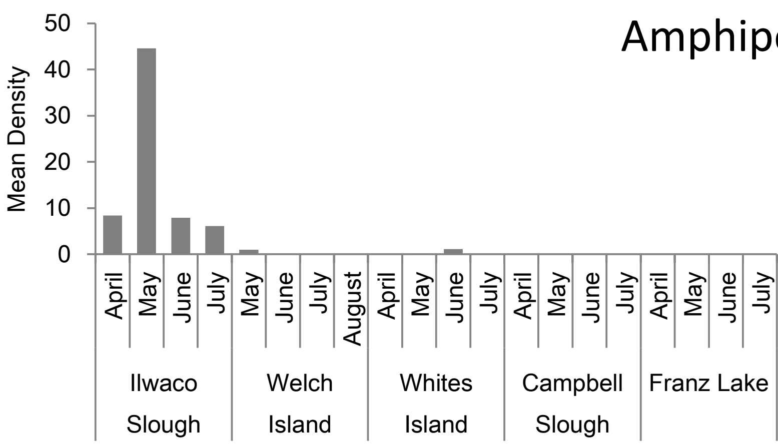
Density

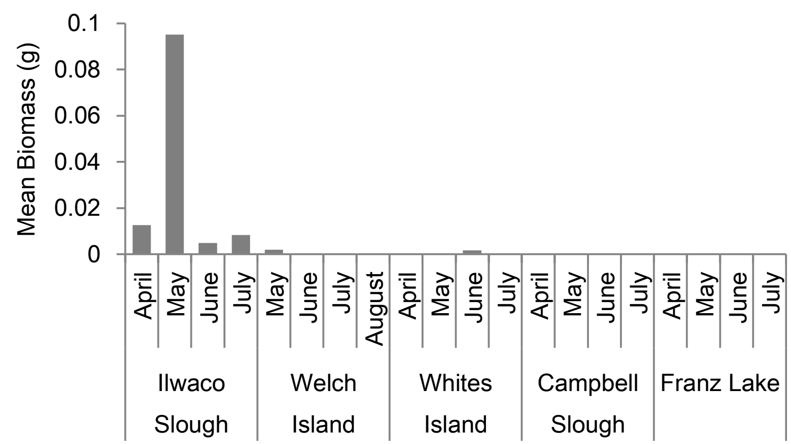
Biomass

Diptera

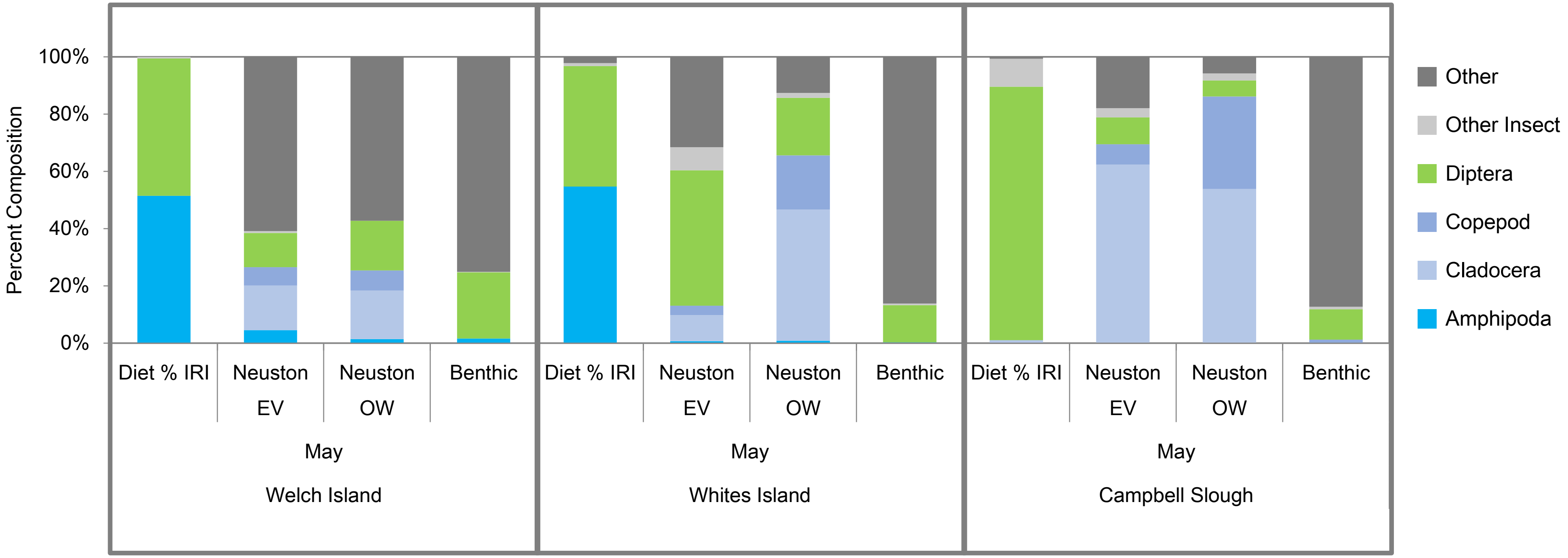


Amphipod





Are the macroinvertebrates sampled representative of prey consumed by juvenile Chinook?



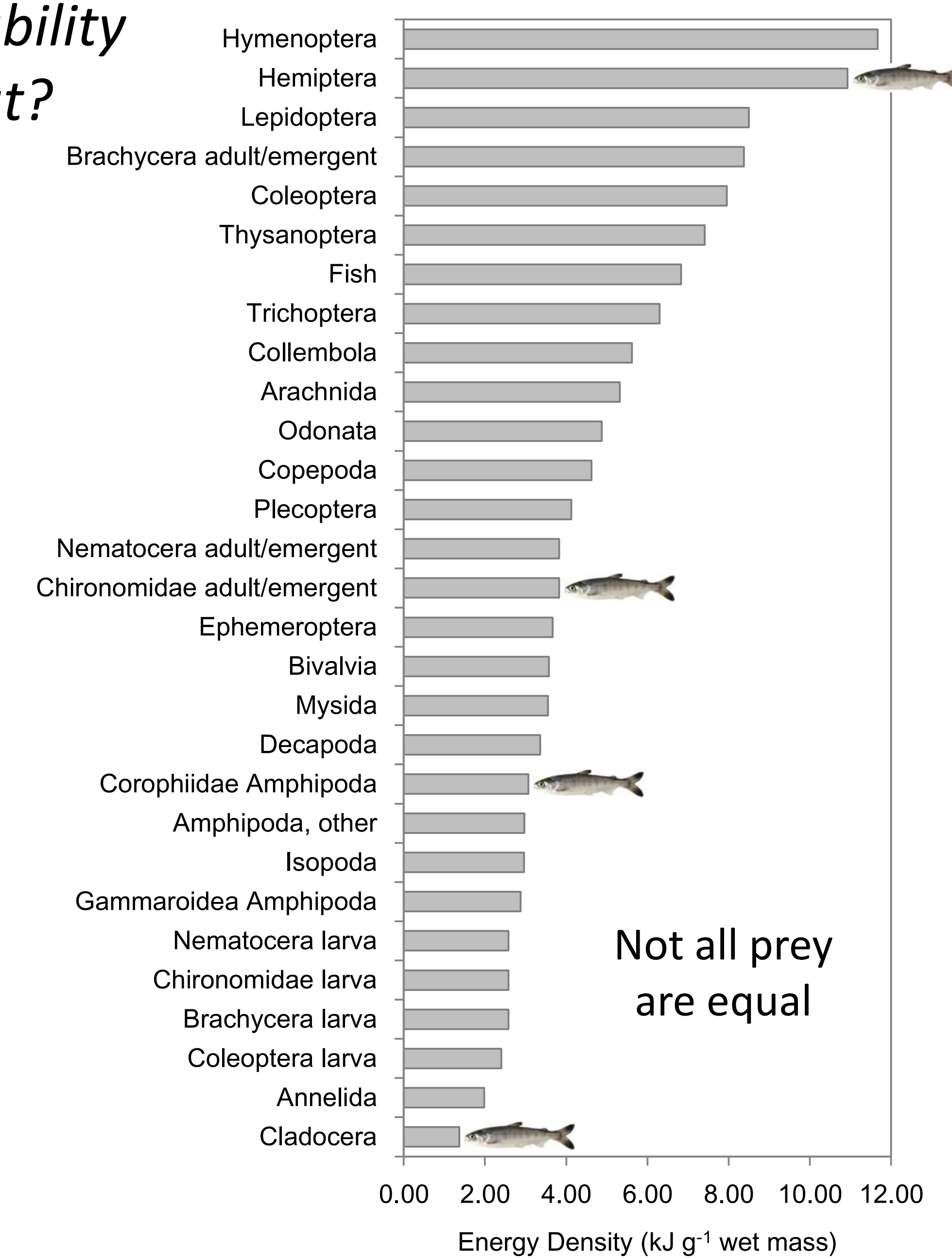
- Diets dominated by Amphipods, Diptera (Chironomids), and other insects.
- Neuston dominated by zooplankton (Cladocera, Copepoda, Ostracoda) and Diptera.
    - Ex. Franz Lake, April 2016 – high densities of copepods in neuston and diets
- Benthic dominated by worms and Diptera.

High variation in both neuston and benthic samples – macroinvertebrate distribution can be very patchy.

We have a hard time sampling amphipods.

- Evidence of juvenile Chinook's strong selection for this taxa?

What can prey selection and availability tell us about the quality of a habitat?



Not all prey are equal

Energy densities were acquired from the literature and compiled in David et al. (2016)

What can prey selection and availability tell us about the quality of a habitat?

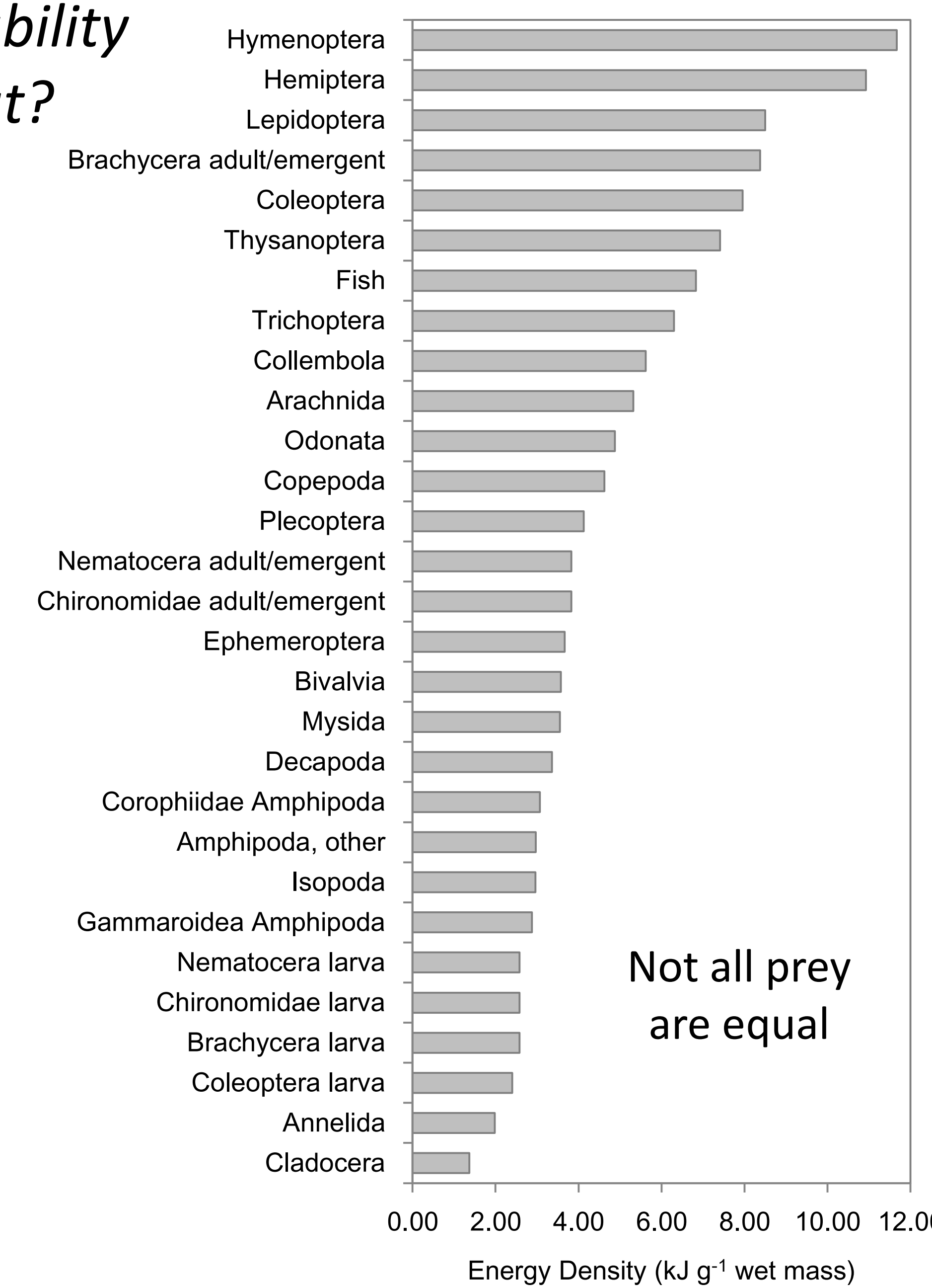
Energy Ration

Energy ration (ER), was calculated as a measure of energy consumption for each juvenile Chinook salmon and is driven by prey availability and quality.

$$ER = \frac{\sum w_i \cdot k_i}{W}$$

w = prey mass consumed of prey taxa *i*
k = energy density (kJ g^{-1} wet mass) of prey taxa *i*
W = total fish mass (g)

Thus, Energy Ration equals kilojoules consumed per gram of fish.

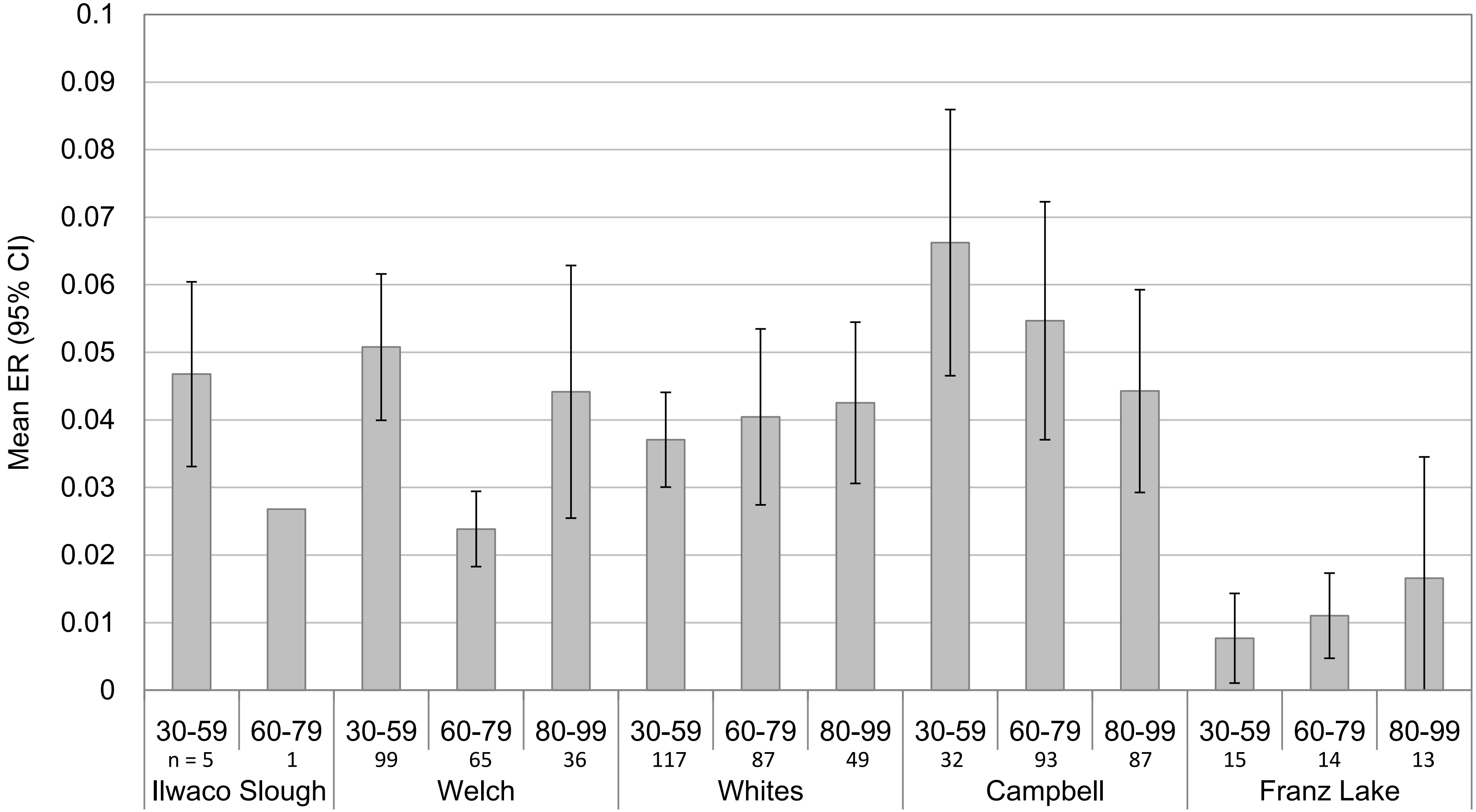


Energy densities were acquired from the literature and compiled in David et al. (2016)

Energy Ration

compiled over 2008-2013, 2015-2016

reflects both fullness and energy consumed



Maintenance Metabolism

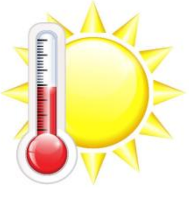
Fiechter et al. (2015) included maintenance metabolism as part of a bioenergetics model to identify the effects of environmental conditions on juvenile Chinook growth and condition in central California.

Maintenance metabolism (J_M) represents the cost of metabolic upkeep and varies with temperature and body mass, such that:

$$J_M = j_m \cdot e^{dT} \cdot W$$

j_m = mass specific maintenance cost at 0° C = 0.003 (Fiechter et al. 2015)
d = temperature coefficient for biomass assimilation = 0.068 (Stuart and Ibarra, 1991)
T = temperature at time of capture
W = fish body mass.

Maintenance metabolism <u>increases with higher temperatures and with fish size</u> such that larger fish in warmer temperatures would have higher metabolic needs

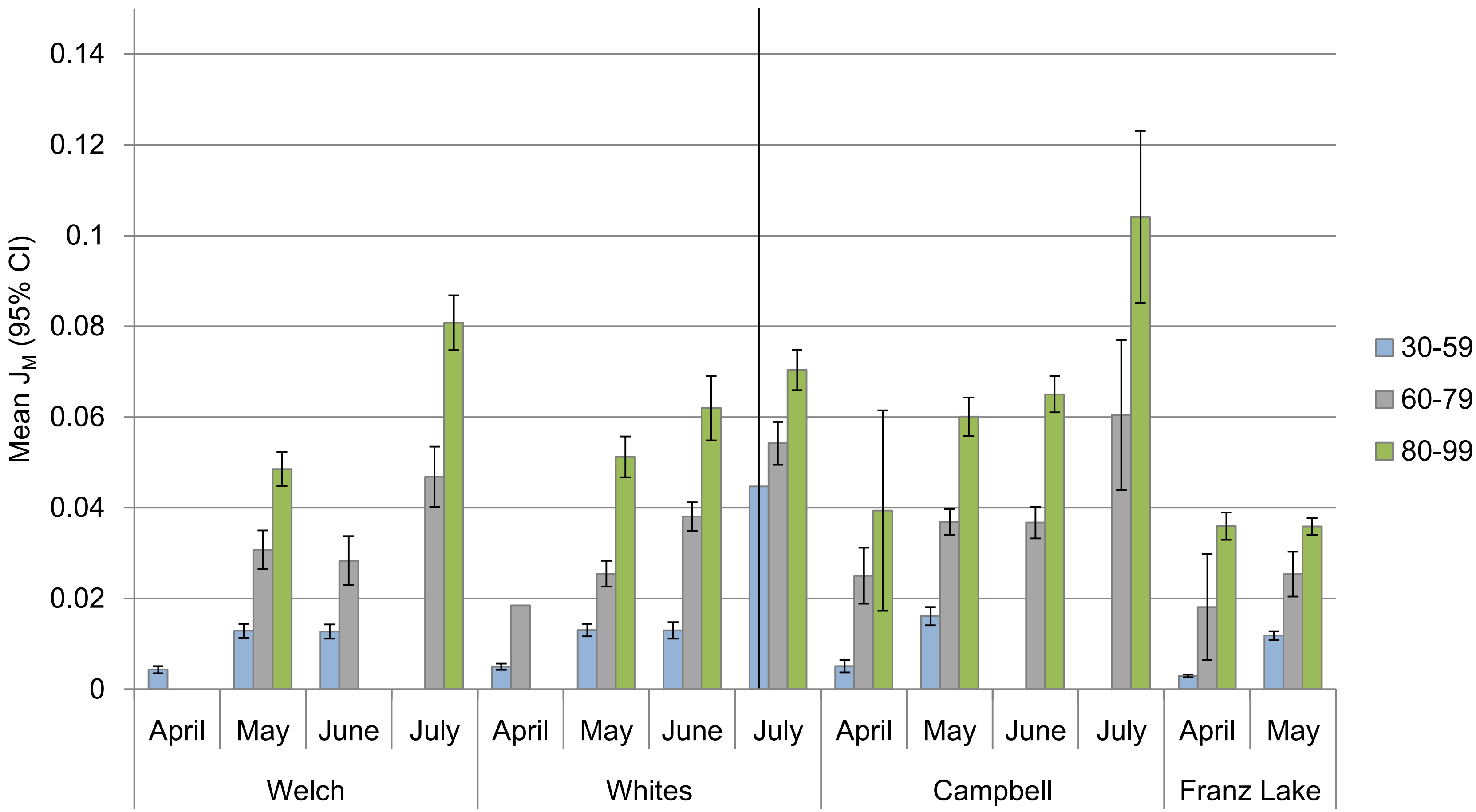


Fiechter, J., D.D. Huff, B.T. Martin, D.W. Jackson, C.A. Edwards, K.A. Rose, E.N. Curchitser, K.S. Hedstrom, S.T. Lindley, and B.K. Wells. 2015.Environmental conditions impacting juvenile Chinook salmon growth off central California: An ecosystem model analysis. Geophysical Research Letters.

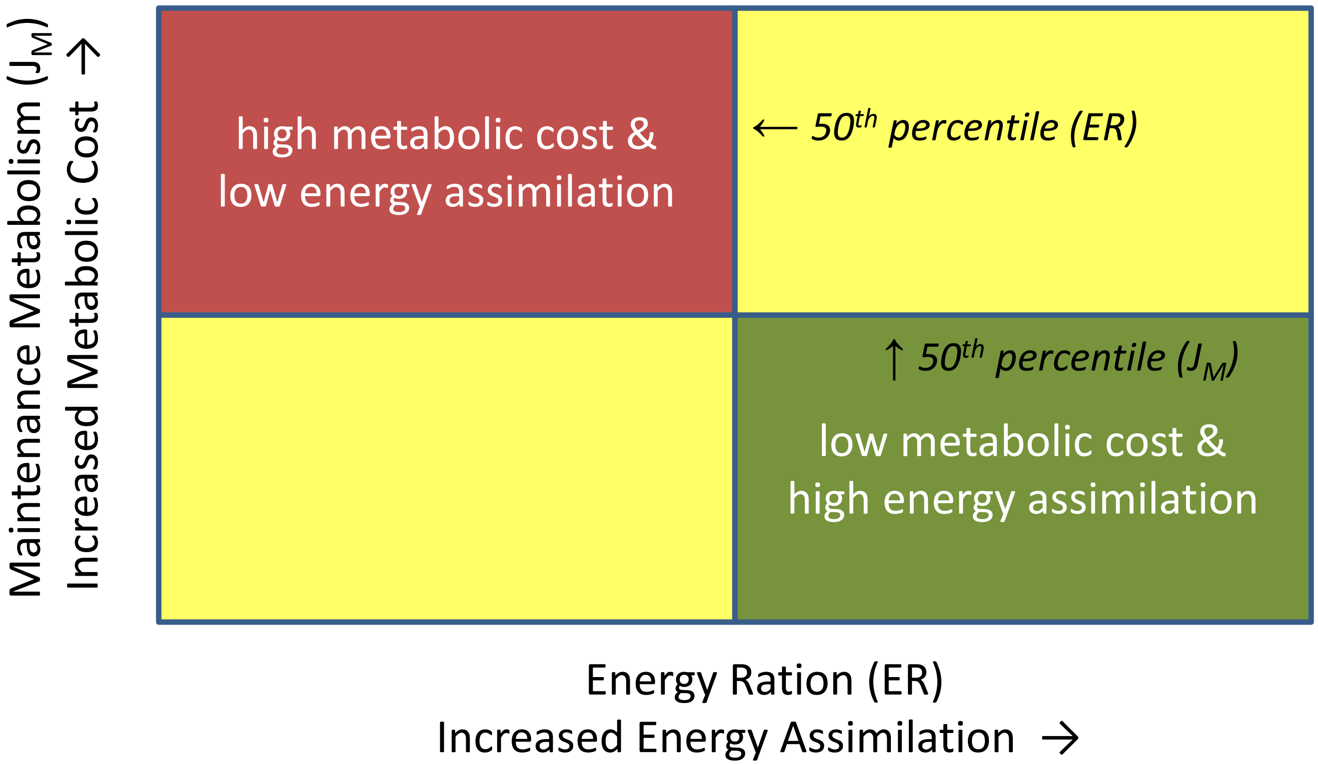
Maintenance Metabolism

compiled over 2008-2013, 2015-2016

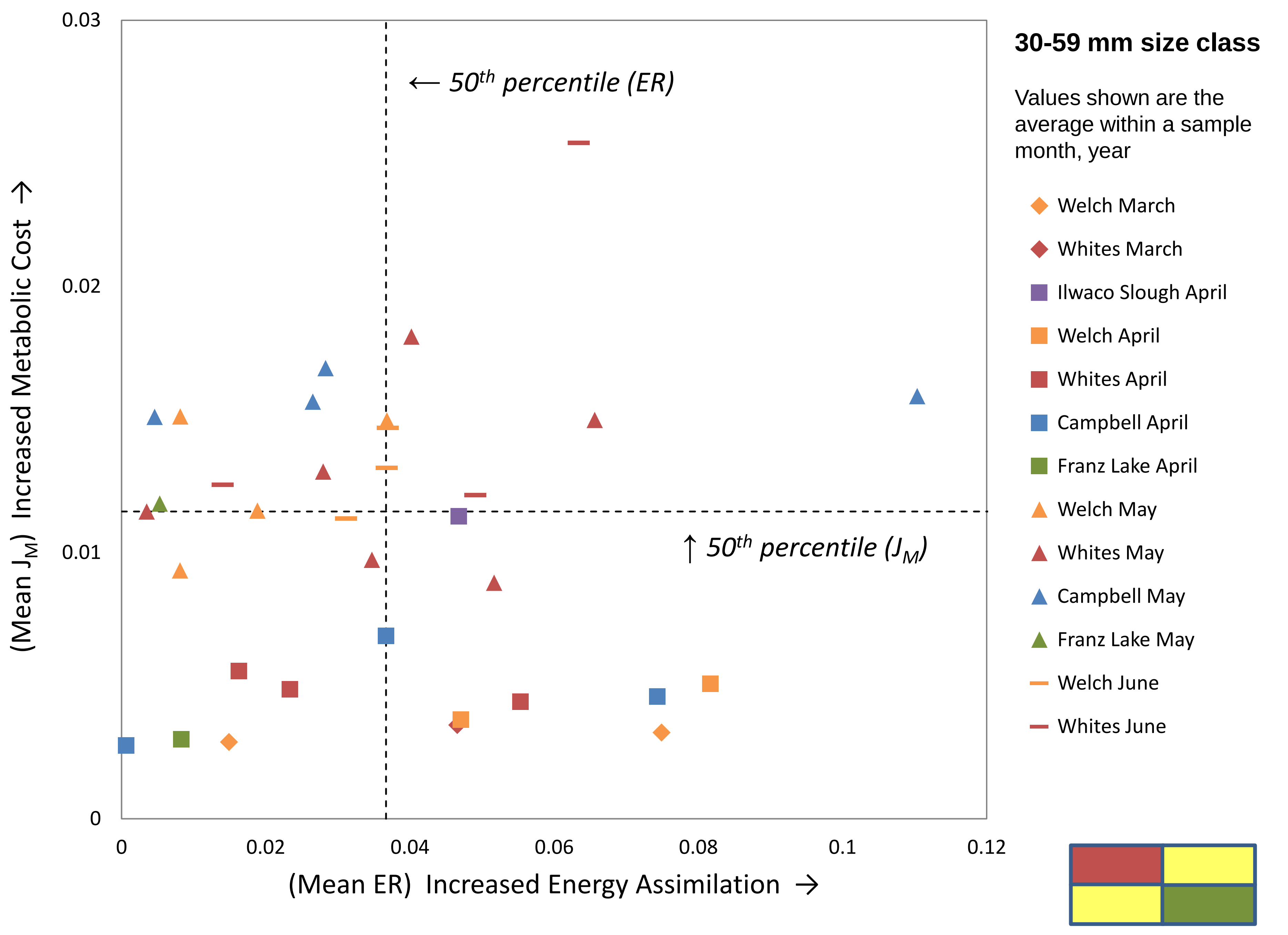
reflects cost of metabolic upkeep

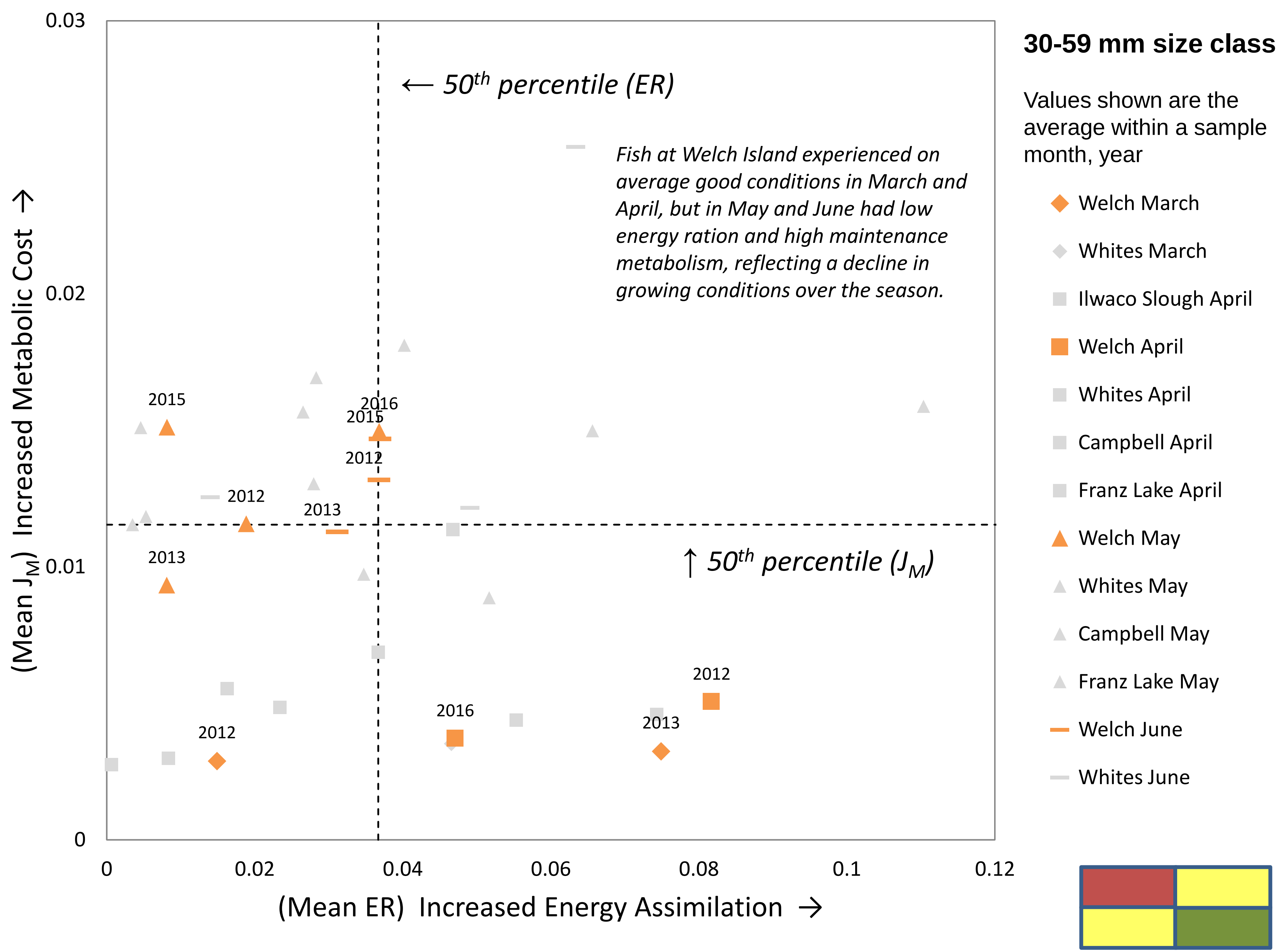


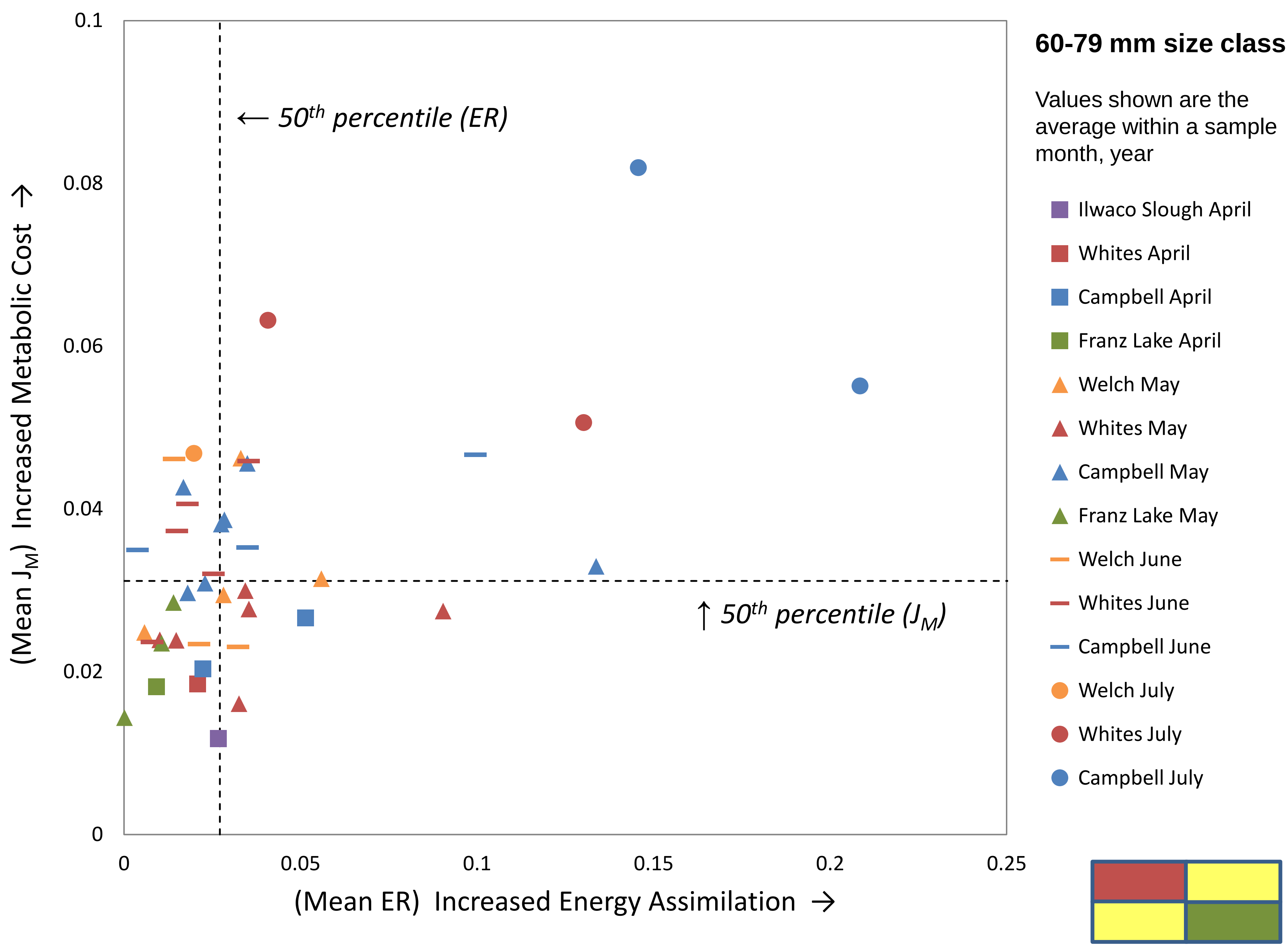
Maintenance Metabolism and **Energy Ration** plotted on a quadrant chart, divided by the 50th percentile, to evaluate the two metrics of potential growth together.



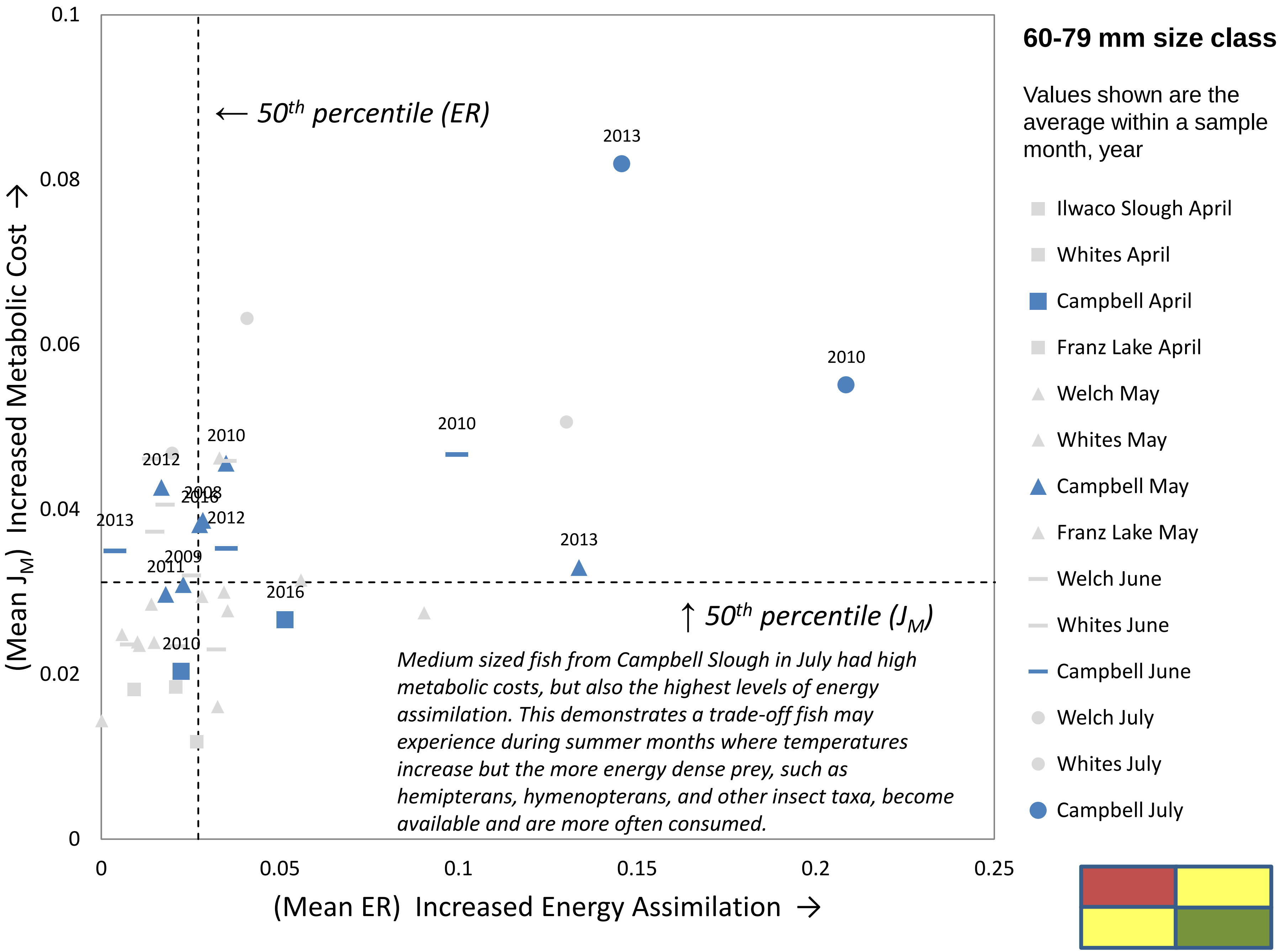
For juvenile Chinook salmon, low metabolic cost and high energy assimilation represent relatively positive growing conditions (lower right quadrant), while high metabolic cost and low energy assimilation represent relatively poor growing conditions (upper left quadrant).

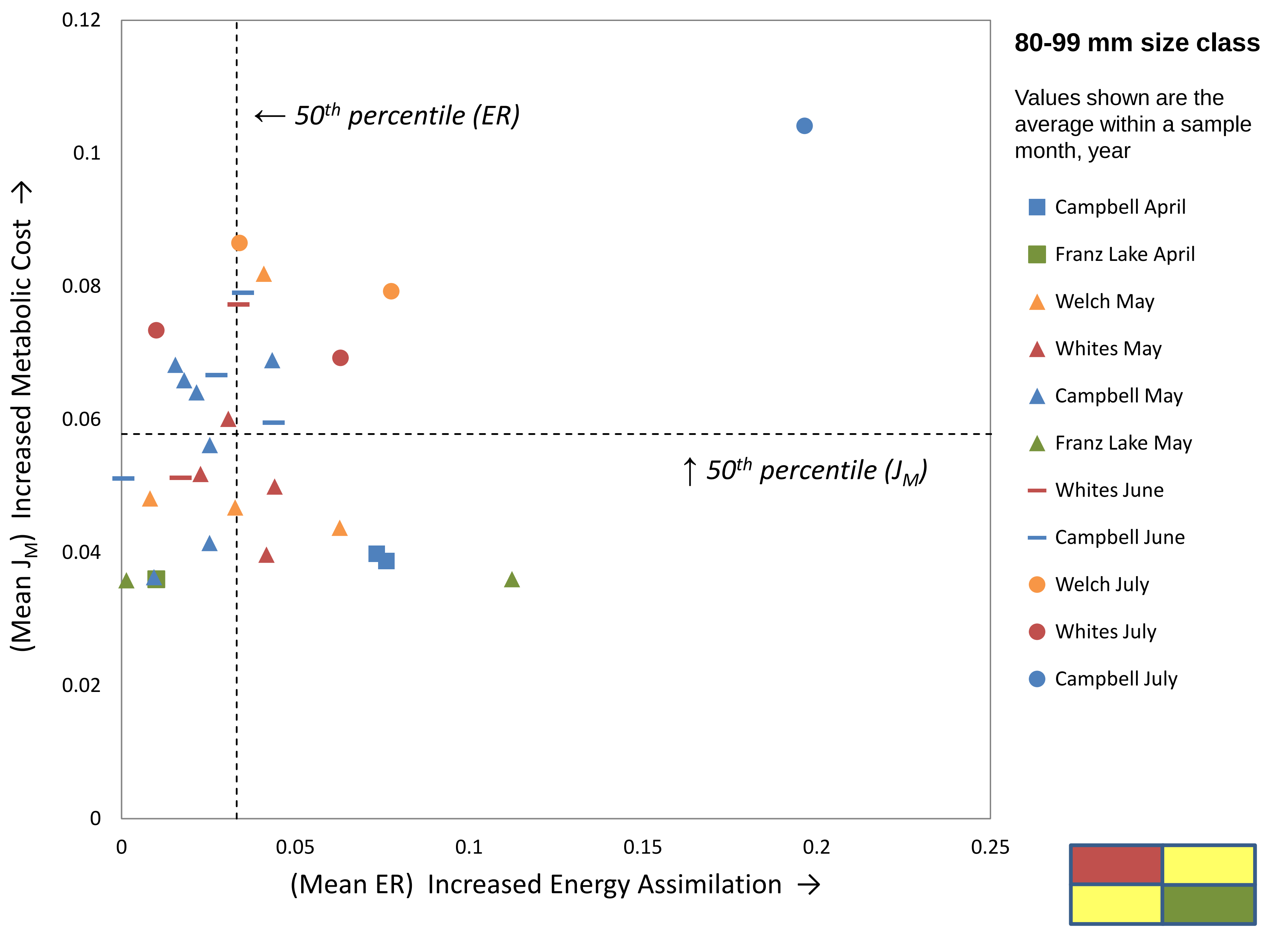

30-59 mm size class
Values shown are the average within a sample month, year
Welch March
Whites March
Ilwaco Slough April
Welch April
Whites April
Campbell April
Franz Lake April
Welch May
Whites May
Campbell May
Franz Lake May
Welch June
Whites June
← 50th percentile (ER)
↑ 50th percentile (J_M)
(Mean J_M) Increased Metabolic Cost →
(Mean ER) Increased Energy Assimilation →
0.03
0.02
0.01
0
0
0.02
0.04
0.06
0.08
0.1
0.12


30-59 mm size class
Values shown are the average within a sample month, year
Welch March
Whites March
Ilwaco Slough April
Welch April
Whites April
Campbell April
Franz Lake April
Welch May
Whites May
Campbell May
Franz Lake May
Welch June
Whites June
← 50th percentile (ER)
Fish at Welch Island experienced on average good conditions in March and April, but in May and June had low energy ration and high maintenance metabolism, reflecting a decline in growing conditions over the season.
↑ 50th percentile (JM)
(Mean JM) Increased Metabolic Cost →
(Mean ER) Increased Energy Assimilation →
0.03
0.02
0.01
0
0
0.02
0.04
0.06
0.08
0.1
0.12
2015
2016
2015
2012
2012
2013
2013
2012
2016
2012
2013



60-79 mm size class
Values shown are the average within a sample month, year
Ilwaco Slough April
Whites April
Campbell April
Franz Lake April
Welch May
Whites May
Campbell May
Franz Lake May
Welch June
Whites June
Campbell June
Welch July
Whites July
Campbell July
← 50th percentile (ER)
↑ 50th percentile (J_M)
(Mean J_M) Increased Metabolic Cost →
(Mean ER) Increased Energy Assimilation →
0
0.02
0.04
0.06
0.08
0.1
0
0.05
0.1
0.15
0.2
0.25


60-79 mm size class
Values shown are the average within a sample month, year
Ilwaco Slough April
Whites April
Campbell April
Franz Lake April
Welch May
Whites May
Campbell May
Franz Lake May
Welch June
Whites June
Campbell June
Welch July
Whites July
Campbell July
← 50th percentile (ER)
↑ 50th percentile (J_M)
Medium sized fish from Campbell Slough in July had high metabolic costs, but also the highest levels of energy assimilation. This demonstrates a trade-off fish may experience during summer months where temperatures increase but the more energy dense prey, such as hemipterans, hymenopterans, and other insect taxa, become available and are more often consumed.
(Mean J_M) Increased Metabolic Cost →
(Mean ER) Increased Energy Assimilation →
0
0.02
0.04
0.06
0.08
0.1
0.05
0.1
0.15
0.2
0.25
2013
2010
2010
2013
2010
2012
2008
2016
2012
2013
2009
2011
2016
2010


80-99 mm size class
Values shown are the average within a sample month, year
Campbell April
Franz Lake April
Welch May
Whites May
Campbell May
Franz Lake May
Whites June
Campbell June
Welch July
Whites July
Campbell July
← 50th percentile (ER)
↑ 50th percentile (J_M)
(Mean J_M) Increased Metabolic Cost →
(Mean ER) Increased Energy Assimilation →
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.05
0.1
0.15
0.2
0.25

Maintenance Metabolism & Energy Ration

- Most sites early in the season (March to May), had at least one occurrence where both high energy assimilation and low metabolic cost occurred in juvenile Chinook salmon.
- A trade-off occurs in the warmer months where metabolic costs are relatively high, but energy dense prey, such as hemipterans, hymenopterans, and other insect taxa, are available and consumed.
- Juvenile Chinook salmon at Franz Lake consistently had below average energy rations. While only collected in April and May, these fish also had relatively low metabolic costs, which may offset (<u>to an unknown degree</u>) the quantity and quality of prey consumed.

HOW CAN WE USE THESE CHARTS?

- Evaluate where/when salmon experience relatively good or poor growing conditions.
- Compare habitat quality across different time scales.
  - How do the conditions at a site change over the juvenile Chinook out-migration season?
  - How do the conditions at a site change over years or decades that experience large scale differences in climate?
- Compare habitat quality among different sites.
  - For example, salmon sampled from a new restoration site could be plotted along the long term averages from the trend sites to provide an evaluation of the new habitat relative to other areas in the estuary. As well as tracking the progress of a restored site over years or decades.