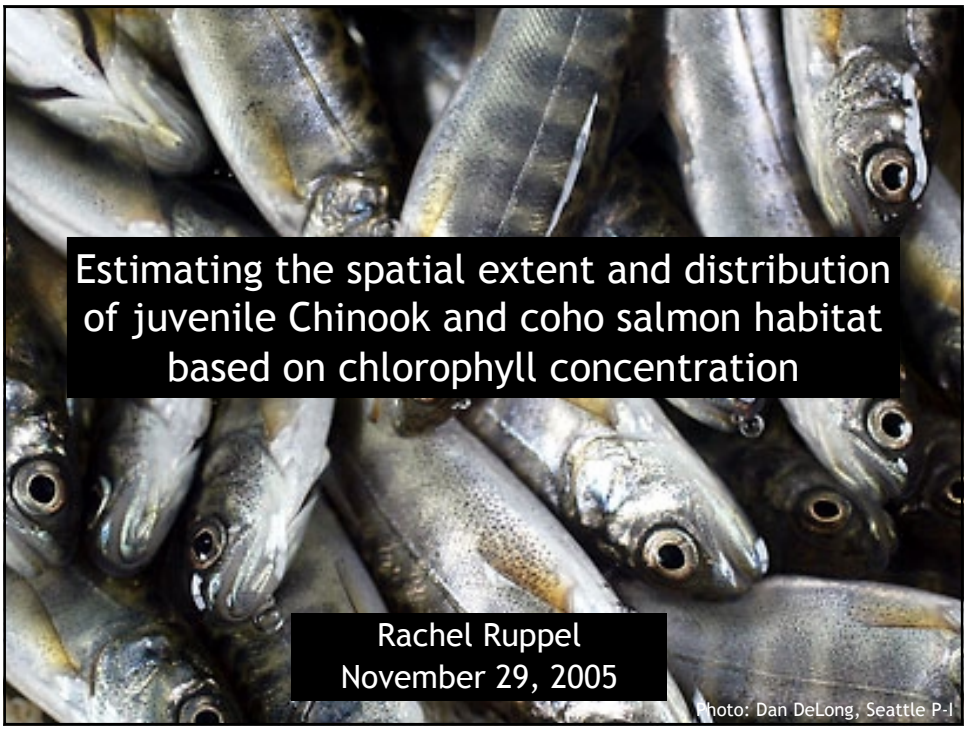
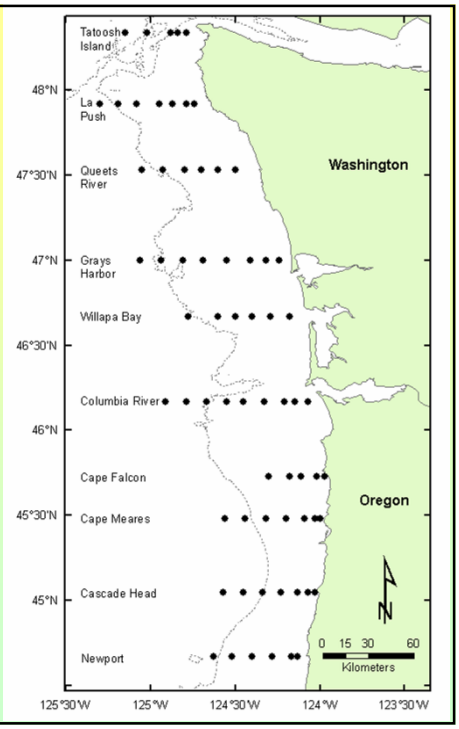

Photo: Dan DeLong, Seattle P-I


Estimating the spatial extent and distribution of juvenile Chinook and coho salmon habitat based on chlorophyll concentration
Rachel Ruppel
November 29, 2005
Photo: Dan DeLong, Seattle P-I

Goal of GLOBEC synthesis:
Identify the physical and biological characteristics of the habitats of juvenile Chinook and coho salmon in the northern California Current

Where are the salmon?
Where is the ocean favorable?

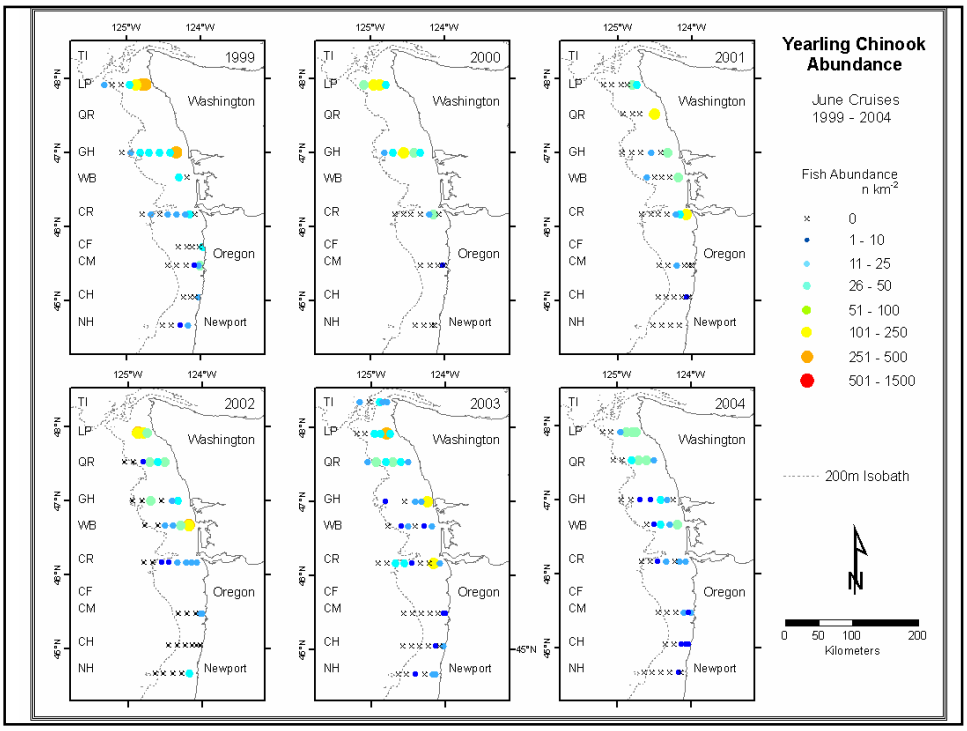
Objective of my research:
Integrate field-collected and remotely-sensed data to define the spatial extent of oceanic habitat for juvenile salmon.



Chlorophyll is positively correlated with resident fish yield, on a regional scale. (Thomson and Ware 2005)
Washington coastal waters have higher chlorophyll than Oregon coastal waters. (Hickey and Banas 2003)

Where are the salmon in relation to chlorophyll concentration?
Can we use chlorophyll to estimate habitat distribution?

General Methods:
Determine relationship of chlorophyll and salmon
- presence/absence
- high catch/low catch
Reclassify satellite images to reflect those relationships
Create a GIS layer of habitat for each cruise
Compare habitat size and distribution among years
Validate model with 2005 data and imagery


Yearling Chinook Abundance
June Cruises 1999 - 2004
Fish Abundance n km-2
0
1 - 10
11 - 25
26 - 50
51 - 100
101 - 250
251 - 500
501 - 1500
200m Isobath
N
0 50 100 200
Kilometers
1999
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2004
Washington
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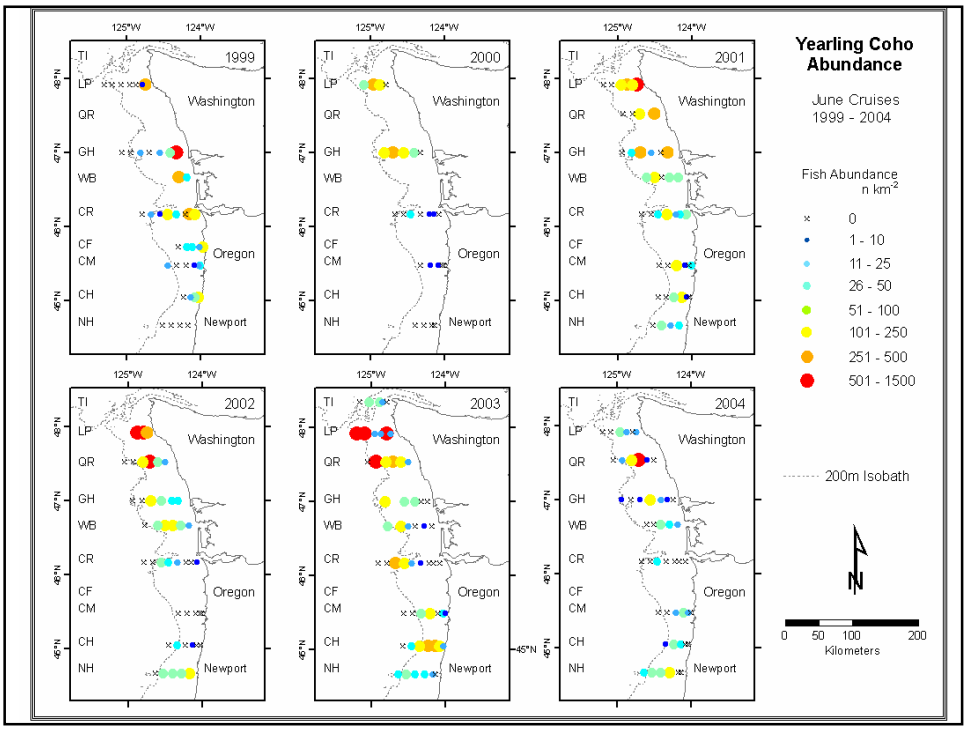
124°W
48°N
47°N
46°N
45°N


Yearling Coho Abundance
June Cruises 1999 - 2004
Fish Abundance n km-2
0
1 - 10
11 - 25
26 - 50
51 - 100
101 - 250
251 - 500
501 - 1500
200m Isobath
N
0 50 100 200
Kilometers
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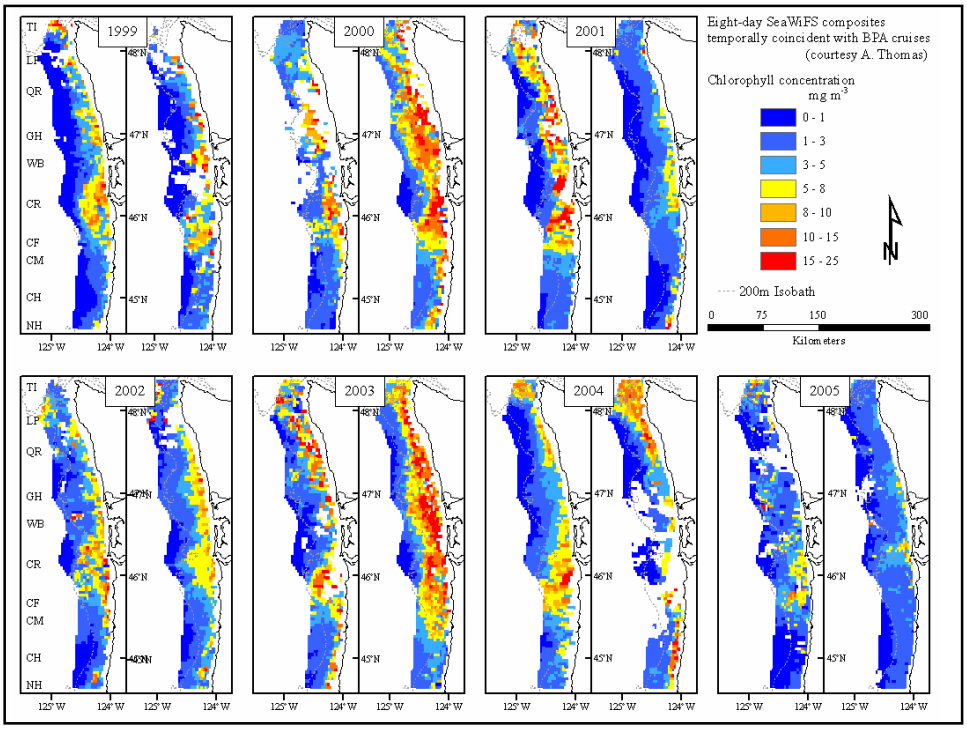
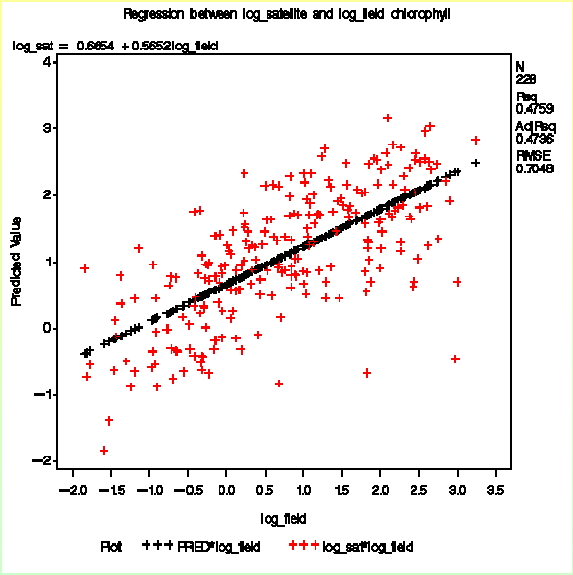


Validate assumptions

1. There is not a difference in habitat preference between Washington and Oregon, despite the much greater number of salmon off Washington.
   Divide dataset into northern and southern regions.
   H_o: Chlorophyll concentration where salmon were caught is not different between northern region and southern region. ANOVA, $\alpha = 0.05$
   Yearling Chinook: $F = 0.73$, $p = 0.39$
   Yearling coho: $F = 0.63$, $p = 0.43$

2. Field-measured and satellite chlorophyll concentration is comparable.
   Regression on log-log transformed data
   $R^2 = 0.47$, $F = 158.97$, $p < 0.01$
   Why log-log transformation?
   - satellite chlorophyll is integrated over depth
   - potential for saturation, maximum satellite chlorophyll is 25 mg m^{-3}
   - not a simple linear relationship between field and satellite
   - helps to normalize the distributions



Statistics

Spearman correlation, α = .05

Salmon abundance is positively correlated with chlorophyll concentration.

yearling Chinook : 0.46, $p < 0.01$

yearling coho : 0.22, $p < 0.01$

Analysis of variance, α = .05 – presence versus absence

The chlorophyll concentration at stations where salmon were caught is different from the chlorophyll concentration at stations where salmon were not caught.

yearling Chinook : F = 36.18, $p < 0.01$

yearling coho : F = 8.00, $p < 0.01$

The average chlorophyll concentration where salmon were caught is higher than the average where salmon were not caught.

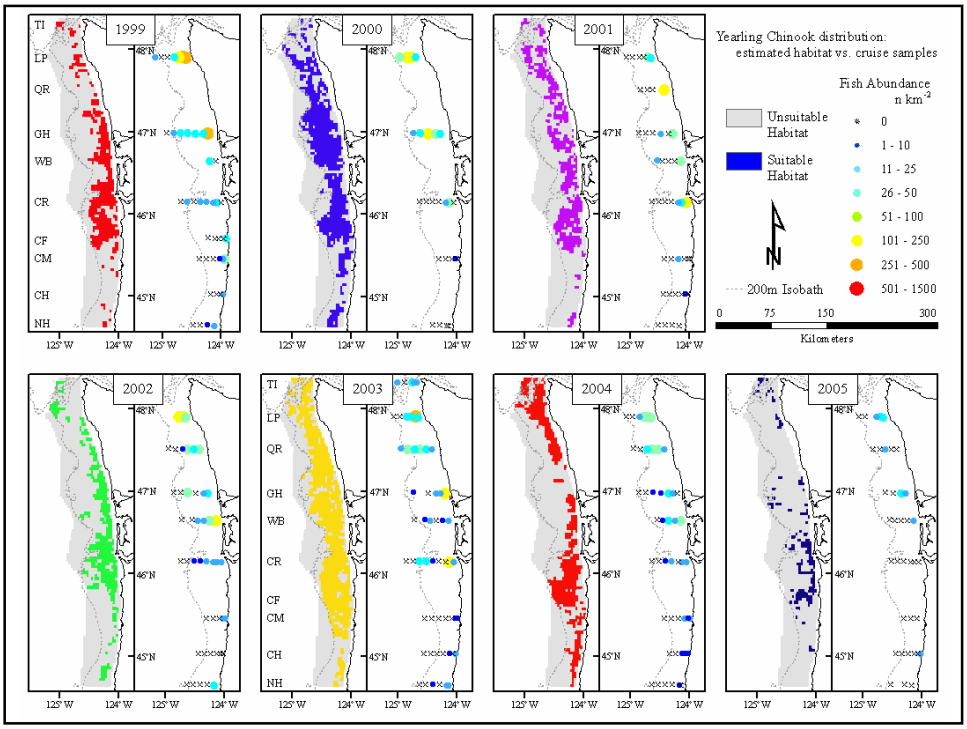
yearling Chinook : 6.04 (±5.14 SD) versus 2.65 (±3.87 SD)

yearling coho : 5.04 (±5.10 SD) versus 3.32 (±4.28 SD)

Classifying suitable habitat:

yearling Chinook: ≥ 6.04 mg m^{-3}

yearling coho: ≥ 5.04 mg m^{-3}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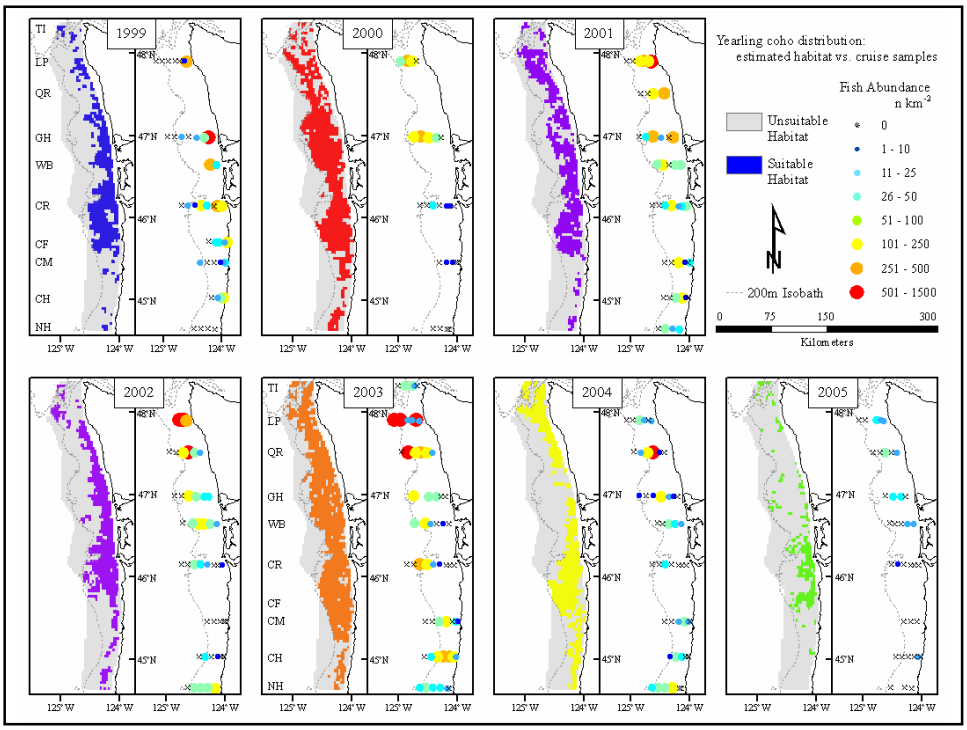
CH
NH
48°N
47°N
46°N
45°N
125° W
124° W
Yearling Chinook distribution:
estimated habitat vs. cruise samples
Fish Abundance
n km-2
Unsuitable Habitat
Suitable Habitat
0
1 - 10
11 - 25
26 - 50
51 - 100
101 - 250
251 - 500
501 - 1500
200m Isobath
0
75
150
300
Kilometers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NH
48°N
47°N
46°N
45°N
125° W
124° W
Yearling coho distribution:
estimated habitat vs. cruise samples
Fish Abundance
n km-2
Unsuitable Habitat
Suitable Habitat
0
1 - 10
11 - 25
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200m Isobath
0
75
150
300
Kilometers

Statistics on the habitat distributions:

ANOVA, α = 0.05 percent habitat of each block, 10 blocks

Salmon habitat size is significantly different by year but not by state.

Yearling Chinook: $F = 4.55$, $p < 0.01$

Year: $F = 5.26$, $p < 0.01$; State: $F = 0.27$, $p = 0.60$

Yearling coho: $F = 4.14$, $p < 0.01$

Year: $F = 4.80$, $p < 0.01$; State: $F = 0.19$, $p = 0.66$

If we break the study area into 3 regions: north, Columbia R., and south, Salmon habitat size is significantly different by year and by region.

Yearling Chinook: $F = 13.71$, $p < 0.01$

Year: $F = 9.57$, $p < 0.01$; Region: $F = 26.13$, $p < 0.01$

Yearling coho: $F = 14.91$, $p < 0.01$

Year: $F = 9.51$, $p < 0.01$; Region: $F = 31.11$, $p < 0.01$

Average Percent Habitat

Yearling Chinook:		2003	46%
		2000	38%
		2004	30%
		2001	25%
Columbia R.	40%	1999	21%
North	27%	2002	19%
South	12%	2005	9%

Average Percent Habitat

Yearling coho:		2003	51%
		2000	44%
		2004	36%
		2001	30%
Columbia R.	48%	2002	27%
North	32%	1999	25%
South	16%	2005	12%

Statistics on high catch versus low catch

Analysis of variance, α = .05

high catch ≥ 0.75 quantile (upper 25% of total catch)

Yearling Chinook:

The chlorophyll concentration at stations of high Chinook catch is different from the chlorophyll concentration at stations of zero or low Chinook catch.

$F = 17.11$, $p < 0.01$

The average chlorophyll concentration at stations of high Chinook catch is higher than the average at stations of zero or low Chinook catch.

6.40 (±4.79 SD) versus 3.65 (±4.68 SD)

Yearling coho:

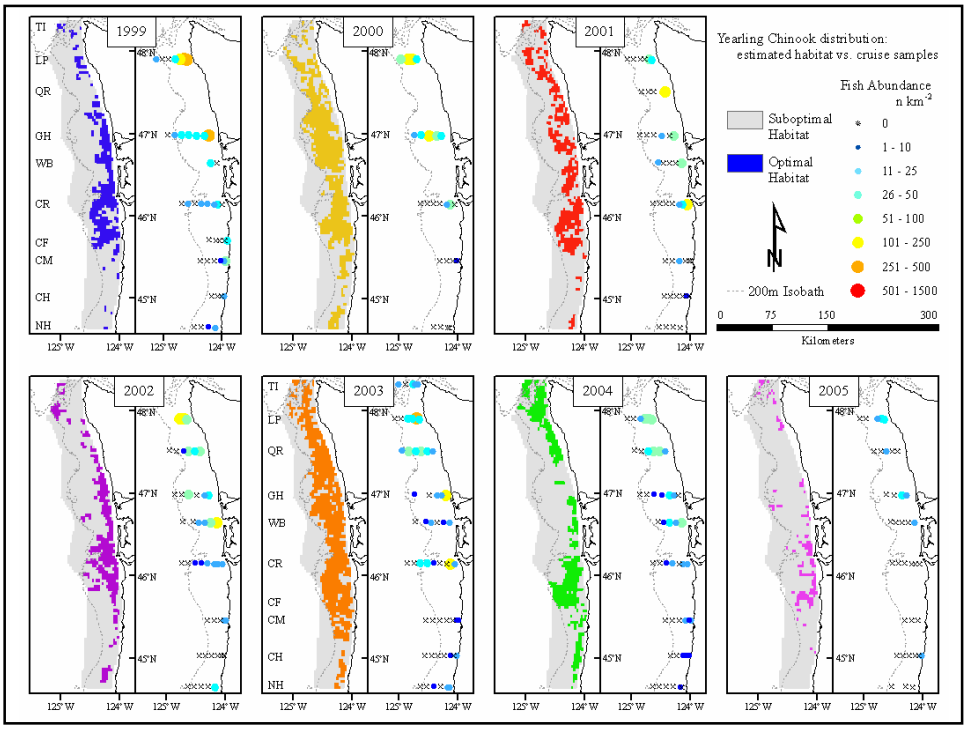
The chlorophyll concentration at stations of high coho catch is NOT different from the chlorophyll concentration at stations of zero or low coho catch.

$F = 1.38$, $p = 0.24$

Classifying optimal habitat:

yearling Chinook: ≥ 6.40 mg m^{-3}

yearling coho: --------



Interpretation of results

Estimating suitable habitat using chlorophyll was successful.

Suitable habitat was limited to the shelf.

- Chinook and coho are “coastal migrants” (Beamish et al. 2005)

Suitable habitat was larger off Washington.

- We catch salmon more often off Washington.

BUT we likely overestimate habitat around the Columbia River.

- Within the plume, other factors may influence salmon distribution.

Estimating optimal habitat was more problematic.

There was no difference in chlorophyll between high and low coho catch.

- Coho have different habitat preferences than Chinook.

Chinook optimal habitat was essentially the same as suitable habitat.

- Other limiting factors contribute to high abundance.

Coho and Chinook juveniles have different habitat preferences.

Retained primary production may influence the distribution of salmon, but cannot explain the trends and patterns in abundance.