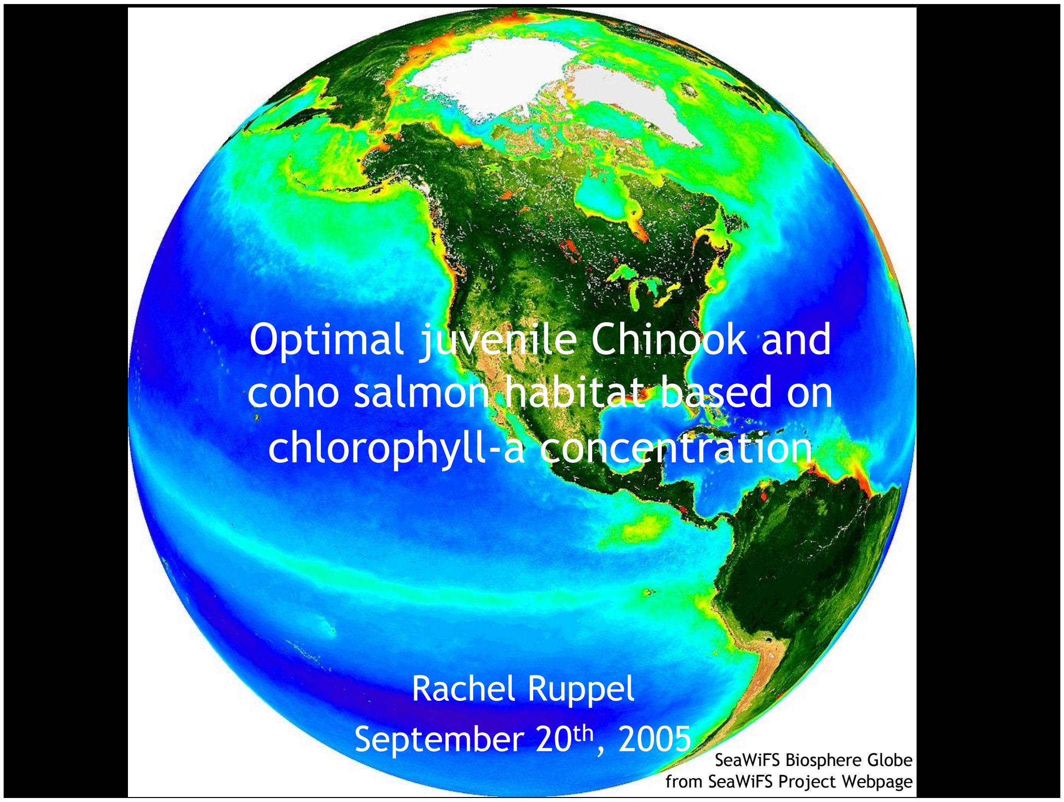
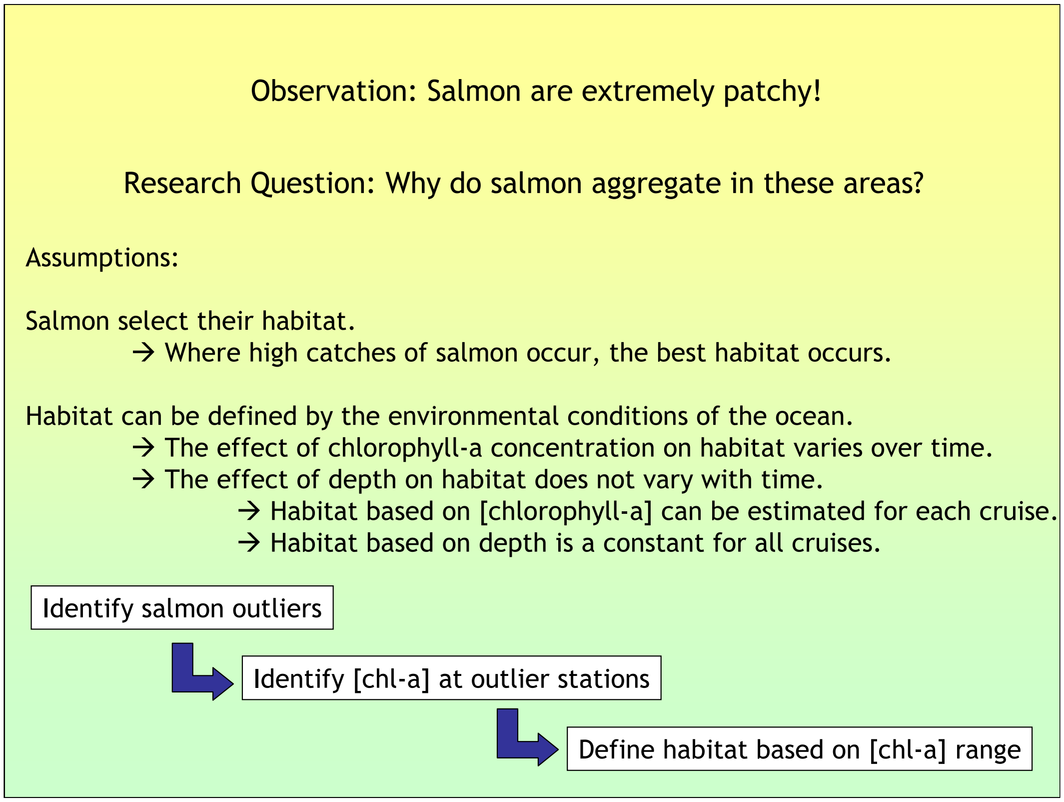


I have been looking at ways to describe and quantify juvenile salmon habitat based on ocean conditions. Using catch data from the June cruises of the BPA project and chlorophyll data from SeaWiFS, I have defined optimal habitat for juvenile Chinook and coho salmon.

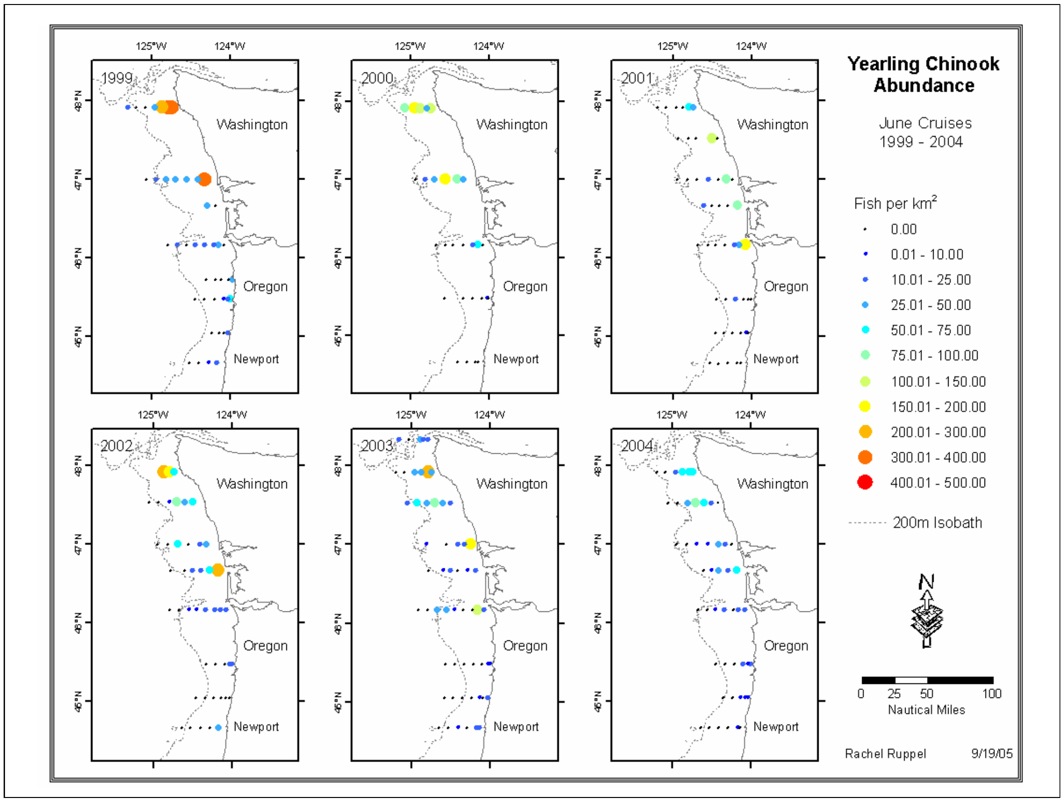


The premise of this study comes from the observed patchiness of juvenile salmon. The majority of the salmon on any cruise are caught in a handful of trawls. If our goal is to analyze habitat, we can ask what makes these areas with lots of salmon different from the rest of the cruise area. If we assume that juvenile salmon can select their habitat, then the best habitat occurs in those places with high catches.

(There was some discussion about whether this assumption is valid, primarily related to the Columbia River plume. Large numbers of fish leave the Columbia River, which could lead to potentially high concentrations of fish in the plume. However, most fish have reached the ocean by late May and we can assume that by late June the fish have dispersed from any initial aggregations. This is supported by the relatively few stations on the CR line with very high catches; these stations are shown in the maps on the next two slides. Therefore, this assumption seems appropriate for this study.)

Another assumption is that ocean conditions can be used to define habitat, in particular chlorophyll-a and depth. Hongsheng Bi has determined that these two parameters explain most of the variation in salmon presence/absence in his logistic regression model. In addition, chlorophyll-a concentration is a proxy for primary production and phytoplankton biomass, the base of the oceanic food web. In this study, the effect of depth on habitat was defined as salmon are not found beyond the shelf, and the effect of [chl-a] on habitat was defined by considering [chl-a] at the locations of very high catches.

The methods were to identify those stations where very high catches of salmon occurred (i.e. outlier stations), then identify the [chl-a] at those locations from the SeaWiFS imagery, and define an optimal [chl-a] range for each June cruise and then reclassify the SeaWiFS image to reflect optimal habitat based on [chl-a].



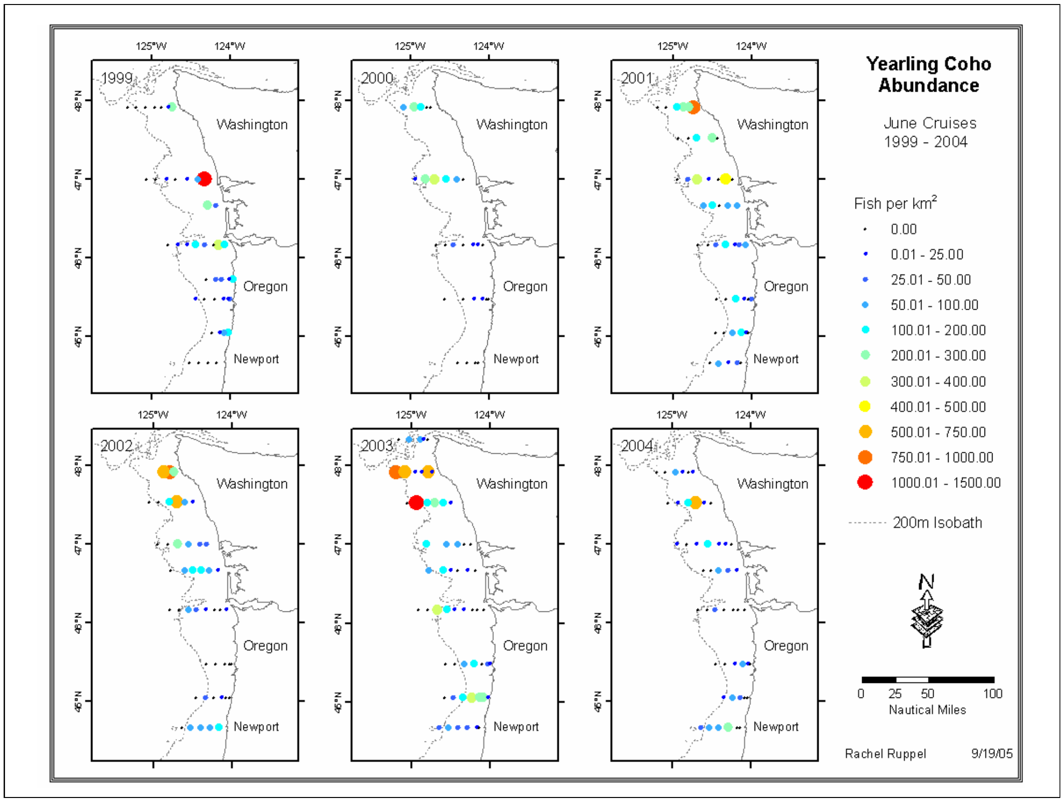
It is quite clear in this map that zero or few juvenile salmon are caught at most stations. The outlier stations, those with very high catch, tend to be nearshore and off Washington for yearling Chinook. The most common transect for outlier stations is the LaPush transect. The outlier stations are summarized in the table below; the map for yearling coho abundance follows on the next slide.

For Notes Below only

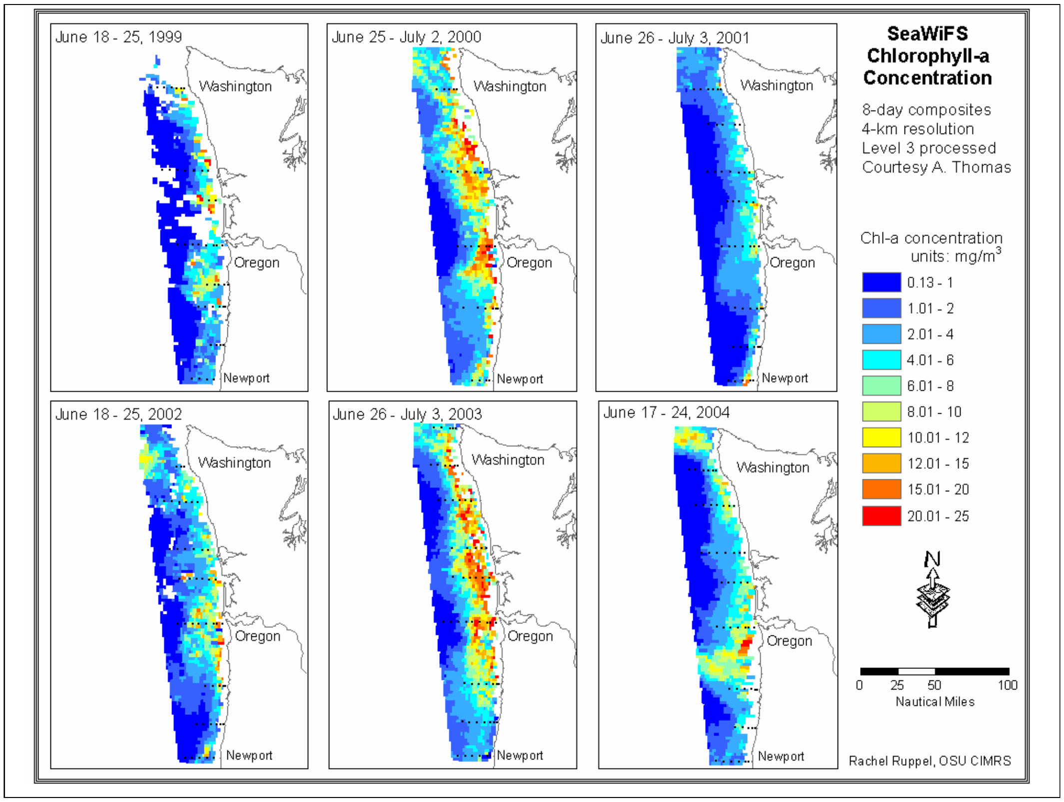
June 1999-2004 BPA Stations Identified as Outliers for Salmon Abundance

Outlier metric is median abundance + 2SD for each year. Note: One outlier was found for yearling coho in June 1999. I changed the metric to median + 1SD, thus 4 outliers.

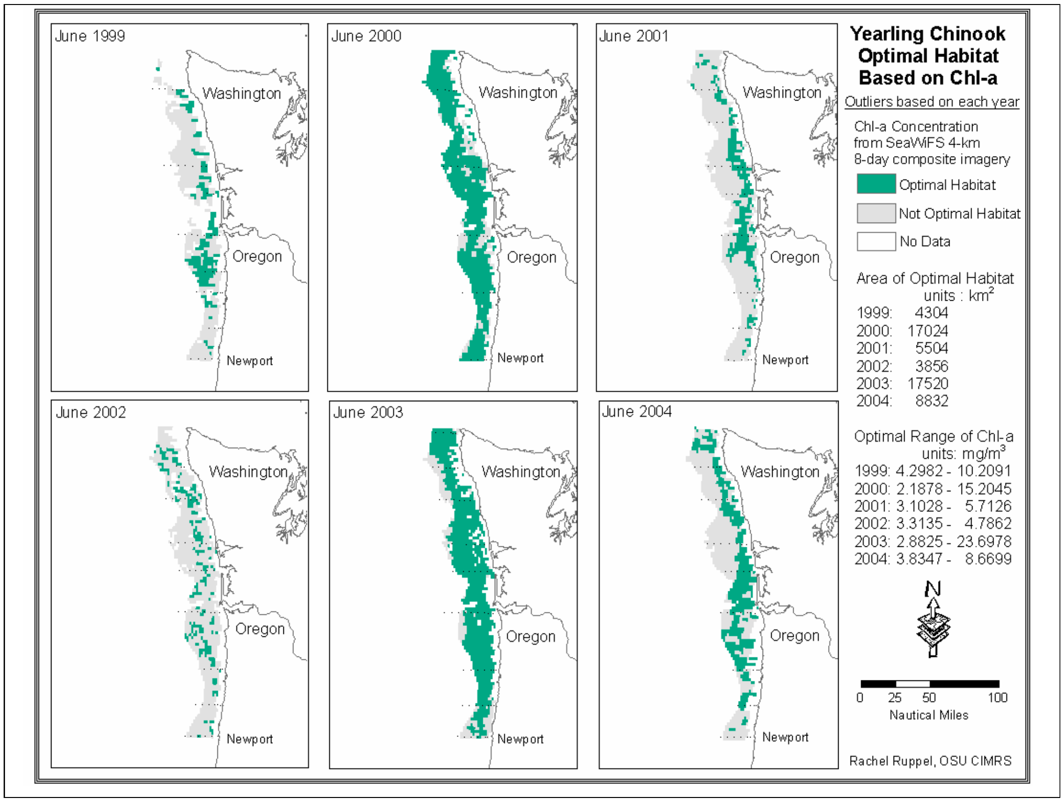
	Yearling Chinook		*Yearling Coho*		
	Station Abundance		Station Abundance		
1999	LP04	334.11	1999	LP04	257.00
	LP06	324.35		GH06	1470.05
	LP09	241.66		WB09	255.19
	GH06	370.41		CR07	329.99
2000	LP09	112.47	2000	LP12	291.84
	LP12	178.35		GH21	303.51
	GH16	176.85		GH26	219.67
2001	QR06	141.21	2001	LP04	816.90
	GH06	83.12		GH06	415.61
	WB05	82.08			
	CR04	157.84			
2002	LP06	172.00	2002	LP06	795.52
	LP09	239.55		LP09	522.65
	WB05	200.16		QR14	618.54
2003	LP06	266.09	2003	LP06	746.78
	GH03	153.32		LP17	553.01
	CR07	136.31		LP22	980.83
				QR24	1295.83
2004	LP04	61.42	2004	QR14	603.35
	LP06	64.03		NH10	234.42
	LP09	72.08			
	QR14	79.86			
	WB05	50.67			



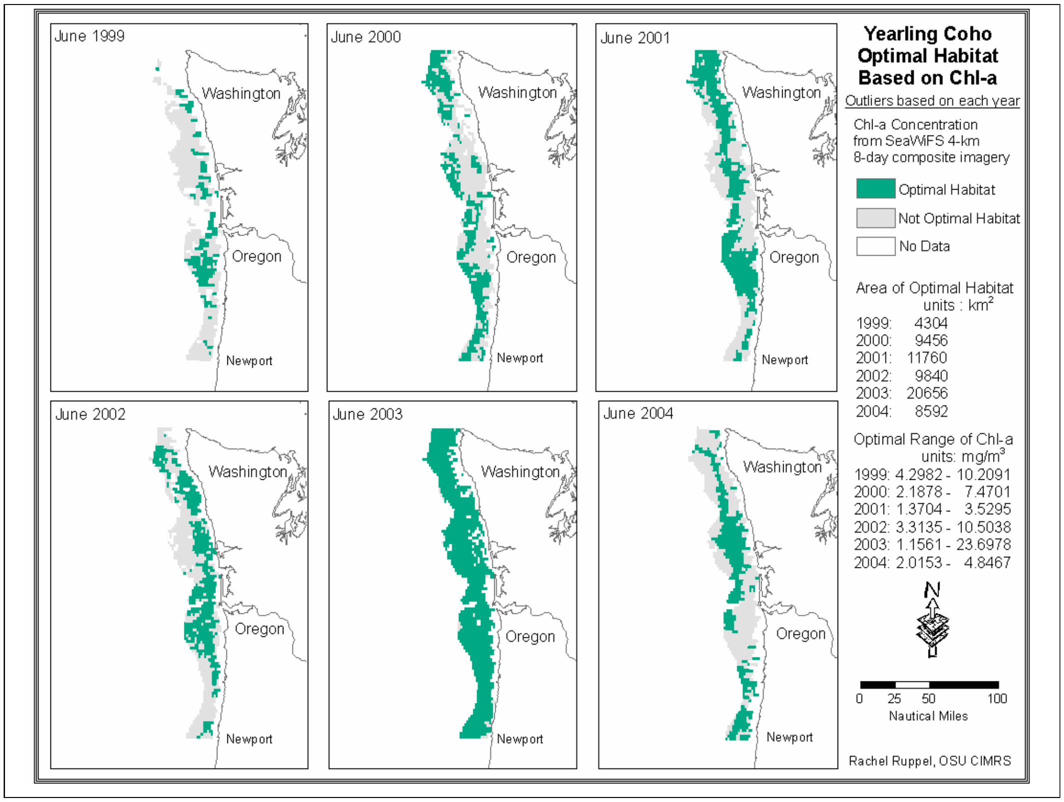
The same patchiness is apparent for yearling coho, as well. The LaPush transect has the most outlier stations, although coho outlier stations tend to range farther offshore and also farther to the south than coho. It is important to note that the scale of fish abundance is much higher for yearling coho.



Once the outlier stations were identified, I could define the [chl-a] at each of those stations using the above SeaWiFS images. Andy Thomas and his student, Peter Brickley, did the processing and made these images available to me. I brought them into GIS and clipped out the area of interest. These are eight-day composites, which helps to overcome the problem of cloud cover, most evident in the June 1999 image. For each cruise, I defined an optimal range of [chl-a] from the outliers detected on that cruise only.



Using that optimal range, I reclassified the SeaWiFS image to reflect optimal habitat. I also limited the area of optimal habitat to the shelf, defined as the 200m isobath. From the legend, you can see that the habitat area and optimal range in [chl-a] were variable between years. 2000 and 2003 had the largest habitat, and 1999 and 2002 had the smallest habitat. The 40% cloud cover in 1999 was a confounding factor.



For yearling coho, 2003 is the year with the largest habitat and 1999 has the smallest habitat. The other four years have relatively similar habitat areas, but dissimilar habitat distributions.

ANOVA: The mean percent habitat area is significantly different among years, α = 0.05

Duncan Groupings: Means with the same letter are not significantly different, α = 0.05

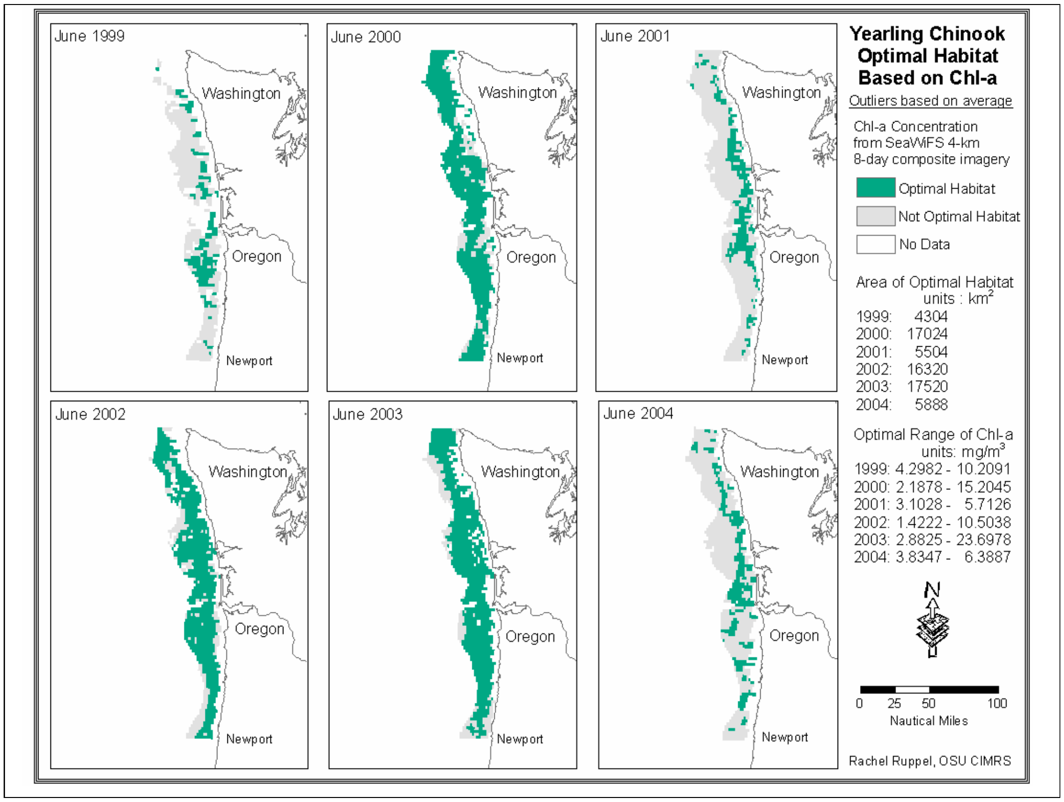
Chinook Annual

Duncan Grouping		Mean	N	Year
	A	0.8093	10	2000
	A			
	A	0.6632	10	2003
	B	0.3929	10	2004
	B			
C	B	0.2260	8	1999
C	B			
C	B	0.1660	10	2001
C				
C		0.1455	9	2002

Coho Annual

Duncan Grouping	Mean	N	Year
A	0.8156	10	2003
B	0.5158	10	2000
B			
B	0.4512	10	2001
B			
B	0.4214	10	2004
B			
B	0.3359	9	2002
B			
B	0.2260	8	1999

To compare habitat area between years in a more quantitative manner, I divided the GIS layer into ten blocks, one for each transect, and calculated the percent of optimal habitat out of the total habitat area for that block. Because blocks were different sizes, I weighted the percentage by the total habitat area for that block. To reduce effects from cloud cover, I removed blocks with more than 50% cloud cover from analysis. ANOVA was done to test the null hypothesis that the mean habitat area is the same for every year, and this hypothesis was rejected. In addition, I found the Duncan groupings, which placed years with similar means into groups labeled A, B, or C. The same patterns evident in the maps are reflected here.



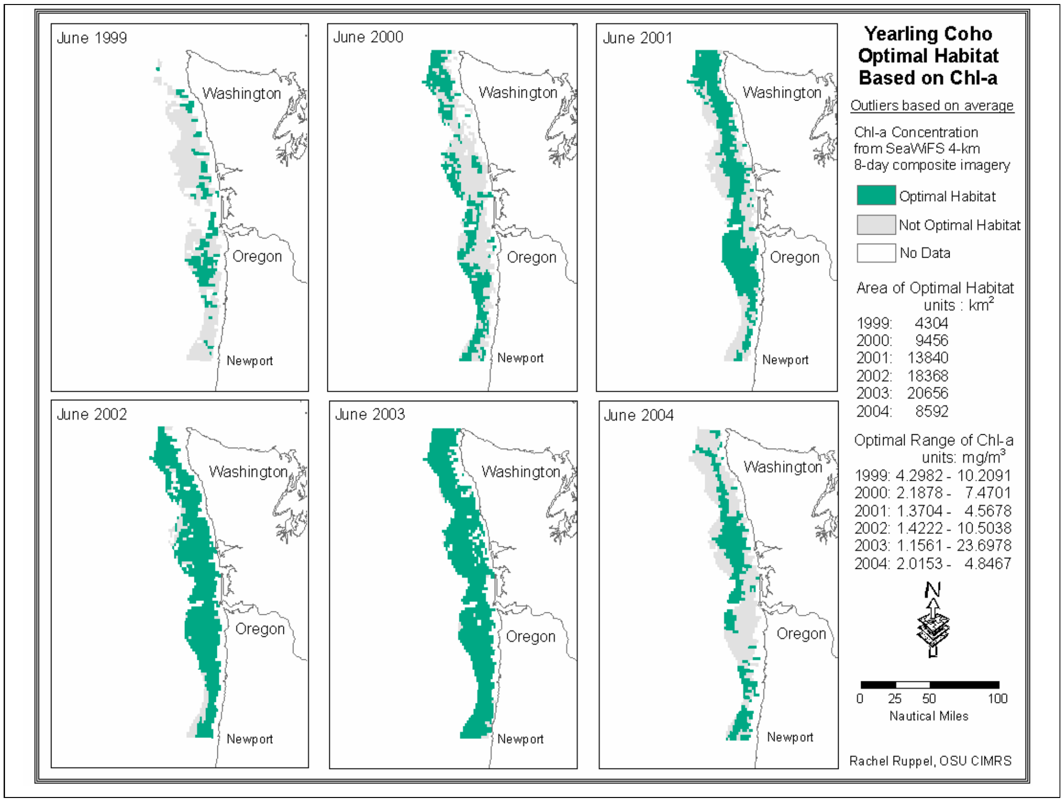
I also tried a second version of the methods, in an effort to look more carefully at interannual variation. The peak abundances of juvenile salmon were often different from year to year, but the method I had used previously defined outliers based on that year's catch alone. In years with very high catches, I may have missed some stations, and in years with very low catches, I may have included some stations that would not be considered outliers in any of the other years. So I combined all six years of data for each species, and defined outlier abundances as higher than the pooled median abundance plus one standard deviation. Then I performed the analysis in the same way as before, just with a new cutoff value to determine outliers.

For Notes Below only

Here is the resulting map for yearling chinook. Four of the years stayed exactly the same as with the first method; for 2002 the habitat area increased by a factor of four, and for 2004 the habitat area decreased slightly.

June 1999-2004 BPA Stations Identified as Outliers for Salmon Abundance
Method for Detecting Outliers: Pool data from all years; calculate statistics, & declare cutoff as median + 1SD

	Yearling Chinook			*Yearling Coho*	
	Station	Abundance		Station	Abundance
1999	LP04	334.11	1999	LP04	257.00
	LP06	324.35		GH06	1470.05
	LP09	241.66		WB09	255.19
	GH06	370.41		CR07	329.99
	CM01	67.76			
2000	LP04	101.58	2000	LP12	291.84
	LP09	112.47		GH21	303.51
	LP12	178.35		GH26	219.67
	LP17	178.35			
	GH10	79.21			
	GH16	176.85			
2001	QR06	141.21	2001	LP04	816.90
	GH06	83.12		LP06	223.96
	WB05	82.08		LP09	251.37
	CR04	157.84		QR06	282.42
				GH06	415.61
				GH21	322.12
				CM10	196.87
2002	LP04	63.88	2002	LP04	276.81
	LP06	172.00		LP06	795.52
	LP09	239.55		LP09	522.65
	QR14	90.96		QR14	618.54
	GH21	62.17		GH21	248.68
	WB05	200.16			
2003	LP06	266.09	2003	LP06	746.78
	QR14	76.98		LP17	553.01
	GH03	153.32		LP22	980.83
	CR07	136.31		QR14	273.71
				QR24	1295.83
				CR30	380.50
				CH02	204.87
				CH05	283.04
				CH10	306.01
2004	LP06	64.03	2004	QR14	603.35
	LP09	72.08		NH10	234.42
	QR14	79.86			



And the resulting map for yearling coho. In 2001, habitat area increased slightly, and in 2002, habitat area almost doubled.

ANOVA: The mean percent habitat area is significantly different among years, α = 0.05

Duncan Groupings: Means with the same letter are not significantly different, α = 0.05

Chinook Average

Duncan Grouping	Mean	N	Year
A	0.8093	10	2000
A			
A	0.6632	10	2003
A			
A	0.6154	9	2002
B	0.2556	10	2004
B			
B	0.2260	8	1999
B			
B	0.1660	10	2001

Coho Average

Duncan Grouping	Mean	N	Year
A	0.8156	10	2003
A			
B A	0.6983	9	2002
B			
B C	0.5177	10	2001
B C			
B C	0.5158	10	2000
B C			
B C	0.4214	10	2004
C			
C	0.2260	8	1999

ANOVA showed again that the mean percent habitat area was different among years, but the Duncan groupings tell a slightly different story from the first method. For yearling Chinook, two groups become evident – large habitat years 2000, 2002, and 2003 and small habitat years 1999, 2001, and 2004. For yearling coho, 2002 and 2003 have the largest habitat and 1999 has the smallest habitat and for the other years, habitat areas are relatively similar.

Further directions I'm planning:

Compare the optimal habitat distribution to the actual distribution of fish for each year – this should shed some light on the accuracy of the method and also the amount of good habitat that is not occupied.

Some suggestions from the synthesis meeting:

There may be a lag between primary productivity and salmon habitat selection – investigate this lag using composites from early June

Define one optimal range of [chl-a] and use it to classify all years. This can be used to go forward or backward in time to determine habitat.

Examine the relationship of habitat area to survival and other data (Growth? Size?)

Include more variables, i.e. SST and zooplankton