Relationship of ocean environmental factors to salmon growth, survival and maturation

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General questions

1. At what scale are we dealing?
2. What variables sufficiently describe the environment of interest?
3. What defines a ‘good’ environment?
4. Can we develop a simple scalar that can act to inform us on the ‘quality’ of the ocean condition?
5. In what ways does the environment relate to salmon dynamics?

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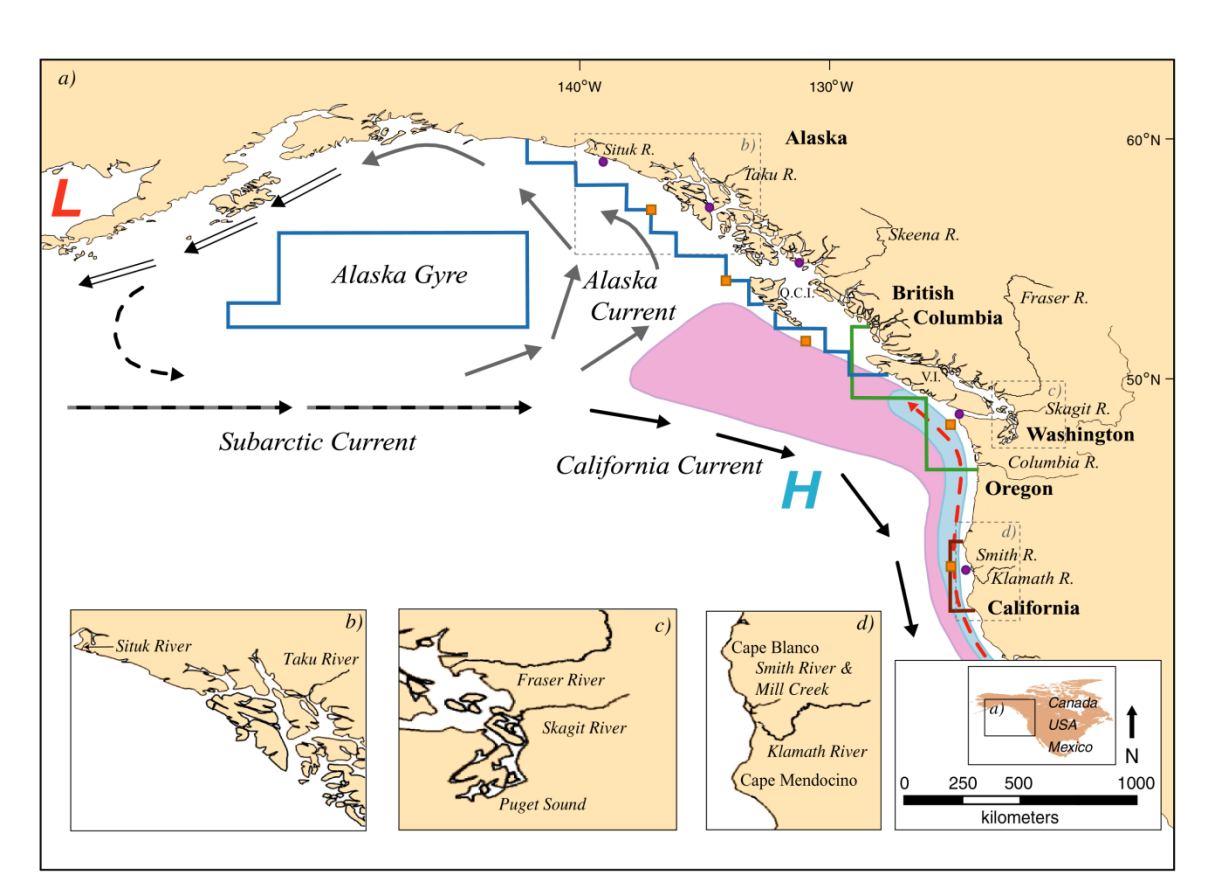
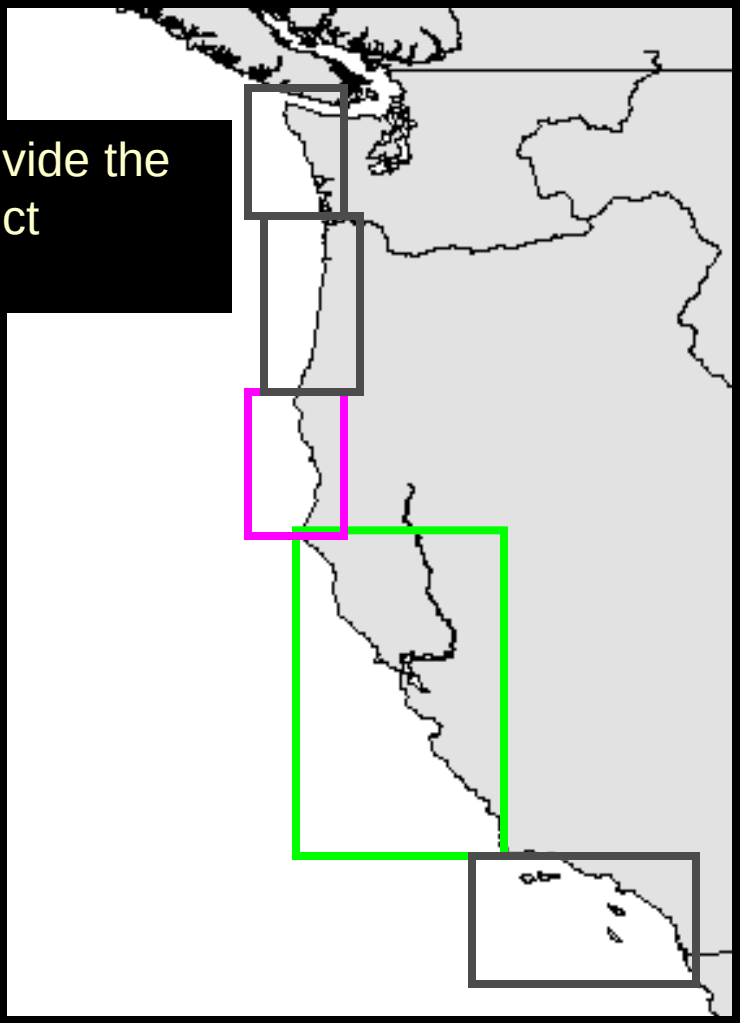


Wells et al. Figure 1

There is large-scale variability but this can only be affectively examined using gross indicators that yield little mechanistic information and they have failed to be fine enough to improve forecasting models

1. At what scale are we dealing?

Based on coastal geography we can divide the California Current into somewhat distinct environments.



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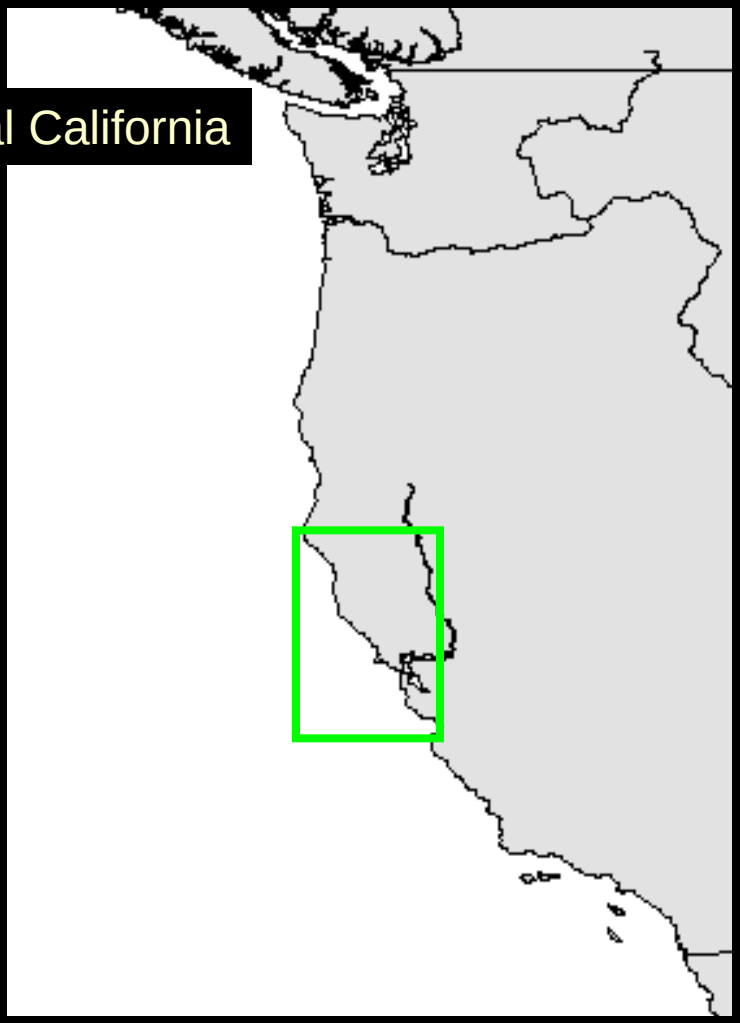
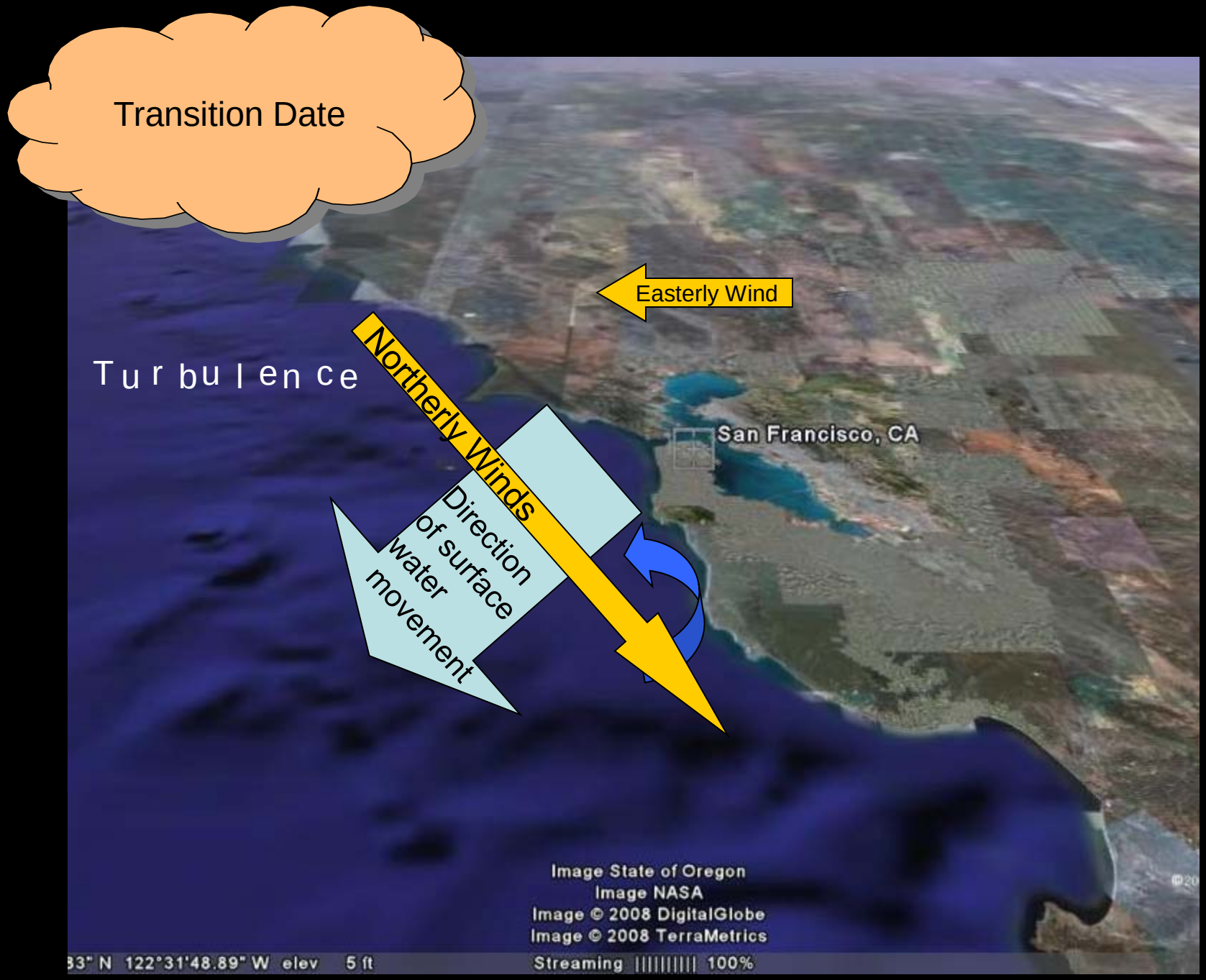
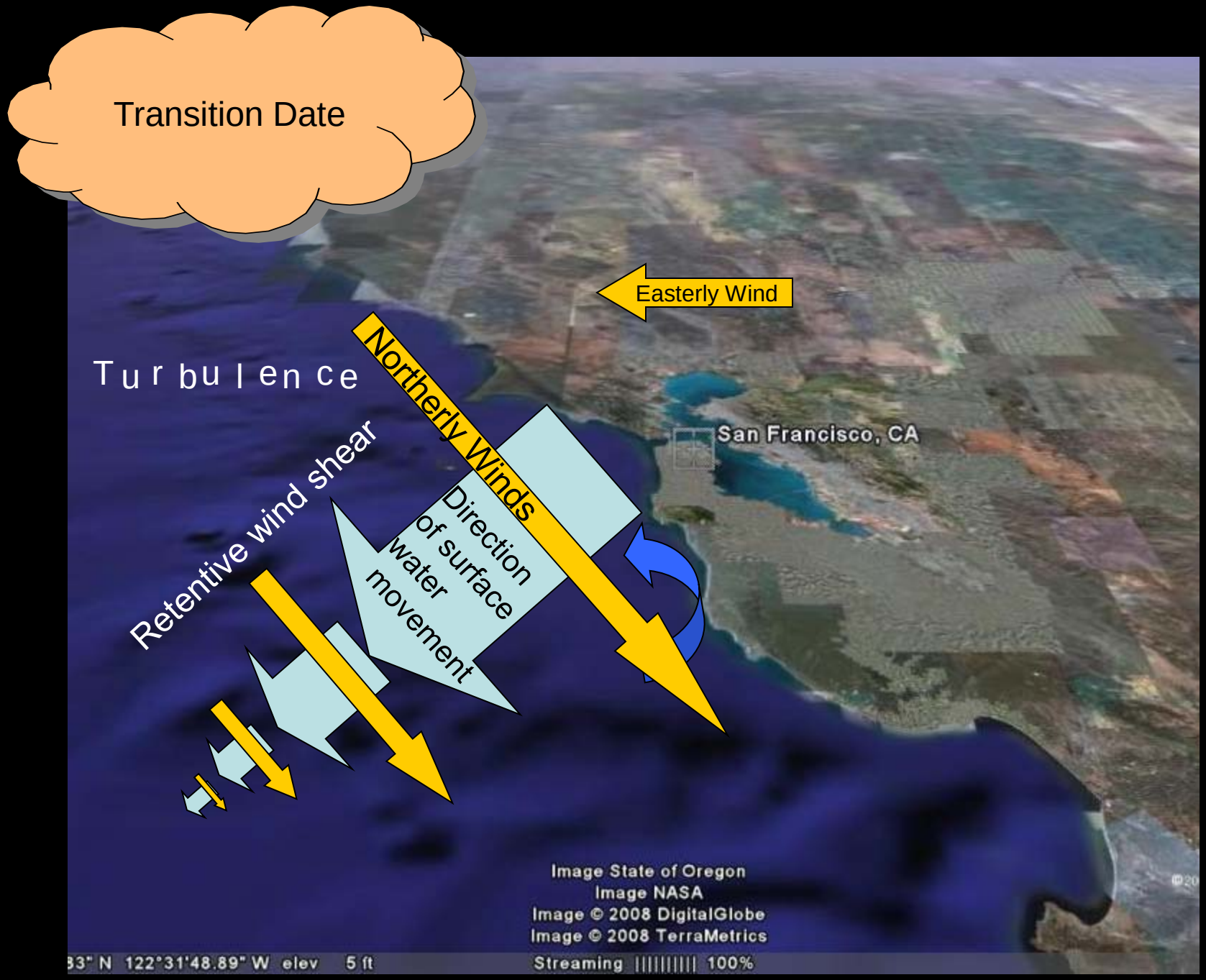
2. What variables sufficiently describe the environment of interest?

Let’s start by examining central California




Transition Date
Easterly Wind
Northerly Winds
Turbulence
Direction of surface water movement
San Francisco, CA
Image State of Oregon
Image NASA
Image © 2008 DigitalGlobe
Image © 2008 TerraMetrics
33" N 122°31'48.89" W elev 5 ft
Streaming 100%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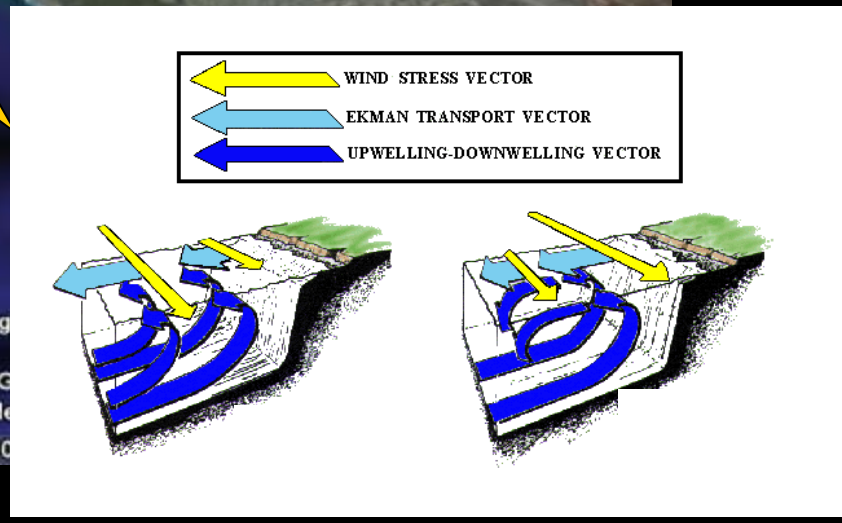


Image State of Oreg
Image NASA
Image © 2008 DigitalG
Image © 2008 TerraMe

33" N 122°31'48.89" W elev 5 ft

Streaming 10

Transition Date

With these conditions SST and SLH are reduced.

Easterly Wind

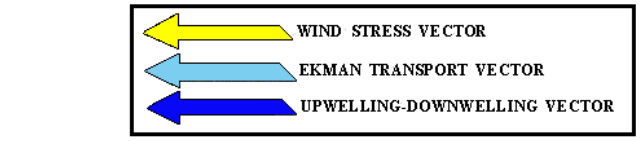
Northerly Winds

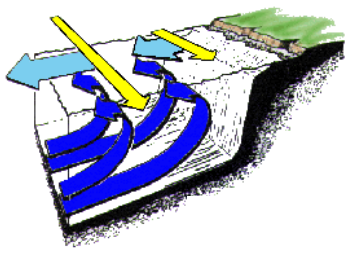
Turbulence

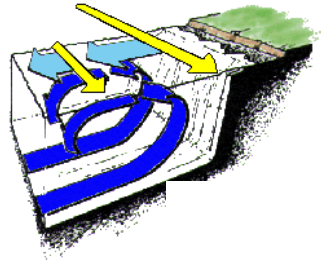
Retentive wind shear

Direction of surface water movement

San Francisco, CA







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Streaming

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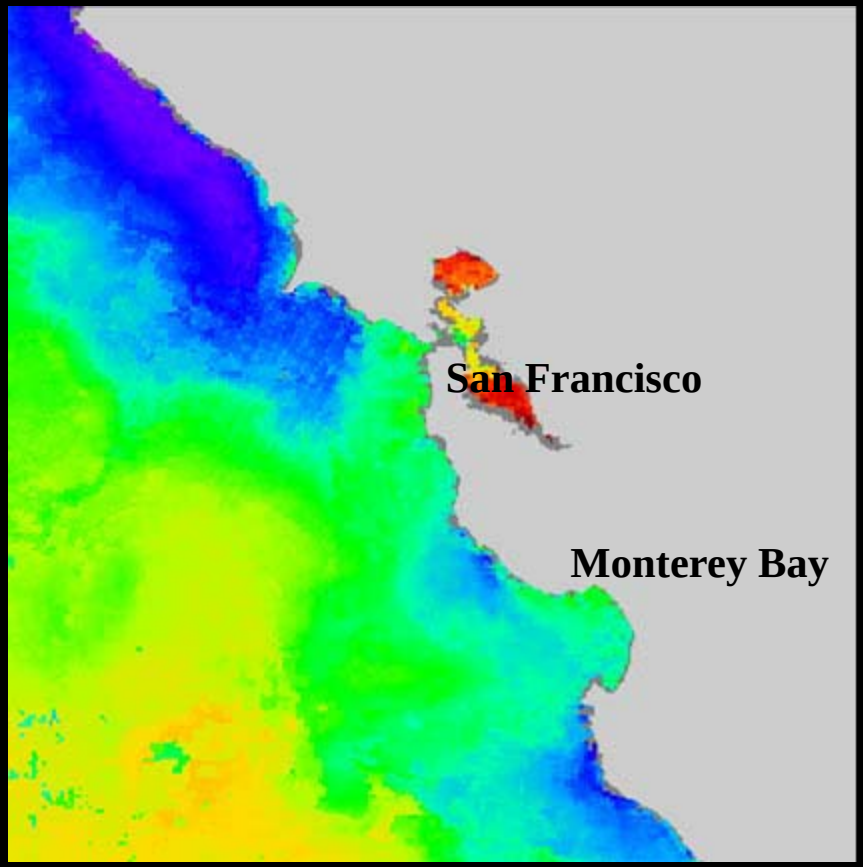
3. What defines a ‘good’ environment?

One that promotes production of the natural community structure?



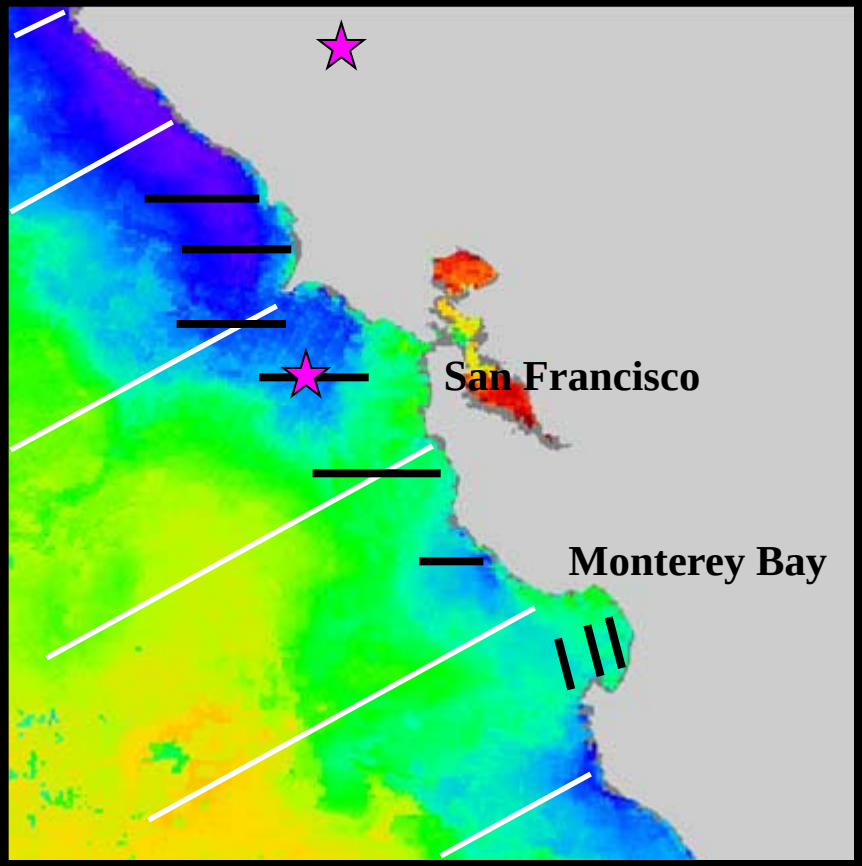
3. What defines a ‘good’ environment?

Biological data

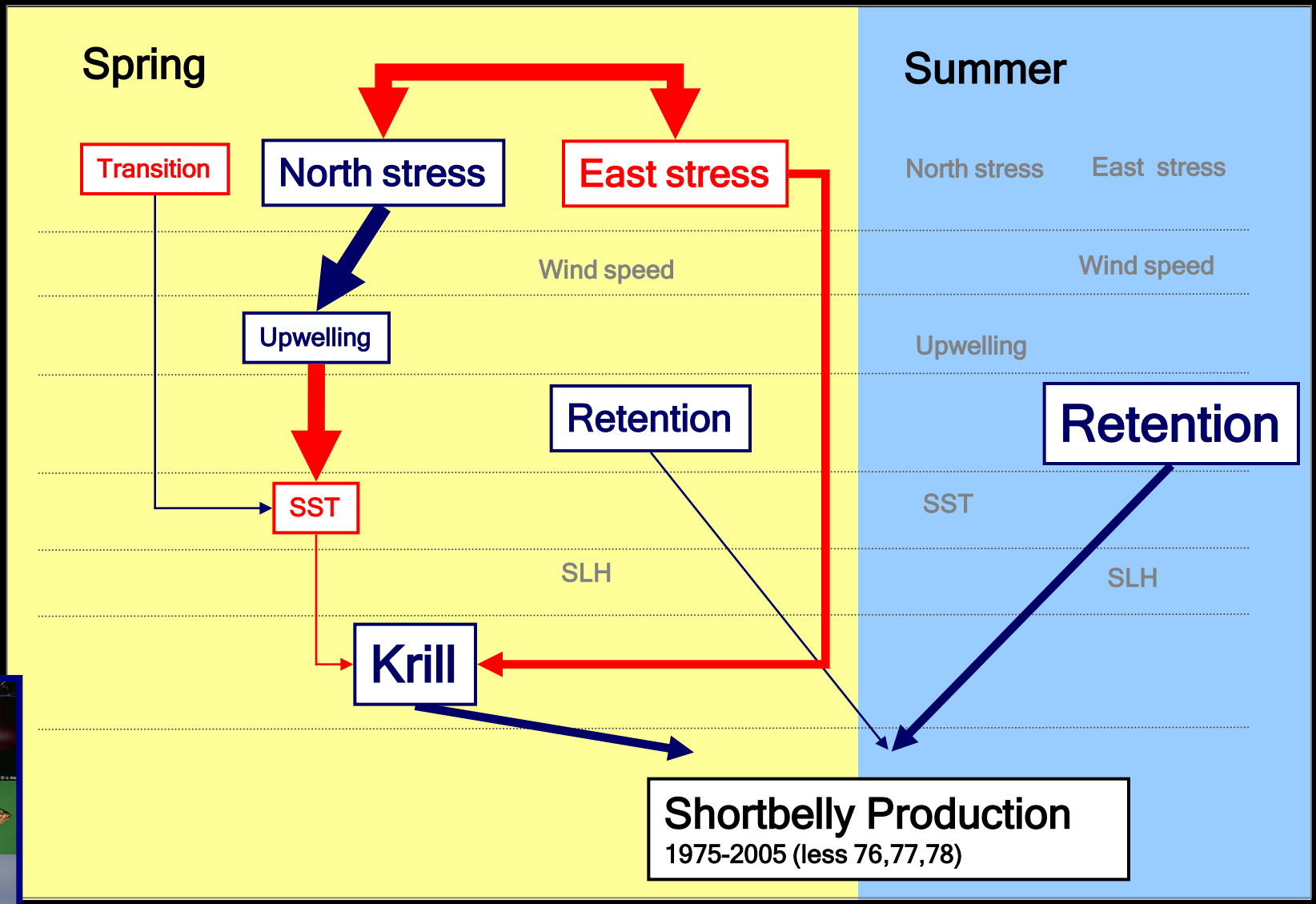
Krill abundance
Rockfish numbers
Seabird nesting success

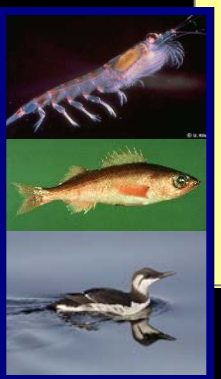
Environmental data

Spring transition date
Wind direction
Wind speeds
Upwelling
Retention
Sea Surface Temp
Sea Level Height



Shortbelly Recruitment Deviations [log(SBProduction)]





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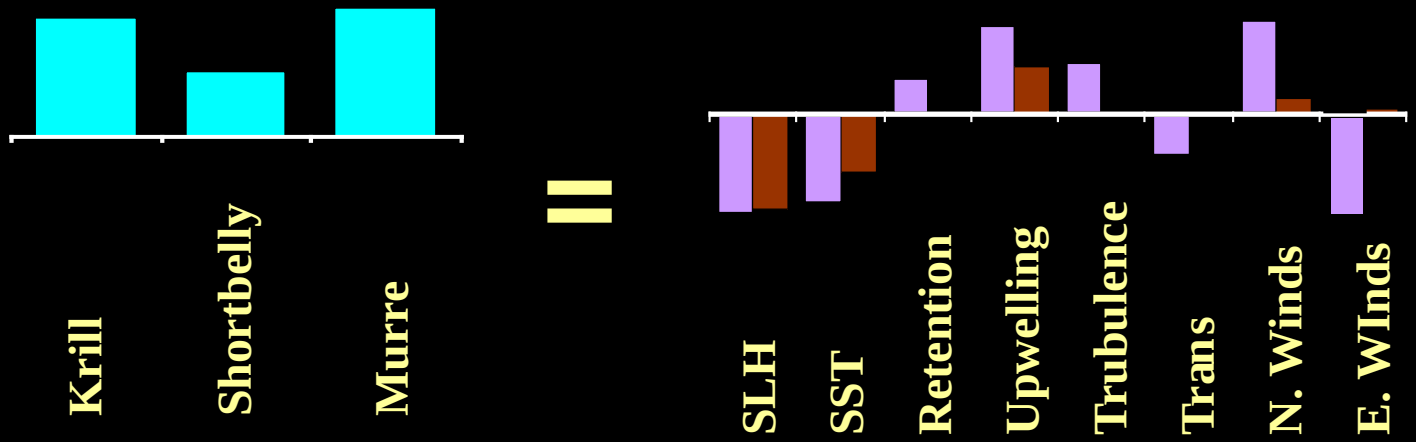
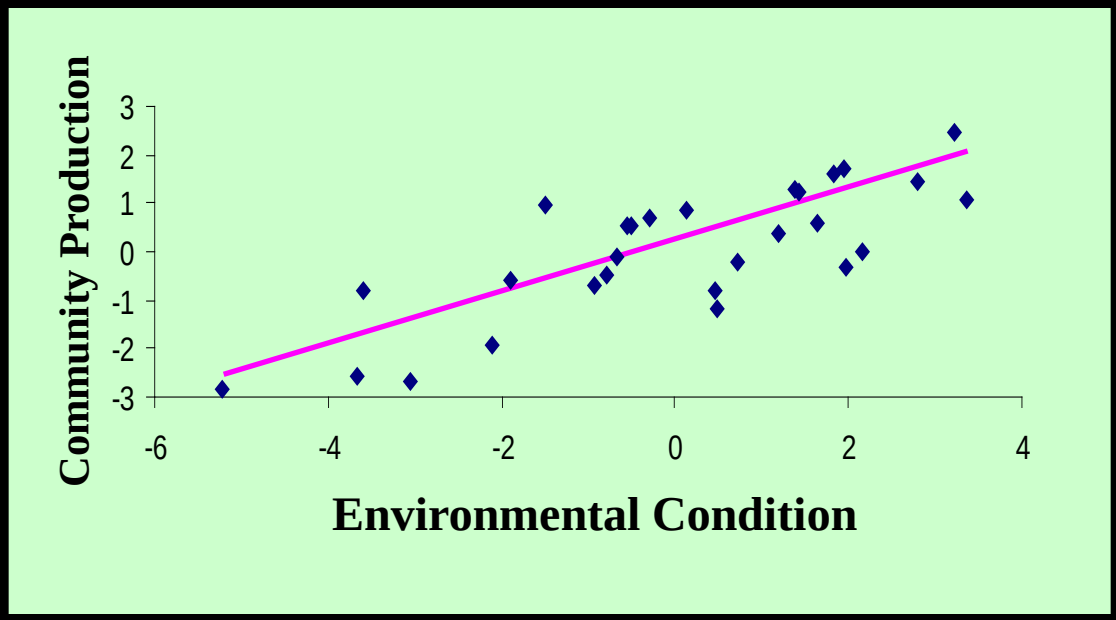
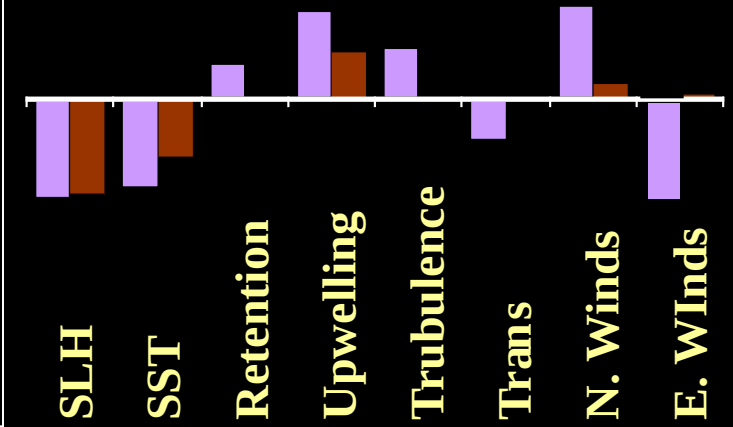
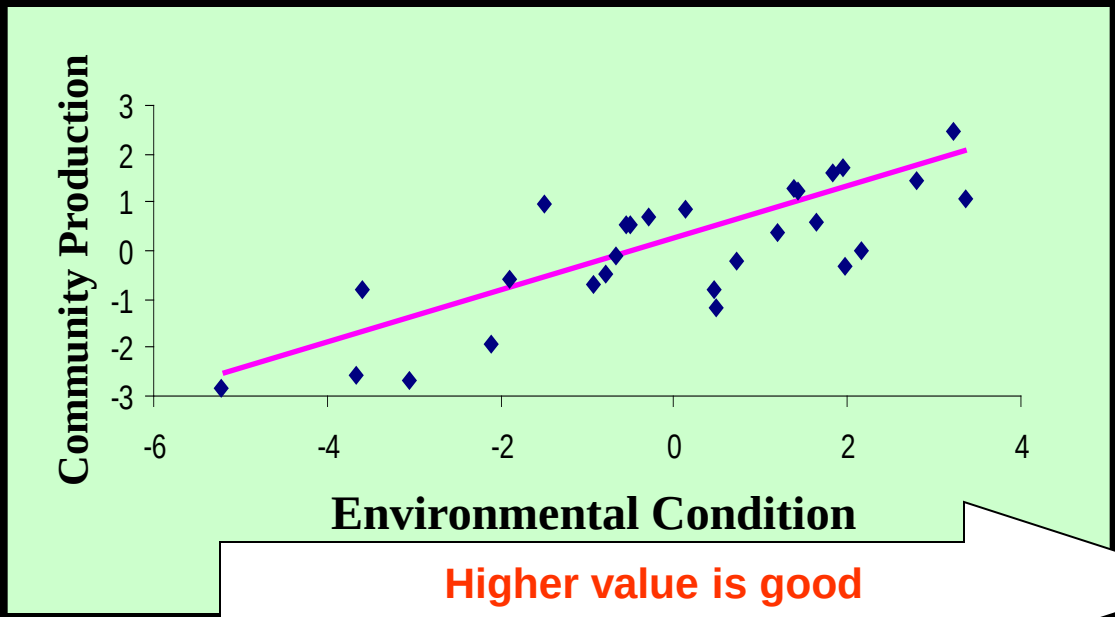




4. Can we develop a simple scalar that can act to inform us on the ‘quality’ of the ocean condition?

This environmental index can act as a indicator of ecosystem productivity and the bars directions allow you to interpret the influence of each variable on system health.





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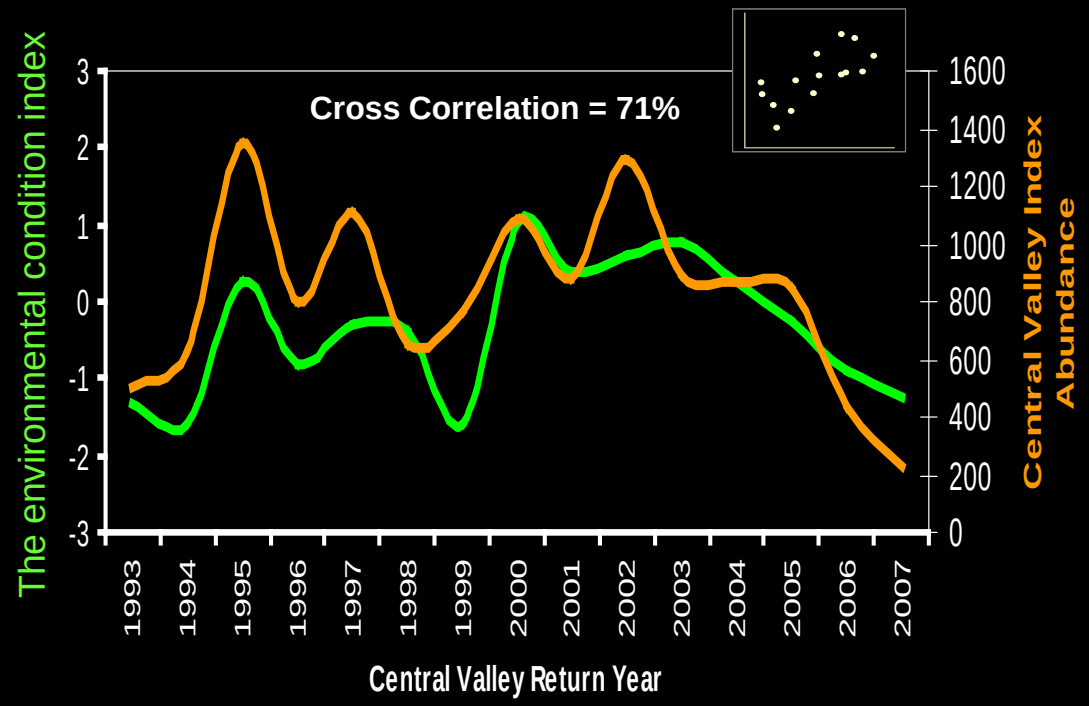
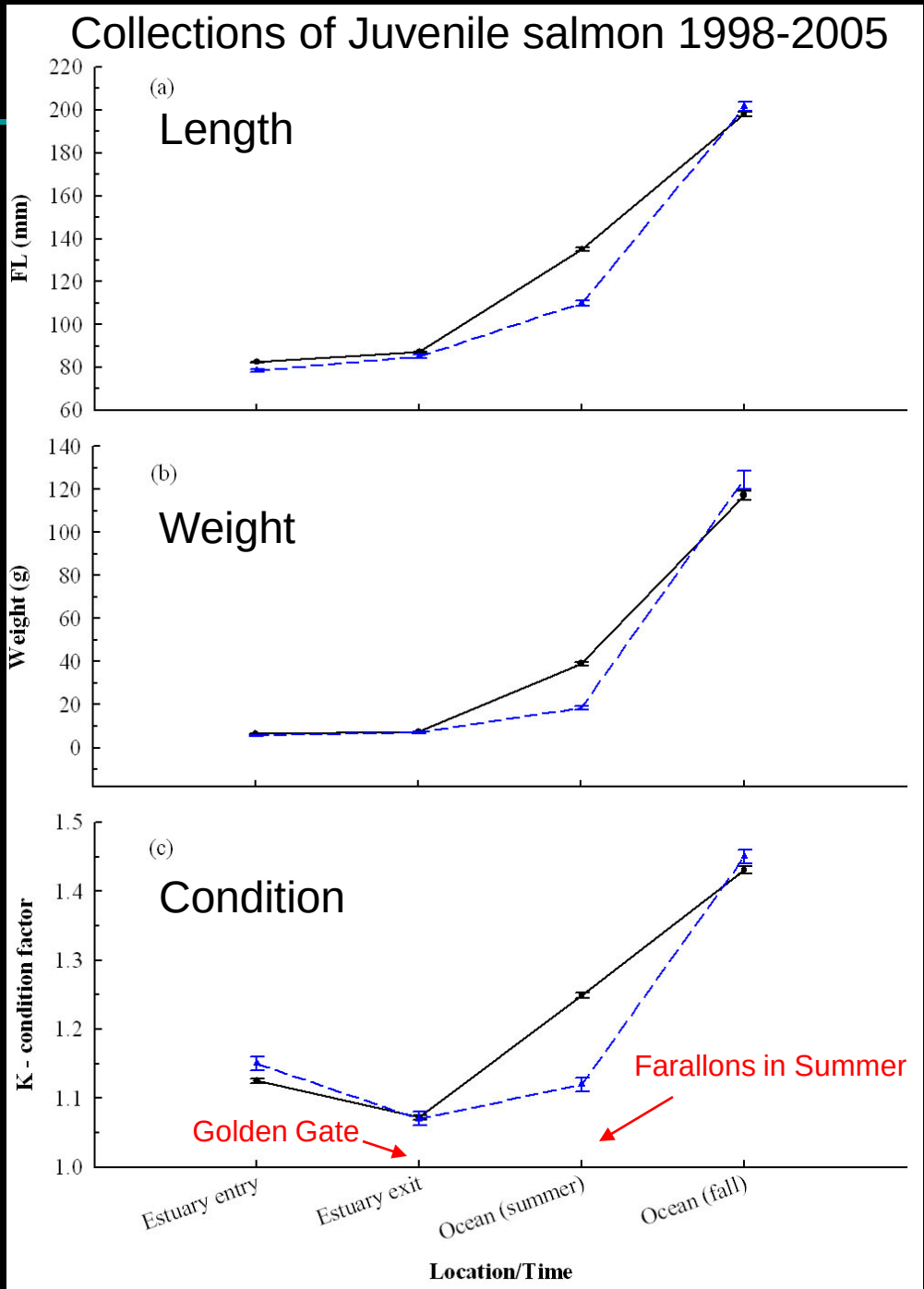
The index leads the Central Valley return numbers in the last 15 years. So, the first relationship to note is that the environment clearly relates to salmon numbers.



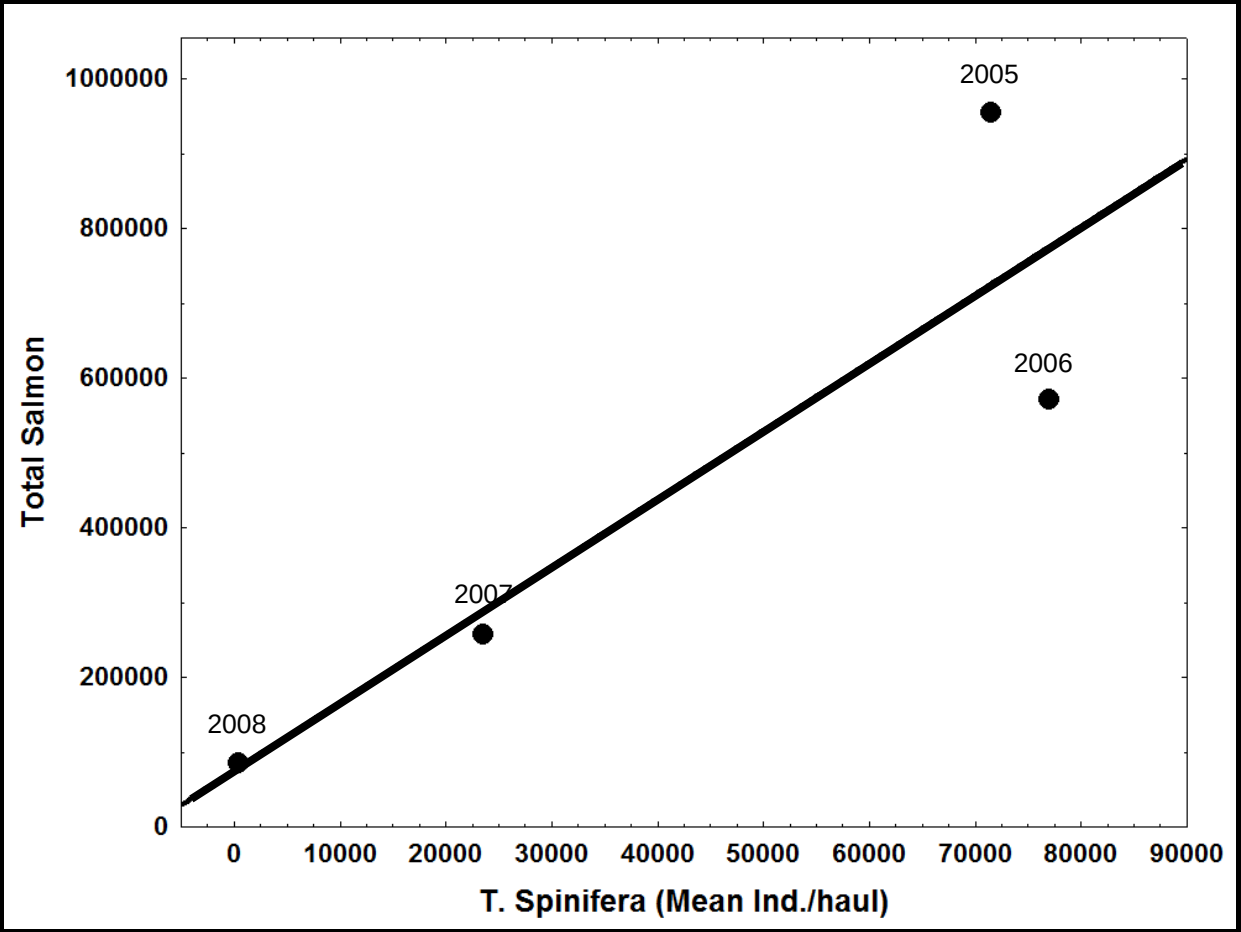
Juvenile Salmon Condition

In 2005, salmon entered ocean at an average condition to previous years but when collected during summer at Farallons they were in much worse condition than average.



Adult Salmon Abundance

Abundance of krill around Farallons ultimately relates to adult abundance (SI Index) two years later.



5. In what ways does the environment relate to salmon dynamics?

So, the environment affects survival and abundance. How about other factors?

Let's look at the variables as they relate directly to salmon and post first year variability (that following the high mortality at emigration).

5. Central Valley: In what ways does the environment relate to salmon dynamics?

Current forecast approach

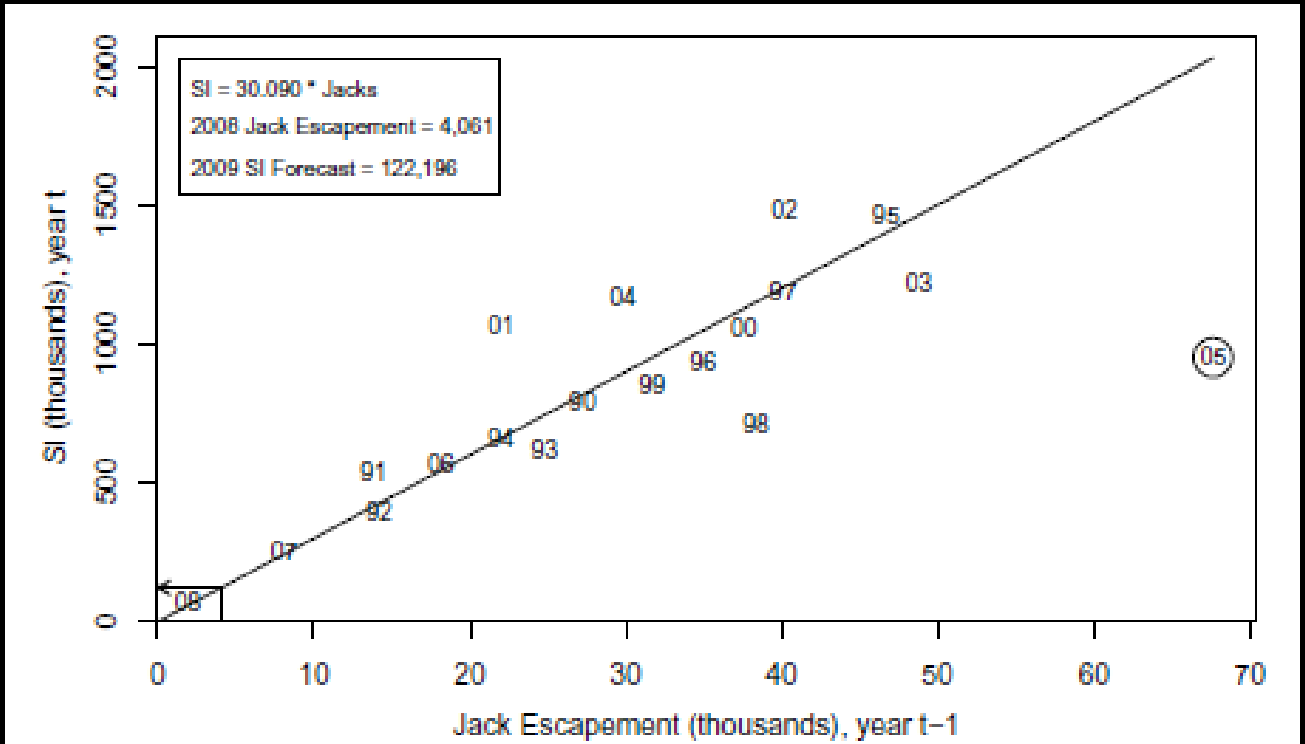


FIGURE II-2. Regression estimator for the SI based on previous year's escapement of Sacramento River fall Chinook jacks, 1990-2008, with 2005 data point omitted. Years shown are SI year. Arrows denote the use of this relationship for the 2009 SI forecast.

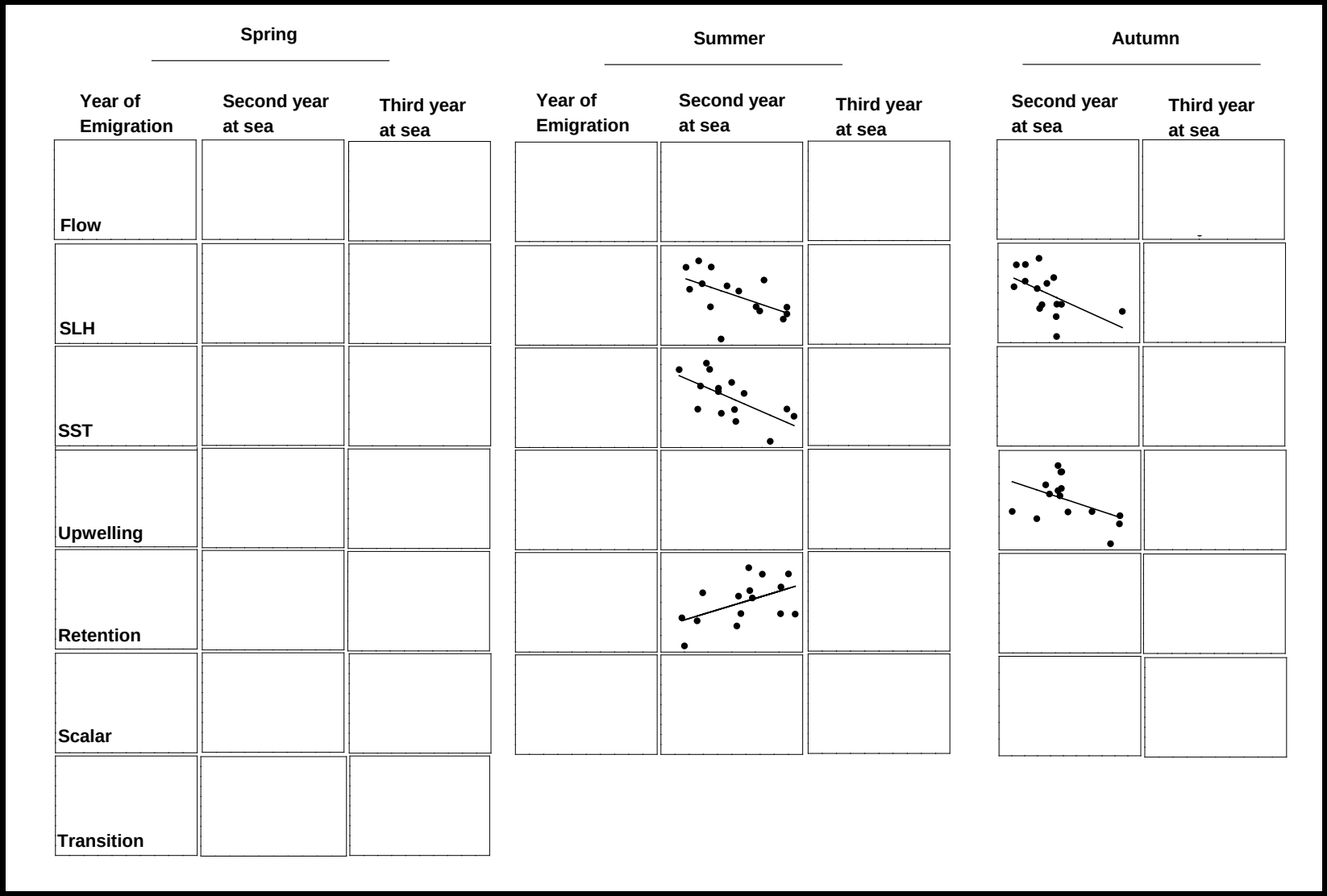
5. Central Valley: In what ways does the environment relate to salmon dynamics?

We use the residuals from this forecasting model to determine the effect of environment on population variability.

We examine relationships for a suite of variables across seasons against the residuals.

Residuals from forecasting model vs. Environmental variable

Residuals
(higher number indicates that the CV was underestimated by the sibling model and vice versa)



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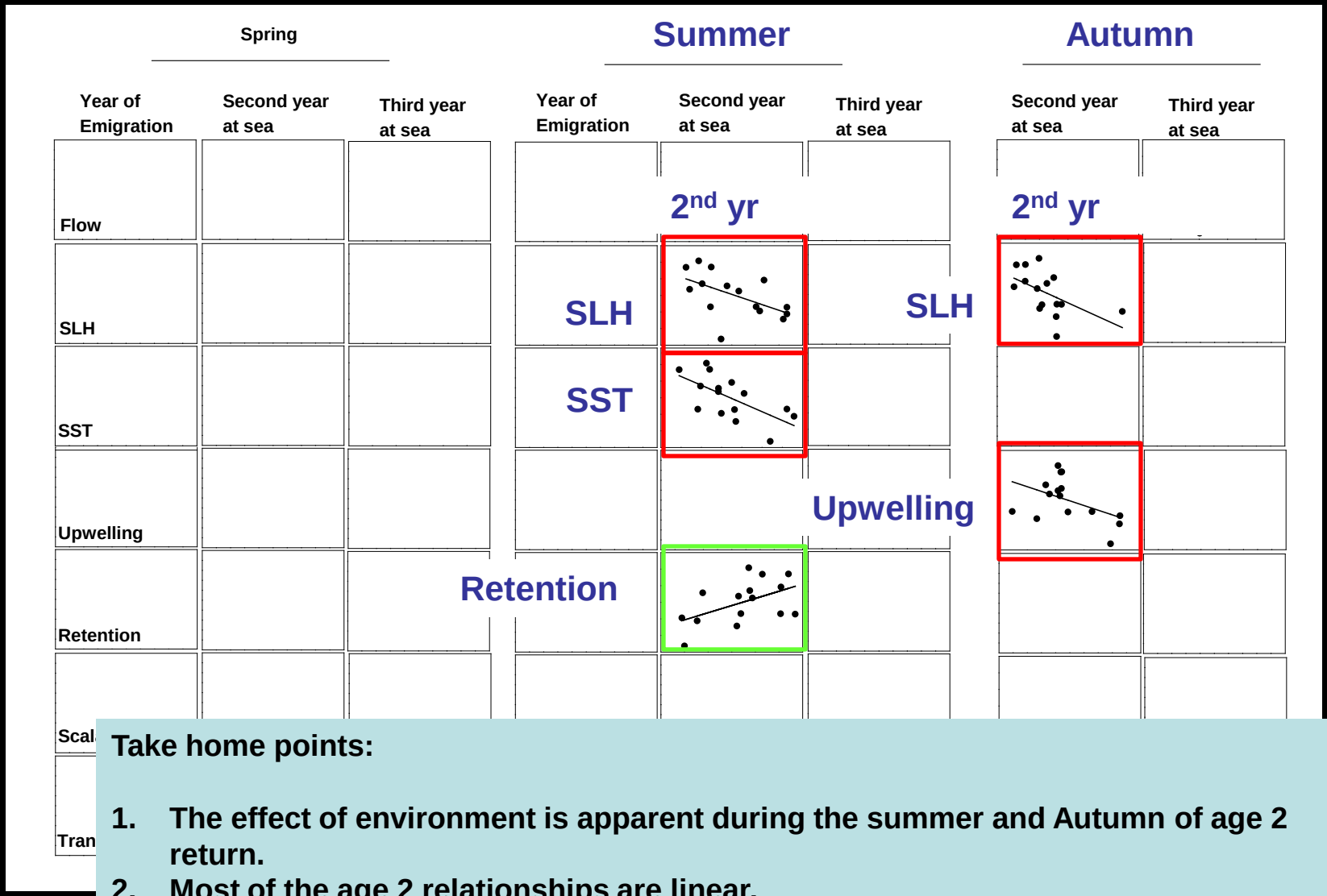


Take home points:

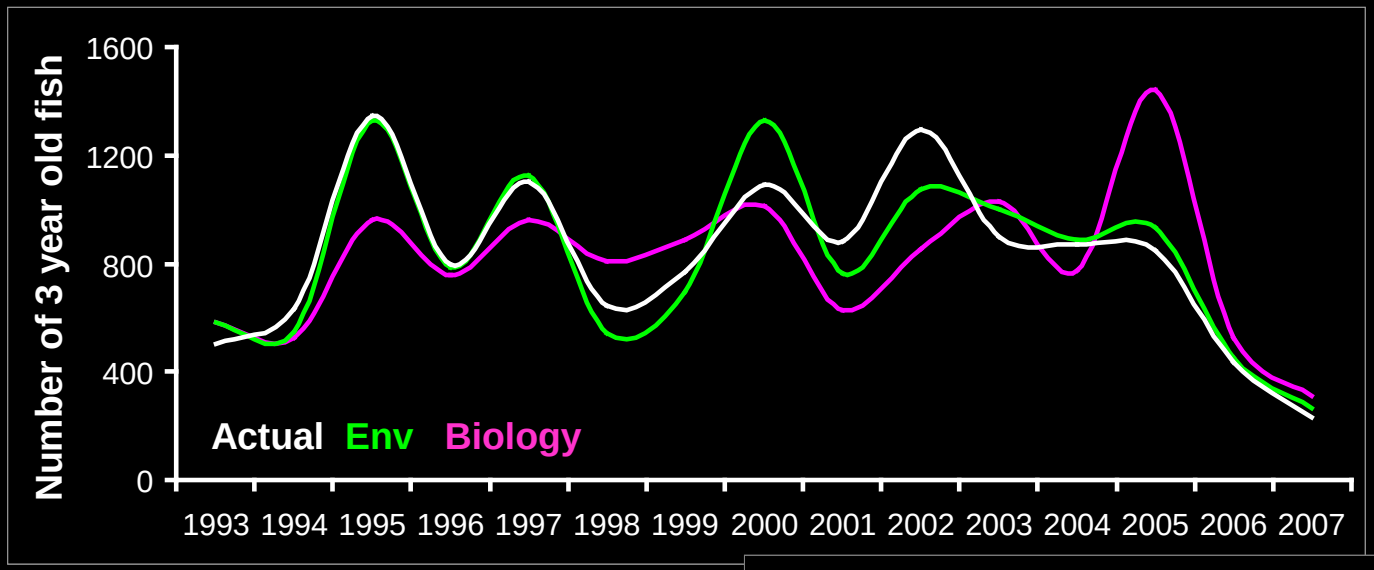
1. **The effect of environment is apparent during the summer and Autumn of age 2 return.**
2. **Most of the age 2 relationships are linear.**
3. **In the second year, conditions conducive to increased production (e.g., lower SST and SLH) cause us to underestimate remaining cohort strength. There will be more Age 3 fish returning than expected!**

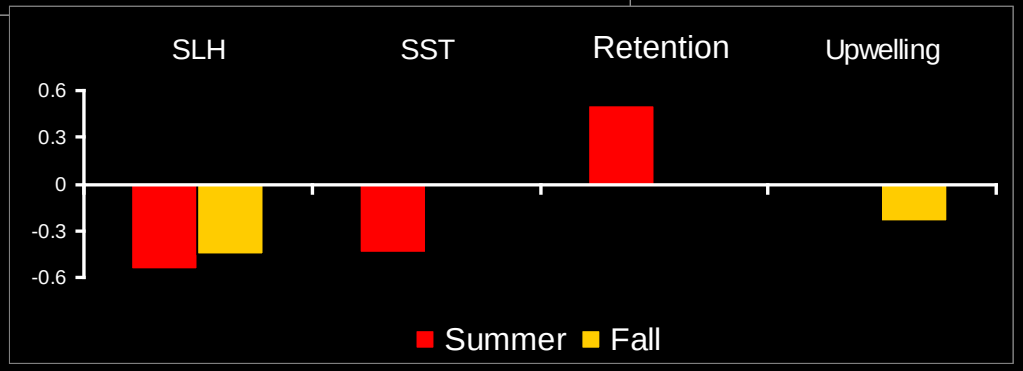
5. Central Valley: In what ways does the environment relate to salmon dynamics?

Using Age 2 returns and environmental variables from the year of emigration and second year consolidated using a statistical model we can build forecasting models that include environmental condition.

Ln(CVI) = 0.28 (Ln(Jack#)) + *0.25(Latent Env Var.)* + 6.63; R^2 = 0.92

Ln(CVI) = 0.83502(Ln(Jack Number)) + - 2.179; R^2 = 0.66

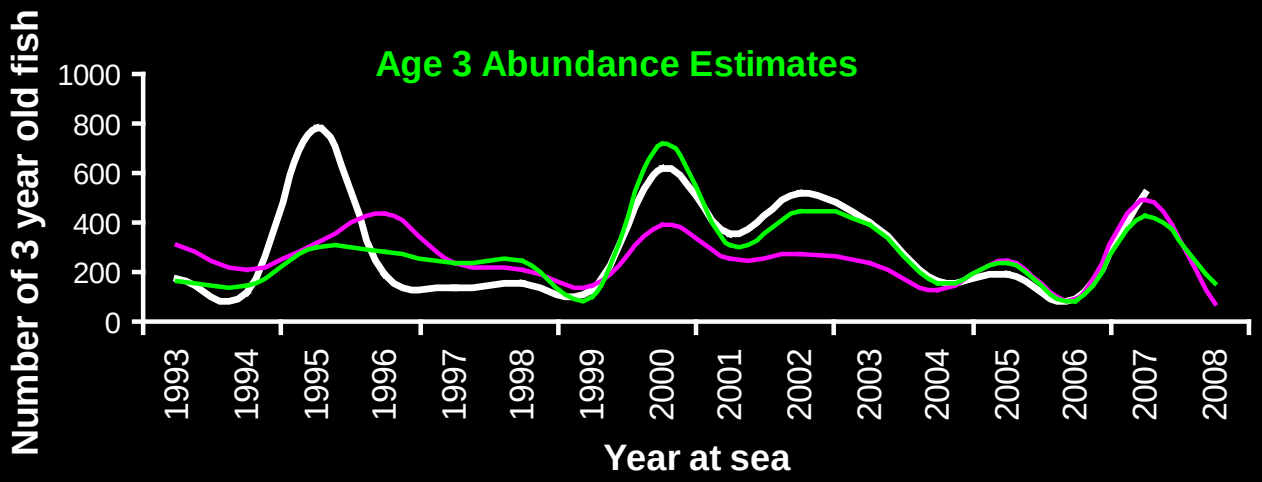


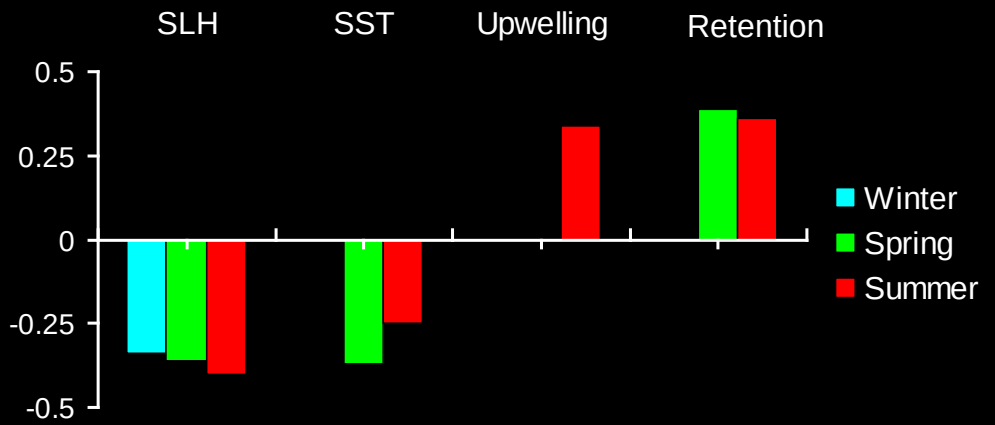


5. Klamath River: In what ways does the environment relate to salmon dynamics?

Ln(Age3) = 0.51 (Ln(Age2)) + *0.40(Latent Env Var.)* + 5.41; R^2 = 0.78

Ln(Age3) = 0.69(Ln(Age2)) + - 3.92; R^2 = 0.44



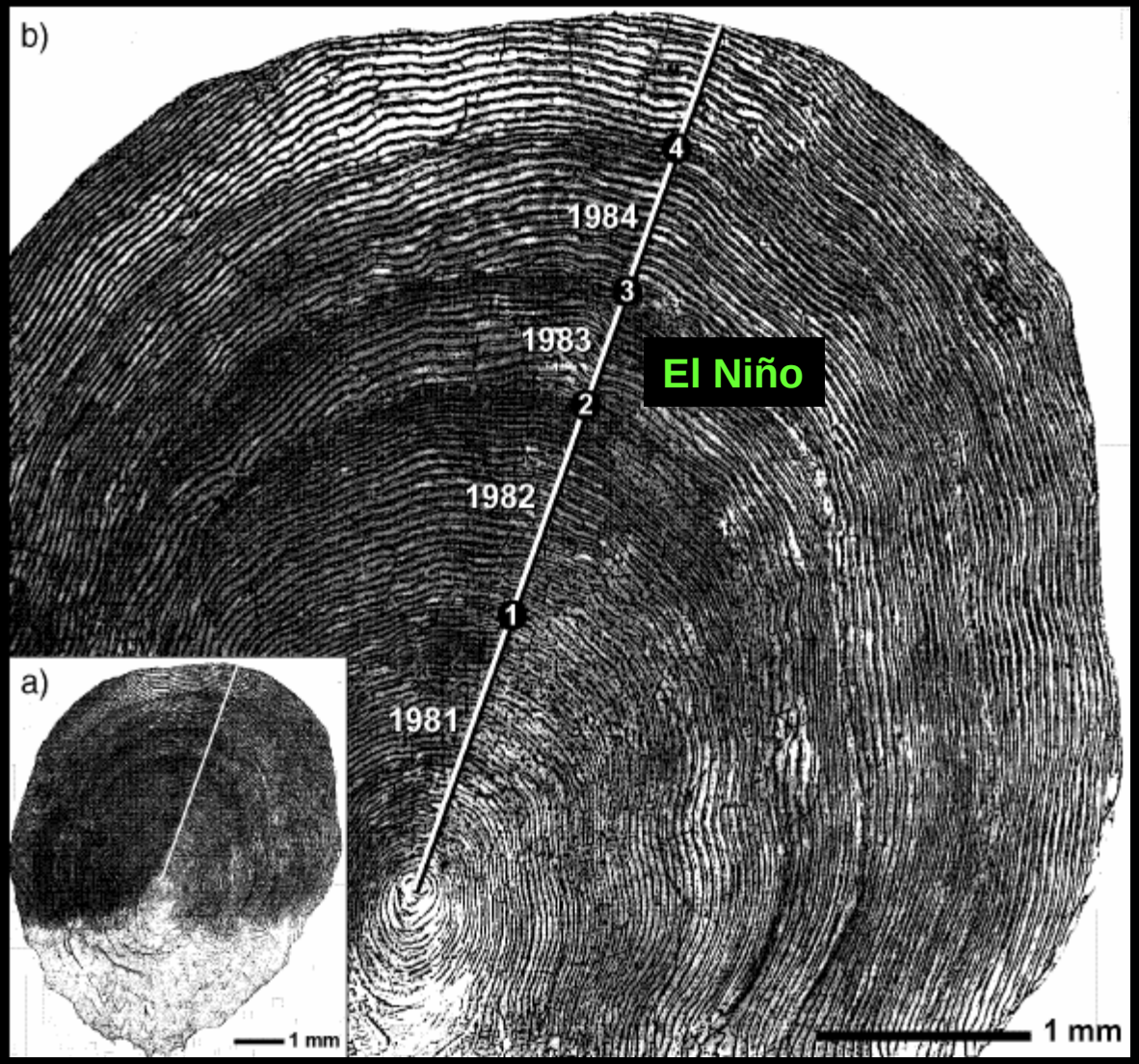


5. In what ways does the environment relate to salmon dynamics?

Let’s now focus on growth and delayed maturation. We will use Northern California Smith River Chinook salmon in this exploration.

5. In what ways does the environment relate to salmon dynamics?

We can use similar tactics to examine the effects of environment on growth



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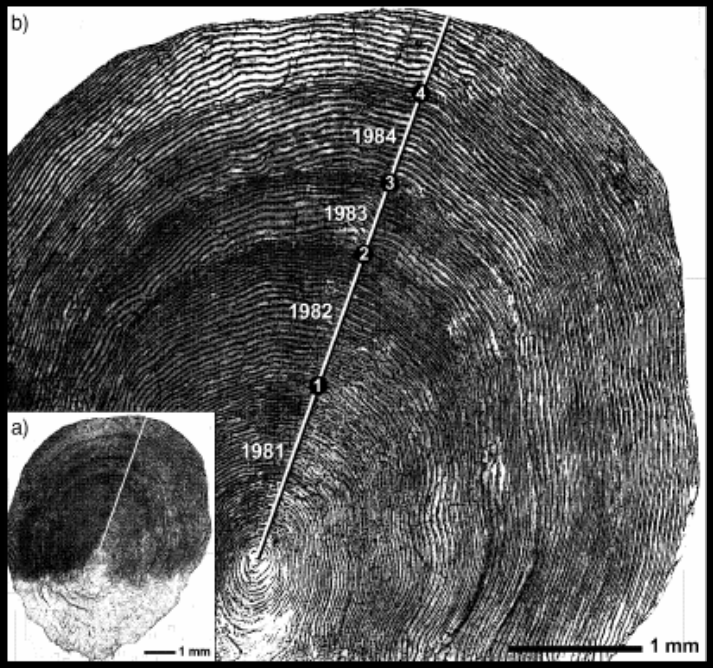

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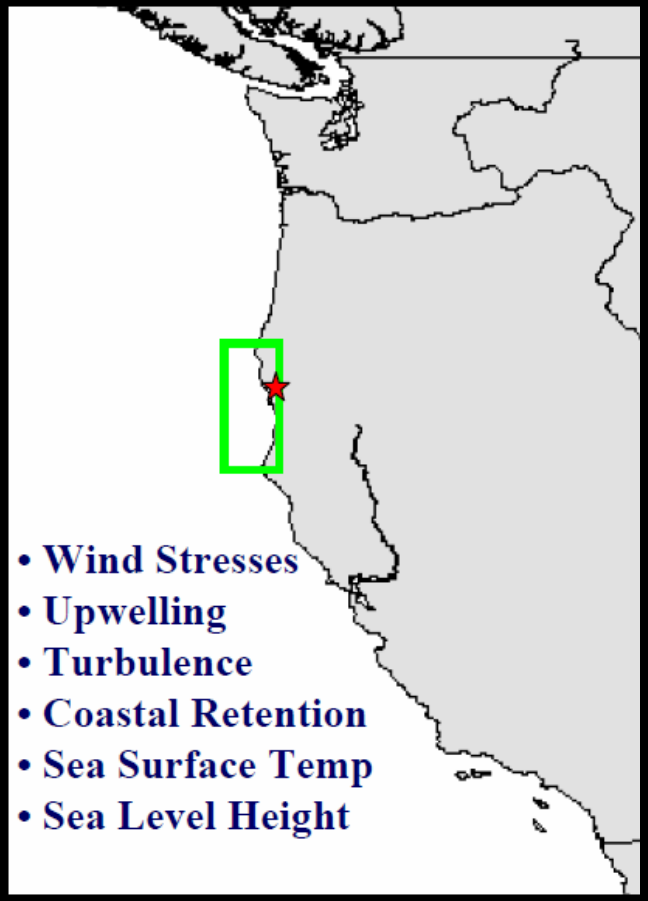
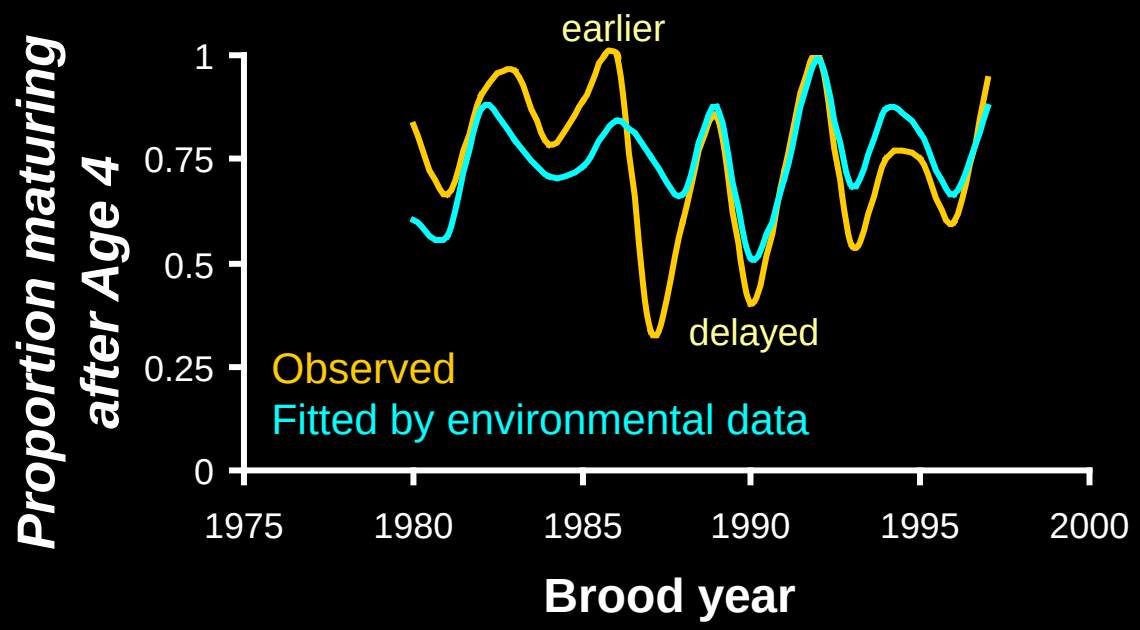


Basically, an environment not conducive to increased productivity leads to slow growth. We also demonstrate that slow growth leads to delayed maturation. And, therefore, increased mortality before fish have opportunity to spawn.

Delayed maturation of females.



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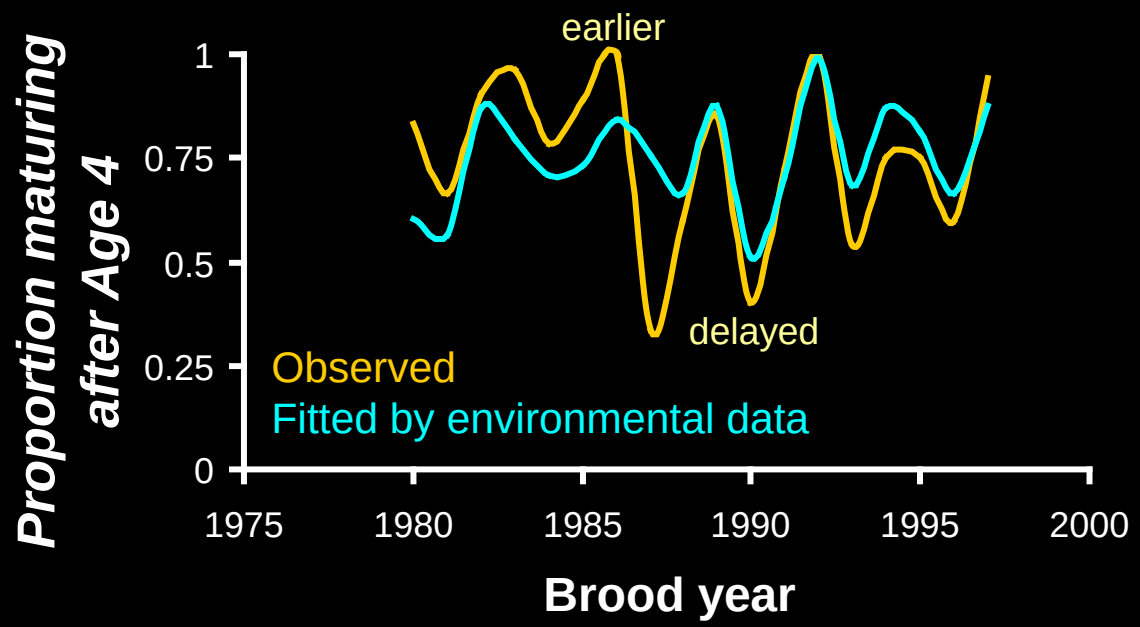

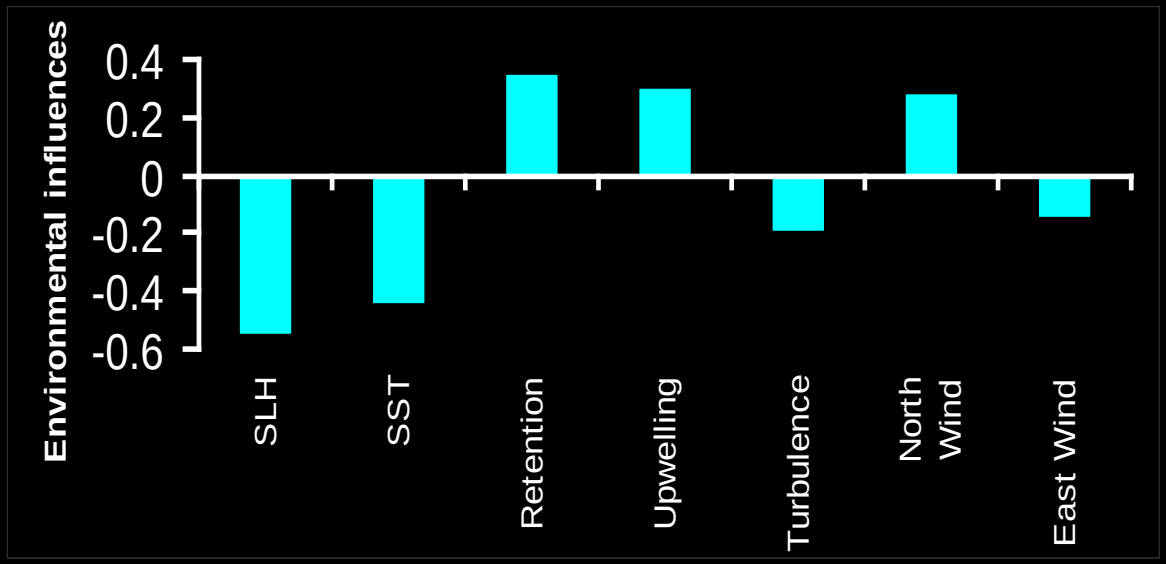

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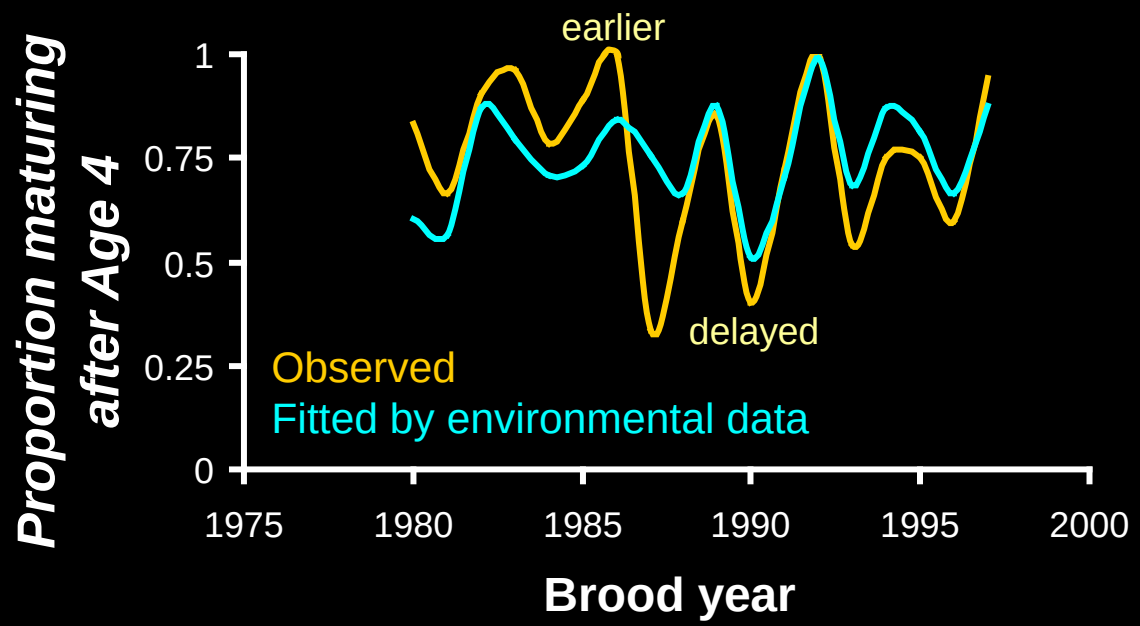
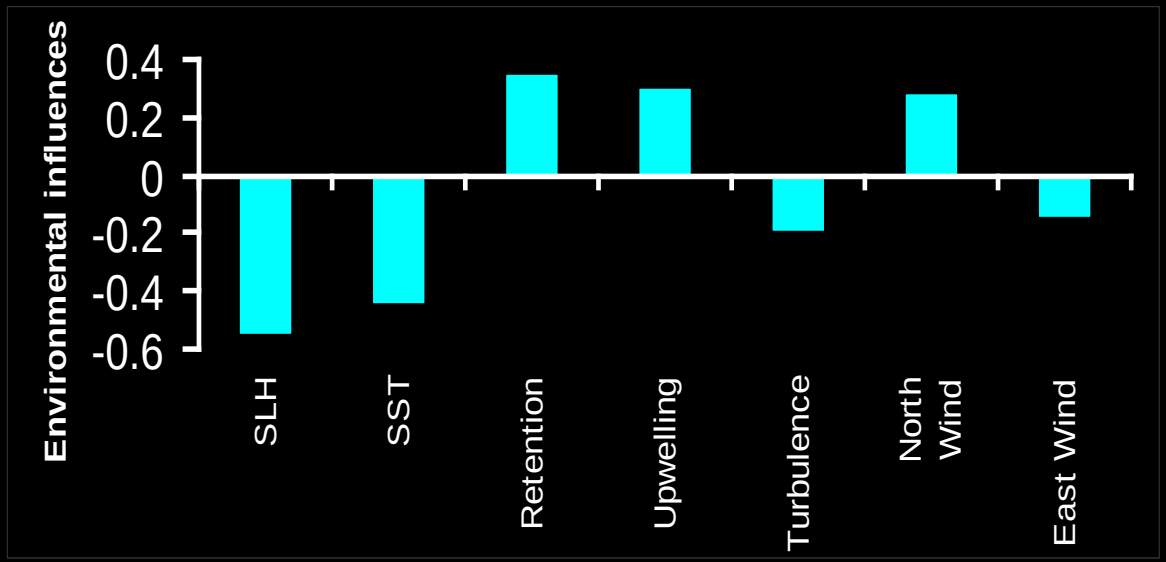
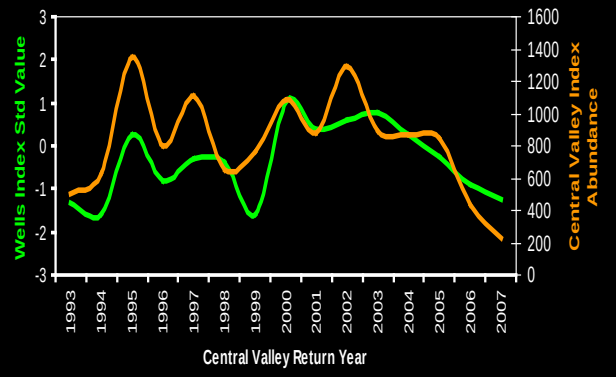


So, a good environment the year before fish typically come home promotes maturing at the appropriate age.

And a poor environment delays maturation.

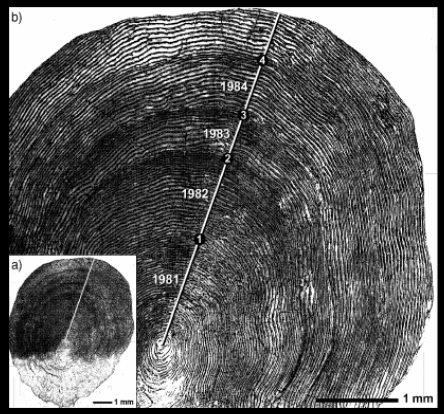


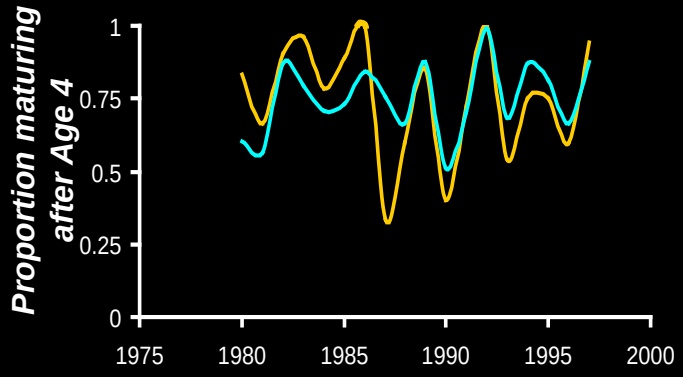
Review the effects of environment on salmon



The environment affects abundance and recent declines may relate to retention locally.

A poor environment can lead to slow growth





A poor environment can lead to delayed maturation of females

Conclusions

We can develop a descriptive scalar that may provide a measure of ocean quality based on the interactions between ocean conditions and production of the community.

We can use these techniques and we learn from them to detect variability in vital rates of Chinook salmon along the California coast.

The mechanisms between environment and Chinook salmon dynamics may be large and regional scale.

The environment not only affects mortality and stock abundance but dramatically affects the maturation dynamics as well of both males and females.

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