The effects of coastal environmental variation on California Chinook salmon (*Oncorhynchus tshawytscha*) as revealed by scale increment analysis

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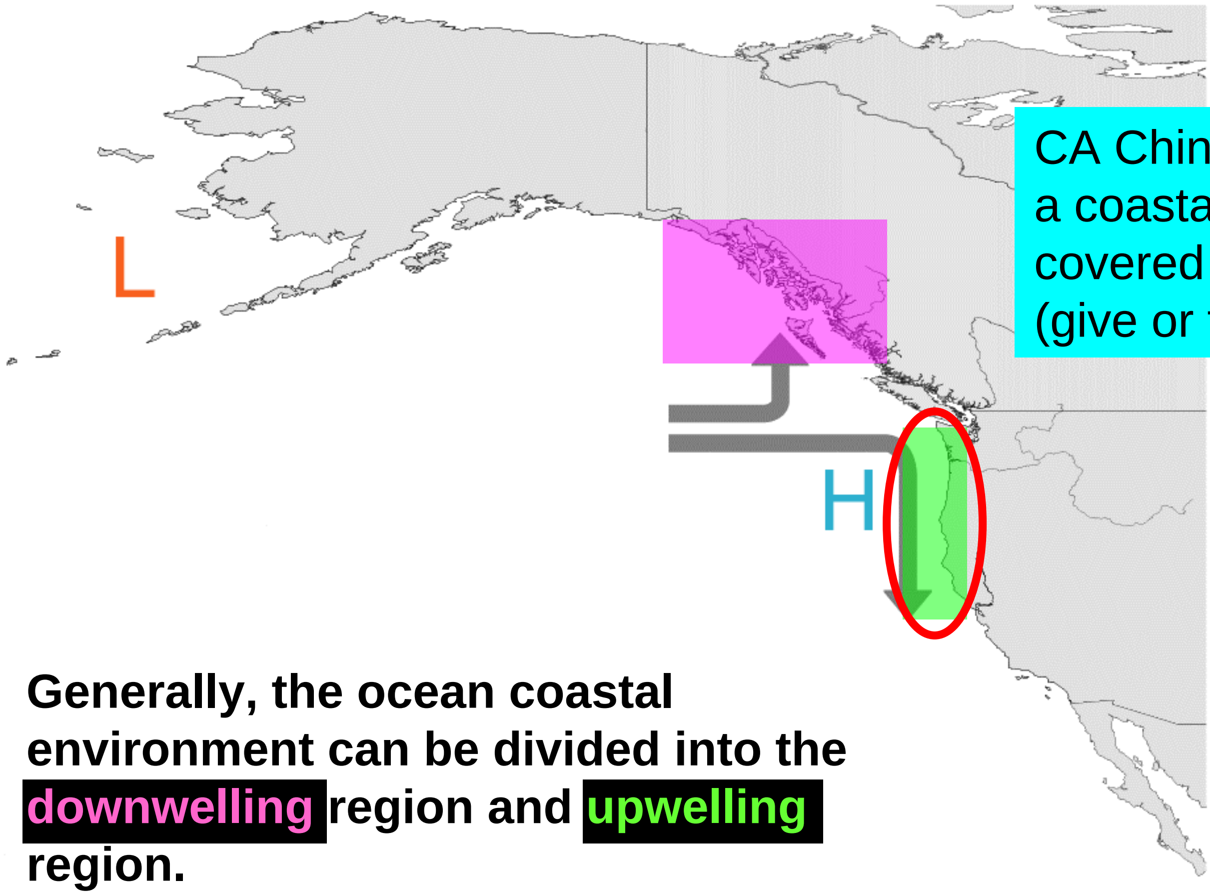
Ocean-type Chinook & Stream-type Chinook

Life history

	Ocean	Stream
FW emigration	0+	1+
Ocean distribution	coastal	GOA and gyre
Return age	~ 1 - 5	~2 - 6

Production regions



CA Chinook which have a coastal distribution covered by the circle (give or take)

Generally, the ocean coastal environment can be divided into the downwelling region and upwelling region.

Overview

I. Defining the growth model

II. Age at maturation

III. Life-stage differences in response to environment

Overview

I. Defining the growth model

California Chinook (female escapement scale samples)

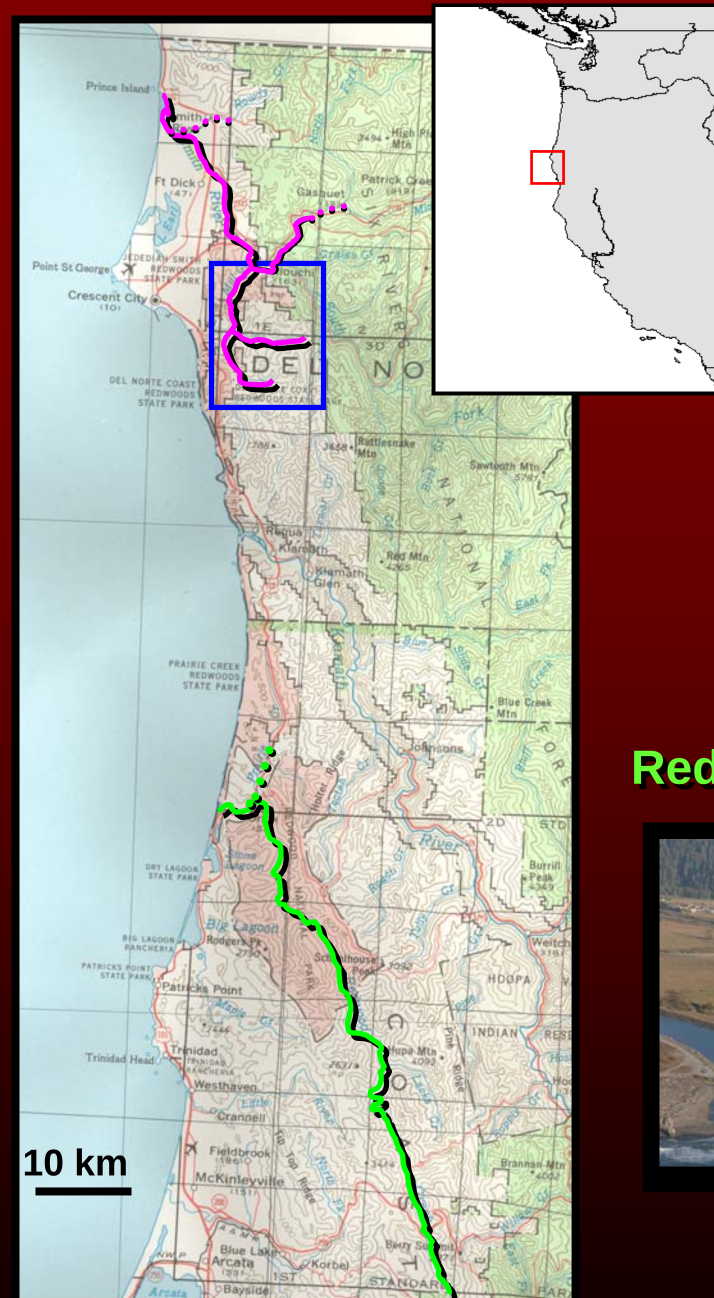
1. Mill Creek, CA (brood yrs 1977 – 2000; *N* = 625)

2. Redwood Creek, CA (brood yrs 1978 – 1992; *N* = 231)

II. Age at maturation

III. Life-stage differences in response to environment

Smith River Estuary



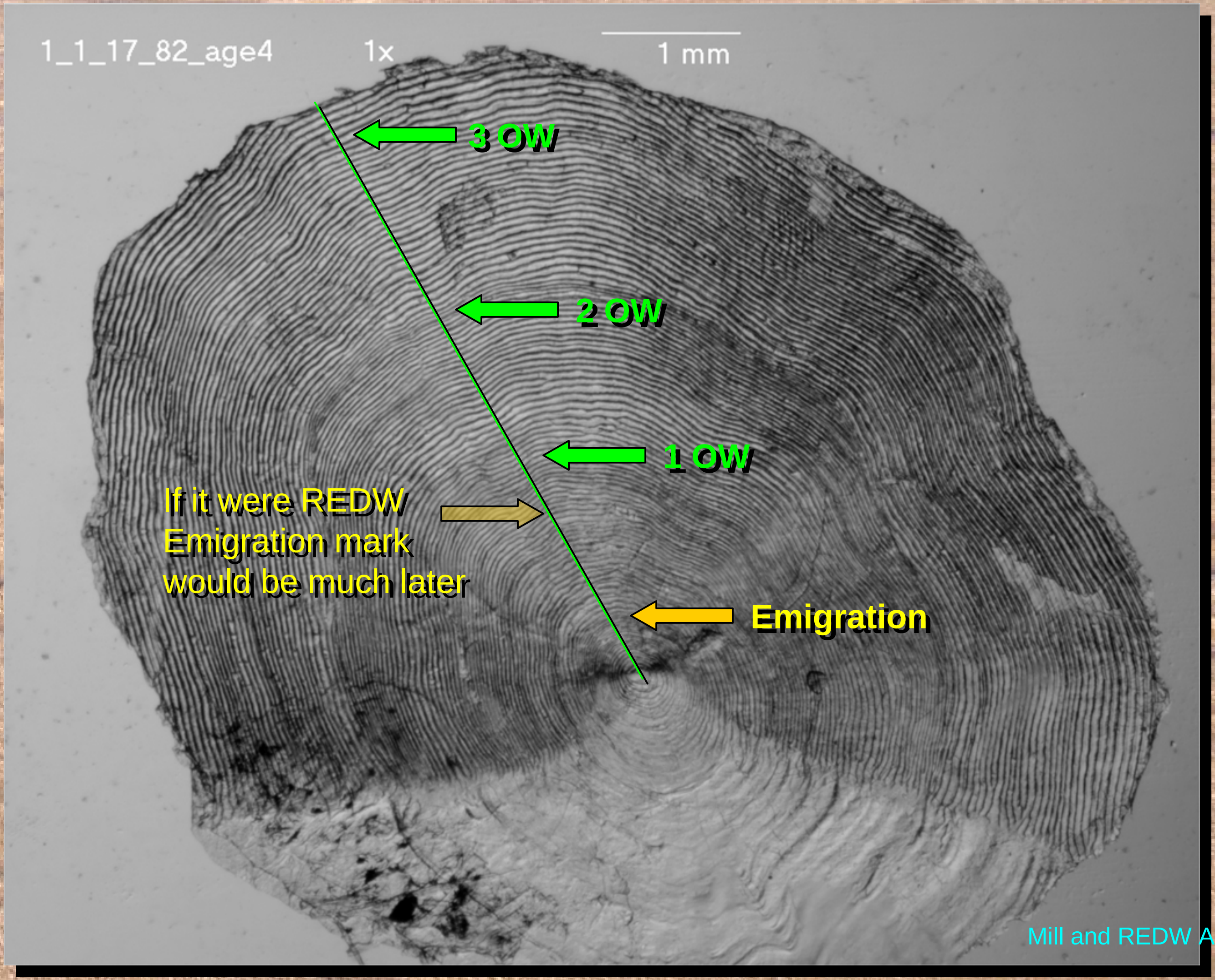
Redwood Creek Estuary

Photos: California Coastal Records Program

Mill and REDW Adult Data

Defining the growth model

Scale analysis

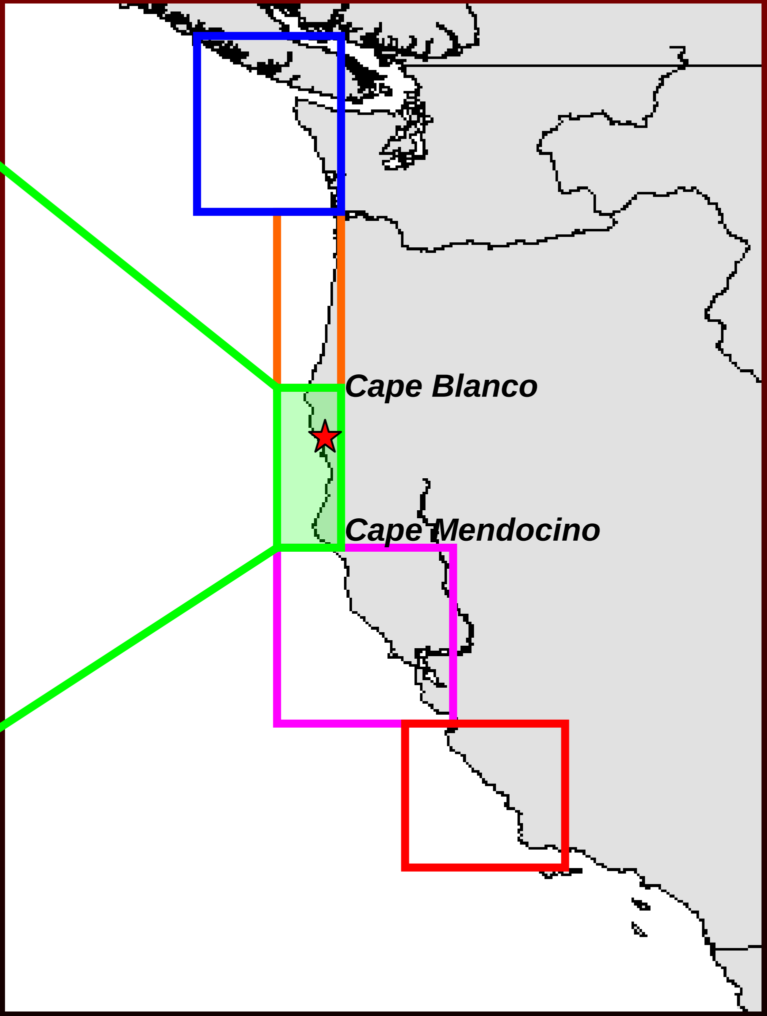


Mill and REDW Adult Data

Defining the growth model

Environmental variables

- $\text{SST}_{\text{spr, sum}}$
- $\text{Upwelling}_{\text{spr, sum}}$
- $\text{Scalar}_{\text{spr, sum}}$
- $\text{NVelocity}_{\text{spr, sum}}$
- $\text{NPseudo}_{\text{spr, sum}}$
- $\text{EPseudo}_{\text{spr, sum}}$
- $\text{Curl}_{\text{spr, sum}}$
- $\text{Mixing}_{\text{spr, sum}}$
- $\text{SLH}_{\text{spr, sum}}$



Defining the growth model

Prin 1: - $Curl_{spr, sum}$, - $SLH_{sum, spr}$, + $Upwelling_{sum}$	*-- transport, upwelling*	30%
Prin 2: - $Mixing_{sum}$, - $Scalar_{sum}$, + $NVelocity_{sum}$	*-- summer turbulence in mixed-layer*	17%
Prin 3: - SST_{sum}, - $NVelocity_{spr}$	*-- SST*	13%
Prin 4: - $Scalar_{spr}$, - $Mixing_{spr}$	*-- spring turbulence in mixed-layer*	11%
Prin 5: - $NPseudo_{sum}$	*-- energy transfer from N wind to surface*	9%
Prin 6: + $EPseudo_{sum}$	*-- energy transfer from E wind to surface*	5%

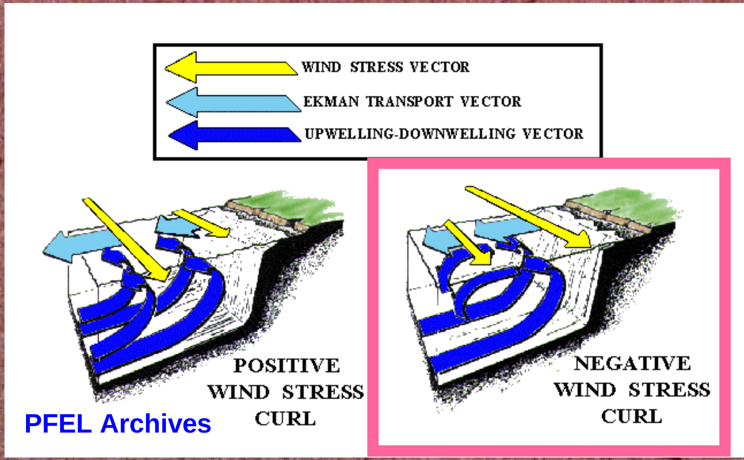
SST_{spr}	SST_{sum}
$Upwelling_{spr}$	$Upwelling_{sum}$
$Scalar_{spr}$	$Scalar_{sum}$
$NVelocity_{spr}$	$NVelocity_{sum}$
$NPseudo_{spr}$	$NPseudo_{sum}$
$EPseuso_{spr}$	$EPseuso_{sum}$
$Curl_{spr}$	$Curl_{sum}$
$Mixing_{spr}$	$Mixing_{sum}$
SLH_{spr}	SLH_{sum}

Mill and REDW Adult Data

Defining the growth model

Mill Creek

Annulus Width = -0.19 *Age* + 0.02 *Prin1* + 0.01 *Prin3* - 0.04 *Prin4* - 0.01 *Prin5* + 1.6



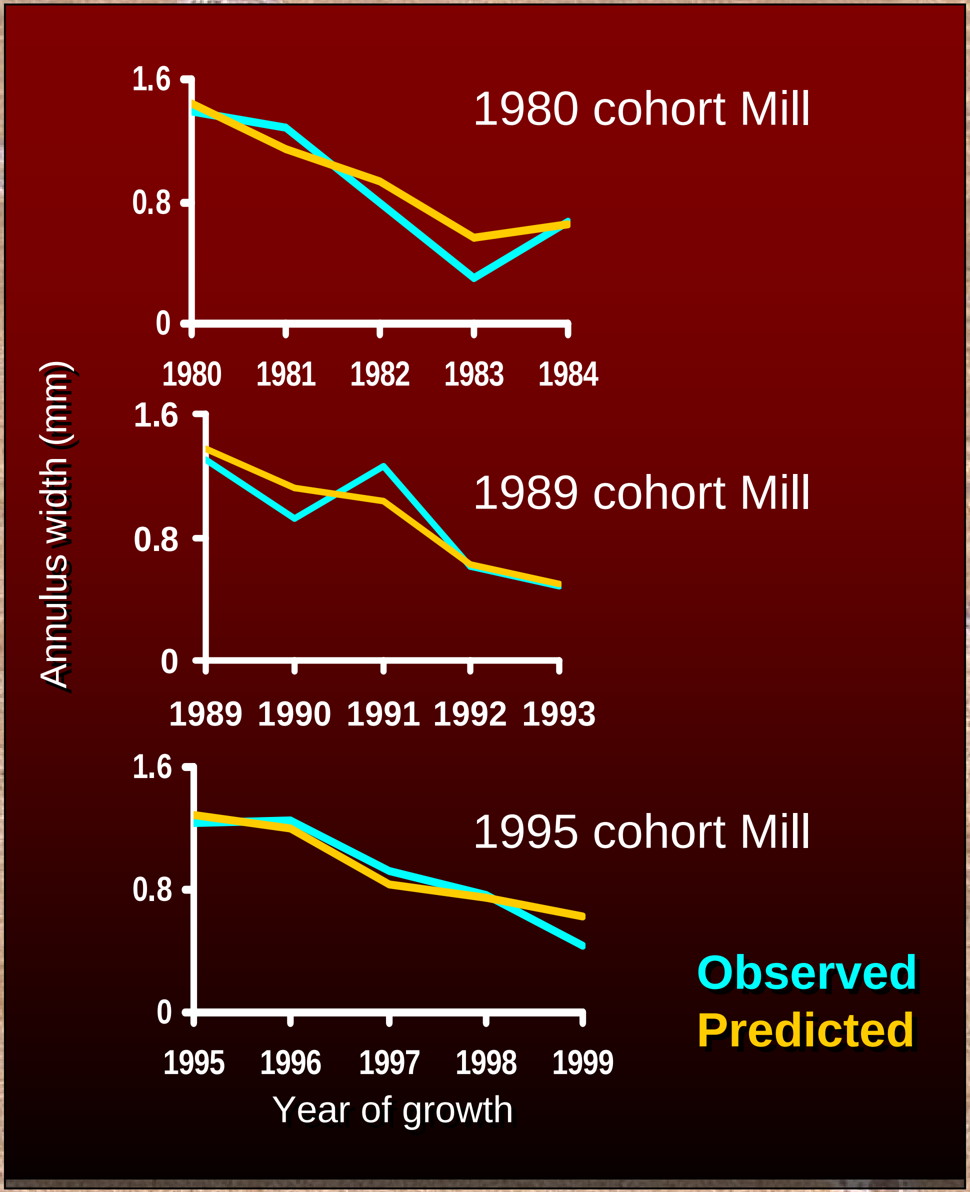
Spring and summer turbulence and upwelling followed by retention of nutrients along coast is good.

Redwood Creek

Annulus Width = -0.16 *Age* - 0.03 *Prin5* + 1.3

Summer N wind stress (strong pressure systems) modify age as a beneficial factor to growth rate.

Defining the growth model



Mill and REDW Adult Data

Defining the growth model

Mill Creek

Length at age $= 4.3(Log_{10}Age) + 0.04\ Prin1 + 0.02\ Prin2 + 0.02\ Prin3 - 0.02\ Prin4 - 0.03\ Prin6 + 1.6$

Spring and summer upwelling followed by retention of nutrients along coast is good.

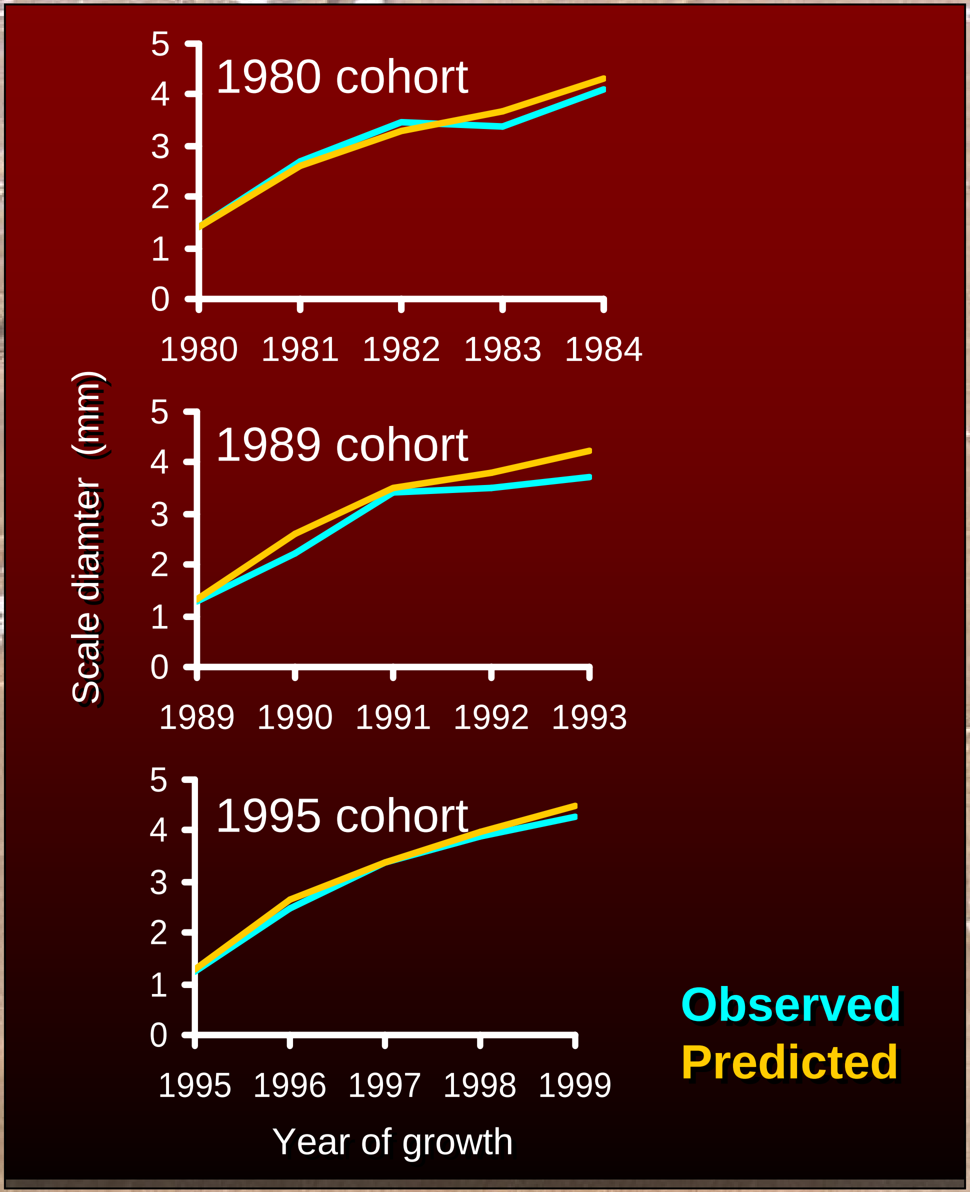
Redwood Creek

Length at age $= 3.8(Log_{10}Age) + 0.03\ Prin1 - 0.02\ Prin2 - 0.02\ Prin4 + 1.2$

Ditto!

Mill and REDW Adult Data

Defining the growth model



Mill and REDW Adult Data

Overview

I. Defining the growth model

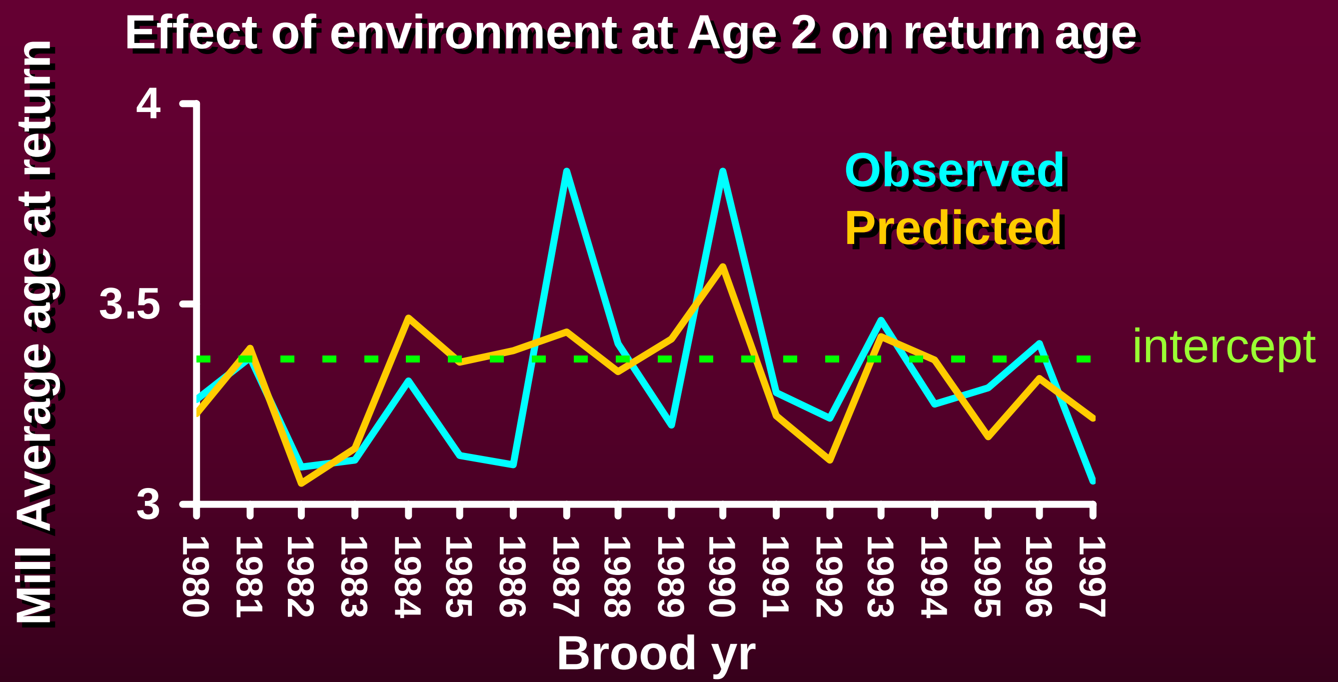
II. Age at maturation

Does an event that happens at a given age (second year at sea in this case) affect the age of return later?

*A basic assumption is that the standardized river section of Mill Creek represents actual change in the population.

III. Life-stage differences in response to environment

Age at maturation



Age@return = 3.4 + 0.06 *Prin1* + 0.12 *Prin6*

Upwelling followed by summer retention of nutrients is good.

Mill and REDW Adult Data

Overview

I. Defining the growth model

II. Age at maturation

III. Life-stage differences in response to environment

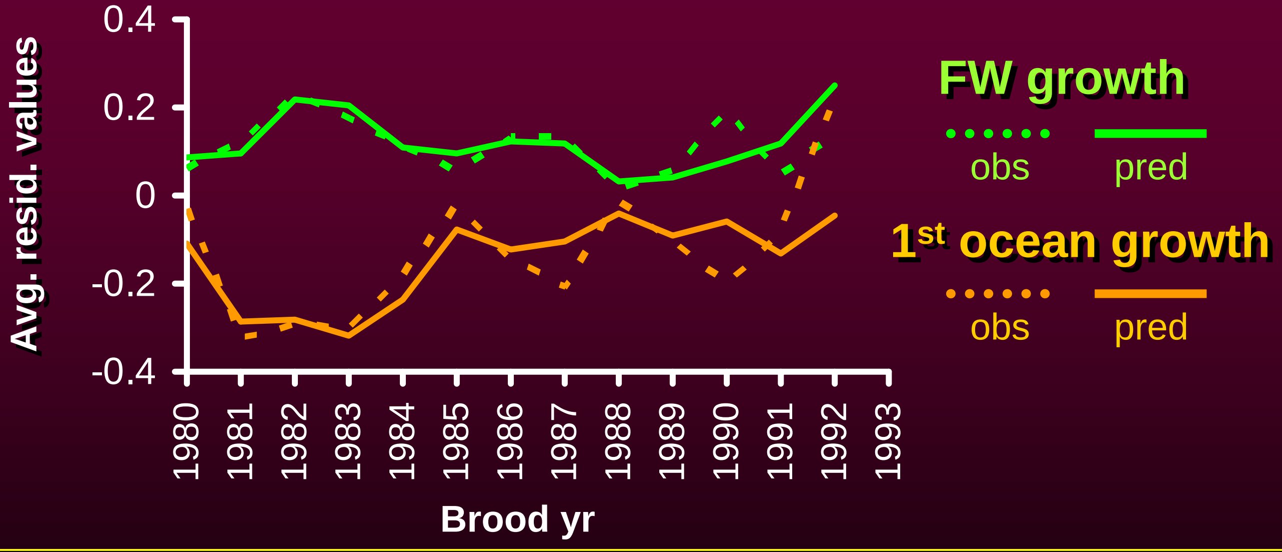
A. Examination of FW and first ocean period on ***returning*** fish

B. Examination of ***juveniles*** before leaving the system.

Life-stage differences in response to environment

Redwood Creek returns

Growth model fit to adult return scale data then the environmental variables (Prins) were fit to the residuals



FW growth = 0.11 - 0.02 Prin2 + 0.02 Prin4 - 0.03 *Prin5* {storms in summer good}

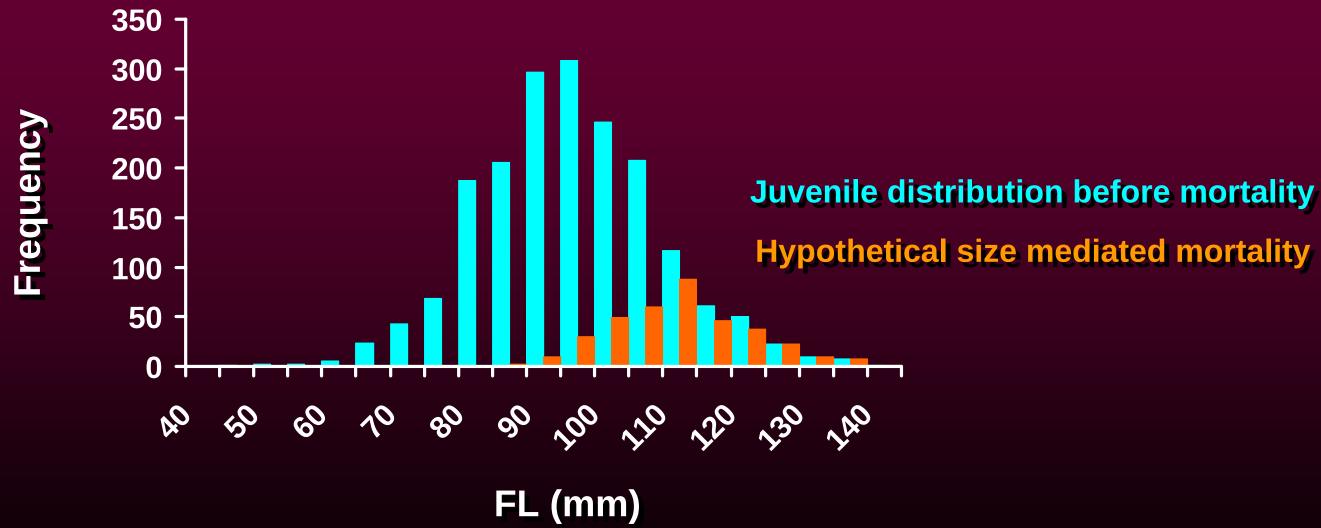
1st ocean growth = -0.16 + 0.04 Prin2 + 0.06 *Prin3* {SST sum, warm is bad}

Mill and REDW Adult Data

Life-stage differences in response to environment

***Hypothetical* distribution following size-related mortality**

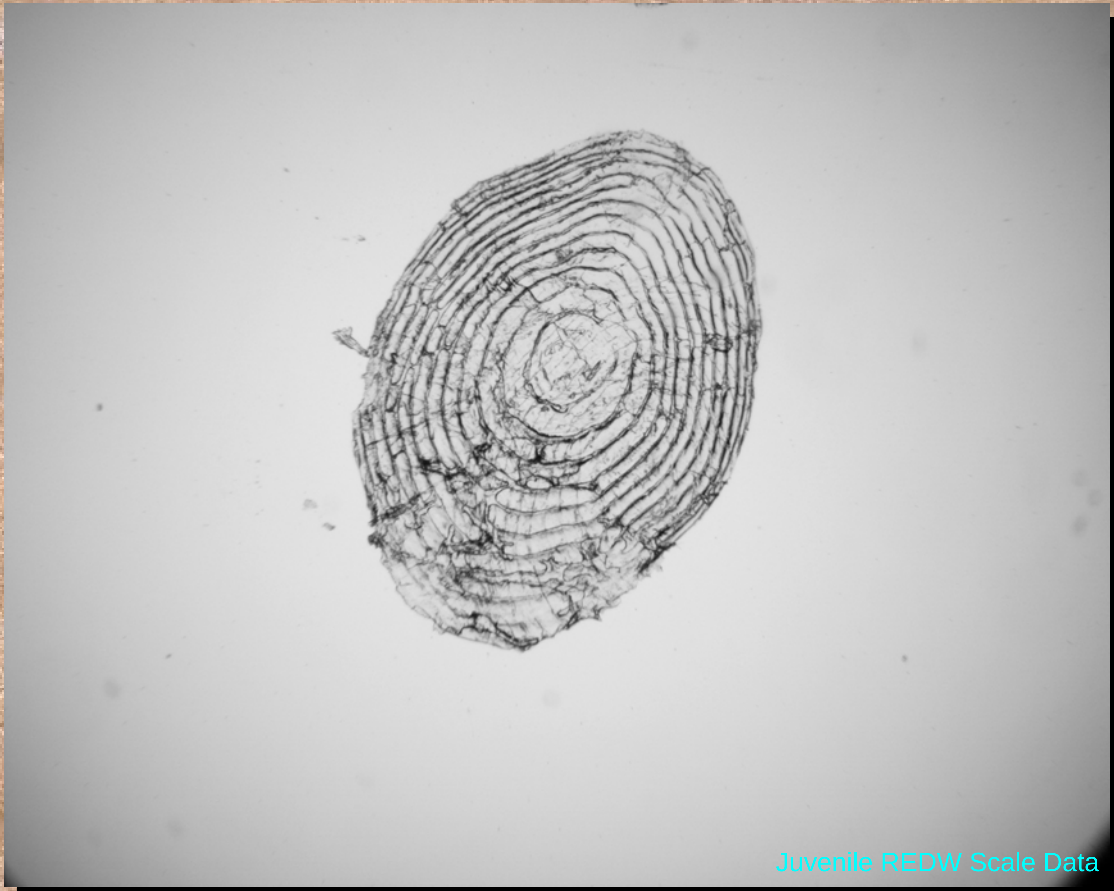
*Are we just seeing a **size-mediated** mortality event?*



Juvenile REDW Scale Data

Life-stage differences in response to environment

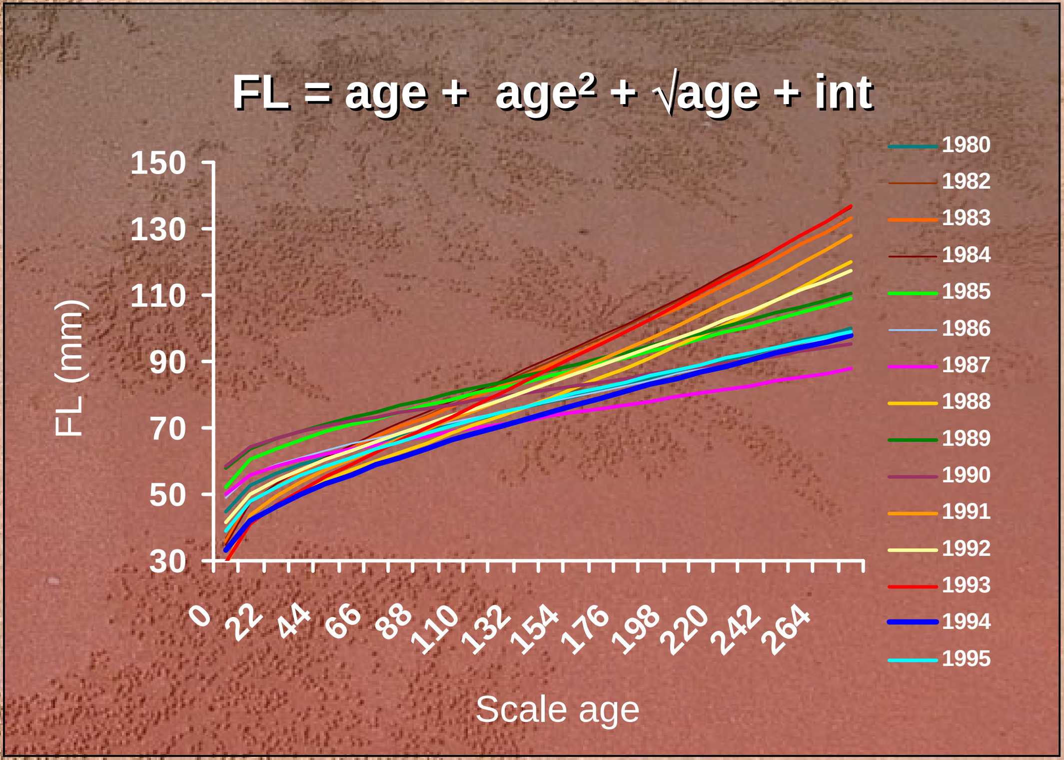
Juvenile Redwood Creek Estuary scale



Collections: NPS; Redwood National and State Parks, CA

Life-stage differences in response to environment

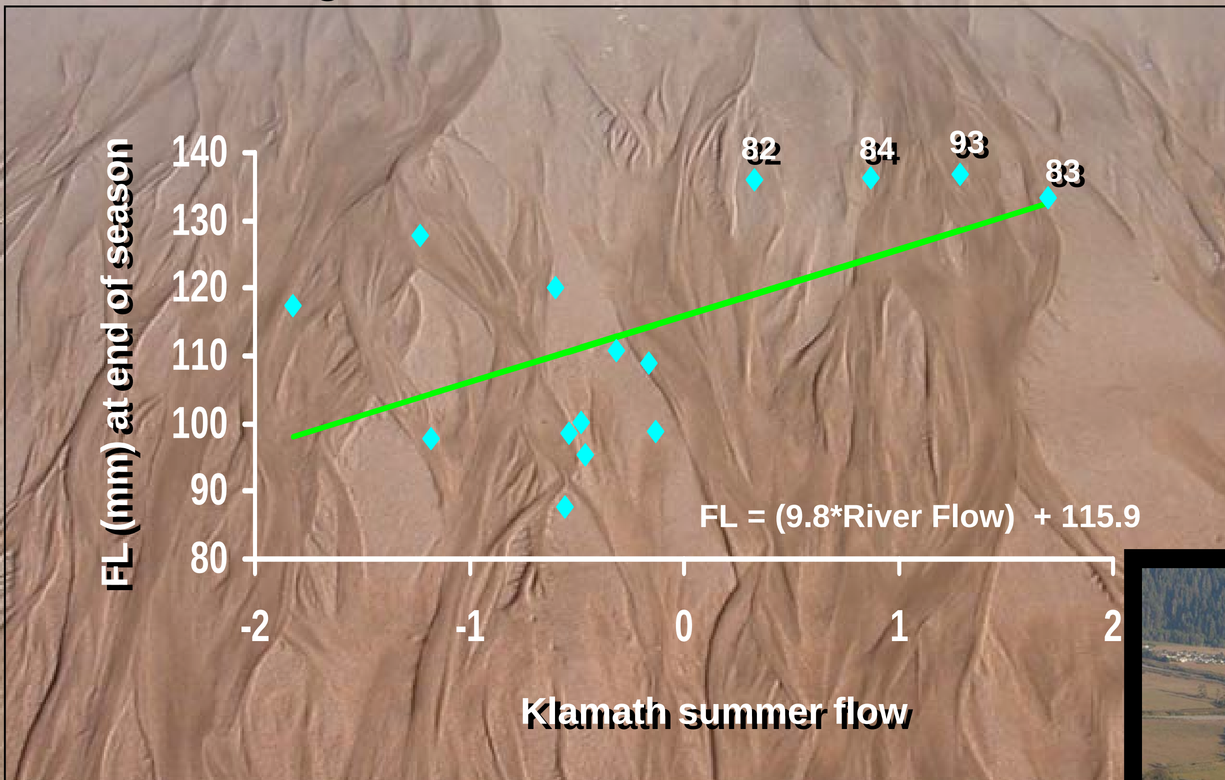
Growth models for juvenile cohorts



Juvenile REDW Scale Data

Life-stage differences in response to environment

River discharge



Juvenile REDW Scale Data

Conclusions

Defining the growth model

1. Mill Creek, CA

   The repeated measures GLM demonstrated that turbulence, upwelling, and nutrient retention/production are the most influential factors related to growth.

2. Redwood Creek, CA

   Growth rate is modified by Northerly wind stresses.

Conclusions

Age at maturation

The stronger the spring and summer curl (i.e. - curl) and summer upwelling during the second year of growth the younger the average cohort age at return.

Conclusions

Life-stage differences in response to environment

Redwood Creek adult returns demonstrated that FW period in scale growth was positively affected by Northerly wind stresses while the first period at sea (late summer-fall) was negatively affected by warmer SST during summer period.

Namely, the two periods related oppositely to ENSO-driven conditions.

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