Carrying capacity & ecosystem models

Eric Ward

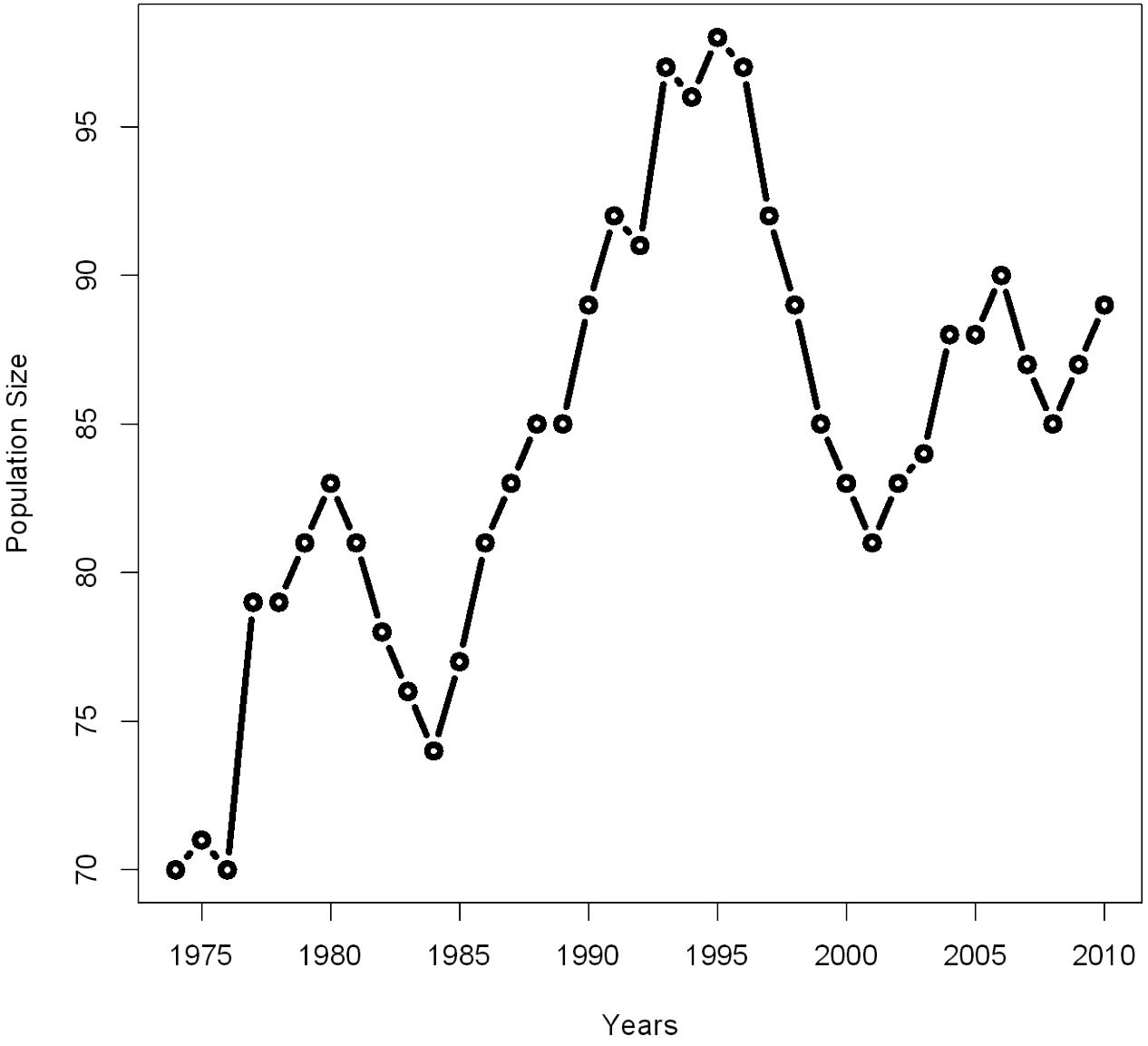
eric.ward@noaa.gov

Estimating Carrying Capacity (K) for Southern Resident killer whales

Eric Ward 9/21/2011

eric.ward@noaa.gov

The Data


Population Size
70
75
80
85
90
95
1975
1980
1985
1990
1995
2000
2005
2010
Years

Simple model

- Logistic model, process error only

  $N(t) = N(t-1) + r*N(t-1)*(1-N(t-1)/K)$

- Gompertz model, process error only

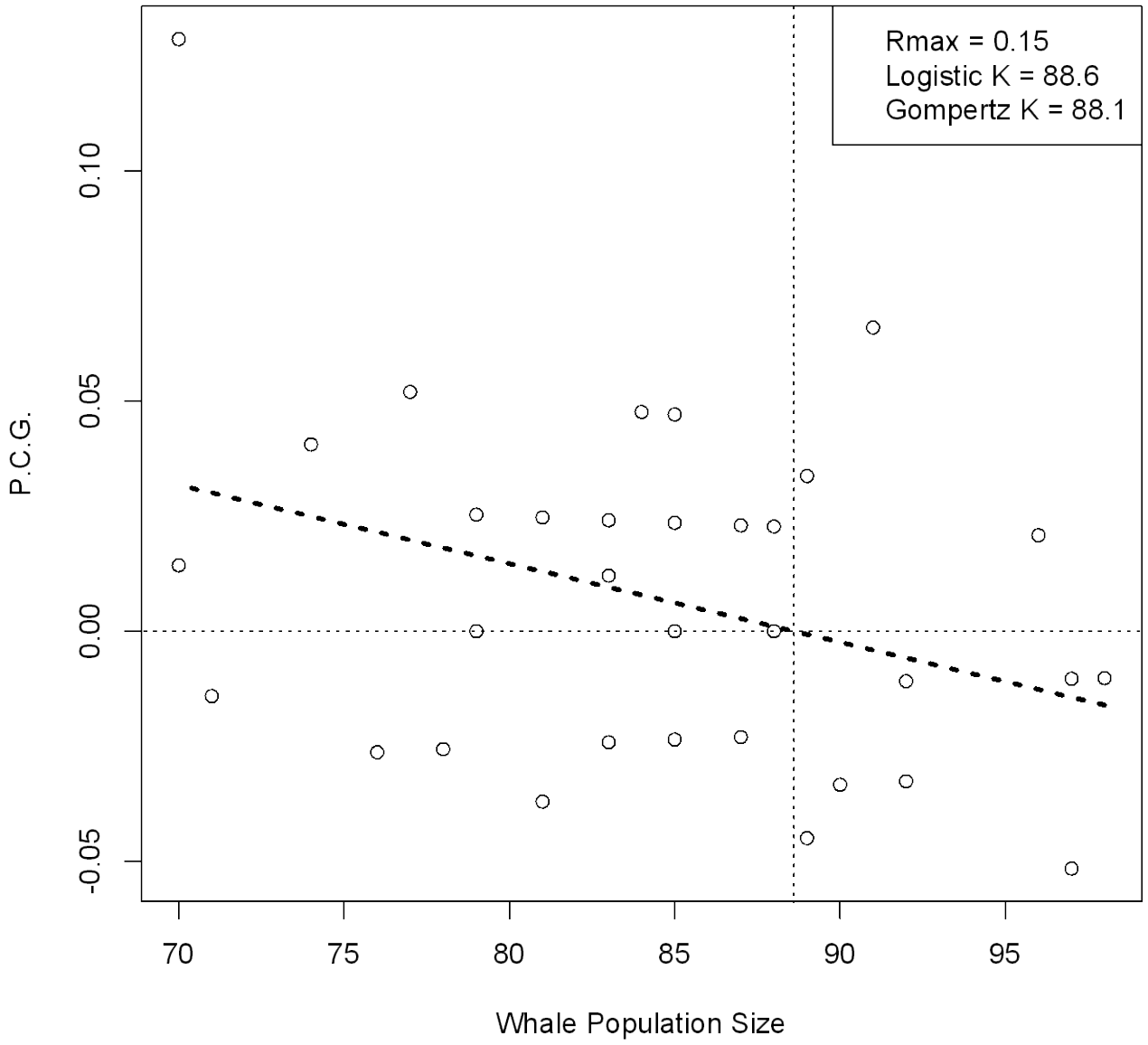
  $X(t) = b*X(t-1) + u;\ \ln(N(t)) = X(t)$

- Assume: errors independent, 3 parameters to estimate: r, K OR u, b AND sigma

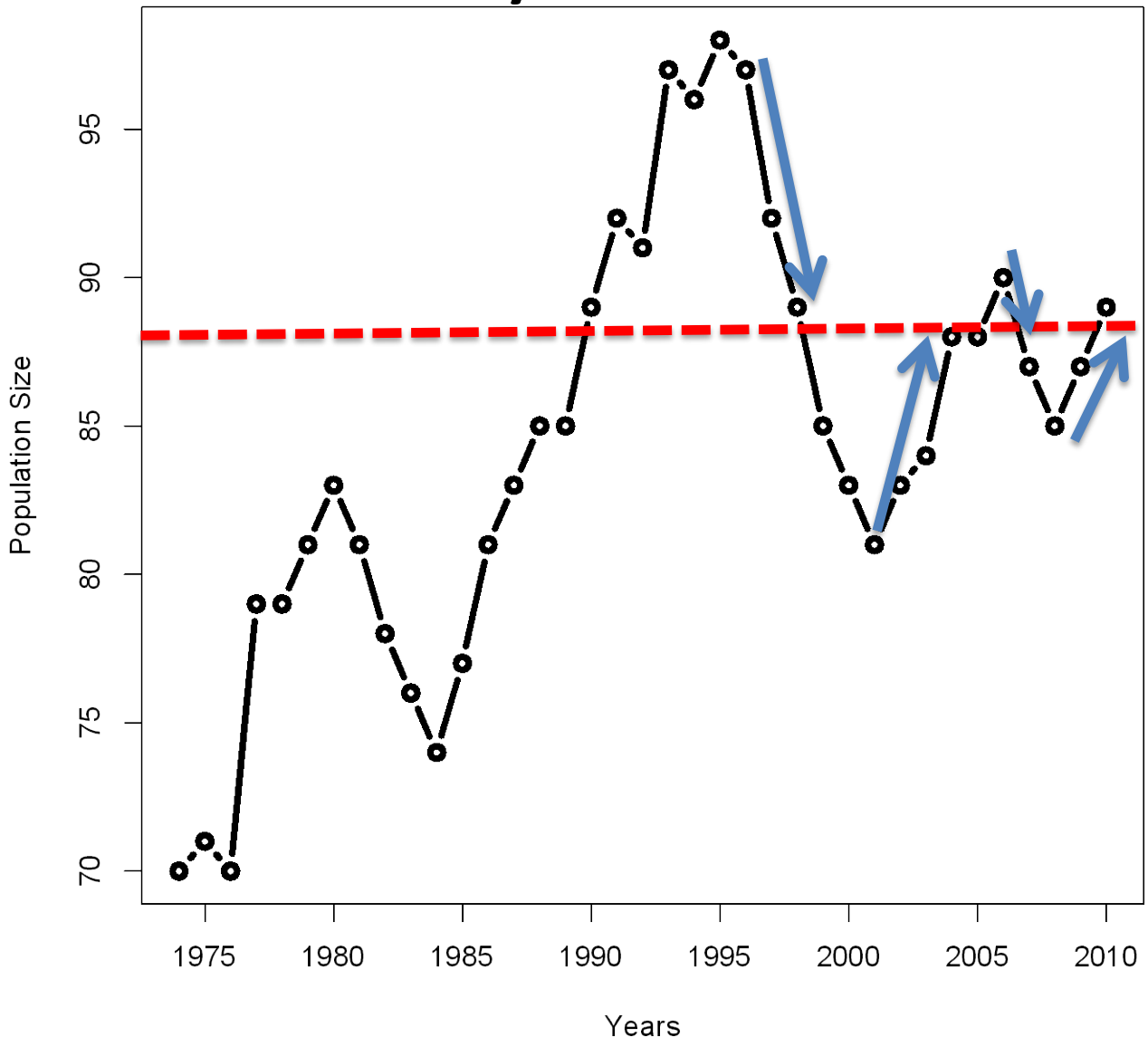
- For Gompertz, carrying capacity (K) derived: u/(1-b)

Dennis & Taper (1994)

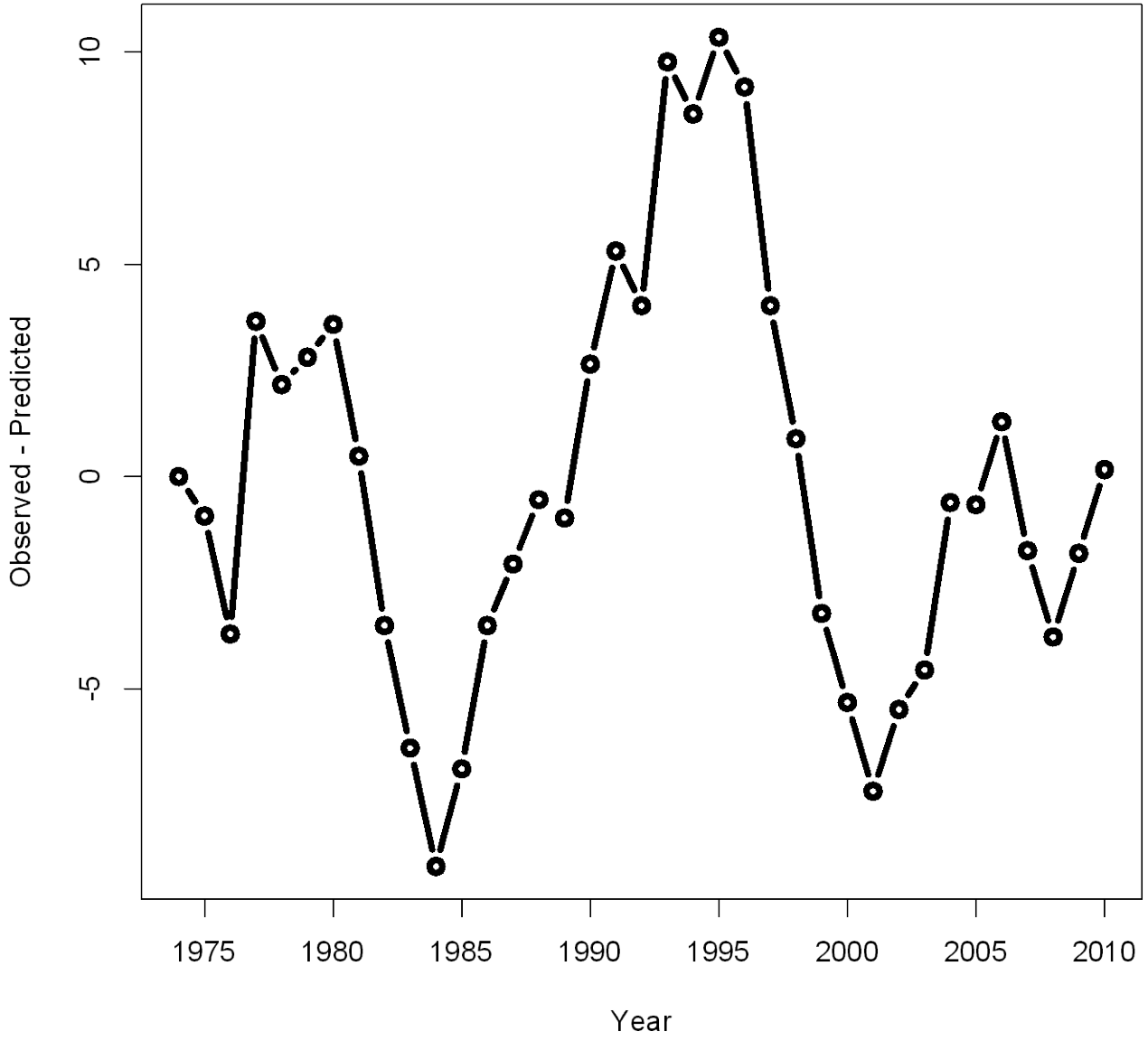
Simple results



Why 86-87?


Population Size
70
75
80
85
90
95
1975
1980
1985
1990
1995
2000
2005
2010
Years

Diagnostics: highly autocorrelated residuals



We need to include autocorrelation

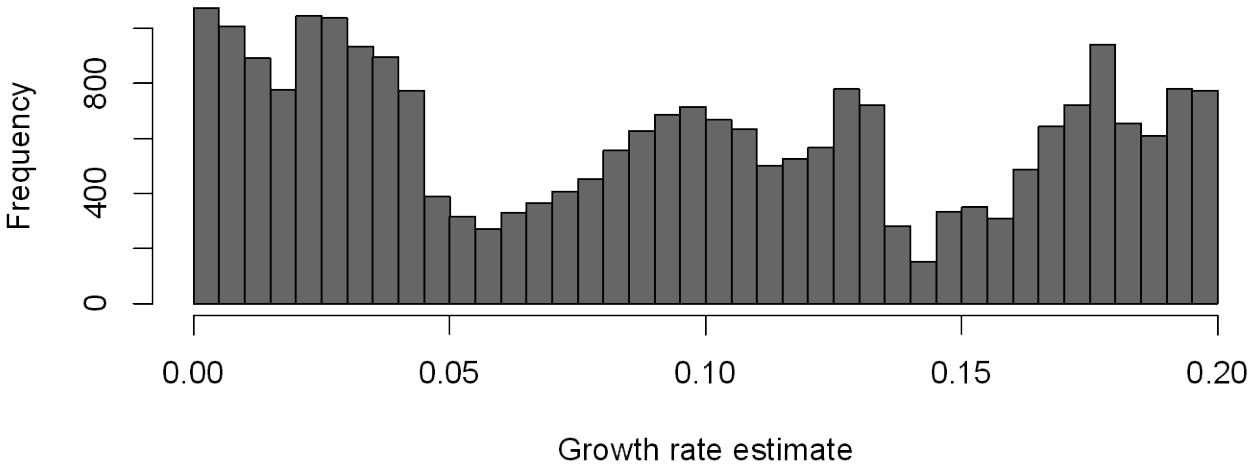
- Make process errors autocorrelated

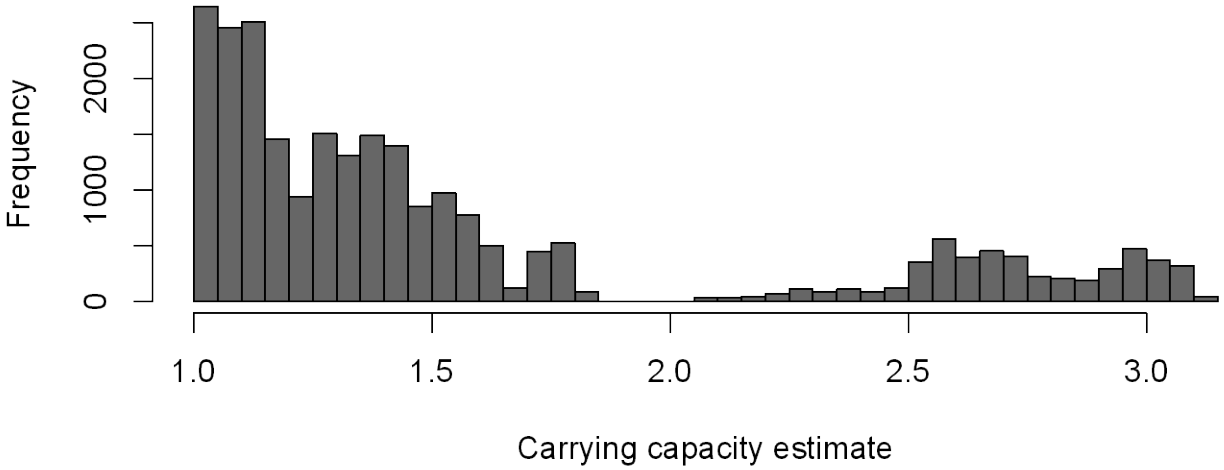
$$w_t = z w_{t-1} + \sigma_{w*} w_t^* \sqrt{1 - z^2}$$

$$w_t^* \approx N(0,1)$$

- Morris & Doak (2002): Quantitative Cons. Bio.

Posteriors: parameters can't be estimated





Other approaches to estimate K

- Matrix models

$S(t) = g(N(t))$

$F(t) = g(N(t))$

- Problem: we don't know anything about mechanism, functional form, which ages/stages affected

- choice is arbitrary, and any PVA results will depend on this choice (or choice of K)

Caswell (2001): Matrix Population Models

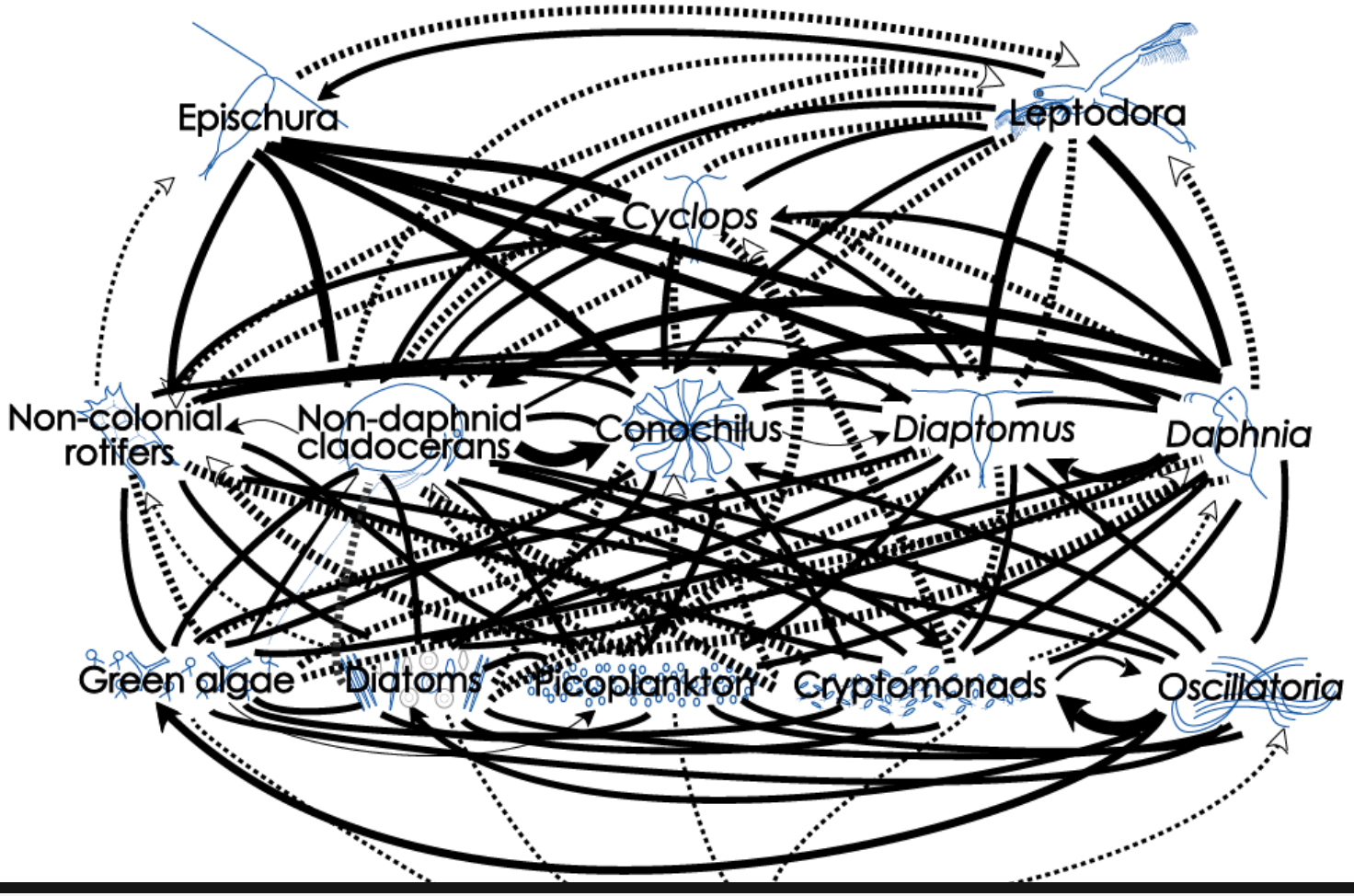
Krahn et al. (2004): BRT

Preliminary thoughts on new ecosystem approaches

Eric Ward 9/21/2011

eric.ward@noaa.gov

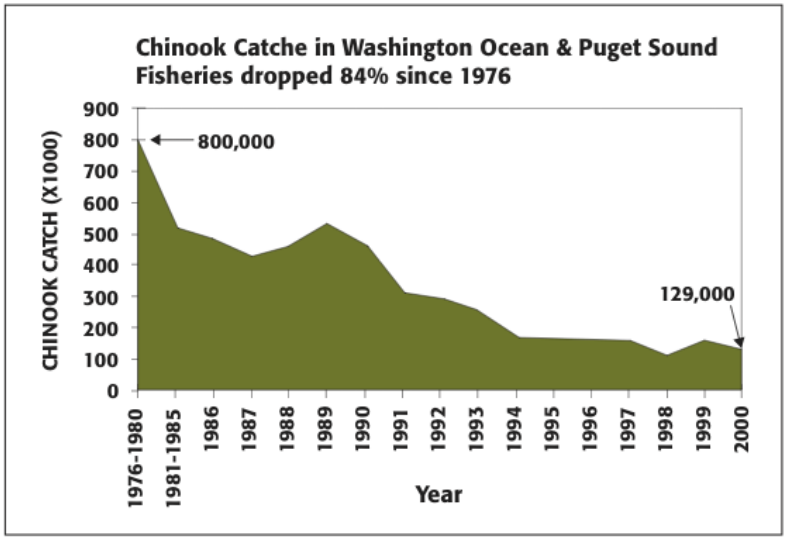
Ecosystem models are complex

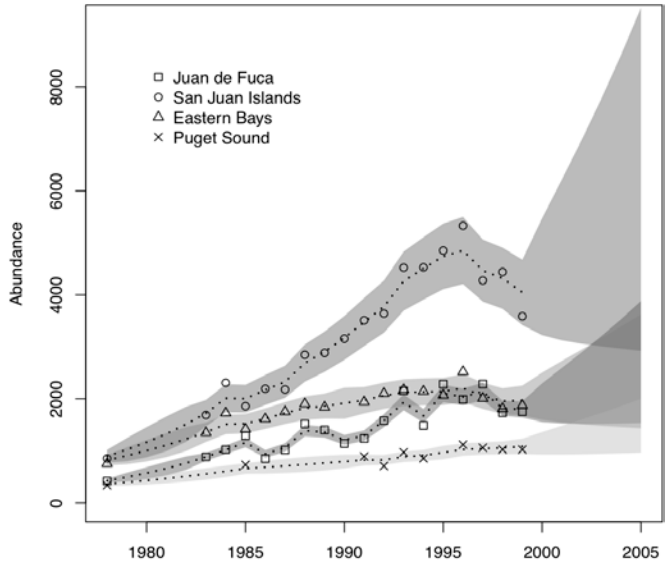


Temperature ... Nutrients .... Photoperiod ... Storm activity ... Fishing pressure ...

Direct perturbations (removals)

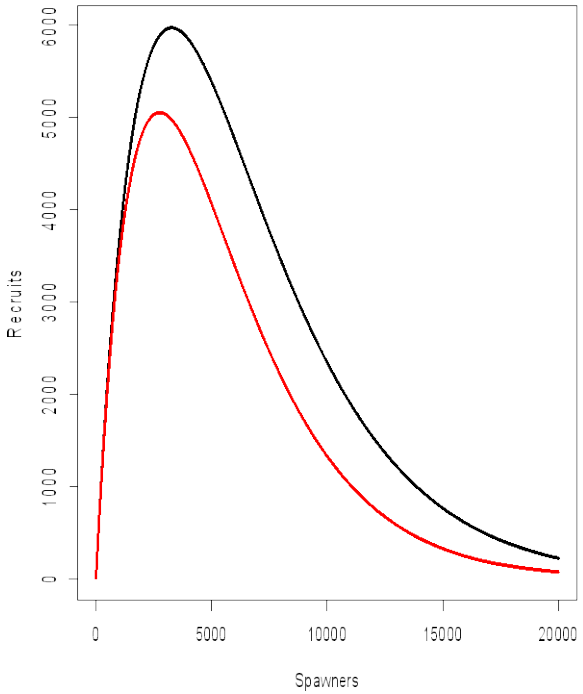
- Orca (1950s-60s removals)
- Seals (??? – 1960s, to 10% of K)
- Salmon (declining catch and biomass since 1970s)
- Herring (declining catch and biomass since 1970s)
- Groundfish (declining catch and biomass since 1980s)





Indirect perturbations

- Increased hatchery production
  - 1/3 spawners are hatchery origin
  - Hatchery PS Chinook have depressed production compared to wild PS Chinook

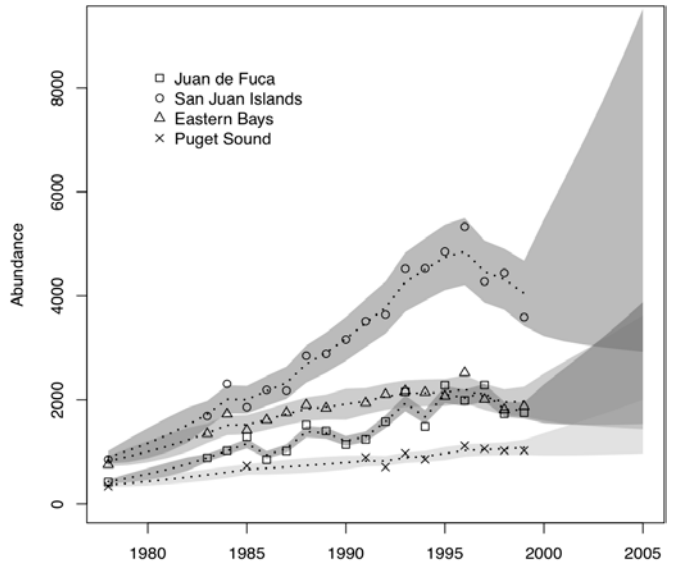


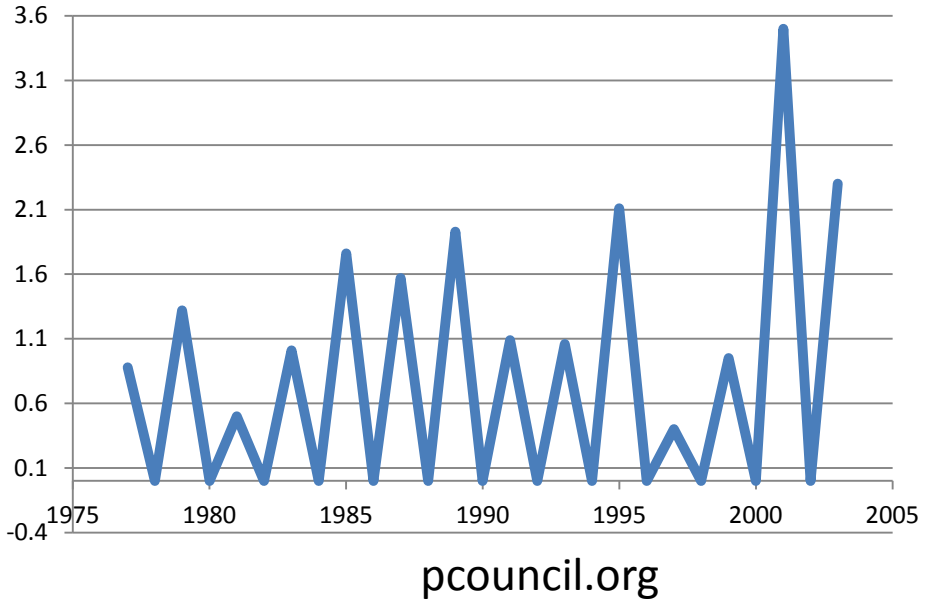
Indirect perturbations

- Habitat alteration (stream flow, water quality, spawning habitat, etc)
  - 2% annual decline in R/S, R/S in 2010 is 30% of 1950s
- Stochasticity
  - Pink salmon
    - Juveniles compete directly with juvenile Chinook (Ruggerone & Getz 2004)
    - Ward et al. (in press): years when pink salmon are absent have higher consumption of rockfish (and non-pink salmon) by seals
  - Environment (PDO, SST, upwelling, etc)

Ward et al. (2011)

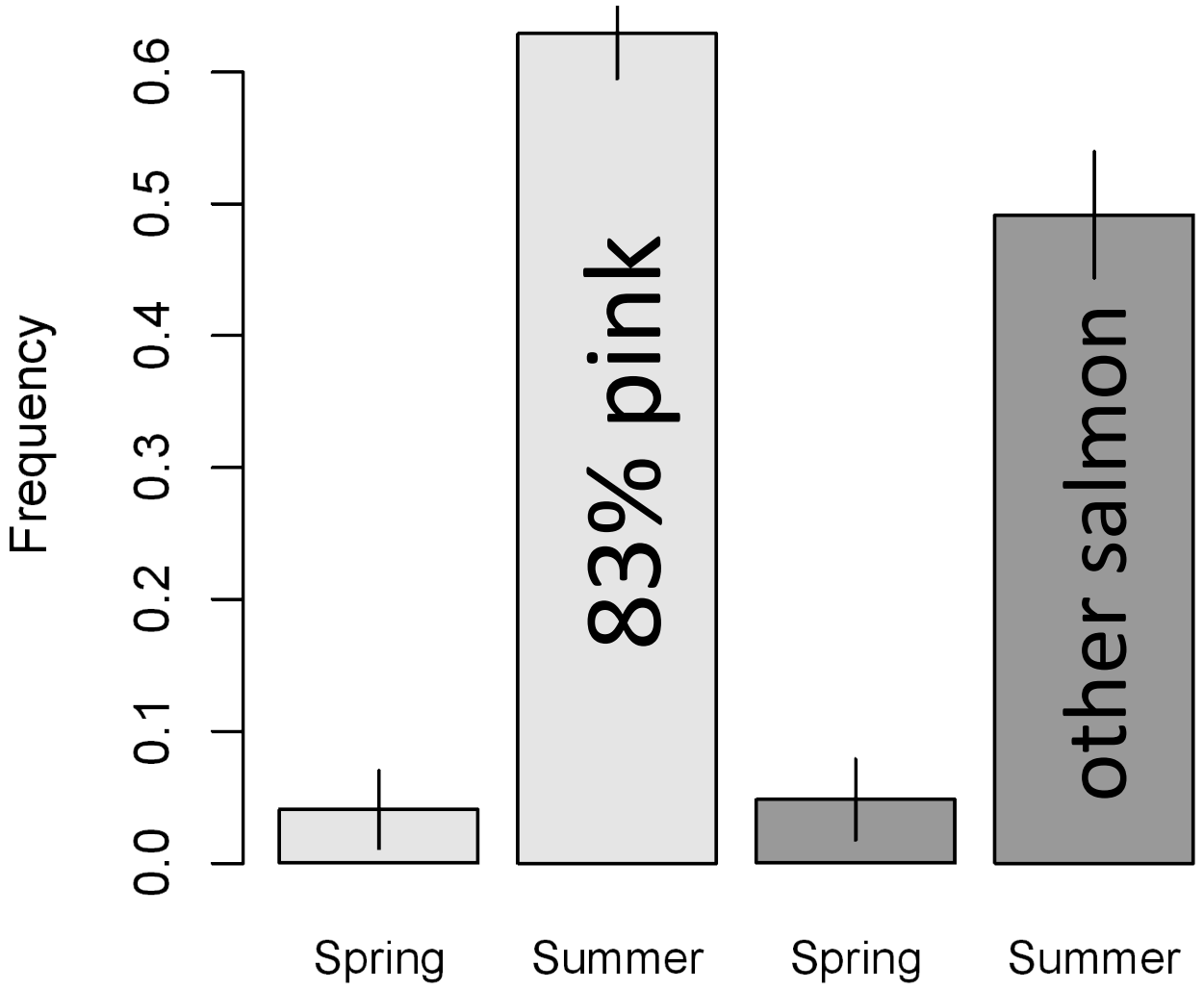
- Seals & pink salmon have increased in Puget Sound (a lot)
- Seals eat a lot of pink salmon when they're around (odd years)





pcouncil.org

Summer diet: seals always eat salmon, even in non-pink years



2005/2007

2006/2008

Small sample sizes:

Seals don't eat many adult Chinook. But ~ 50% of juvenile salmon are Chinook

Data source: M. Lance, S. Jeffries, WDFW; Ward et al. (2011)

Previous approaches to modeling PS dynamics

- Ecopath / Ecosim:
  - Mass balance model

- PS South basin: Preikshot, Beattie & NWIFC (2001)
  - How is 1999 ecosystem different from 1970?
  - Less dogfish, cod, skates/rays, flatfishes, hake, pollock, herring, rockfishes, forage fishes, coho
  - More chum/pink adults, resident juvenile Chinook

http://www2.fisheries.com/archive/publications/reports/9-6.pdf

Less biomass & less harvest

Table 10.2: Changes in the biomass (B) and harvest (Y) at Trophic levels VI through I in SPS over the period from 1970 to the end of the 1990s.

Trophic level	**1990s B**	**1970s B**	**1990s Y**	**1970s Y**
	tons/km²	tons/km²	tons/km²	tons/km²
VI	0.013	0.02	0	0
V	0.377	1.019	0.032	0.04
IV	7.448	14.552	0.323	0.464
III	127.197	145.953	3.471	3.967
II	874.202	886.357	22.013	22.063
I	1452.156	1452.156	0	0

More recent Ecopath approach

- PS Central basin: Harvey et al. (2010)

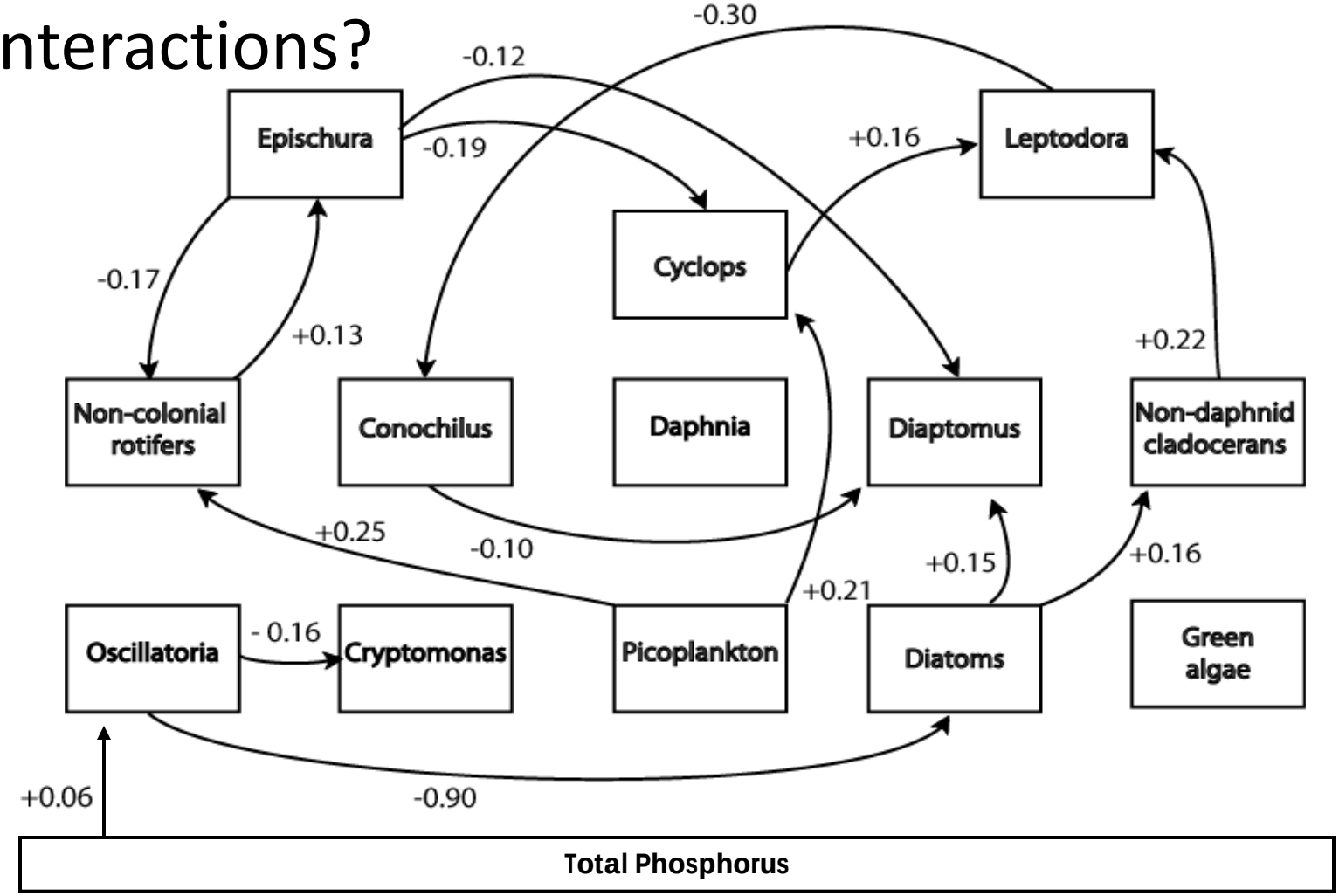
- Rare species in central basin not included
  - Killer whales
  - Sockeye salmon
  - Sixgill sharks, halibut, sablefish, sturgeon
- Northern Puget Sound model
  - C. Harvey (TBD)

http://www.nwfsc.noaa.gov/assets/25/7363_08042010_120050_MassBalanceModelTM106WebFinal.pdf

Alternative MARSS approach

- Objective: use well established time series methods to infer interactions (& stability) through time series of community data

MARSS models: What are the strong species interactions?



How are environmental factors affecting species?

Hampton, Scheuerell, & Schindler 2006

Questions

- Can we estimate (sensible) interactions of Puget Sound food web?

- Have there been changes in ecosystem carrying capacity / stability over time?
  - Environmental regime shifts (e.g. PDO)

Current Progress

- Model development (done, R package 'MARSS' on CRAN)
- Data collection stage
  - Good data: killer whales, harbor seals, salmon
  - Ok data: herring
  - Data needs: cod, pollock, hake, rockfishes, other marine mammals (sea lions and others?), other fishes?, primary production?

Data issues: Gadids

- Entirely fishery-dependent:
- Pacific cod CPUE (1955-1998)
  - Almost no research vessel estimates (1987-1989)
  - New fisheries have emerged since 1995 (no data)
- Pollock (through early 1990s)
  - No effort, only landings
- Hake
  - Limited spatial coverage (other than Port Susan)
- Gustafson et al. (2000)

http://www.nwfsc.noaa.gov/publications/techmemos/tm44/tm44.htm

Orca Oceanography

Jim Irvine[1] and Bill Crawford[2]

[1]Fisheries & Oceans Canada, Pacific Biological Station
Nanaimo BC Canada

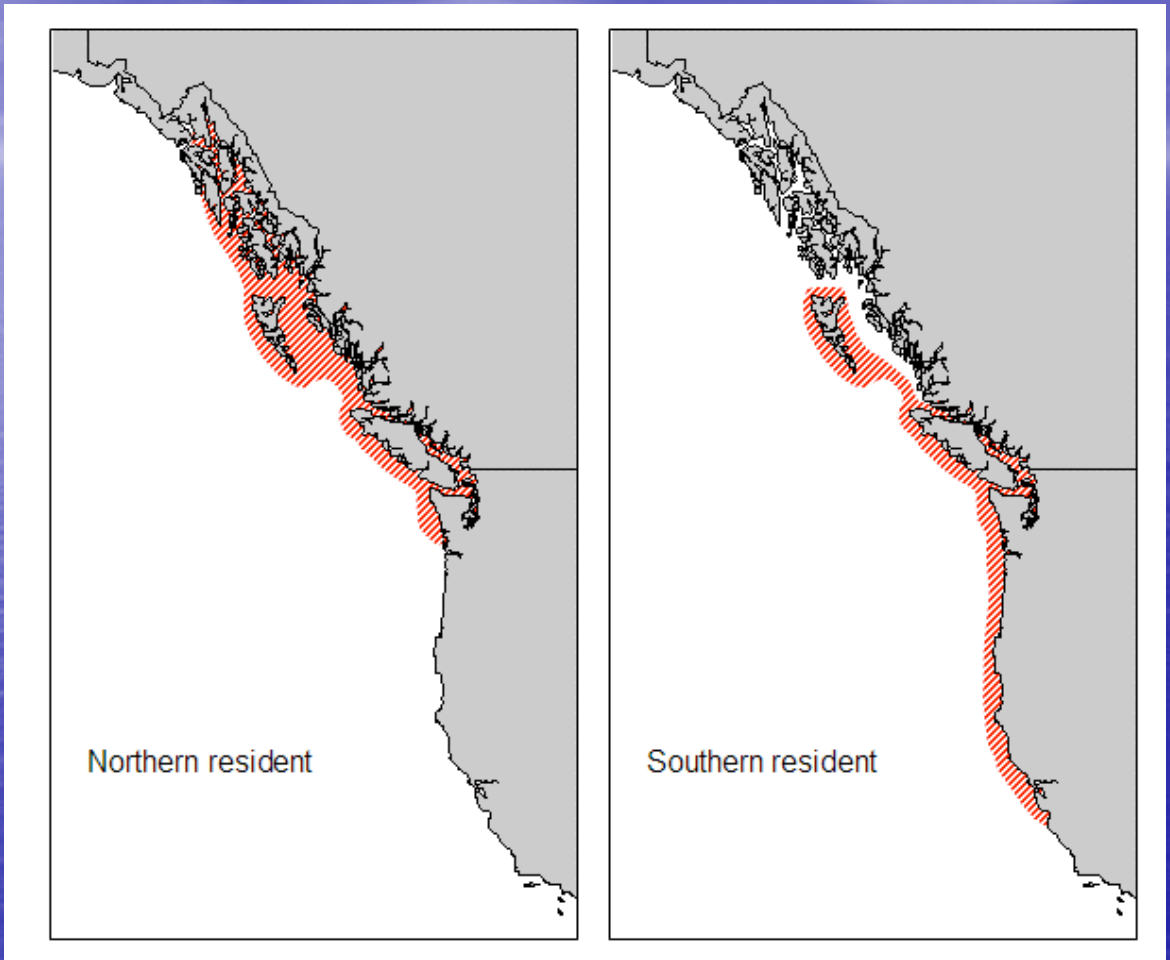
[2]Fisheries & Oceans Canada, Institute of Ocean Sciences
Sidney BC Canada

21 Sept 2011 NOAA
DFO Workshop
Seattle

Background

- Southern resident Orcas not doing as well as northern residents
- Distributions of two groups overlap
- Can oceanographic information help explain differential mortality and growth patterns of these 2 groups?

Ranges of northern (left panel) and southern (right panel) populations of resident killer whales.



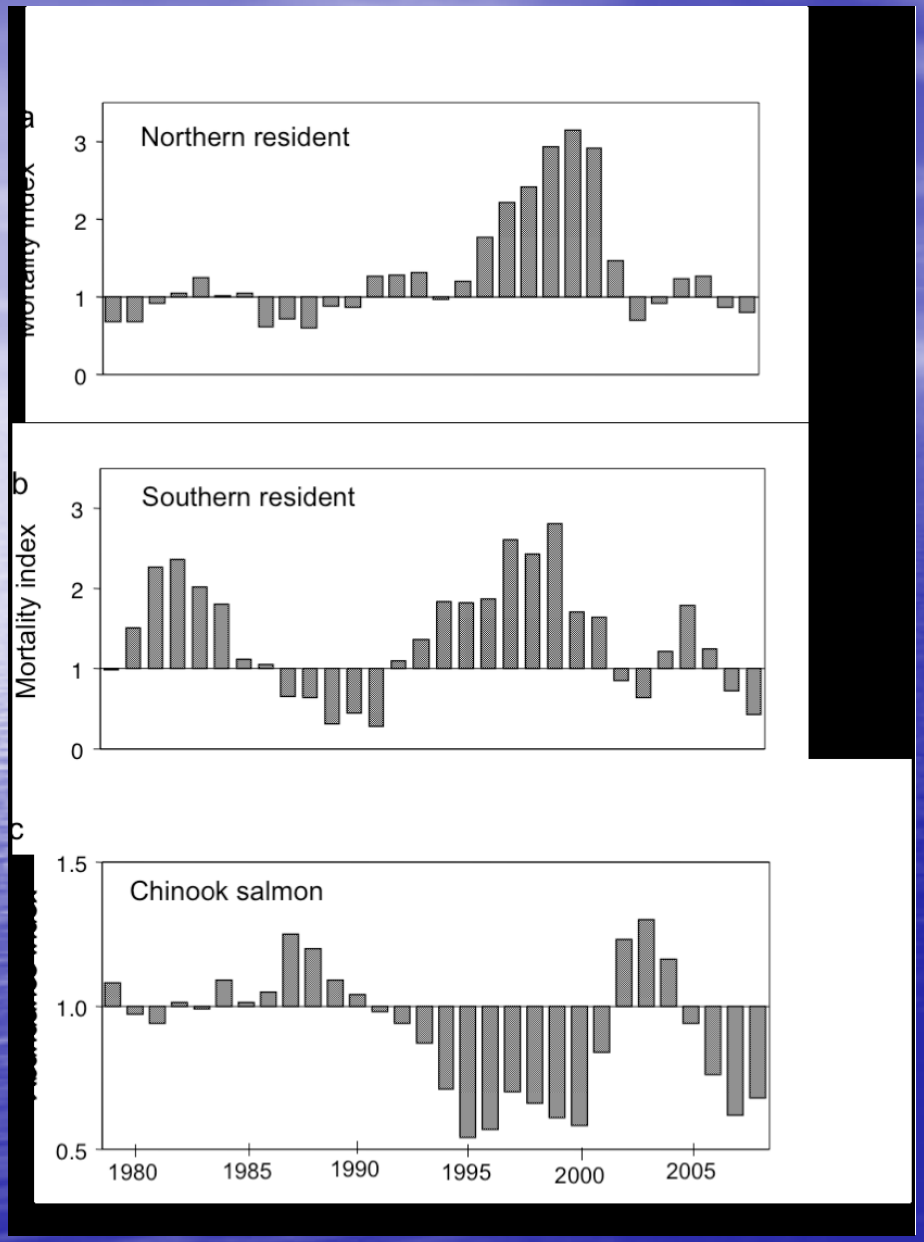
From: Ford et al. 2010

Oceanography 101

- North Pacific surface current bifurcates near southern BC into the Alaska and California currents
- S BC (area of Orca overlap) in transition zone between coastal downwelling (Alaskan) and upwelling (California current)
- Ocean “productivity” can be indexed by:
  - Satellite-derived chlorophyll concentrations
  - Duration and extent of upwelling-favourable (northwesterly) winds
  - SST, PDO, ENSO, spring transition, etc

Objectives

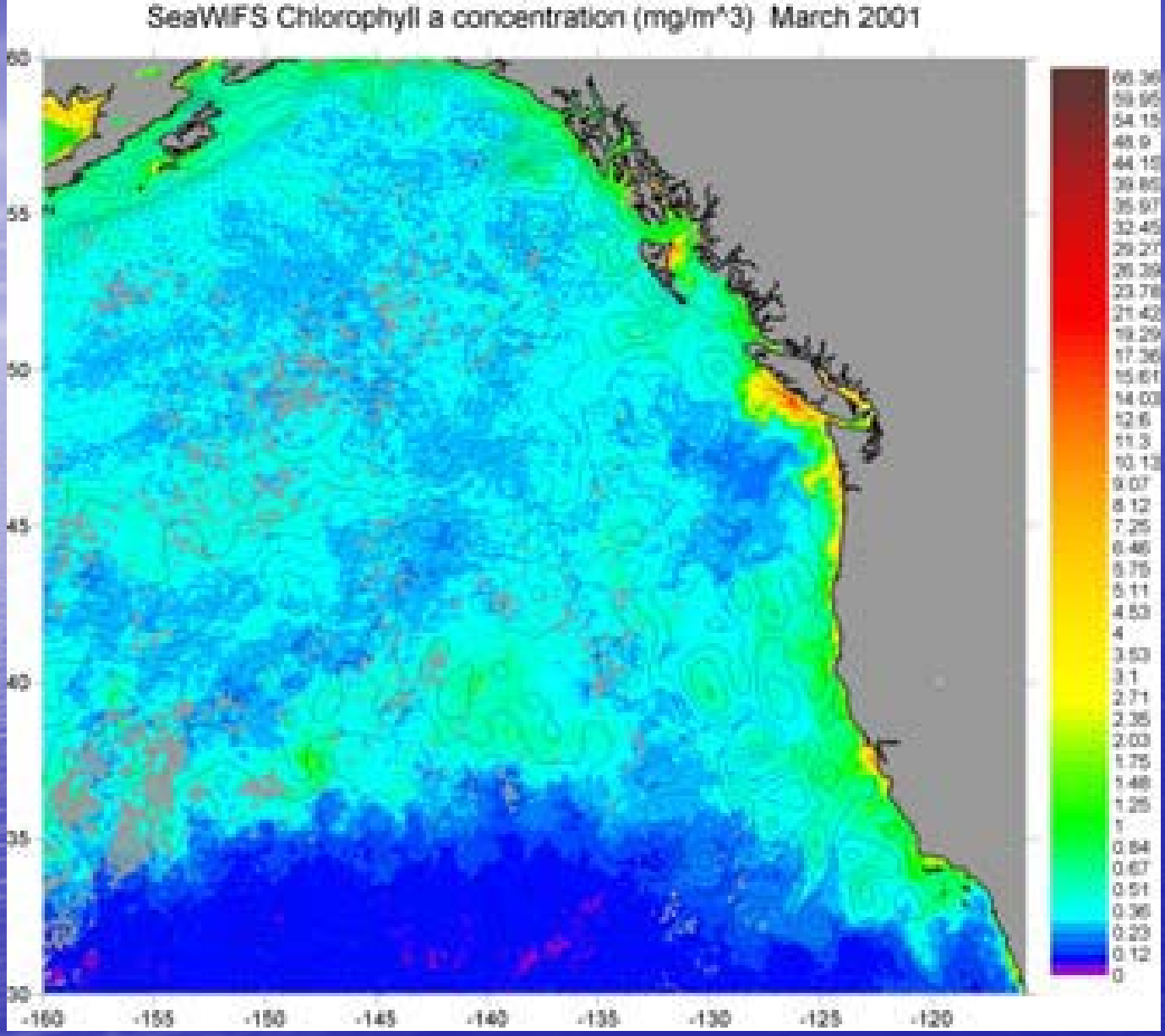
- Preliminary examination of two (of many) productivity indices and potential linkages with Orca time series
- Consider whether quantitative analyses are warranted



Annual indices of mortality of northern & southern resident Orcas & abundance of Chinook salmon, 1979-2008.

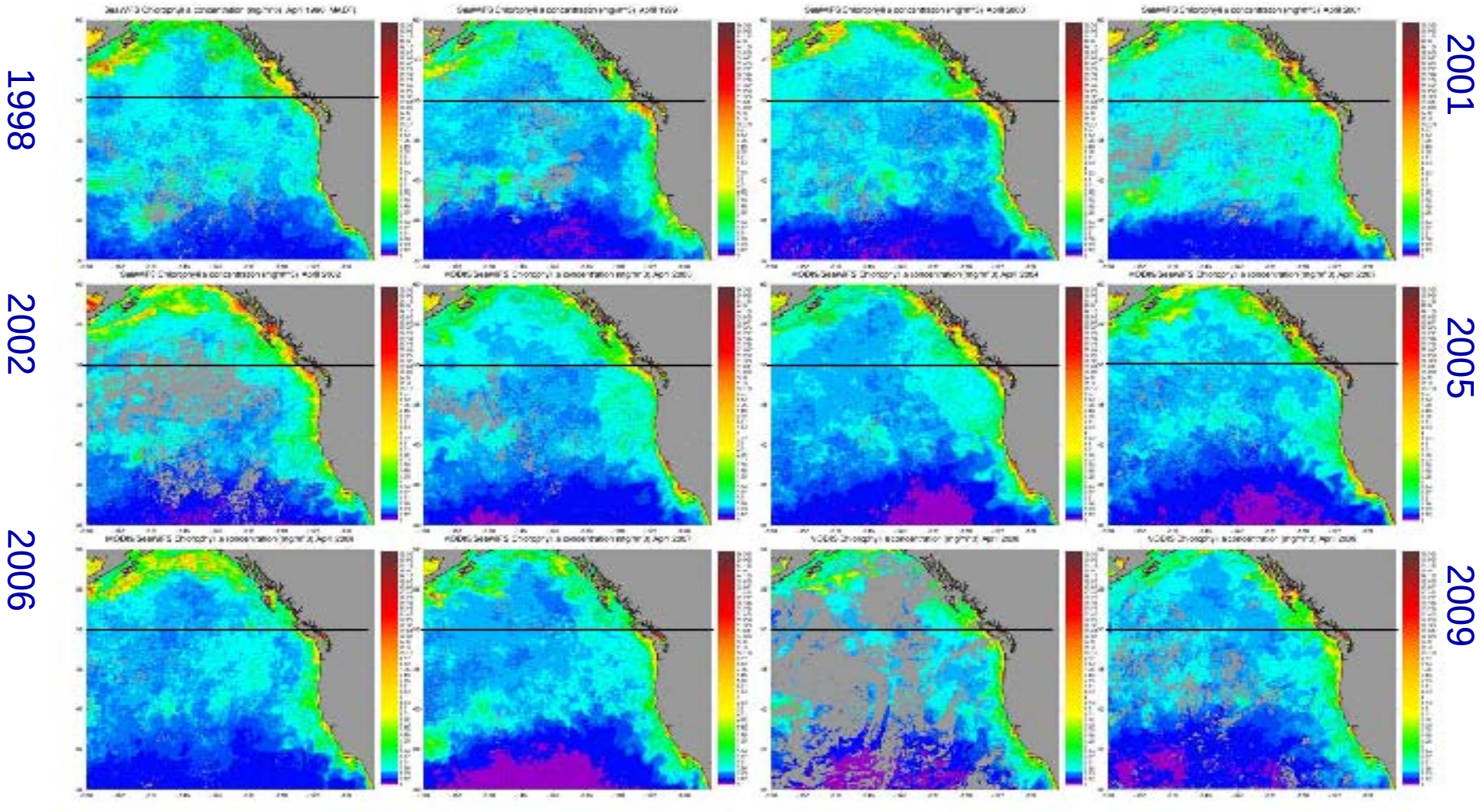
Comparison of S+N mortality patterns reveal periods when mortalities co-vary & periods (e.g. 1979-1984) when they do not.

From: Ford et al 2010



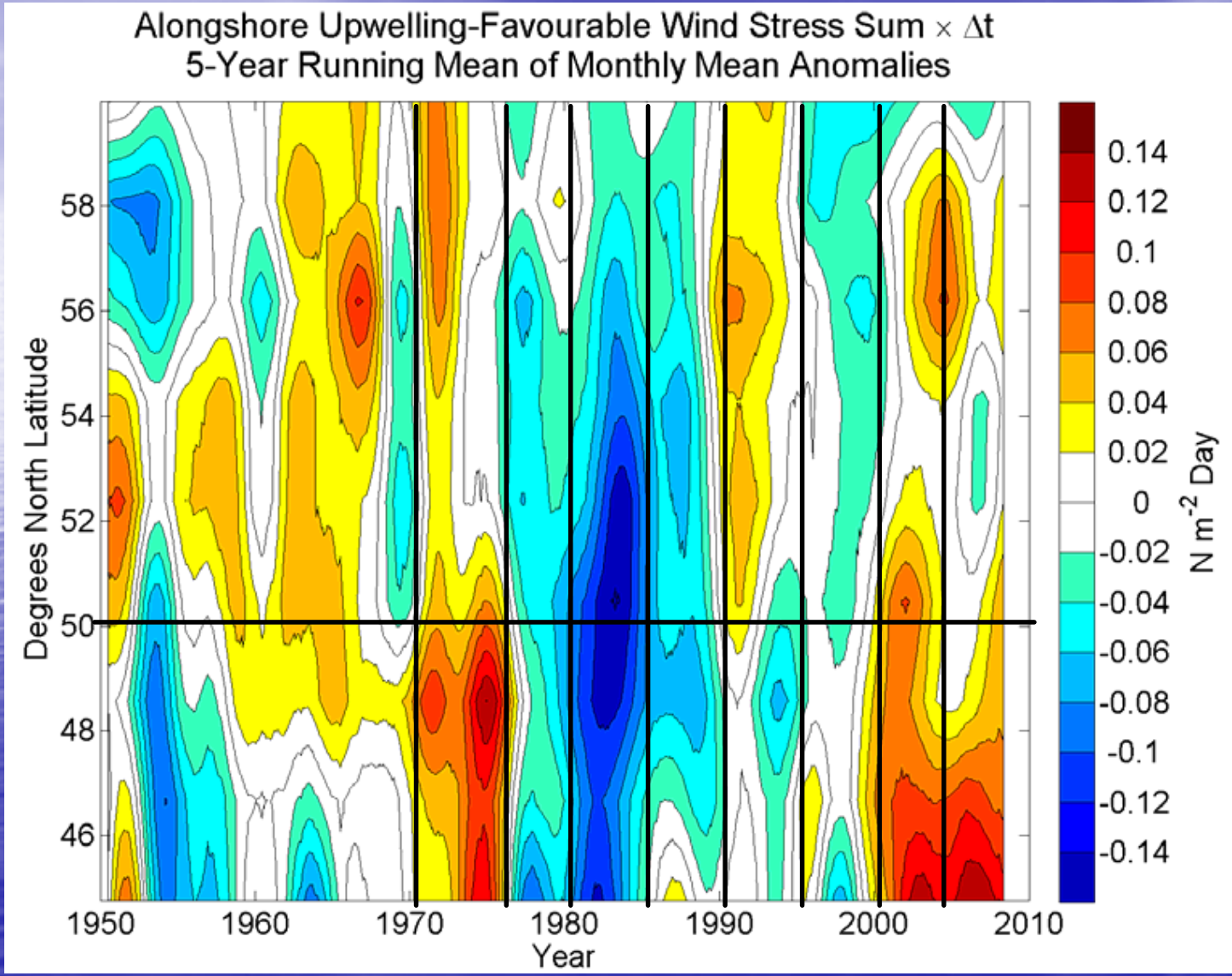
Coastal chlorophyll concentrations vary along the coast (March 2001 shown)

Chlorophyll concentrations can be compared among years



April 1998-2009 surface estimates shown, horizontal line at 50º

Northerly winds producing upwelling (good for critters) also vary spatially and temporally. Vertical lines at 5 yr intervals and horizontal line at 50°



From Hourston and Thomson 2011

e.g. During 1970-75 and 2000-09, upwelling better in southern regions; 90-95 better in north

NB only upwelling winds contributed to this anomaly time series so it is biased to April-Sept.

Summary/Next Steps

- Temporal patterns in ocean productivity vary between Alaska and California current regions
- Productivity may be correlated with Orca (and chinook) mortality & growth (with appropriate time lags)
- Examine statistical relationships with a view to better understanding mechanisms

References

Ford, J.K.B, Wright, B.M., Ellis, G.M., and Candy, J.R. 2010. Chinook salmon predation by resident killer whales: seasonal and regional selectivity, stock identity of prey, and consumption rates. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/101. iv + 43 p.

Hourston, R., and R. Thomson. 2011. Wind-driven upwelling/downwelling along the West Coast. Pg. 40-45 *in* Crawford, W.R. and J.R. Irvine. 2011. State of physical, biological, and selected fishery resources of Pacific Canadian marine ecosystems in 2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/054. x + 163 p.