Climate Change Impacts on the Pelagic Ecosystem of Southern California: Trophic Level Comparisons and Connections

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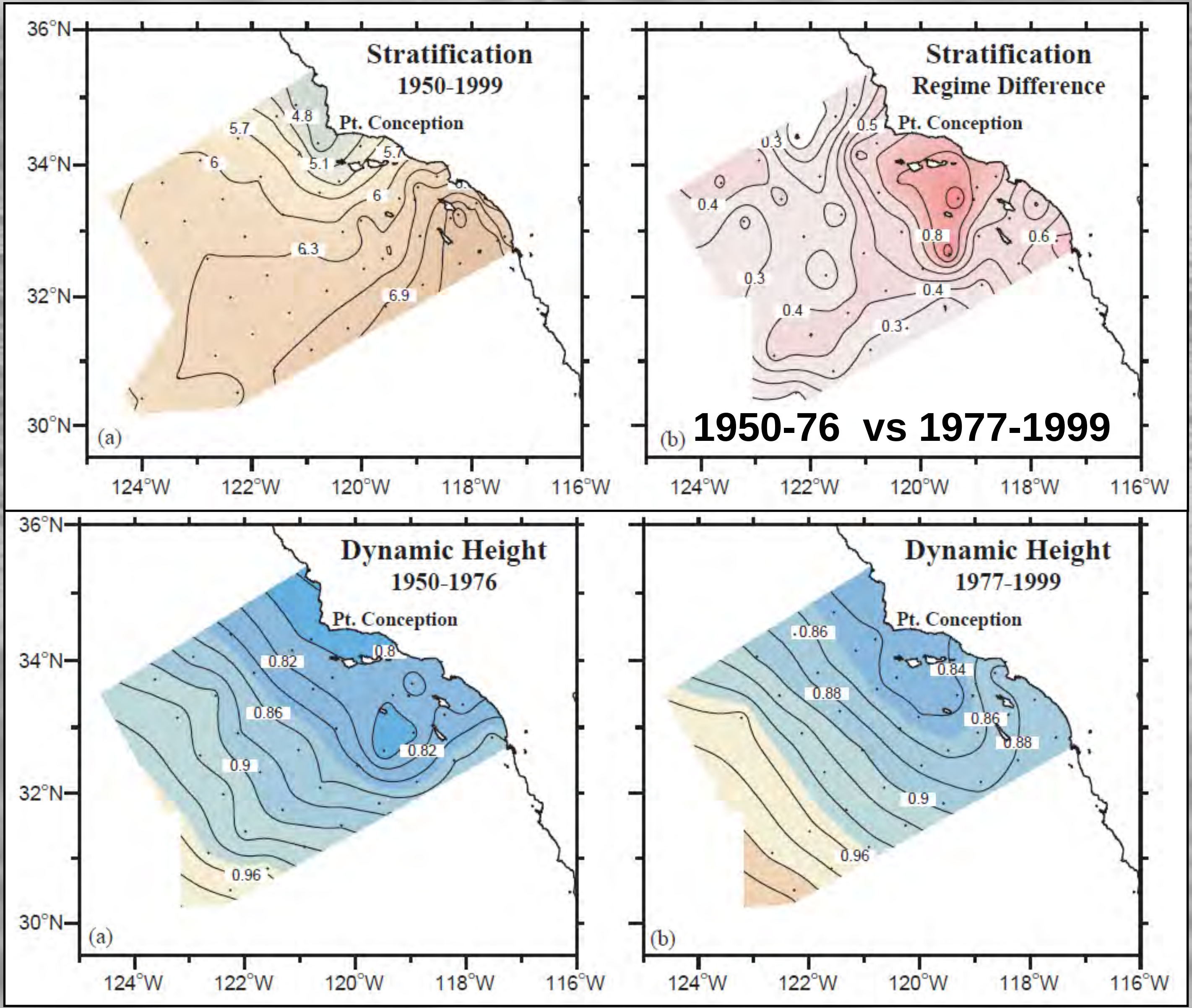
Anthropogenic Warming - Stratification Hypothesis

Bograd and Lynn (2003)



Questions

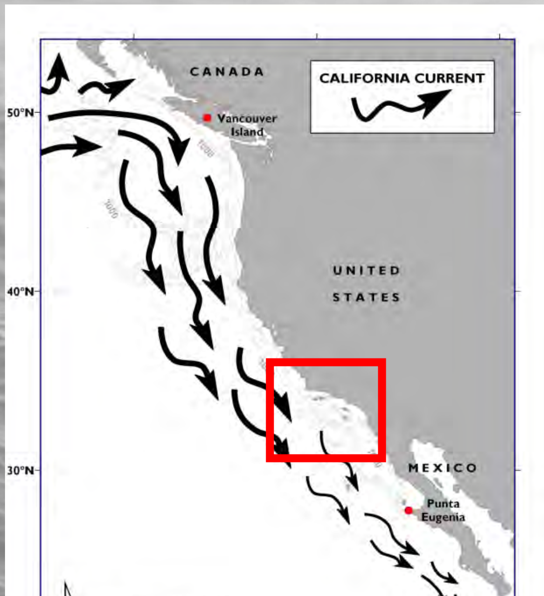
as stratification has changed, how have mid and upper trophic levels responded?

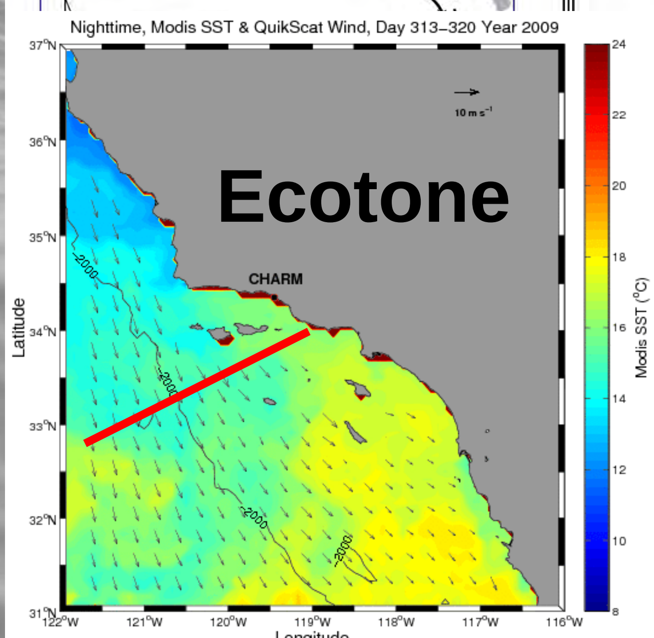
Specifically:

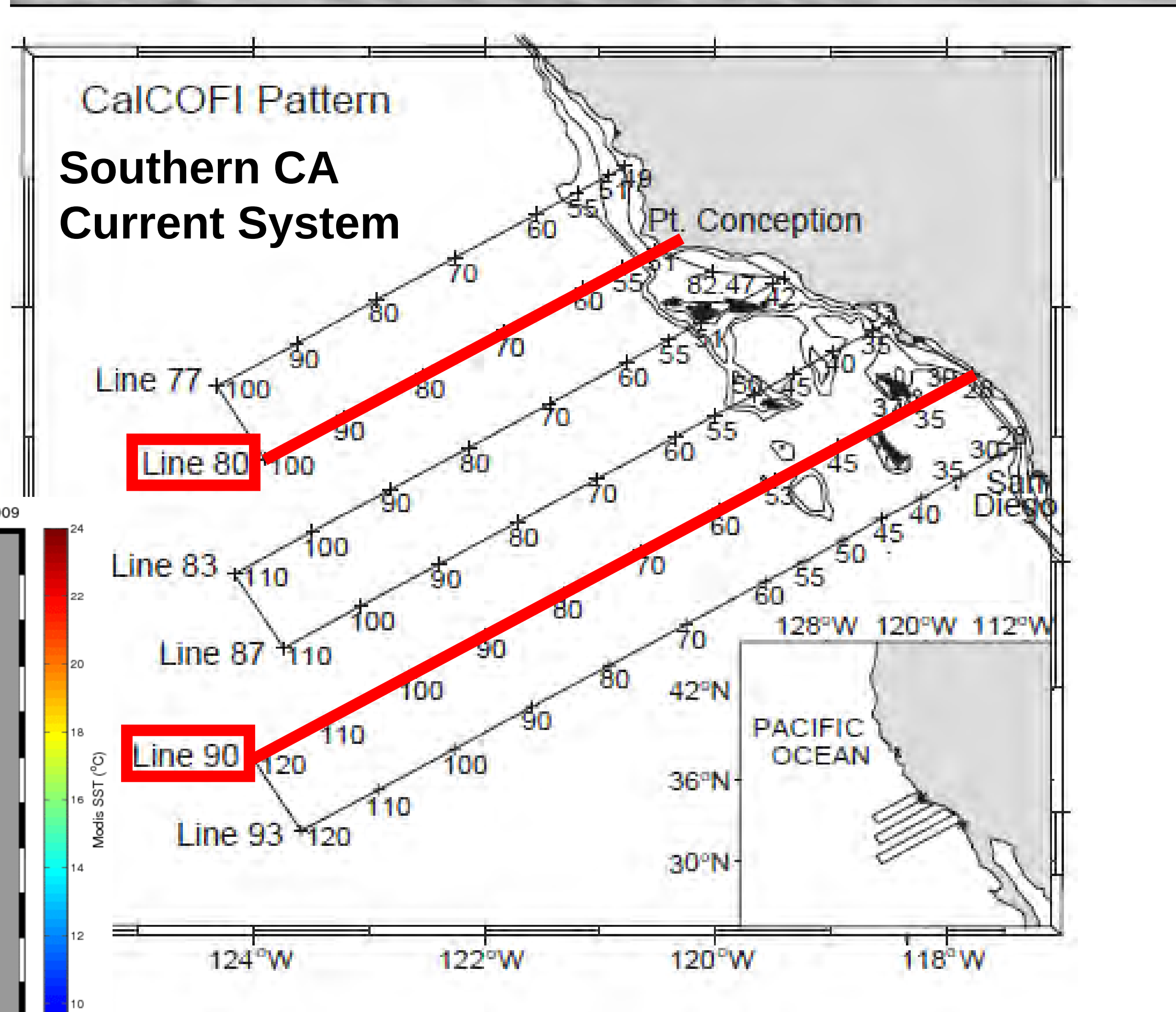
- **are trends in upper- (seabirds) and mid-trophic levels (icthyoplankton and mesozooplankton) abundance off southern California similar? Can they be related?**
- **Do patterns of change relate to physical drivers of the ecosystem (i.e., upwelling and stratification)?**
- **Does unidirectional or cyclic climate change best explain these results?**

CalCOFI/CCE LTER study area, 6 Lines, 30ºN-35ºN

(Hydrography – Lines 80 & 90)







Mesozooplankton, Fish, and Seabird Time Series

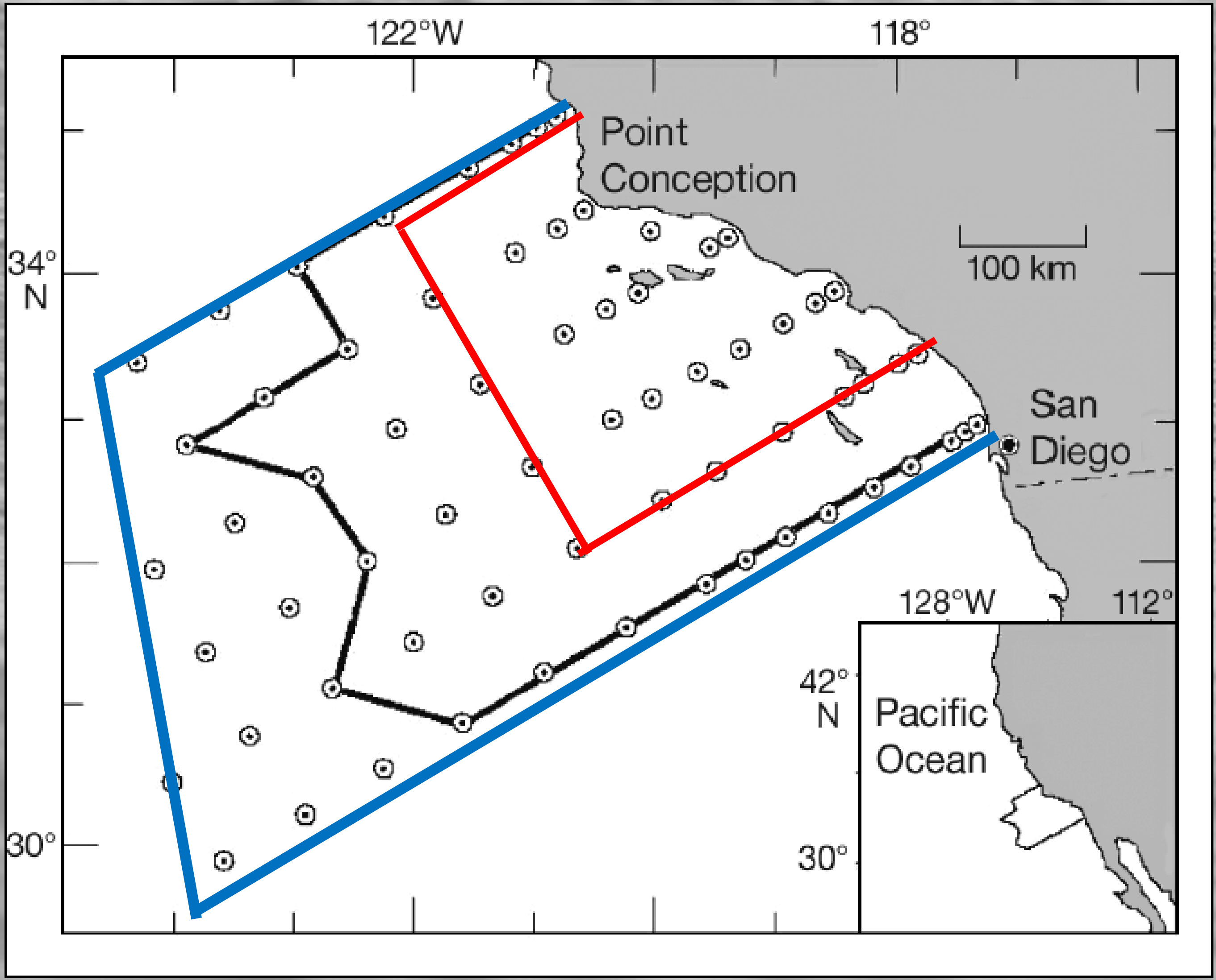
Seabird Abundance
(no. km^{-2}) (1987-2011)
(visual observations between stations)

Larval Fish Abundance
(no. m^{-2}) (1951-2008)

(ah…yes, these are not larval fish, nor are they anchovies…)

Euphausiid Abundance
(no. m^{-2}) (1951-2011)
(Bongo nets)

Sectors of the CalCOFI grid summarized for krill (red), fish (black), and seabird (blue) abundance



Fish: Hsieh et al. (2009), Koslow et al. (2011); Krill: Lavaniegos and Ohman (2007)

Trend and Integration Analyses

(1) "nominal" rank correlation (Spearman)

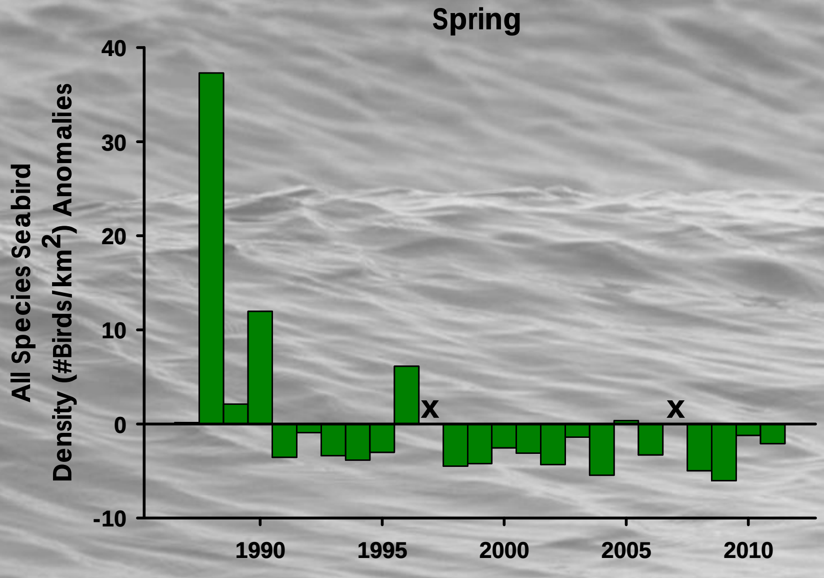
(2) "nominal" non-linear regression (2^{nd} order) to test for curvature (cyclicity) in trends

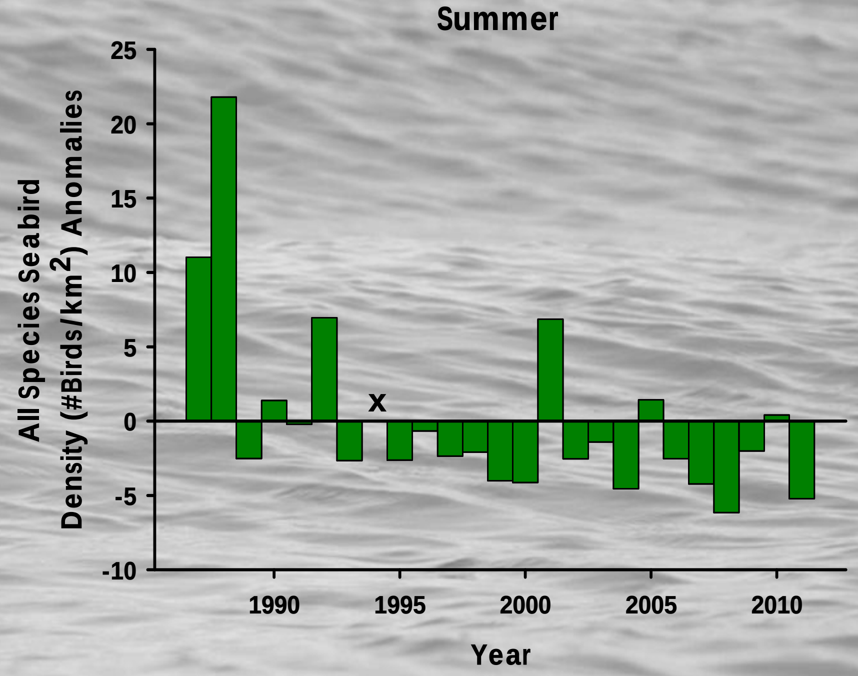
(3) by season: robustness of trends; lagged effects prey and physics?

(4) negative binomial (poisson) regression, detrended variables, to relate seabird abundance to prey abundance, stratification and upwelling..

Caveats: no correction for autocorrelation, gaps in series, seabirds generally do not consume larval fish (index to other age/size classes)

Seabird Abundance by Season

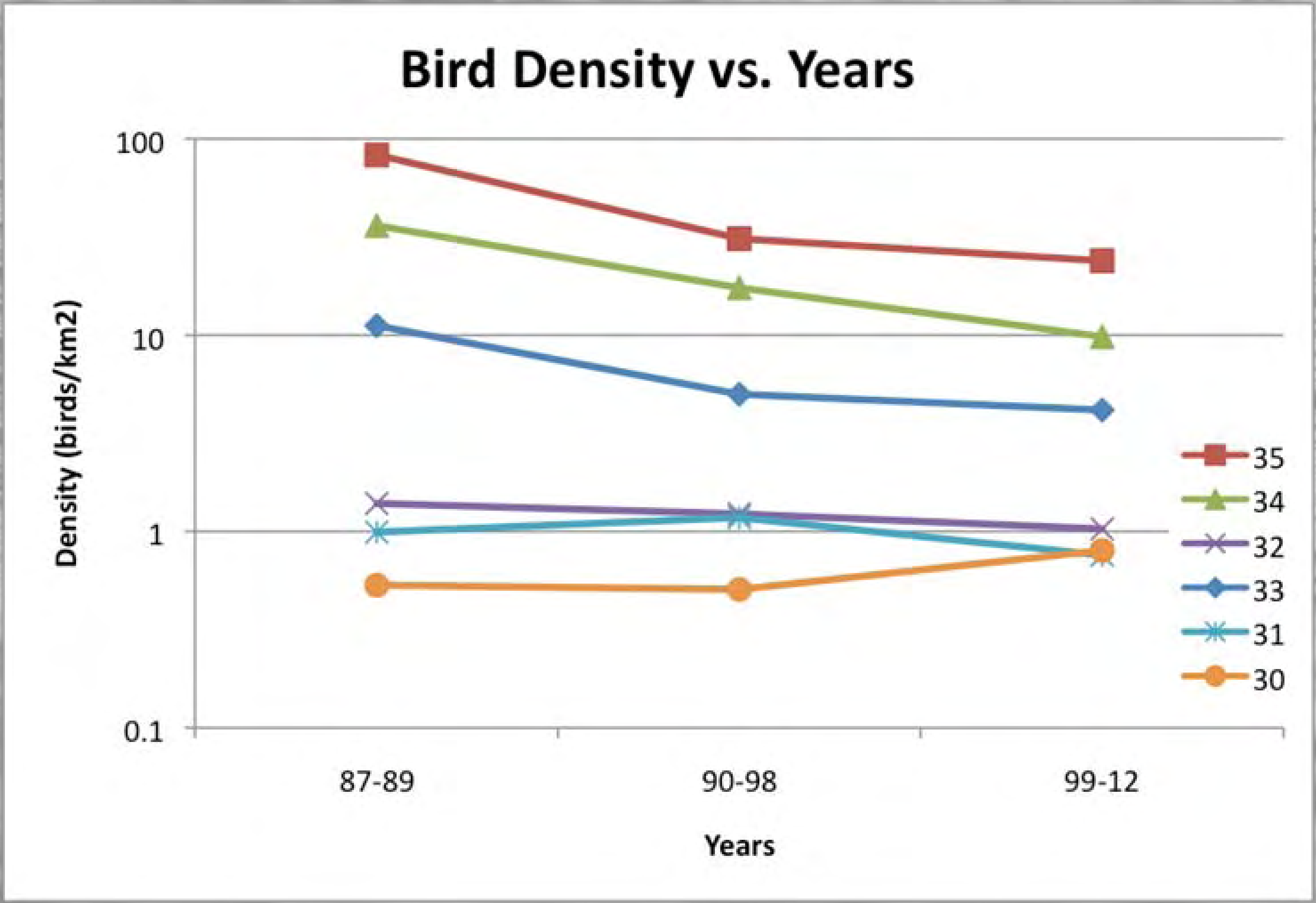




- ➢ **Spring: linear decrease (no quadratic effect in GLM)**
- ➢ **Summer: linear decrease (same…)**

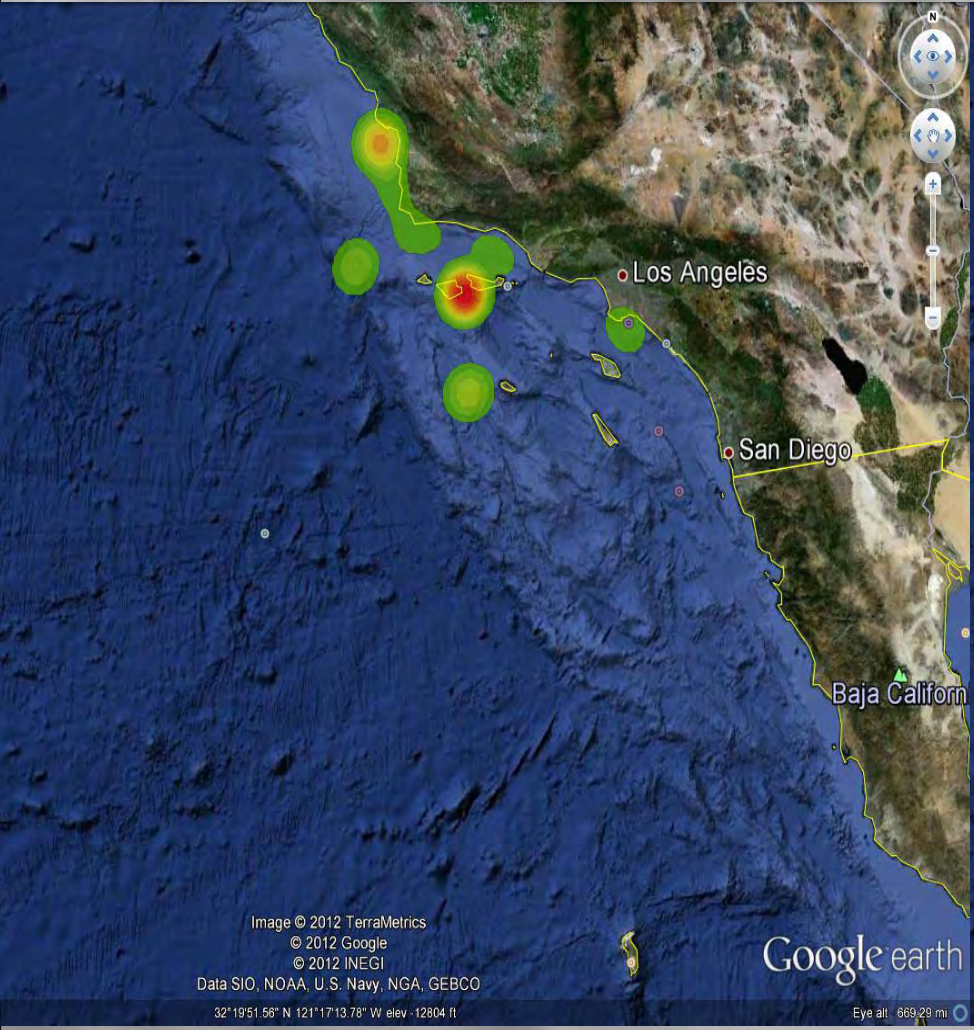
(x denotes missing survey)

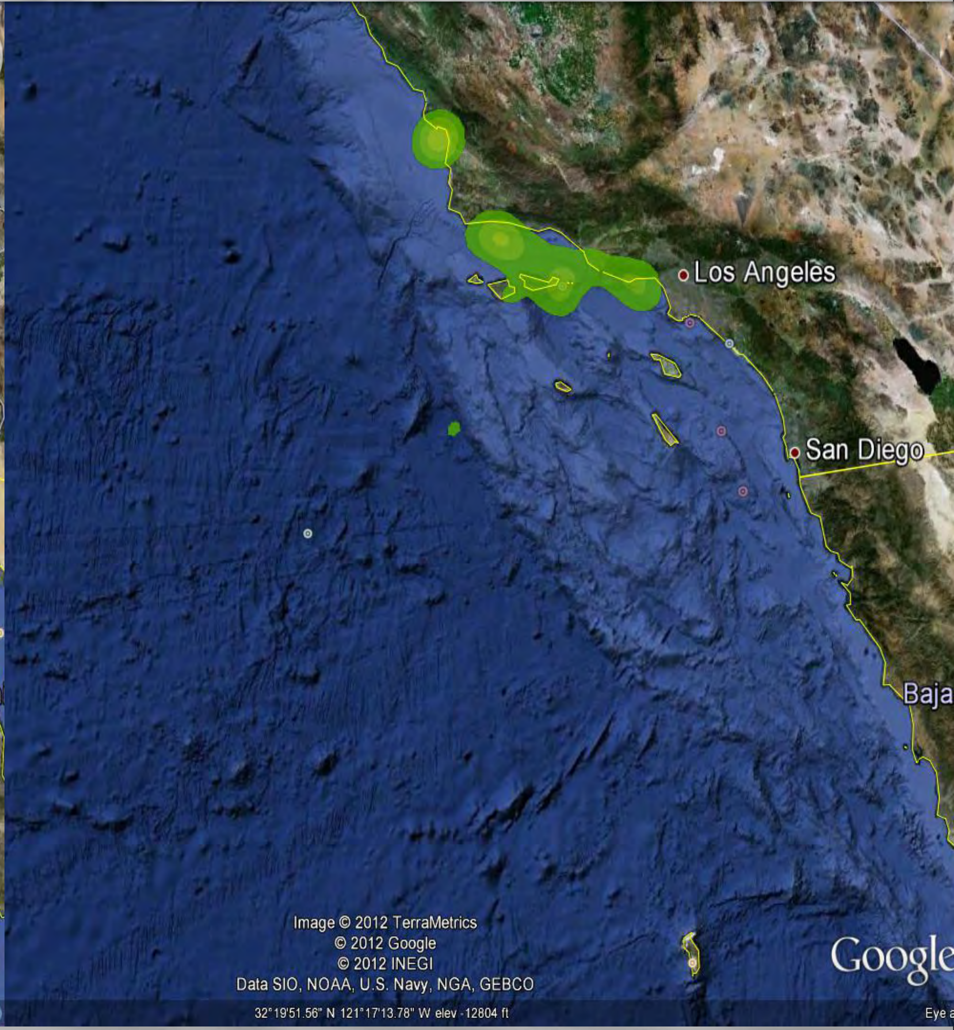
Seabird Abundance by Latitude & Period



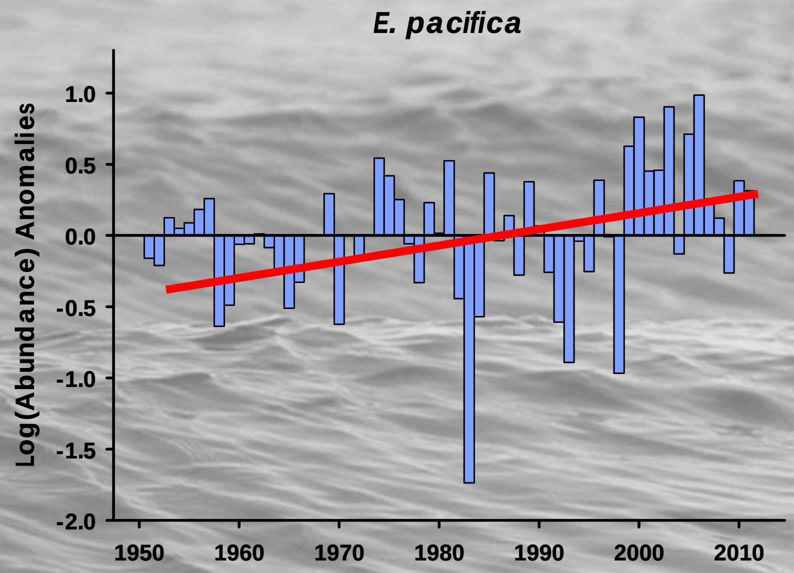
- ➢ **decline in northern (> 32N) sector, across putative "regimes"**

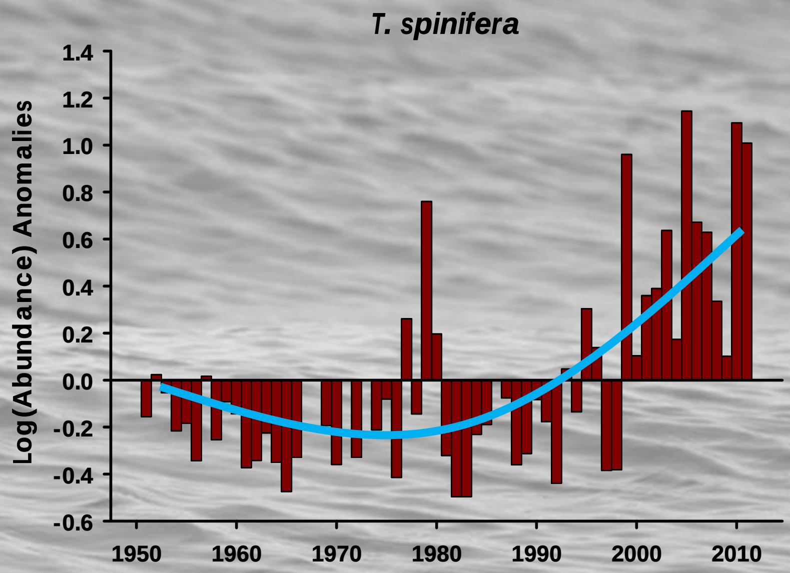
Seabird Habitat Use, 1987-1989 to 1990-1998 (shoreward collapse)



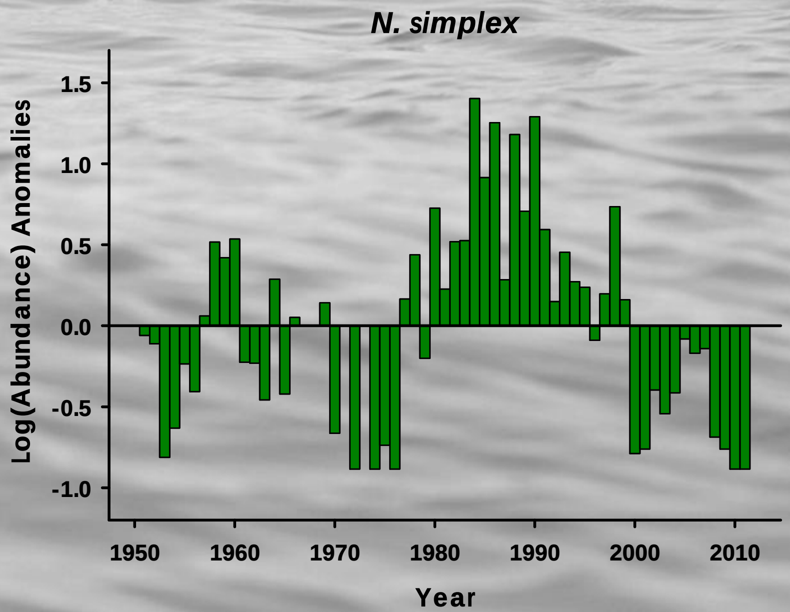


Krill Abundance

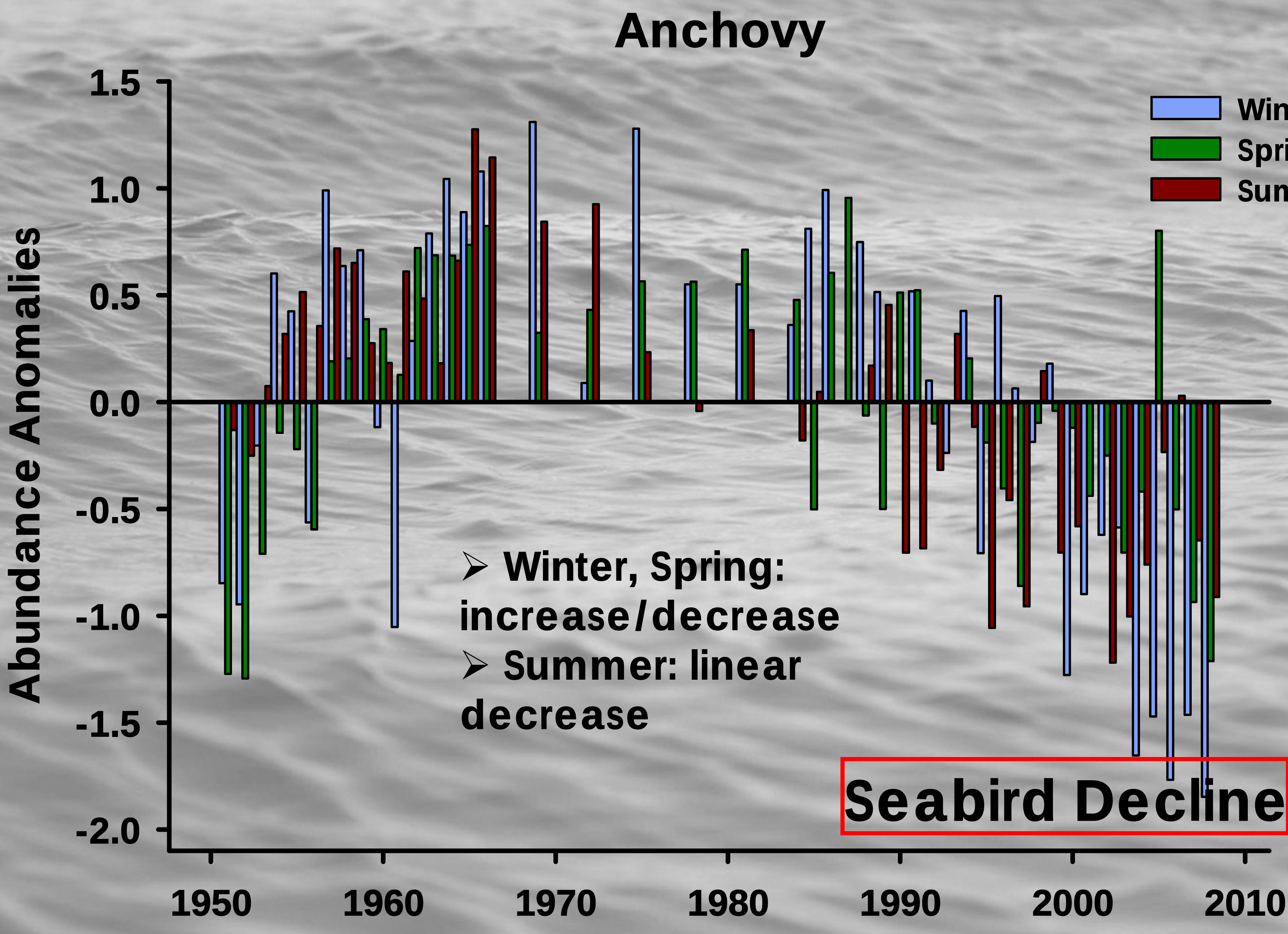




- ***E. pacifica*** **(coastal/slope): linear increase**
- ***T. spinifera*** **(coastal-neritic): decrease/increase (significant quad term)**
- ***N. simplex*** **(coastal): increase/decrease (...2 times)**



Coastal-Neritic Species (e.g.)



Summary of Pelagic Ecosystem Change

- **Upwelling33:** cyclic increase/decrease (not shown)
- **Thermal Stratification:** increase (Bograd and Lynn 2003)
- **Small Plankton Volume**: decrease (not shown)
- **Krill**: increase; reorganization (subtropical *N. simplex* decrease; subarctic *T. spinifera* increase)
- **Fish**: coastal/neritic: cyclic with recent decline (e.g. anchovy, note: sardine increase, recovery); oceanic species (mesopelagics): T. Koslow, S8, TH 1710
- **Birds**: decrease, northern sector, coastal/neritic spp.; shoreward redistribution

Connections?

Stepwise GLM – Effects of Fish on Seabird Abundance

	Predictor Entered	df	Chi^2	p-value
Spring				
Step 1	Area	1	0.00	0.948
2	Date	1	21.65	0.000
3	Stratification, Winter	1	1.15 (1)	0.423
3	Stratification, Spring	1		0.624
4	Upwelling, Winter	1	3.64 (2)	0.068
4	Upwelling, Spring	1		0.348
5	Zooplankton, Line 80	1	10.62 (2)	0.574
5	Zooplankton, Line 90	1		0.571
6	Mesopelagic Fish	1	38.21 (8)	0.830
6	Flatfish	1		0.000
6	Anchovy	1		0.000
6	Hake	1		0.000
6	Sardine	1		0.000
6	Croakers	1		0.000
6	Mackerel	1		0.000
6	Rockfish	1		0.000

Some Answers…

- Seasonal trends in bird, fish and plankton abundance?; are they related?
  - Some contrasting trends (krill); few apparent "shifts", curvilinear and linear change mainly.
  - Yes, connected: action in northern, coastal-neritic sector for birds and fish
- Do patterns of change relate to trends and variability of the physical environment?
  - Maybe (stratification [AGW] – upwelling [cyclic] interaction?)
- Does unidirectional or cyclic climate change best explain these results?
  - Both apparent, but cyclic dominant (upwelling to fish to birds in north, anchovy may be key)…

Conclusion: It's <u>not</u> a question of natural environmental variability versus AGW, but rather how and when they interact with each other to force ecosystem change…

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