COMPARISON OF THE EFFECTS OF THE 1976-77 NORTH PACIFIC CLIMATE SHIFT ON THE CALIFORNIA AND JAPANESE SARDINE HABITATS—

Approaching the problem by basin-scale ocean modeling.

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PICES 13TH ANNUAL MEETING
HONOLULU

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OBJECTIVES OF PRESENTATION:

-- Examine mechanisms that produce the synchrony in productivity changes in the Japanese and California sardine populations

BACKGROUND:

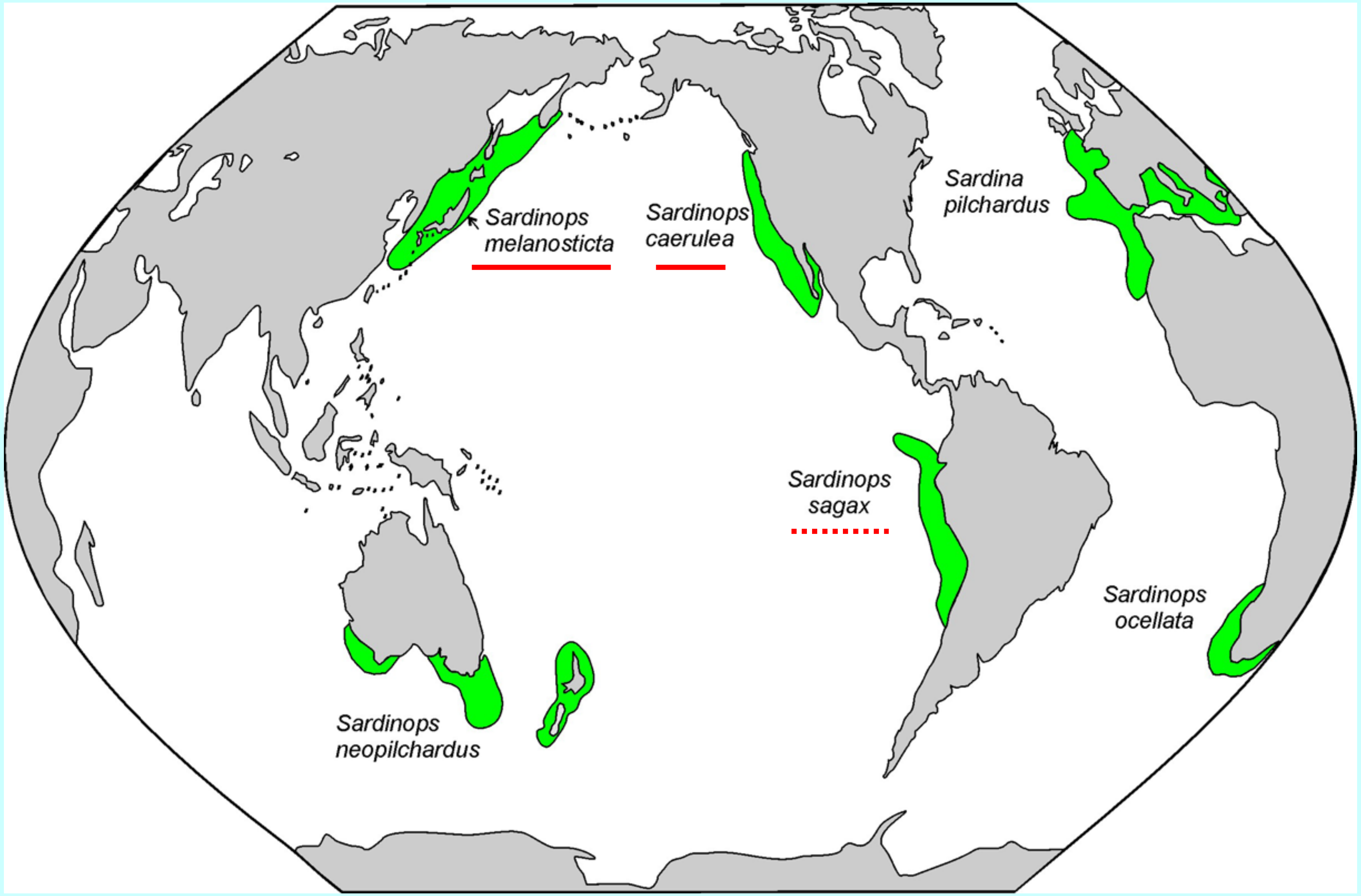
-- Geography of Pacific sardine populations = major ocean boundary current systems.

-- Observed "synchronies" in rise and fall of catches in Pacific sardine populations:
California – Japan – Peru-Chile.

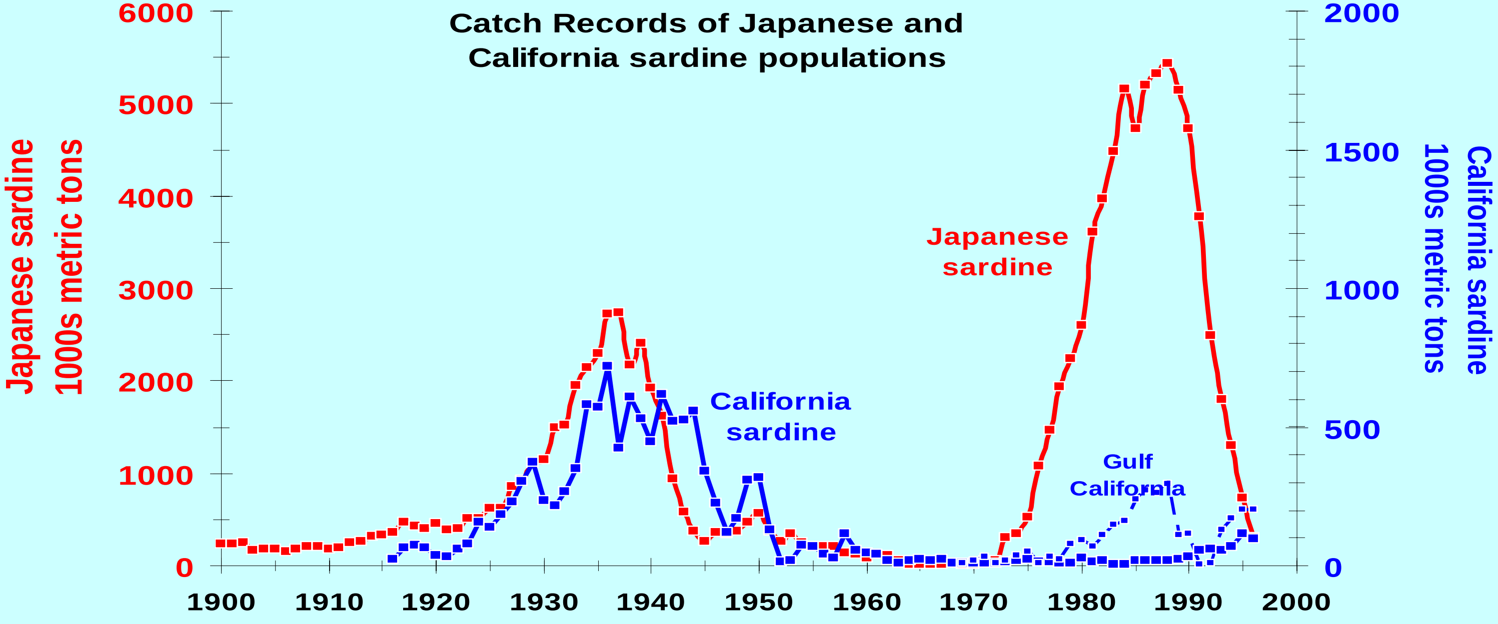
-- Interdecadal shifts in ocean climate regimes produce changes in productivity, abundance, and distribution/ranges of the sardine populations of the North and South Pacific ➔ expansion / contraction of favorable habitat.

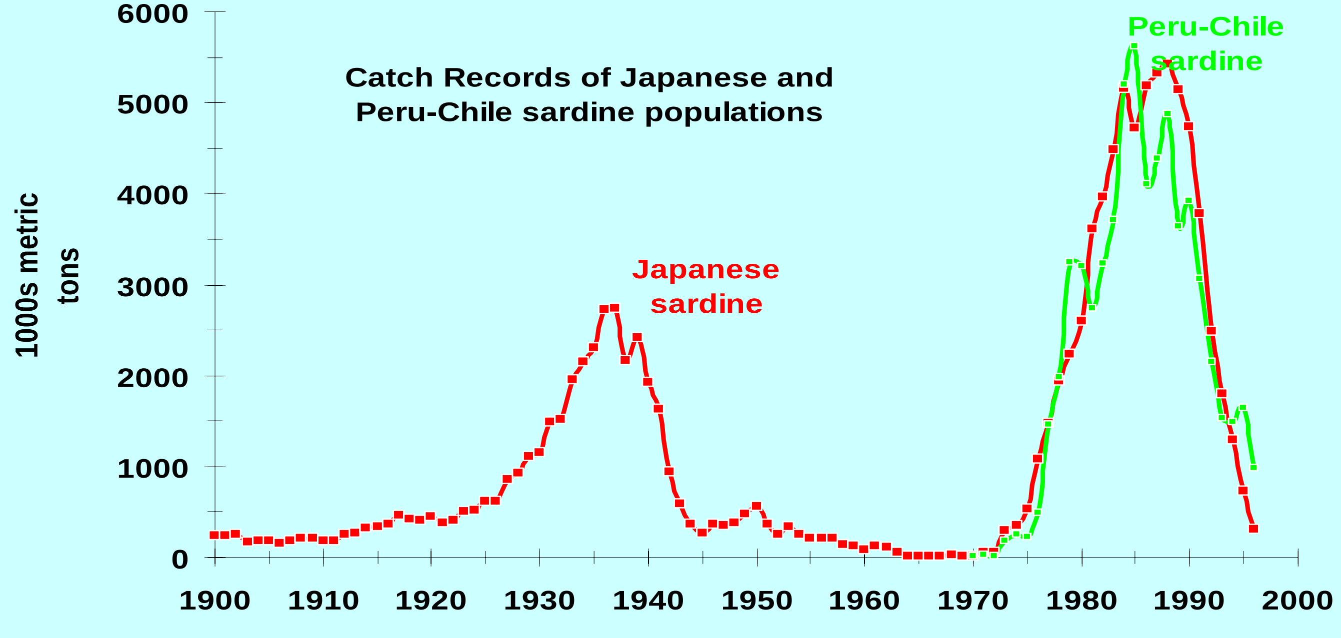
-- Observed relationships between productivity of populations and temperature, but no clear explanation of these relationships:
California: warmer = better // Japan: cooler = better.

Geography of sardine populations



Synchronies in catch records (hard data but mixes fishing with environment)



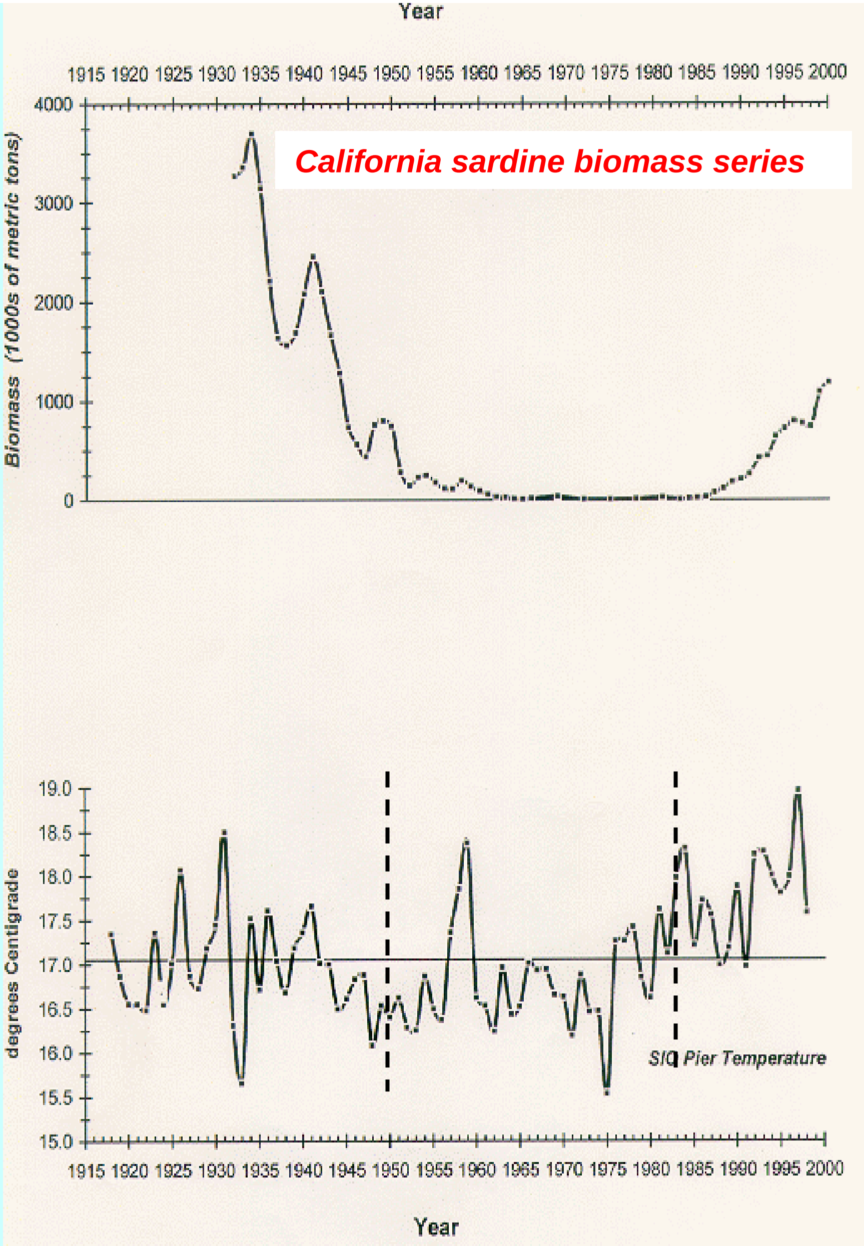


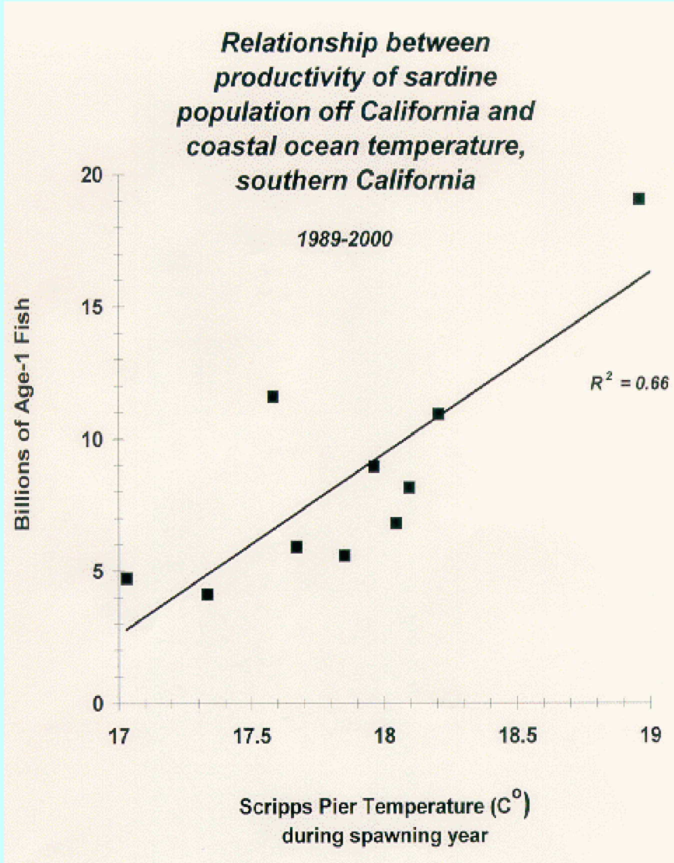
History of sardine abundance

(1932-2000 biomass)

in the *northeast* Pacific

compared to annual coastal temperature off southern California

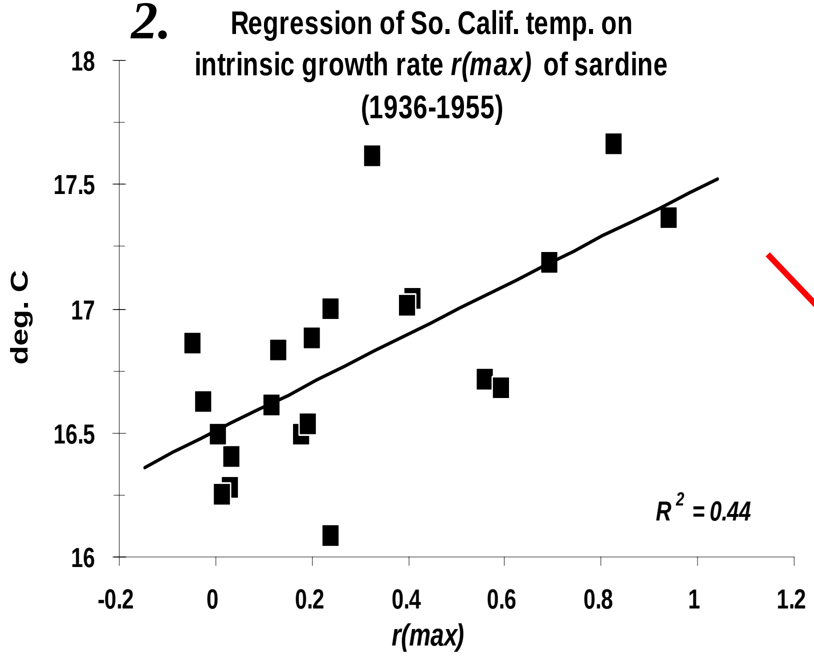




Coastal ocean temperatures off *Southern California*--Note interdecadal temperature shifts in early 1940s and at 1976-77

A DIGRESSION:
Investigating cause of lag in recovery of the California population...

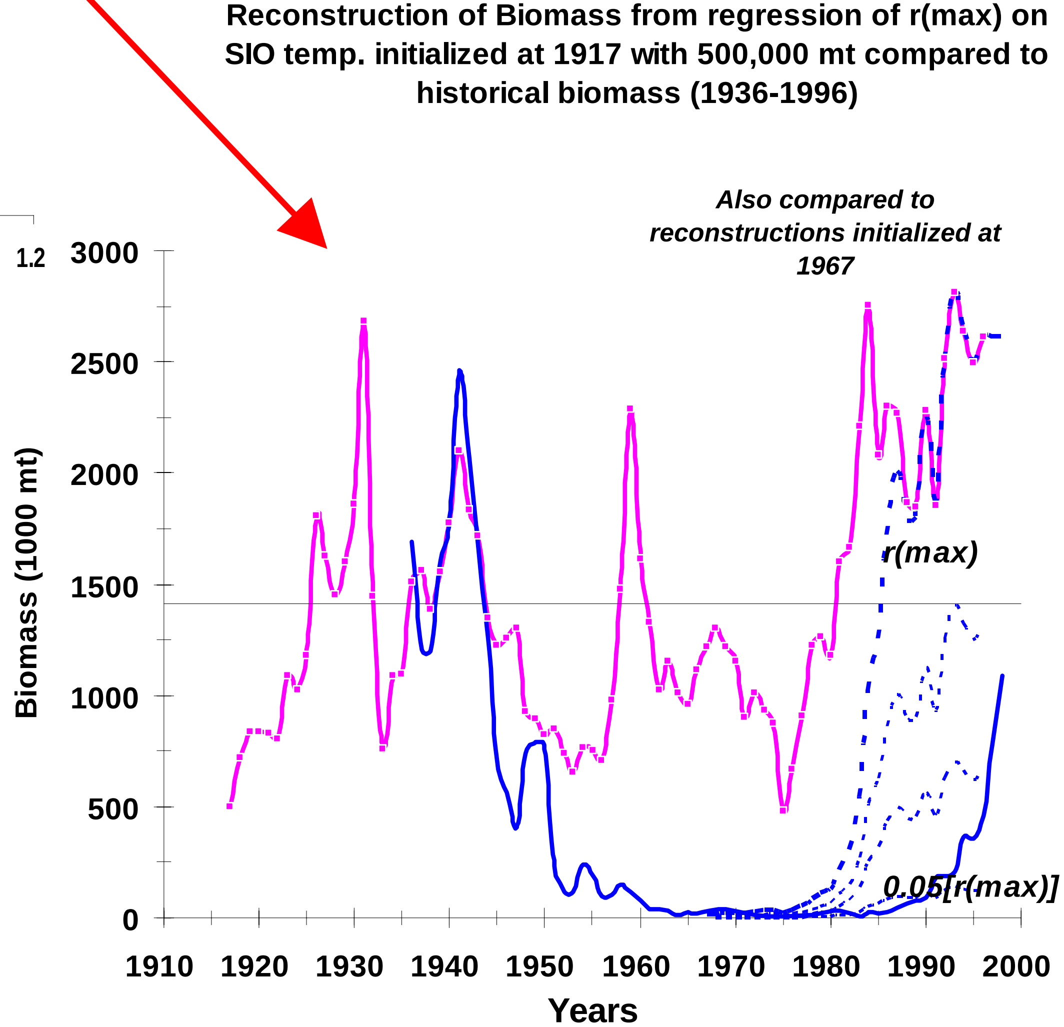
2.



$$\left(\frac{1}{B_h}\right)\frac{dB_h}{dt} = r_{h(\max)} - b_h B_h - F$$

1. **Removing Effects of Fishing from rate of population growth...**

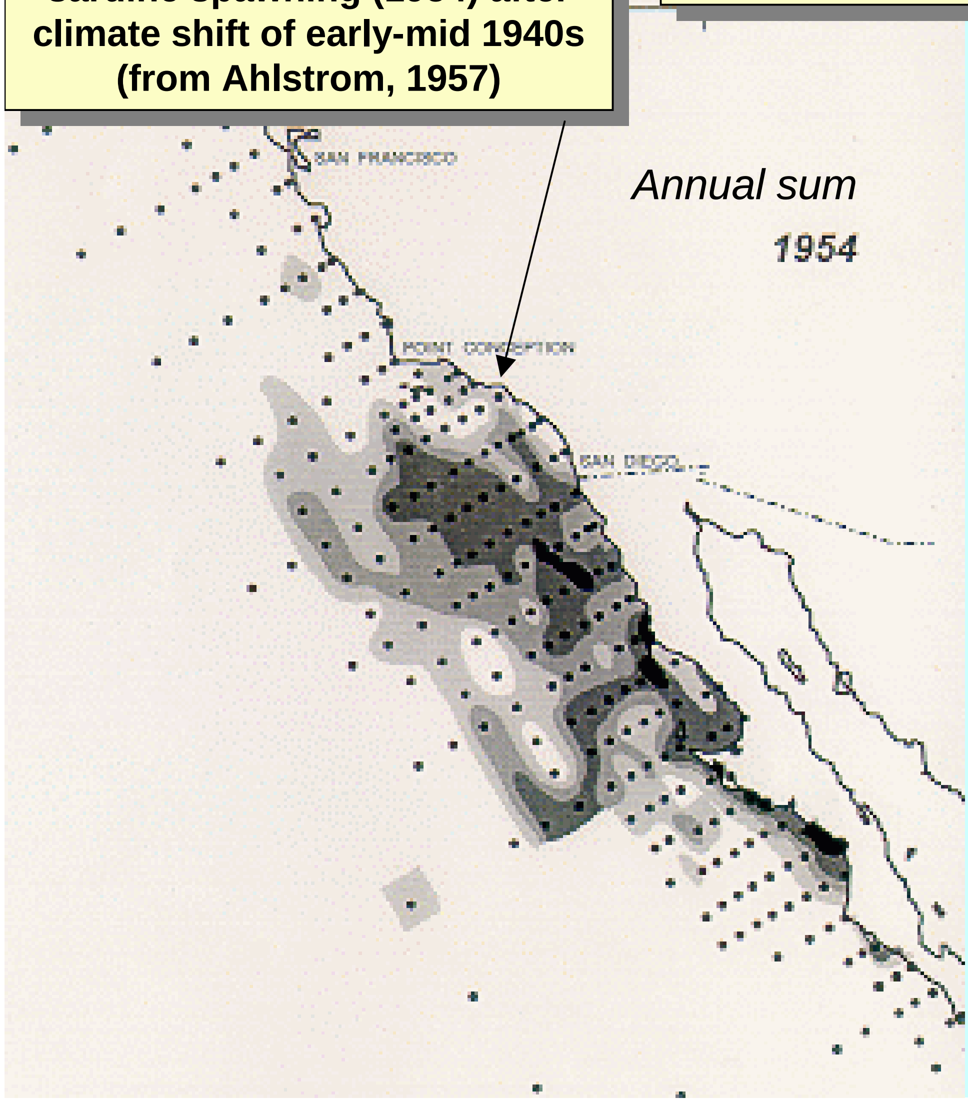
3.



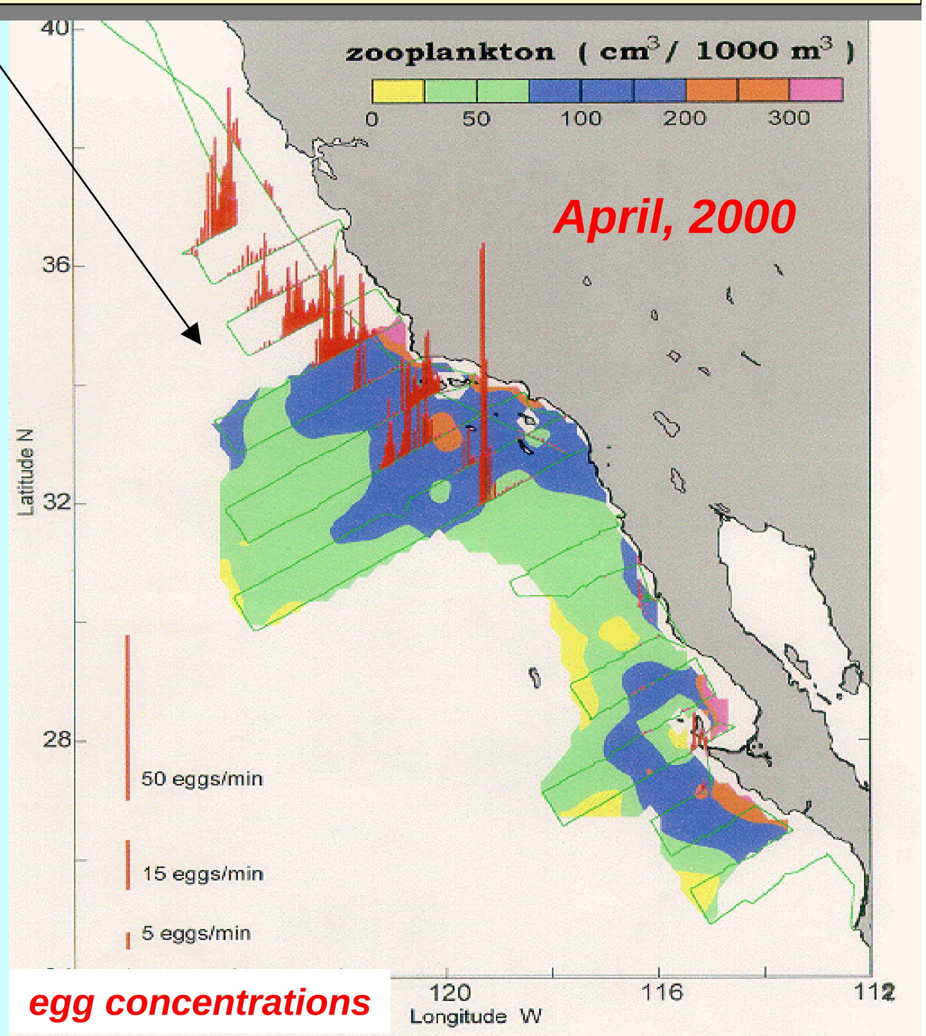
(Baumgartner, in prep.)

EXPANSION OF CALIFORNIA SARDINE RANGE AFTER CLIMATE SHIFT

Representative distribution/concentration of sardine spawning (1954) after climate shift of early-mid 1940s (from Ahlstrom, 1957)

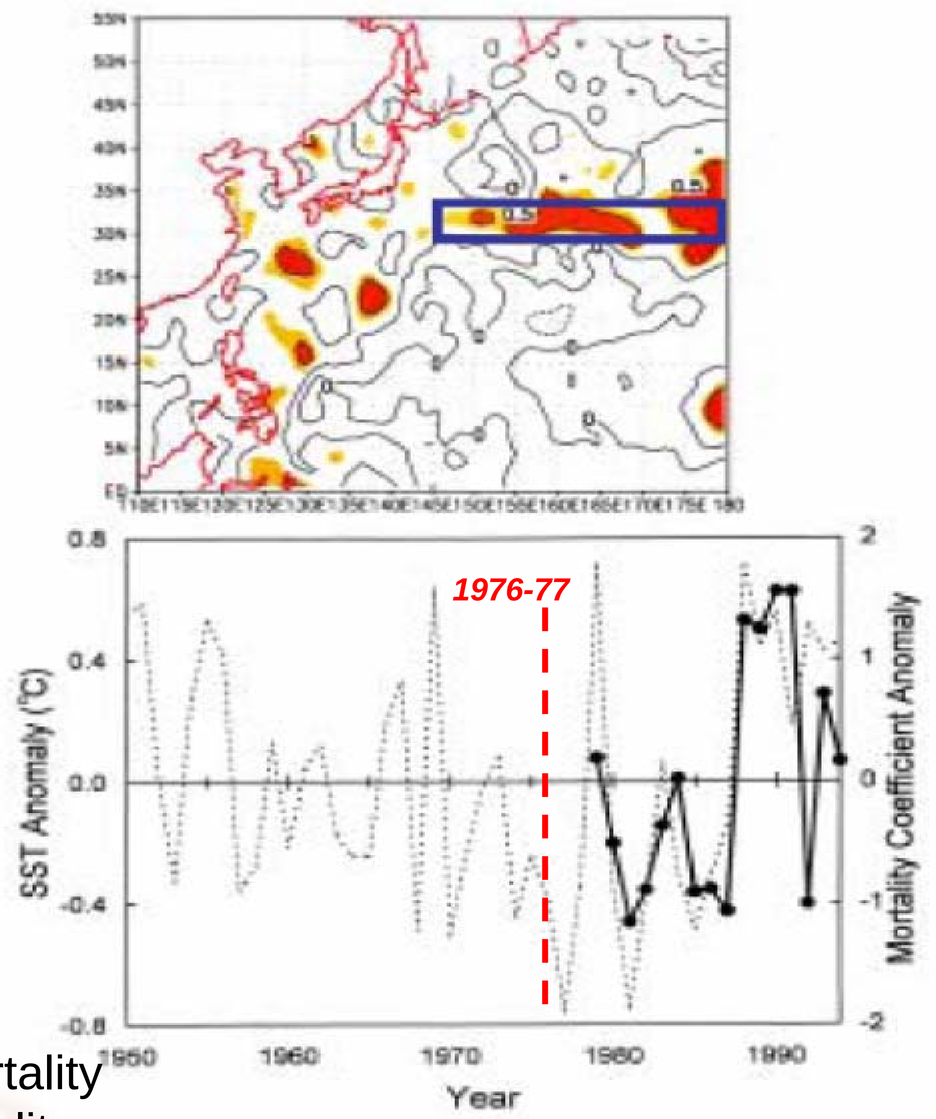


Distribution of sardine spawning during April, 2000, in relation to zooplankton distribution after the climate shift of the mid-late 1970s. (combined CUFES surveys by CalCOFI and IMECOCAL)



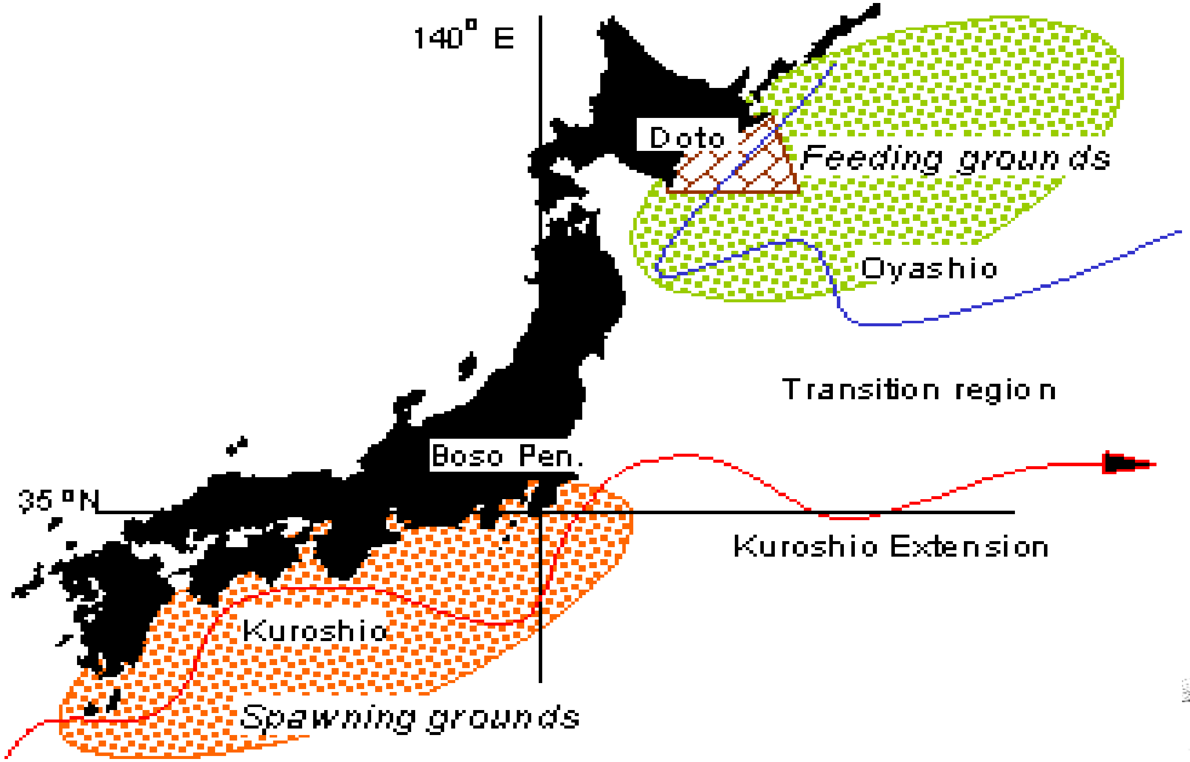
Survival rates of sardine young-of-the year and winter-spring SSTA in the Kuroshio Extension-southern edge (Yasuda and Noto, 2004 CLIVAR OSM)

Life cycle of Japanese sardine

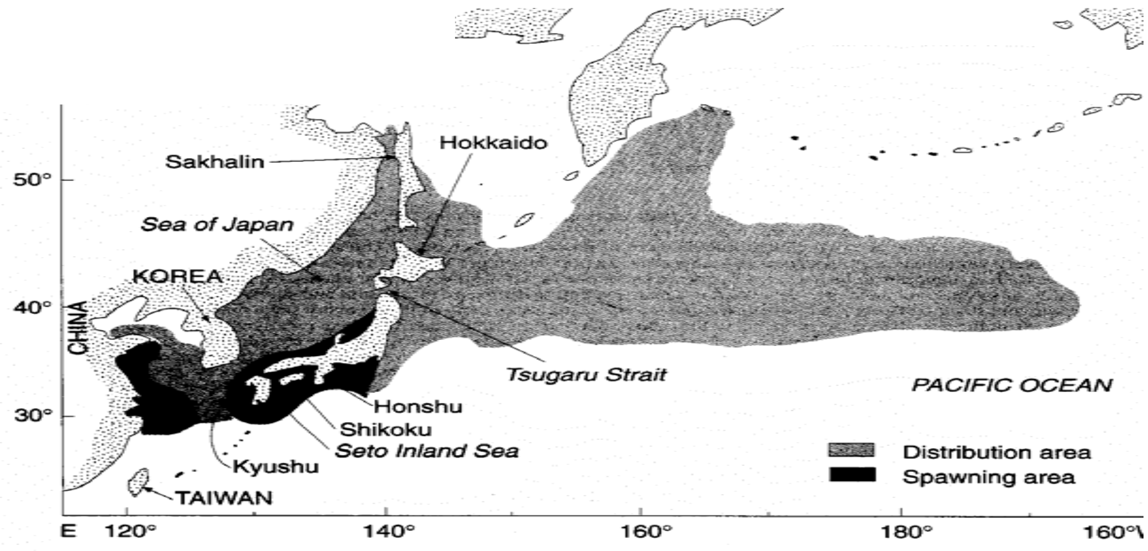


-- High SST: high-mortality

-- Low SST: low-mortality



Expansion of the range of the Japanese sardine in the late 1970s – 1980s



MODELLING APPROACH:

Define simultaneous changes in structure of the California and Japanese sardine habitats from basin-scale model of the ocean circulation

-- Use basin-scale, general circulation model to create a simplified version of the 1976-77 climate regime shift in the North Pacific.

-- Examine the regional responses of the ocean model to this simplified "canonical regime shift" in terms of the consequences to the pelagic habitats of the California and Japanese sardine.

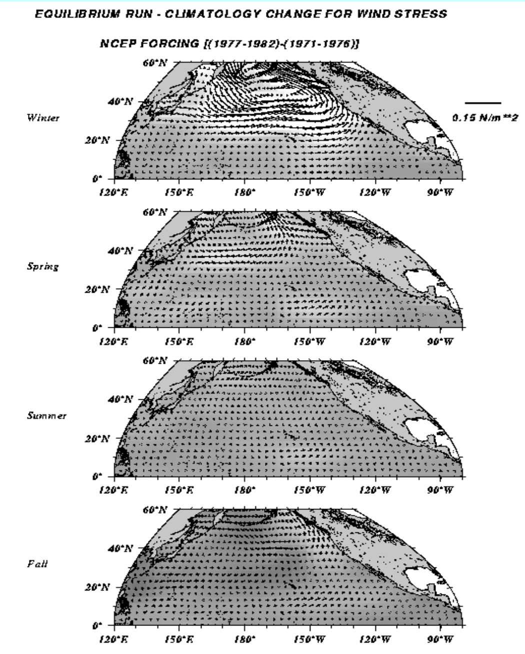
Introduction to the OPYC model:

10 isopycnal layers coupled to a bulk surface mixed-layer model,

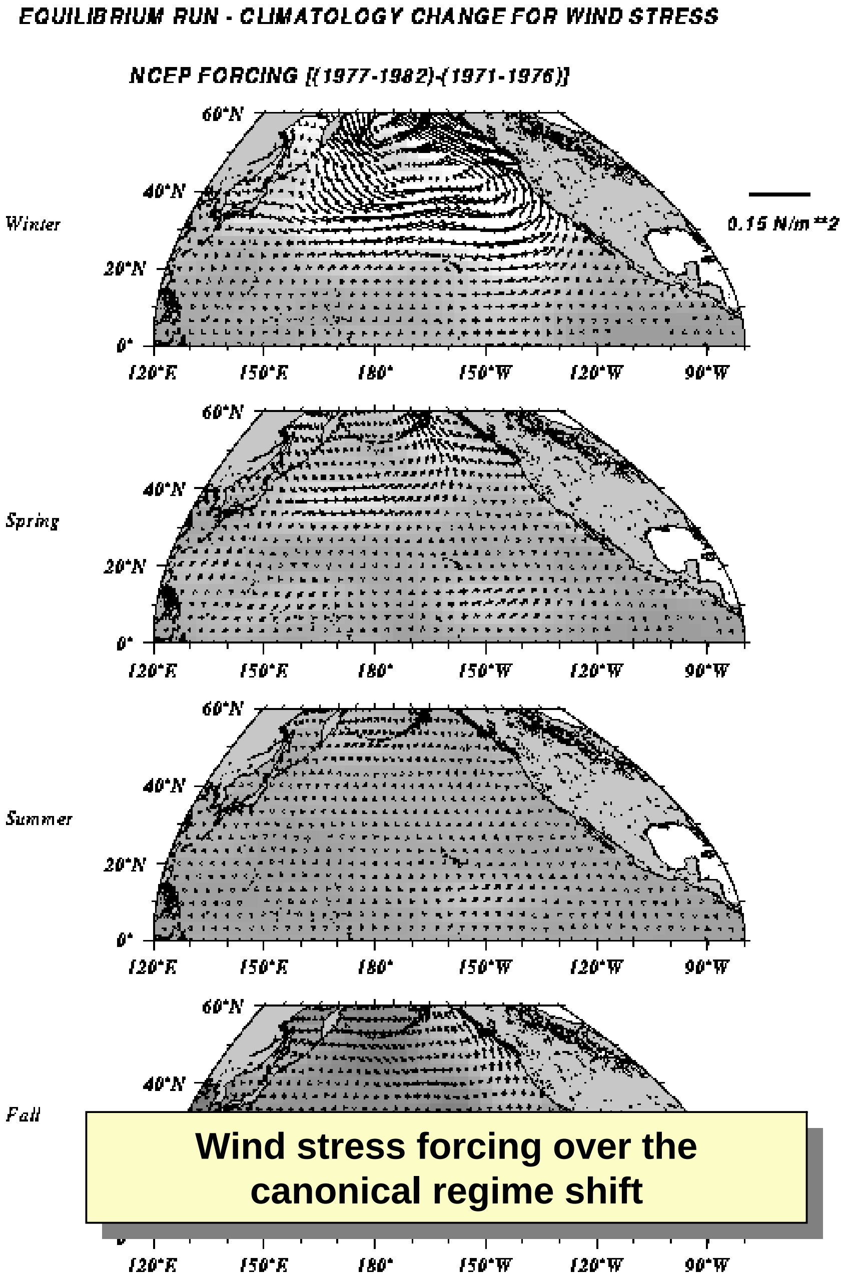
resolution 1.5^{o} in mid-latitudes, increased to 0.65 around equator,

seasonal anomalous forcing computed from NCEP fields.

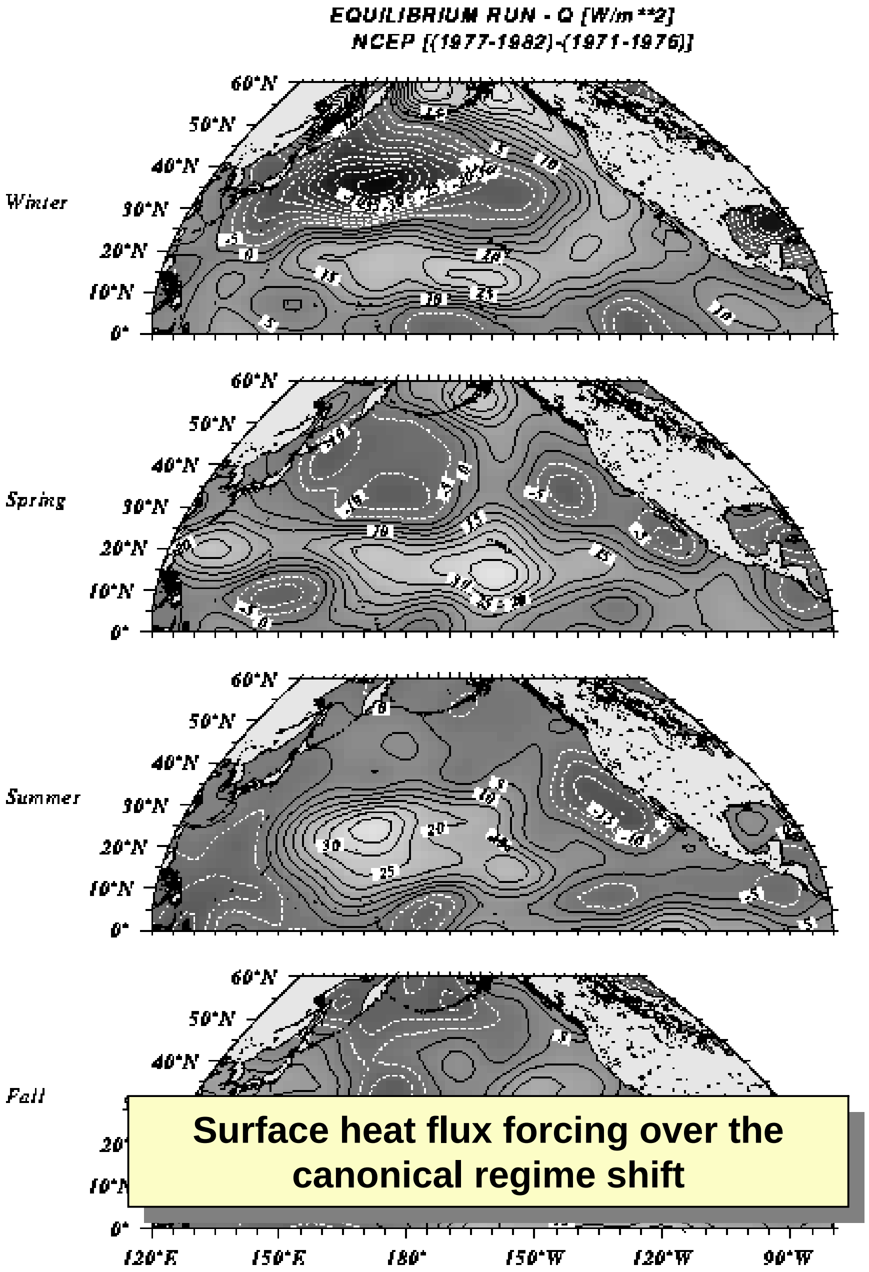
It is retrospective model: no feedback from ocean to atmosphere.



Using the OPYC model to define a canonical regime shift with averaged atmospheric forcing to examine ocean response-- based on differences between six years prior to and six years after the 1976-77 event



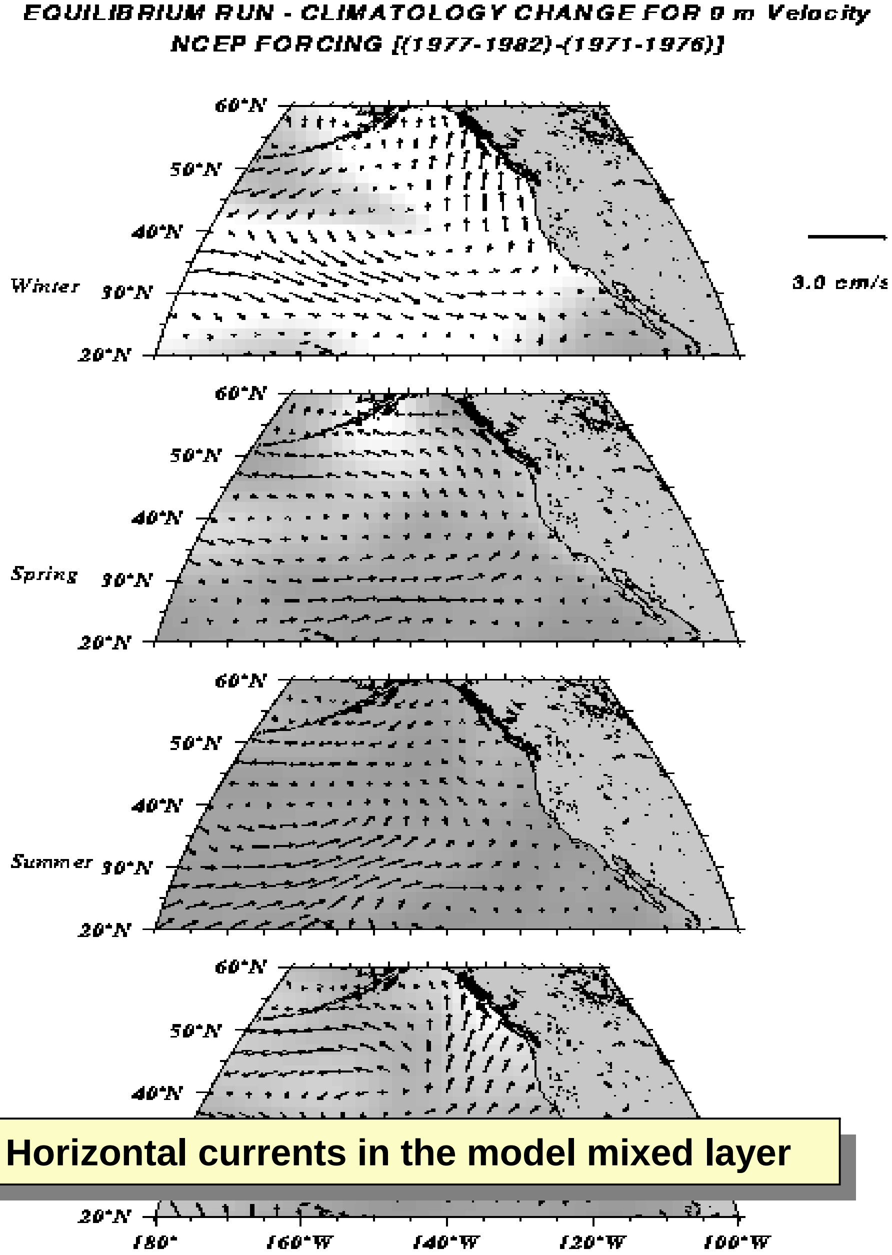
Wind stress forcing over the canonical regime shift



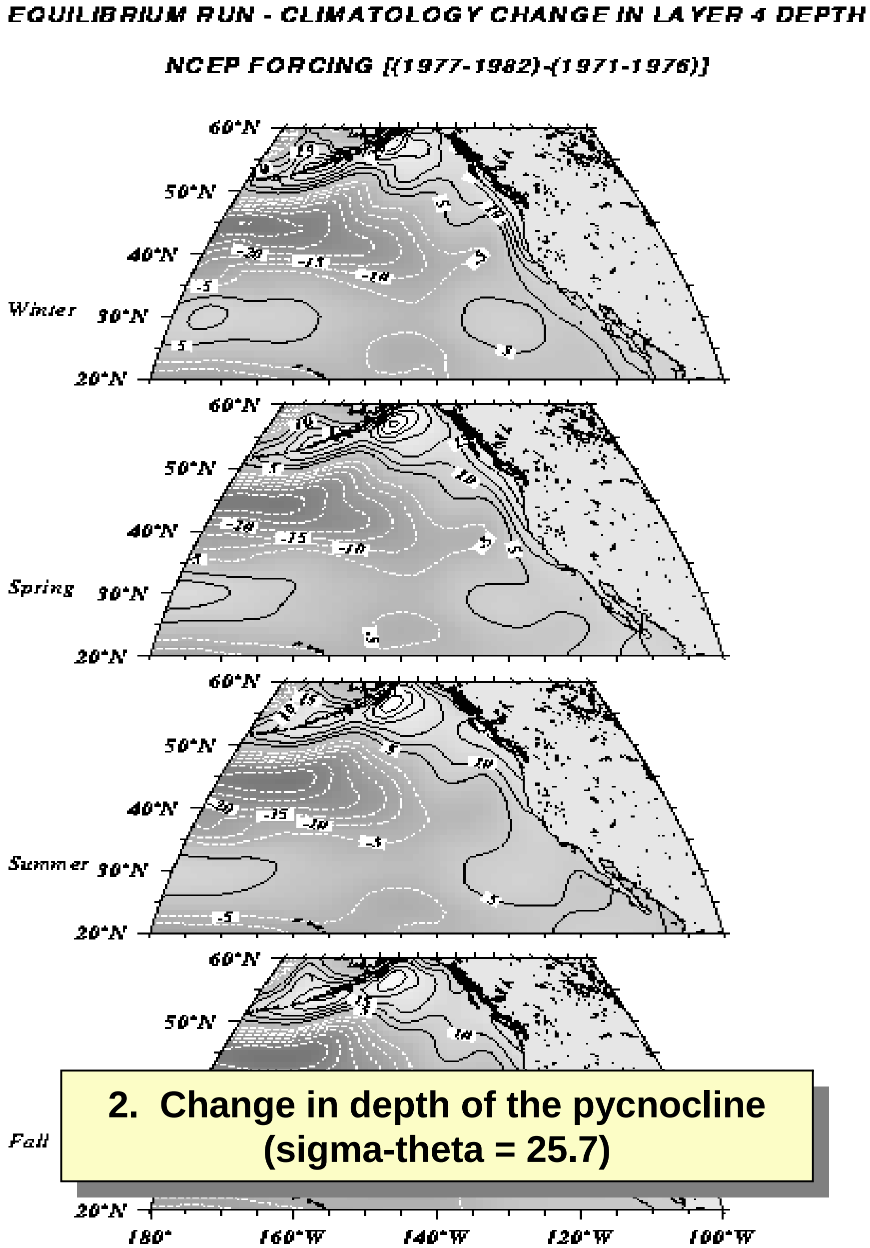
Surface heat flux forcing over the canonical regime shift

OCEAN MODEL RESPONSE → CHANGES IN HABITAT STRUCTURE / DISTRIBUTION INFLUENCING CALIFORNIA SARDINE ABUNDANCE, AND DISTRIBUTION IN THE NORTHEAST PACIFIC

Regional ocean responses of NE Pacific to forcing over the canonical shift
=change in physical dynamics and conditions of the sardine habitat



1. Horizontal currents in the model mixed layer

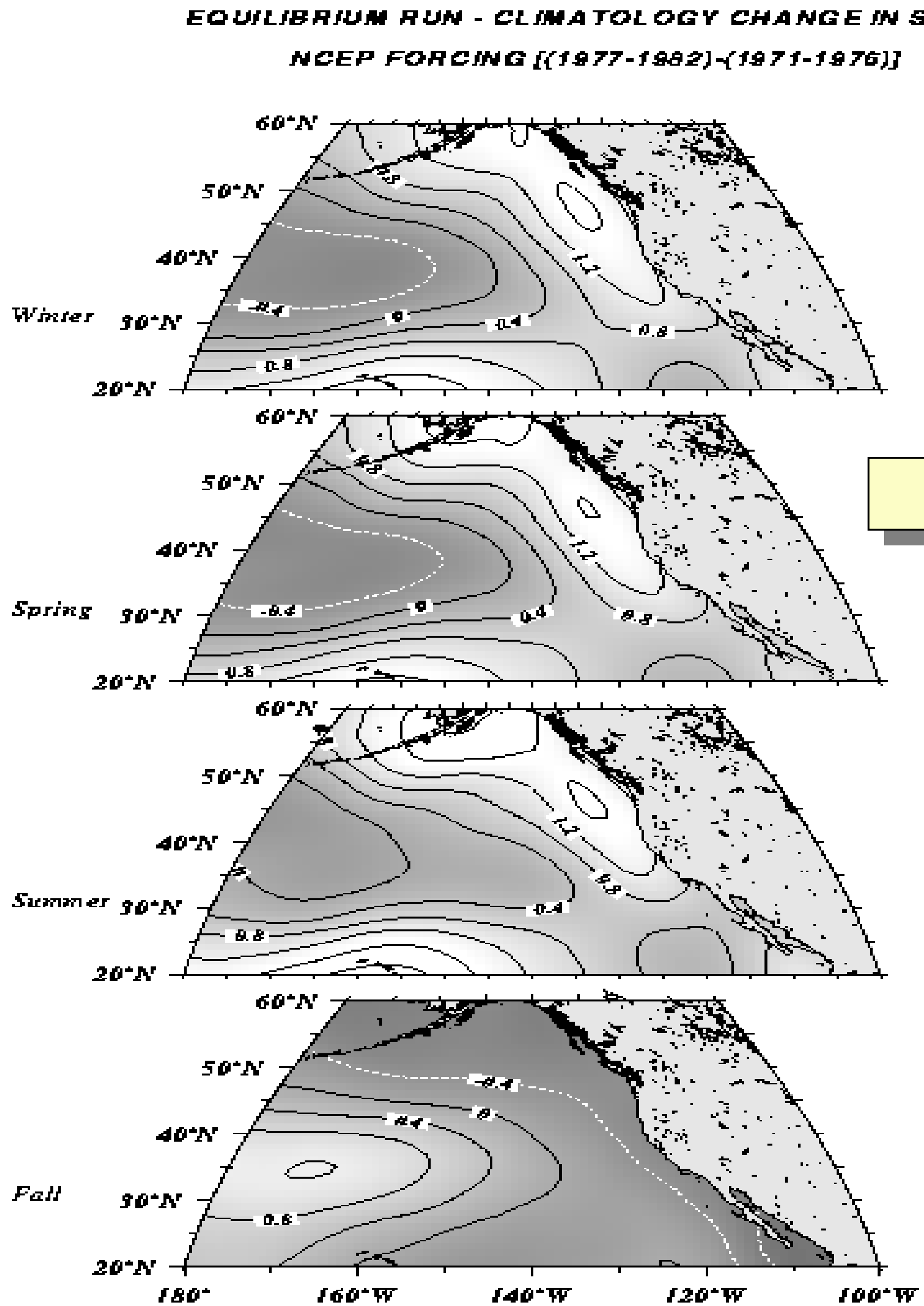


2. Change in depth of the pycnocline (sigma-theta = 25.7)

3. Change in SST

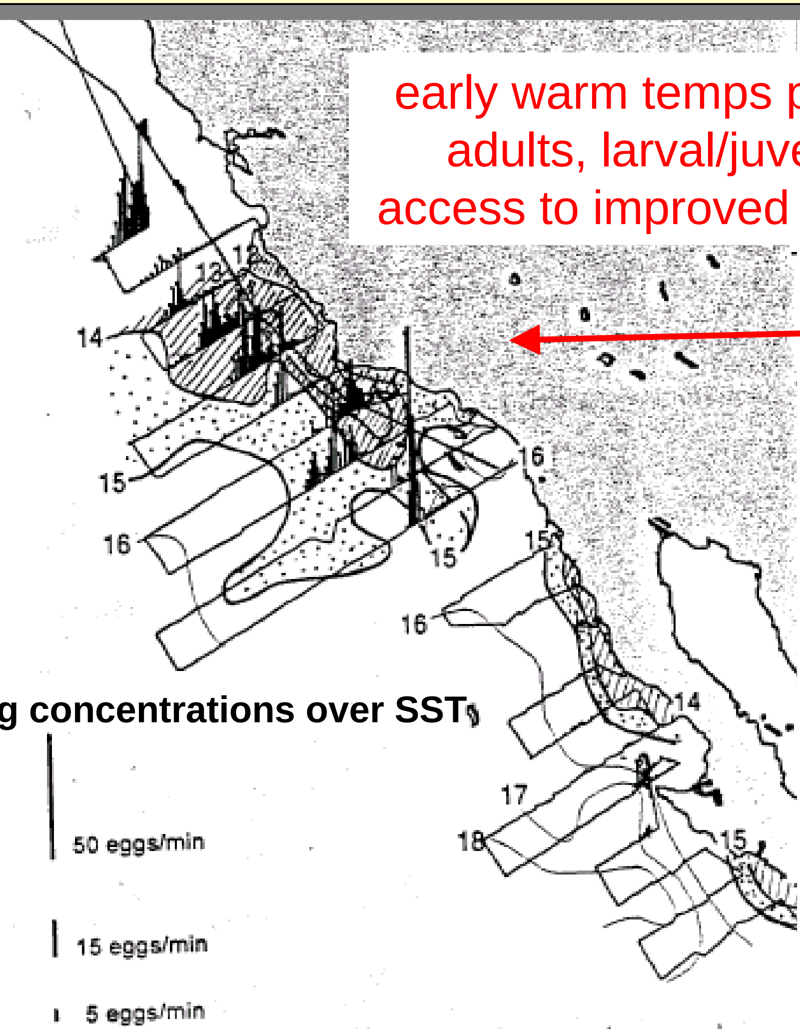
Note distribution of SSTA along eastern boundary:

warming north of Pt. Conception, little change off Baja California

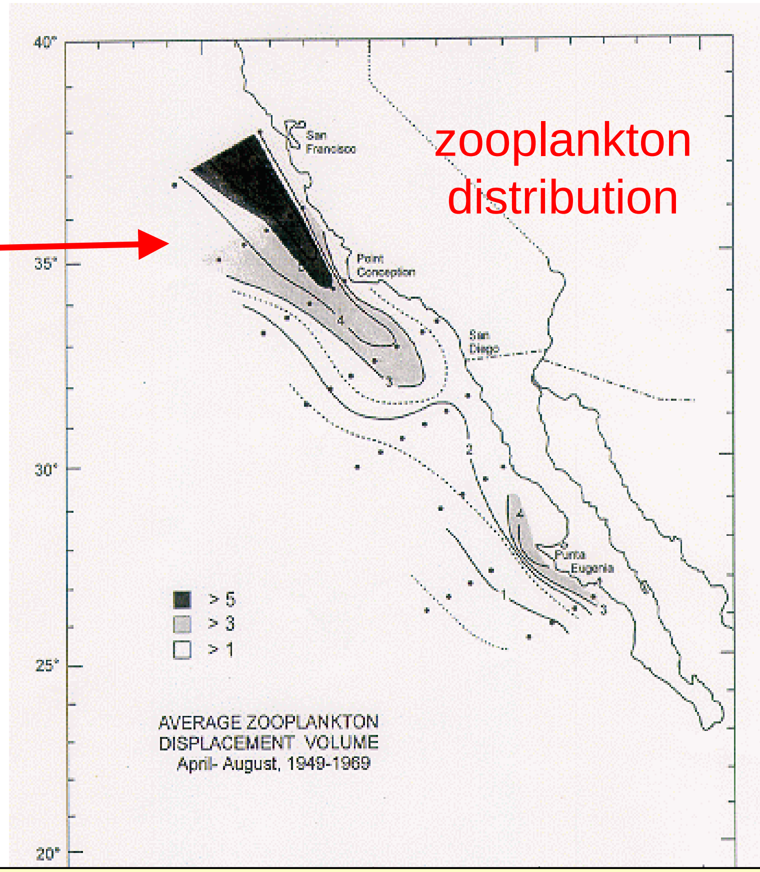


Spawning - temperature distribution in Feb–April after climate shift is similar to temperature distributions for June prior to climate shift.

Conclusion: after 1976-77 climate shift, early-season spawning allowed to occur in rich zooplankton pastures north of Pt. Conception (seasonal access to rich food source = Feb. - July vs. June-July before the 76-77 shift)



egg concentrations over SST



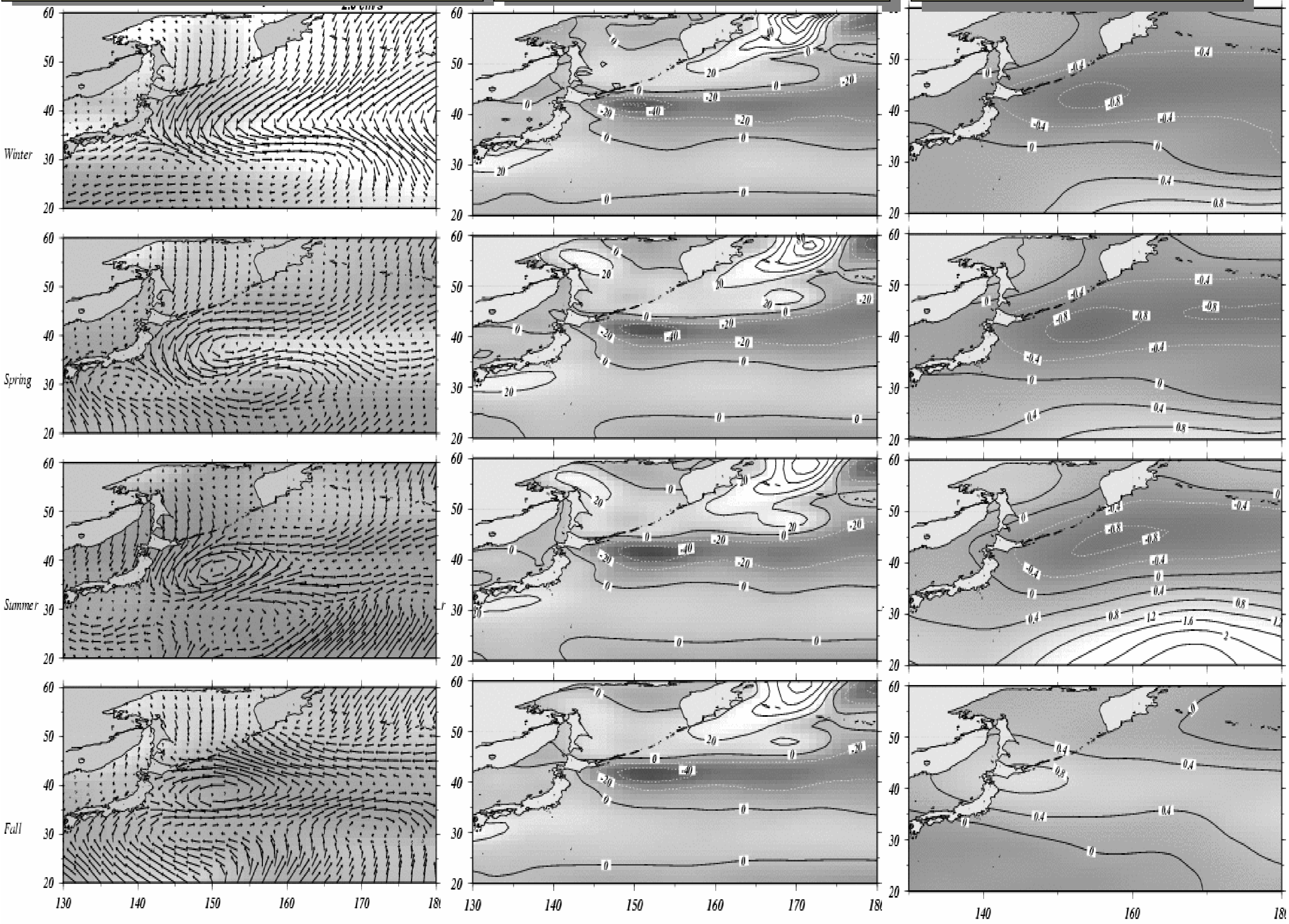
Averaged distribution of sardine food (1949-1969) from CalCOFI macrozooplankton surveys (ml/m³)

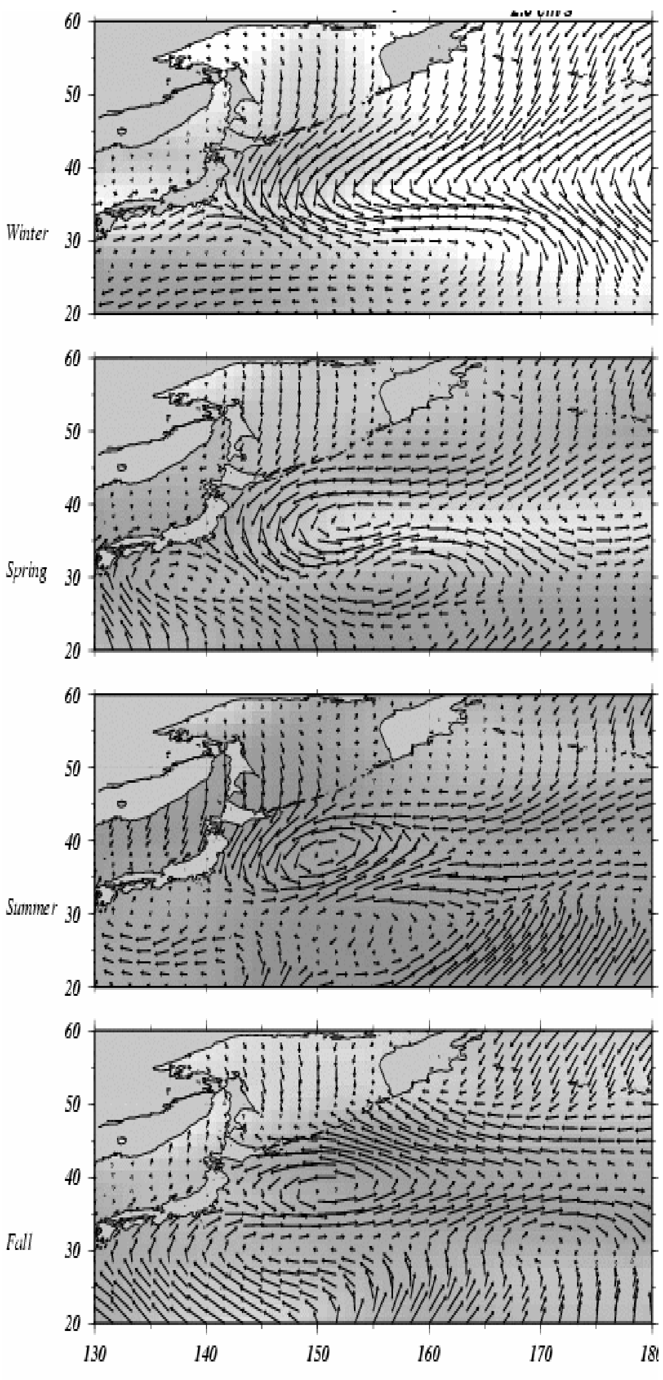
OCEAN MODEL RESPONSE → CHANGES IN HABITAT STRUCTURE / DISTRIBUTION INFLUENCING JAPANESE SARDINE ABUNDANCE, AND DISTRIBUTION IN THE NORTHWEST PACIFIC

1. Horizontal currents in the model mixed layer

2. Change in depth of the pycnocline

3. Change in SST





After climate shift of mid-1970s, changes in circulation improved access of both adult and juvenile stages to better feeding conditions

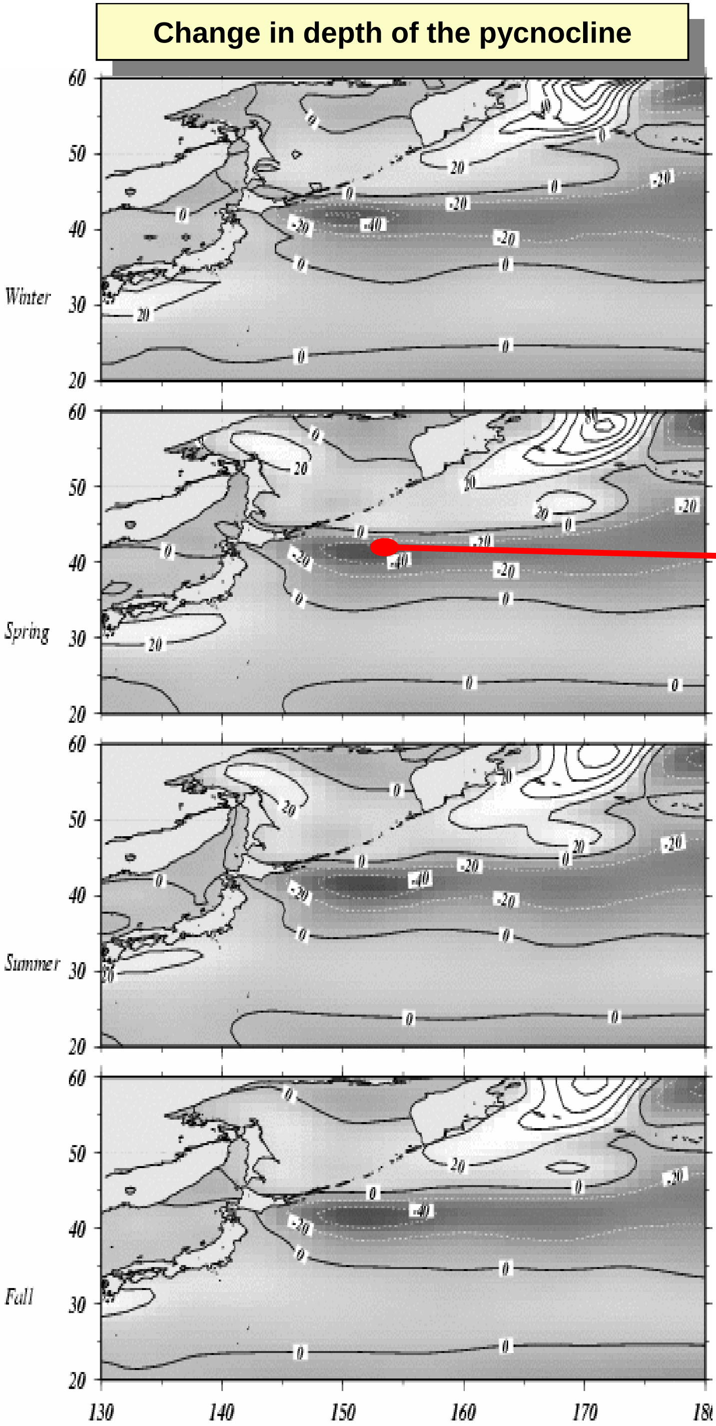
-- spawning area expanded, egg/larval drift enchanced by increased advection in Kuroshio Extens. in Winter-Spring

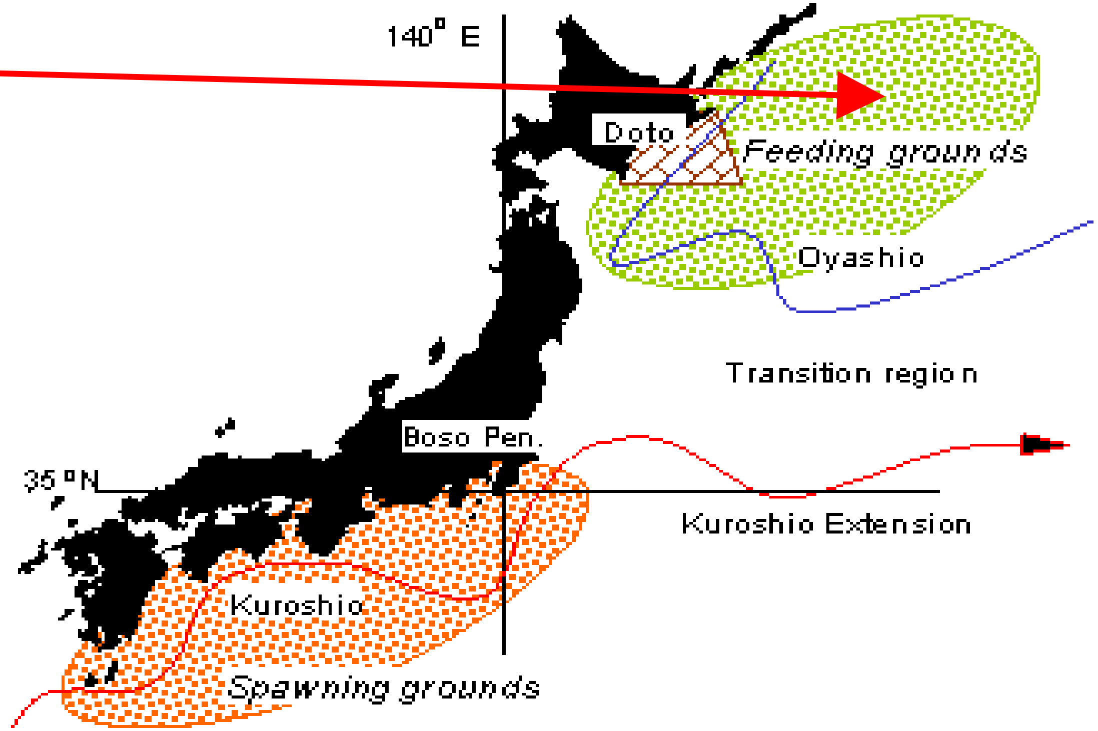
--juvenile migration to Oyashio region aided by increased cyclonicity in Spring-Summer

Enrichment of adult and juvenile feeding grounds by uplift of nutricline by cyclonic circulation off northern Japan

➔ increased survival of juveniles,

➔ improved egg quality from adults





CONCLUSIONS

LIFE HISTORIES OF EACH SPECIES ARE ADAPTED TO DIFFERENT PHYSICAL MECHANISMS OF INTERDECADAL CHANGE IN THE TWO SYSTEMS

REGIONAL DYNAMICAL RESPONSES TO CLIMATE SHIFT IN 1970s PROVIDED IMPROVED ACCESS TO ENRICHED FEEDING GROUNDS FOR BOTH THE ADULTS AND JUVENILES LEADING TO ENHANCED REPRODUCTIVE SUCCESS IN BOTH SYSTEMS

NEXT QUESTION

WHY IS CALIFORNIA HABITAT STILL FAVORABLE WHILE JAPANESE HABITAT HAS BECOME MARGINAL?