CLIMATE CHANGE EFFECTS ON FISH AND FISHERIES:

forecasting impacts, assessing ecosystems responses, and evaluating management strategies

Sendai, Japan. April 25-29, 2010

Spatial dynamics of small pelagic fish in the California Current system on the regime time-scale. Parallel processes in other species-ecosystems.

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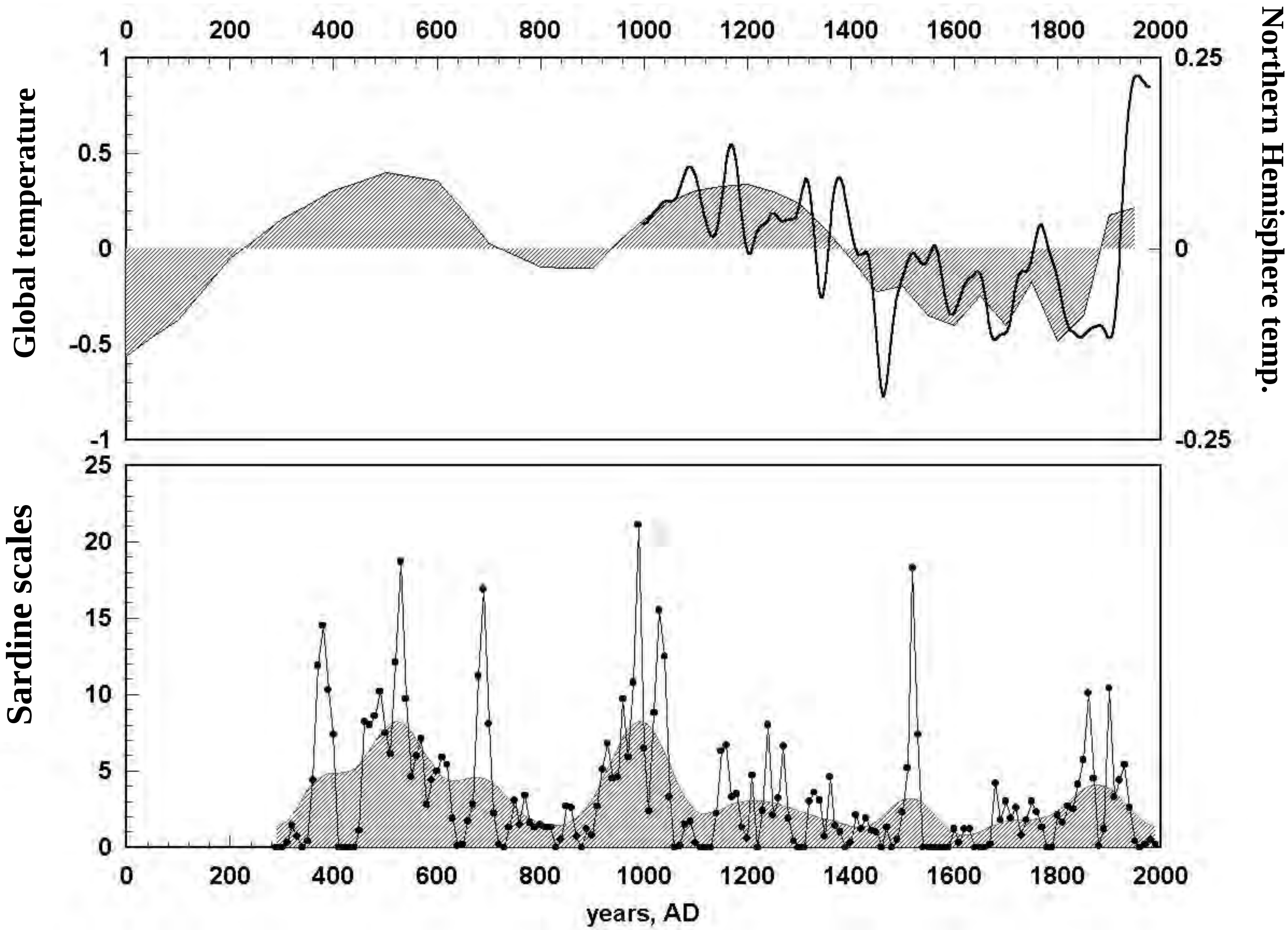
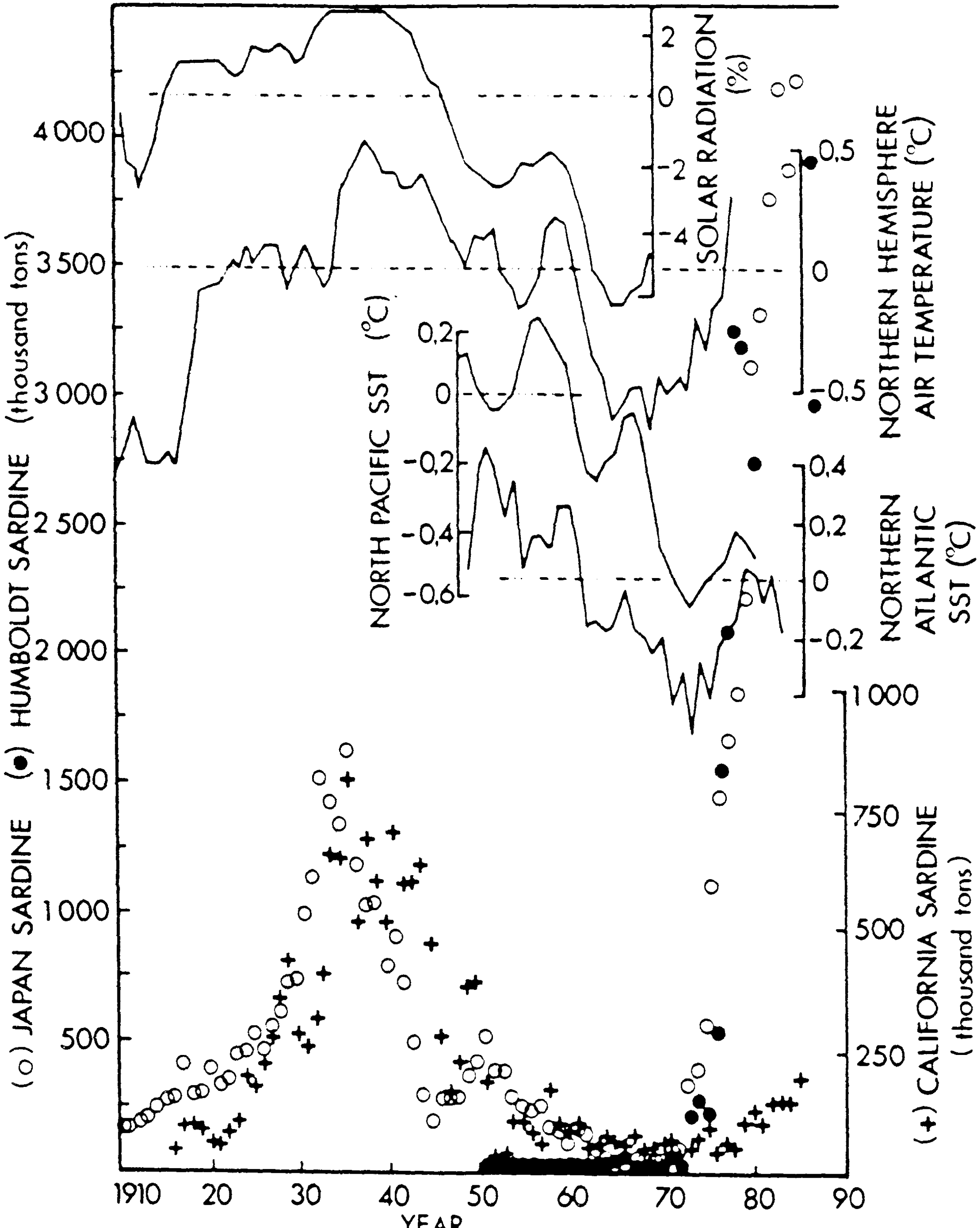
BACKGROUND (1/3)

Until recently our understanding of fish population dynamics has been on the basis of time-series analysis : e.g. Multidecadal variation of biological and environmental indices



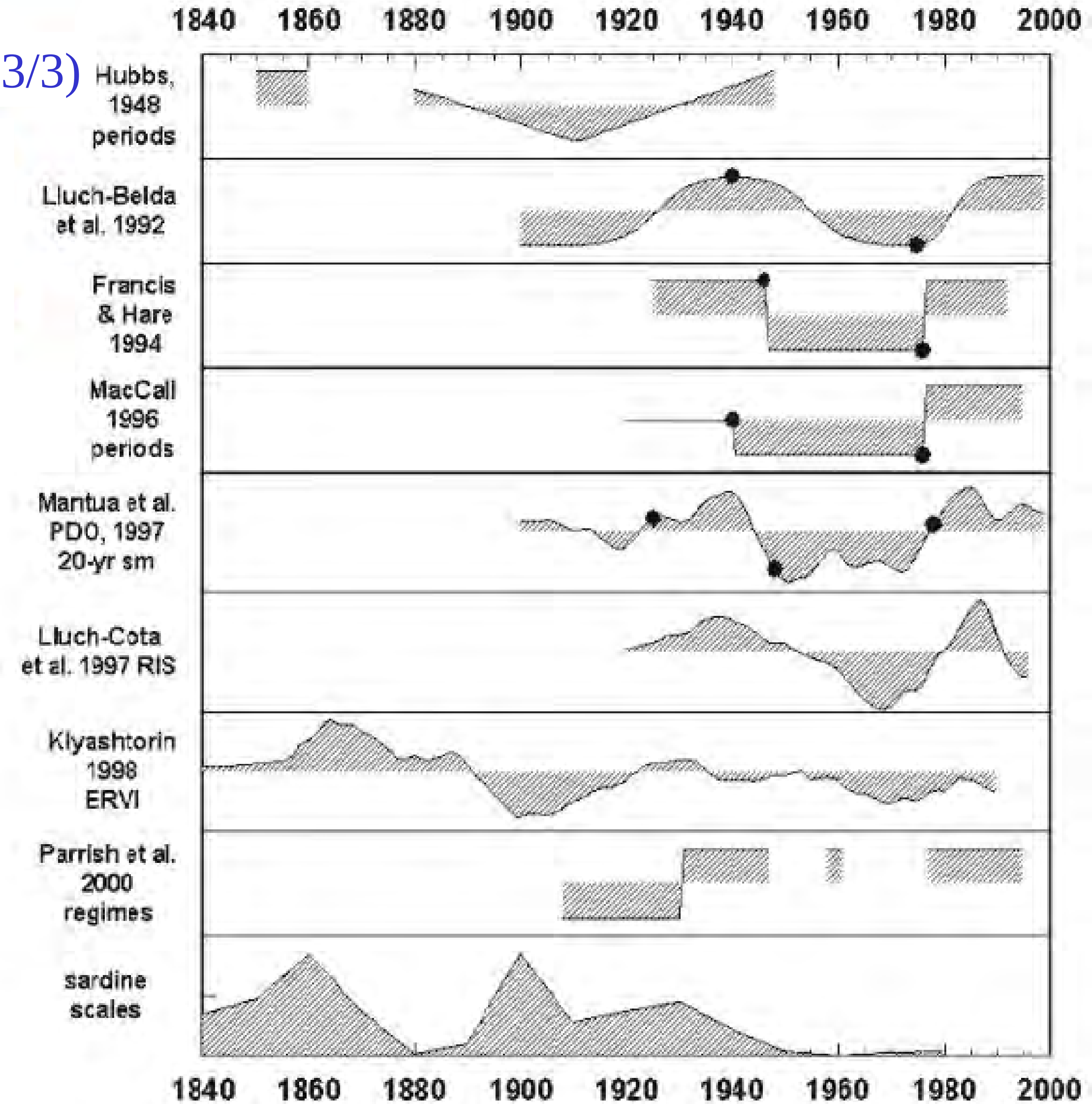
BACKGROUND (2/3)



- sardine catch records from well separated ecosystems shown **global synchronic**

BACKGROUND (3/3)

- The regimen shifts has been shown also for **other species-ecosystems**, or using other environmental indicators



- There is no doubt that the **unidimensional analysis** of time-series of information has been useful to advance in the understanding of population dynamics and their relations with climatic variability.

- More recently, the spatial scale has been incorporate into the analysis of population dynamics

CLIMATE CHANGE EFFECTS ON FISH AND FISHERIES: forecasting impacts, assessing ecosystem responses, and evaluating management strategies

SPATIAL IMPACT OF CLIMATE CHANGE ON SPECIES DISTRIBUTION

- Registering or modeling the response of fish to warming conditions

THE RESPONSES OF FISH TO CLIMATE VARIABILITY REGISTERED/ASSUMED ARE:

- GEOGRAPHICAL DISTRIBUTION SHIFTS (there is not mention of the direction of the movements)
- POLEWARD SHIFTS (as a response of increase in water temperature)
- THE SOUTHERN LIMIT OF DISTRIBUTION OF A SPECIES IS MOVING NORTHWARD SUCH THAT IT MAY DISAPPEAR FROM ITS MORE TROPICAL DISTRIBUTION
- EXPANSION OF THE SPECIE DISTRIBUTION NORTHWARD

THE STRUCTURE OF THE SPATIAL DISTRIBUTION CHANGES RECORDED/ASSUMED ARE:

- SIMPLE EXPANSION-CONTRACTION
- CHANGES IN THE CENTRE OF DISTRIBUTION
- CHANGES IN THE CENTRE AND BULK OF BIOMASS DISTRIBUTION

AIM OF THIS PRESENTATION:

•Show **differences in the spatial responses** of small pelagic species to long-term climate variability in the California Current system (1931-1997).

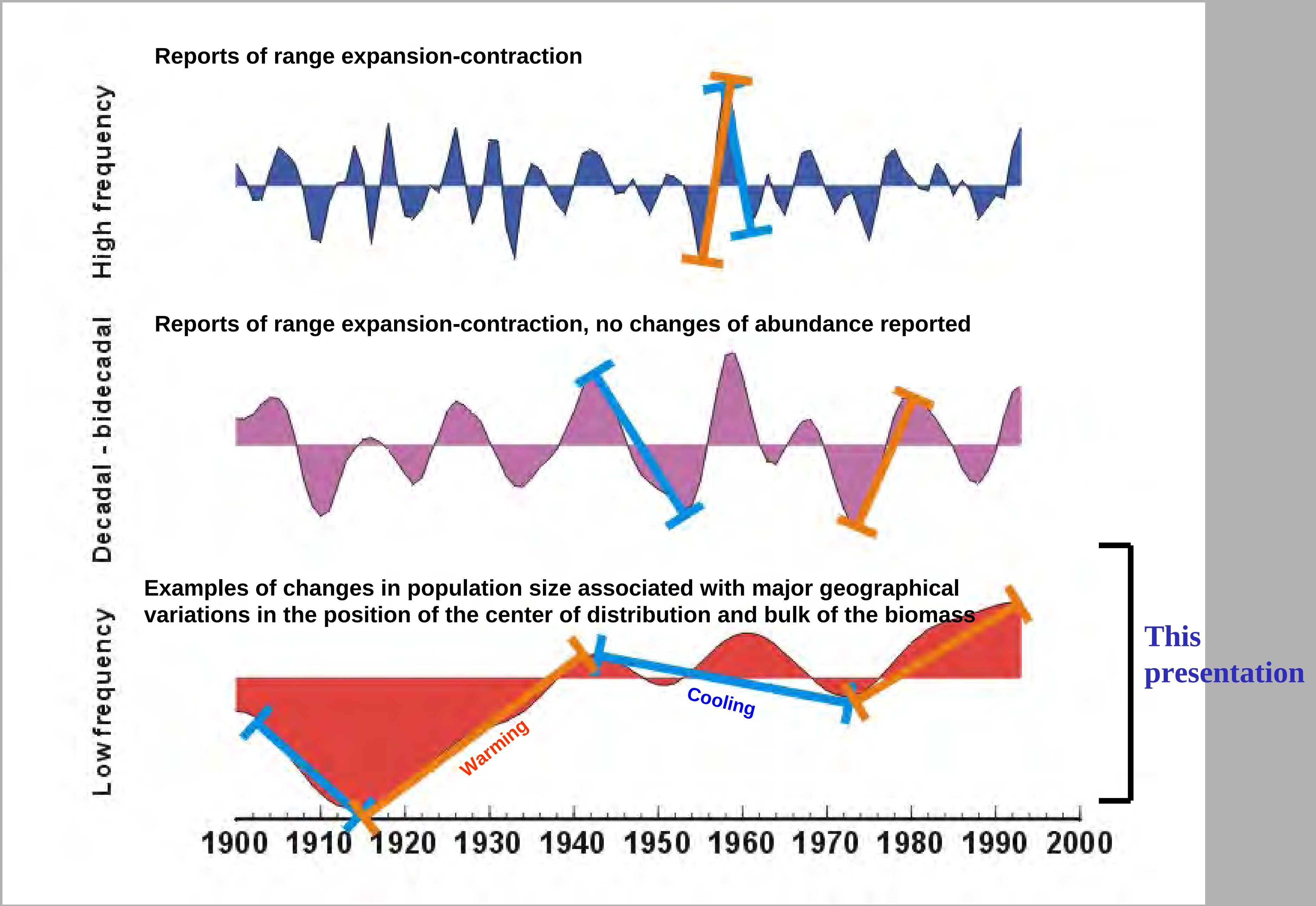
For prediction purposes, it is warning that the magnitude of spatial and abundance changes relying in a single observation of populations´ response to past climate variability is highly uncertain.

-Fish migrations occur at different spatial-temporal scales

-There is a superposition of climate variability in different scales affecting ecological processes (e.g. tropical species in CCS)

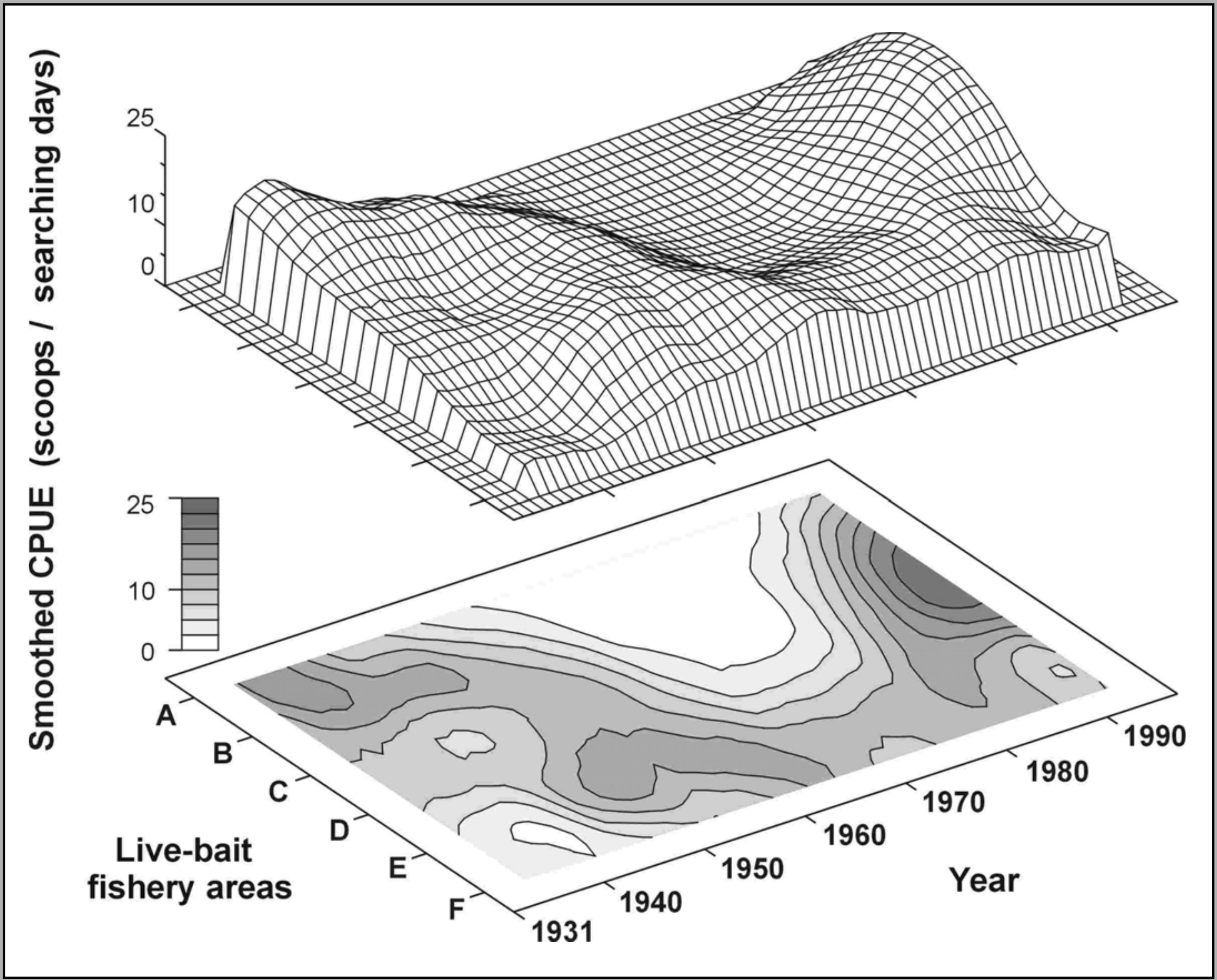
Evaluating management strategies: e.g. California sardine

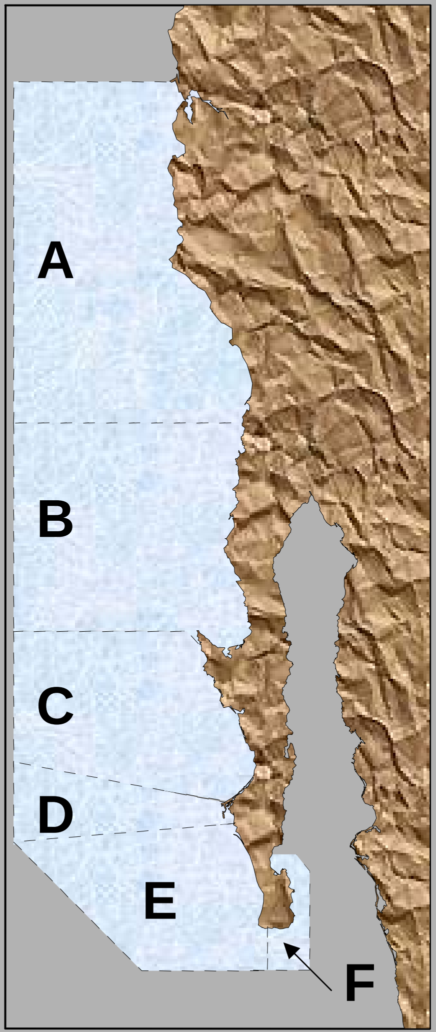
Decomposition of SST frequencies - California Current system



Adapted from Lluch-Belda et al. 2001

Spatial variability of Pacific sardine at regime time-scale (1931-1997)





Rodríguez-Sánchez et al. (2002)

The question arising is:

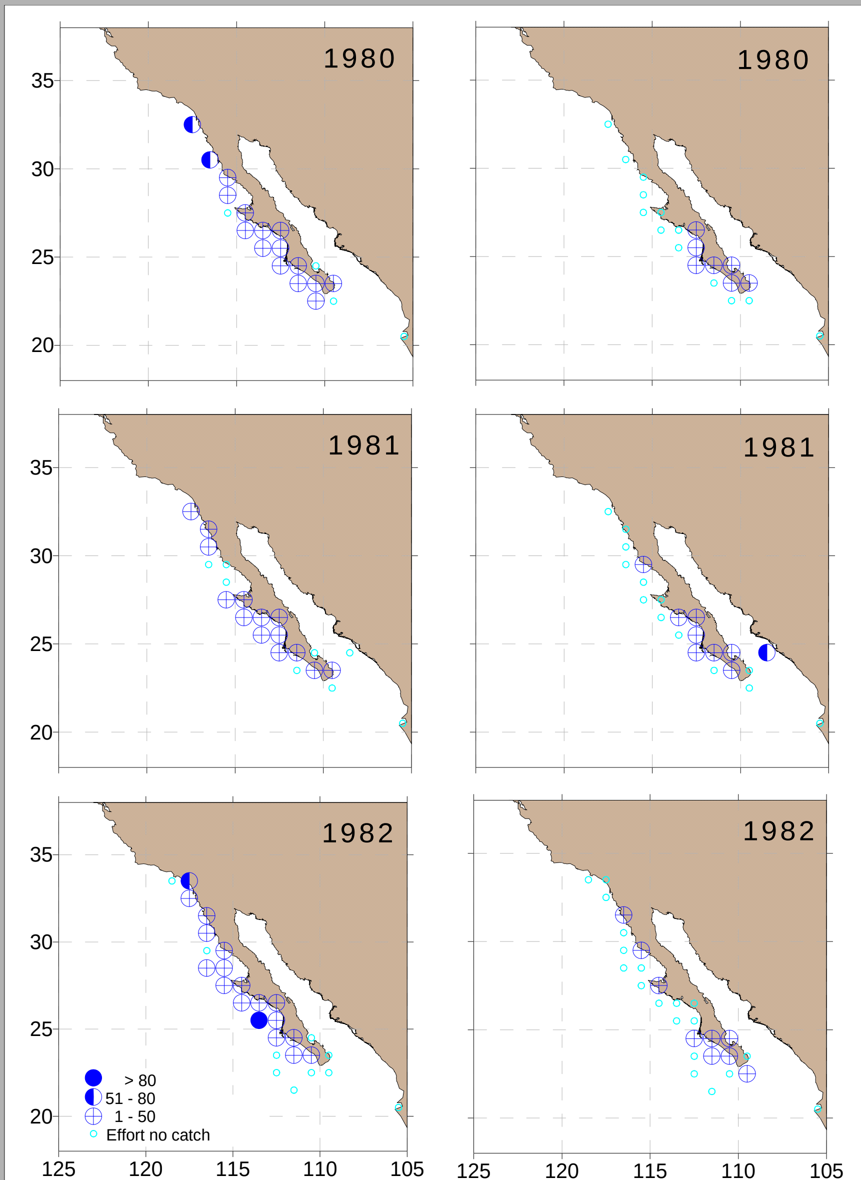
Is this natural pattern of variation recorded only in the Pacific sardine?

In this work:

1) the large-scale, long-term (1931-1997) variability of **tropical specie**s in the California Current system is included in the **sardine-anchovy** analysis

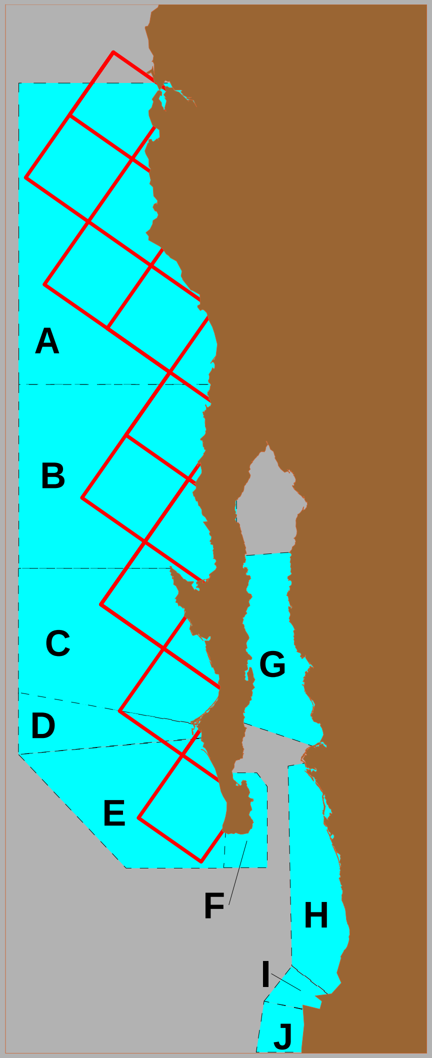
2) examples of similar spatial process are shown for other species and communities from other ecosystems

TUNA BAITBOATS



Their small pelagic fish catch data are devoid of bias induced by searching for large schools in high-abundance areas

- Tunas are the target fish species
- Boats do not search for a particular kind of bait nor in a particular location
- Young stages of clupeoid fish are used as live bait
- Boats replenish their fishponds at the nearest location
- The amount of live bait required for operation is small



LIVE-BAIT FISHERY AREAS

- **ANNUAL CPUE BY SPECIE (1931-1997)**

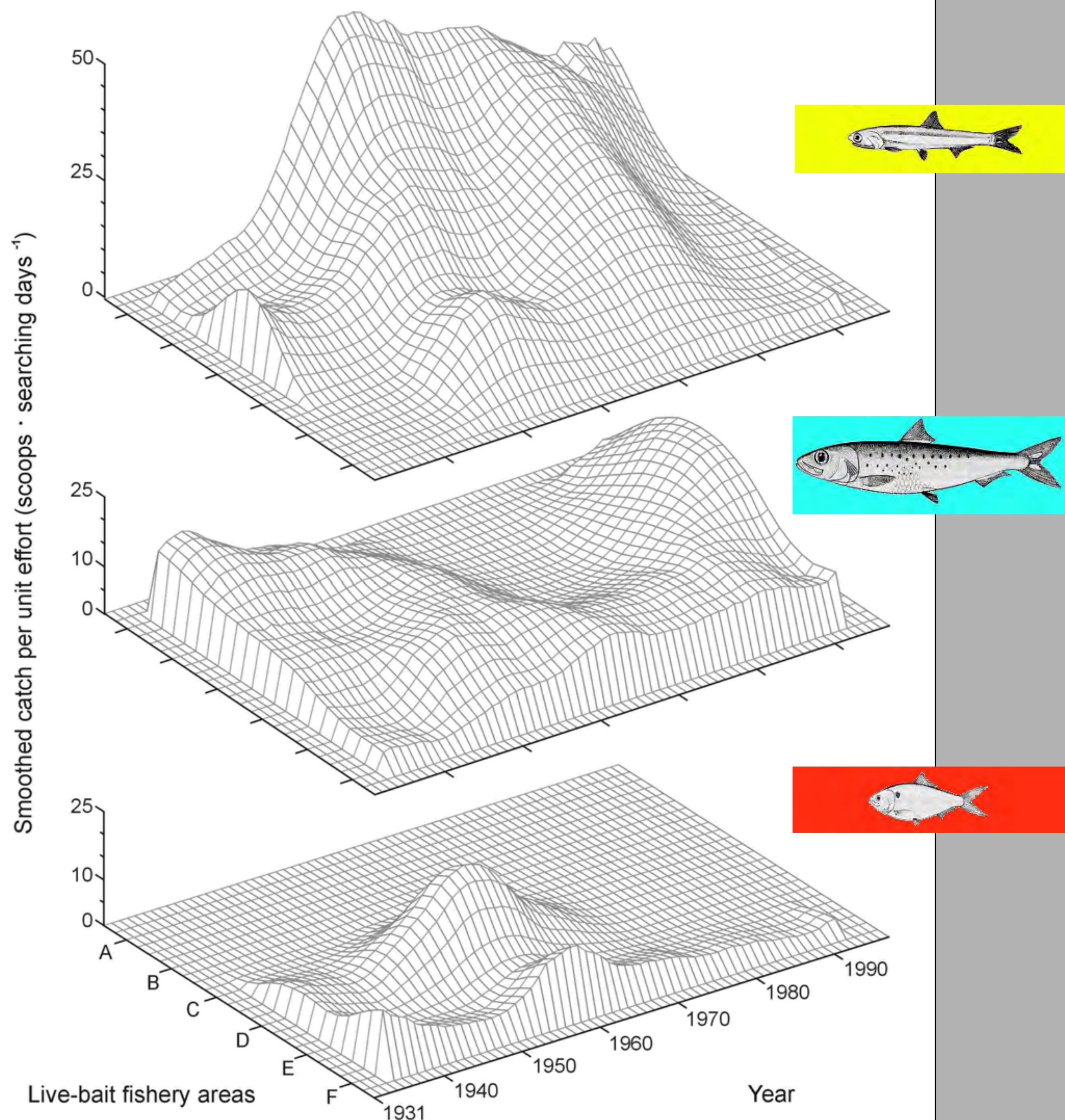
SARDINE	*Sardinops caeruleus*
NORTHERN ANCHOVY	*Engraulis mordax*
TROPICAL SPECIES	*Harengula thrissina*
	Opisthonema spp.
	Cetengraulis mysticetus

CPUE = CAPTURE IN SCOOPS BY SEARCHING DAYS

TIME SERIES OF SST

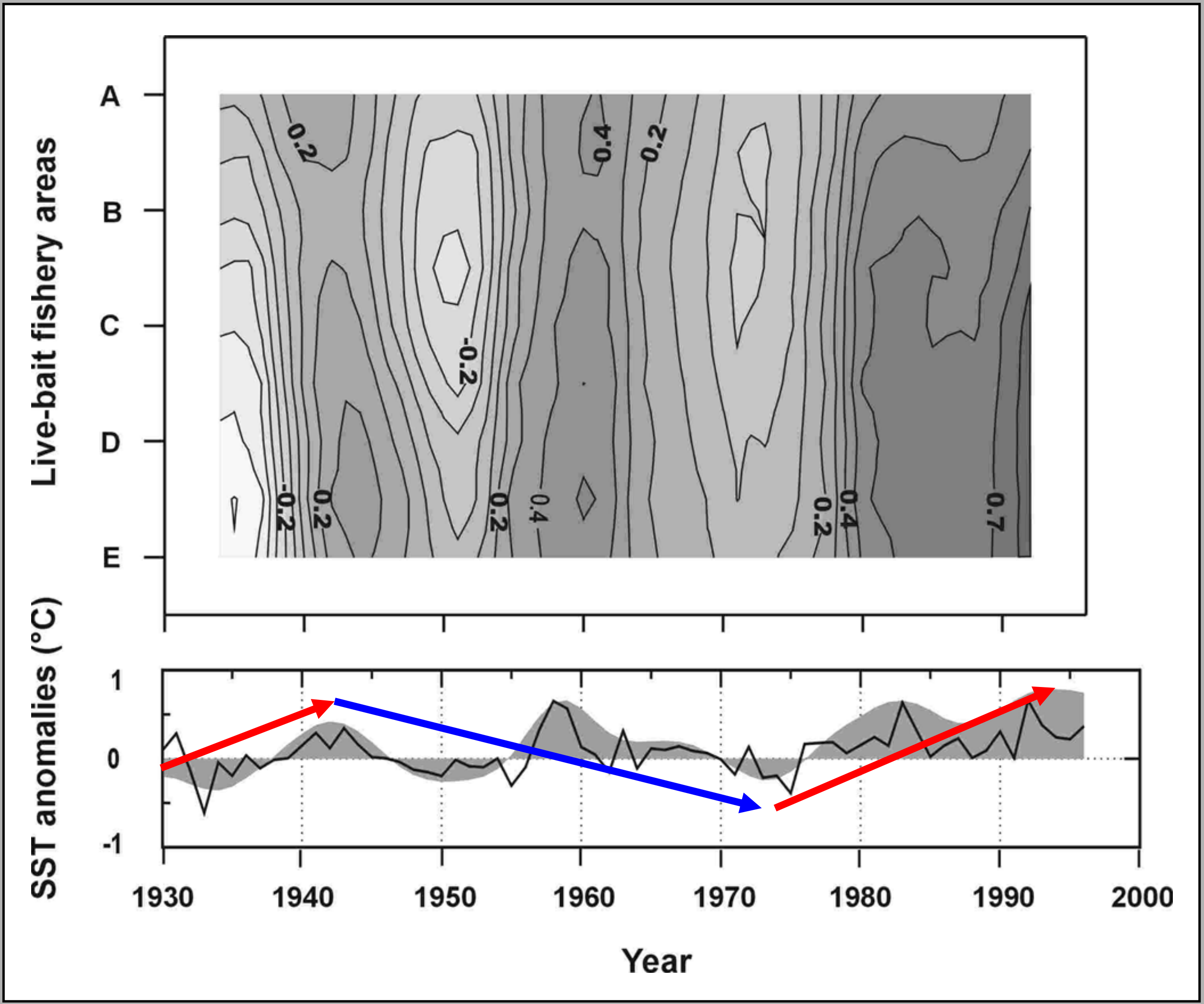
- **FROM COADS DATABASE (1900-1996)**

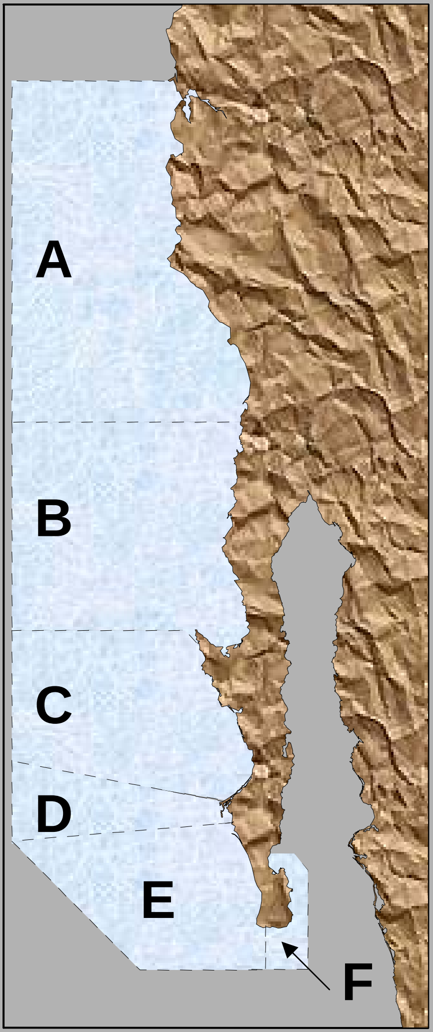
SQUARES OF 2 X 2 DEGREES



Smoothed catch per unit effort (scoops · searching days -1)
50
25
0
25
10
0
25
10
0
A
B
C
D
E
F
Live-bait fishery areas
1931
1940
1950
1960
1970
1980
1990
Year

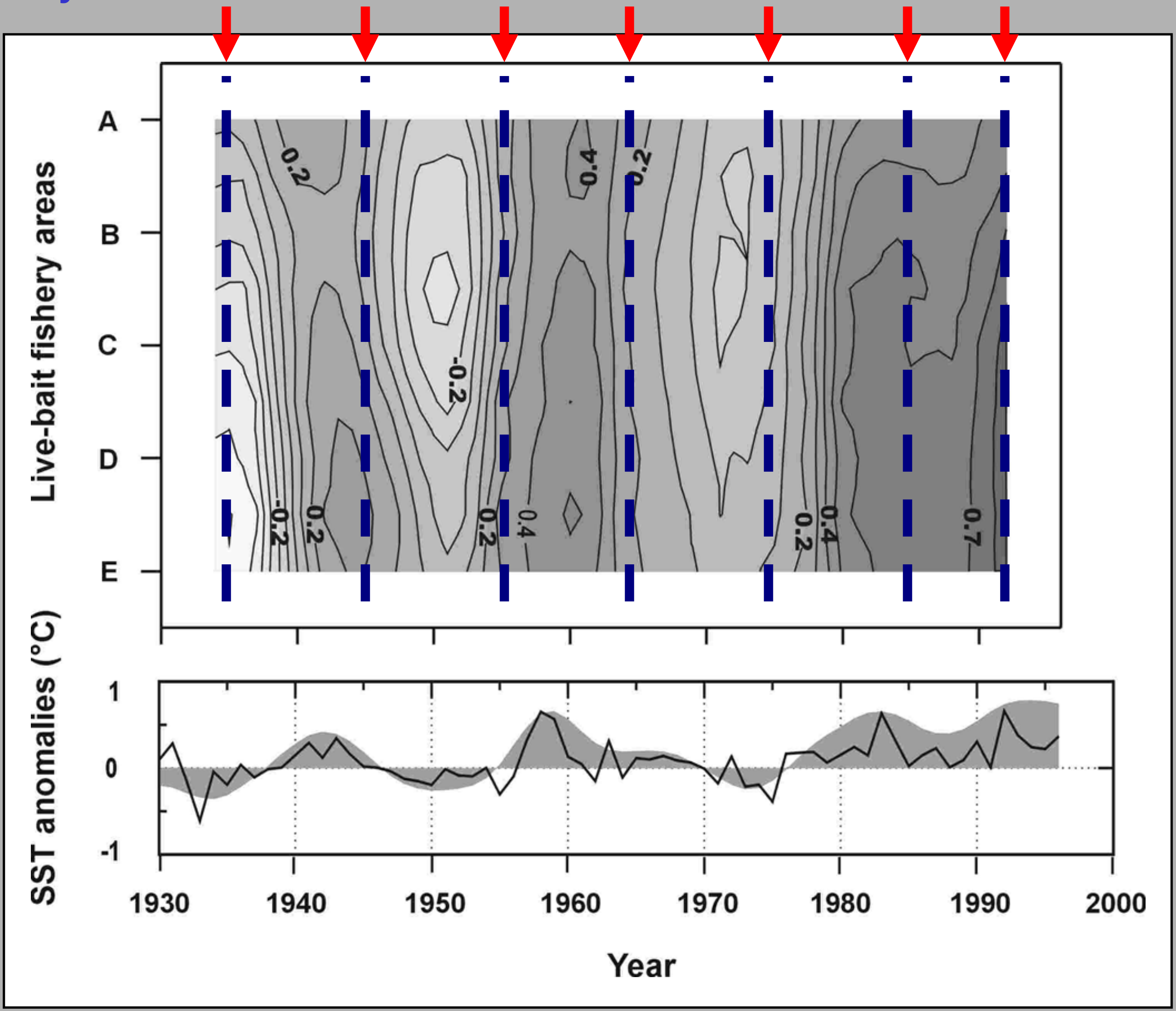
Spatial distribution of SST anomalies

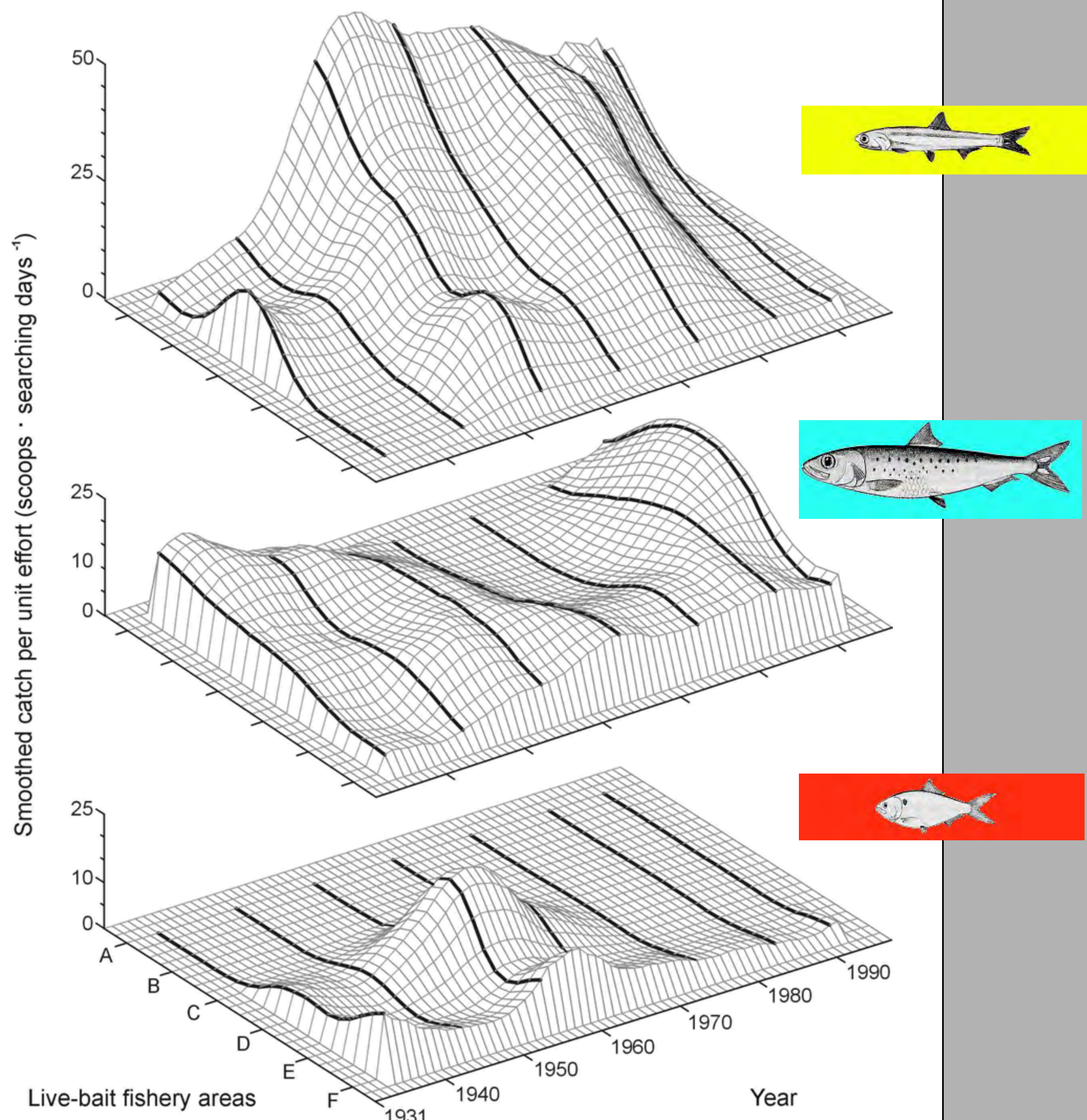




Rodríguez-Sánchez et al. (2002)

Selected years: 1935 1945 1955 1965 1975 1985 1992





Smoothed catch per unit effort (scoops · searching days -1)
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1931
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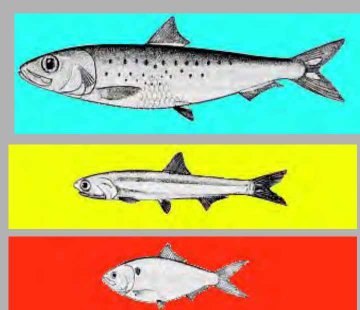
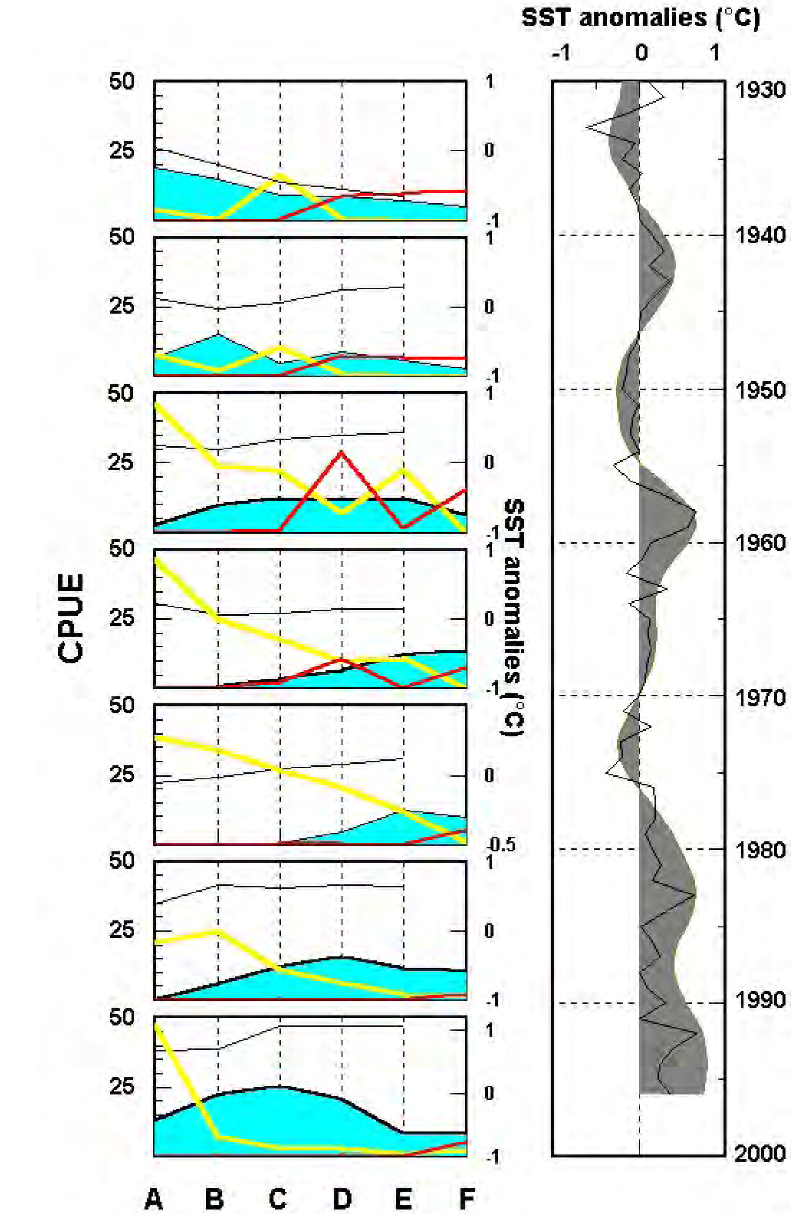
Spatial dynamics of small pelagic fish in the California Current system on the regime time-scale

SST anomalies

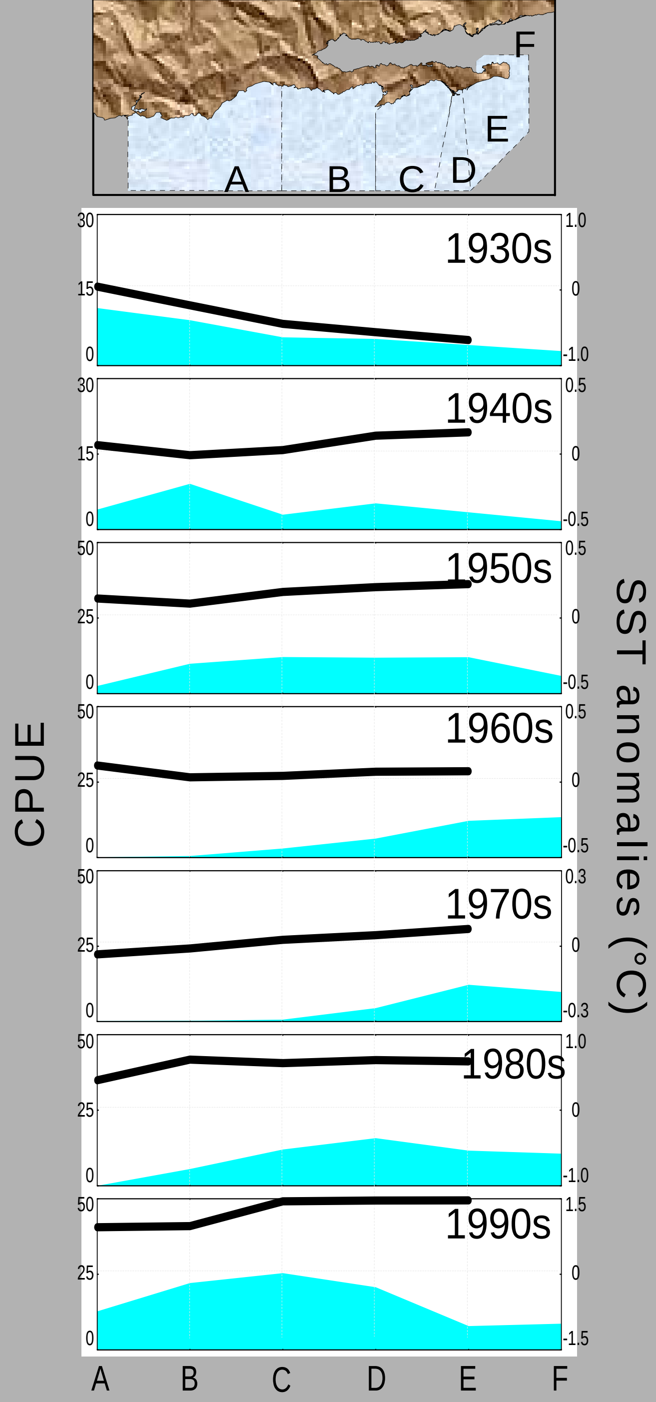


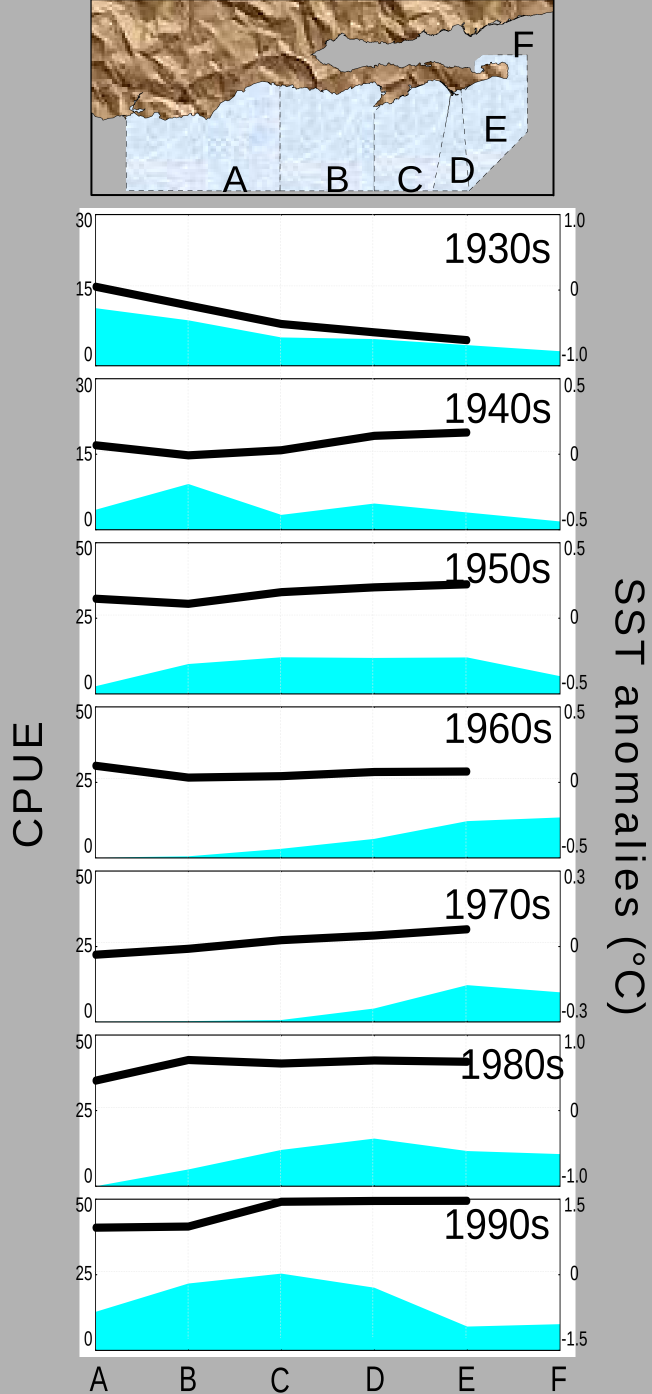


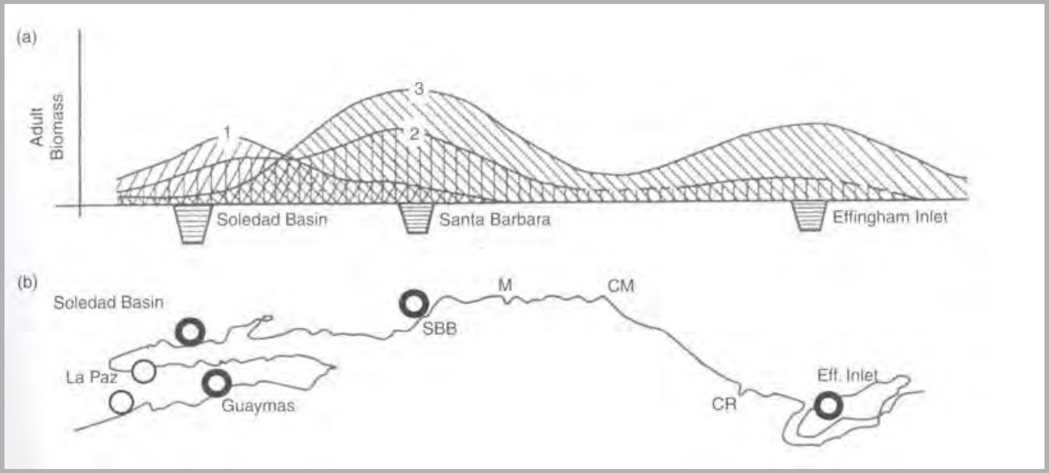
LIVE BAITFISHERY AREAS

Spatial dynamics of California sardine

- During the 1940´s regime shift sardine abundance declined in the northern areas as the first sign of ocean-climate and population interaction, with less apparent changes in the south.
- Changes in the southern areas were observed almost a decade later.
- After the 1970´s regime shift sardine abundance changes in northern areas were observed almost a decade later than the changes in the south, when sardine population was moving its location northward.



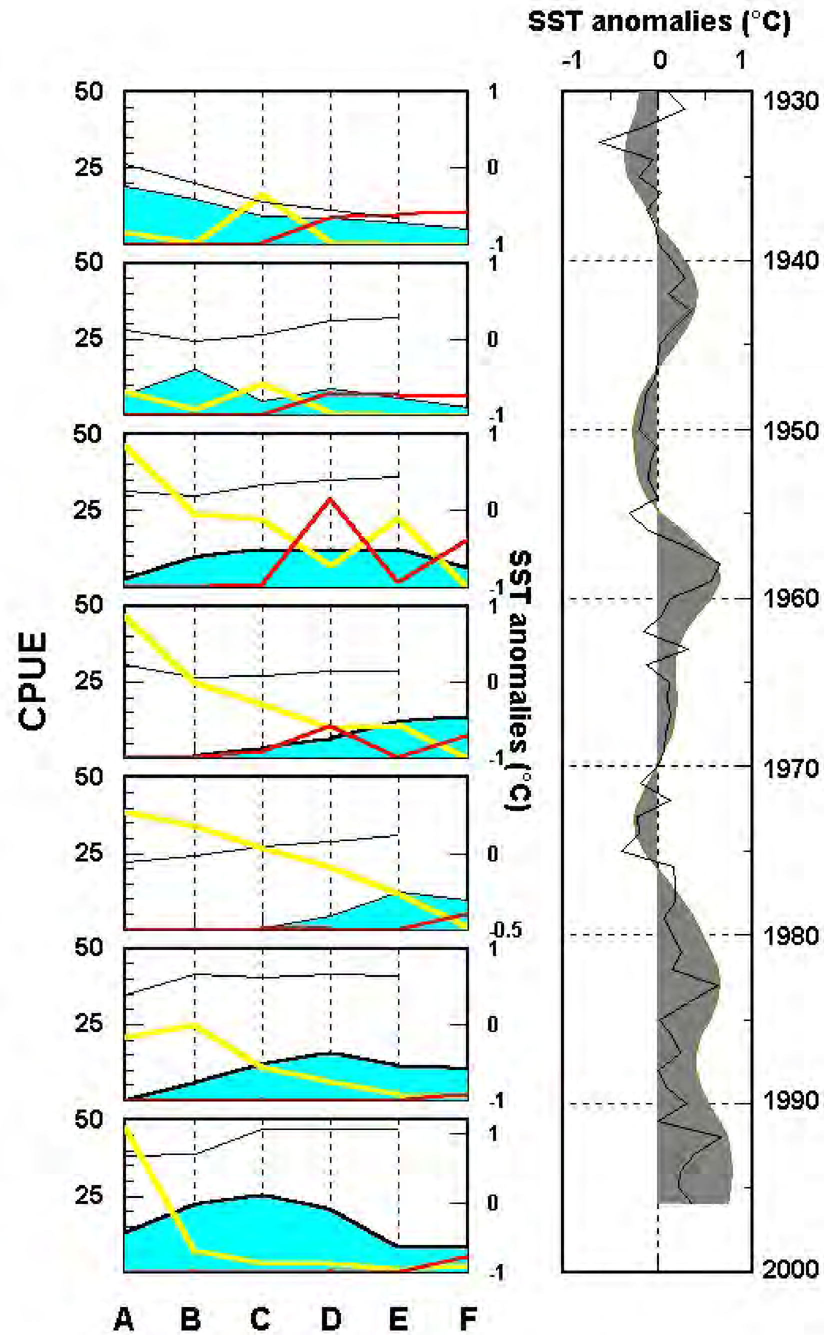




Model of Population abundance and distribution of the California sardine from sedimentary records (Field et al. 2009)

Spatial dynamics of Northern anchovy

- The spatial pattern of abundance for the northern anchovy (*Engraulis mordax*) appears to be inversely related to sardine population abundance.
- Anchovies increased where and when sardines were either absent or at a low population level



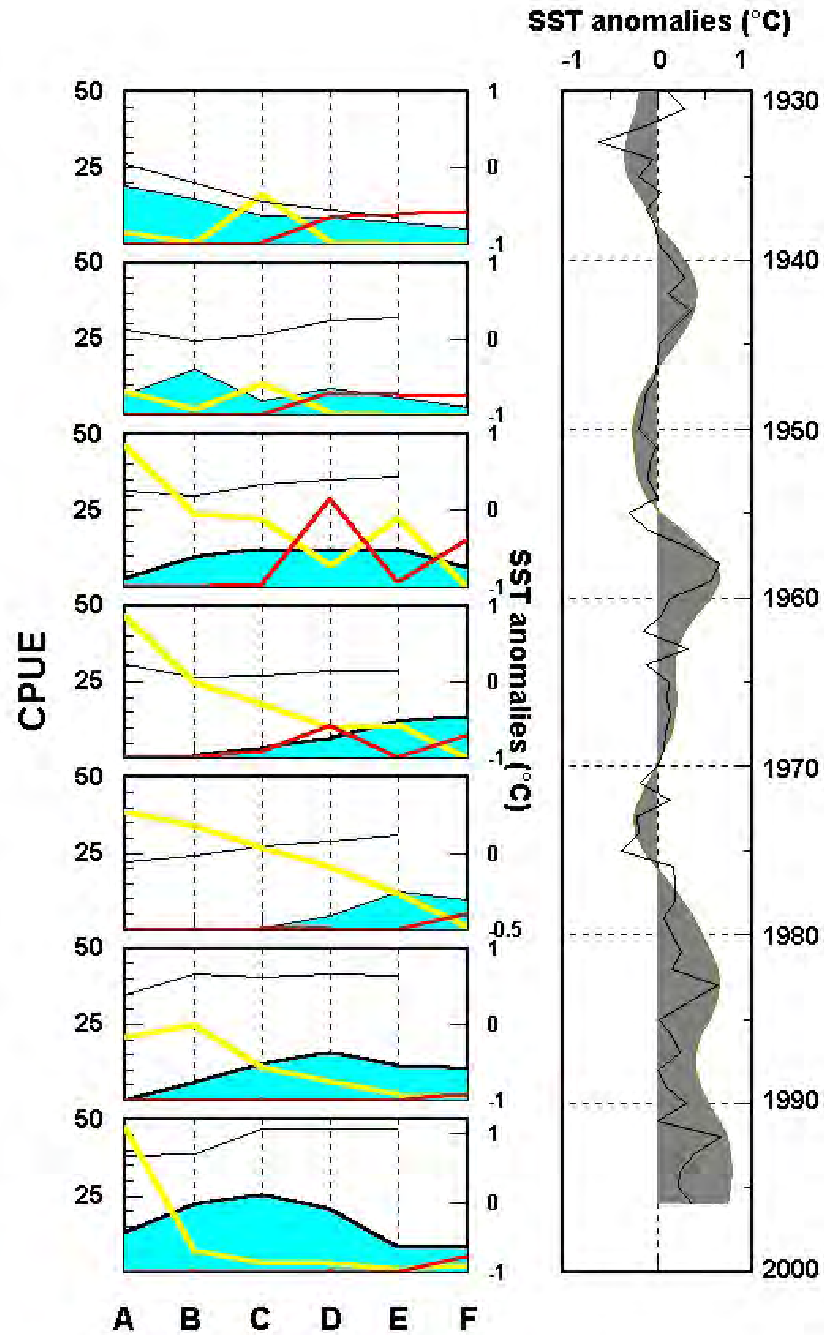
Spatial dynamics of tropical species

- Tropical species reached higer abundance levels during the 1920s-1940s warming period than those of the 1970s-1990s warming period.

- The warming phases are not of the same intensity

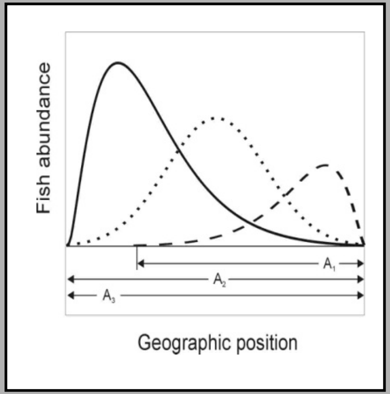
For <u>prediction</u> purposes, it is warning that the magnitude of spatial and abundance changes relying in a single observation of populations´ response to past climate variability is highly uncertain.

- Fish migrations occur at different spatial-temporal scales
- There is a superposition of climate variability in different scales affecting ecological processes (e.g. tropical species in CCS)



AIM OF THIS PRESENTATION:

•Show **differences in the spatial responses** of small pelagic species to long-term climate variability in the California Current system (1931-1997).



•The fish population change its location within ocean habitat

•A non geo-stationary dynamic model

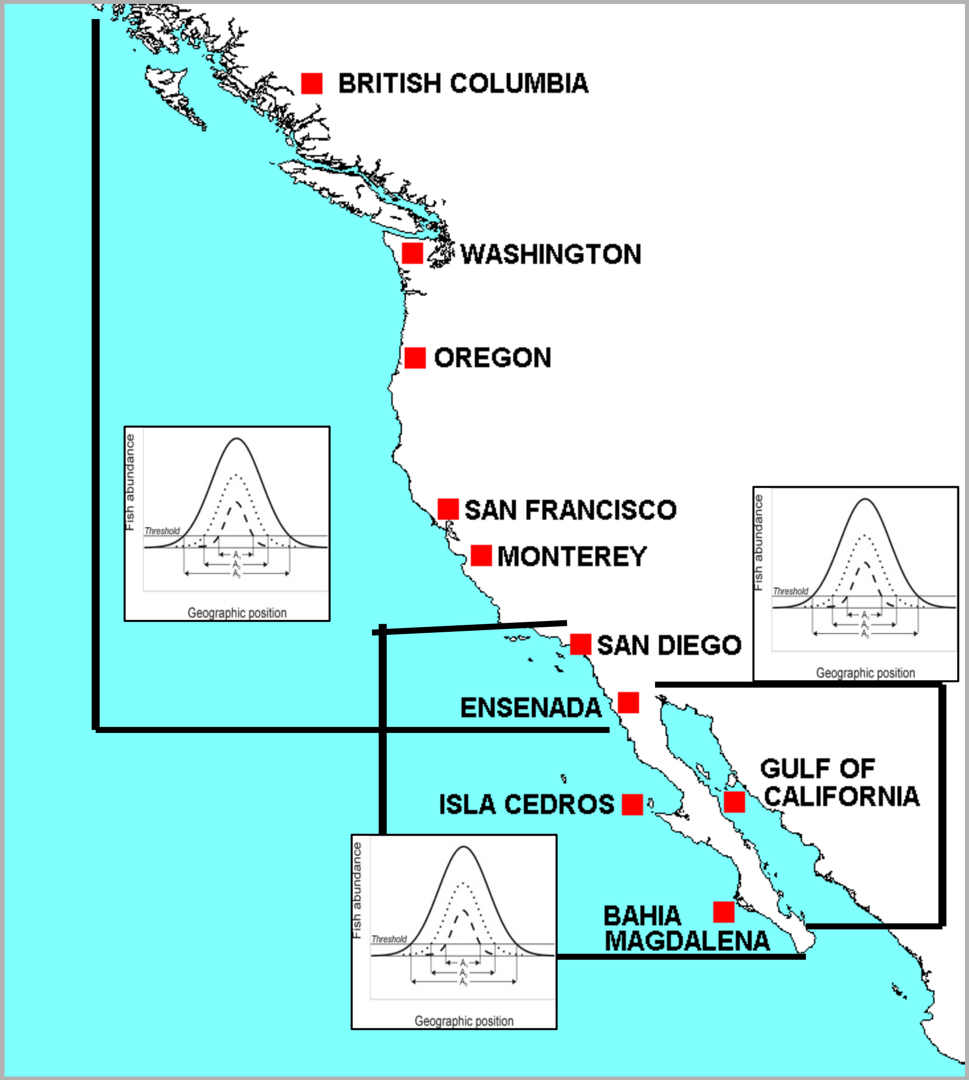
The spatial dynamics of northern anchovy appears to be inversely related to sardine population abundance.

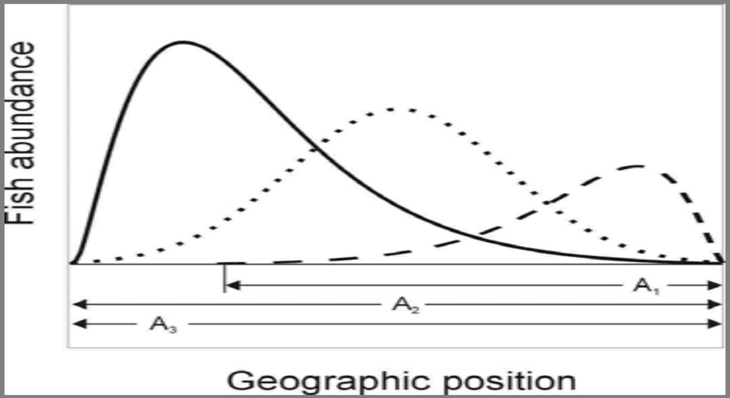
• The northern limit changes with population abundance increase-decrease

• Homogeneous spread

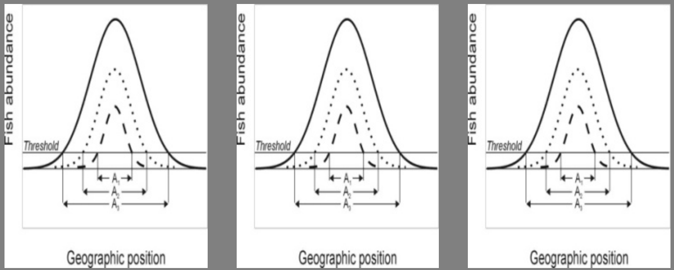
Evaluating management strategies: e.g. California sardine

Sardine return to the north part of California Current ecosystem



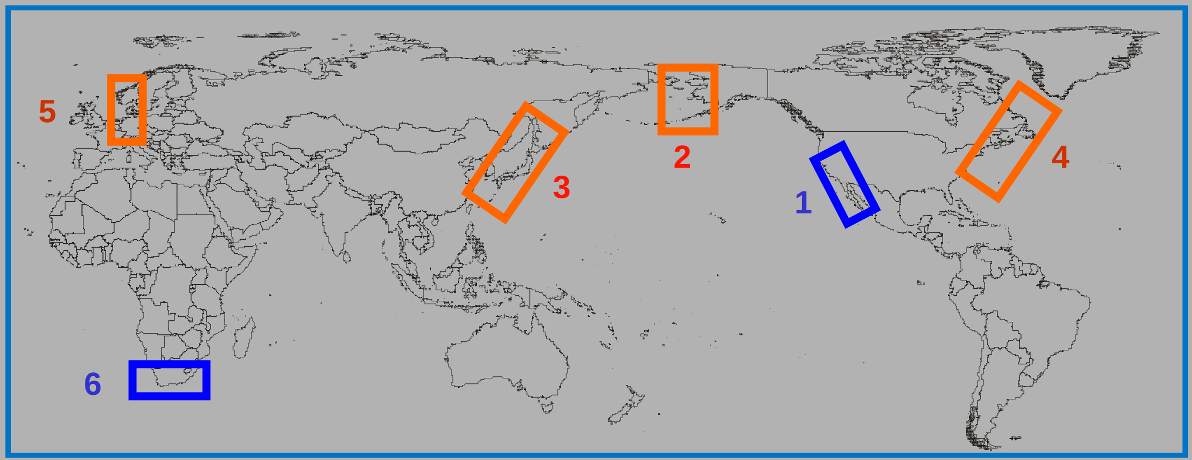


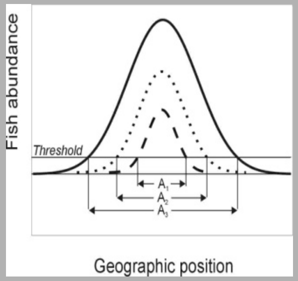
versus

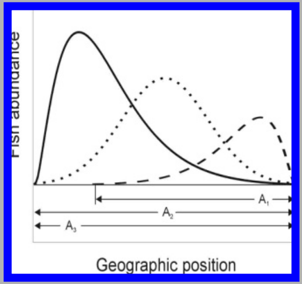


Sardine recovered in the north part of California Current ecosystem as a result of a conservative management policy

Ecosystems where changes in the position of the center of distribution and bulk of biomass of some species are reported (examples):

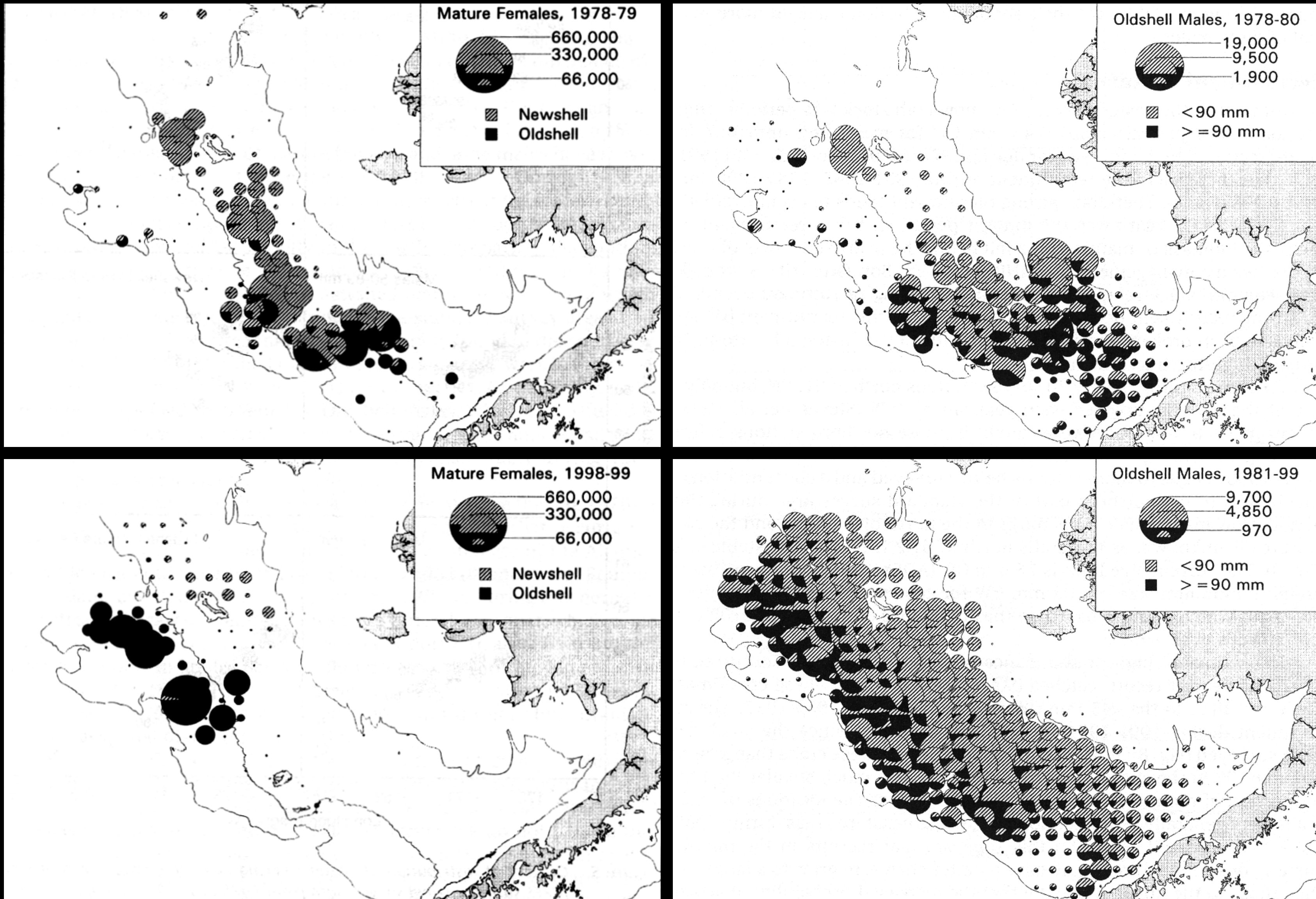






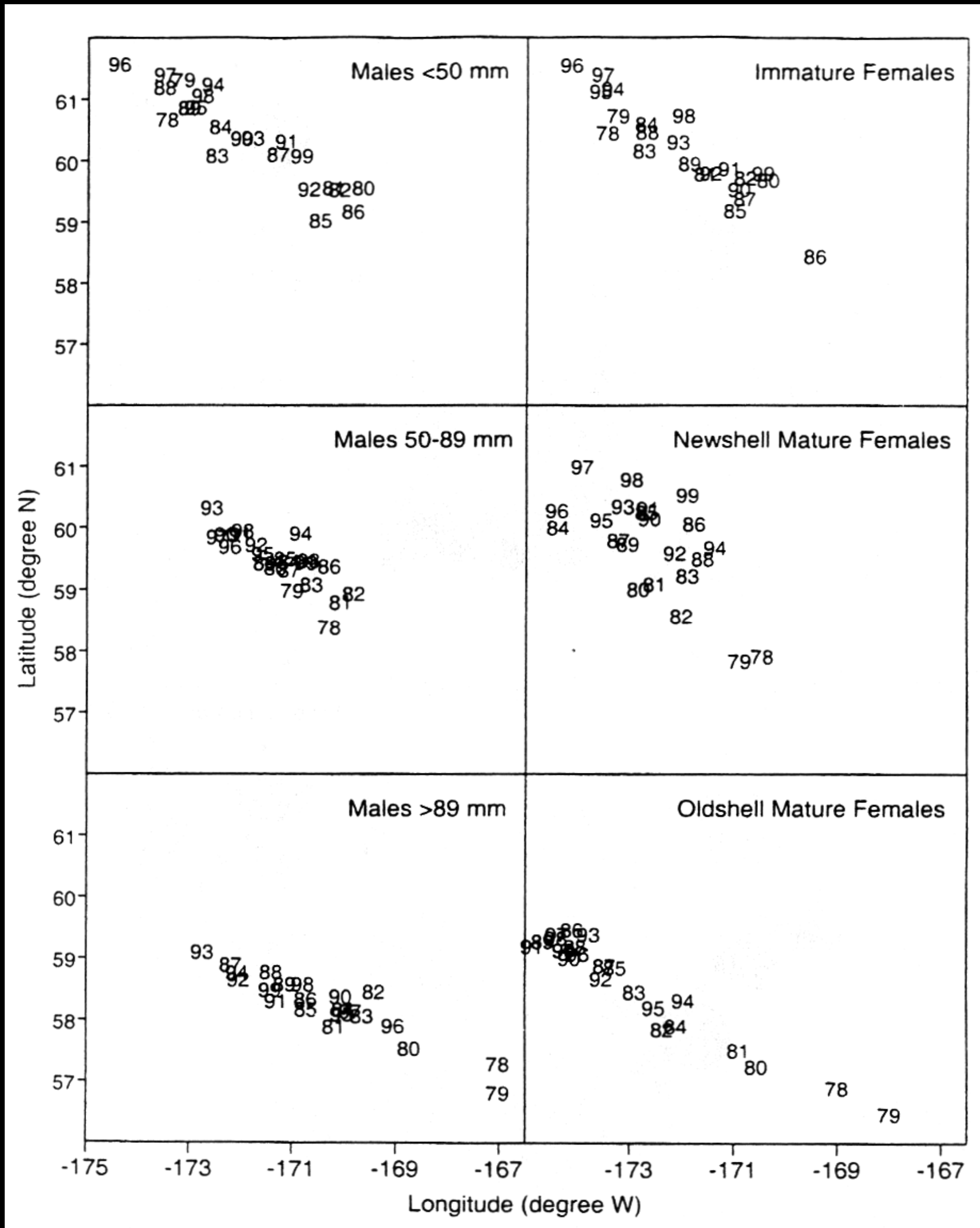
No.	Ecosystem/ author	Species	Time frame	Regime condition
1	**California Current System** (Rodríguez-Sánchez et al 2001, 2002)	Small Pelagic Fish	1931 – 1997	Cooling and Warming conditions
2	**Eastern Bering Sea** (Zheng et al. 2001)	Snow Crab	1978 - 1999	Warming conditions
3	**Japan Sea** (Kidokoro et al. / In: Saitoh et al. 2004)	Japanese common squid	1981 - 1998	Warming conditions
4	**Northwest Atlantic** (Garrison 2001)	Continental Shelf Fish Community	1966 – 1999	Cool and Warming conditions
5	**Northern Sea** (Perry et al. 2005)	Demersal Fish	1977 - 2001	Warming conditions
6	**Southern Benguela** (van der Lingen et al. 2005)	Benguela Sardine	1987 - 2004	Warming conditions

EASTERN BERING SEA: Snow crabs (1/2)



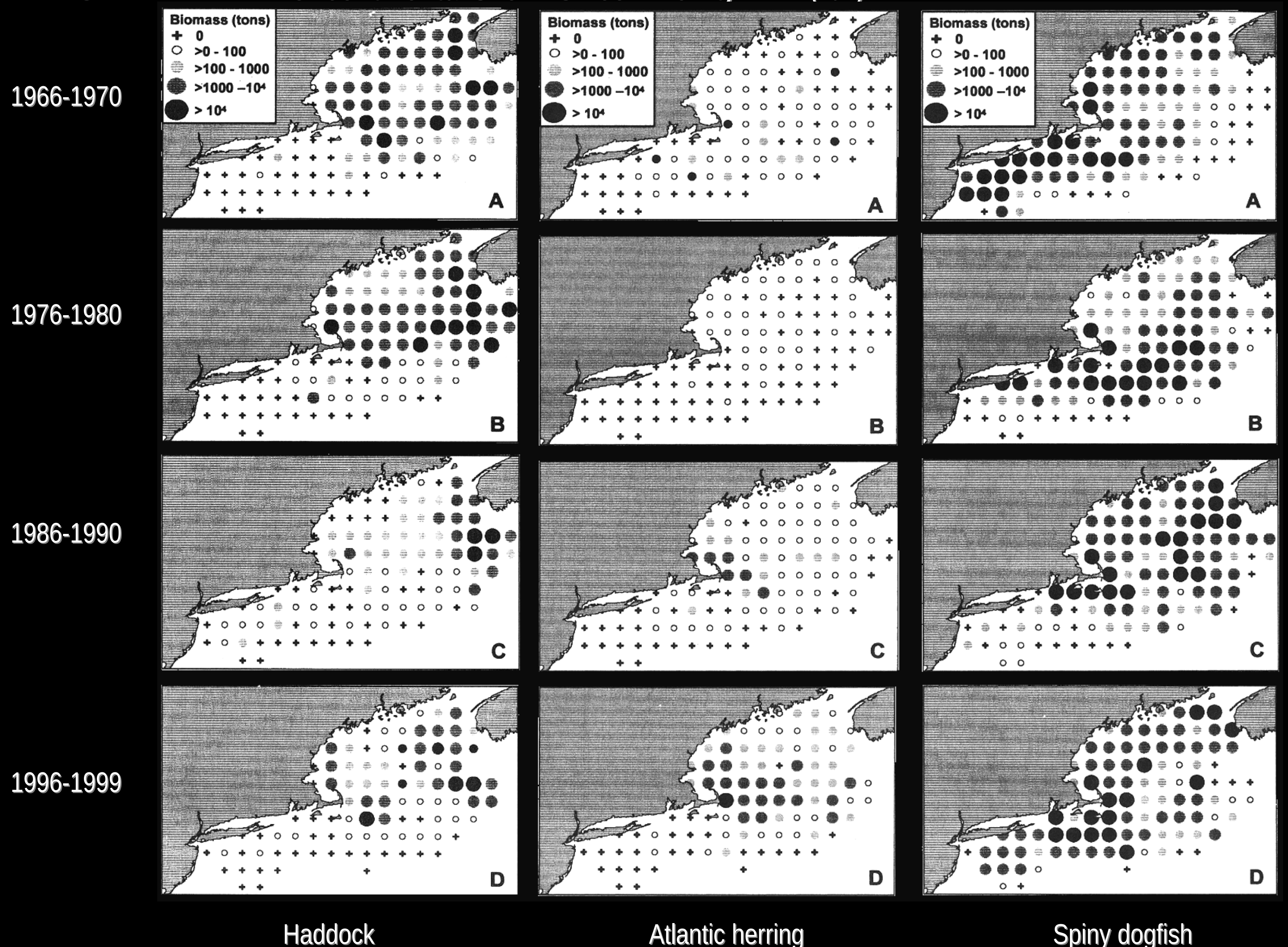
Distributions of snowcrabs in the eastern Bering Sea derived from NMFS summer trawl survey data. Density is expressed as the number of crabs per square nautical mille (from Zheng et al. 2001)

EASTERN BERING SEA: Snow crabs (2/2)



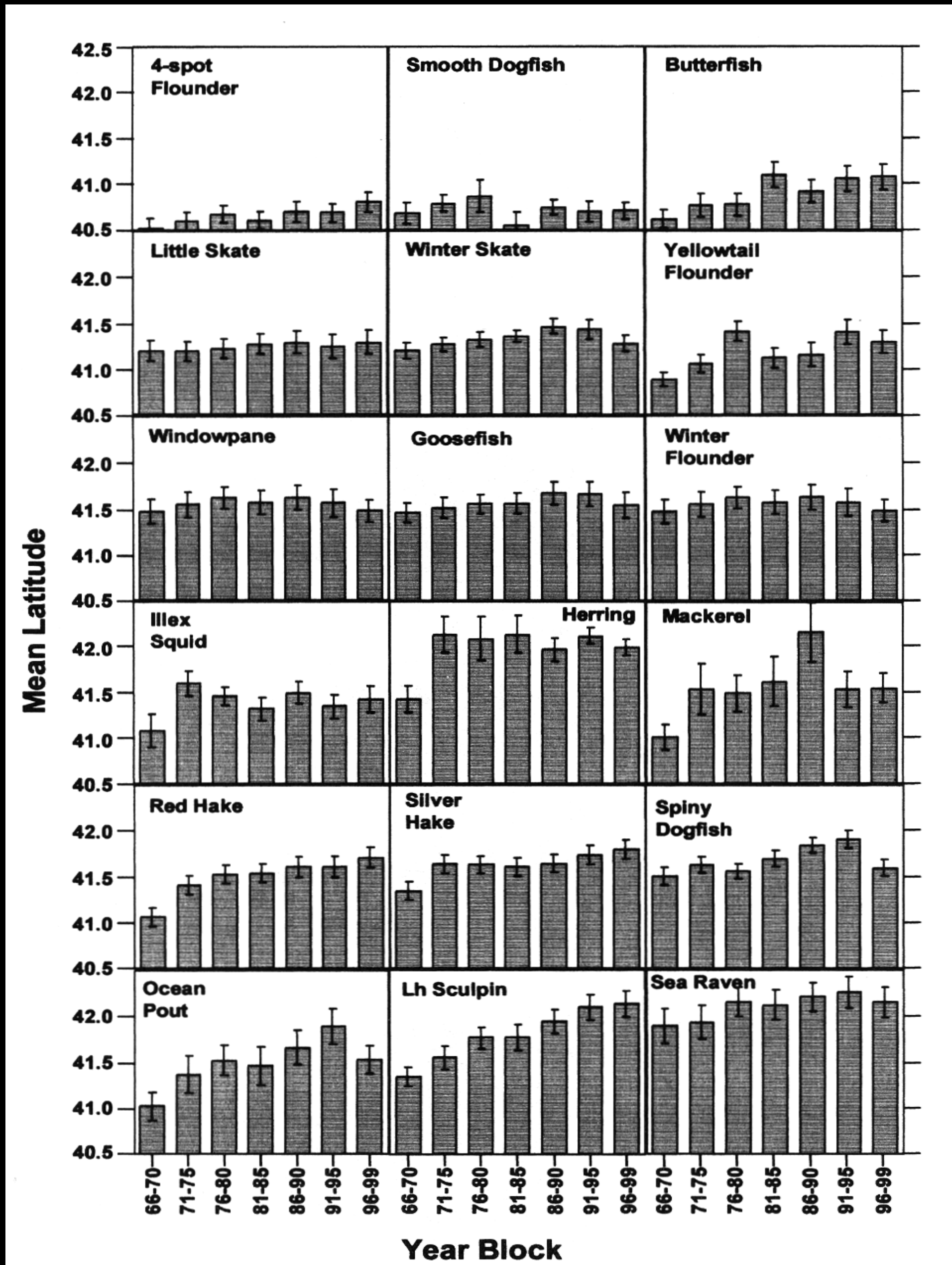
Centers of distribution of eastern Bering Sea snow crab derived from NMFS summer trawl survey data from 1978 to 1999. Years are plotted as data points (from Zheng et al. 2001)

NORTHEASTERN ATLANTIC: continental shelf fish community (1/2)



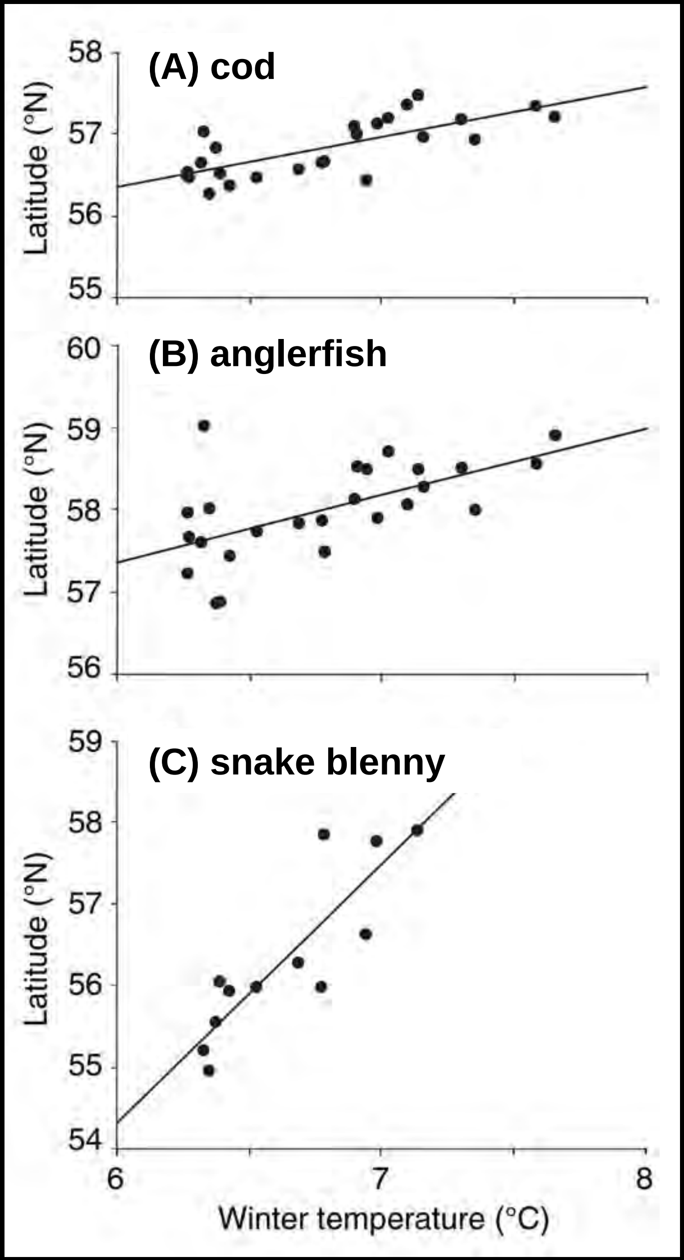
Estimated biomass in 0.5º cells in four time blocks (from Garrison 2001)

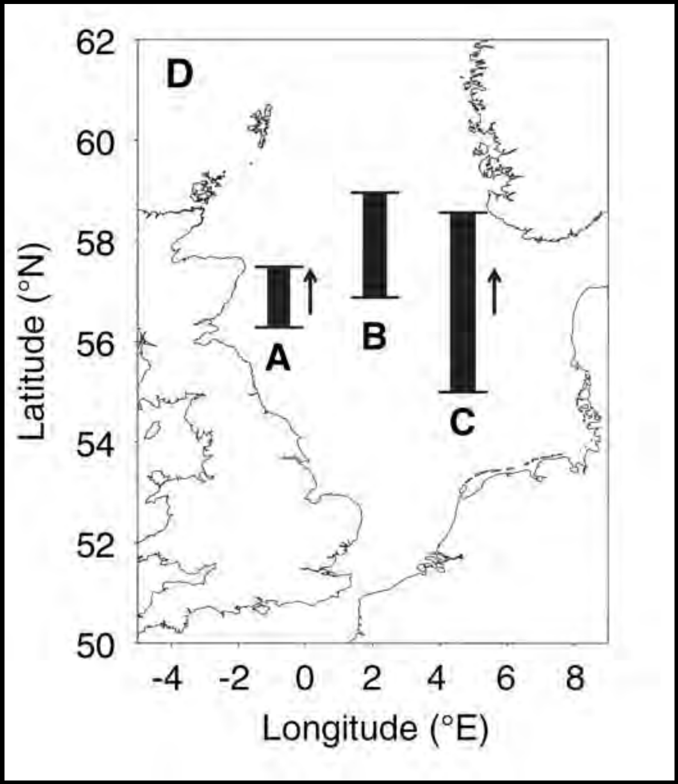
NORTHEASTERN ATLANTIC: continental shelf fish community (2/2)



Mean latitude of occurrence for 18 species of fish across 5-year time blocks from 1966 to 1999 (from Garrison 2001)

Northern Sea: Demersal Fish (examples of fish distributions that have shifted north with climatic warming)





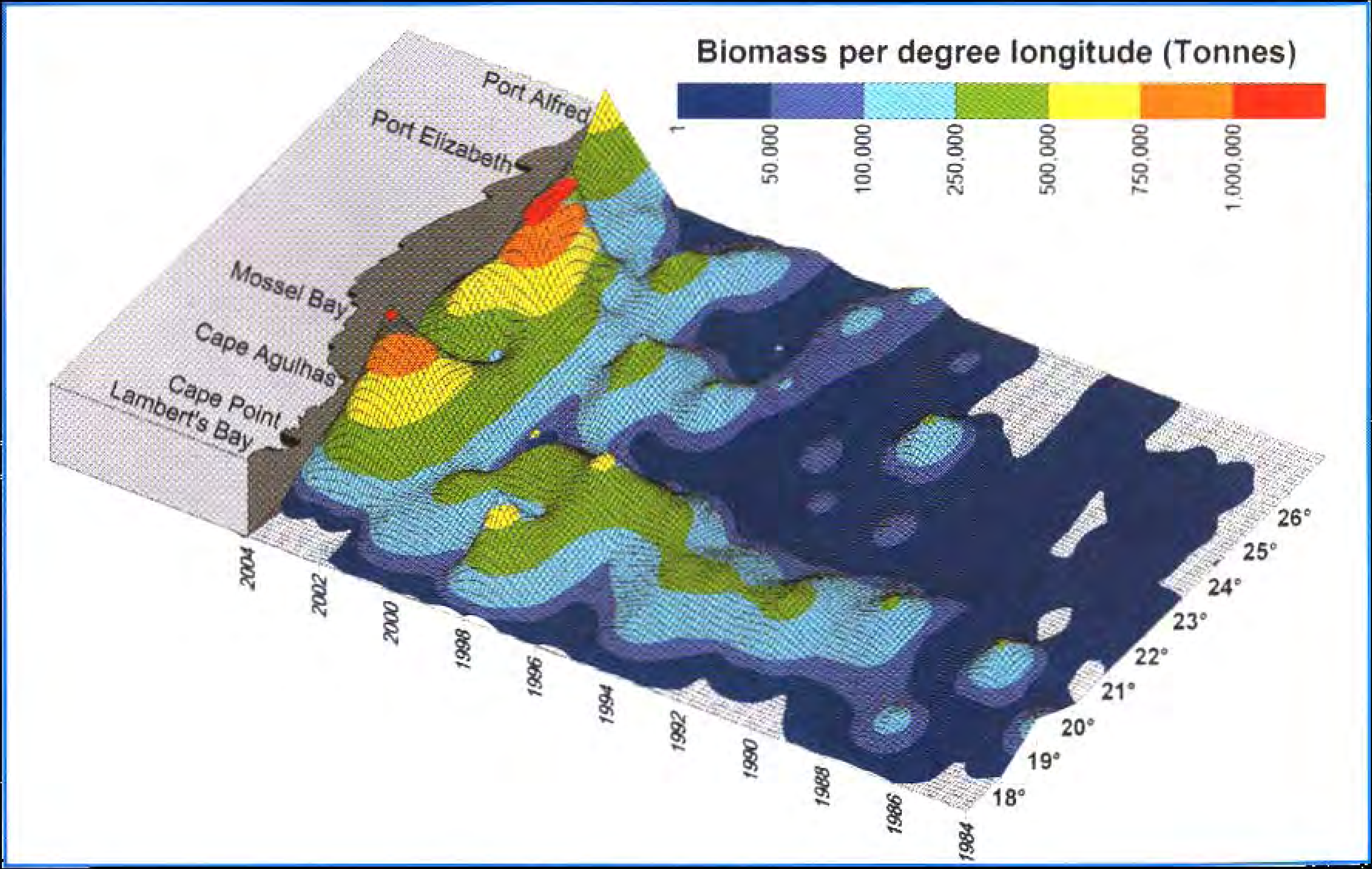
Ranges of shifts in mean latitude are shown for (A), (B), and (C) within the North Sea.

- Bars illustrate only shift ranges of mean latitudes, not longitudes.
- Arrows indicate where shifts have been significant over time, with the direction of movement

Relationships between mean latitude and 5-year running mean winter bottom temperature.

From Perry et al. (2005)

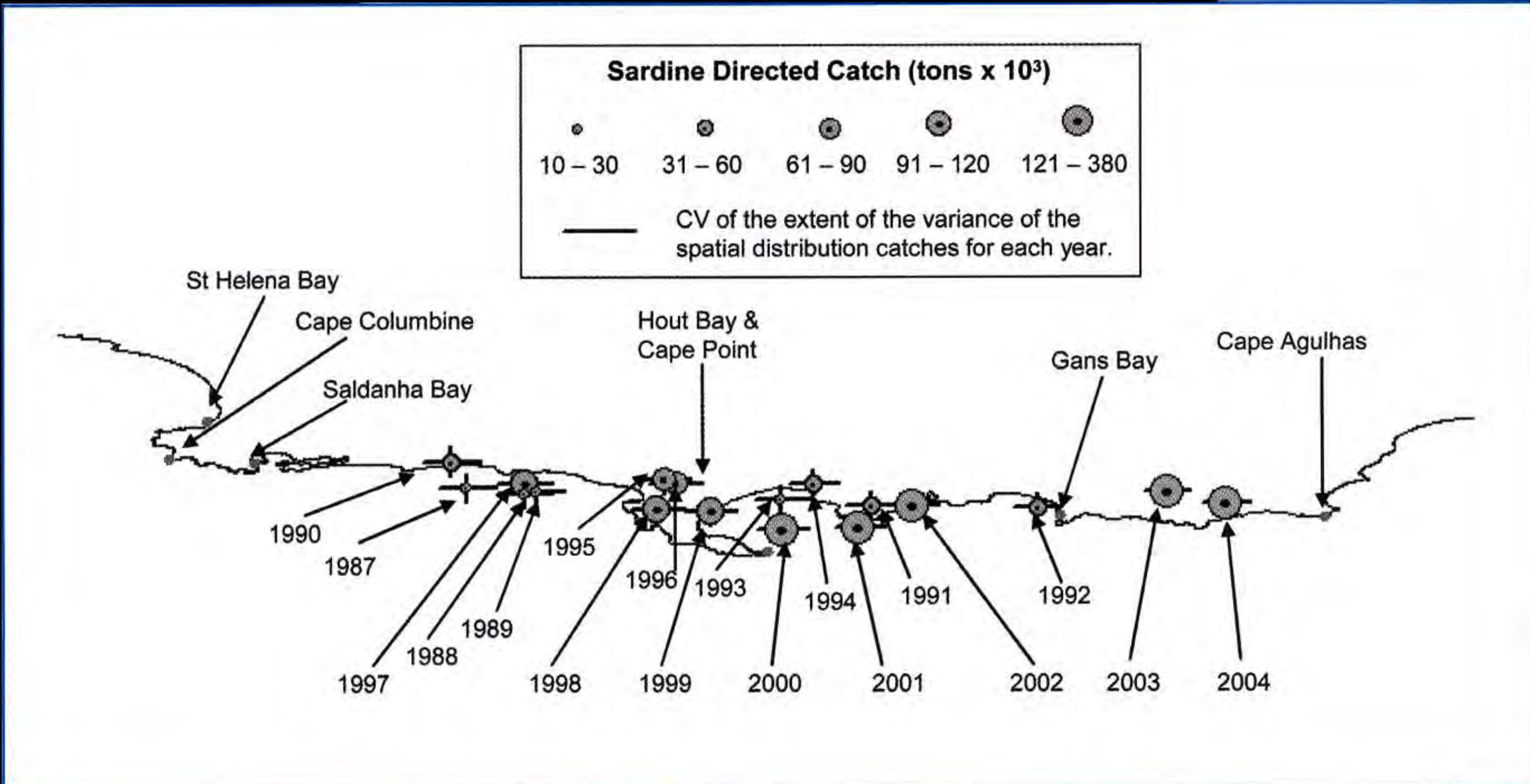
Southern Benguela: Benguela sardine (1/2)



Biomass of sardine as observed during annual spawner biomass surveys 1984-2004

From van der Lingen et al. (2005)

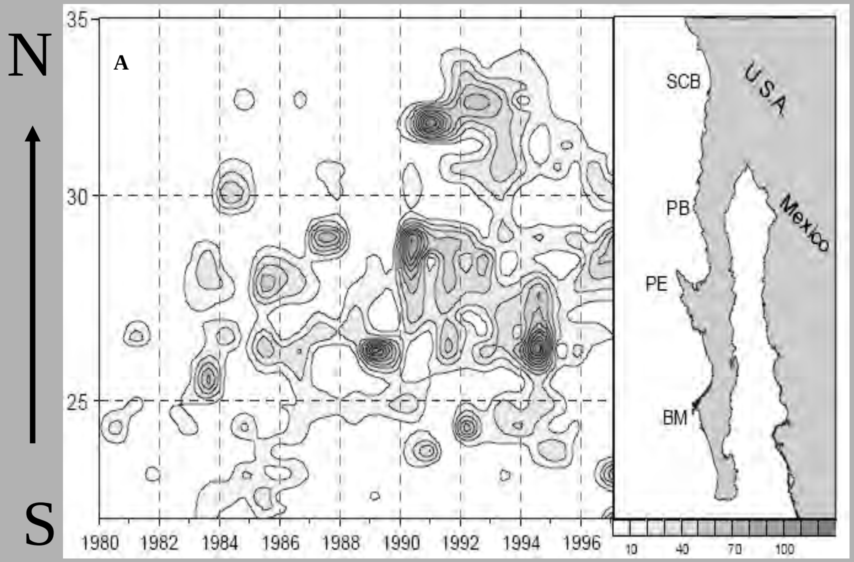
Southern Benguela: Benguela sardine (2/2)

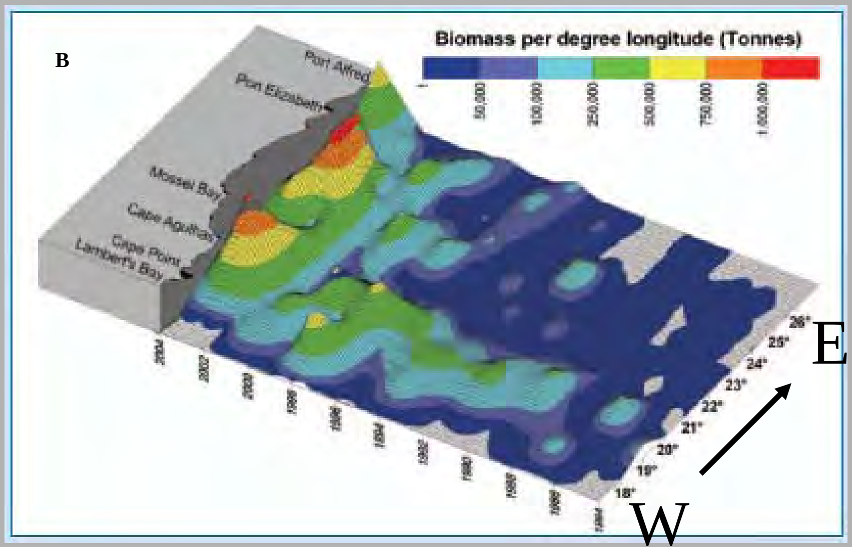


Annual centre of gravity of sardine catches

From van der Lingen et al. (2005)

Evaluate the influence of oceanographic fronts on interannual changes in the distribution and relative abundance of sardine in the California and Southern Benguela Current system

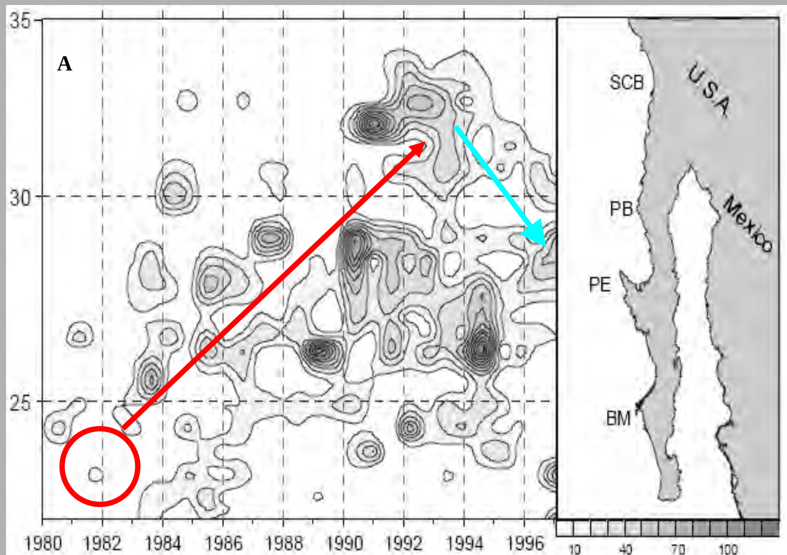




A) California Current system
Northward shift (1984-1997)

B) Southern Benguela system
Eastward shift (1984-2004)

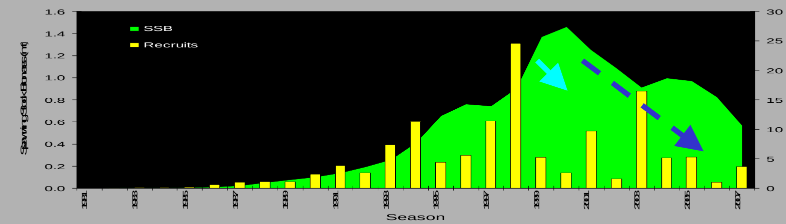
N



S

SSB and Recruitment

From Hill et al. 2007

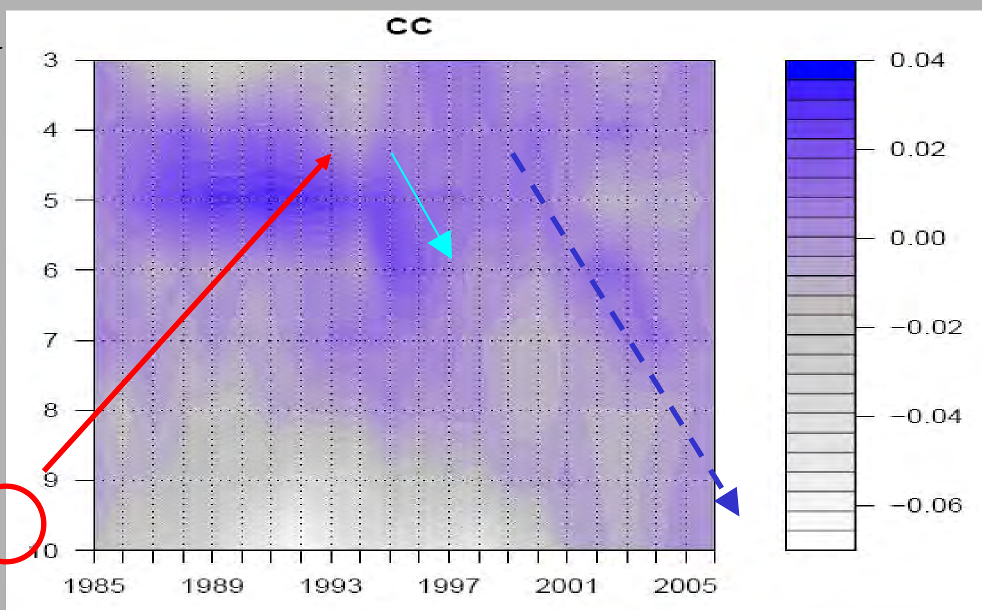


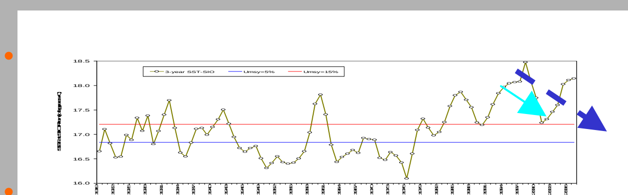
1981 2007

SST at SIO Pier

From Hill et al. 2007

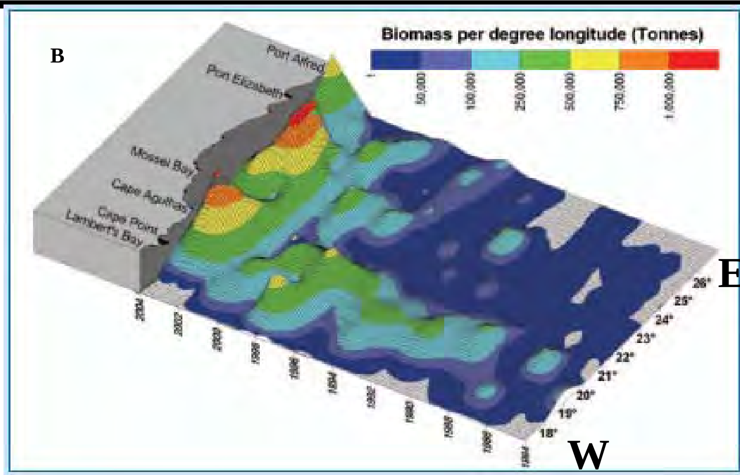
N

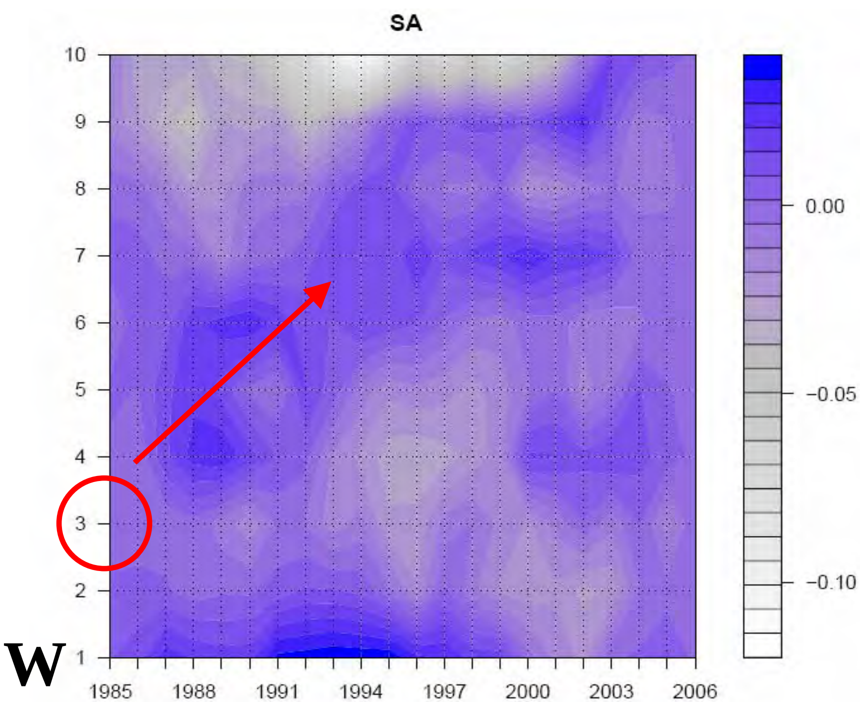




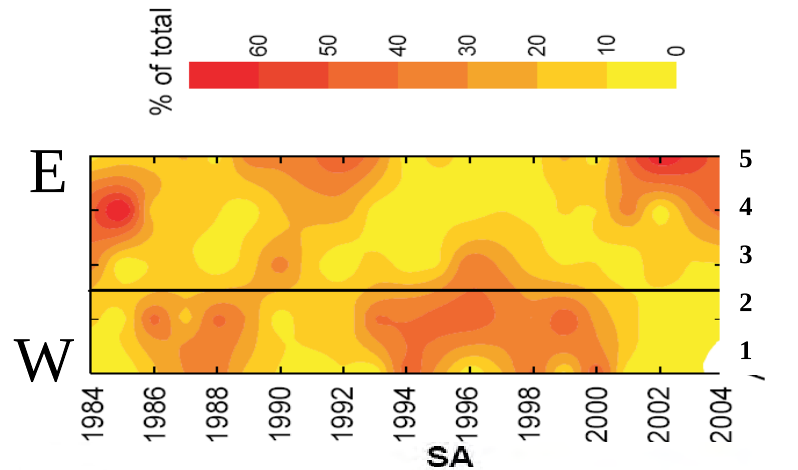
1917 1976 2007

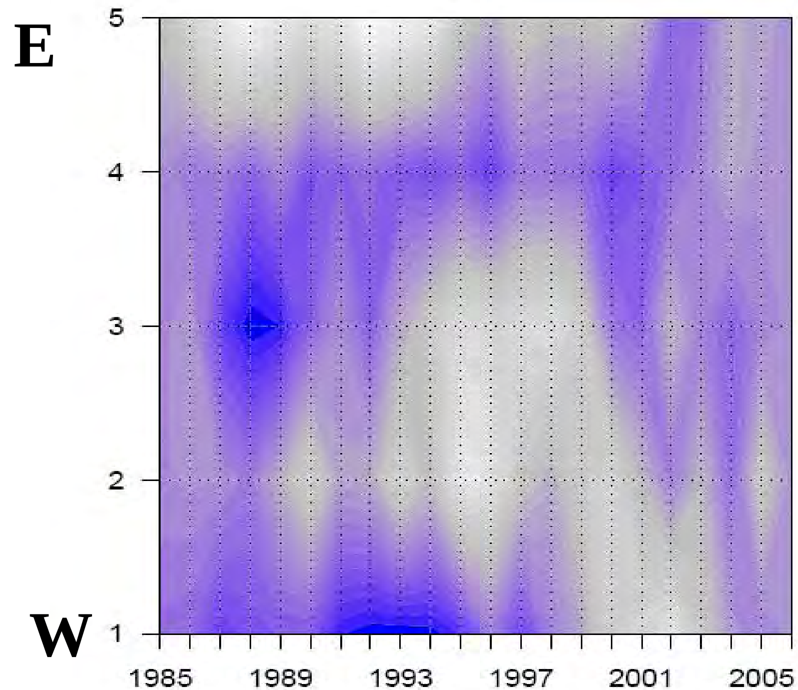
SARDINE BIOMASS





SARDINE EGGS





Thank you