PICES/GLOBEC Symposium

Honolulu, Hawaii

April 19-21, 2006

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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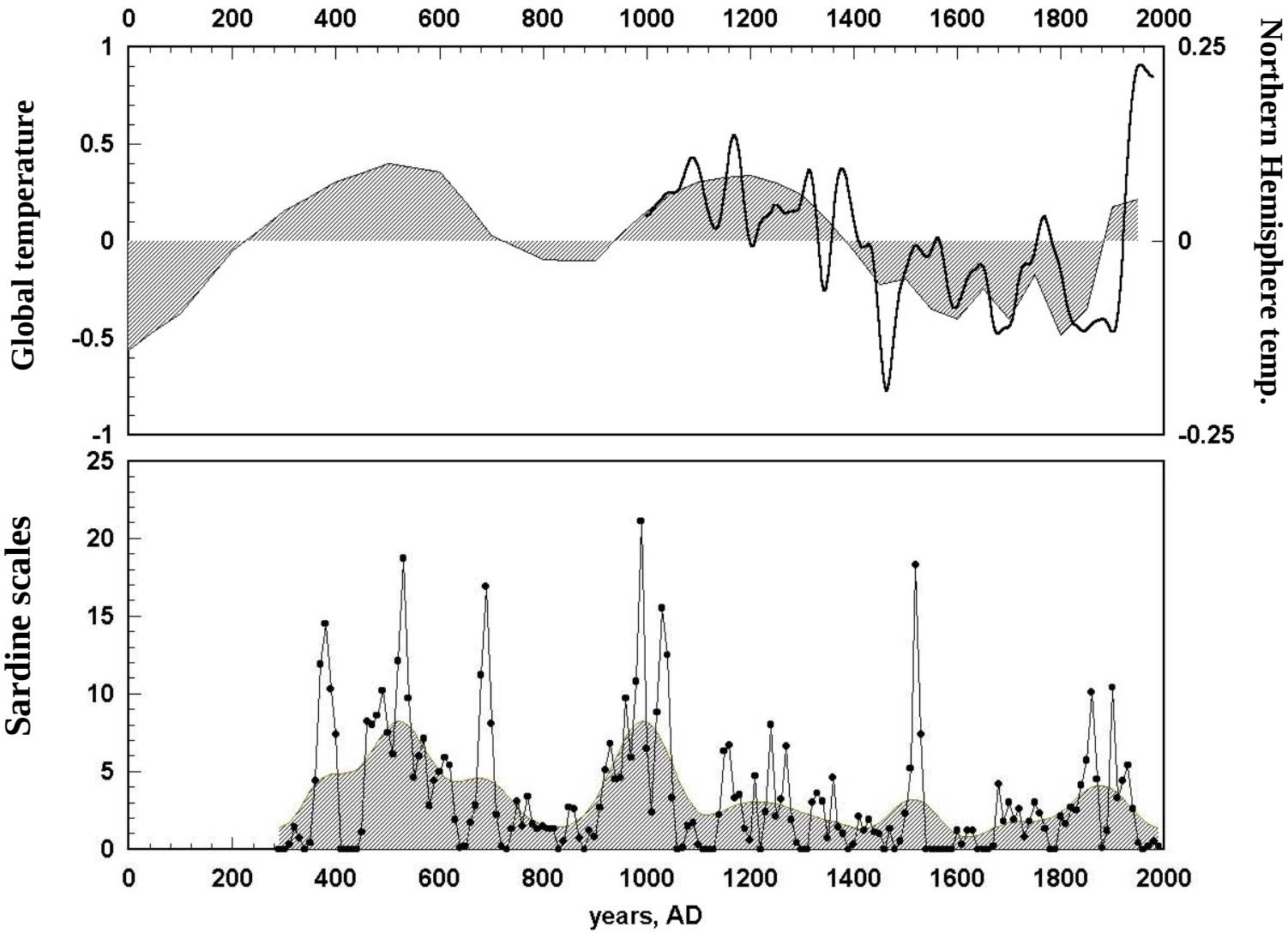
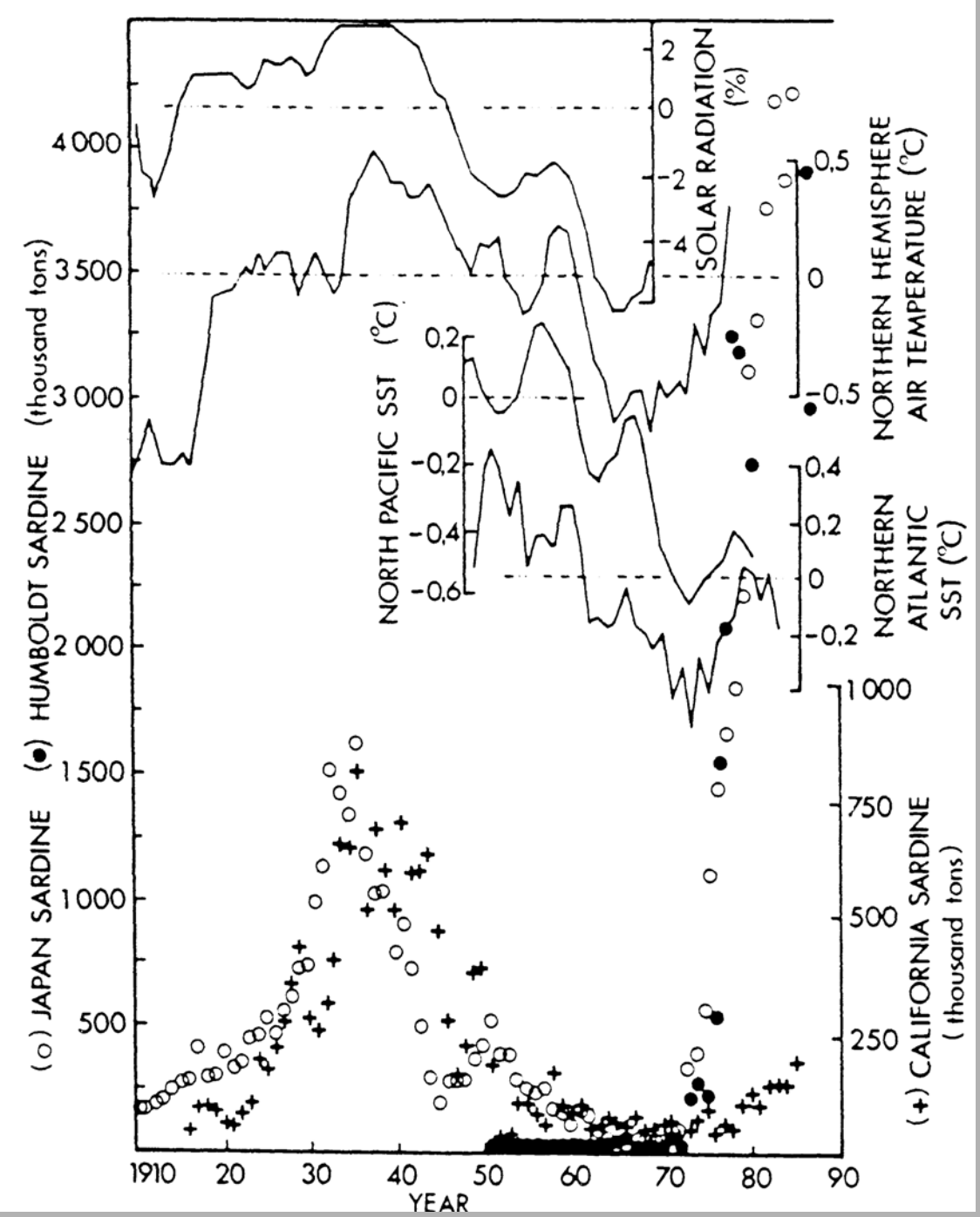
BACKGROUND (1/3)

What have we learned from analysis of time-series of information ? :

- Multidecadal variation of biological and environmental indices



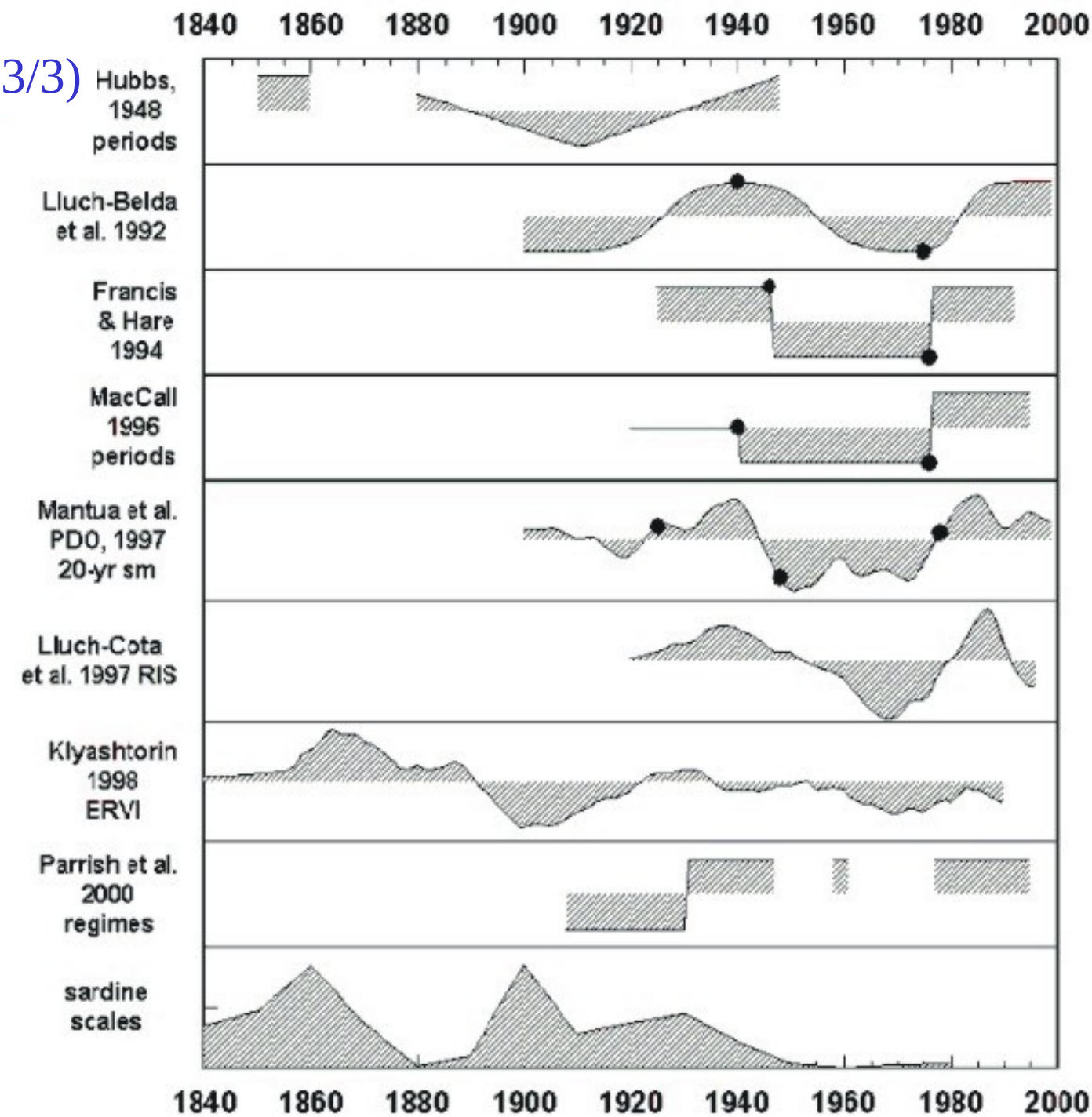
BACKGROUND (2/3)



- sardine catch records from well separated ecosystems shown **global synchronic** : The Regime Hypothesis

BACKGROUND (3/3)

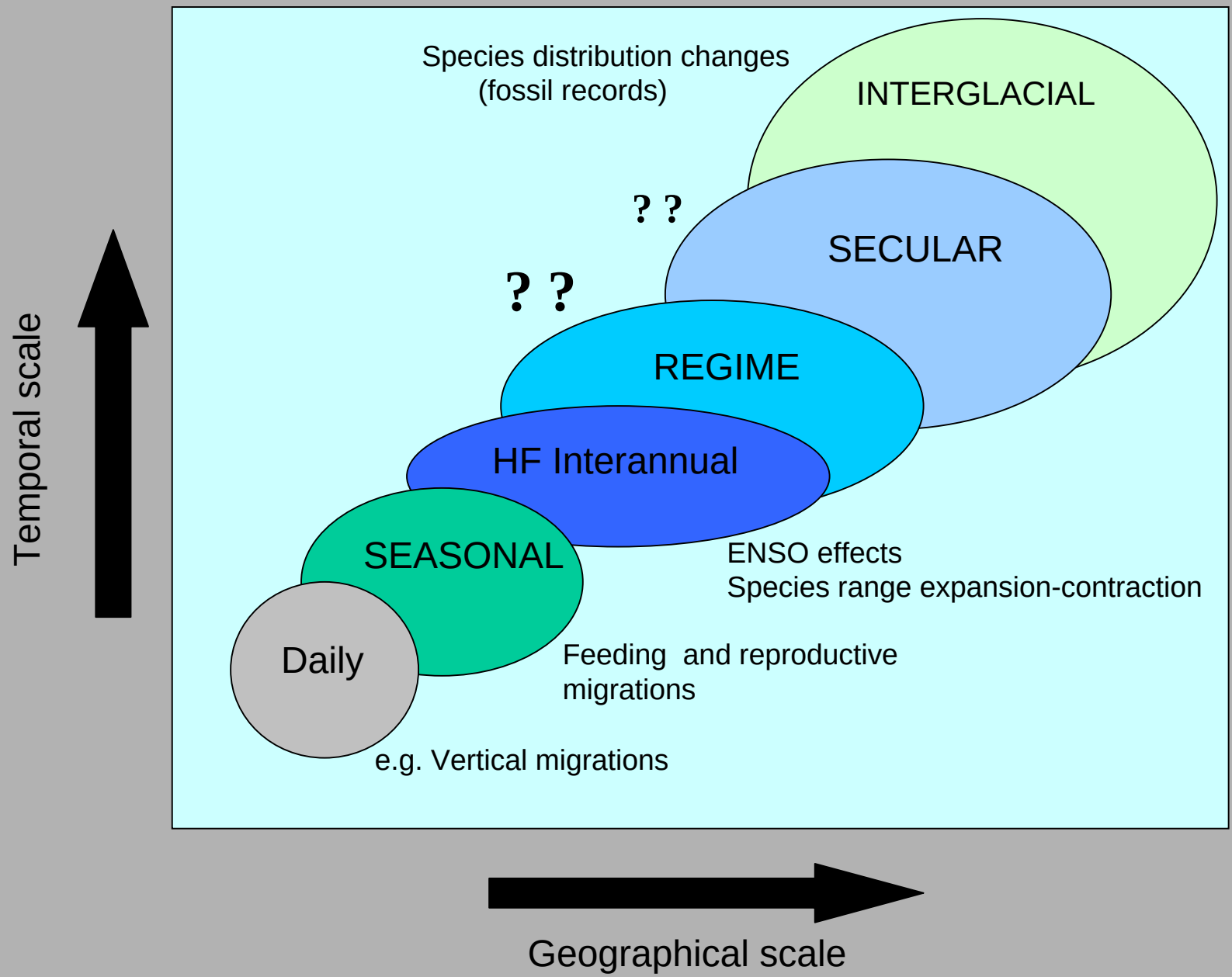
- The regimen variation has been shown also for **other species-ecosystems**, or using other environmental indicators



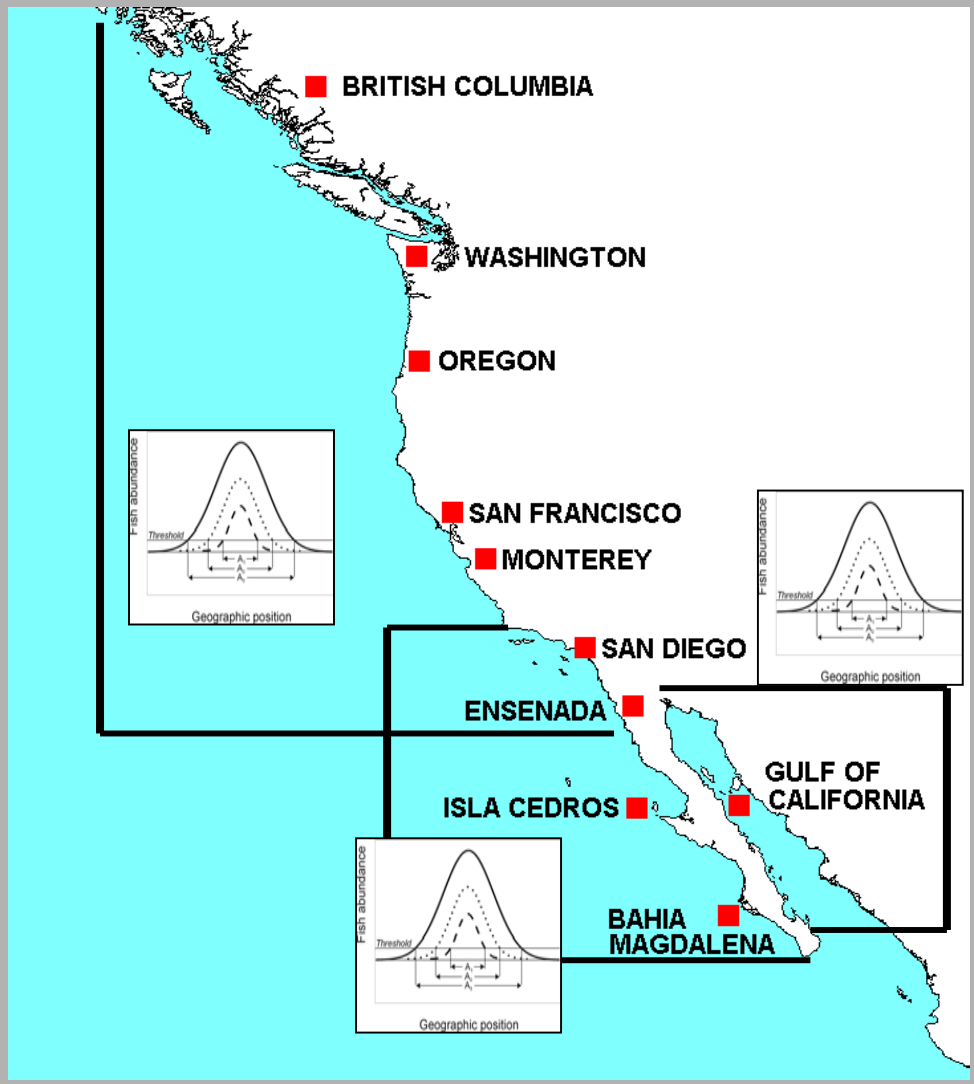
No doubt that the **unidimensional analysis** of time-series of information has been useful to advance in the understanding of population dynamics and their relations with environmental variability.

But …

ECOLOGICAL PROCESS ON SPATIAL-TEMPORAL SCALES



ECOLOGICAL PROCESS ON SPATIAL-TEMPORAL SCALES



Problems for spatial analysis

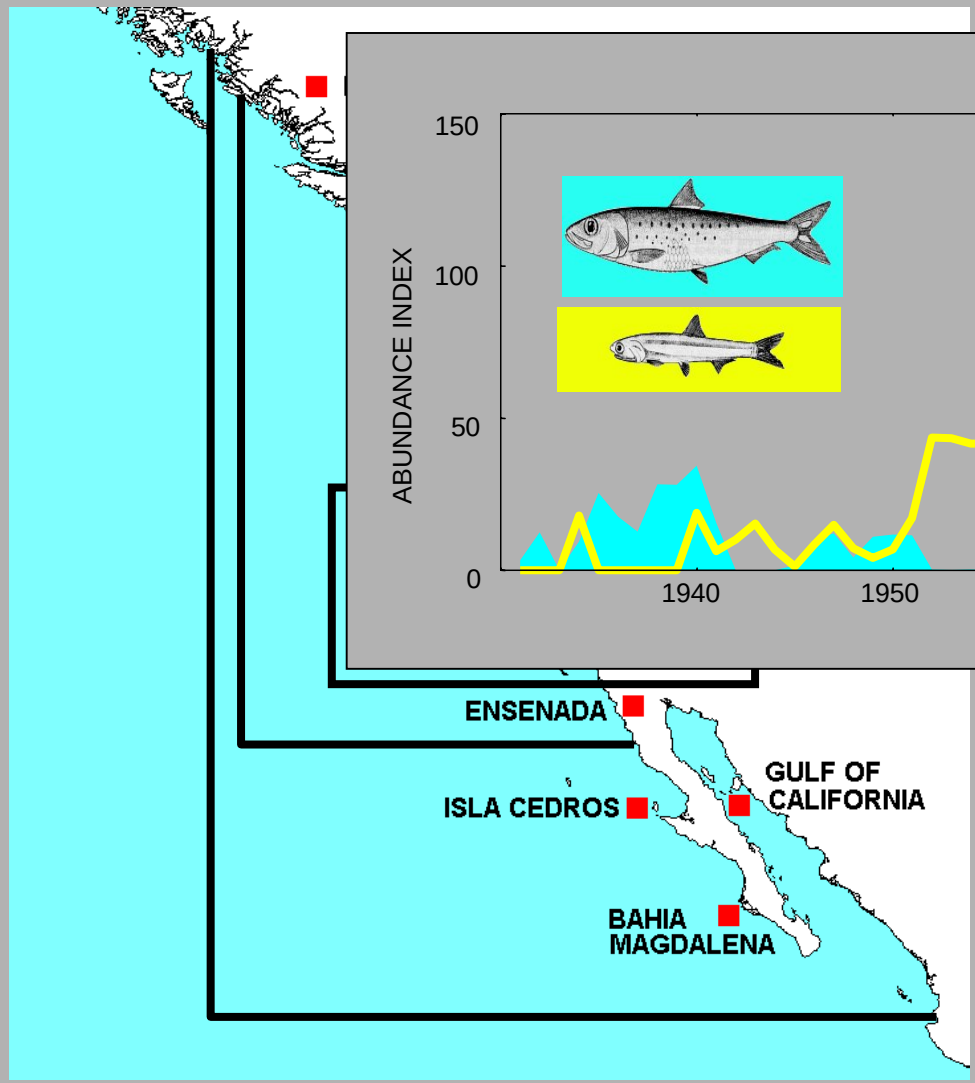
e.g. Small pelagic fish in the California Current system.

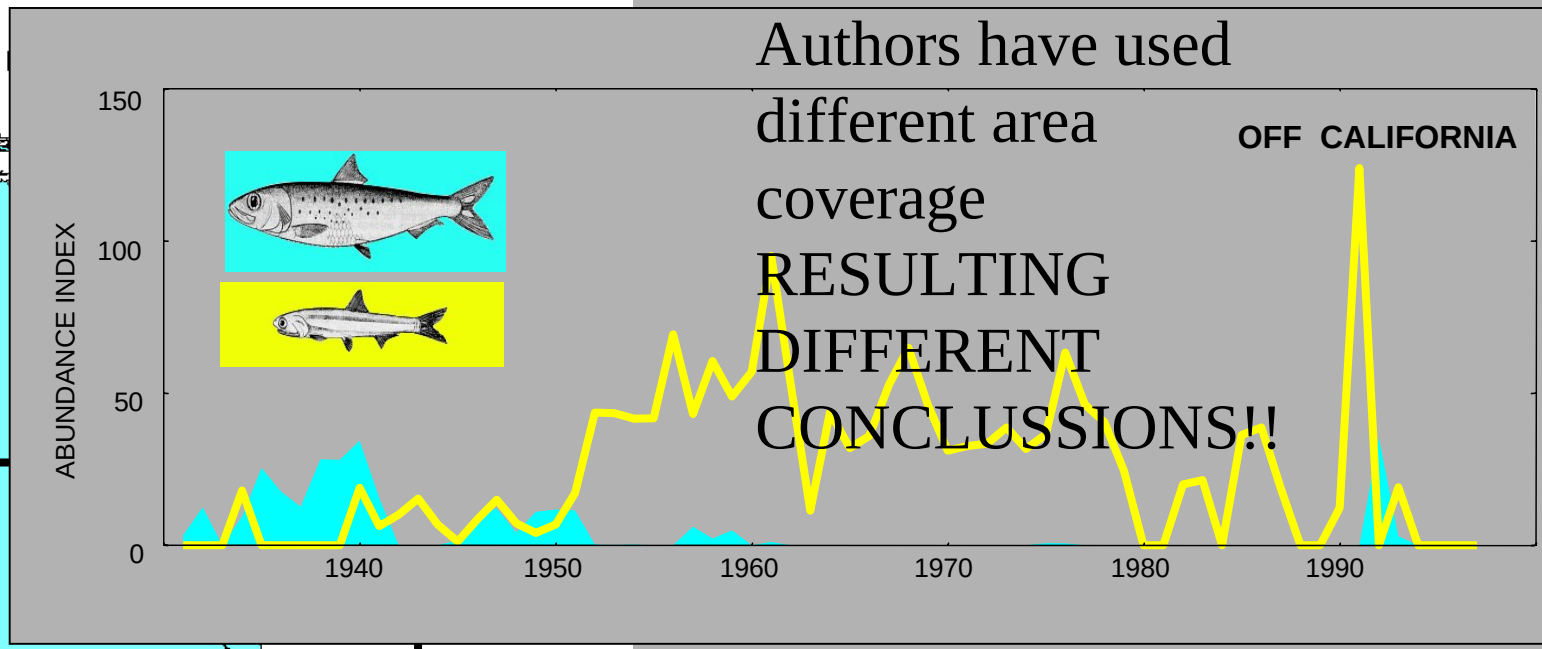
- Species with wide geographical variation
  - Transboundary distribution
- Assumptions of different populations or stocks within species distribution
  - Lecomnte et al. 2004: genetic study

Data from commercial fishing

- Relatively continuous in time for each port
- Different time-area coverage
- No comparative indices are available between ports
- Important gaps between ports

DATA FROM COMMERCIAL FISHING





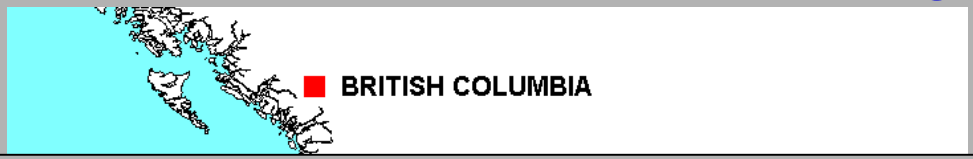
Authors have used different area coverage RESULTING DIFFERENT CONCLUSSIONS!!

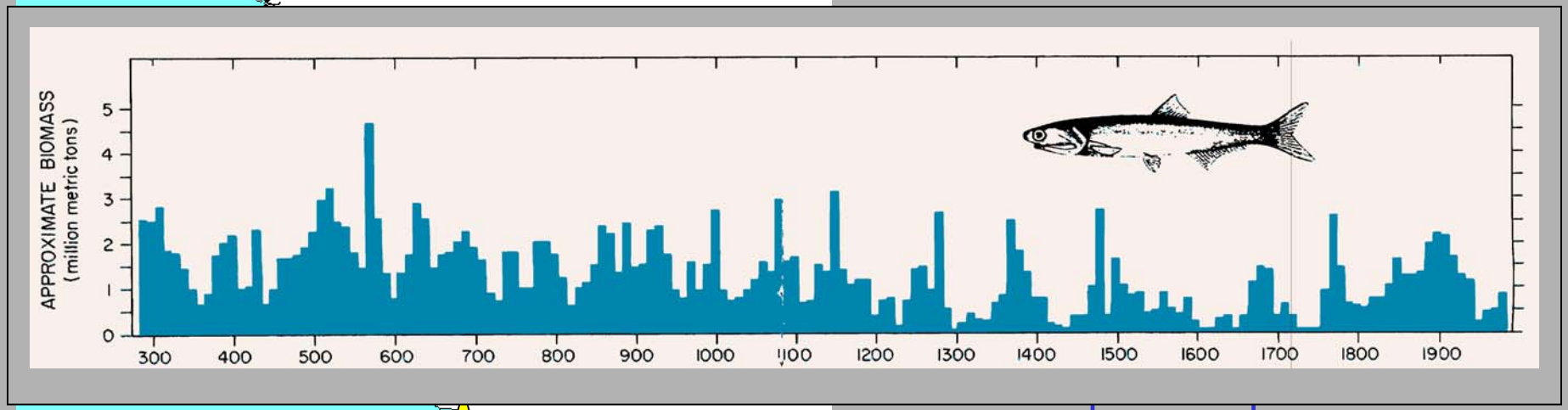
Analysis over time-scale only

as representatives of a stock variability

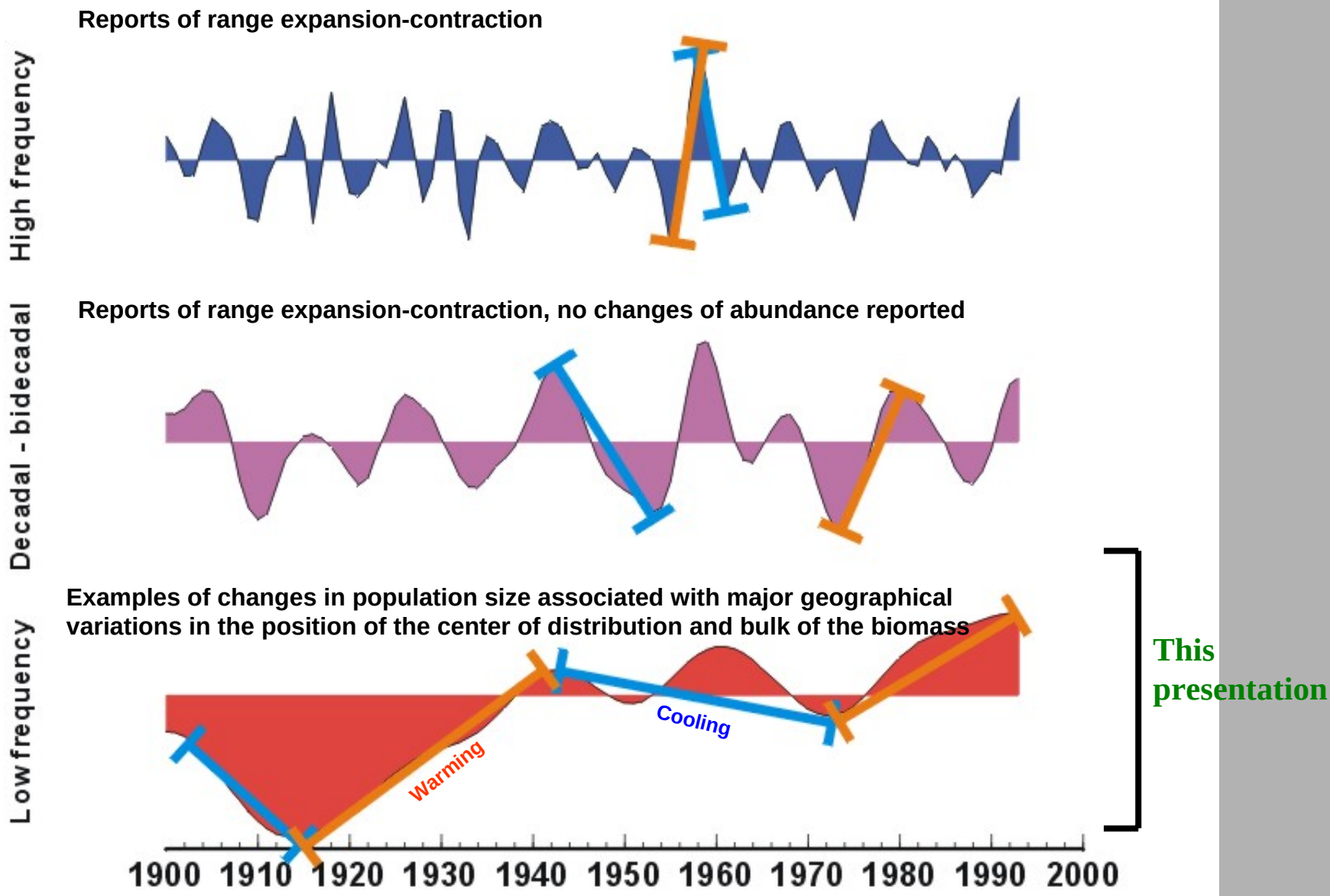
OTHER ABUNDANCE INDEX

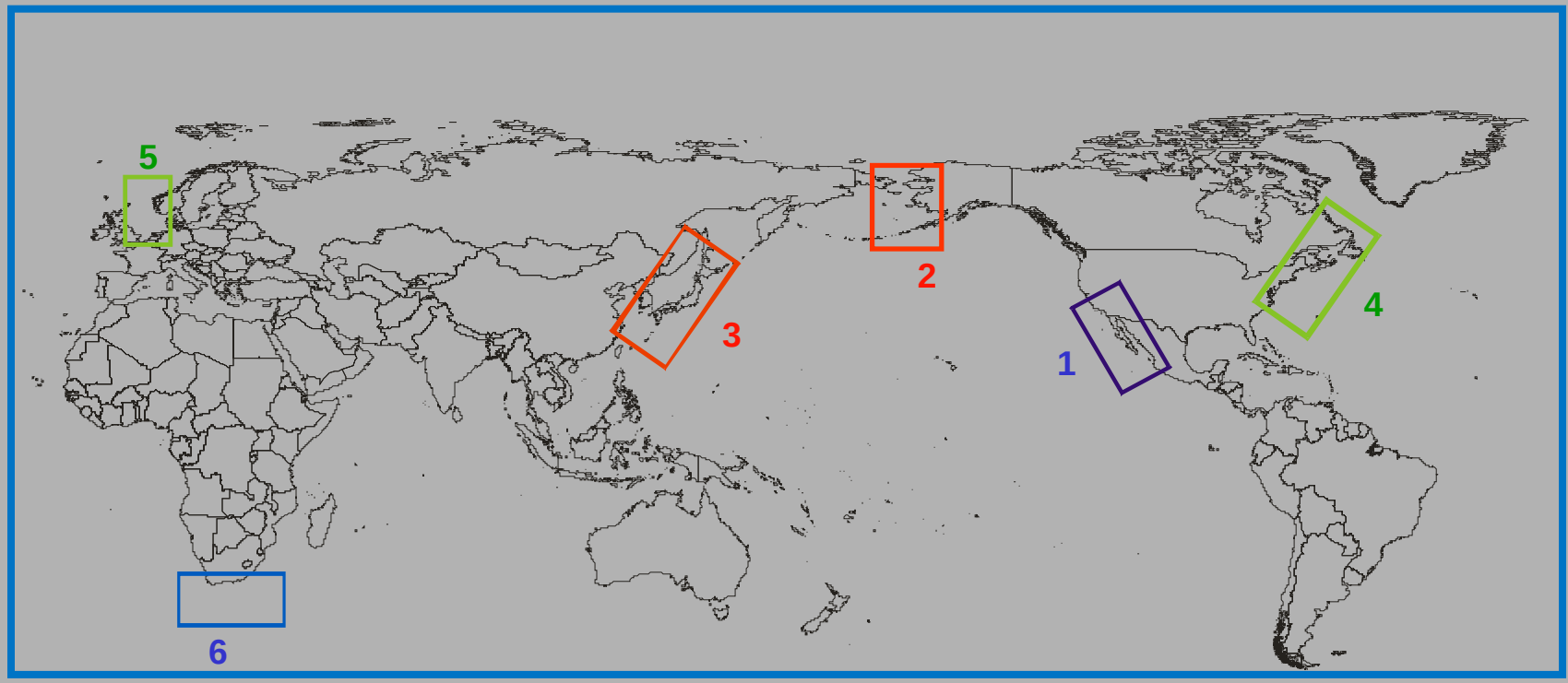
e.g. abundance of scales in a core sample of sediments





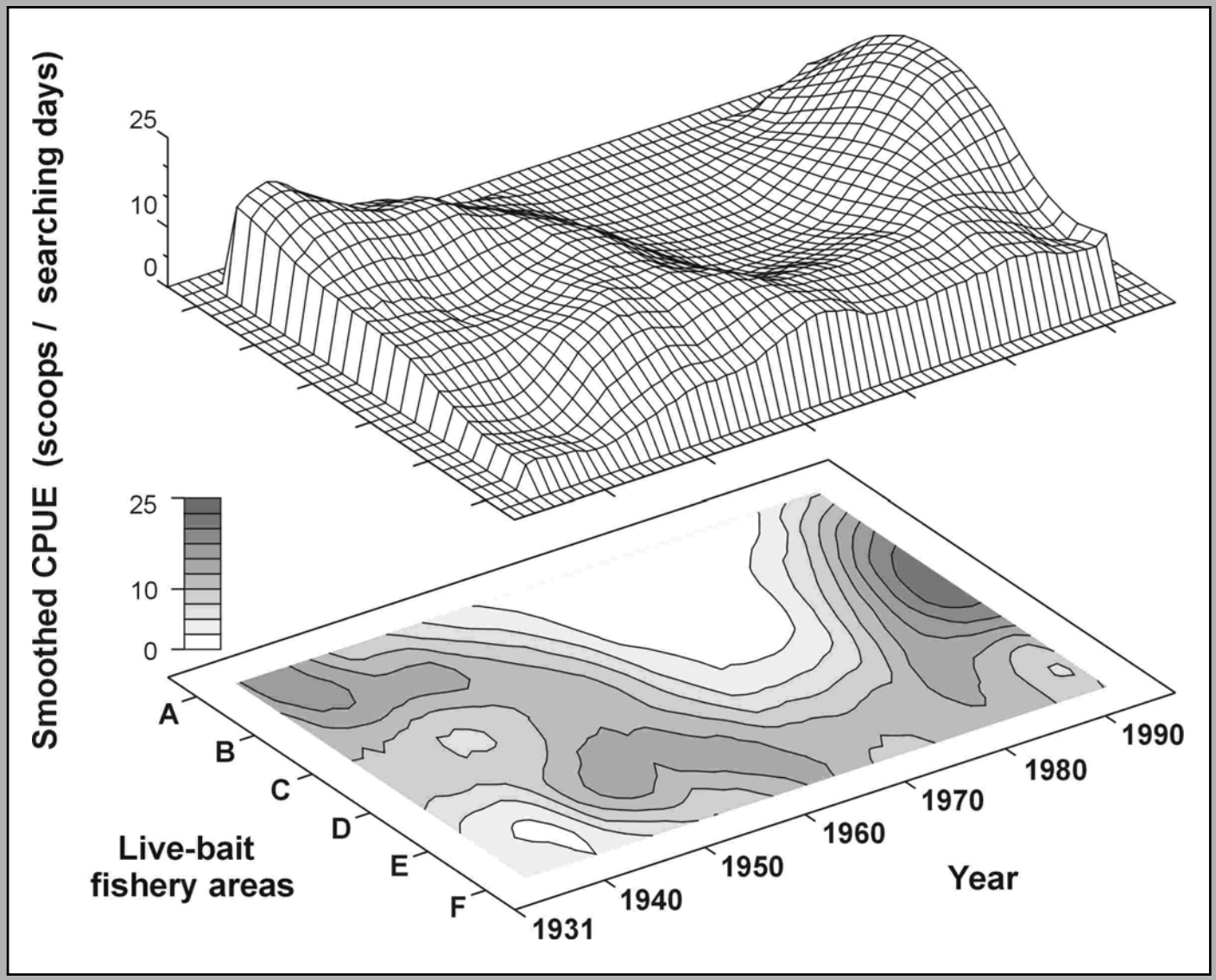
analysis over time-scale only

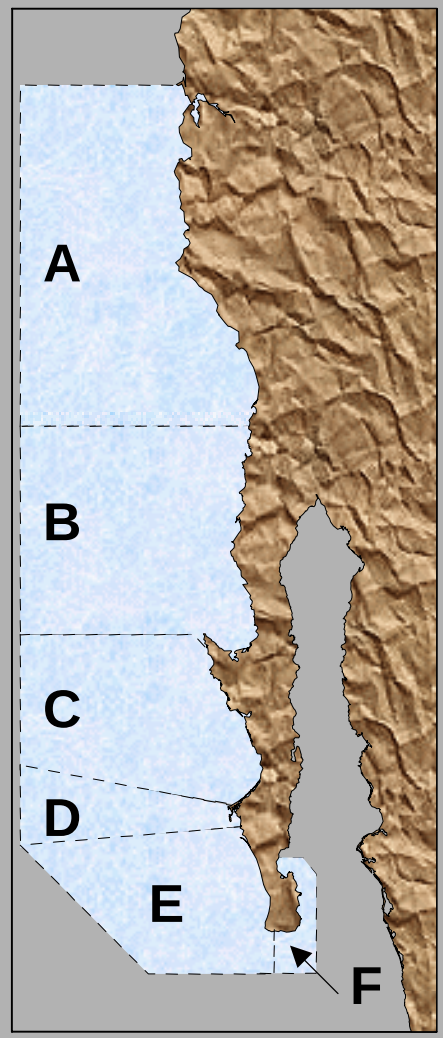

High frequency
Reports of range expansion-contraction
Decadal - bidecadal
Reports of range expansion-contraction, no changes of abundance reported
Low frequency
Examples of changes in population size associated with major geographical variations in the position of the center of distribution and bulk of the biomass
Warming
Cooling
1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
This presentation

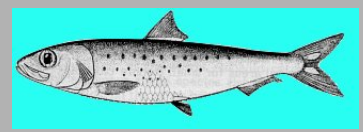


No.	Ecosystem/ author	Species	Time frame	Regime condition
1	**California Current System** (Rodríguez-Sánchez et al 2001, 2002)	Small Pelagic Fish	1931 – 1997	Cooling and Warming conditions
2	**Eastern Bering Sea** (Zheng et al. 2001)	Snow Crab	1978 - 1999	Warming conditions
3	**Japan Sea** (Kidokoro 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

Spatial variability of Pacific sardine at regime time-scale







Rodríguez-Sánchez et al. (2002)

The question arising is:

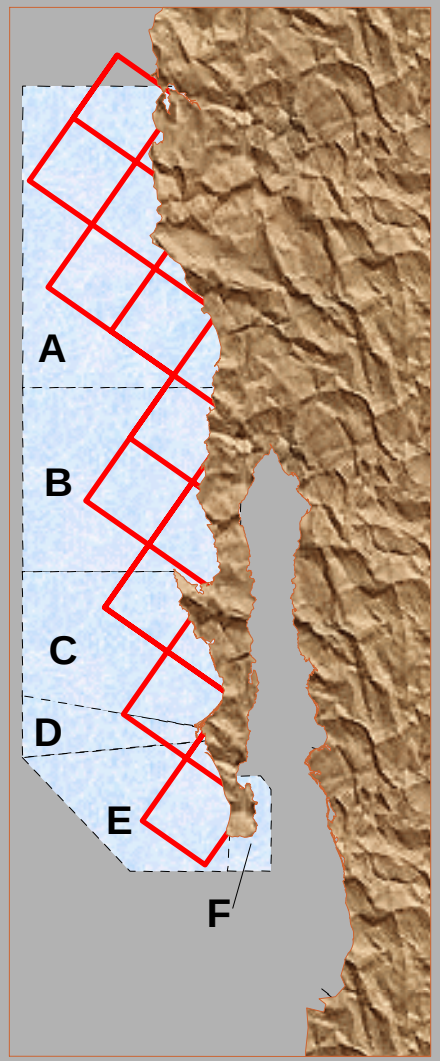
Is this natural pattern of variation only recorded in the Pacific sardine?

In this work:

1) the large-scale, long-term (1931-1997) variability of tropical species in the CCS is included in the sardine-anchovy analysis.

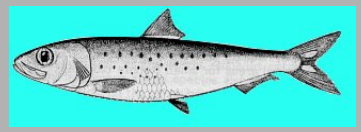
2) examples are shown for other species and communities from other ecosystems

LIVE-BAIT FISHERY AREAS



- Annual CPUE by specie (1931-1997)

SARDINE *Sardinops caeruleus*



NORTHERN ANCHOVY *Engraulis mordax*

TROPICAL SPECIES *Harengula thrissina*

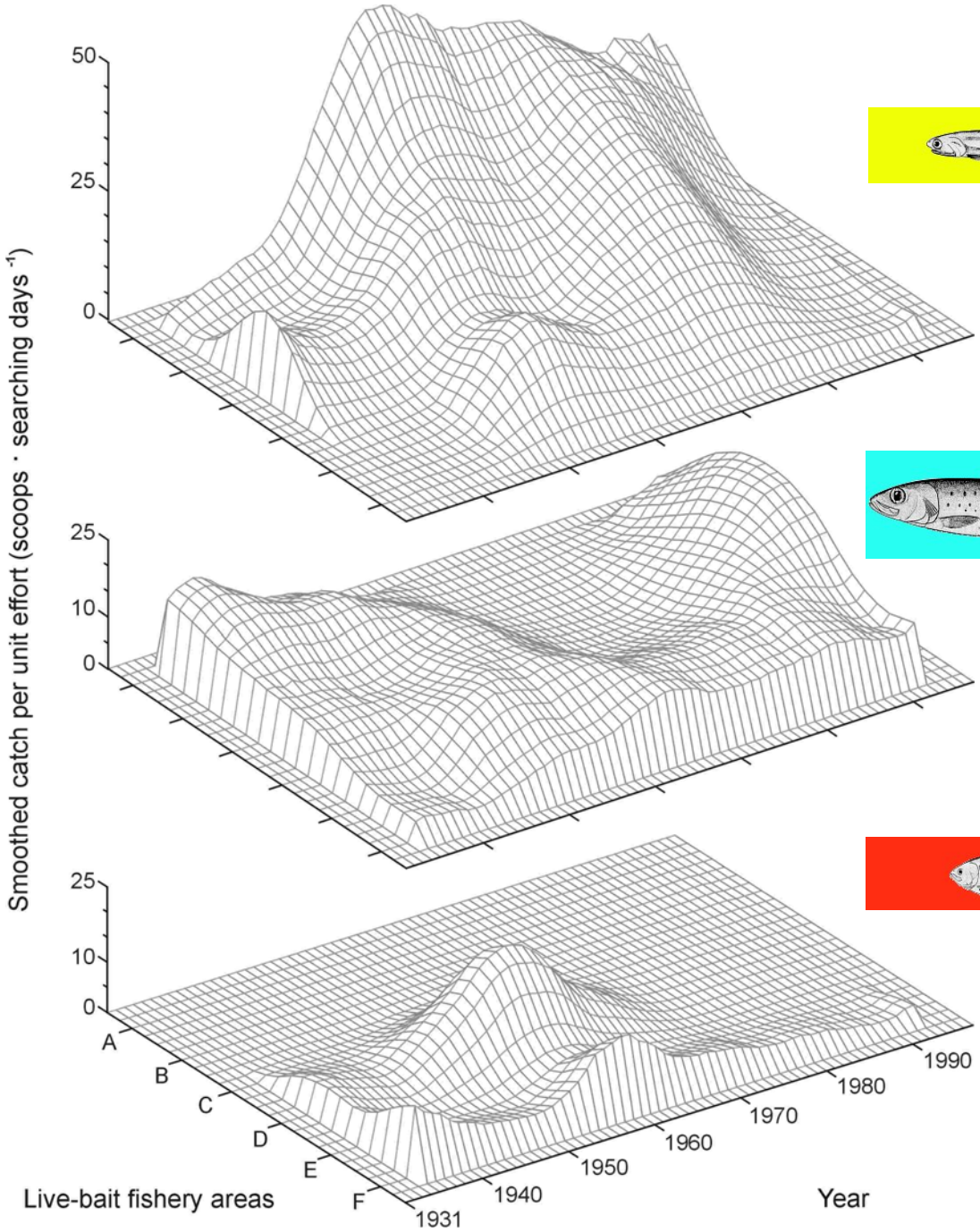
Opisthonema spp.

Cetengraulis mysticetus

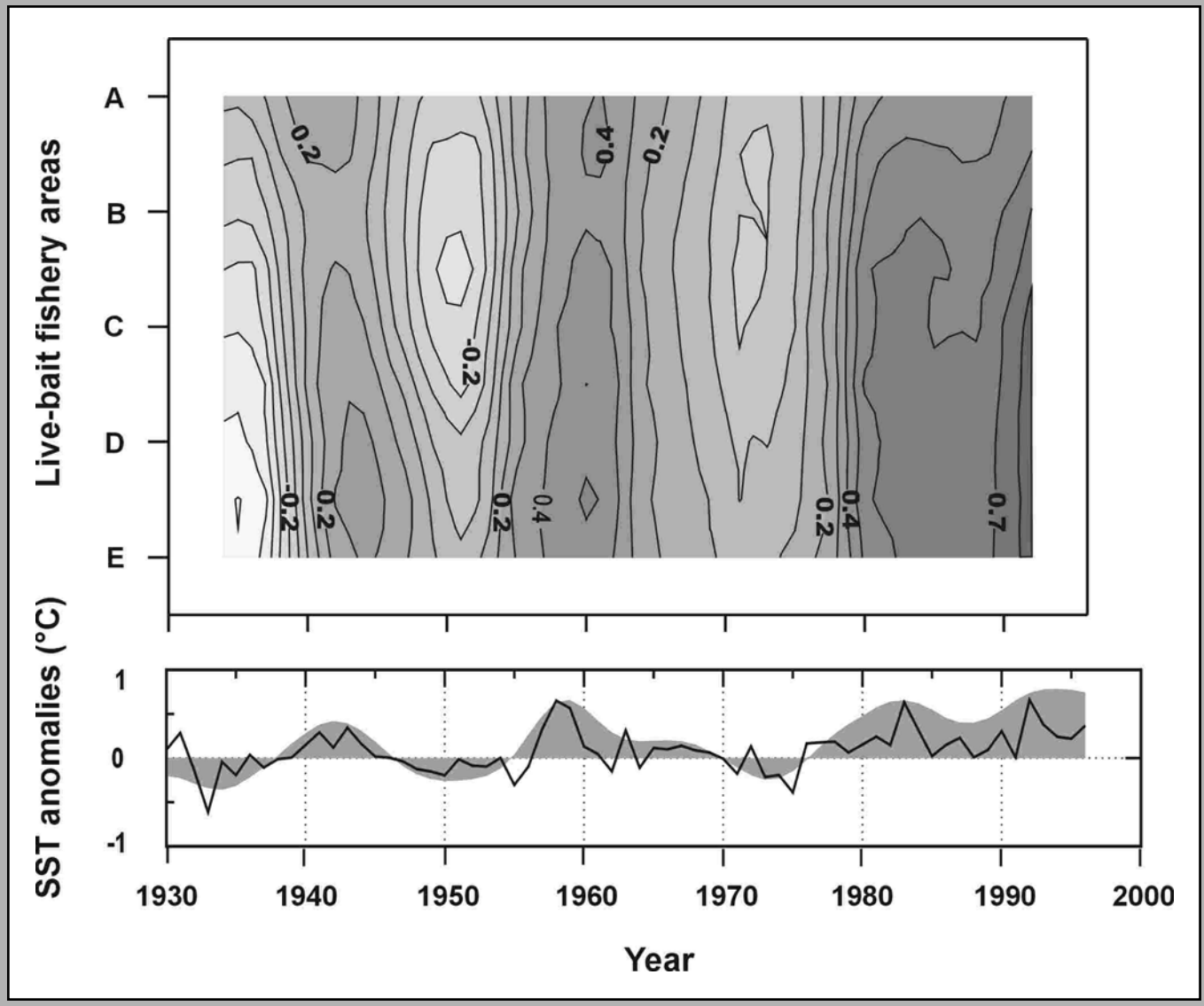
TIME SERIES OF SST

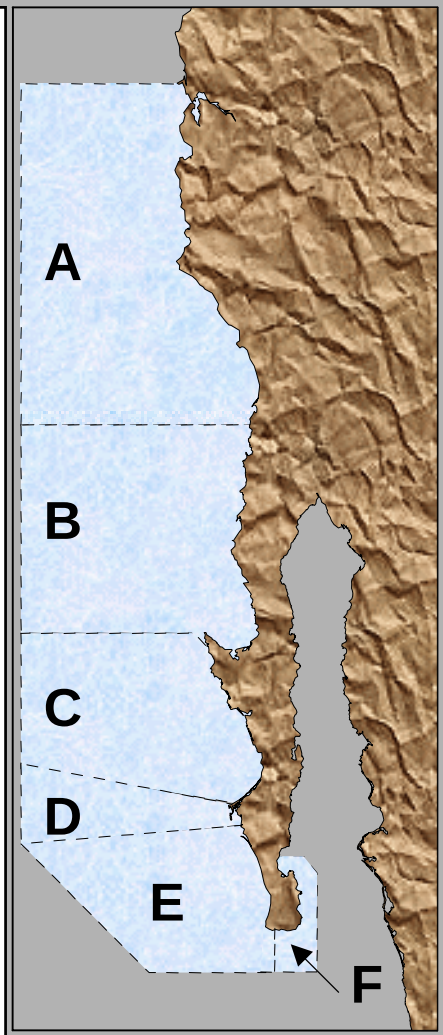
- From COADS database (1900-1996)

squares of 2 X 2 degrees

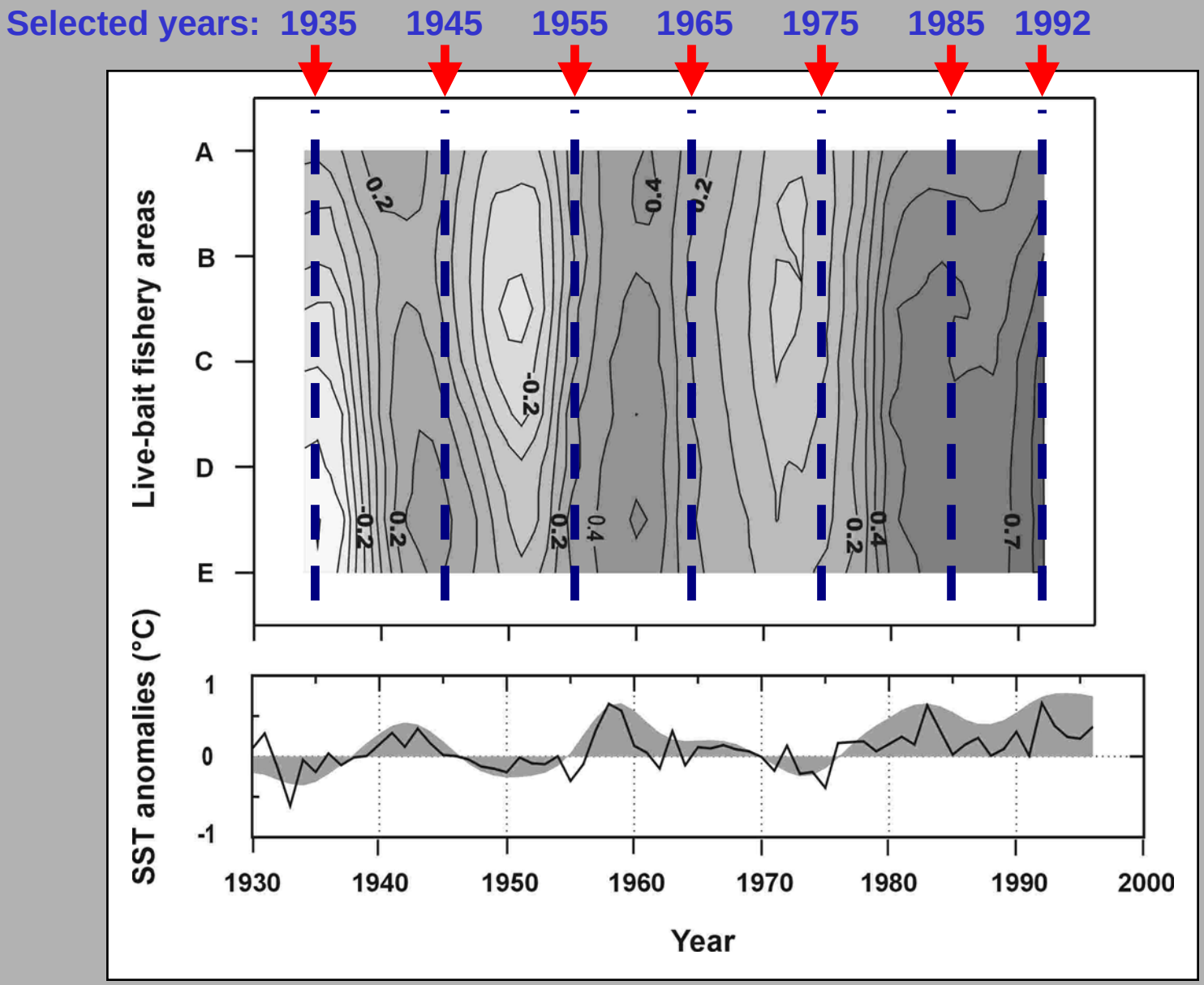

Smoothed catch per unit effort (scoops · searching days -1)
50
25
0
25
10
0
25
10
0
A
B
C
D
E
F
Live-bait fishery areas
1931
1940
1950
1960
1970
1980
1990
Year

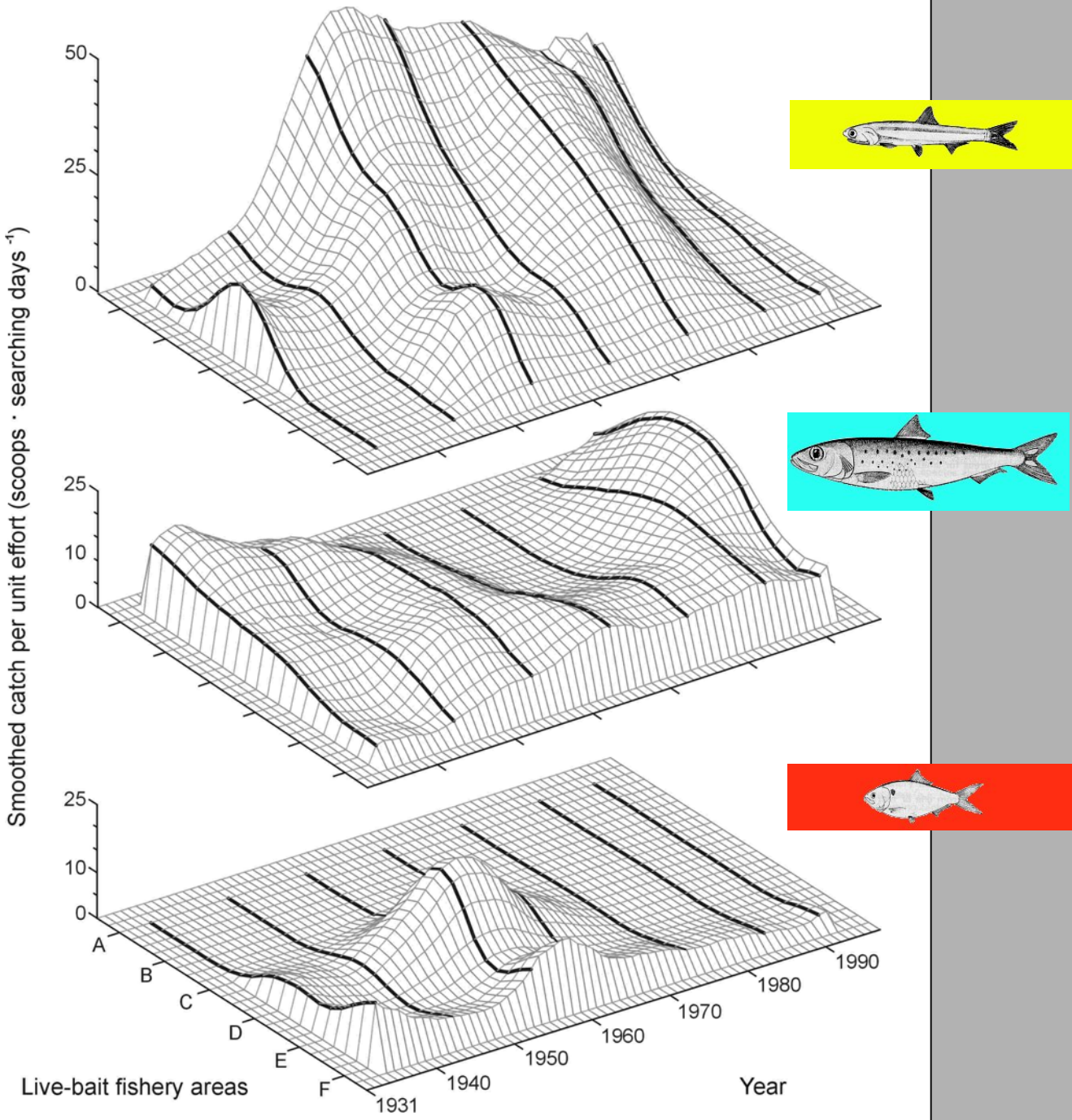
Spatial distribution of SST anomalies



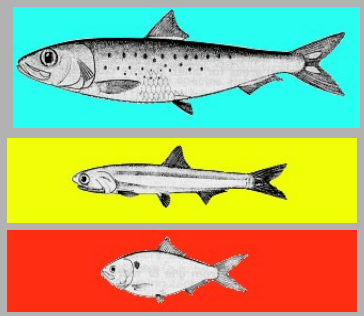


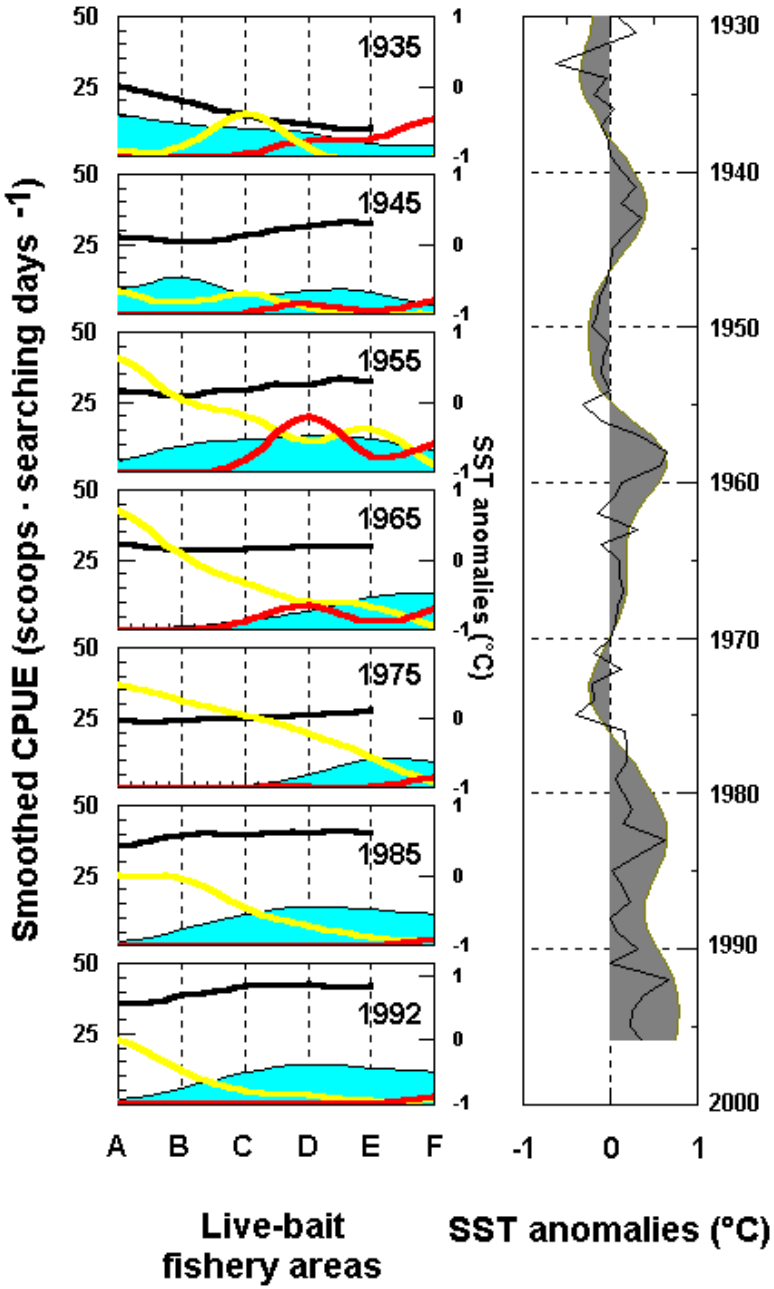
Rodríguez-Sánchez et al. (2002)

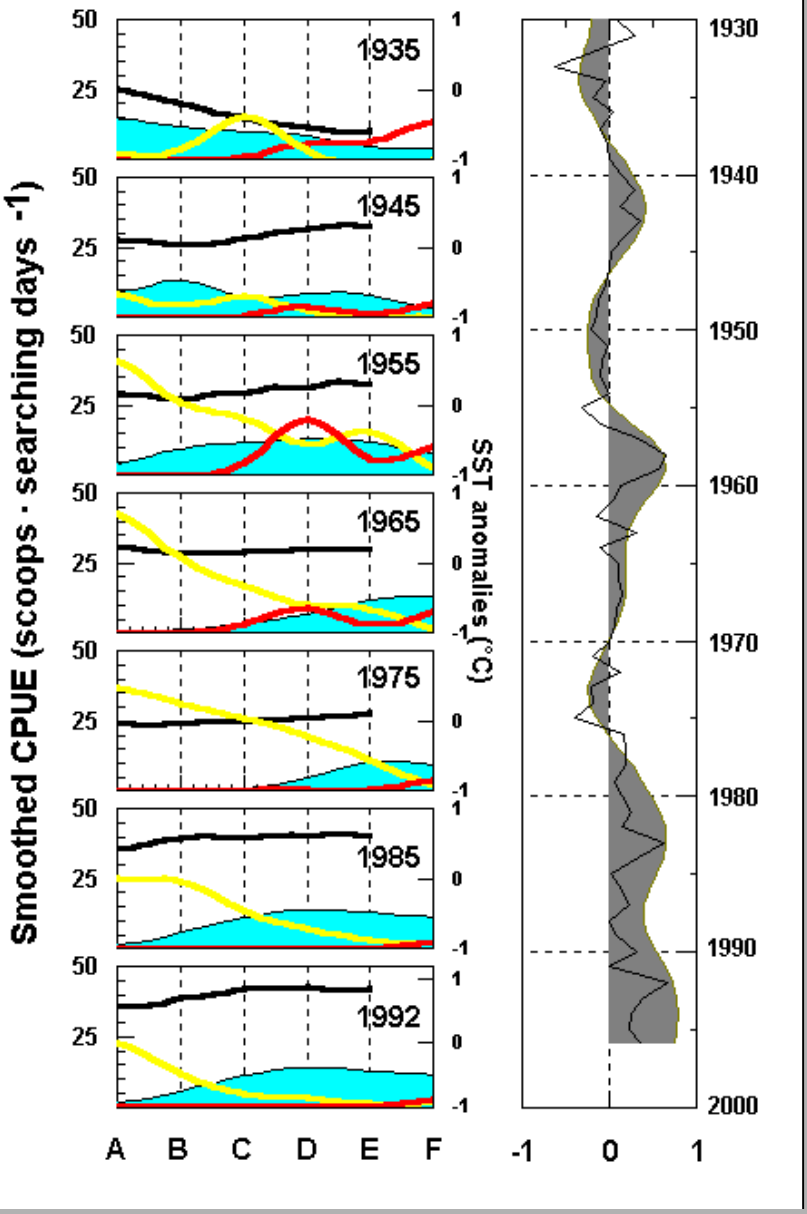

Selected years: 1935 1945 1955 1965 1975 1985 1992
Live-bait fishery areas
A
B
C
D
E
-0.2
0.2
-0.2
0.2
-0.2
0.4
0.2
0.2
0.4
0.2
0.4
0.7
SST anomalies (°C)
1
0
-1
1930
1940
1950
1960
1970
1980
1990
2000
Year


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

LARGE-SACALE LOW-FREQUENCY VARIABILITY OF SST ANOMALIES AND SMALL PELAGIC FISH ABUNDANCE







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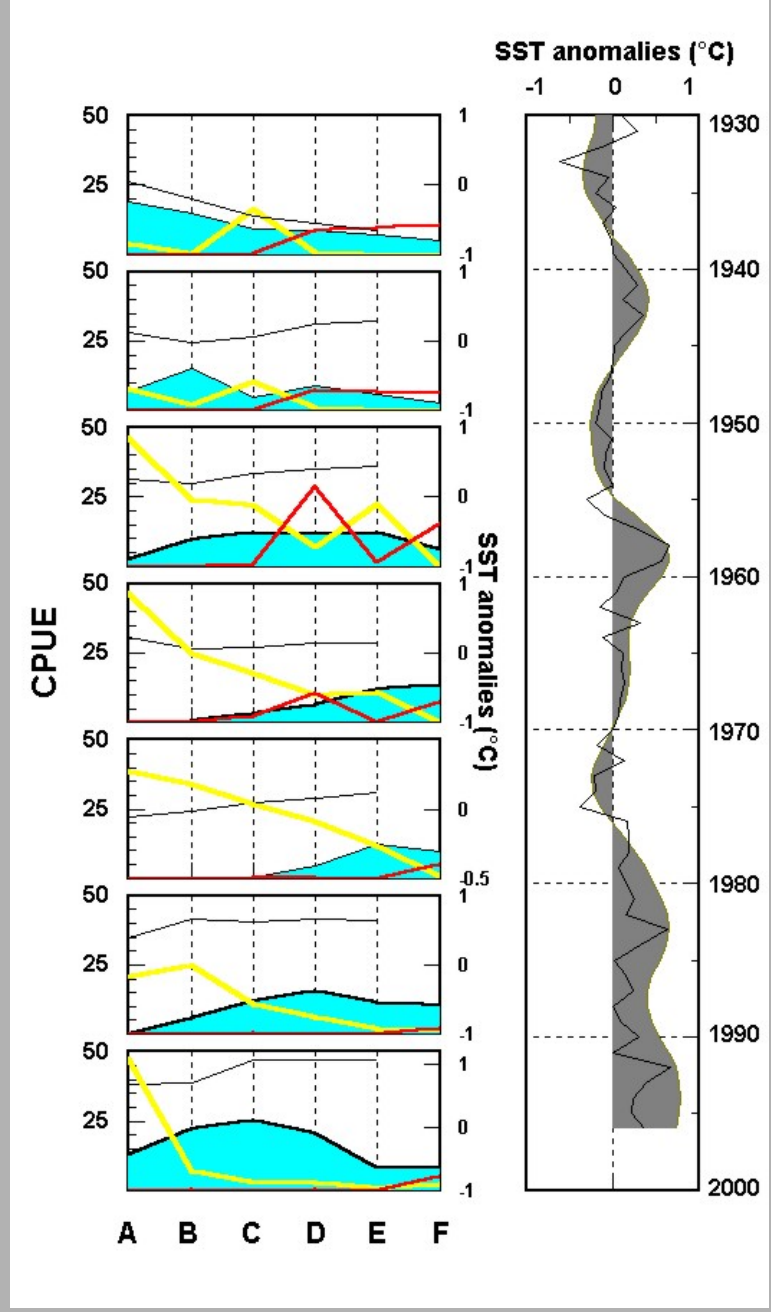
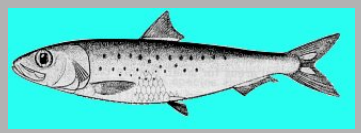
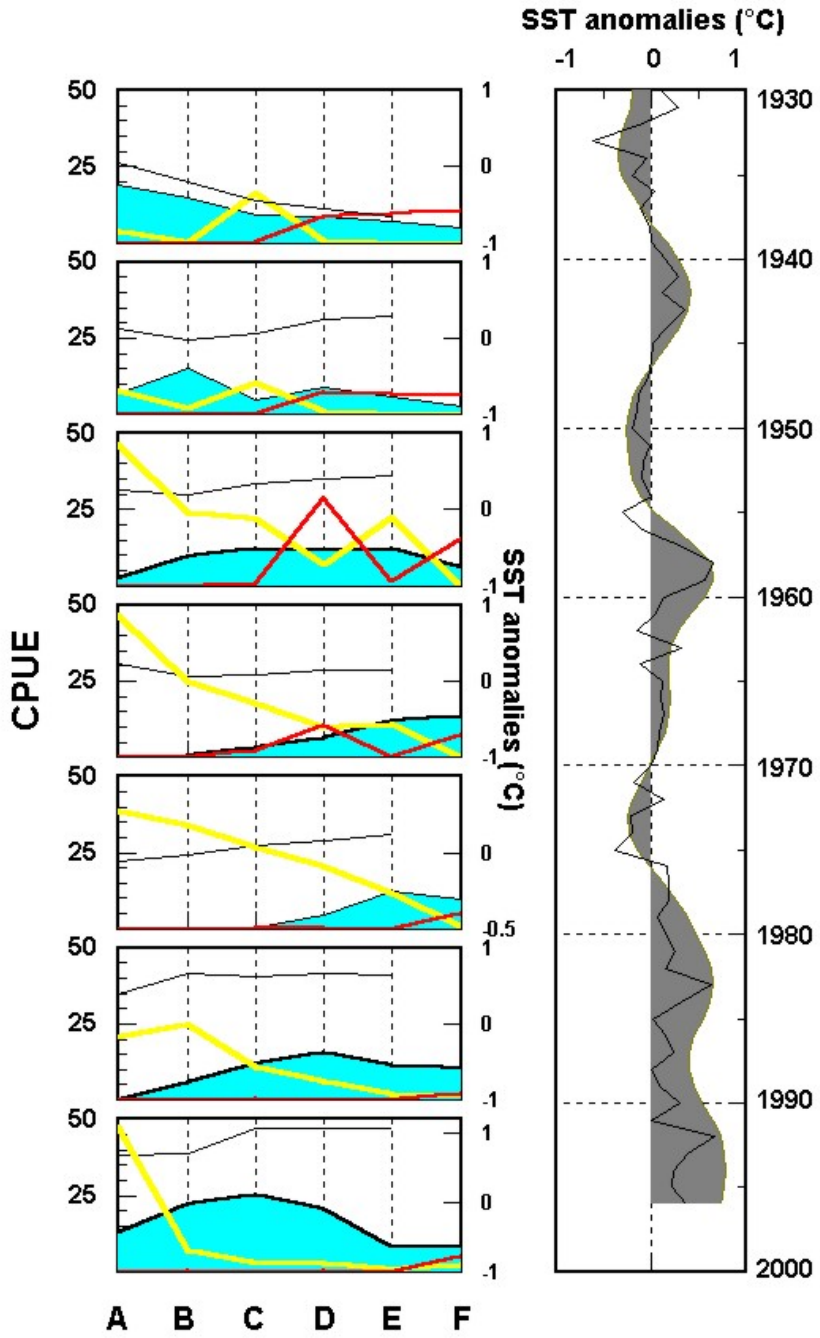


"Annual slides from the cakes" = 10-year average

LARGE-SACALE LOW-FREQUENCY VARIABILITY OF SST ANOMALIES AND SMALL PELAGIC FISH ABUNDANCE



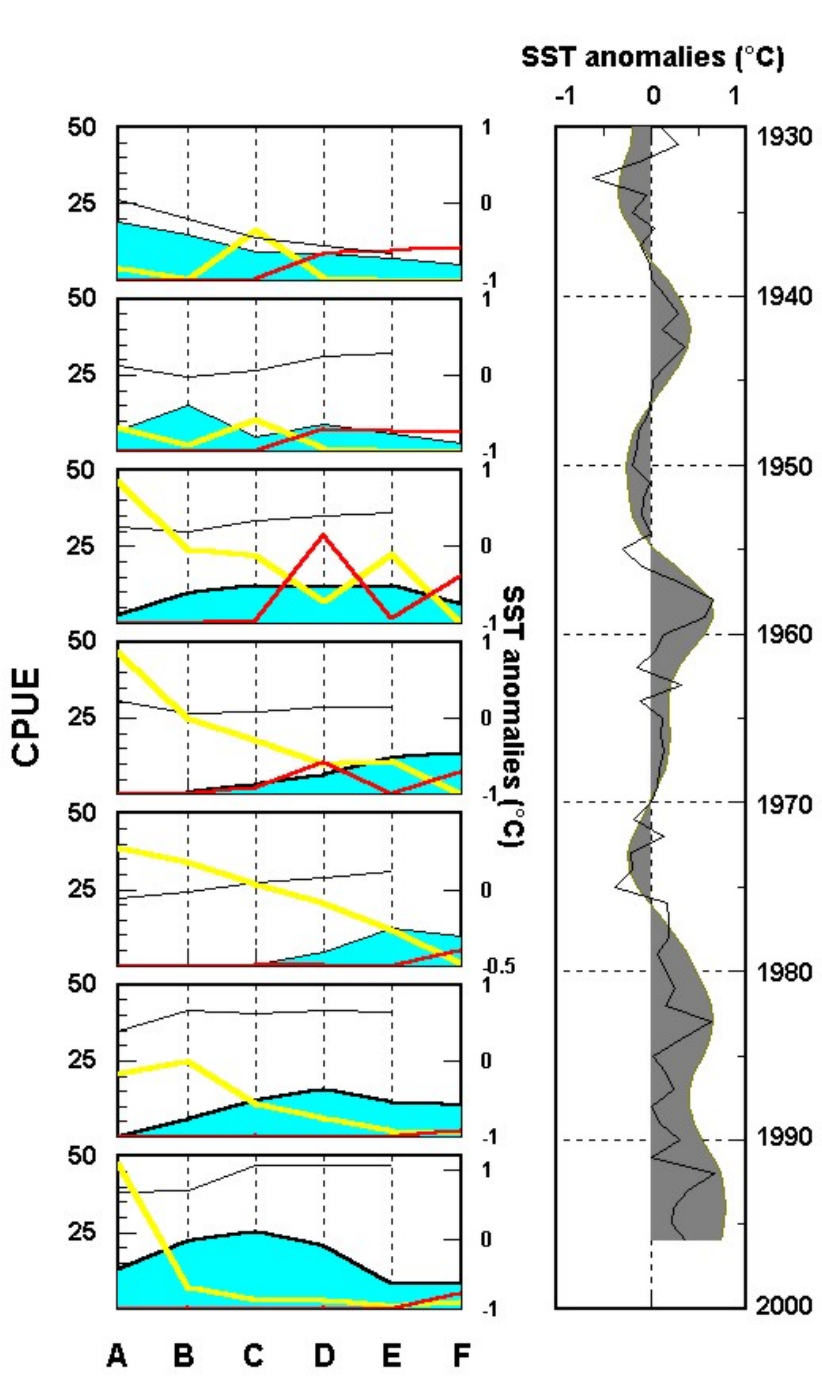
- **During the 1940´s regime shift sardine abundance declined in the northern areas as the first sign of ocean-climate and population interaction, with less apparent changes in the south.**
- **Changes in the southern areas were observed almost a decade later.**
- **After the 1970´s regime shift sardine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



LARGE-SACALE LOW-FREQUENCY VARIABILITY OF SST ANOMALIES AND SMALL PELAGIC FISH ABUNDANCE

- **The spatial pattern of abundance for the northern anchovy (*Engraulis mordax*) appears to be inversely related to sardine population abundance.**

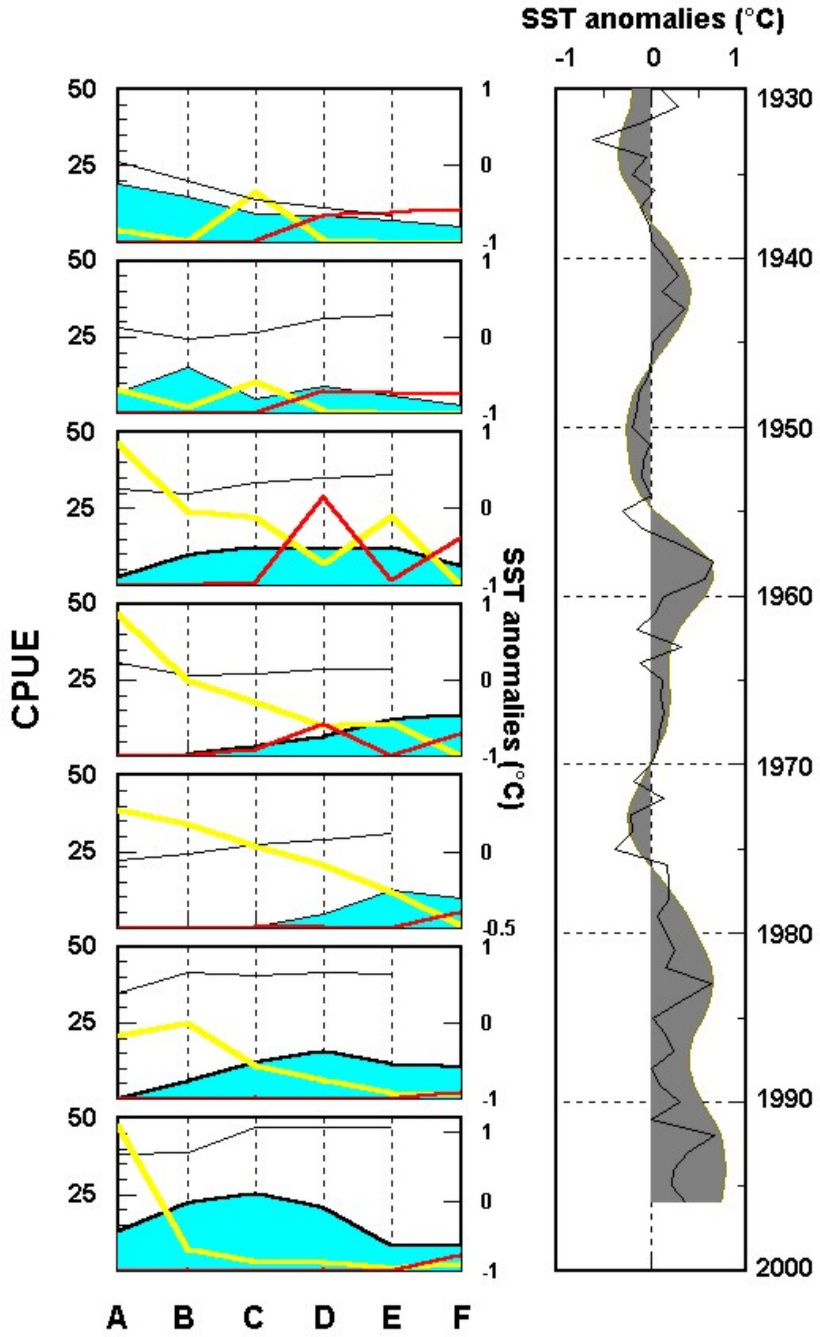
- **Anchovies increased where and when sardines were either absent or at a low population level**



LARGE-SACALE LOW-FREQUENCY VARIABILITY OF SST ANOMALIES AND SMALL PELAGIC FISH ABUNDANCE

- **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**

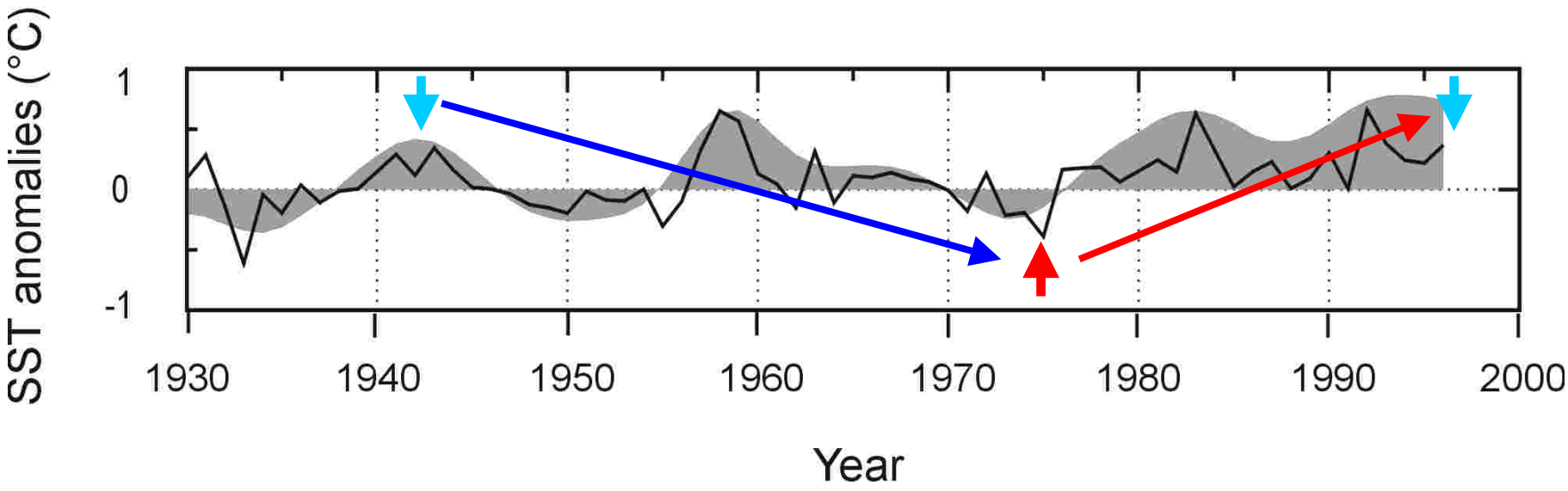


For other species-ecosystems:

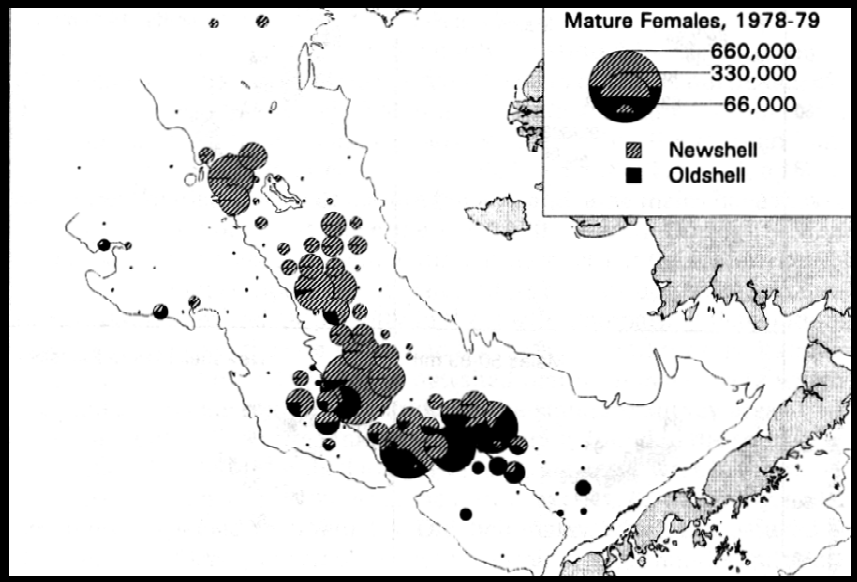
- The authors of the reports are explicit in suggest or conclude:

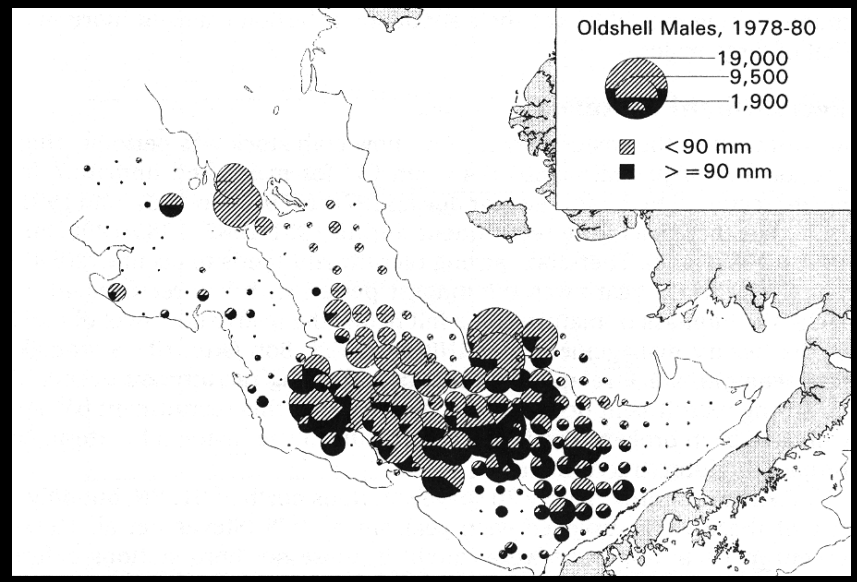
  "… climatic regime shifts appear to have forced a changing population size associated with major geographical variations in the position of the center of distribution and bulk of the biomass …"

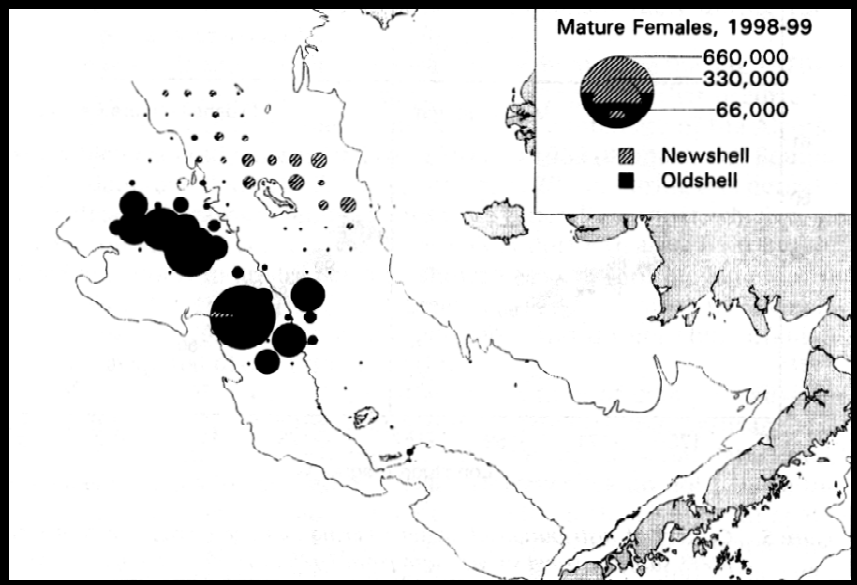
- No my interpretation of their results.

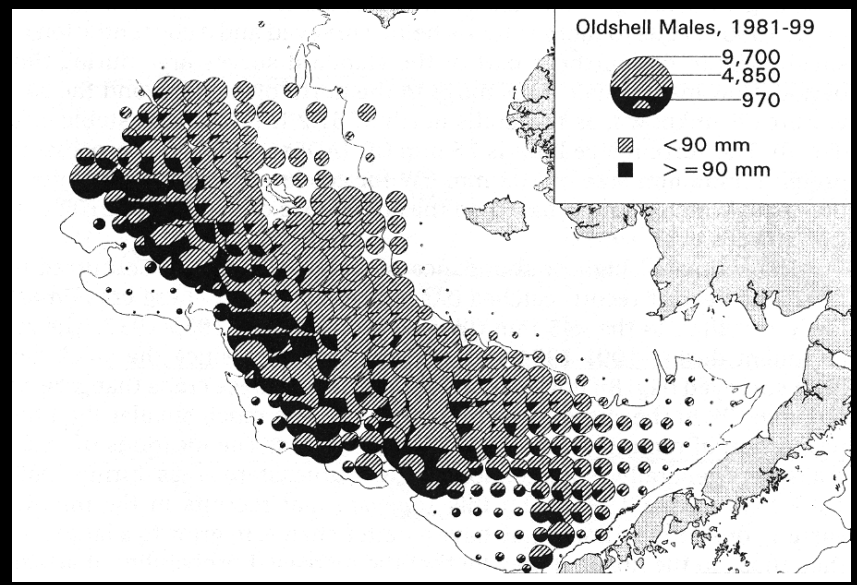

SST anomalies (°C)
1
0
-1
1930
1940
1950
1960
1970
1980
1990
2000
Year

EASTERN BERING SEA: Snow crabs (1/2)



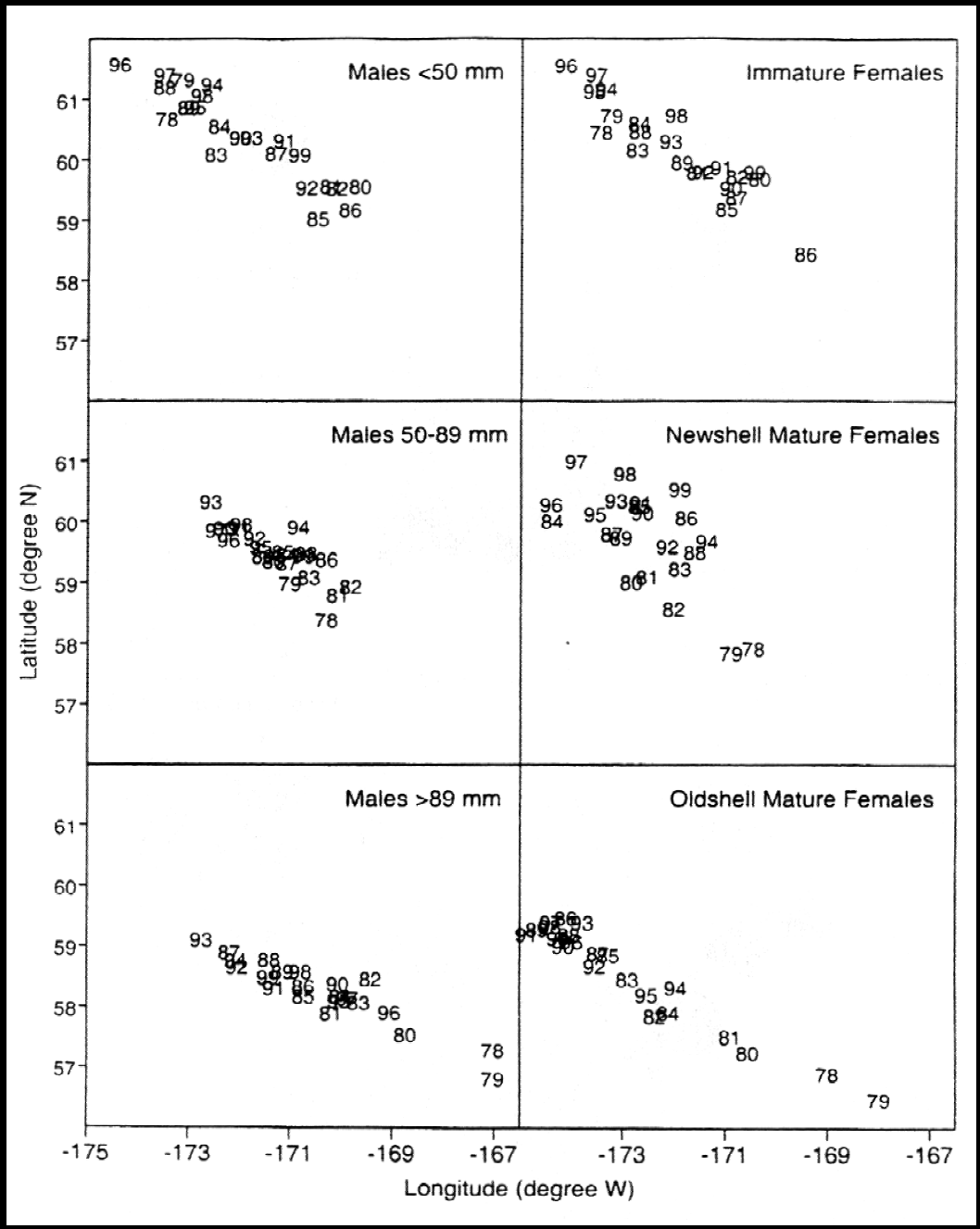






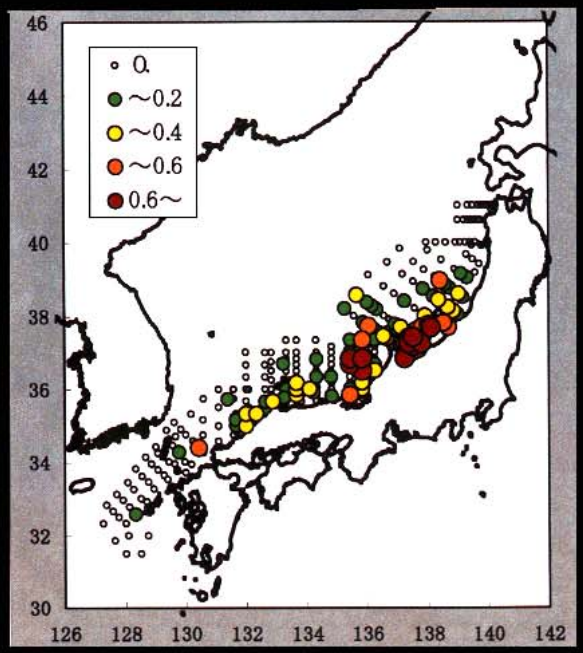
Distributions of snowcrabs in the eastern Bering Sea derived from NMFS summer trawl survey data. Density is expressed as the number of crabs per square nautical mille (from Zheng et al. 2001)

EASTERN BERING SEA: Snow crabs (2/2)

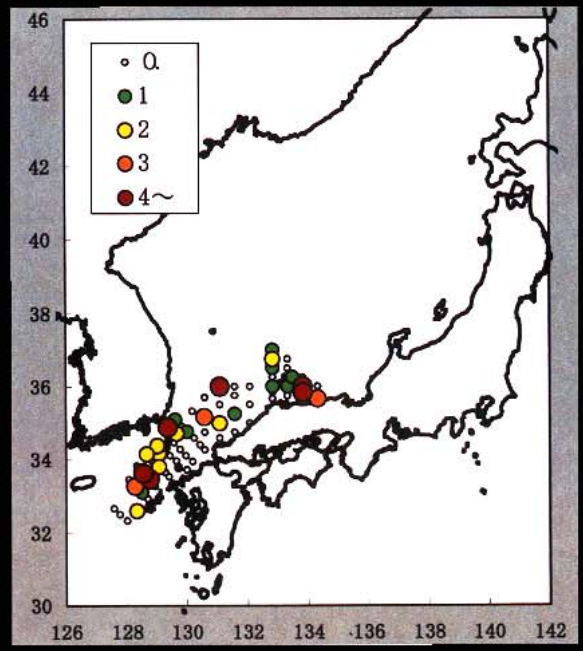


Centers of distribution of eastern Bering Sea snow crab derived from NMFS summer trawl survey data from 1978 to 1999. Years are plotted as data points (from Zheng et al. 2001)

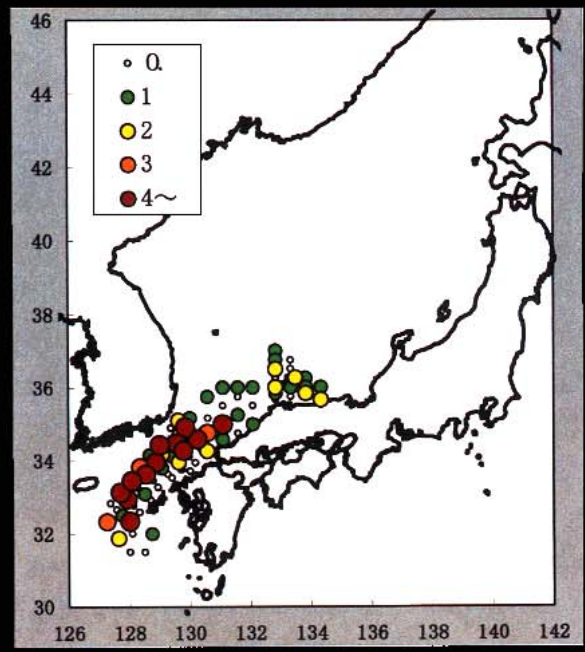
NORTHWESTERN PACIFIC: Japanese common squid



Low stock period
(average of 1981-1986)



High stock period (1995)

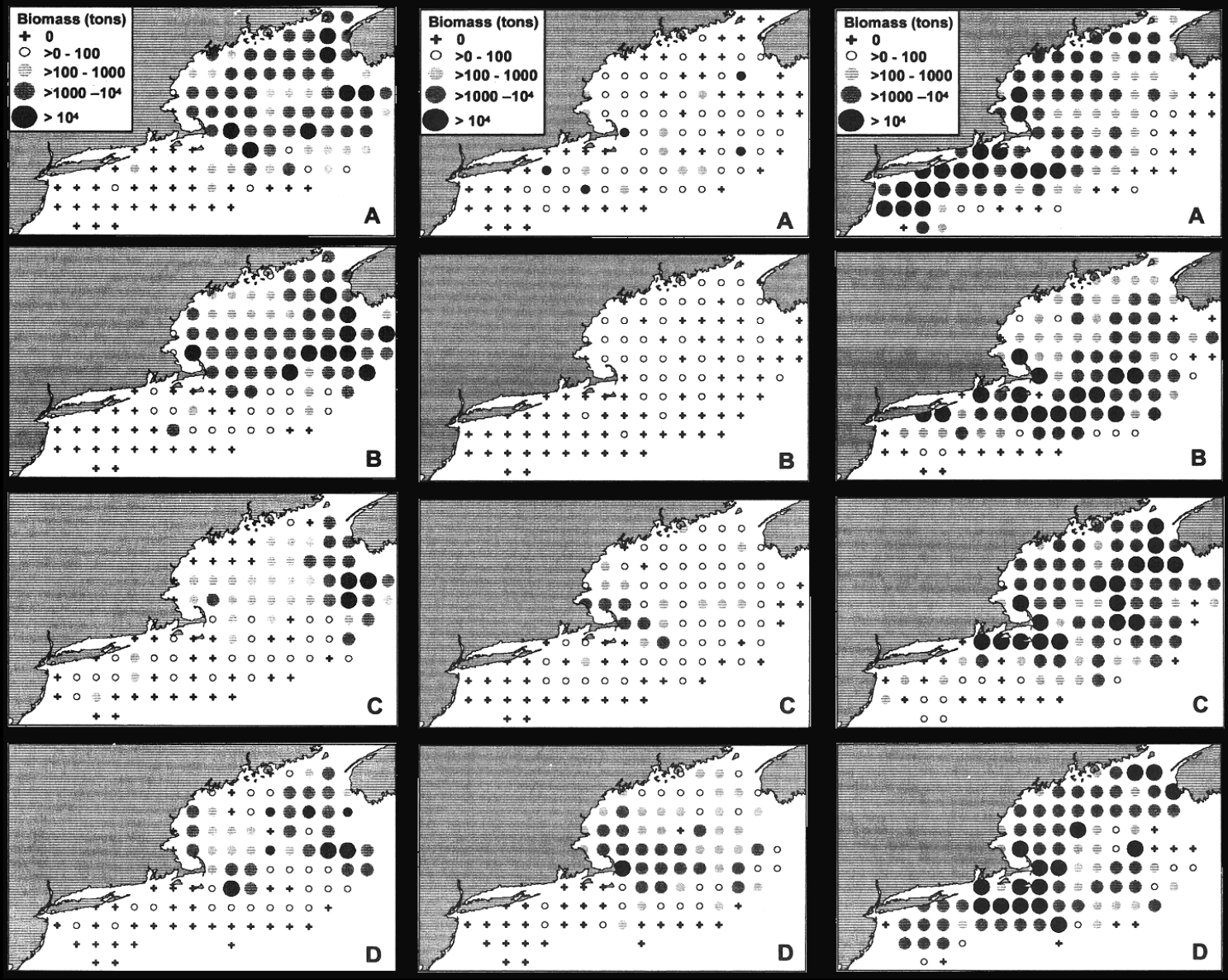


High stock period (1998)

No distribution changes were observed

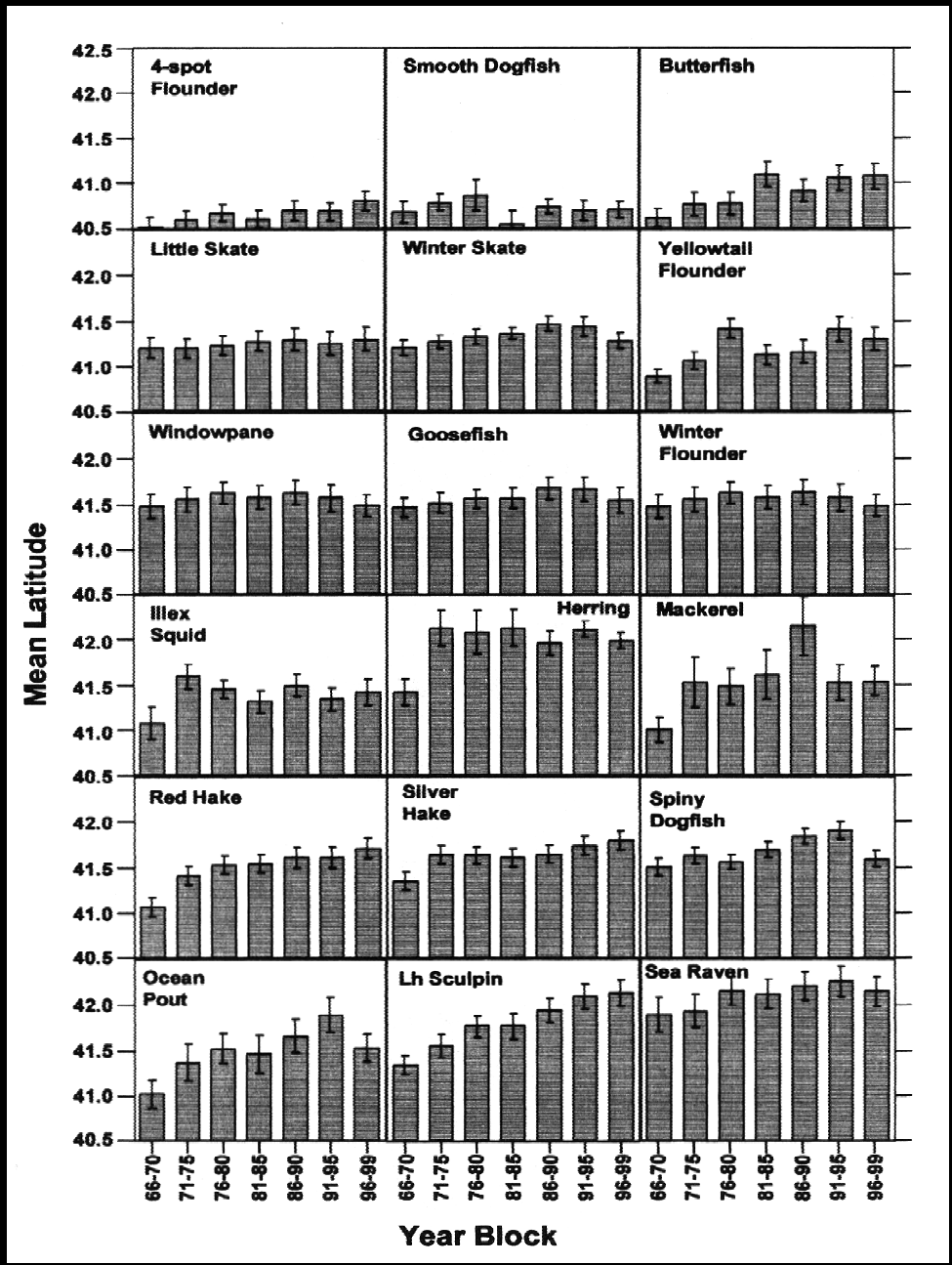
Shift of spawning ground of Japanese common squid based on the larval distribution pattern (October-November) (From Kidokoro et al.)

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



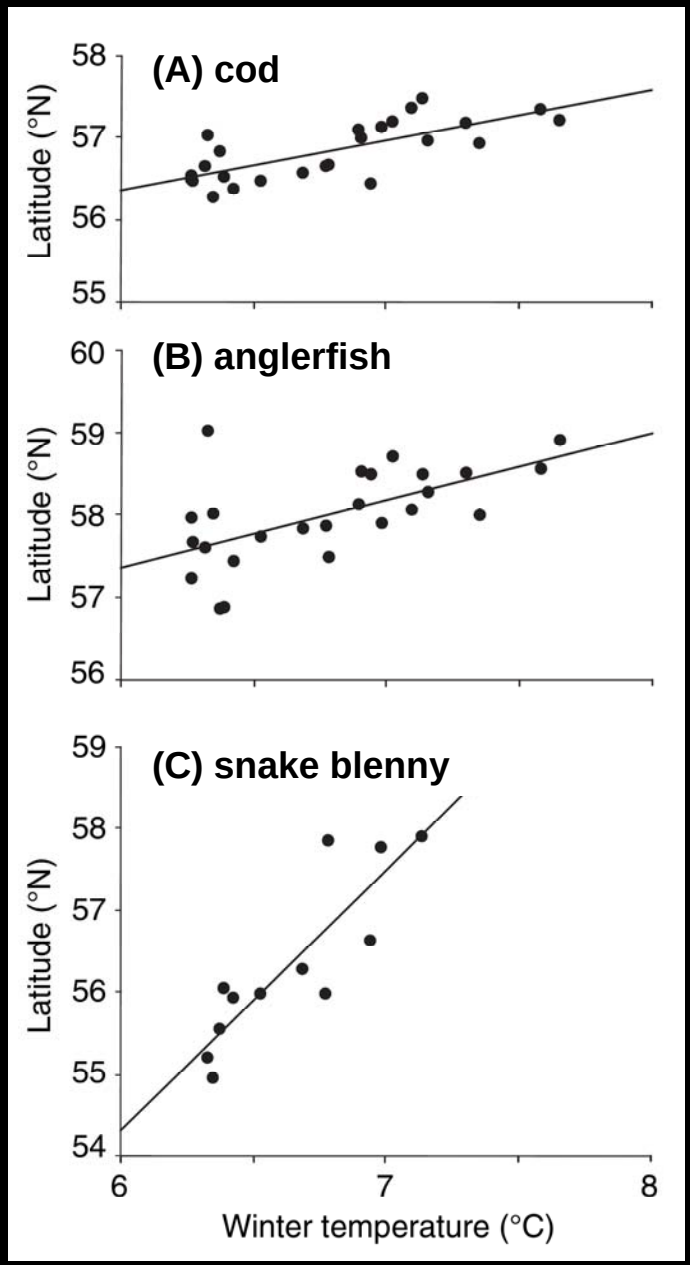
Estimated biomass in 0.5º cells in four time blocks (from Garrison 2001)

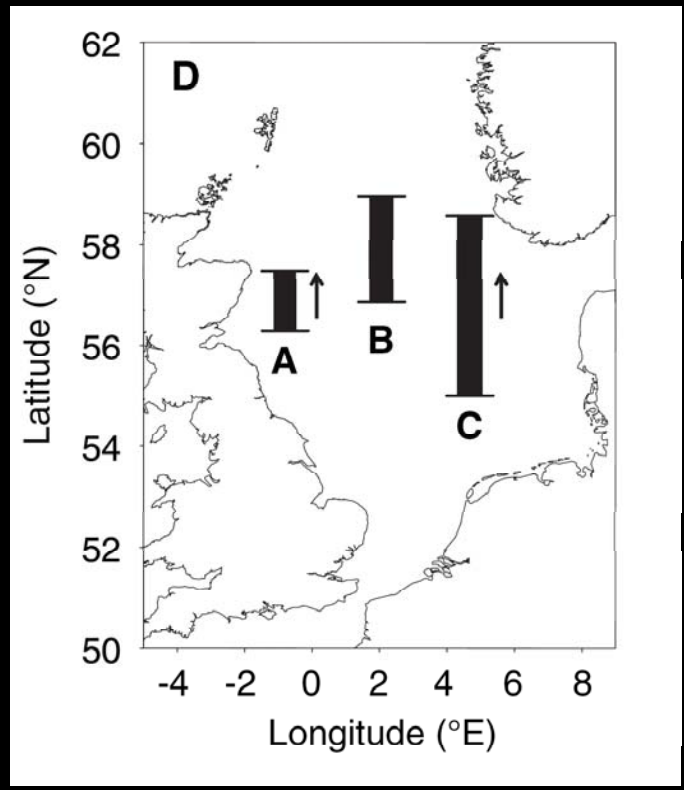
NORTHEASTERN ATLANTIC: continental shelf fish community (2/2)



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)





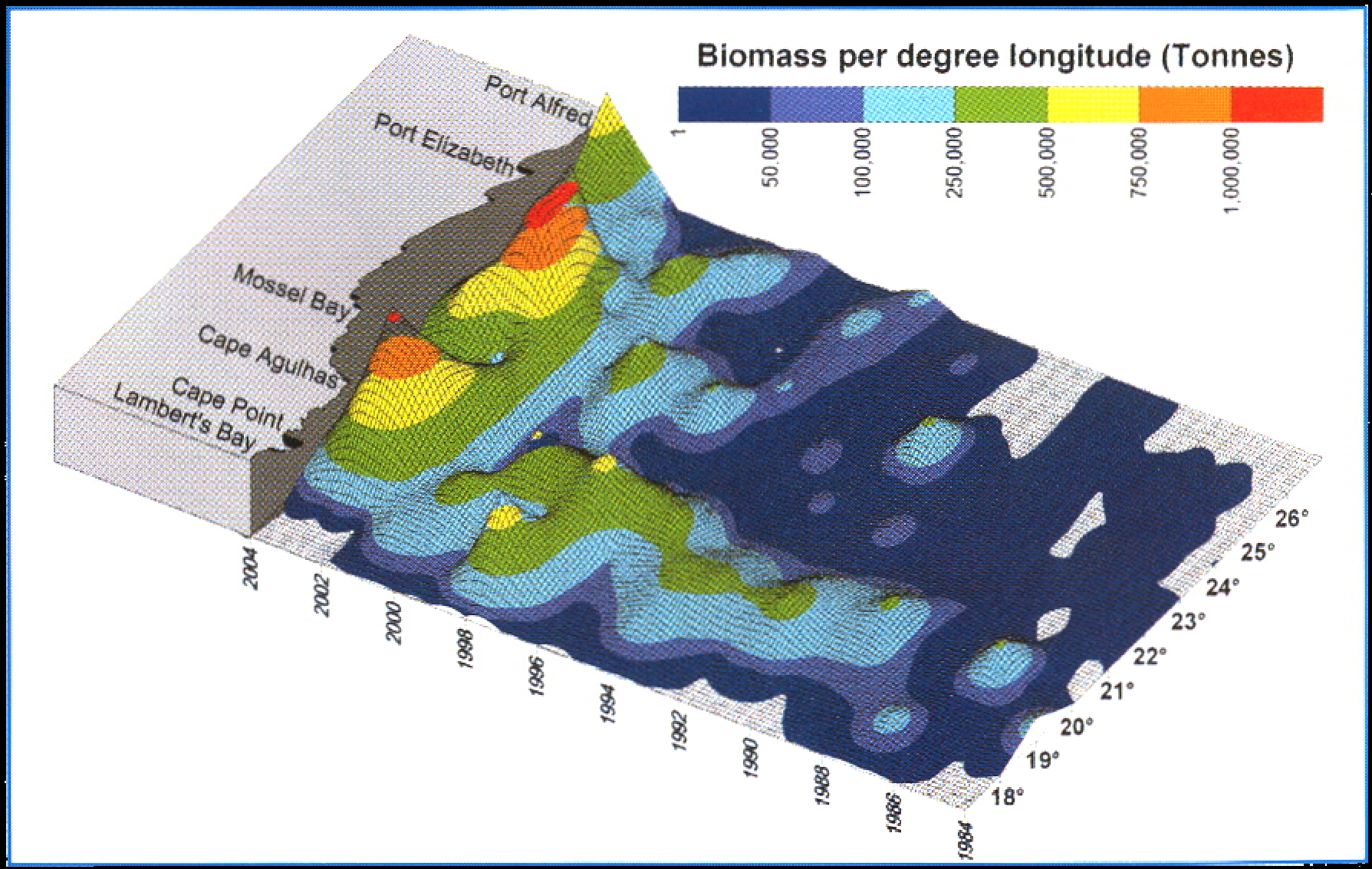
Ranges of shifts in mean latitude are shown for (A), (B), and (C) within the North Sea.

- 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)

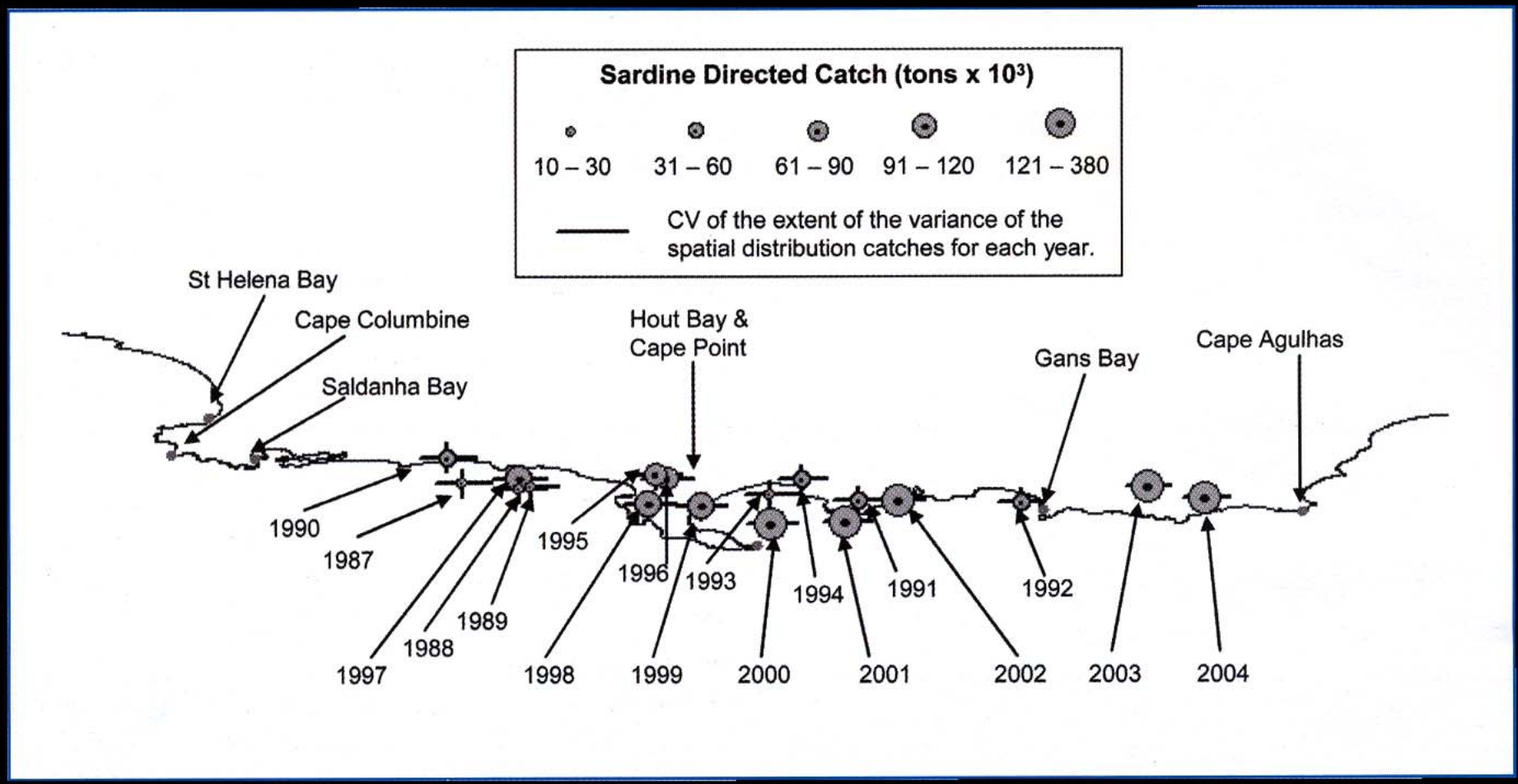
Southern Benguela: Benguela sardine (1/2)



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)

Possible causes of geographical shift:

- **Fishing pressure**

  e.g. Pacific sardine

  - The most valuable and accessible resources were depleted first (e.g. fishery off California)

  - Low harvest rate when the change of distribution occurred (e.g. southern distribution of sardine)

  e.g. Snow crab

  - Smaller size and incomplete spatial overlap of mature female with commercial-size males (their spatial distribution change more than that of large males)

- **Regimen shift in climate and physical oceanography**

  - seawater temperature changes was the common proxy

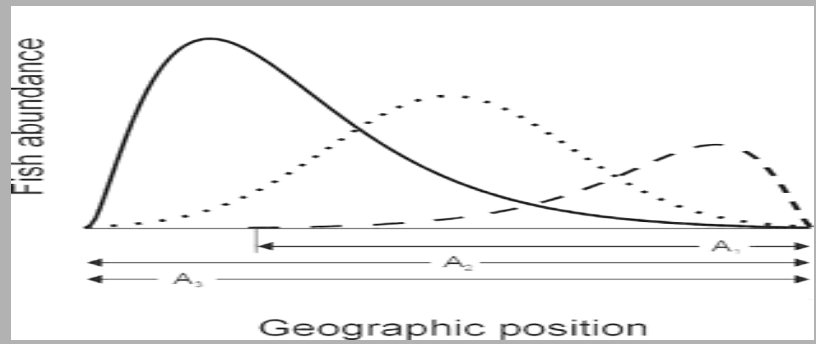
What is the importance and implications of this process ?

Ecosystem

- Biological indices (species highly sensitive to low-frequency climate events and can be regarded as integrator of environmental variables)
- Global synchrony
  - Formerly: Benguela sardine out of phase *vs* Jap.+ Cal.+ Peru sardine (Now simultaneous geo-shifts)
  - Now: out of phase Japanese sardine *vs* Californian sardine ?
- Ecological consequences: As prey species (e.g. small pelagic fish) of large predators

Fishery management

- Economic impact (e.g. increase distance, increase cost of fleet operation)
- Different interpretations about population dynamics (e.g. Pacific sardine) >>>>>>>>>>>>>>>>>>>>

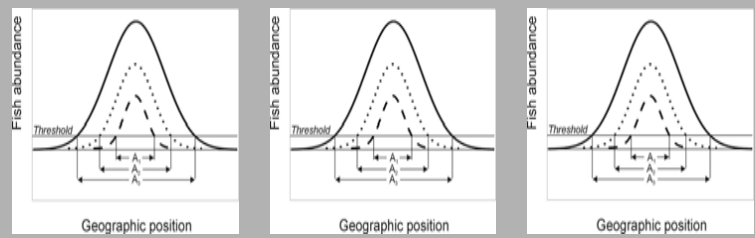


Sardine return to the north part of California Current ecosystem

versus

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

versus



Conclusion/ Recommendation

It is time for a reappraisal of the dynamics of fish populations on the regime time scale, **incorporating spatial processes** into fishery modelling to improve our understanding of the effects of low-frequency climate change on the distribution, abundance, and production of fish populations in the large ecosystems.

Thank you