An integration of the sardineanchovy regime variation at the North Pacific ocean

Daniel Lluch-Belda, Alec D. MacCall, and Paul E. Smith An integration of the sardineanchovy regime variation at the North Pacific ocean

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•sardine and anchovy population changes have occurred at approximately the same time in widely separated areas of the world oceans, which implies the existence of a global forcing cause.









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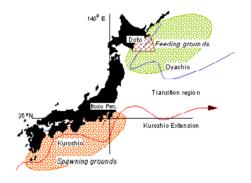
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- Sardine population growth begins while areas are still cool and their decline starts when the area is warm. Growth periods during the early part of the Century (1910-1940) occurred at much lower temperatures than during the last regime shift (1976-1990s)

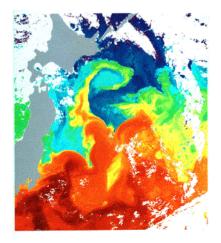


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- Synchrony was lost during the last regime: Japanese and Humboldt sardines started declining during the mid 1980s; no clear sign of decline has yet been seen in California sardines.

catch data, mechanism (temperature), symmetry in mechanisms, synchrony

- The growth of the Japanese sardine population expands toward offshore northeastward (Nakai,1962; Kawasaki,1983; Watanabe,1996; etc.)
- It has been well known that large population is associated to offshore expansion

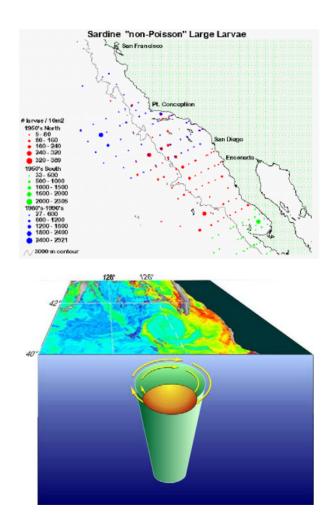


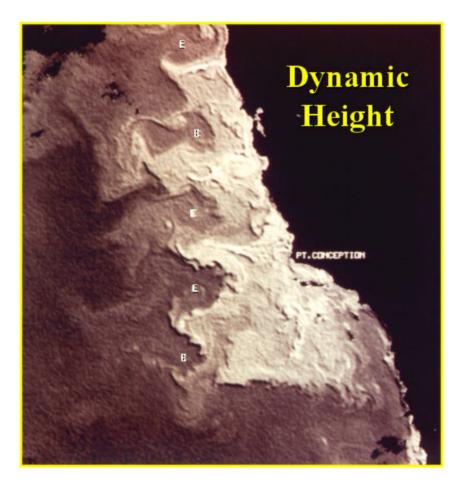


- At the eastern boundary regions sardine population growth was related to poleward expansion
- Decline was related to contraction to most equatorward areas



 It has now been postulated that there are two principal spawning habitats at the California Current: inshore and offshore (Logerwell and Smith, 2001)



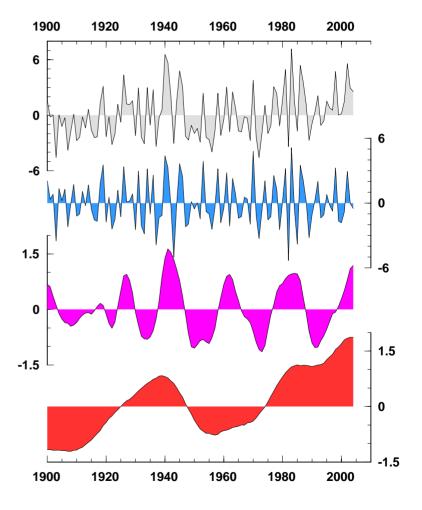


- Offshore spawning is associated to eddies and fronts and permits sporadic occurrence of large size cohorts
- Inshore spawning results in continuing moderate size cohorts

 MacCall (2001) developed an integrative hypothesis based on interdecadal alternating strong and weak modes of boundary current flow and related reproduction.

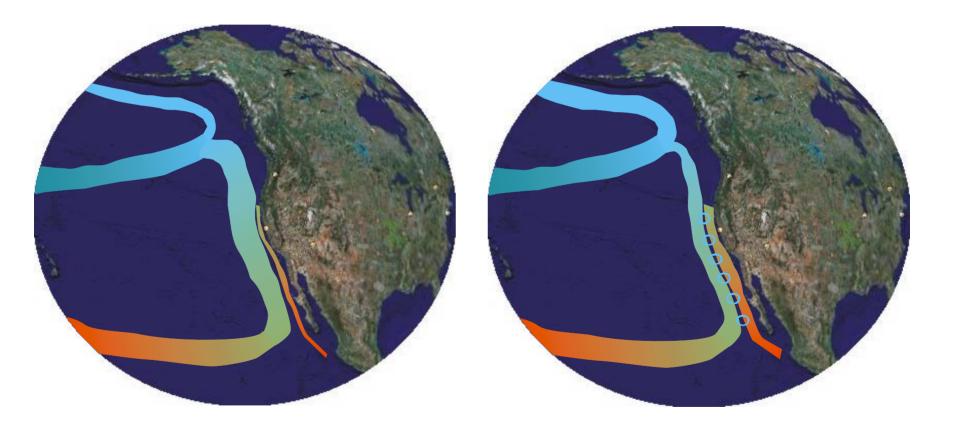
Mode of current flow	Weak, slow flow	Strong, fast flow
Coastal sea level	Higher	Lower
Water motion	Enhanced meandering	Reduced meandering
Frontal area	Increased	Decreased
Offshore larval retention	Favourable	Unfavourable
Temperature anomaly		
Eastern Pacific	Warm	Cool
Japan	Cool	Warm
Nutrient supply		
Eastern Pacific	Reduced (lower lat. source)	Enhanced (higher lat. source)
Japan	Enhanced (Oyashio intrusion)	Reduced
Sardine abundance	Increased	Decreased
Anchovy abundance		
California	Slight decrease	Slight increase
Perú/Chile	Strong decrease	Strong increase
Japan	Slight decrease	Slight increase

Analysis of longer than one year changes in the California Current System (several variables). Main scales of change are the high frequency (<10 years), the decadalinterdecadal (10-20 years) and the low frequency (>50 years).

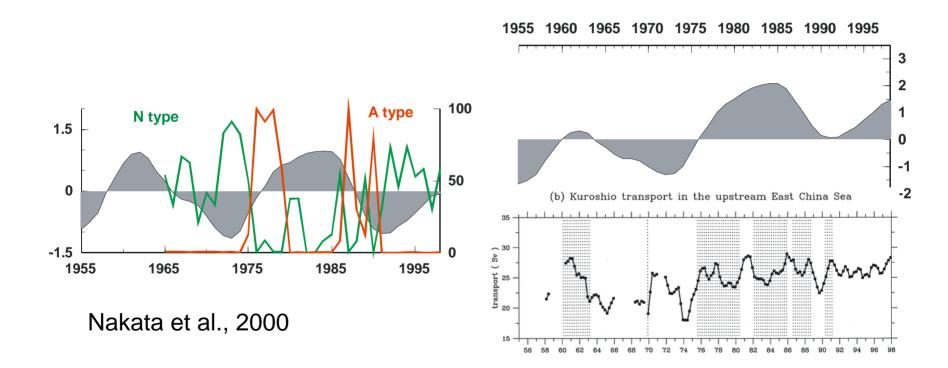


Filtered ALPI showing these scales.

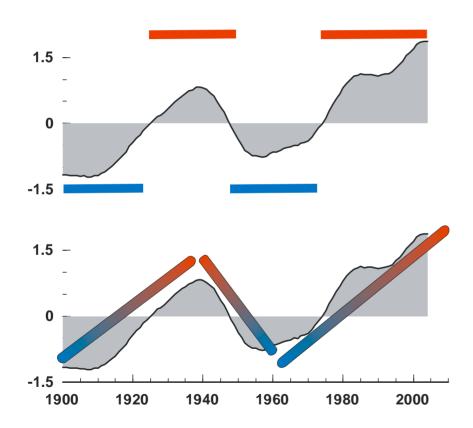
All the main scales of change result in similar physical processes, all of them related to intensification/ relaxation of the California Current



Japan system and ALPI



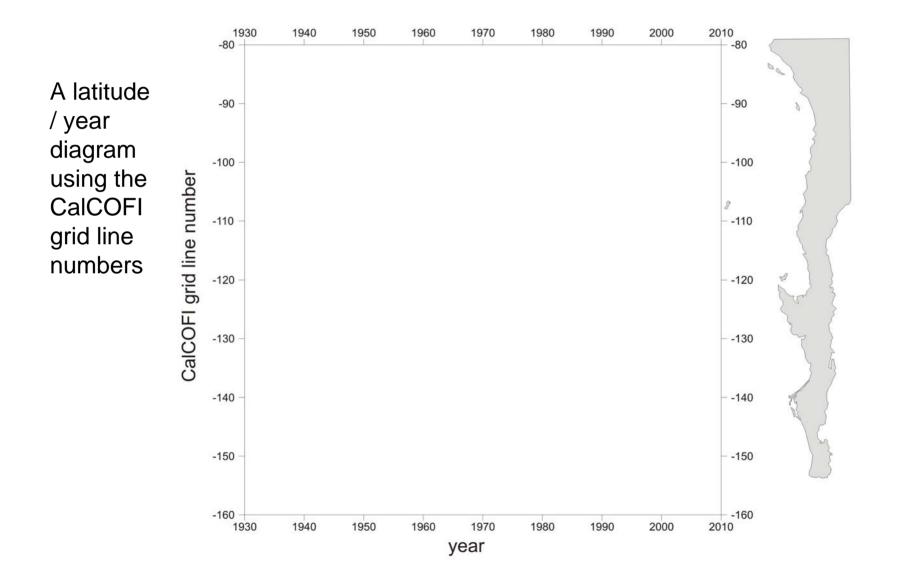
Qiu and Miao, 2000

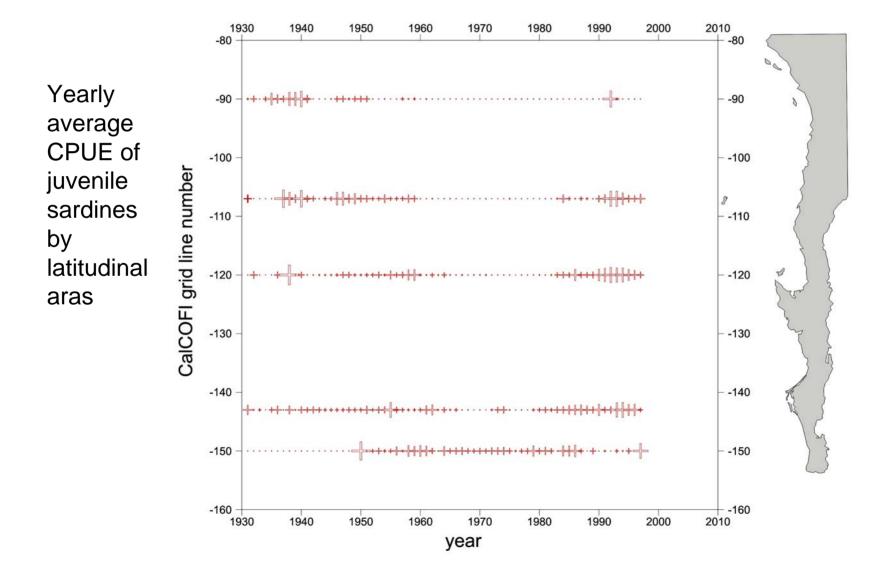


 variation is related to sustained periods of change separated by abrupt trend reversals, rather than to warm or cool intervals

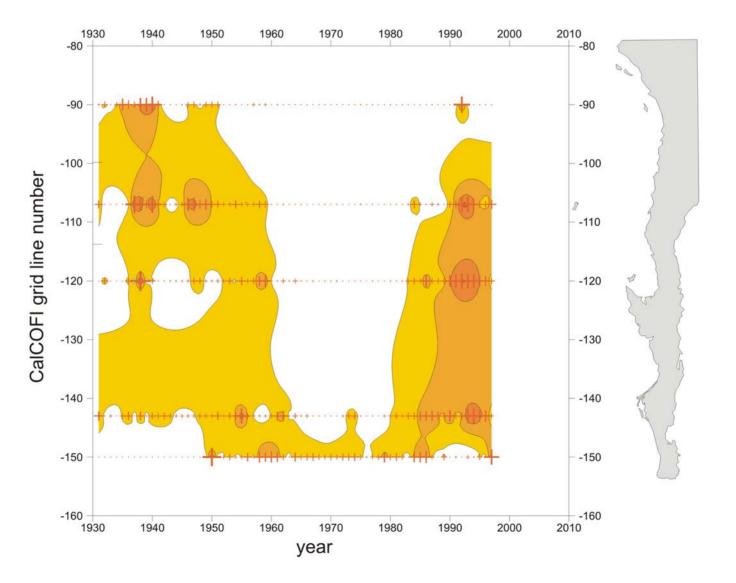
Other observations

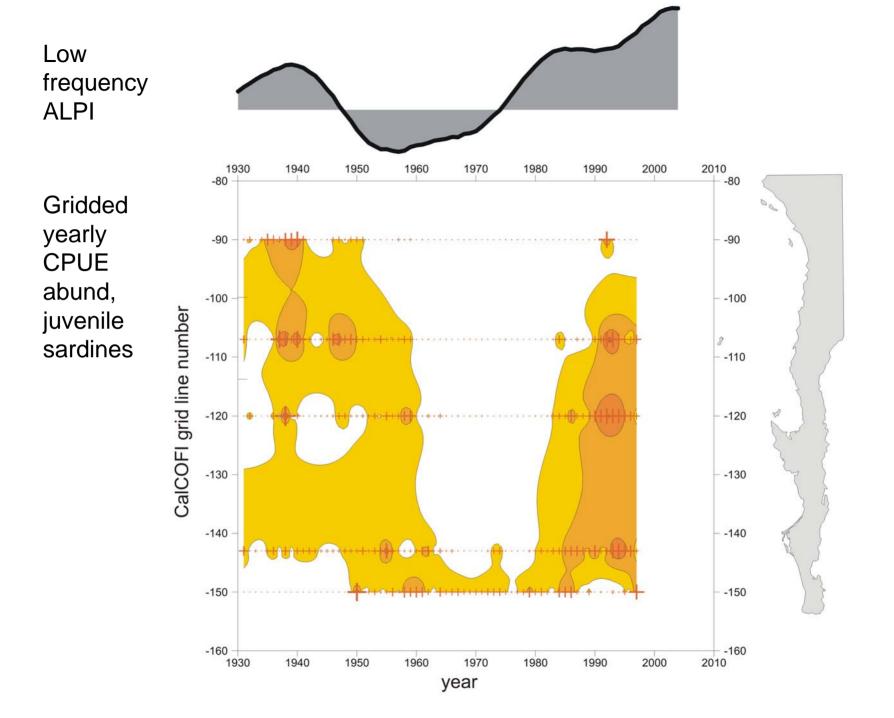
Data independent from the sardine fishery shows that at the California Current sardine populations expand (polewards) during warming/relaxed regimes and contract (equatorwards) during cooling/intensified current.



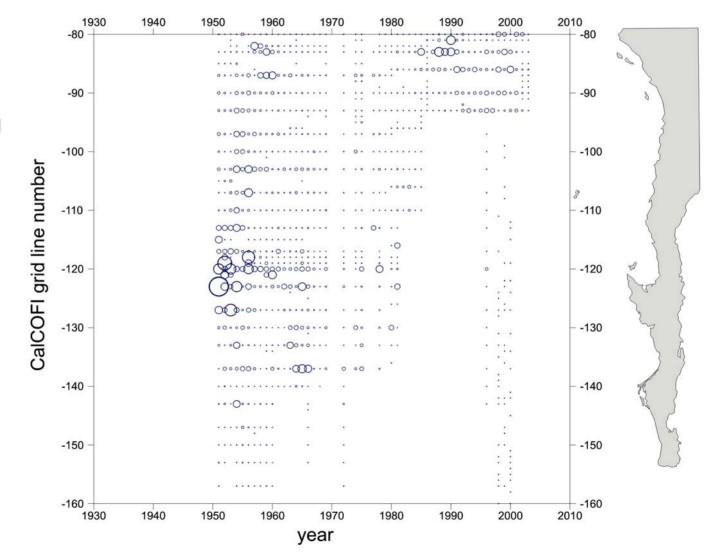


Gridded yearly CPUE abund, juvenile sardines



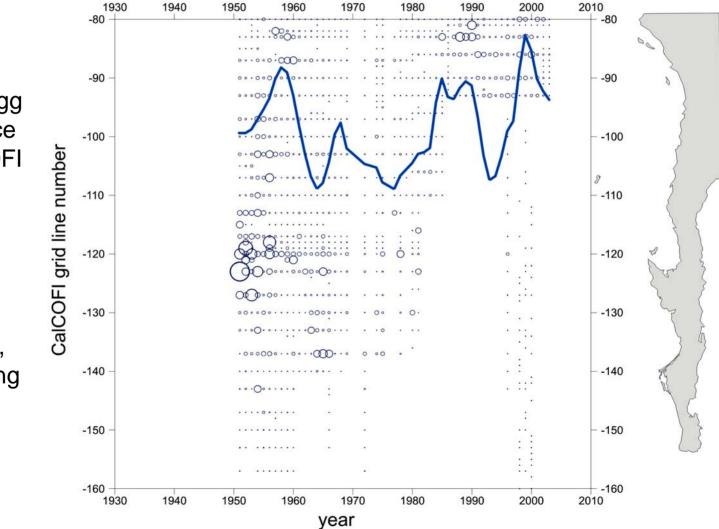


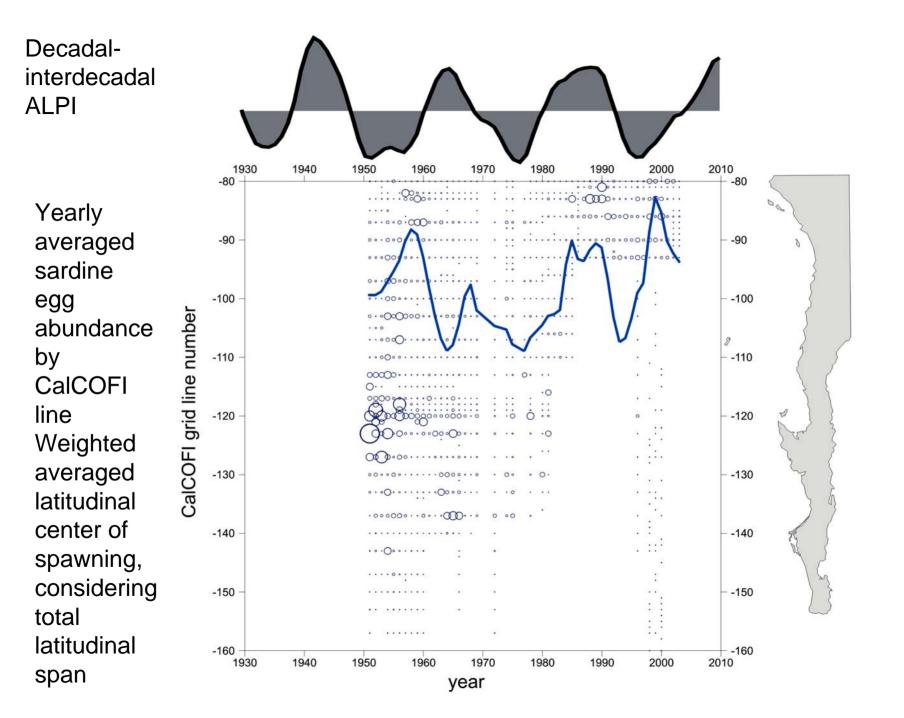
Yearly averaged sardine egg abundance by CalCOFI line



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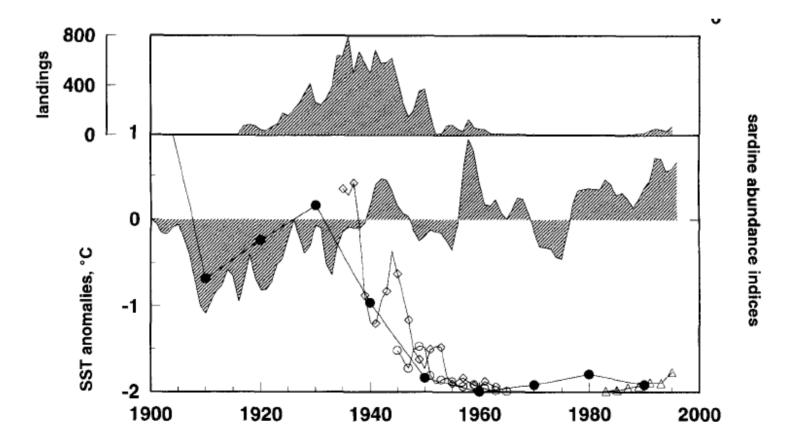
Weighted averaged latitudinal center of spawning, considering total latitudinal span





Synchrony

- During the late 1940s, the sardine population began declining during the 1930s. There is the possibility that it was accelerated by heavy explotation
- The present sardine population increase has very much controlled harvesting, thus the population has not yet collapsed



Conclusions

- New ideas permit integrating a renewed version of the regime's hypothesis, keeping the core of the former
- Crucial piece is the finding that there are two spawning habitats for sardines, one giving rise to abundant cohorts sporadically
- New framework for hypothesis is the integrative proposal based on intensification/relaxation of gyres
- The way processes occur along time is redefined as continuously changing periods separated by abrupt trend reversals
- Clearly research is still needed to propose and test hypotheses on mechanisms underlying these variations and potential implementation of forecast and incorporation to management