Mechanisms of Fish Population Dynamics to Climatic Forcing: Comparative Study on Selected Stocks Representing Five Life-history Strategies in the North Pacific

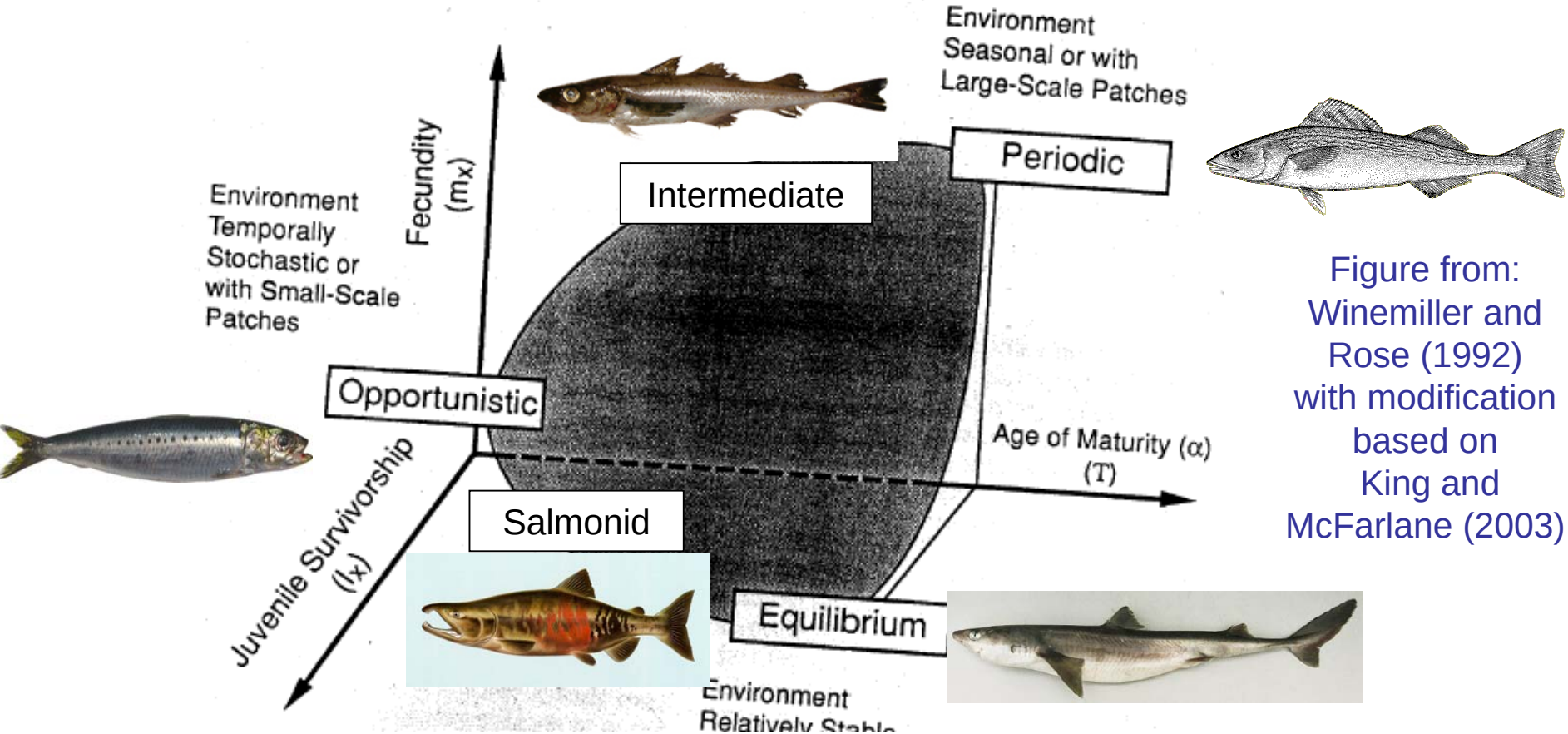


Figure from: Winemiller and Rose (1992) with modification based on King and McFarlane (2003)

Akihiko Yatsu and CFAME* Task Team

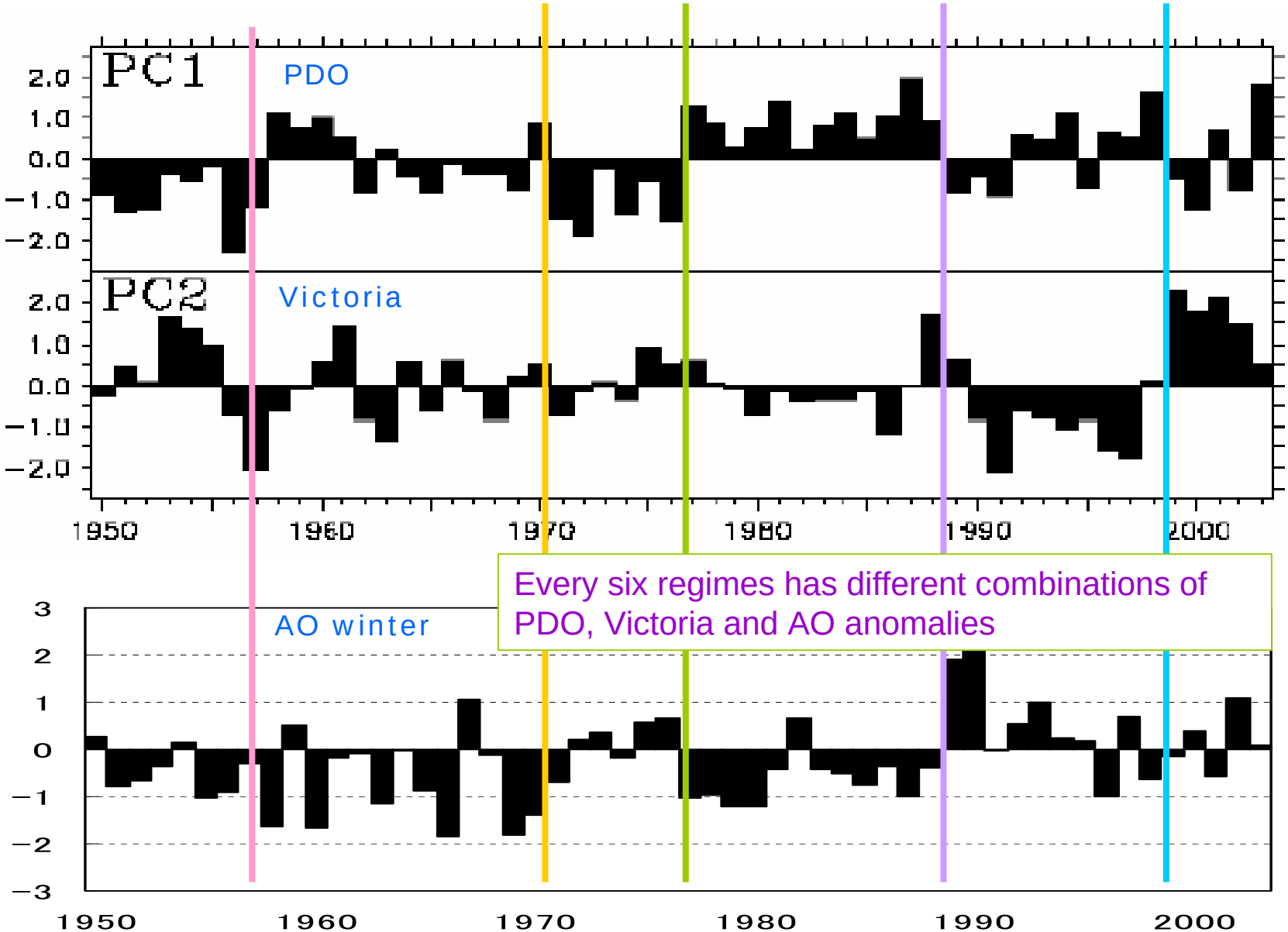
* Climate Forcing And Marine Ecosystems

Five life-history strategists and regime shifts (RS)

Strategist	Species examined	Expected responses to RS	Reasons	Remarks
Opportunistic	Sardine	Immediate and drastic	Short lifespan and high reproductive rate	
Intermediate	Walleye pollock	Oscillatory	Juveniles are opportunistic but good year-classes followed by strong density-dependence	Cannibalism (esp. Eastern Bering Sea)
Salmonid	Pink salmon	Immediate and drastic but twice, *K* respond quickly	Fresh water and marine habitats Empirical evidences	Artificial propagation
Periodic	Sablefish, Halibut	Immediate but gradual	Low frequency variation in spawner biomass	Older ages of recruitment
Equilibrium	Dogfish	Slight	Low fecundity and stable early survival rate	Most susceptible to fishing or deteriorations of environments

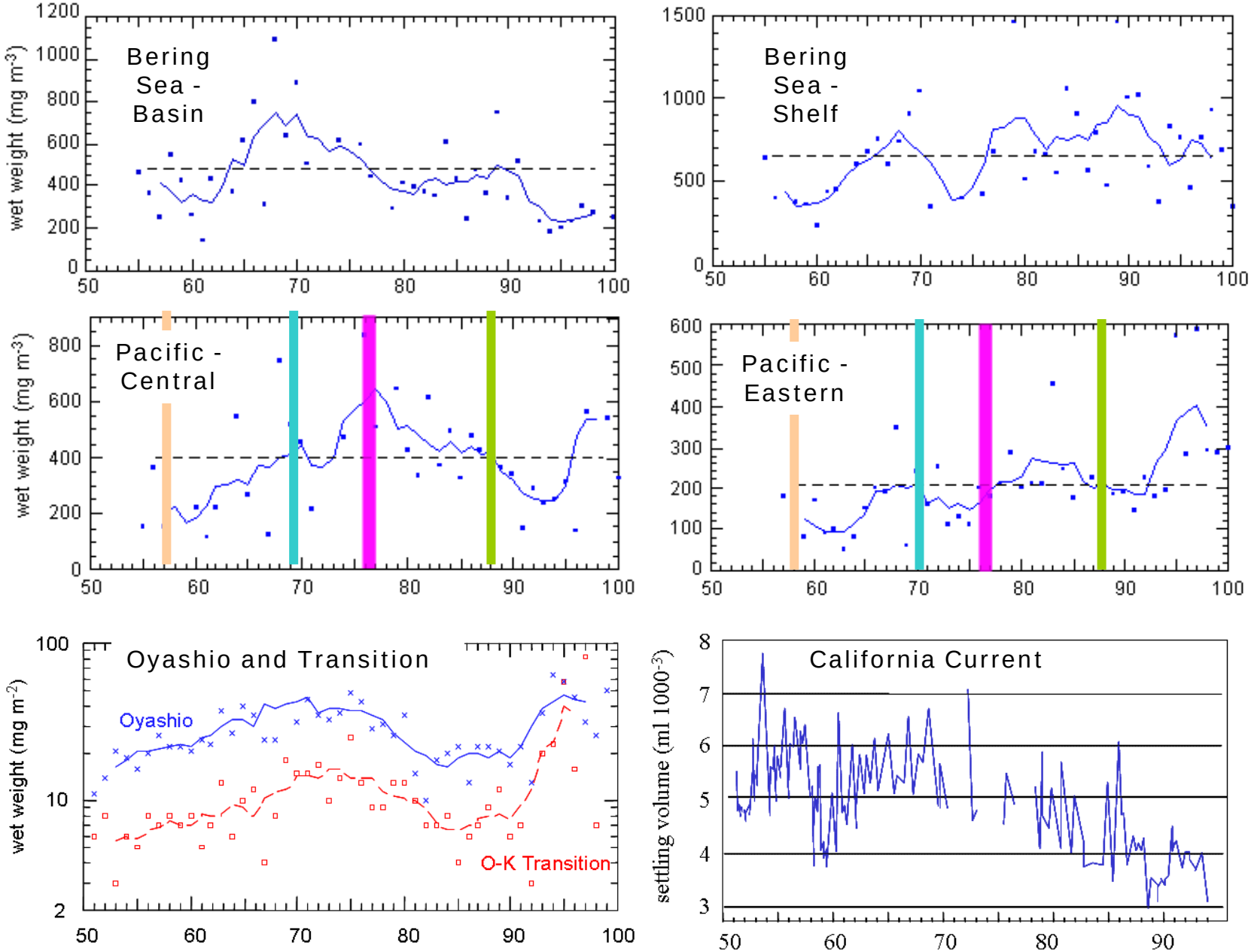
PDO, Victoria, AO and SST regime shifts

(regime shift years: after Yasunaka and Hanawa, 2002)



Every six regimes has different combinations of PDO, Victoria and AO anomalies

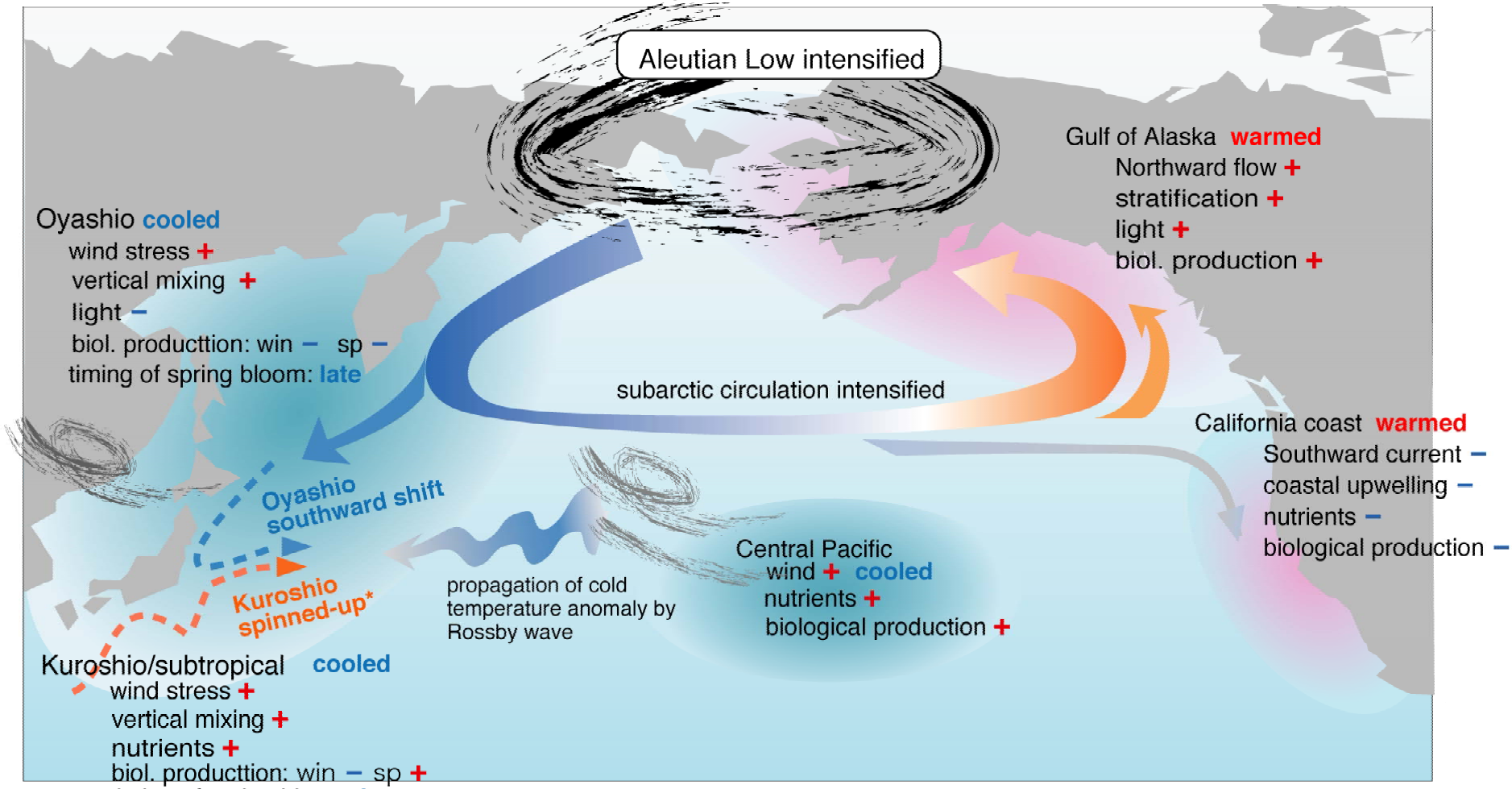
Summer mesozooplankton (Tadokoro 2005 unpublished)



Wintertime climate and winter-spring production: 1976/77RS

After 1976/77 Regime shift

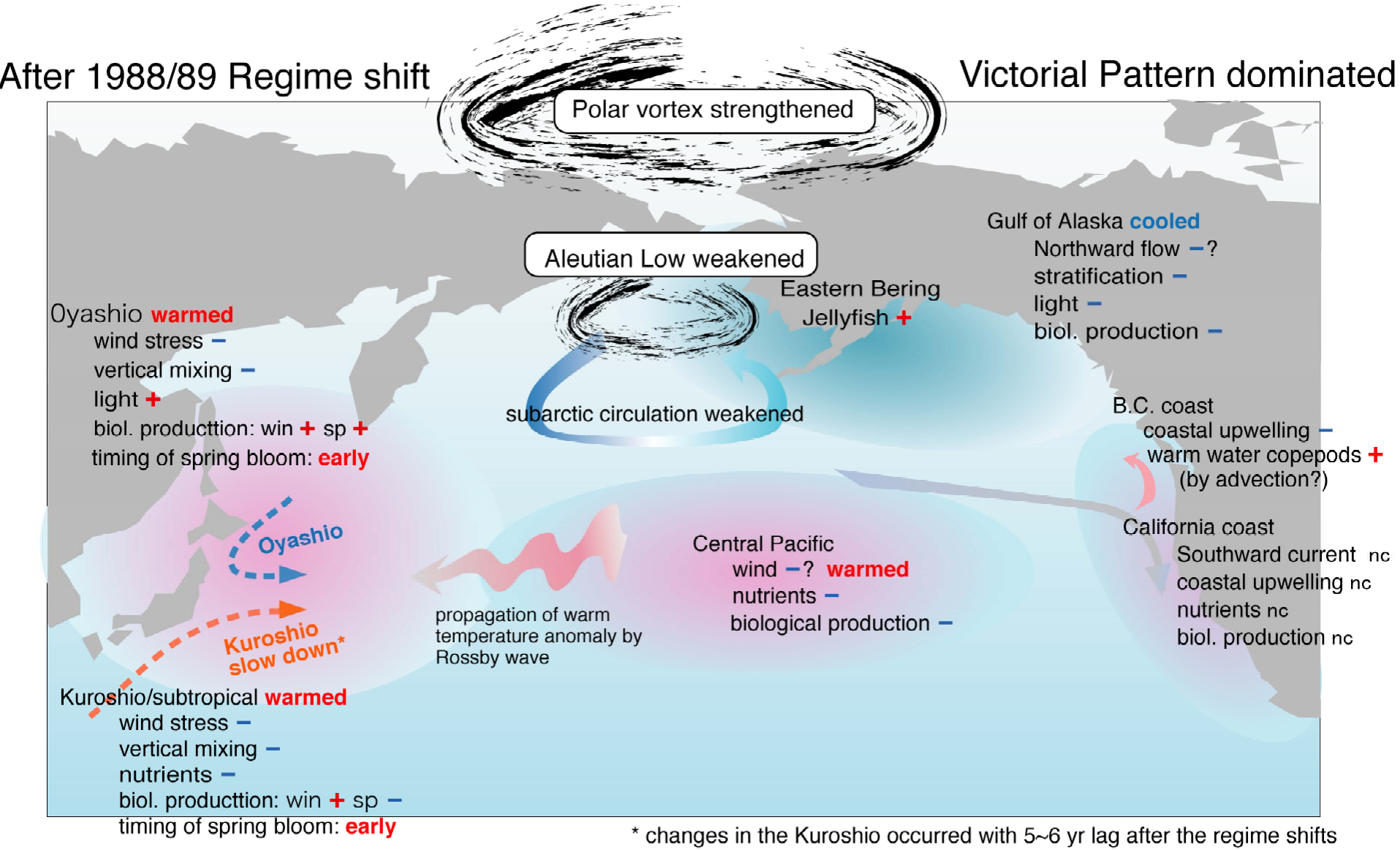
PDO pattern dominated



* changes in the Kuroshio occurred with 5~6 yr lag after the regime shifts

(modified from Chavez et al 2003. * information of the western North Pacific added by Chiba)

Wintertime climate and winter-spring production: 1988/89RS

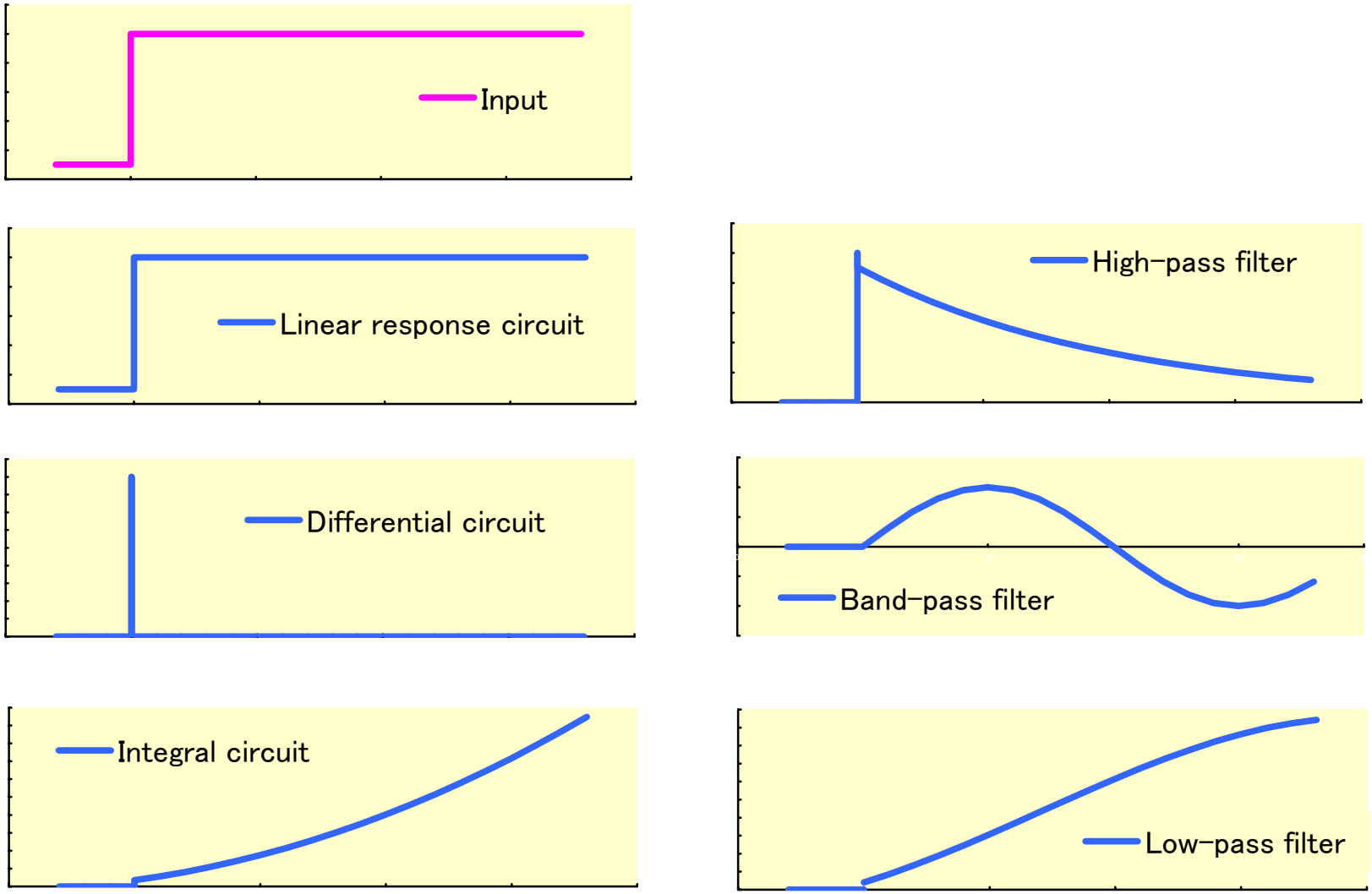


* changes in the Kuroshio occurred with 5~6 yr lag after the regime shifts

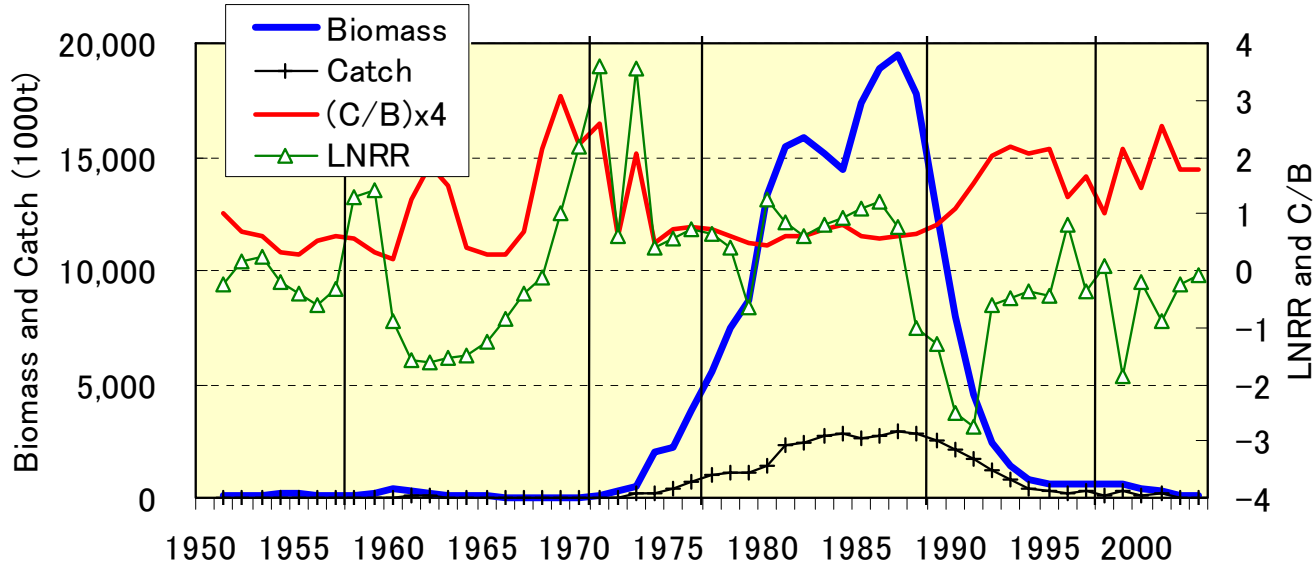
(Fig by Chiba based on various sources)

Possible responses to a climatic regime shift

(modified from Hanawa, 1998)

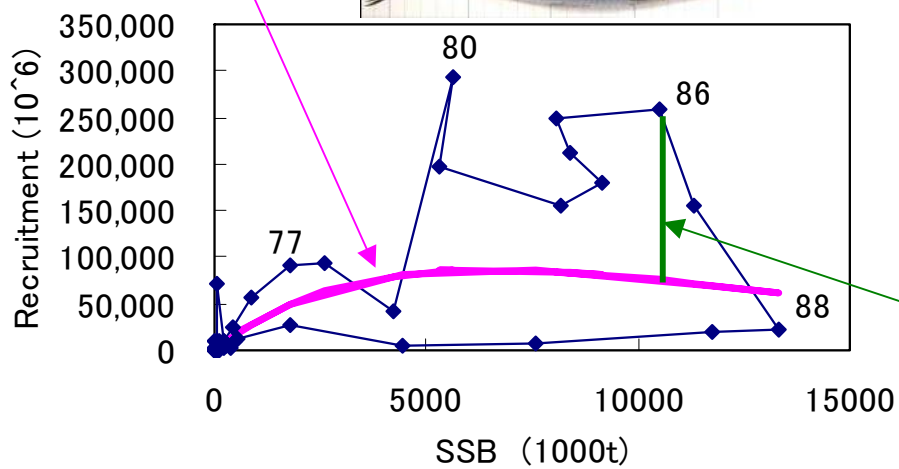


Measures of responses (Japanese sardine)



Vertical lines: regime shift years detected in SST field over the Pacific (Yasunaka and Hanawa, 2002) except 1998

Ricker curve



P/B: Production / Biomass

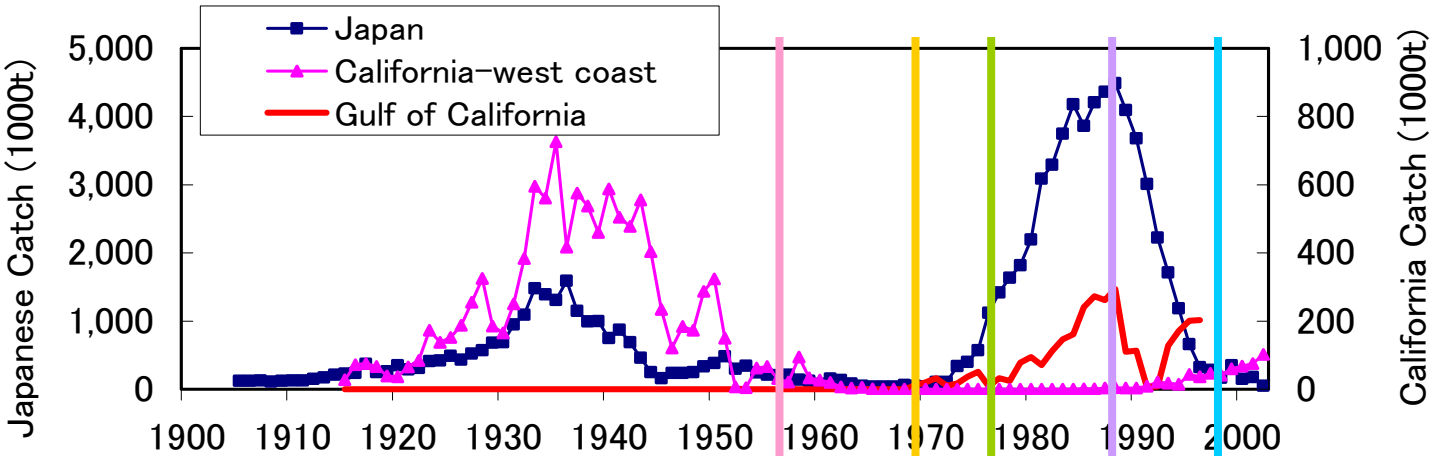
($P_t = B_{t+1} - B_t + Catch_t$)

RPS: Recruitment number per spawning biomass

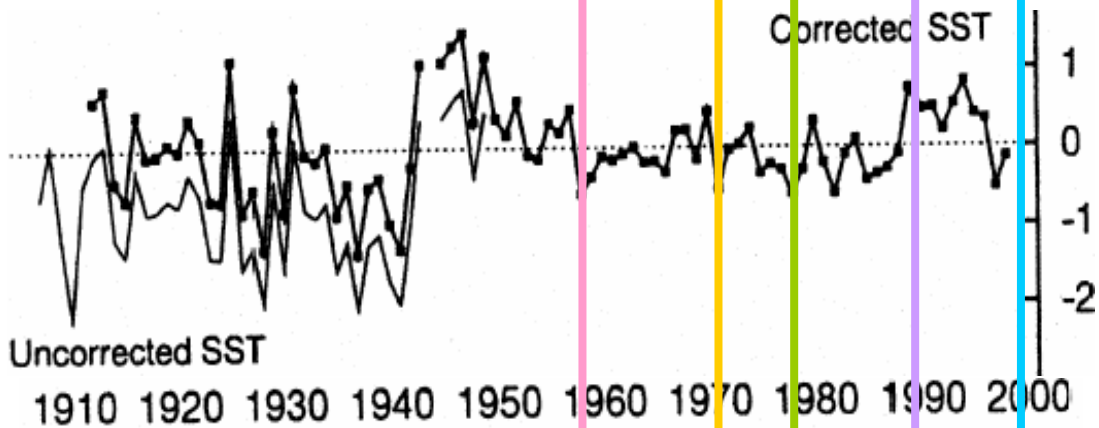
LNRR=

ln (Recruitment Residuals)

Japanese and California sardine catch and SST anomaly

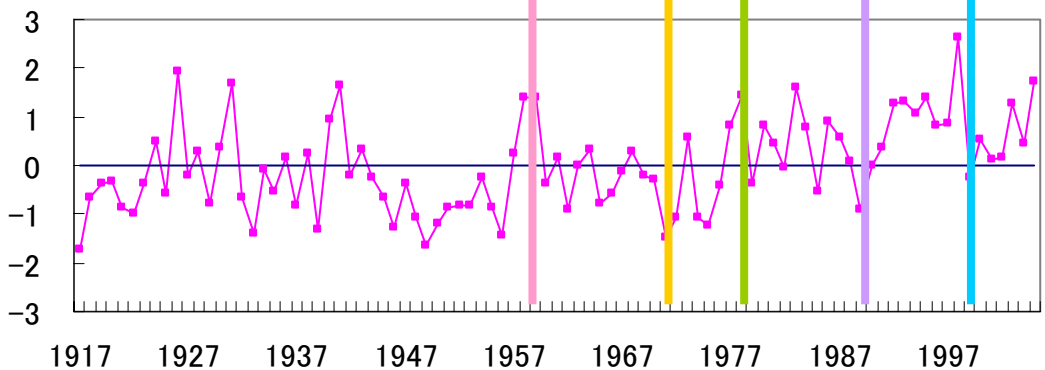


SST anomaly is opposite except after the 1988/89 RS



Kuroshio Extension winter SST Noto (2003)

Low SST> positive LNRR > high catch

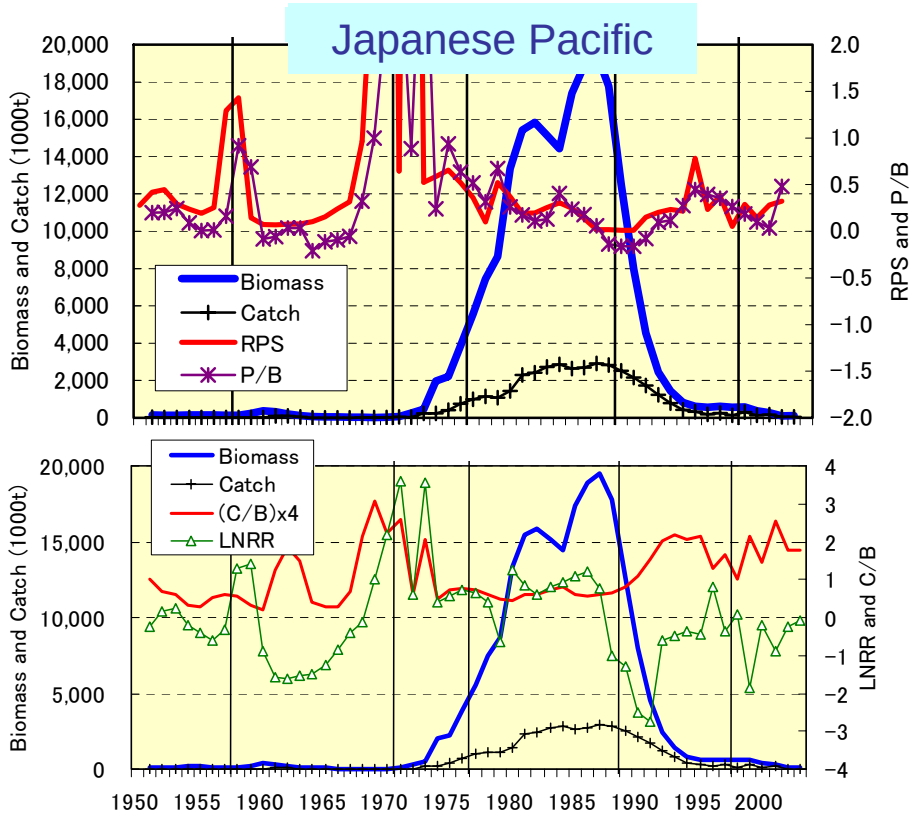


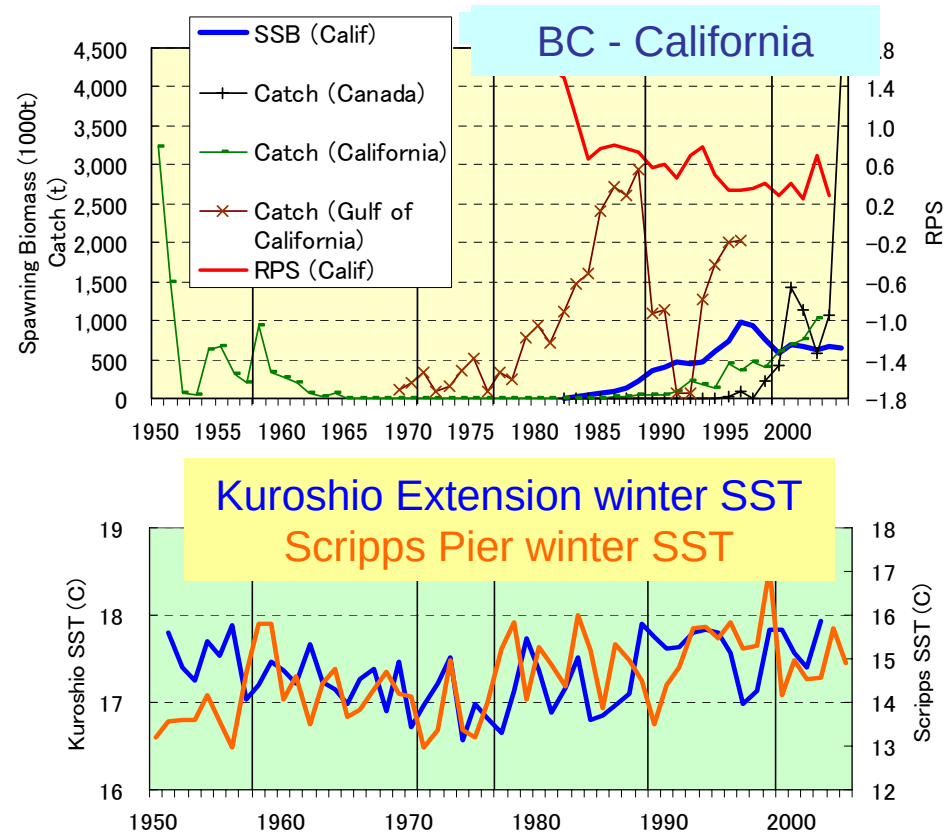
Scripps pier winter SST

High SST> positive LNRR > high catch

ftp://ccsweb1.ucsd.edu/shore/active_data/lajolla_sio/temperature

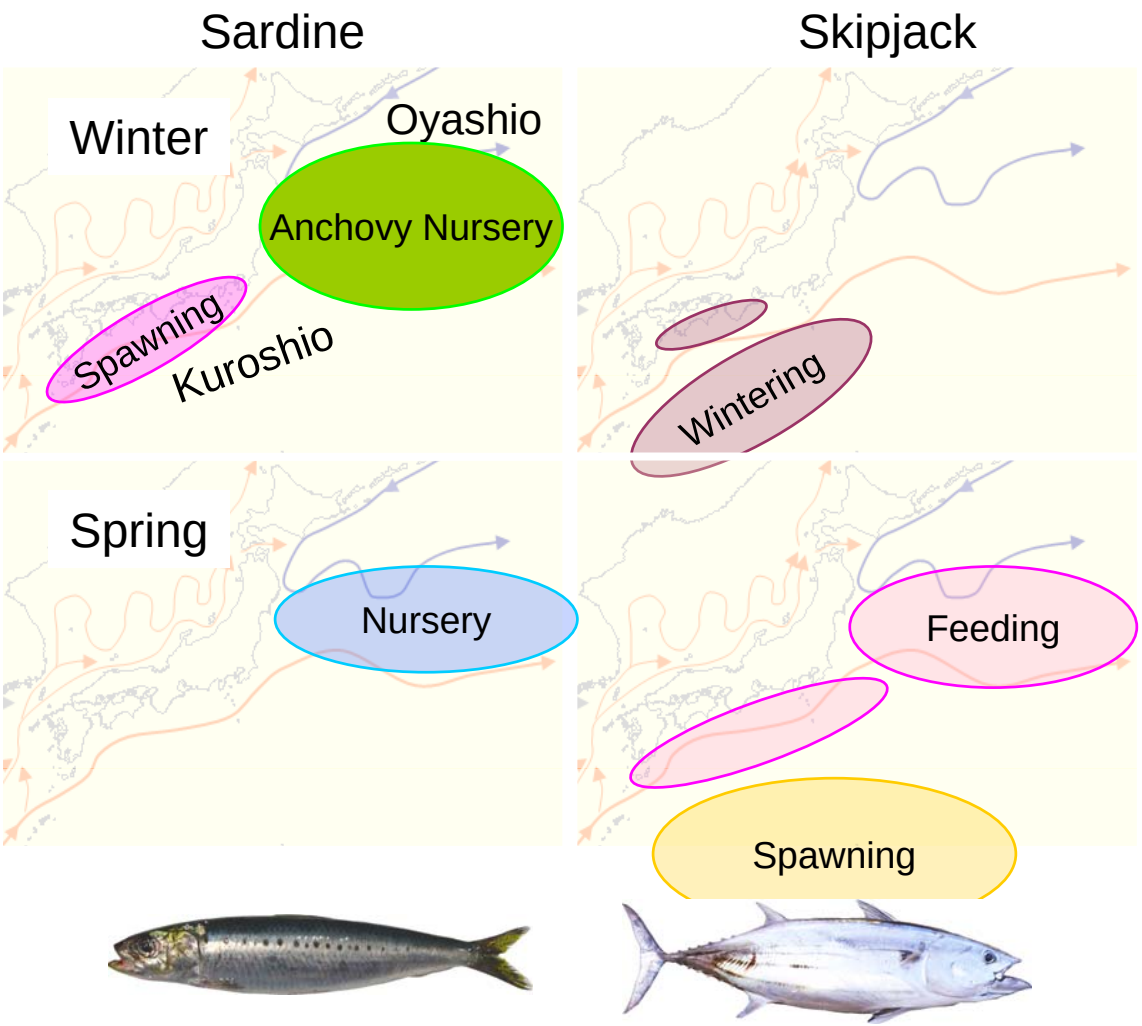
Sardine (opportunistic strategist) recruitment = age 0





- Regime effect is usually evident in LNRR, RPS and P/B; most prominent in LNRR
- Pulse-like response of LNRR (within + - 3)
- RPS since 1980's: Japanese sardine < California sardine
- SST of Kuroshio and California is opposite except for 1990s when Japanese sardine collapsed and California sardine recovered

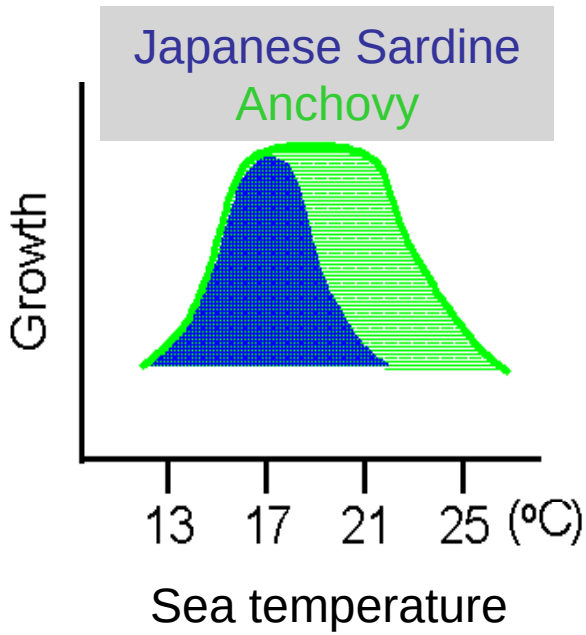
Connectivity to a predator



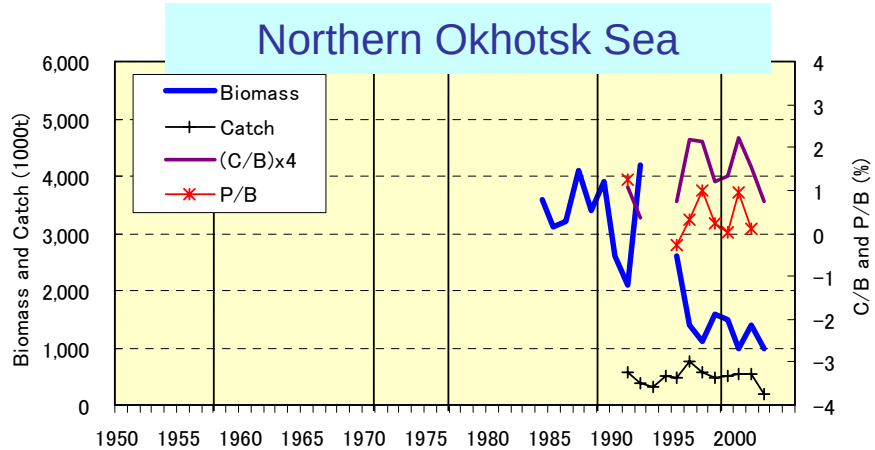
Higher SST would enhance arrival of skipjack and biomass of Japanese common squid

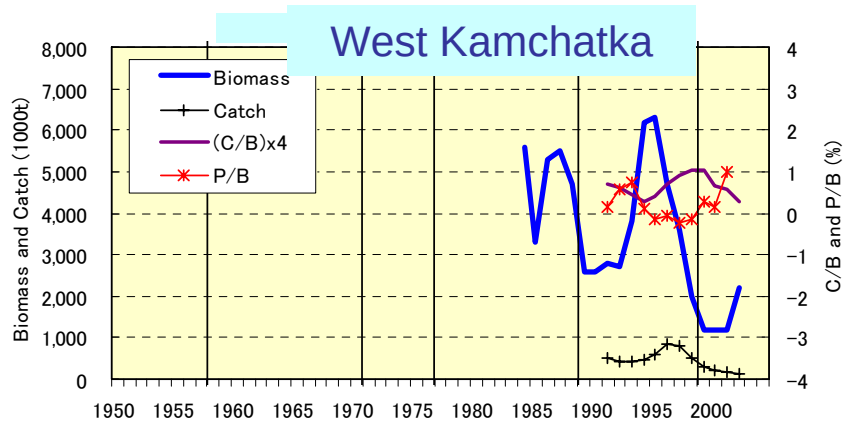
Temperature hypotheses for sardine/anchovy cycle

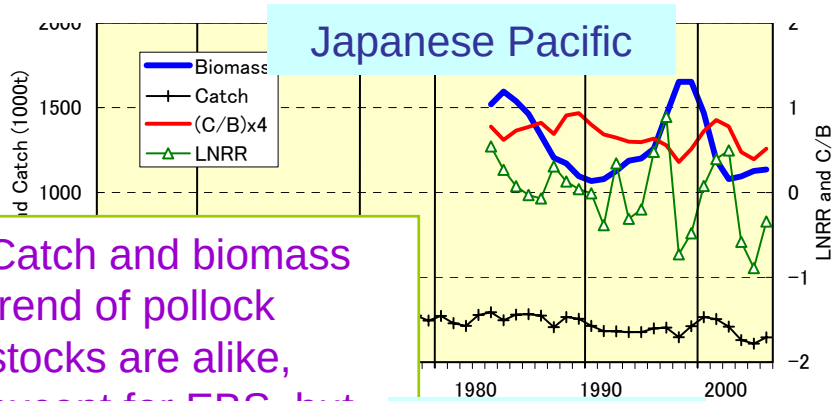
- Optimum temperature under sufficient prey (Takasuka et al., 2004 PICES, Takahasi et al., 2004 PICES)
- Connectivity to tropical predators (Yatsu et al., 2005 PICES)

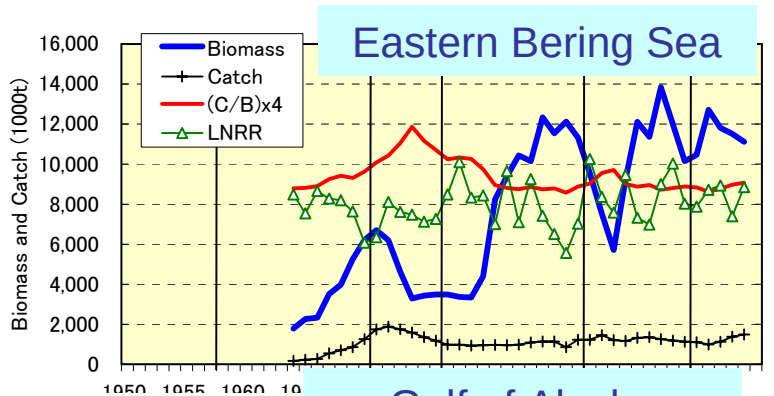


Walleye Pollock (intermediate strategist) recruitment = age 3-4





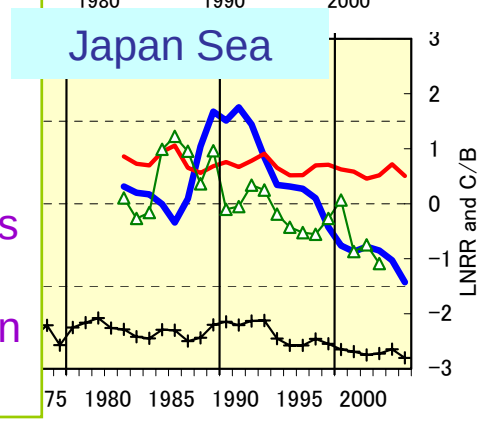


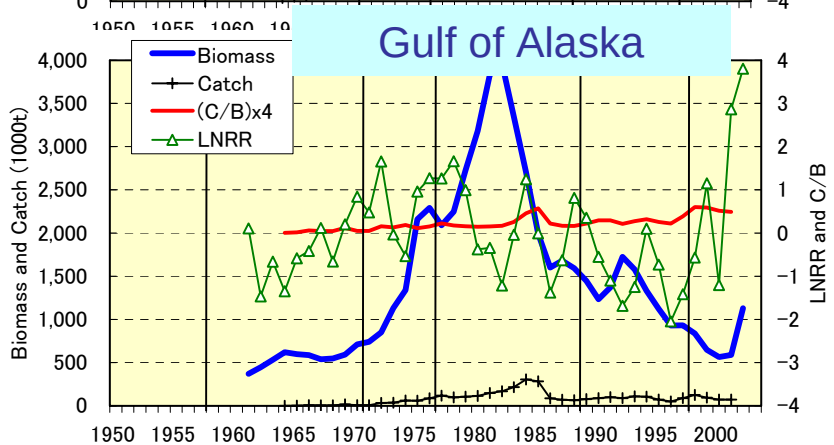


Continuously warm after 1977

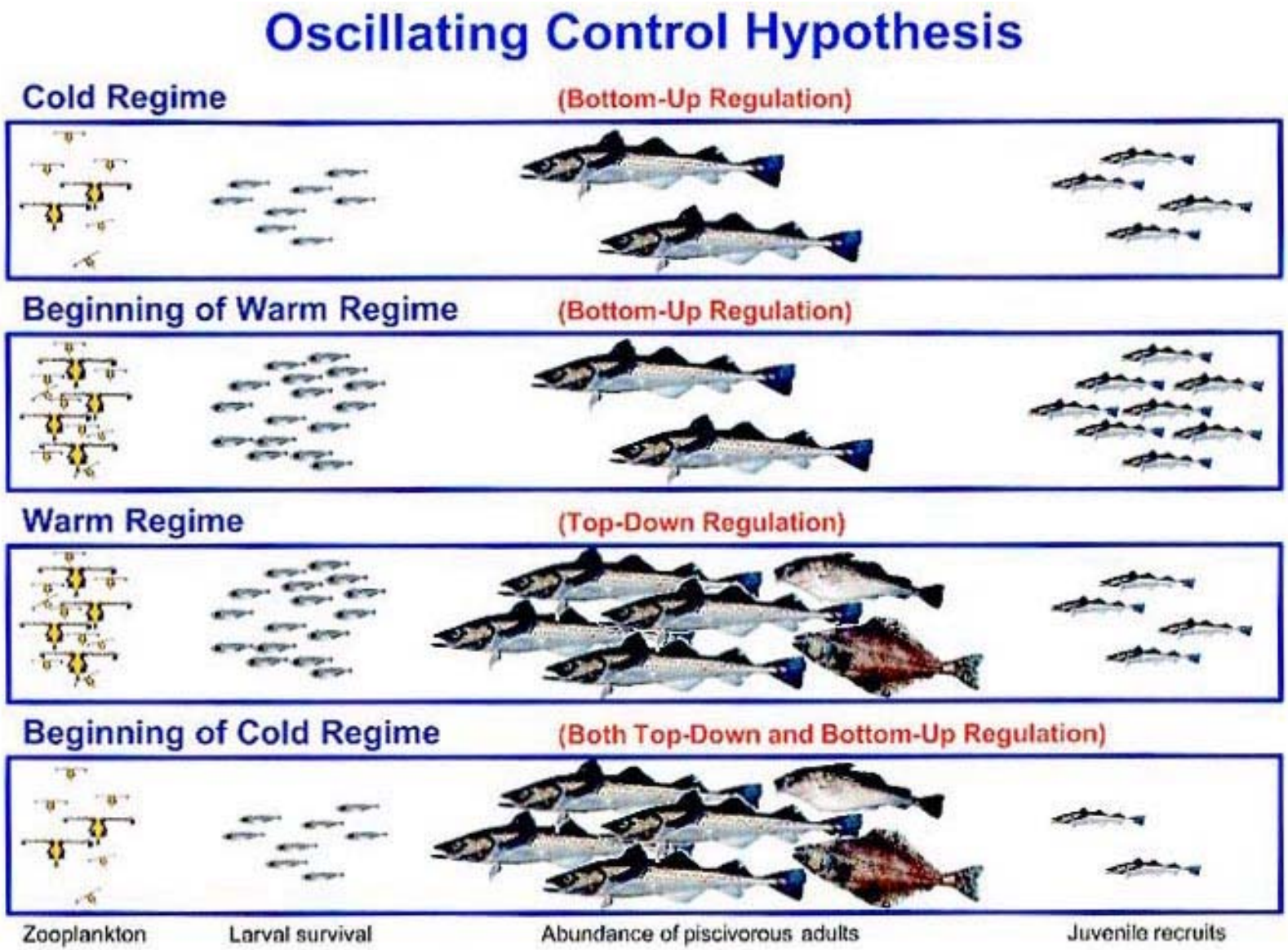
Catch and biomass trend of pollock stocks are alike, except for EBS, but differs in peak periods

Response of LNRR is much milder than in sardine (almost within + -1)



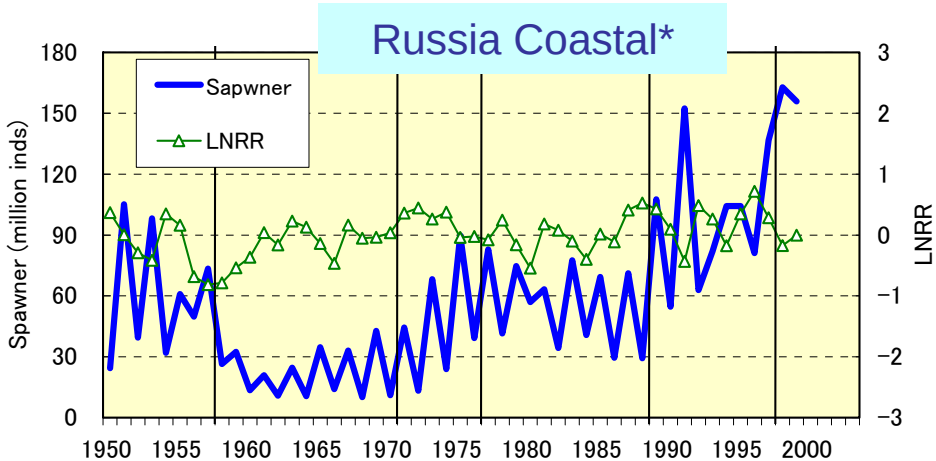


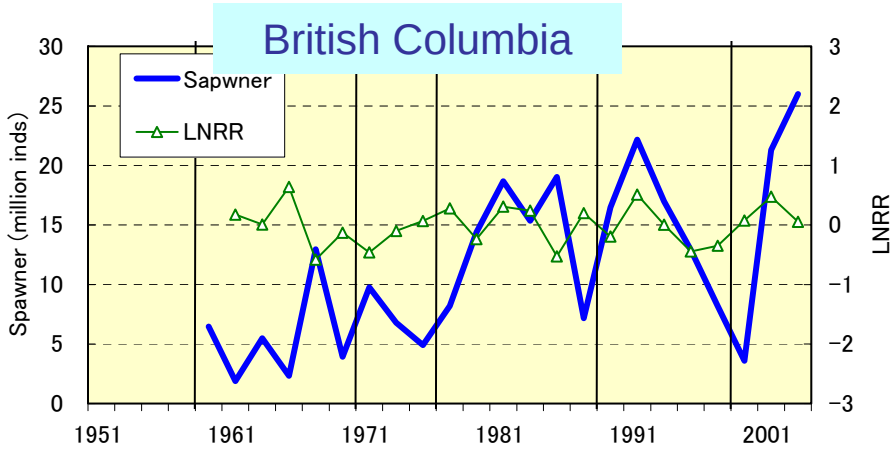
Pollock in Bering Sea (Hunt et al., 2002)

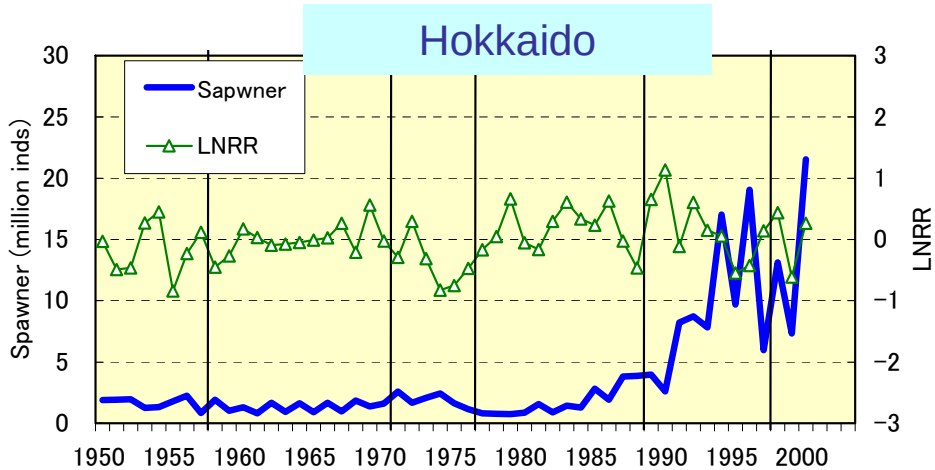


G.L.Hunt, Jr. and P.J. Stabeno, Progress in Oceanography 55, 2002

Pink salmon (salmonid strategist) recruitment = age 2







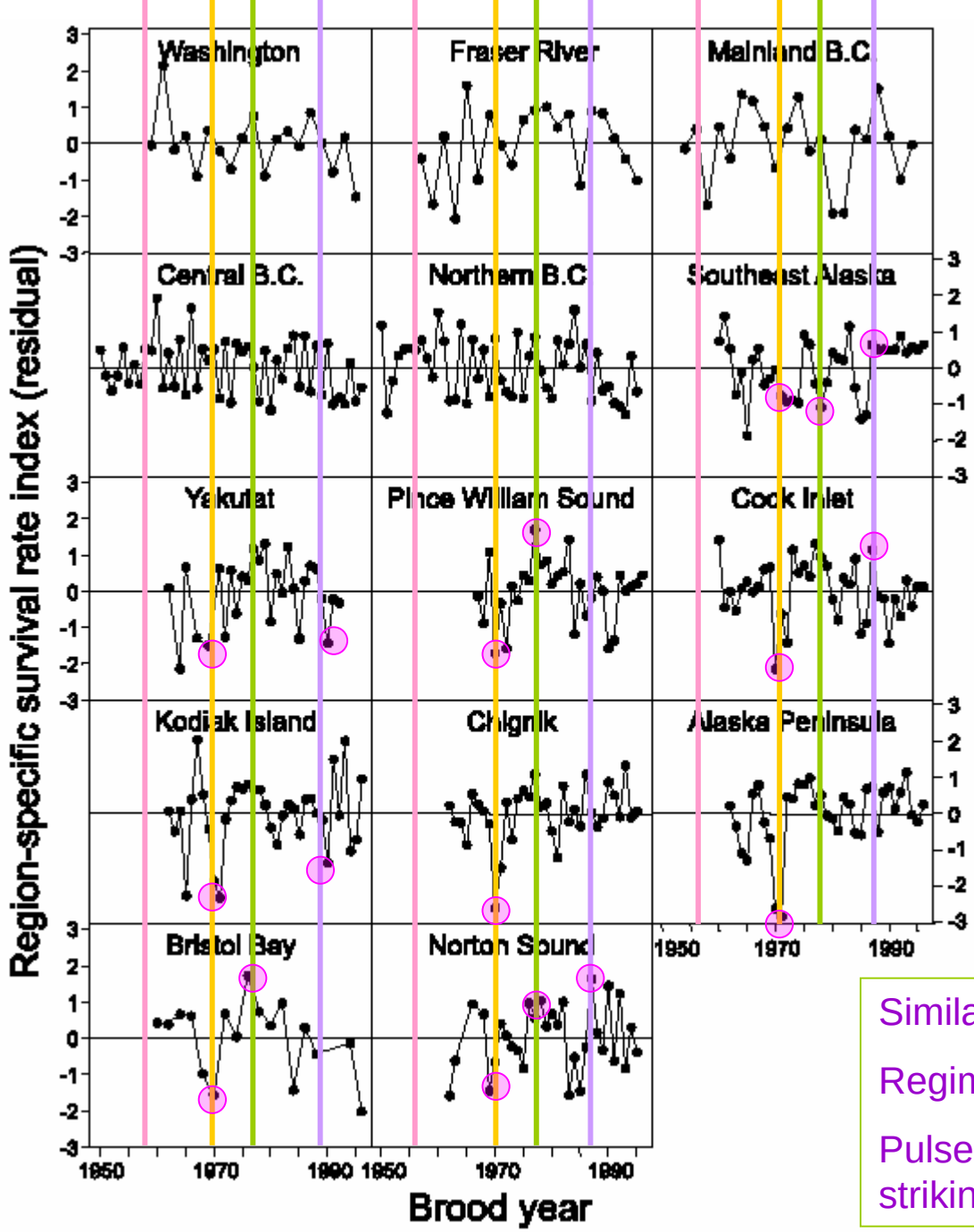
*Catch data (Eggers et al. (2004 PICES ESR) lagged by two years

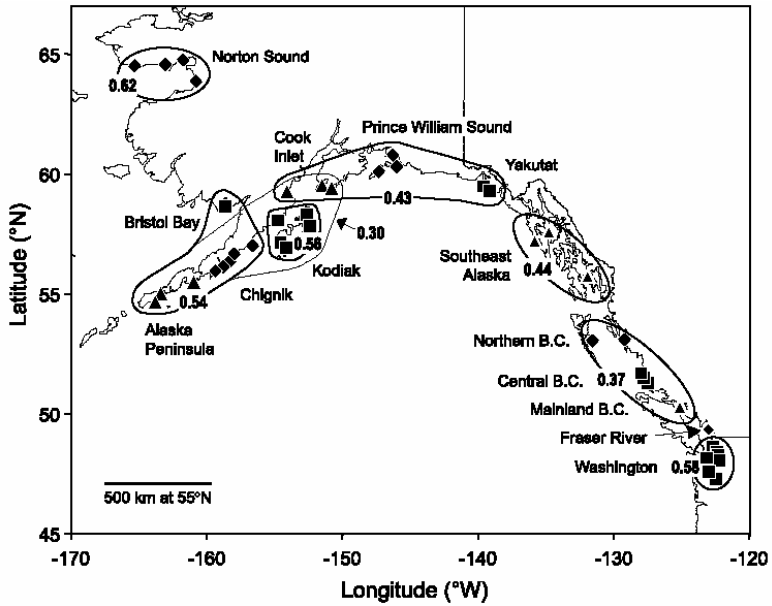
Decadal signal and pulse-like responses of LNRR to some RS in Russian and Hokkaido stocks

No distinct response of LNRR to RS in BC stock

LNRR is milder (<+- 1) than sardine and pollock (but variable in Alaskan populations: Pyper et al. 2001 see next)

Pink salmon recruitment residuals and their inter-regional correlations (Pyper et al.,2001, JCFAS) and regime shift years





Similarities within regions (circled)

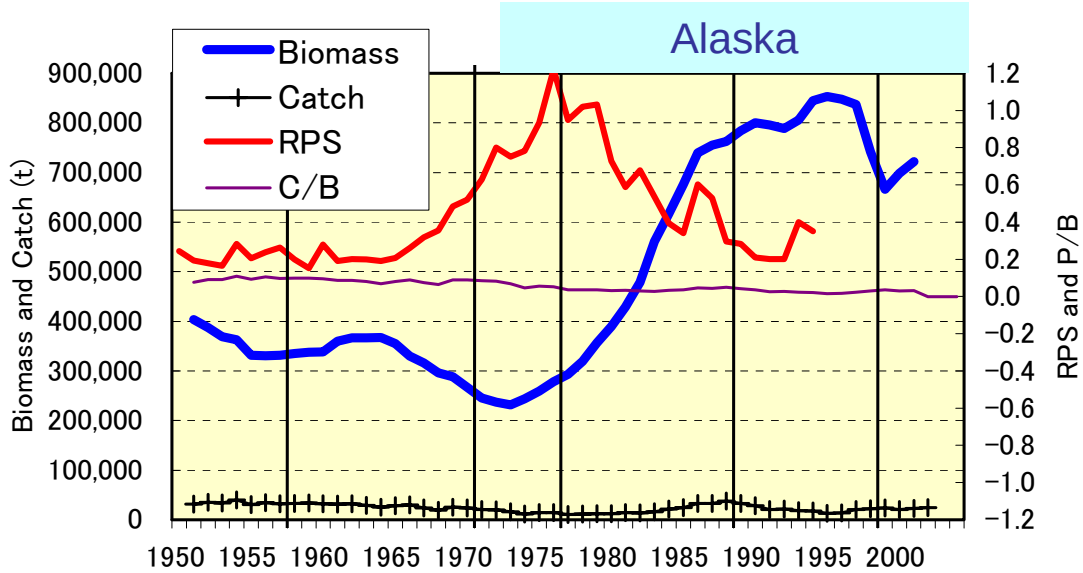
Regime effect is not so evident

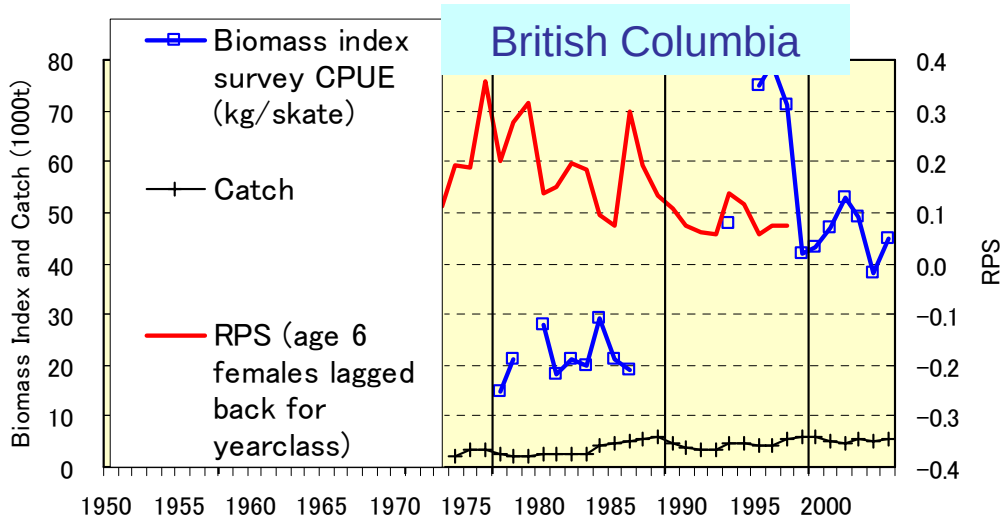
Pulse-like effect of 1970 and 1976 shifts are striking in Bering Sea & Northern GOA

Halibut (periodic strategist) recruitment = age 6

Low frequency RPS variability; could be due to the older age of recruitment or nature of periodic strategists?

Biomass trend lagged almost two decades from RPS





Sablefish (periodic strategist) recruitment = age 4

Pulse-like responses of RPS or year-class index to some RS years

Decadal signal is somewhat evident

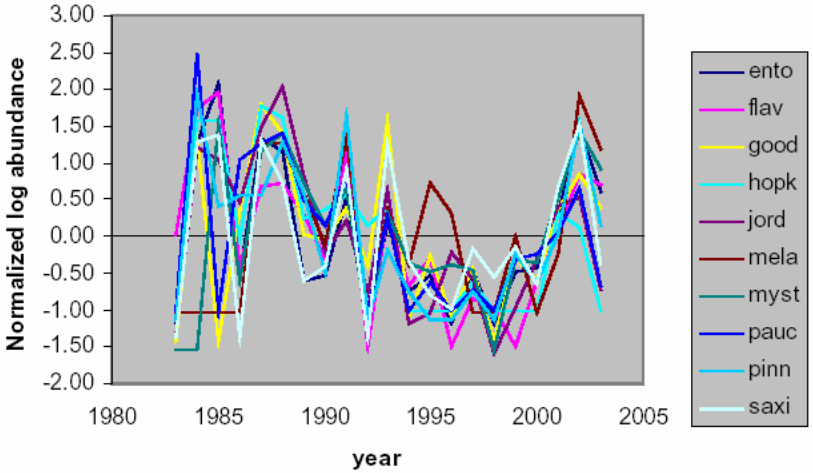
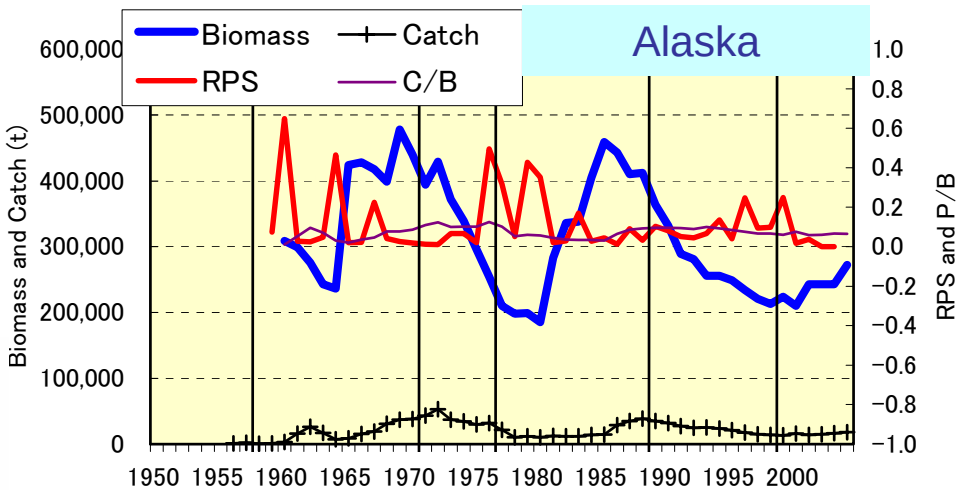
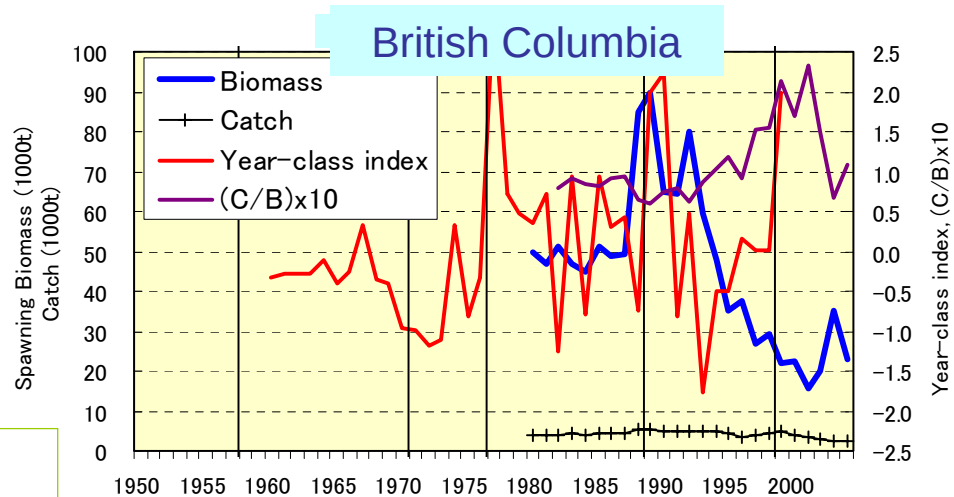
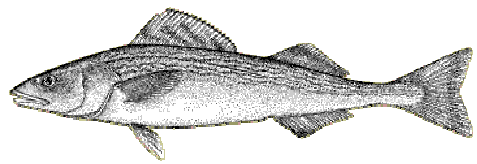


Fig. A2.15 Fluctuations in abundance of juvenile rockfish off central California, as measured by catch rates in midwater trawls. Preliminary results for the 2004 survey appear similar to 2002.



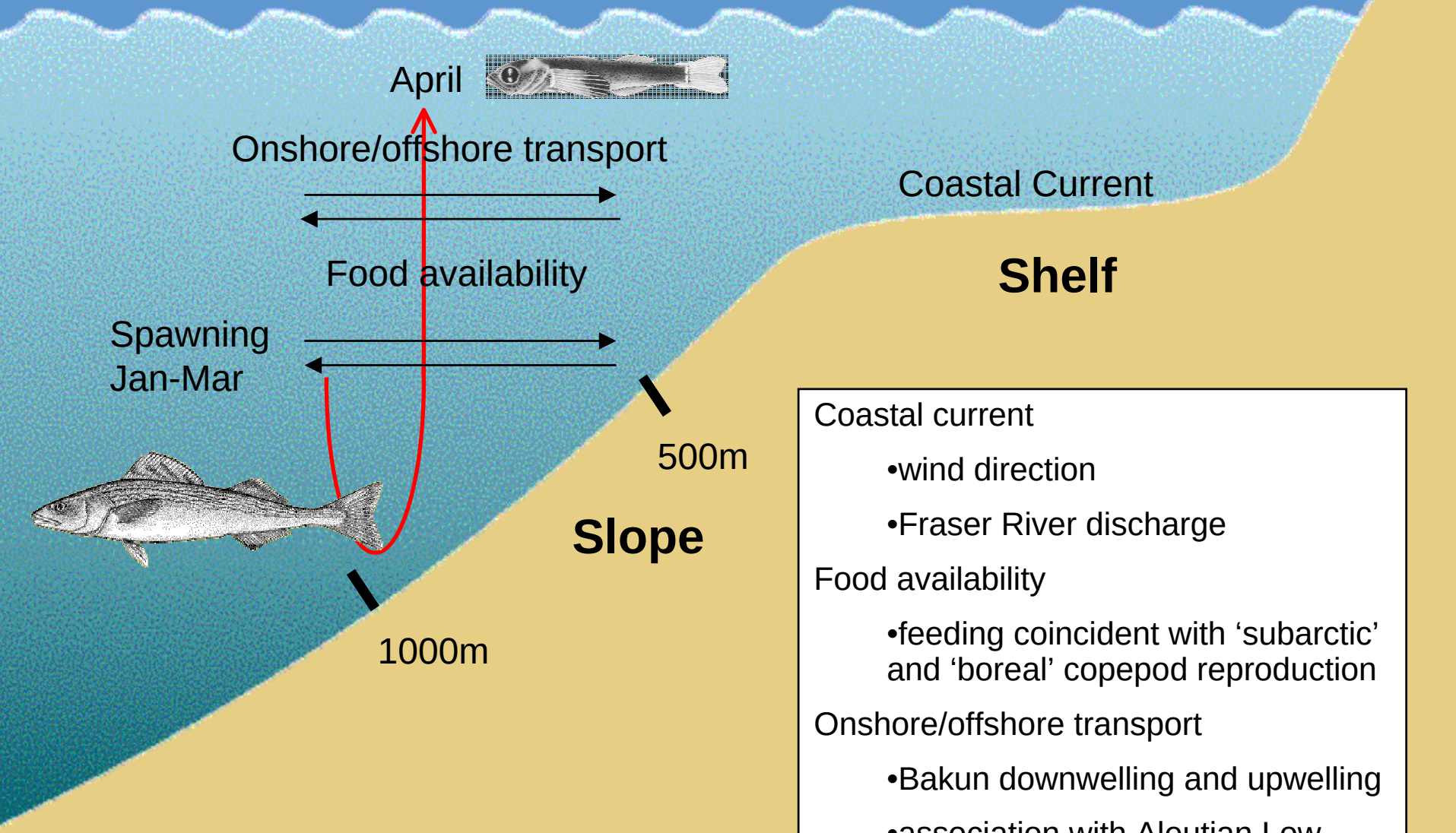


Decadal pattern of age-0 recruitment of California rock fishes (FERRRS Report): recruitment of periodic strategist is gradual rather than shifts



Conceptual model of sablefish year-class

(McFarlane and Beamish 1992; McFarlane et al. 1997; King et al. 2001)



Coastal current

- wind direction
- Fraser River discharge

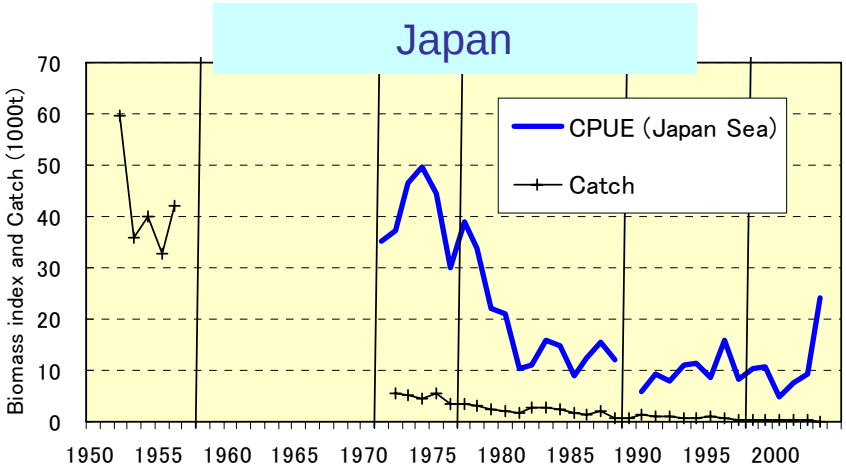
Food availability

- feeding coincident with ‘subarctic’ and ‘boreal’ copepod reproduction

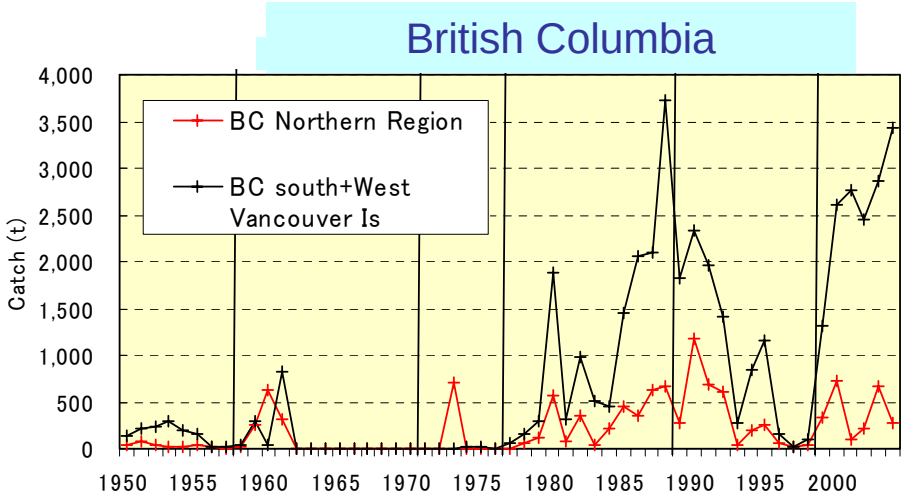
Onshore/offshore transport

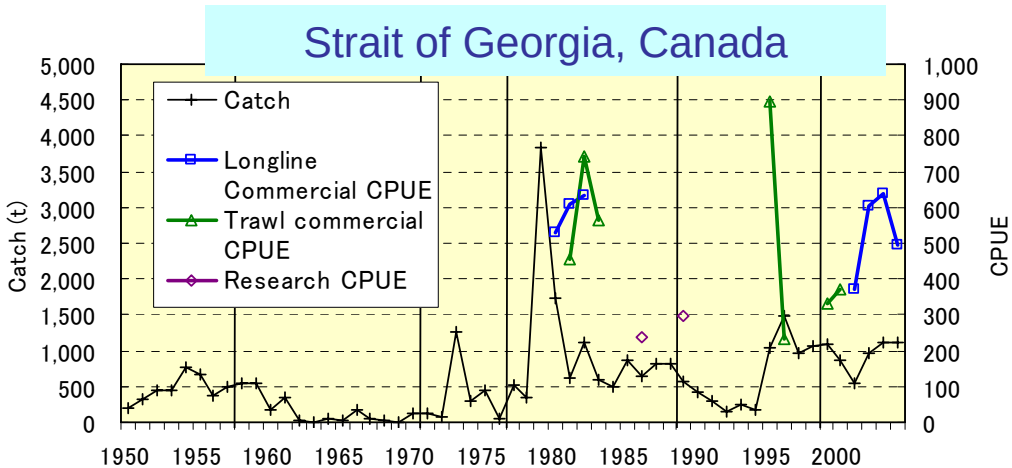
- Bakun downwelling and upwelling
- association with Aleutian Low

Dogfish (equilibrium strategist)



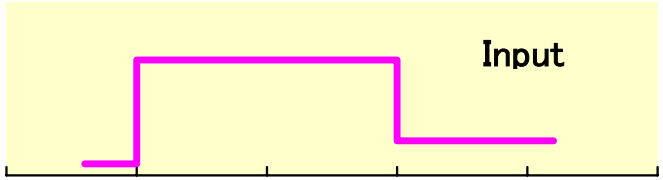
Over fishing ?

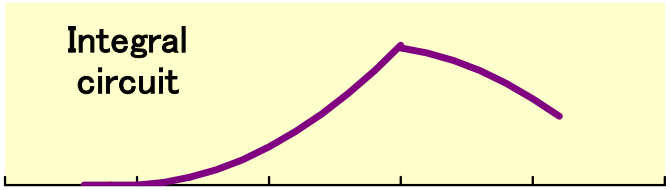




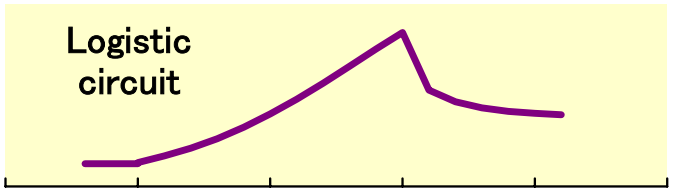
Stable biomass since 1970s?

Conclusion 1: seve
responses to climatic





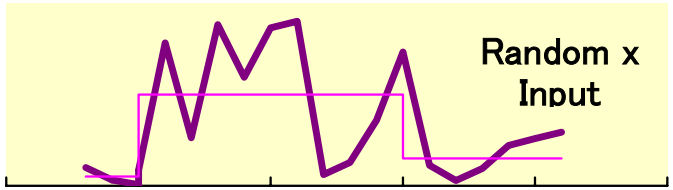
Biomass of ZP, pink salmon, halibut, sablefish



Biomass of sardine, pollock

LNRR of sardine & some pink salmon

More drastic in sardine



LNRR of pollock without apparent relation to RS years

Conclusion 2:

Ecosystem response to RS is unique to regions

RS affects all ecosystem levels with differentials in time and space

Biomass and RPS trend of periodic strategists may lag almost two decades

RS effects are clearest in opportunistic strategists followed by salmonids, but not always apparent

Biomass and LNRR are keys to understand mechanisms of ecosystem responses to regime shifts