Epipelagic and mesopelagic fishes in the southern California Current System: ecological interactions and oceanographic influences on their abundance

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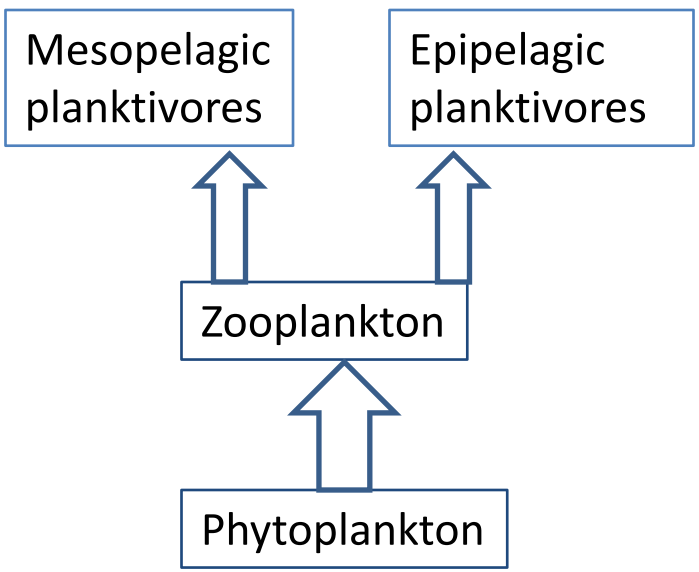
Questions

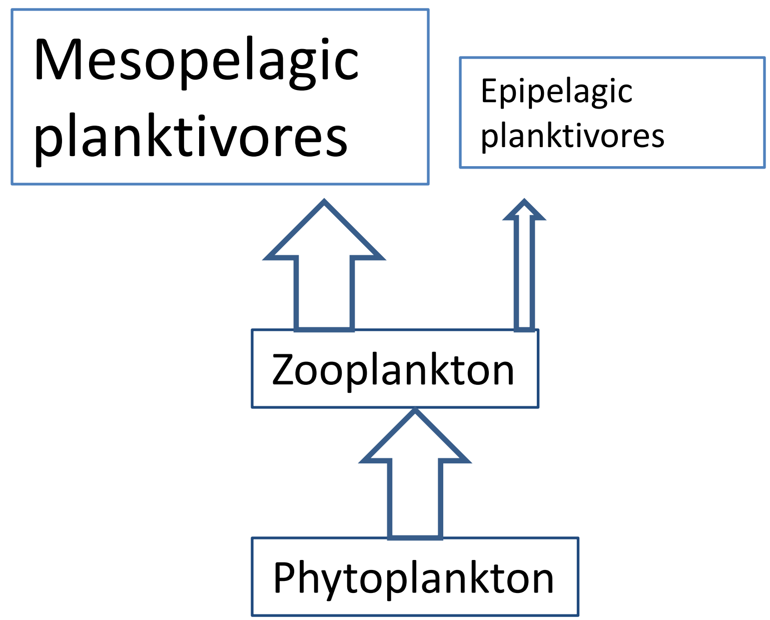
- Are upwelling (and other) food webs wasp-waisted, dominated by a few pelagic planktivore species (e.g. sardine, anchovy) that drive the dynamics of their predators & prey?
- What are the impacts of changing planktivore populations on their competitors & predators?
  - Model predictions
  - Testing model results with the CalCOFI time series
- If equilibrium-based steady state models (mass balance/Ecopath/Nemuro/Atlantis, etc) do not reflect the dynamics of the California Current Ecosystem, how are we to understand its dynamics?

Equilibrium-based models pose an implicit paradigm & hypothesis

Assume a simple mass balance model for a marine system

If the meso-planktivores increase (decrease), the model predicts a commensurate decrease (increase) in epi-planktivores, all else remaining constant.

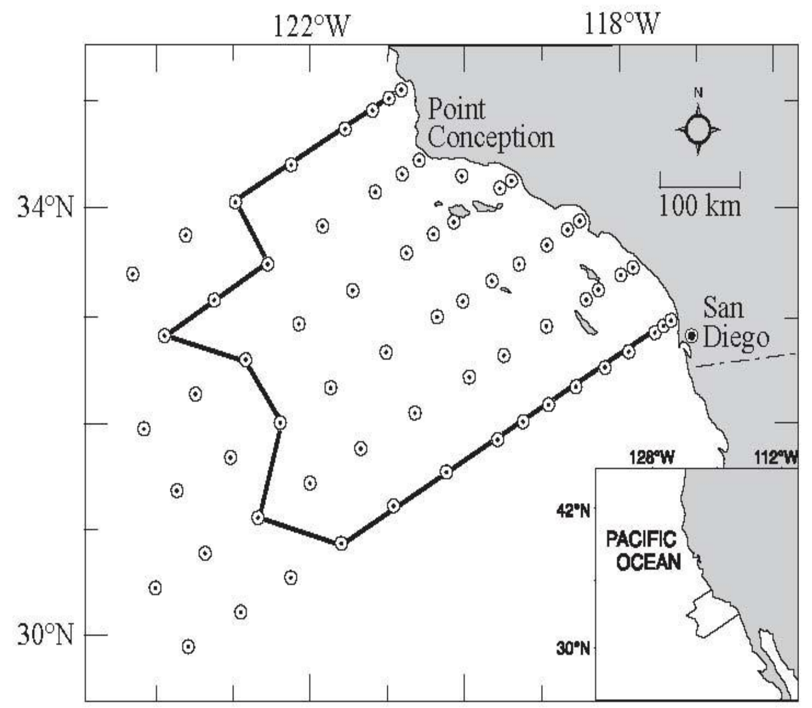




Changes in epi-planktivores should lead to similar, - correlated changes in meso-planktivores

Model/hypothesis test based on CalCOFI time series

- CalCOFI ichthyoplankton time series, 1951-2010
  - Monthly/quarterly sampling
  - Oblique net tows to 210 m depth at 55 core stations
  - All fish larvae removed, identified, enumerated (~500 taxa)
  - Proxies for adult spawning biomass: mostly pre-flexion, very early stage
- Method
  - Annual means estimated for each taxon over consistently sampled portion of grid
  - Rare species removed (0 > 50% of years)
  - 86 taxa consistently sampled, 1951-2010
  - Annual means log-transformed
  - PCA carried out



Dominant pattern based on PCA

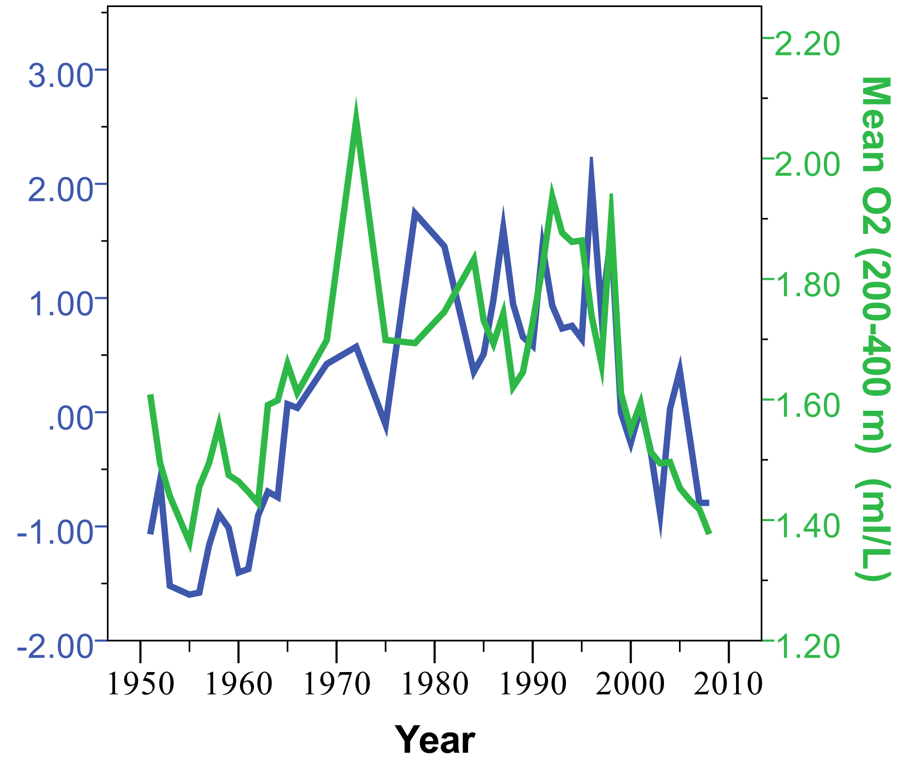
(Koslow et al 2011)

PC 1 (20.5% var explained):

24/27 taxa with loadings ≥ 0.5 mesopelagic from 10 families:

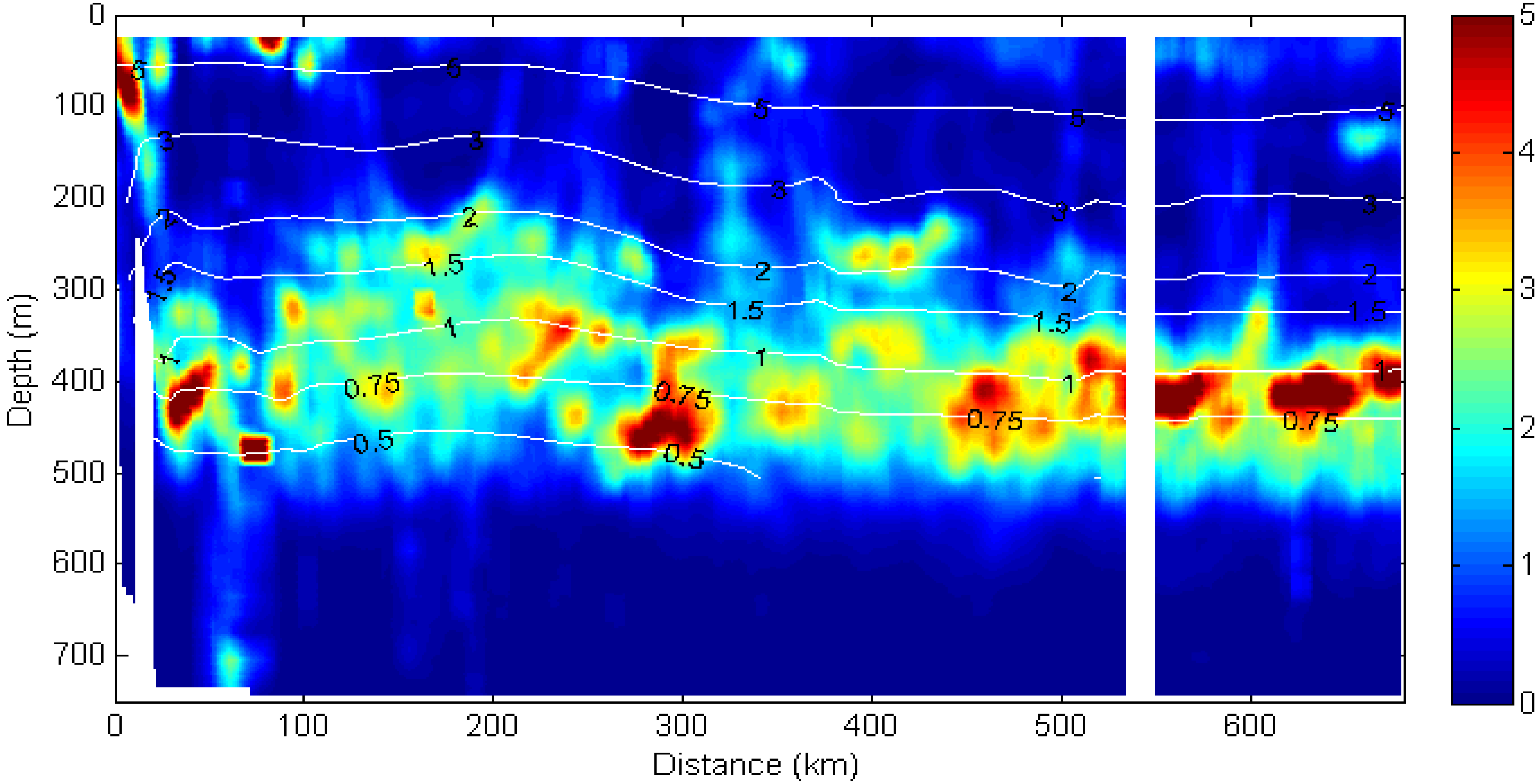
Myctophidae, Gonostomatidae, Sternoptychidae, Stomiidae, Phosichthyidae, Scopelarchidae, Argentinidae, and Microstomatidae, Paralepididae, Bathylagidae

Includes vertical migrators & non-migrators, plankton feeders & predators

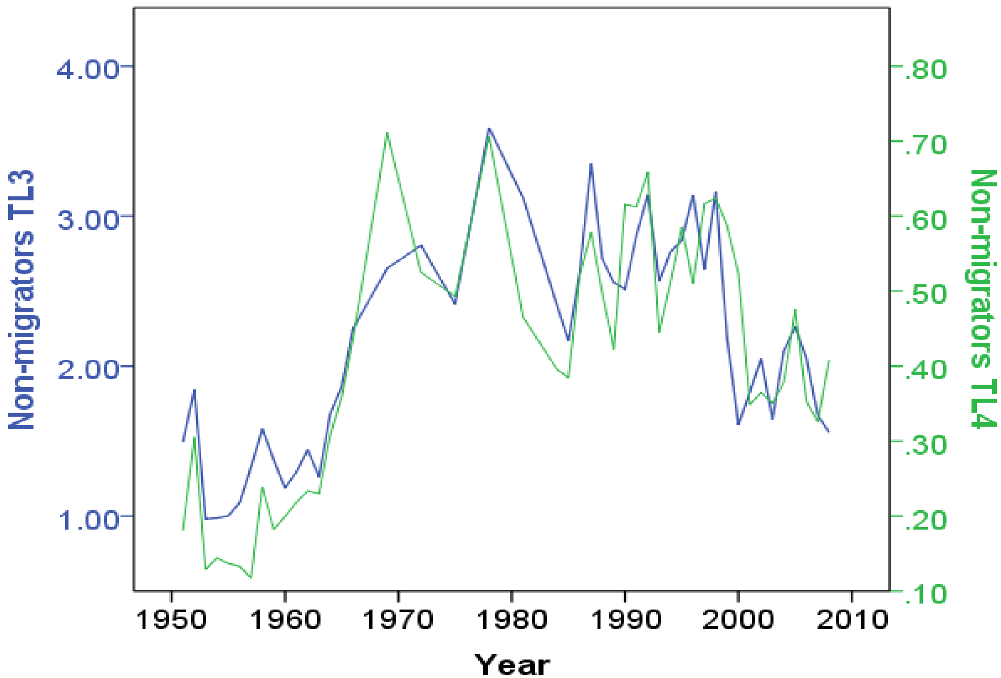


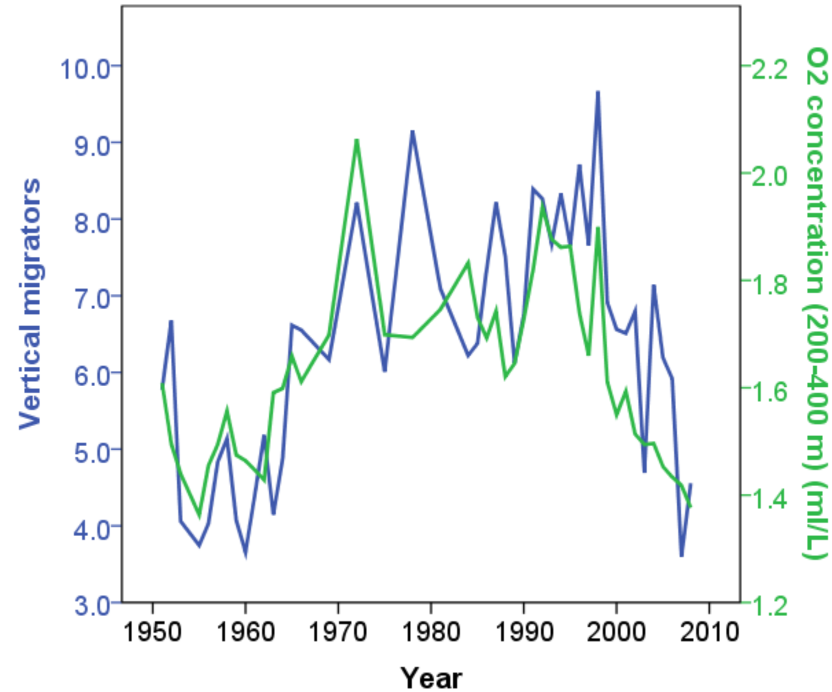
PC 1		O_2 (200-400 m)	PDO	MEI	NPGO	SST	Upwelling
	R	0.75*	0.56**	0.47*	-0.23	0.45?	-0.25
	N* (corrected for autocorrelation)	8	26	30		20	

Hypothesis: Expanding OMZ increases predation vulnerability of midwater fauna



OMZ has shoaled 41 m on average since 1980s (Bograd et al 2008), equivalent to a factor of 2.5 in light level





	VM	NM-3	NM-4
NM-3	.88*** (15)		
NM-4	.76*** (16)	.85*** (13)	
O_2	.75*** (16)	.77** (13)	.68* (13)

Consistent very strong + correlations between midwater groups (migrators, non-migrators, plankton feeders & predators): r = 0.76 – 0.88.

	Vertical migrators	Non-migrators TL3	Non-migrators TL4
Hake	0.48* (26)	0.51* (22)	0.43* (23)
Anchovy	0.41? (19)	0.57* (16)	0.53* (16)
Jack mackerel	0.37* (45)	0.30 ns (16)	0.21 ns (46)
Pacific mackerel	0.47* (25)	0.62** (21)	0.38* (22)

Consistent + correlations among potential meso- and epipelagic competitors & predators (except sardine): r ~ 0.4 – 0.6

Consistent with pattern of bottom-up forcing related to food availability, advection or other environmental forcing
No evidence for compensatory changes due to +/- changes in competitors (mesopelagic v epipelagic planktivores/piscivores)

Relationships with environmental variables

(N*): # independent data points, corrected for autocorrelation

?: 0.10<p<0.05; *: p<0.05; **: p<0.01; ***: p < 0.001

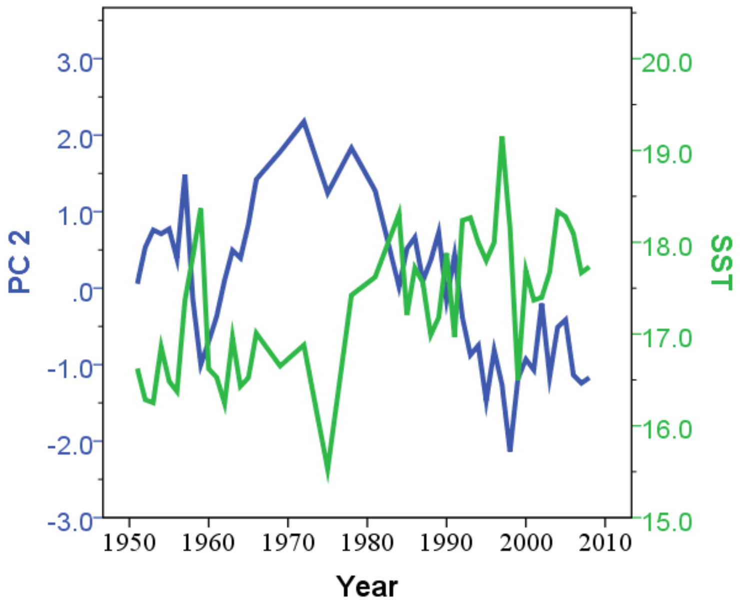
	$DeepO_2$	SST	T_{200}	Upwelling	MEI	PDO	NPGO
Vertical migrators	0.75*** (16)	0.10 ns	0.20 ns	-0.35* (46)	0.47** (36)	0.33* (46)	-0.39* (26)
Non-migrators TL3	0.77** (13)	0.13 ns	0.22 ns	-0.14 ns	0.42* (35)	0.43** (46)	-0.41* (25)
Non-migrators TL4	0.68* (13)	-0.02 ns	0.28? (45)	-0.20 ns	0.34* (36)	-.21 ns	-0.27 ns (24)
Hake	0.32 ns (21)	-0.06 ns	0.02 ns	0.06 ns	0.18 ns	0.32* (46)	-0.36* (38)
Anchovy		0.00 ns		0.25 ns	0.22 ns	0.32* (42)	0.17 ns
Jack mackerel		0.29* (38)		-0.25 ns	0.26? (45)	0.28? (37)	-0.37* (30)
Pacific mackerel		0.25 ns (36)		-0.12 ns	0.30 ? (37)	0.59*** (29)	-0.11 ns

Summary of correlations

- Consistent + correlations between potential competitors (epipelagic & mesopelagic (migrators & non-migrators) planktivores) & mesopelagic predators & prey inconsistent with dynamics of mass balance models
- Correlations with environment inconsistent with bottom-up dynamics
  - Mesopelagics + correlation with MEI
  - Epi- & mesopelagics + correlation with PDO (+PDO = warm phase, shallow upwelling)
  - — correlation with NPGO = shallow upwelling, low salinity, nutrients & chl in the CalCOFI area
- Correlations NOT consistent with a simple bottom-up model – but what then?

If not competitive interactions & productivity, what is driving fish assemblages in the California Current (other than O_2)?

- Return to PCA of CalCOFI ichthyoplankton data
- PC 2: explained 12.4% variance
- 6 out of 7 of the most abundant species in CalCOFI ichthyoplankton time series loaded highly:
  - Pacific sardine (-)
  - Pacific hake, northern anchovy, *Sebastes* spp., 2 mesopelagics (*Stenobrachius leucopsarus, Leuroglossus stilbius)* (+)



Significant – correlations with SST: r = -0.50*** and SF sea level: r = -0.30* (proxy for advection of the California Current) at lag of 1 year

MOSER ET AL.: LARVAL FISH IN CALIFORNIA CURRENT, 1954–1960
CalCOFI Rep., Vol. XXVIII, 1987

PC 2 dominant species were identified as a 'northern' affinity assemblage (Moser et al. 1987)

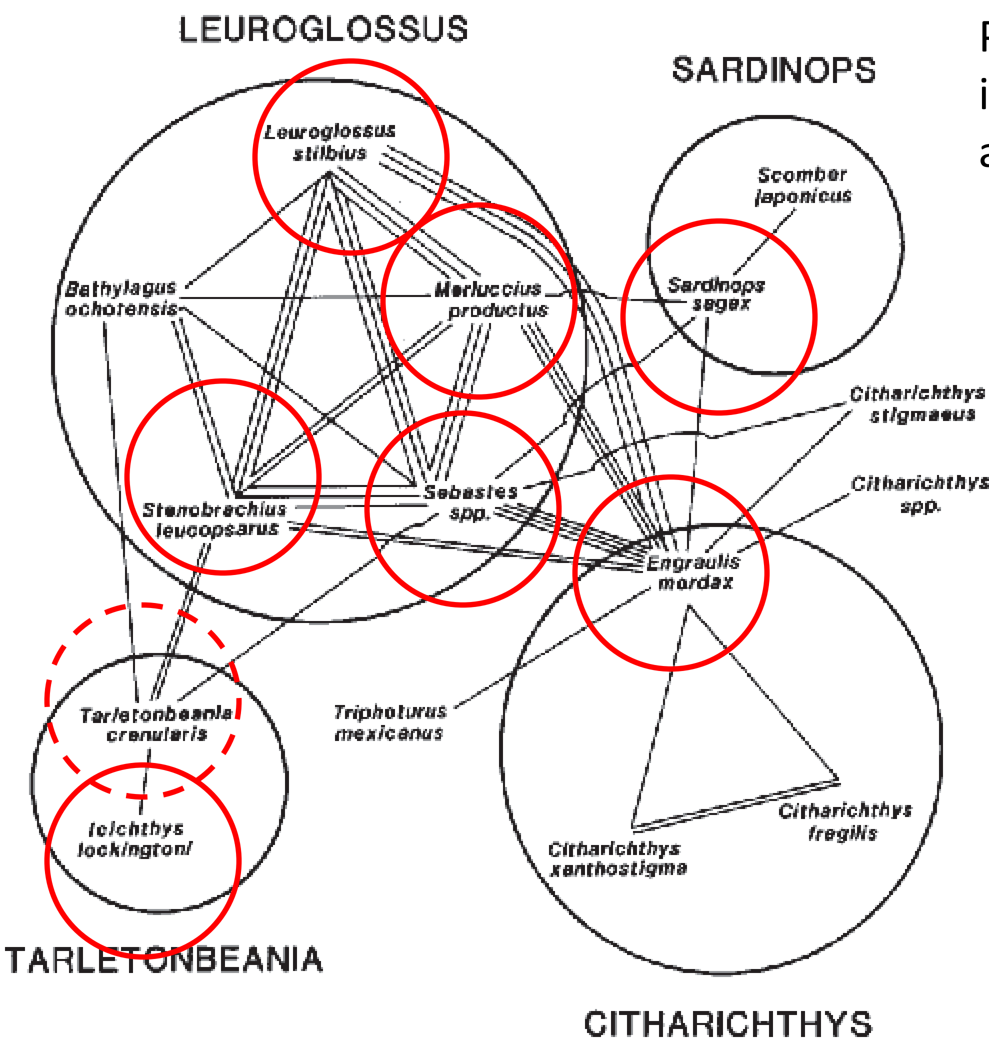
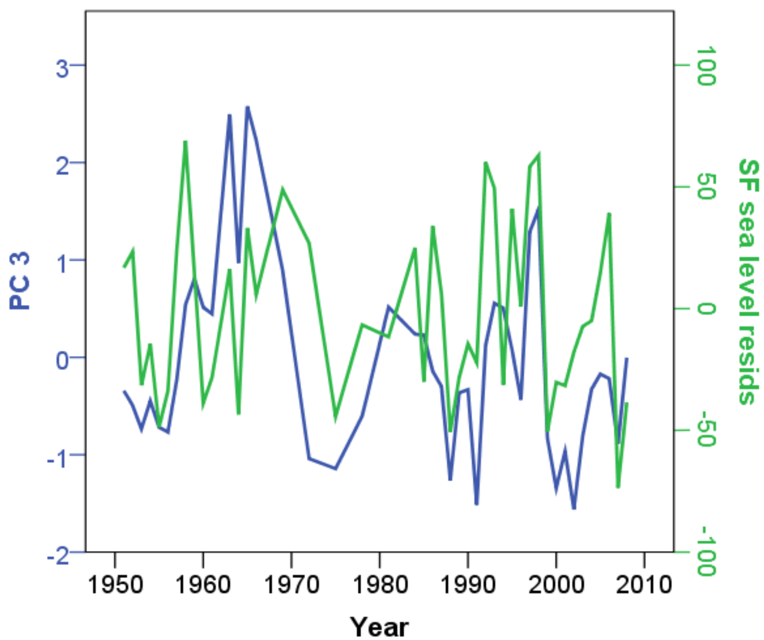


Figure 8. The northern complex of recurrent groups and associates from pooled (1954–60) CalCOFI data. The number of connecting lines indicates the approximate affinity index value. A single line represents an affinity index from 0.30 to 0.39; a double line is 0.40 to 0.49; a triple line is 0.50 to 0.59; and four lines represent an affinity index of 0.60 or greater.

PC 3: explained 6.8% variance

Dominant species from a reef & coastal, southern affinity assemblage (Moser et al. 1987):

Tonguefish (*Symphurus atricaudus*), blacksmith (*Chromis punctipinnis*), Pacific barracuda (*Sphyraena argentea*), cuskeels (*Ophidion scrippsae, Chilara taylori*), blennies (*Hypsoblennius* spp.), croakers (Sciaenidae), sand dabs (*Citharichthys* spp.), and cabezon (*Scorpaenichthys marmoratus*)



Significant + correlations with SST: r = 0.35* and SF sea level: r = 0.46**

Assemblages defined by water mass affinities exhibit relative dominance based on advection of California Current:

Strong flow from N enhances dominance of cool-water fauna

Enhanced from S enhances dominance of coastal warm-water fauna

Summary

- Mesopelagic fishes (migrators/non-migrators, planktivores/piscivores) have fluctuated coherently since 1951, highly correlated with deepwater O_2
- Changes among mesopelagic groups highly + correlated, also correlated with epipelagic planktivores
  - Equilibrium model assumptions& predictions of wasp-waist paradigm appear strongly violated
- Epi- & mesopelagic planktivores in the CCE also do not appear driven by bottom-up dynamics (productivity)
- Advection/water mass relationships appear to be the dominant drivers of fish communities in the CCE (an ecotone): spatially co-occurring larvae vary coherently over time
- Models simulating the CCE need to highlight the role of water masses & advection in driving assemblage dynamics on interannual – decadal time scales


Questions?
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