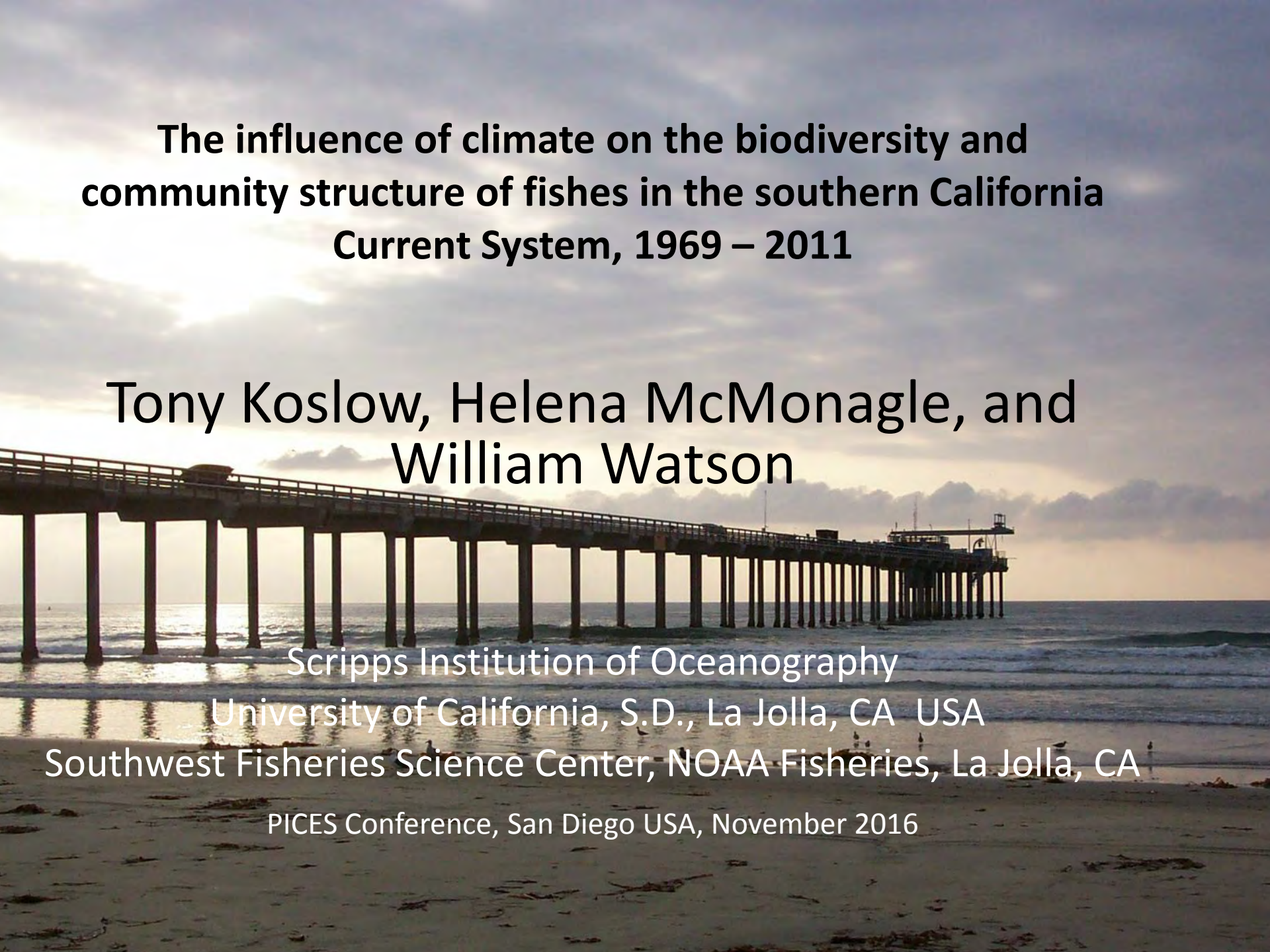

The influence of climate on the biodiversity and community structure of fishes in the southern California Current System, 1969 – 2011

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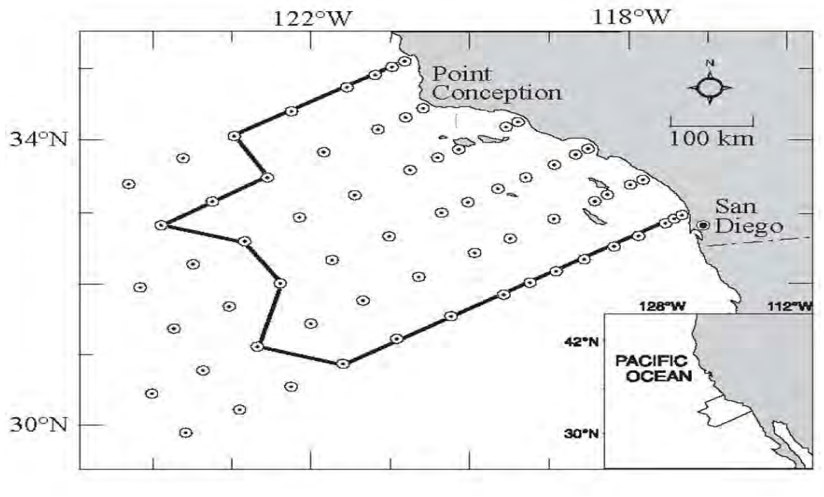
Overview of talk

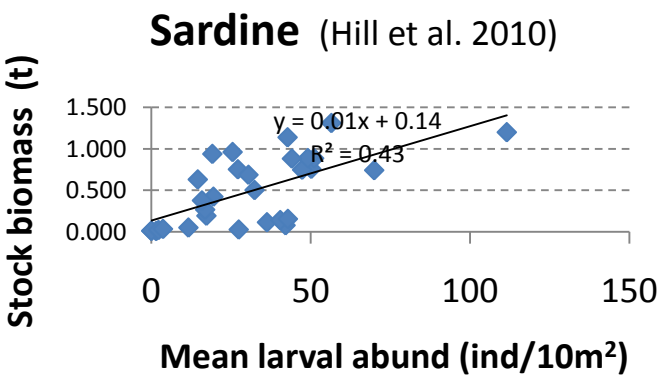
- Review of past work showing significant, coherent changes in abundance across broad groups of fish taxa and relationships with ocean forcing
- Examine how these trends in regional fish communities may have affected biodiversity: species richness and evenness/community dominance structure

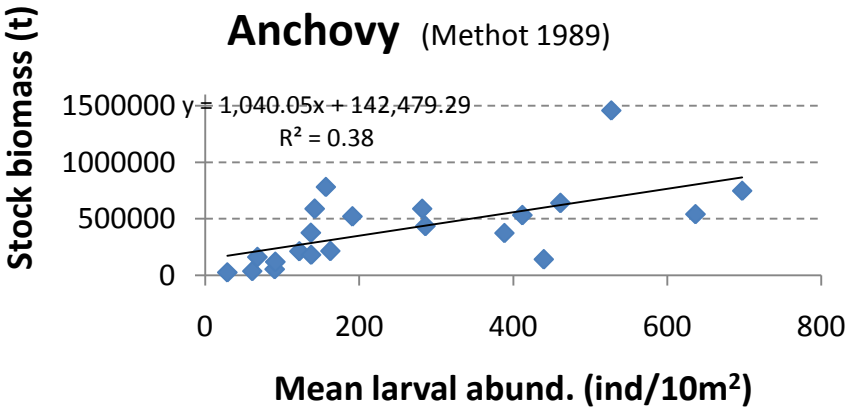
The CalCOFI ichthyoplankton time series is used to assess changes to adult fish populations in the California Current Ecosystem

- CalCOFI ichthyoplankton time series, 1951-2010
  - Monthly/quarterly sampling
  - CTD casts to 500 m:
    T, S, nutrients, O_2, chl, O_2
  - Oblique net tows to 210 m depth, fish eggs/larvae
    removed, identified, enumerated (~500 taxa)



Larvae sampled primarily at preflexion stage
Their abundance is correlated with adult abundance from stock assessments





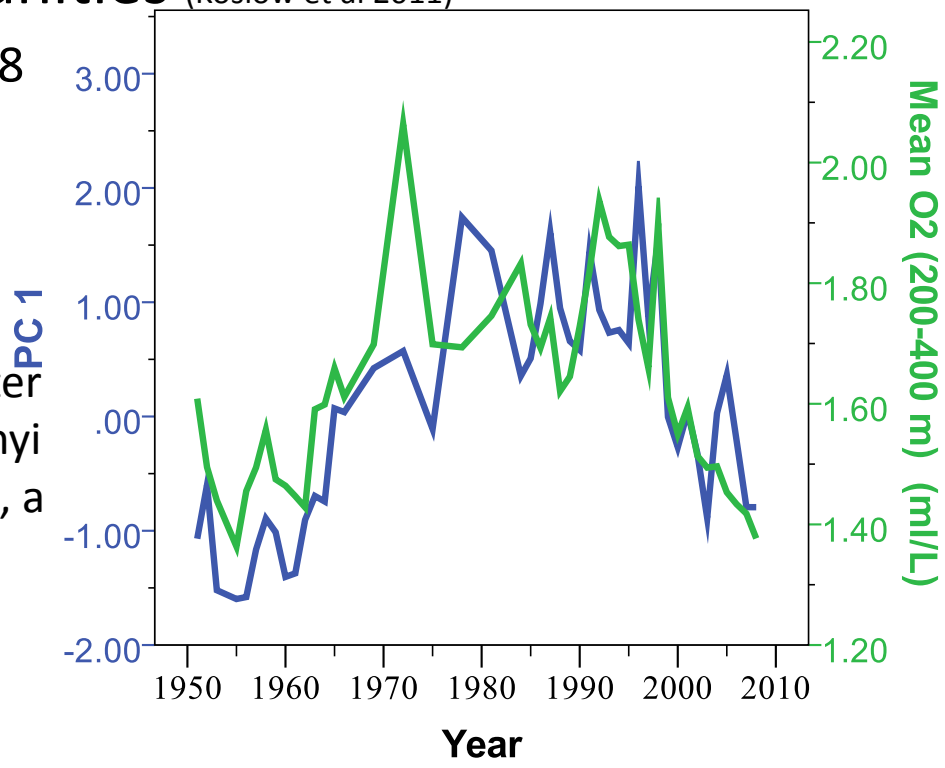
Relationships between ichthyoplankton and stock biomass also noted for California halibut & rockfishes

PCA indicates significant environmental impacts across broad fish communities (Koslow et al 2011)

86 taxa consistently sampled, 1951-2008 over 6 core CalCOFI transects

PC 1 (20.5% var explained):

- 24/27 taxa with loadings $\geq$ 0.5
- mesopelagic from 8 families:
  - Myctophidae, Gonostomatidae, Sternoptychidae, Stomiidae, Phosichthyidae, Scopelarchidae, Argentinidae, and Microstomatidae
- Includes vertical migrators & non-migrators, plankton feeders & predators
- O2: declined 20% since 1980s (Bograd et al 2008, McClatchie et al 2010)
- Mesopelagics: factor of 2.7 difference 1951-60 & 1999-2008 vs 1966-99



Declining deepwater O2 predicted in global climate models, now observed globally, esp OMZs.
Mesopelagics: dominant plankton consumers, prey of dolphins, squid, predatory fishes.

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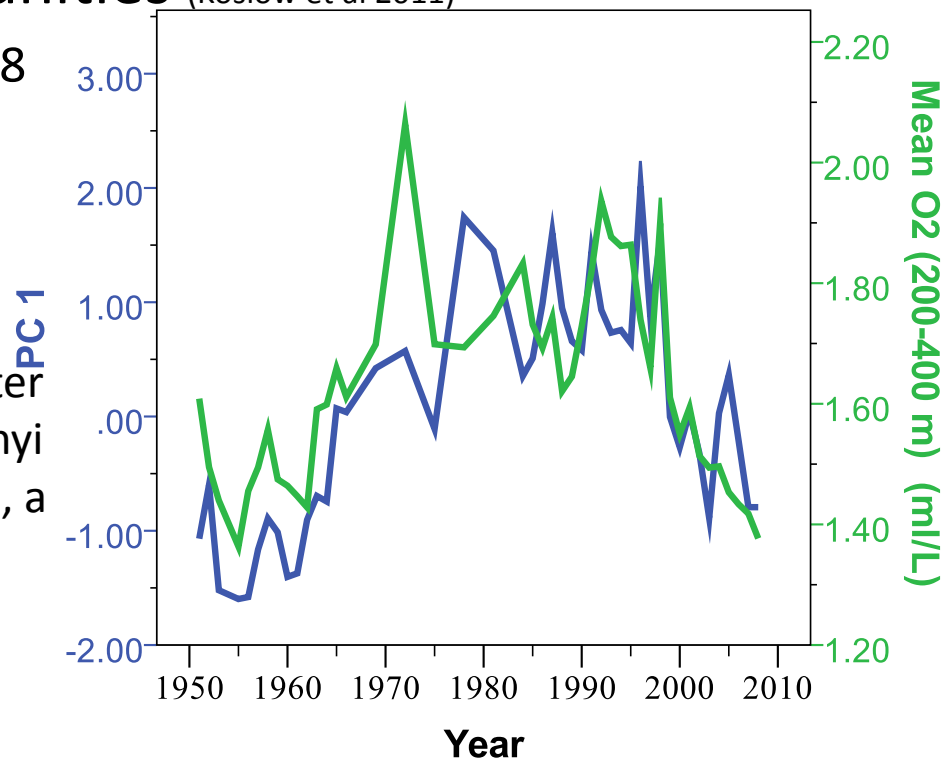
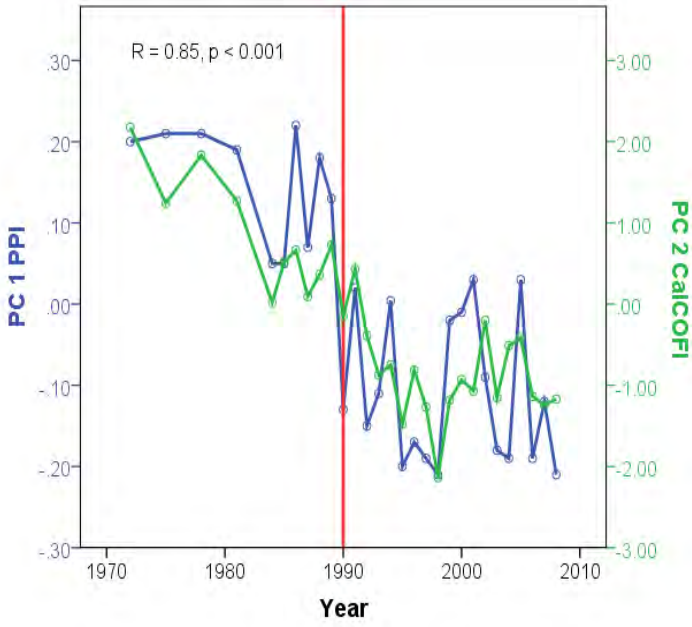


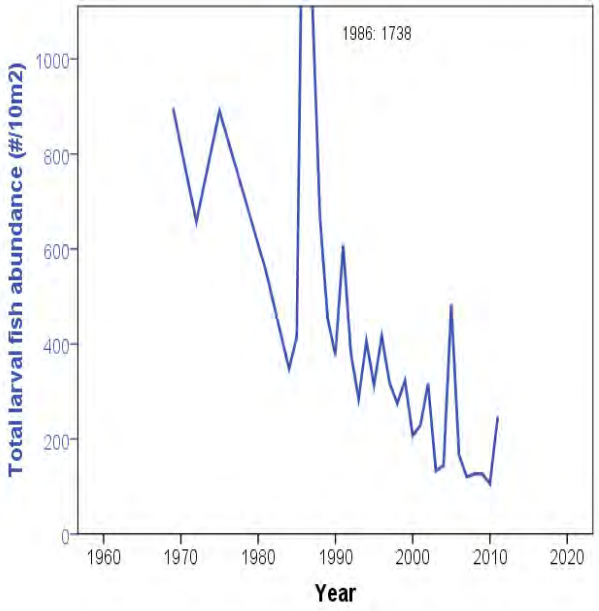
PC 1	O_2 (200-400 m)	PDO	MEI	NPGO	SST	Upwelling
R	0.75*	0.56**	0.47*	-0.23	0.45?	-0.25

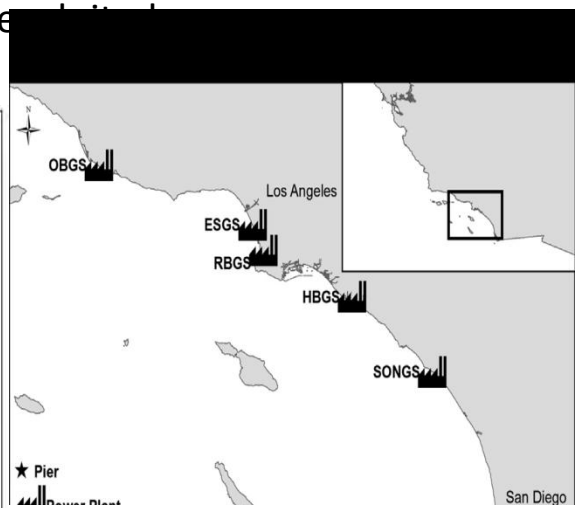
Declining deepwater O2 predicted in global climate models, now observed globally, esp OMZs.
Mesopelagics: dominant plankton consumers, prey of dolphins, squid, predatory fishes.

PC 2 (CalCOFI): declining trend of dominant fishes in CCE, mostly endemics & cool-water affinity taxa

- 72% decline in overall CalCOFI larval fish abundance since 1969
- PC 2 (CalCOFI) explains 12.4% var, 6 of the 7 most abundant species in ichthyoplankton time series loaded highly (> 0.5). 76% decline (since ~1970 (83% without sardine included):
  - Pacific hake, northern anchovy, rockfish (*Sebastes* spp.), 2 mesopelagics (myctophid (*Stenobrachius leucopsarus)* & bathylagid *(Leuroglossus stilbius)*) (+)
  - Pacific sardine (-) (Koslow et al 2013)
- PC 1 (PPI): 44% var explained for 21 nearshore fishes
  - 78% decline, 1972-83 -> 1990-2010 (Miller & McGowan 2013)
- PC 2 (CalCOFI) & PC 1 (PPI) highly correlated (R = 0.85)despite limited overlap in species, indicating decline of fishes across the CC system: nearshore & offshore fishes: epi- & mesopelagic, benthopelagic; several trophic levels, exploited and une







Temporal coherence seen in an assemblage of fishes whose larvae spatially co-occur

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

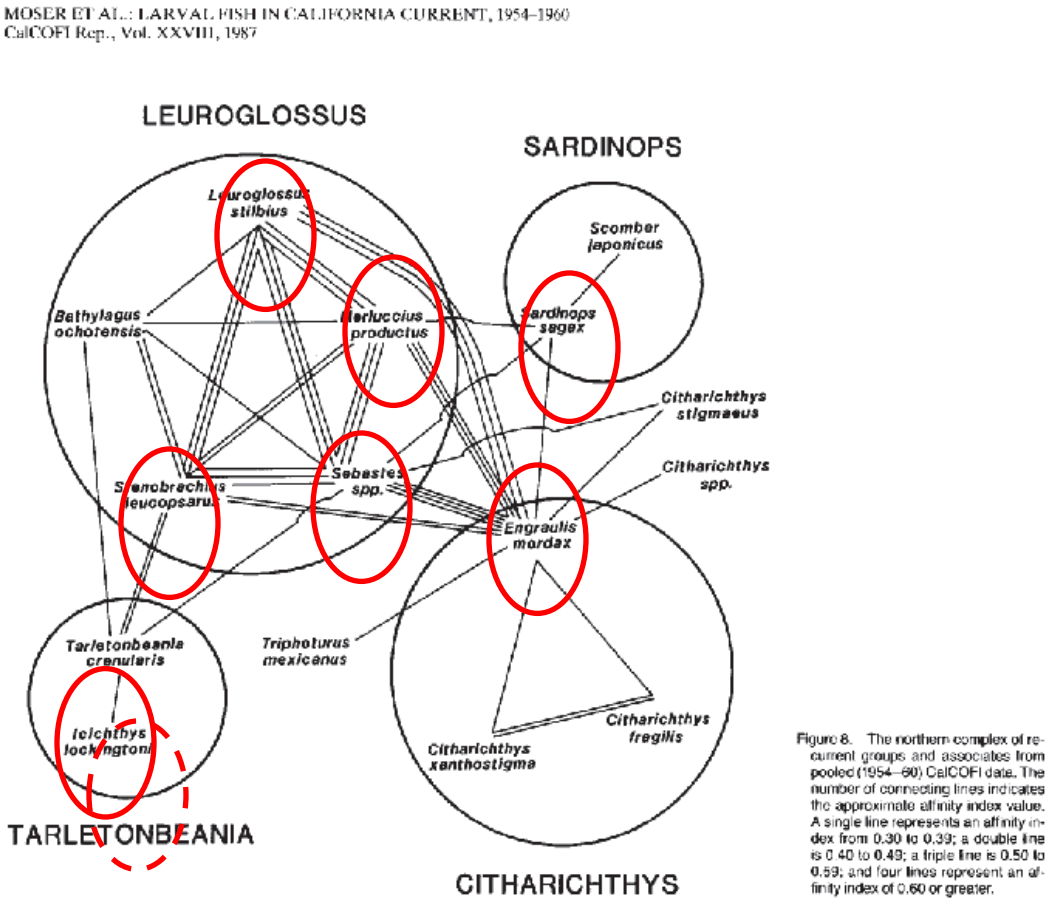
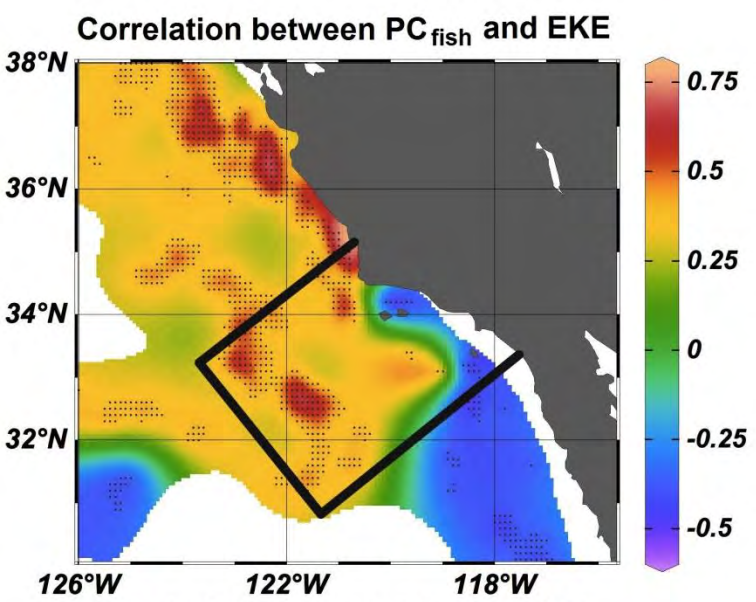
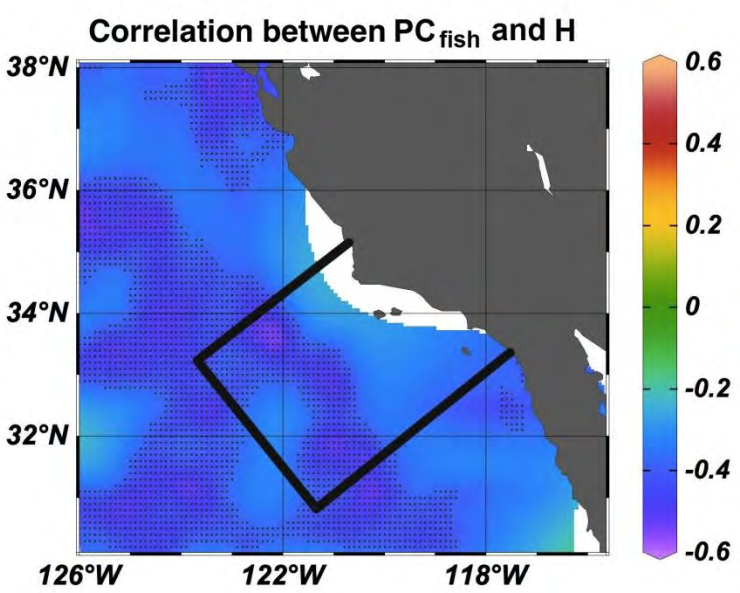


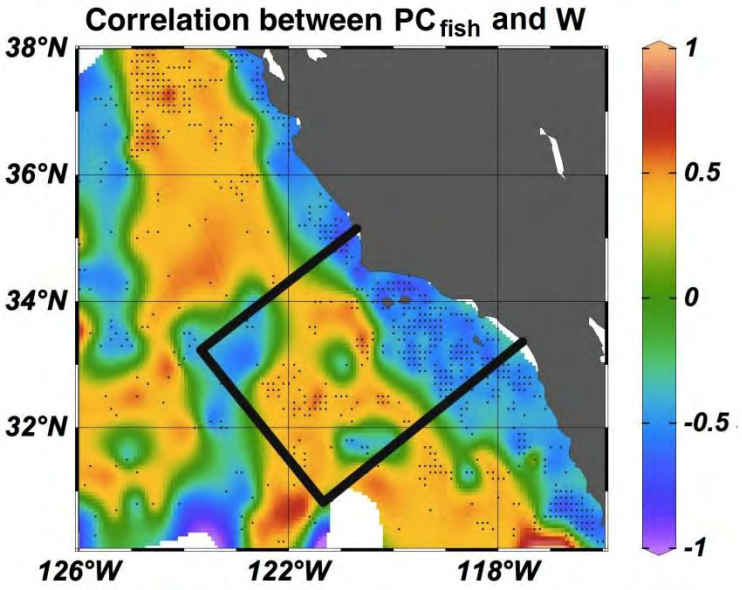
Figure 8. The northern complex of recurrent groups and associates from pooled (1954–60) CalCOFI data. The number of connecting lines indicates the approximate affinity index value. A single line represents an affinity index from 0.30 to 0.39; a double line is 0.40 to 0.49; a triple line is 0.50 to 0.59;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

Are these patterns local (SCB is an ecotone) or do they extend across the Pacific?

Distributions of *Stenobrachius leucopsarus* & medusafish *(Icichthys lockingtoni)* extend to Japan







Declining fish in CC system: links to climate:

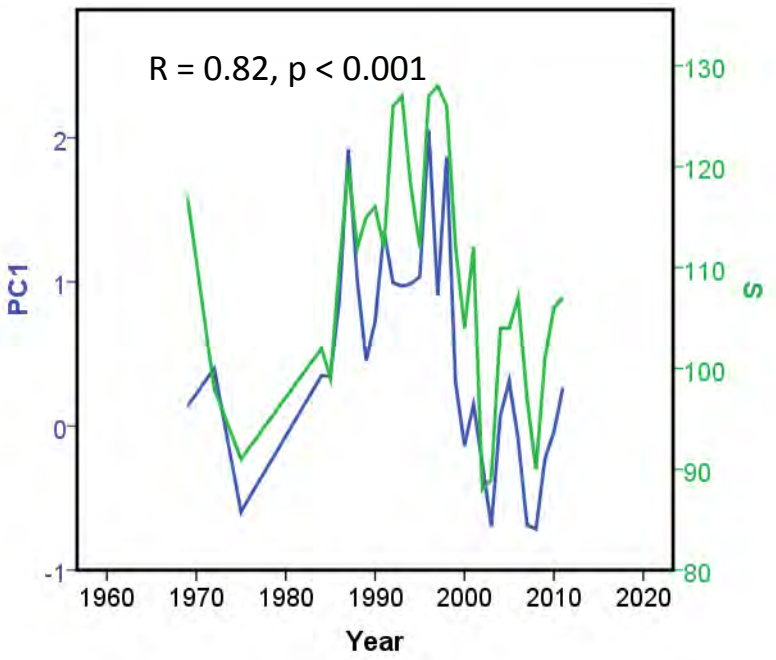
Significant relations to data-assimilative ROMS output for EKE, heat content (H) and upwelling (W), spatial correlations similar to PC1 for those variables.

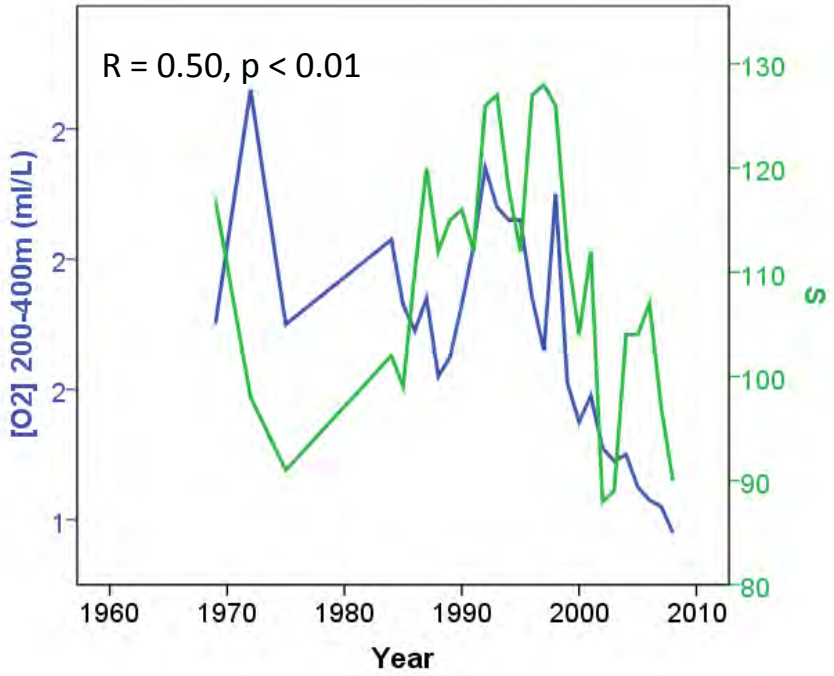
(-) correlation with spiciness (input of subtropical water), heat content, SST

(+) correlation with zooplankton DV, W, EKE (transport of CC)

	T_{10}	Spiciness	Log Zoo DV	EKE EOF 1	H EOF 1	W EOF 1
PC_{fish}	-0.57***	-0.53***	0.70***	0.40*	-0.42*	0.67***

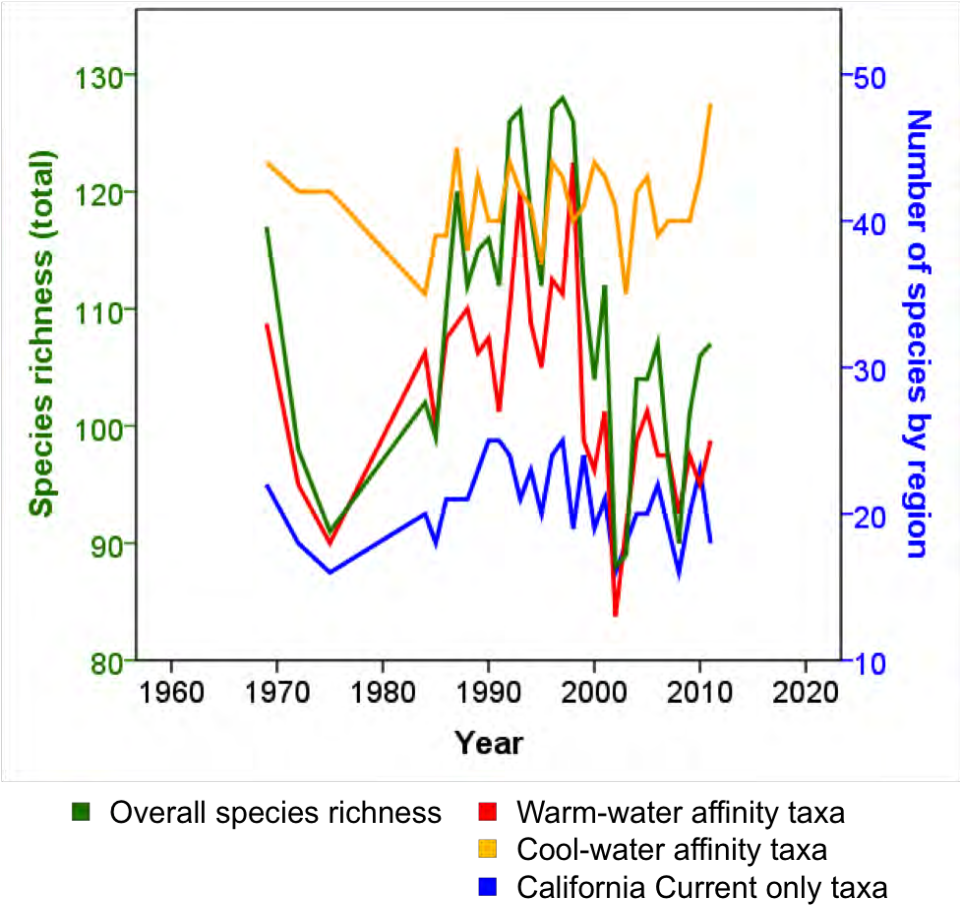
Species richness and mesopelagics /environment





	PC 1	PC 2	Deep O_2	T_{10}	W	MEI	PDO	NPGO
S	0.82***	-0.07	0.50**	0.39*	-0.42*	0.47*	0.44*	-0.48**

Species richness changes by biogeographic affinity



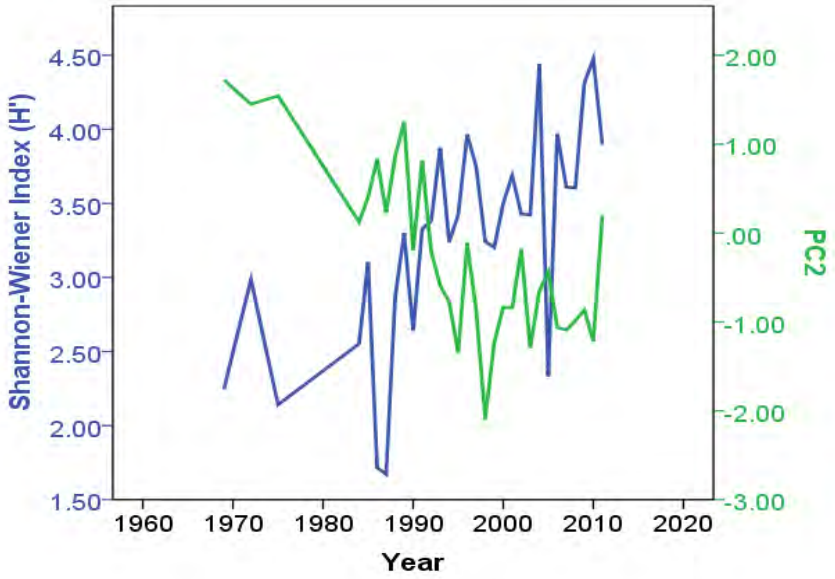
Changes in S closely linked to changes in warm-water affinity taxa

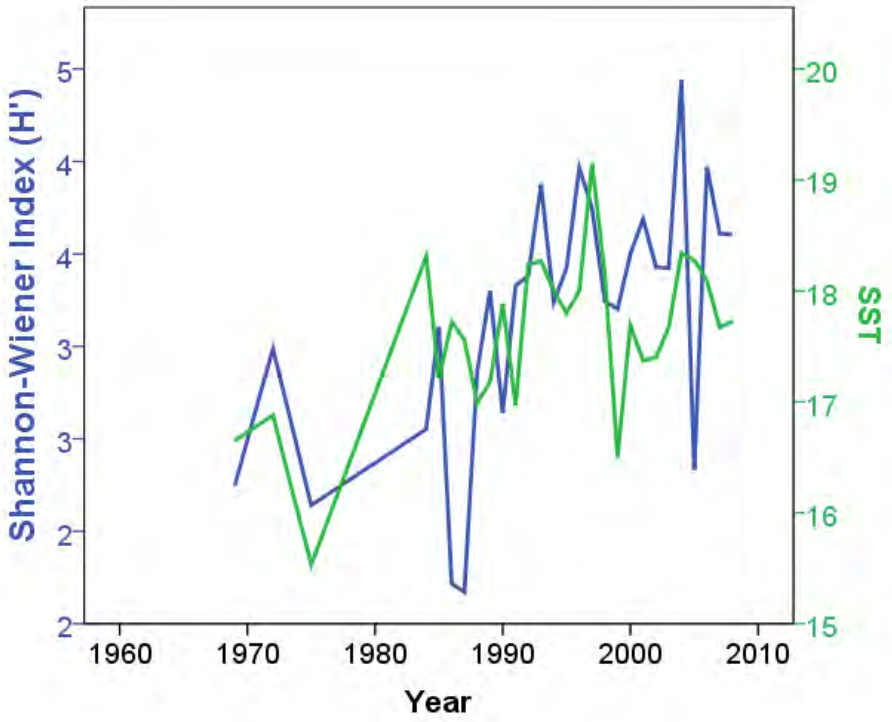
No significant change in #s of CC endemics or cool-water affinity taxa

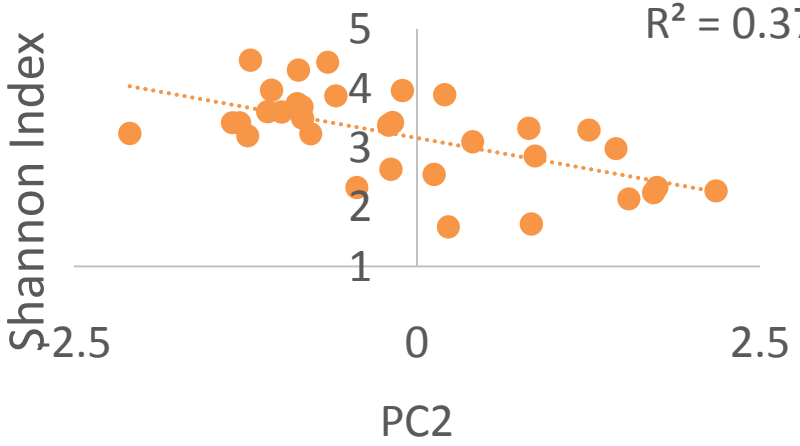
Hypothesis: CalCOFI region is an ecotone
S sensitive to influx of warm-water affinity taxa during warmer periods: + PDO/MEI/SST and their decline during cool-water periods

Shannon-Wiener Index (H') (~Evenness)

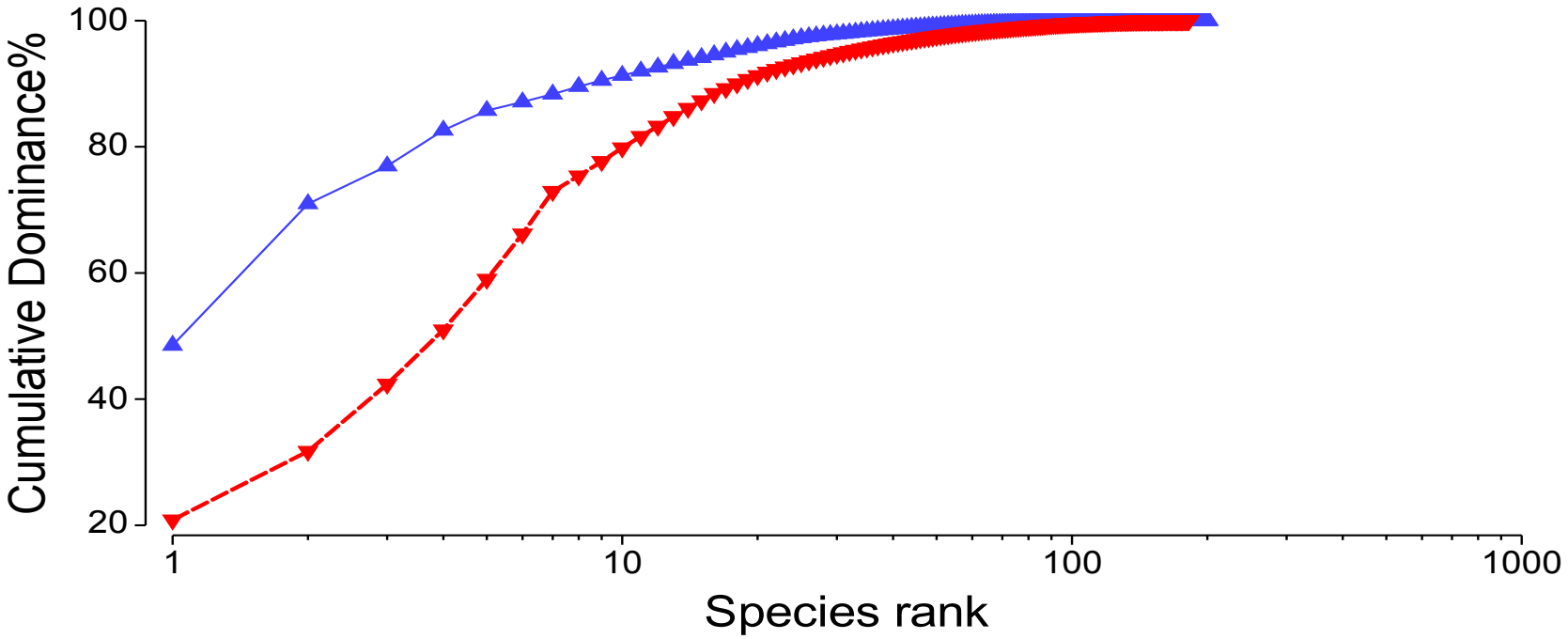
	PC 1	PC 2	Deep O_2	T_{10}	W	MEI	PDO	NPGO
H'	-0.21 †	-0.55**	-0.20 †	0.39*	0.59**	-0.03 †	-0.11 †	0.01 †







Community dominance in high PC2/low evenness years (blue) and low PC2/high evenness years (red)



10 of the 11 most abundant ichthyoplankton loaded significantly on PC 2, including northern anchovy, Pacific hake, rockfishes (*Sebastes* spp), *Leuroglossus stilbius, Stenobrachius leucopsarus*

Their decline significantly altered the dominance structure of the fish assemblage

Summary

- CalCOFI ichthyoplankton time series indicate coherent trends in
  - mesopelagic fishes in relation to midwater O_2
  - Decline since 1969 of dominant cool-water and CC endemic fishes in relation to EKE (CC transport), upwelling, heat content
- Species richness (+) correlated with warm-water mesopelagic fish abundance, indicating movements of warm-water taxa in & out of the SCB but no replacement of CC endemics or cool-water fauna
- Evenness (Shannon-Wiener Index, H') (-) correlated with PC 2: abundance of dominant cool-water fishes
  - Decline of dominant cool-water fishes (e.g. anchovy, hake, rockfishes, *Leuroglossus stilbius, Stenobrachius leucopsarus*) significantly altered the dominance structure of the fish assemblage
  - The increase in H', a measure of diversity, following the decline of the dominant fish taxa in the CCE indicates that biodiversity can prove an ambiguous measure of ecosystem status

Questions?

Collaborators

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Steve Bograd
Elliott Hazen
Mike Jacox
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