Fishes as indicators of ecosystem change and how they can be incorporated into coastal ocean observing systems

Tony Koslow

Scripps Institution of Oceanography
University of California, S.D., La Jolla, CA USA

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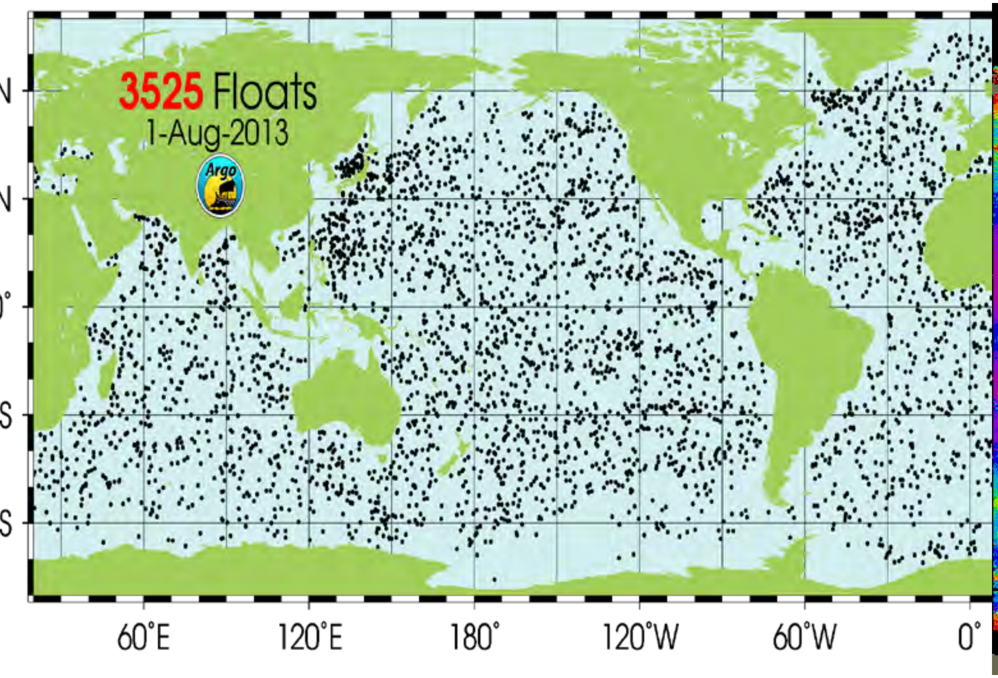
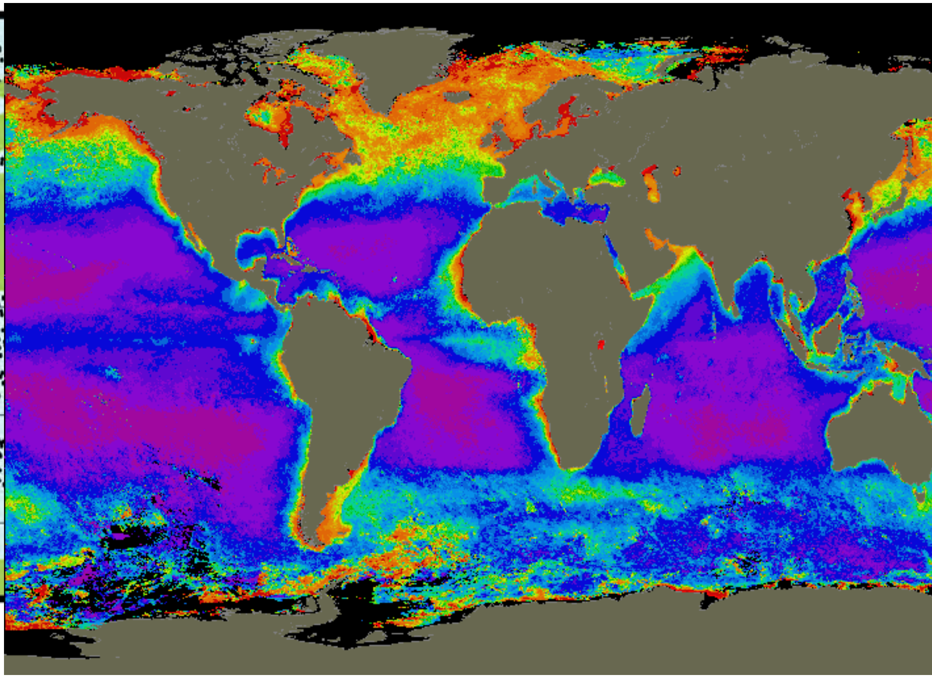
Issues & questions

- The state of ecological time series for the oceans today
- Fishes as indicators of ecological change in the oceans
- Ichthyoplankton time series: a bridge between conventional fisheries management & EBM/SOE?
- The way forward: national & international networks of ichthyoplankton time series

The state of ecological time series
Global GOOS

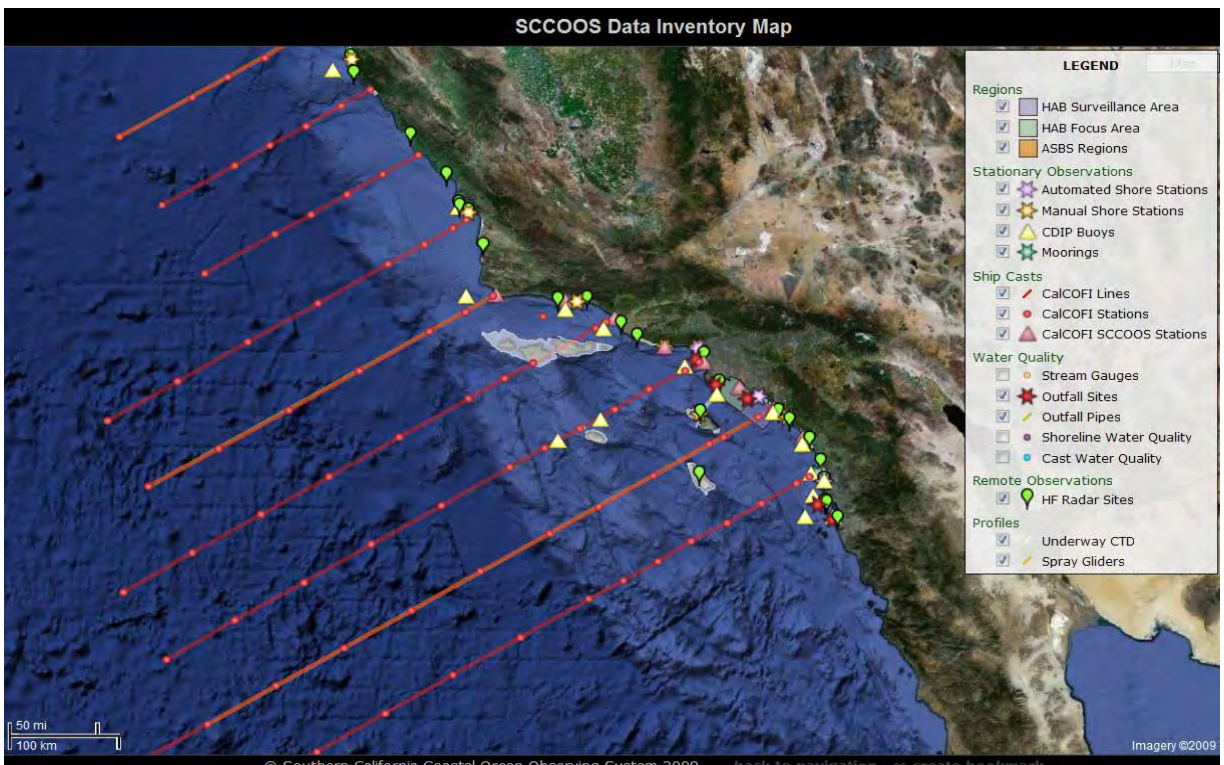
GOOS established in 1990s
Notable successes in global programs that measure readily quantified variables (e.g. T, S, chl), with satellites, Argo





Coastal observations, including GOOS

- Fishery time series
- Nearshore stations: primarily measure T, S, nutrients, O_2, HABs
- Variables related to coastal hazards: winds, waves, sea level
- *But ecological time series, particularly to species resolution, are largely neglected!*
    - required to assess shifts in diversity, distribution & abundance
    - – HOT, BATS: limited to physics & biogeochemistry; zooplankton analyzed in bulk
    - – Zooplankton: sampled by CPR and some shore lines/stations, e.g. NH line (Oregon), A-line (Japan)

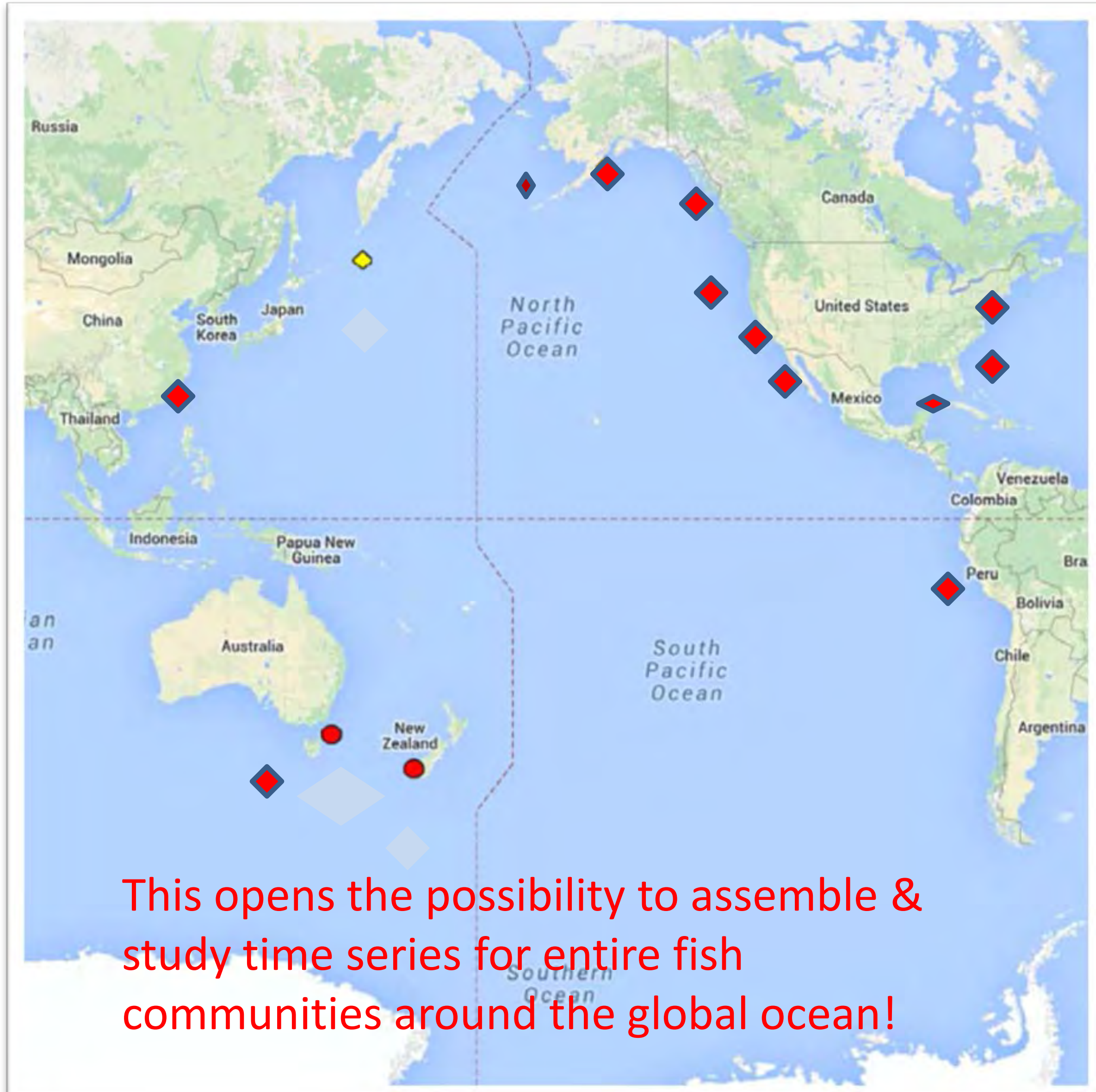


Ichthyoplankton time series:
Species-resolution fishery-independent fish community time series

In fact there are a number of ichthyoplankton time series that to date have been used primarily to monitor commercial species…..

Egg production surveys to estimate spawning stock are common but noted for their formidable data requirements & wide confidence limits.

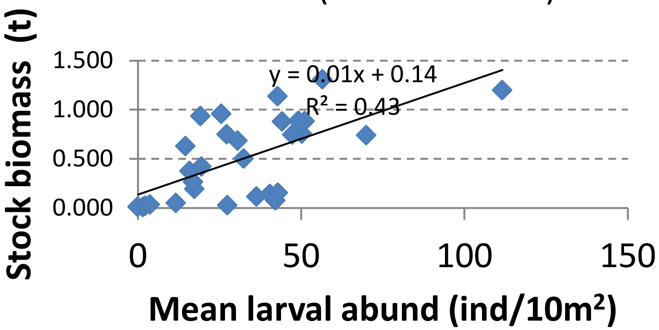
However, larval abundance alone provides effective indices of spawning stock biomass



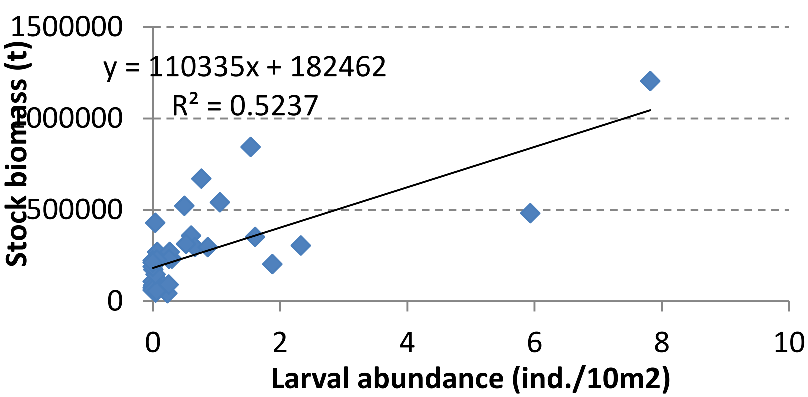
This opens the possibility to assemble & study time series for entire fish communities around the global ocean!

Ichthyoplankton as proxies for spawning stock biomass

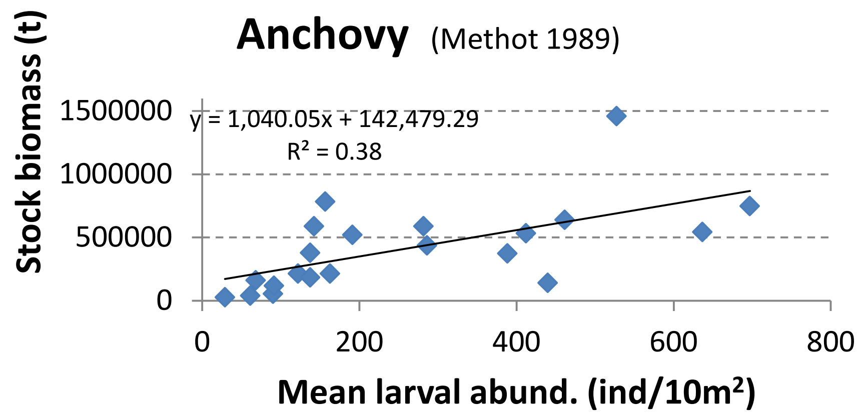
Sardine (Hill et al. 2010)



Pacific mackerel (Crone et al 2009, 2011)



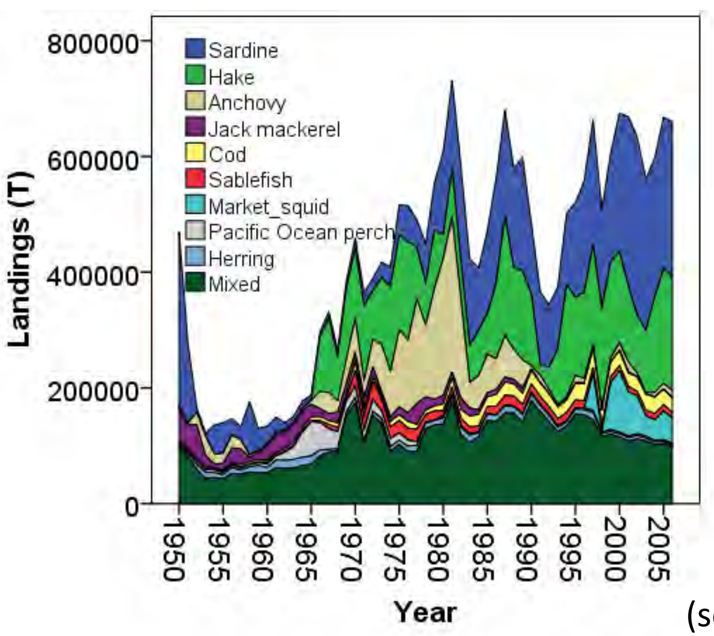
Anchovy (Methot 1989)



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

Why sample ichthyoplankton to assess fish communities?

- Importance of fish for human well-being
  - ~ 1 billion people depend on fish as their primary source of protein
- Importance for the ecology of the oceans
  - Link between plankton and higher trophic levels (fish, squids, seabirds, mammals)
- Sensitive to climate and human stressors: overfishing, habitat loss, pollution, changing temperature, eutrophication, ocean acidification and deoxygenation
- Commercial fisheries data contain multiple biases
  - Market influences, misreporting , etc
- Commercial fishes represent a small proportion of marine fish species
- Commercial data fail to reflect trends in fish communities

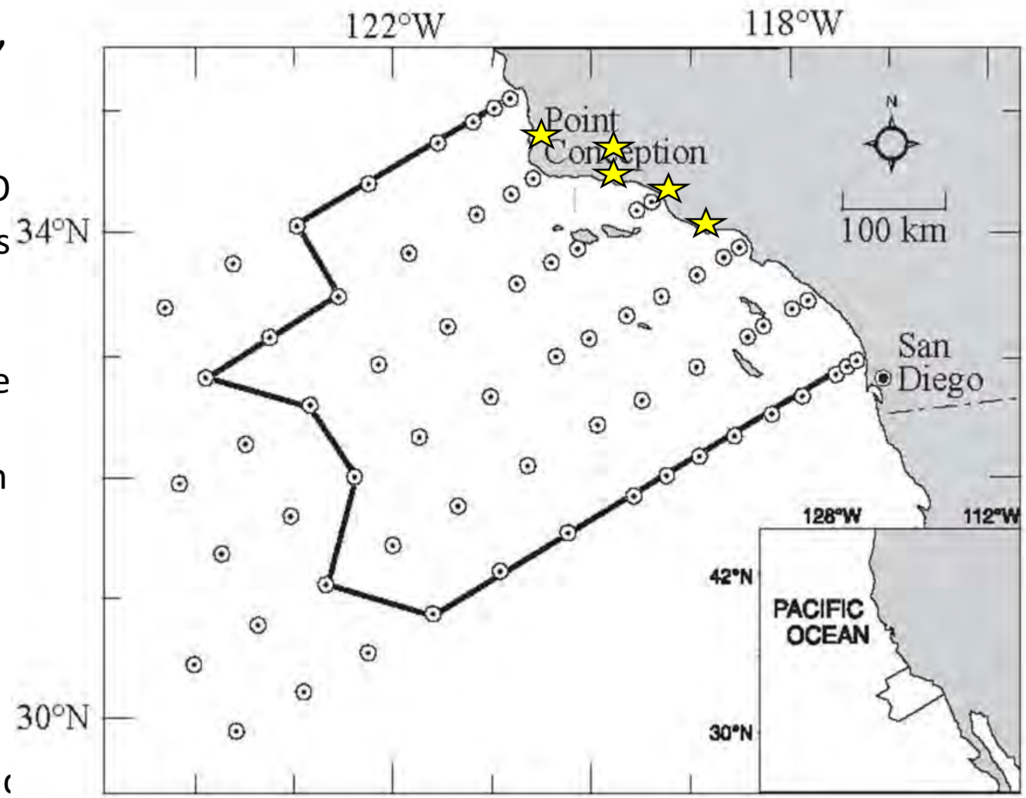


- California Current landings: stable since ~1980 with interannual variability

(source: SAUP)

Fishery-independent sampling programs: What do they tell us?

- CalCOFI ichthyoplankton time series, 1951-2010
  - Monthly/quarterly sampling
  - CTD casts to 500 m: T, S, nutrients, O
  - Oblique net tows to 210 m depth, fis eggs/larvae removed, identified, enumerated (~500 taxa)
  - Rare species removed (0 > 50% of ye leaving 86 taxa
  - Annual means over consistently sam region provide proxies for spawning biomass



- Power plant intakes, 1972-2010
  - 5 power plants, intakes at 10 – 27m ((x = 14m)
  - Impinged material sampled 5 – 13 times/yr (x = 8.8)

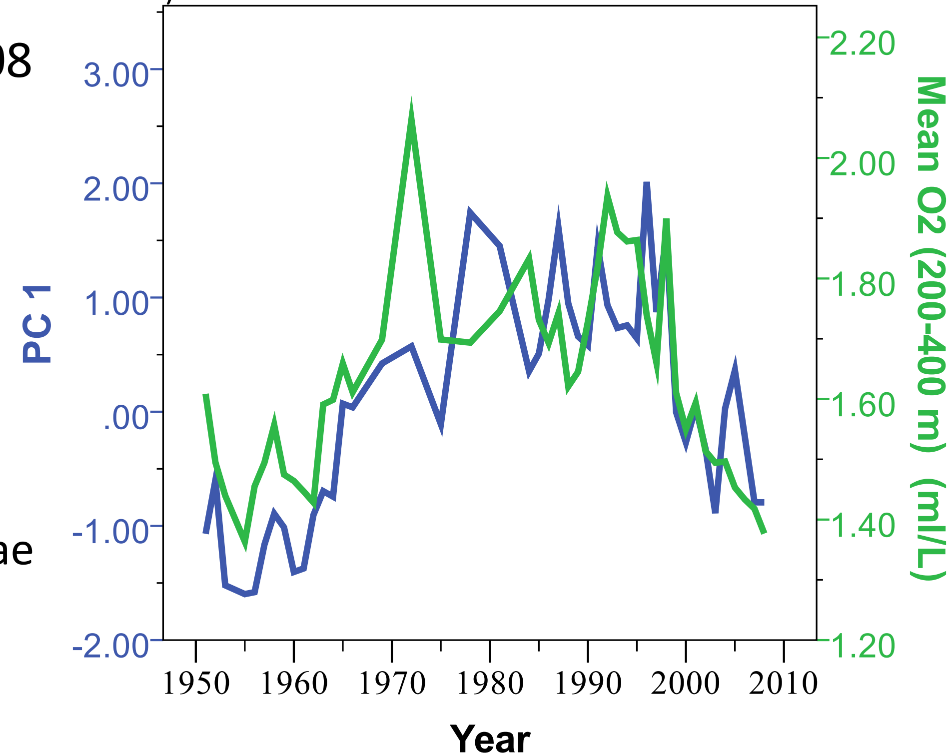
  - PCA carried out on both time series

CalCOFI ichthyoplankton data: impacts of climate change? (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 ≥ 0.5 mesopelagic from 8 families:
  - Myctophidae, Gonostomatidae, Sternoptychidae, Stomiidae, Phosichthyidae, Scopelarchidae, Argentinidae, and Microstomatidae
- Includes vertical migrators & non-migrators, plankton feeders & predators

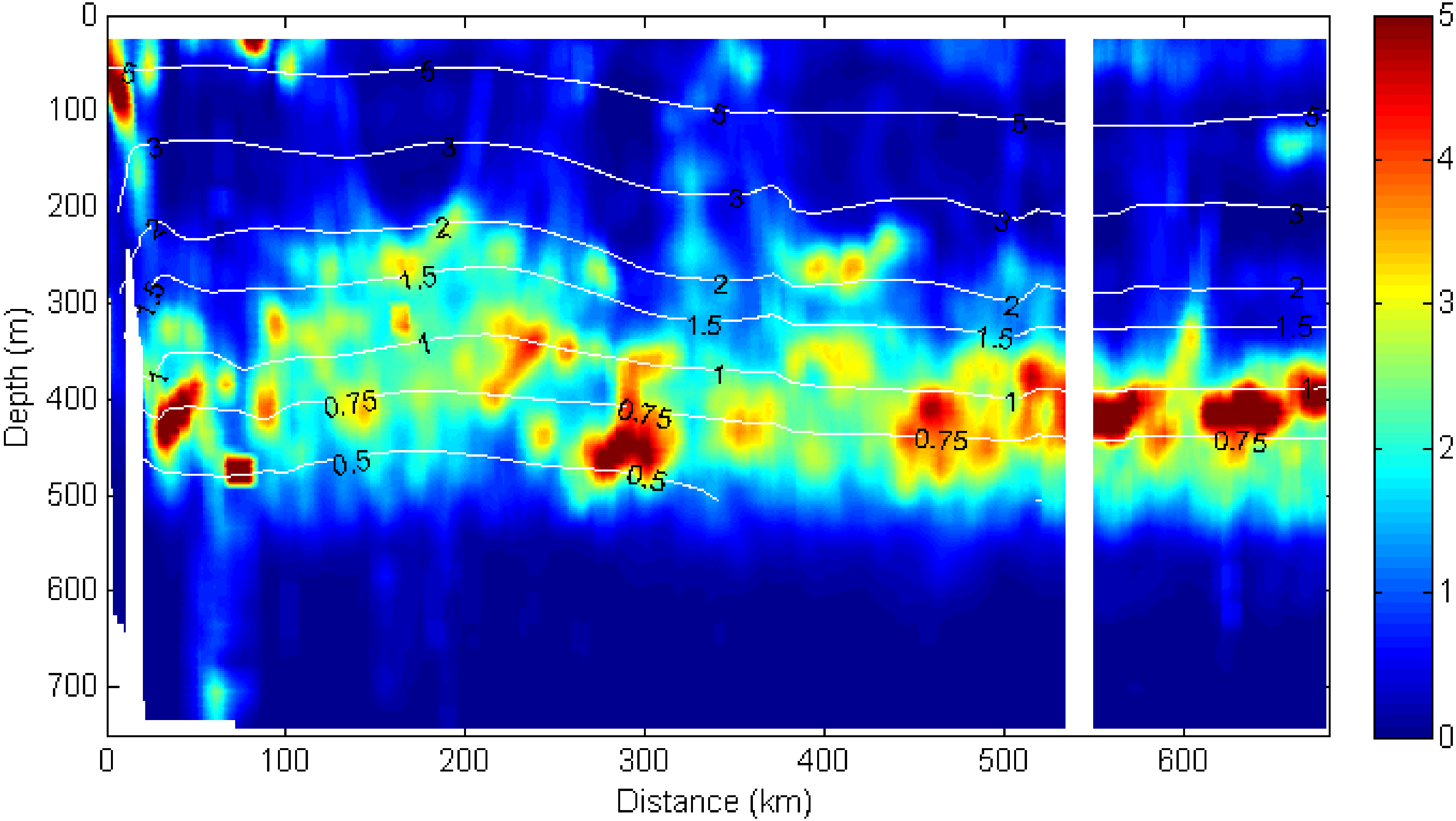


PC 1	O_2 (200-400 m)	PDO	MEI	NPGO	SST	Upwelling
R	0.75^{*}	0.56^{**}	0.47^{*}	-0.23	$0.45^{?}$	-0.25

Declining deepwater O2 predicted in global climate models, now observed globally, esp OMZs.

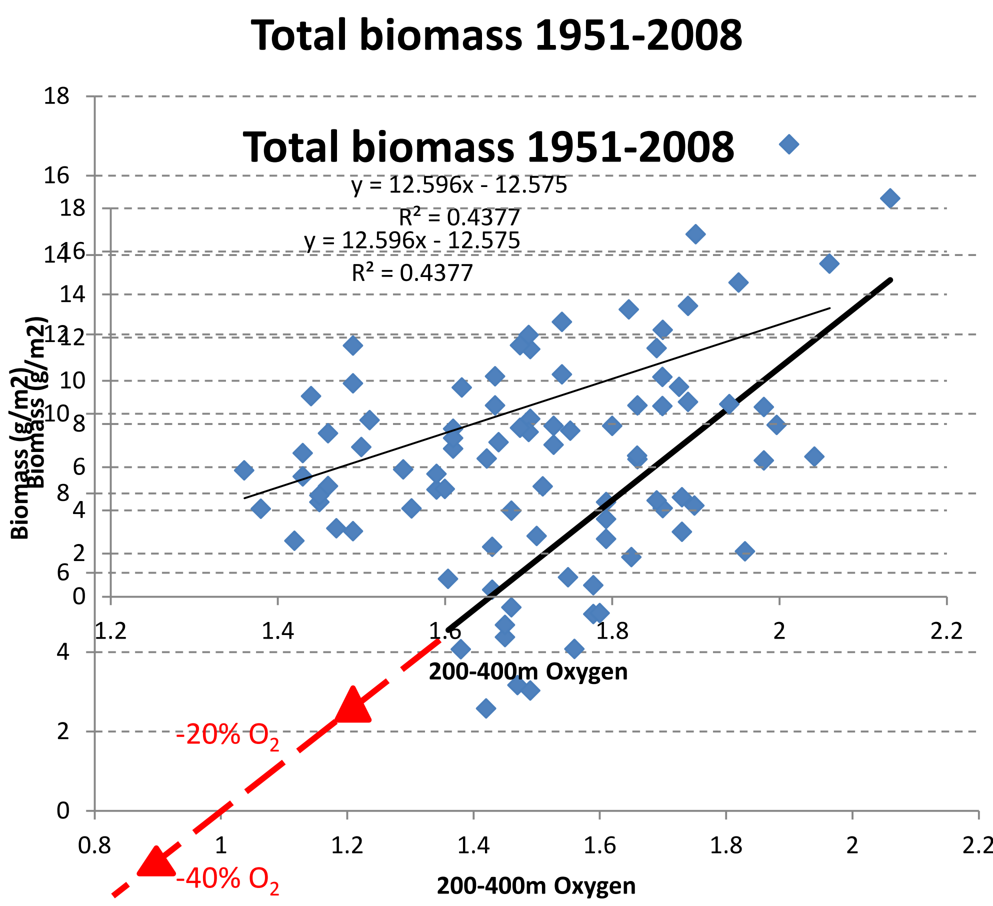
Mesopelagics: dominant plankton consumers, prey of dolphins, squid, predatory fishes.

Daytime distribution of midwater fish above Oxygen Minimum Zone
Jan 2010 CalCOFI cruise, 6 transects combined



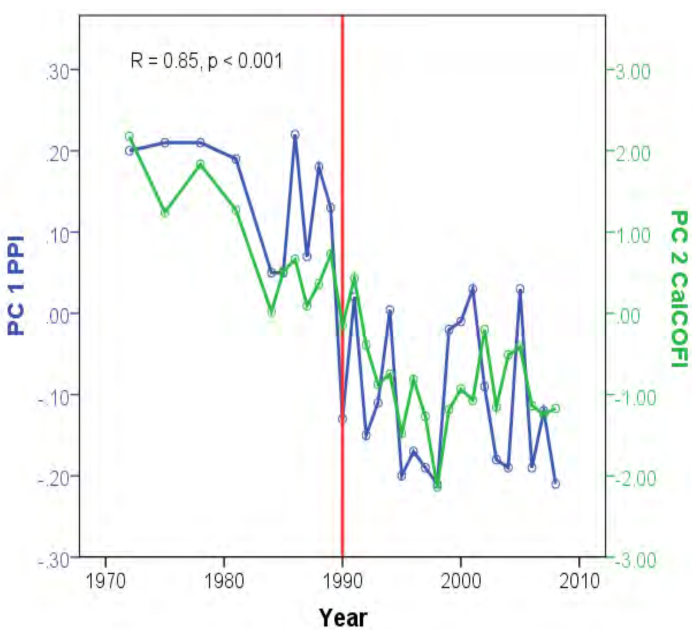
Implications of climate change & deoxygenation

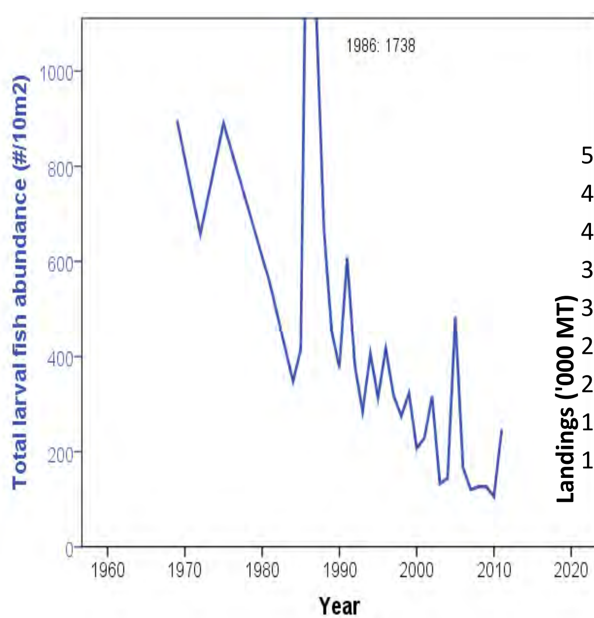
- Mesopelagic fish biomass estimated from recent acoustic/trawl studies in CalCOFI area; past values estimated from relative abundance of total mesopelagic fish larvae
- 3.5-fold range in estimated biomass of mesopelagic fish, 1951-2008
- Extrapolation of a further 20-40% decline in O_2 concentration implies disappearance, if linear trend continues!
- Is the southern CCLME unique as an ecotone or are mesopelagics elsewhere on the west coast & N Pacific responding similarly to declining O2?

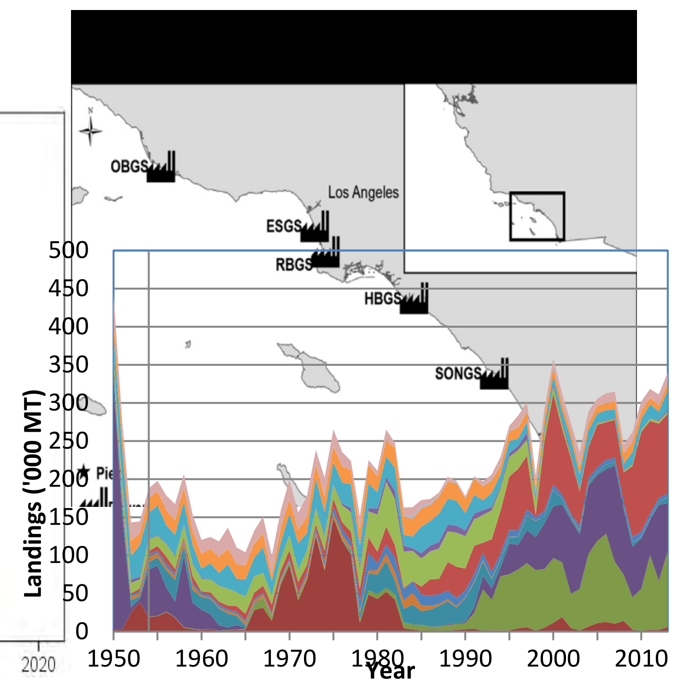


PC 2 (CalCOFI) & PC 1 (PPI): dominant fishes' trend

- 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 unexploited
- *Trends not captured by the commercial landings data*



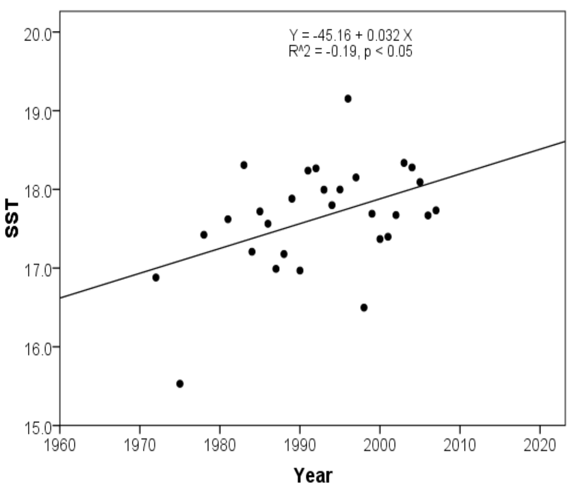


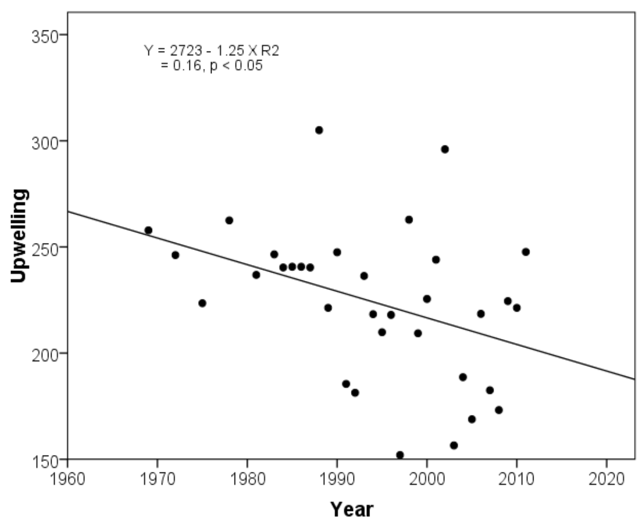


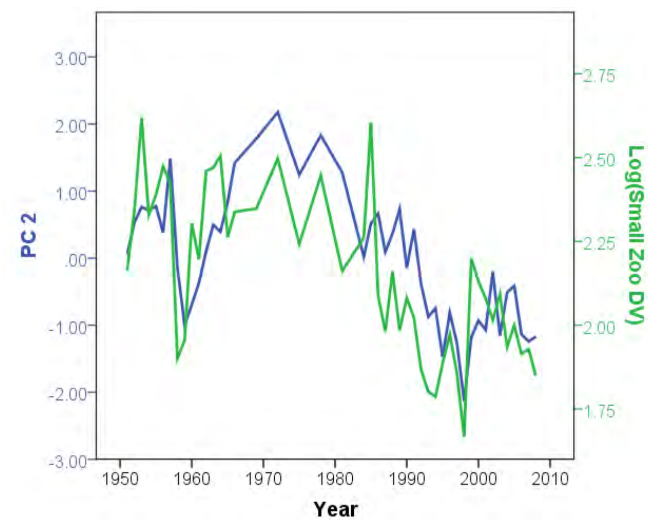
Declining fish in CC system: links to climate

- Decline correlated (-) with increasing SST, (+) with upwelling (declining), and SD sea level (SL), a proxy for advection of the CC (advects nutrients, zooplankton in southern CC), indicators of declining productivity
- Not correlated with large-scale climate indices (MEI, PDO, NPGO)

	SST	**Upwelling**	**SD SL**	**Zoo DV**
PC1 (PPI)	-0.58**	0.52**	-0.53*	0.66***
PC 2 (CalCOFI)	-0.54***	0.42**	-0.45**	0.71***







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)

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

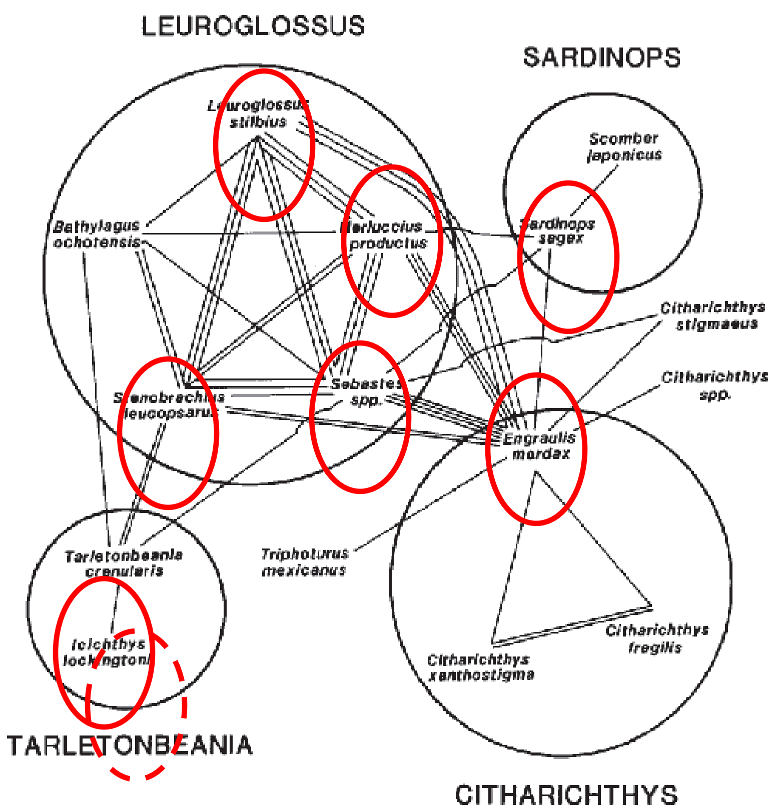
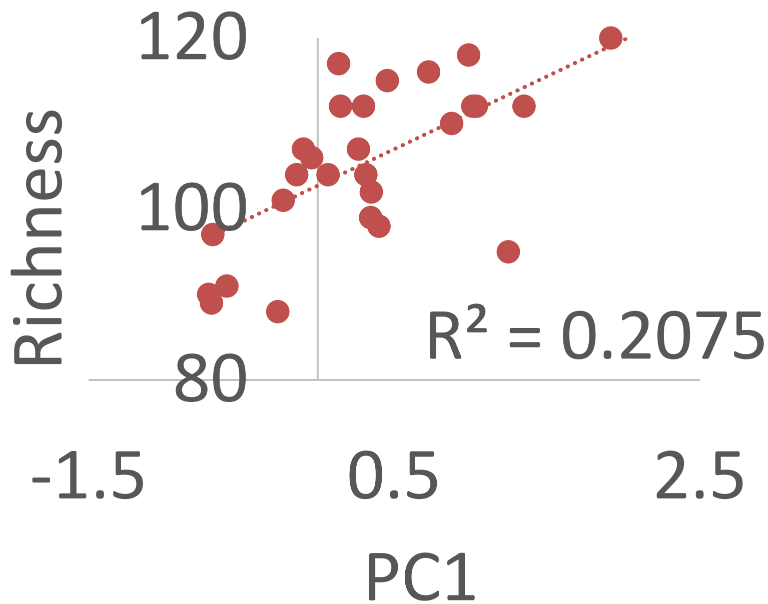


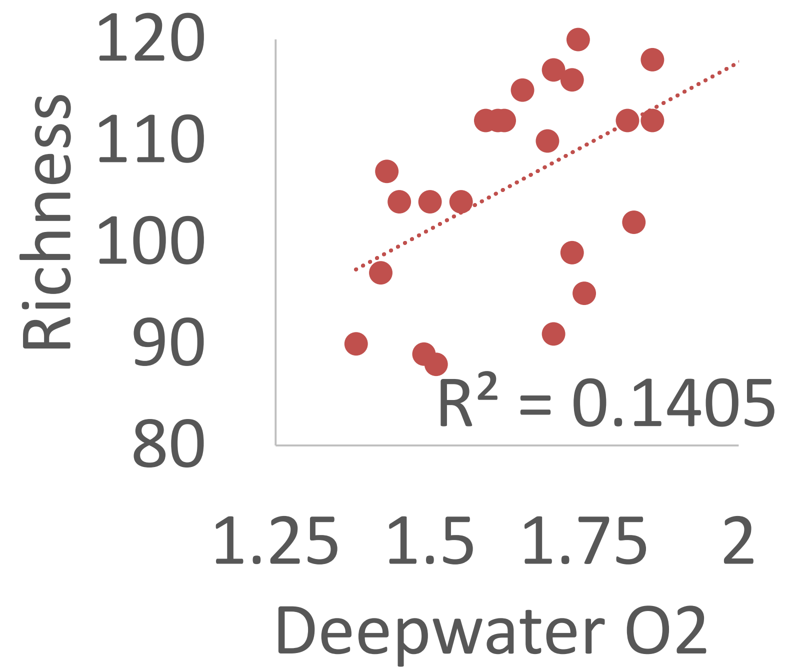
Figure 8. The northern complex of recurrent groups and associates from pooled (1954–60) CalCOFI data. The number of connecting lines indicates the approximate affinity index value. A single line represents an affinity index from 0.30 to 0.39; a double line is 0.40 to 0.49; a triple line is 0.50 to 0.59;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

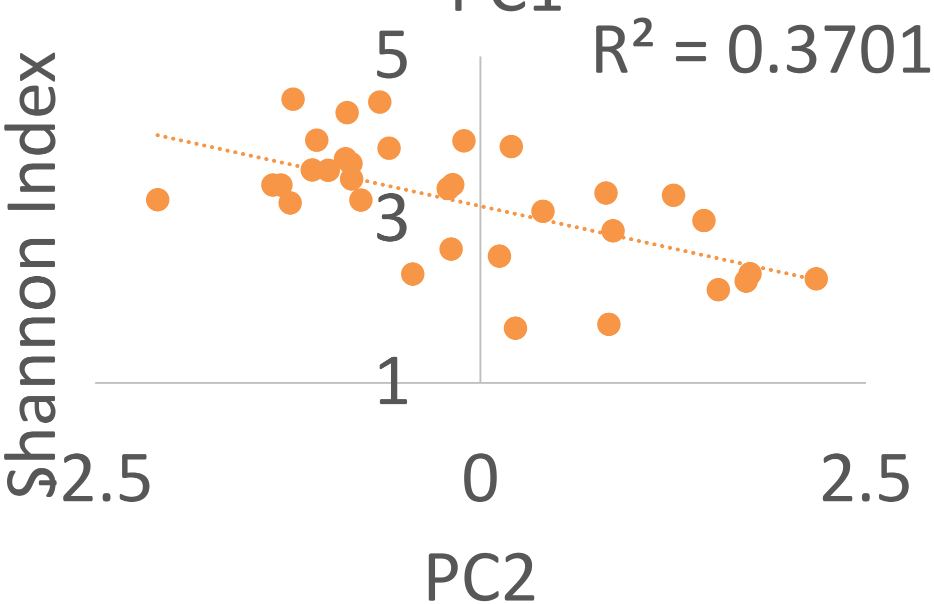
Are these patterns local (SCB is an ecotone) or do they extend across the Pacific?

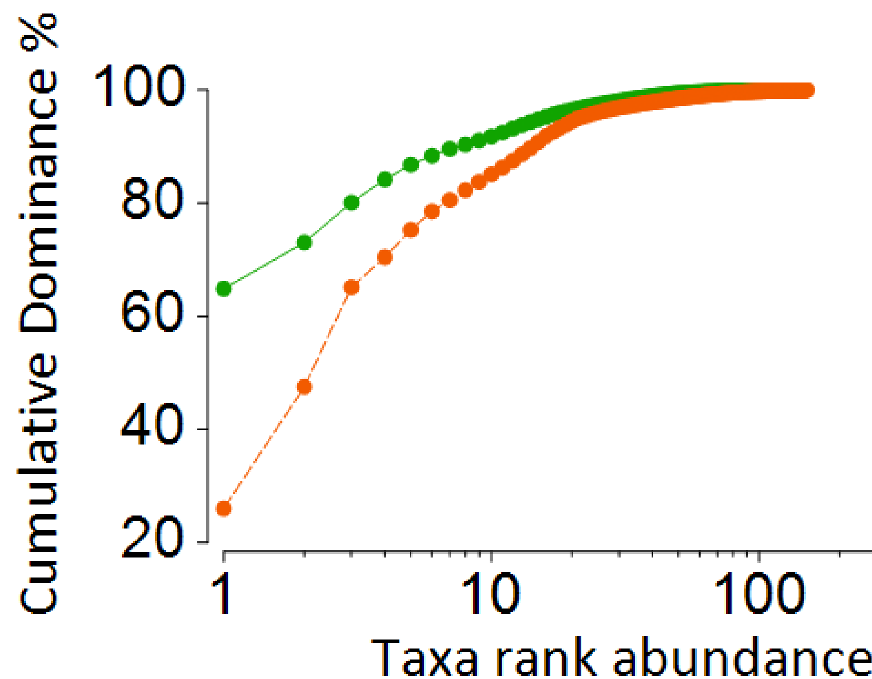
Distributions of *Stenobrachius leucopsarus* & medusafish *(Icichthys lockingtoni)* extend to Japan

Climate and fish community diversity: CalCOFI analysis









Critical role of fish time series in global observing systems

- Fish communities (e.g. midwater fishes, assemblages with cool- or warm-water affinities) provide sensitive, ecologically important EOVs readily sampled via the ichthyoplankton
- Fishery landings tell very little about underlying productivity and ecosystem status
  - Biases
  - Commercial fishes represent a limited proportion of regional fish populations
- The status of fish communities as input to EBM and stock assessments:
  - Recent declines of cool-water fishes (incl. anchovy, hake) may be community-wide/ecosystem responses, largely to climate forcing, not isolated population responses to fishing
- Status of fish communities: critical input to state of the environment reports

The future: networks of ichthyoplankton time series to assess large-scale response of fishes to environmental forcing

- US, Canada, Mexico: potential for collaboration to assess climate response of fish populations along the west coast of North America
- US-wide potential for collaboration among NOAA labs in Alaska, Pacific, Atlantic & Gulf of Mexico
- Potential for Pacific-wide network?

Proposed ichthyoplankton monitoring

- Where there are ichthyoplankton surveys for stock assessment
  - Sort, identify & enumerate ALL fish larvae to lowest taxa possible
  - Expand seasonal coverage to year-round to sample all spawning fishes
    - reduced sampling in “off” seasons possible
- Introduce ichthyoplankton sampling into ocean obs programs
  - Reduced sampling (single transect) captures patterns in abundance of key taxa & dominant multivariate patterns

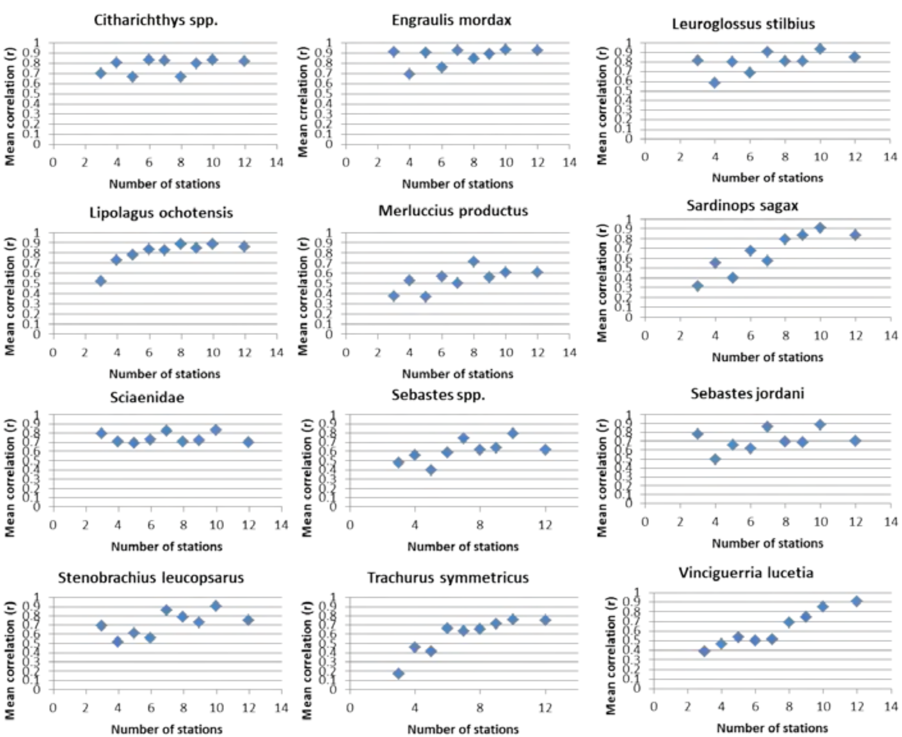
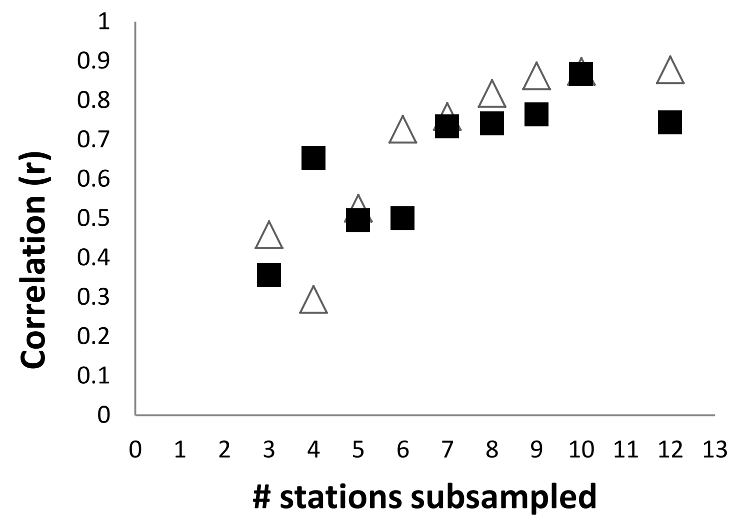
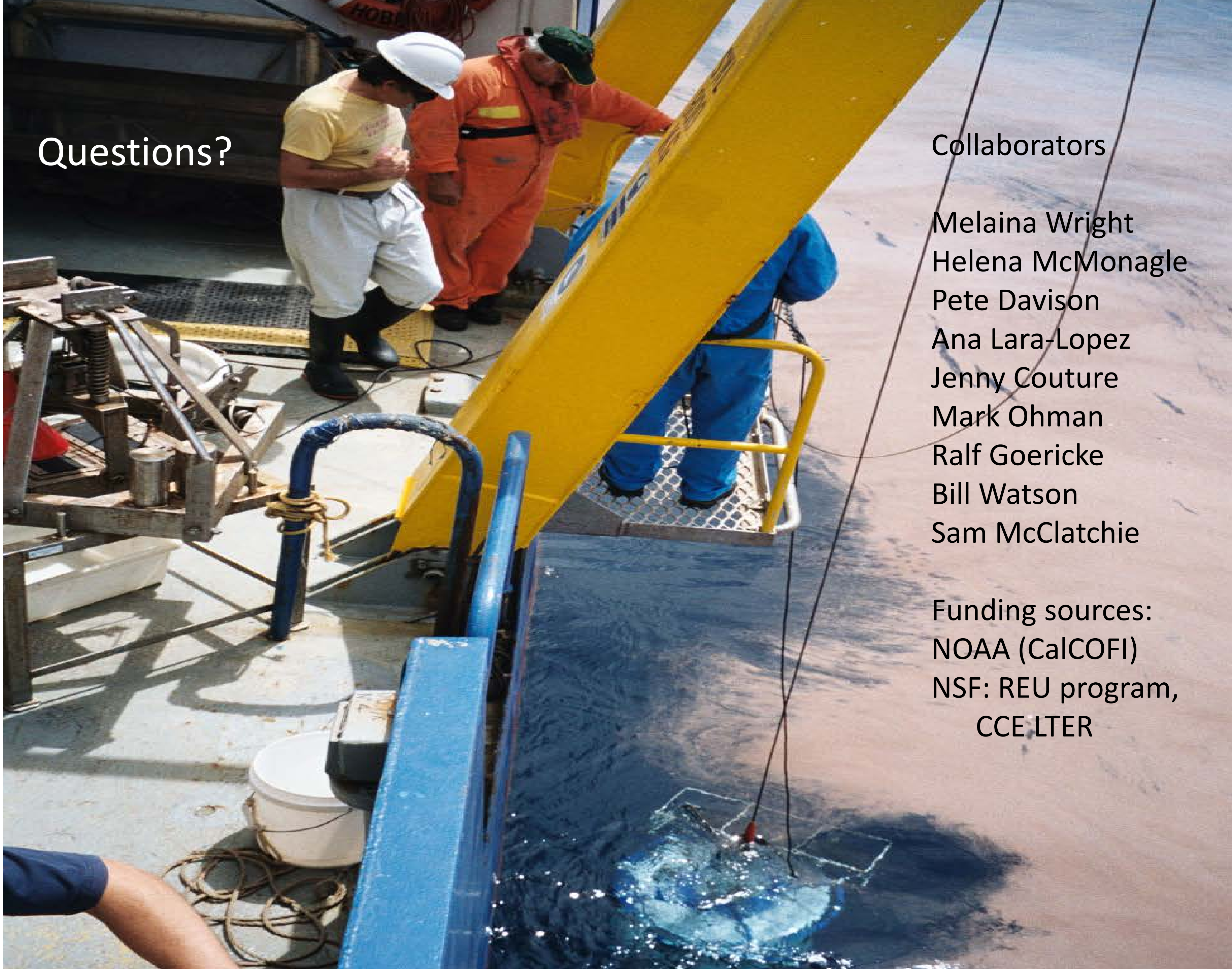


Figure 3. Correlations between the log-tranformed abundance time series of the 12 most abundant taxa of the full CalCOFI data set and the abundance time series of those taxa for transects or fractions of transects. Mean correlation values were calculated for subsamples sharing the same number of sampling stations.



Summary

- Fish are essential ocean variables that need to be monitored systematically in LMEs of the world ocean
  - Importance to human economies and health
  - Ecological importance
  - Sensitivity to climate and anthropogenic influences
- Commercial fishery data are inadequate: biases & limited taxonomic coverage
- 70% decline in fish fauna of the CC since 1970 not reflected in fish landings, chl, or primary production
- A representative global system of species-level time series is required: consistent, systematic ocean obs programs in representative LMEs: CalCOFI or reduced-sampling model
- The cost is modest and the spinoffs are substantial:
  - Development of interdisciplinary marine science infrastructure: capacity-building
  - Understanding impacts of anthropogenic stressors in relation to climate variability & change
  - Inputs to stock assessments & IEA/SOE reports
    - enhances client support/sustainability of ocean obs programs



Questions?

Collaborators

Melaina Wright
Helena McMonagle
Pete Davison
Ana Lara-Lopez
Jenny Couture
Mark Ohman
Ralf Goericke
Bill Watson
Sam McClatchie

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