Design of ocean observation systems: sampling requirements to monitor fish population and community trends as Essential Ocean Variables

Tony Koslow and Melaina Wright

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

PICES Conference, Yeosu, Korea, October 2014

Questions

- Why do we need to sample fish communities?

- How well are fish communities sampled today?

- What are the impediments to observing fish communities?

- What is a way forward?

Why sample fish communities?

- Importance 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 few percent of marine fish species
- Commercial data fail to reflect trends in fish communities
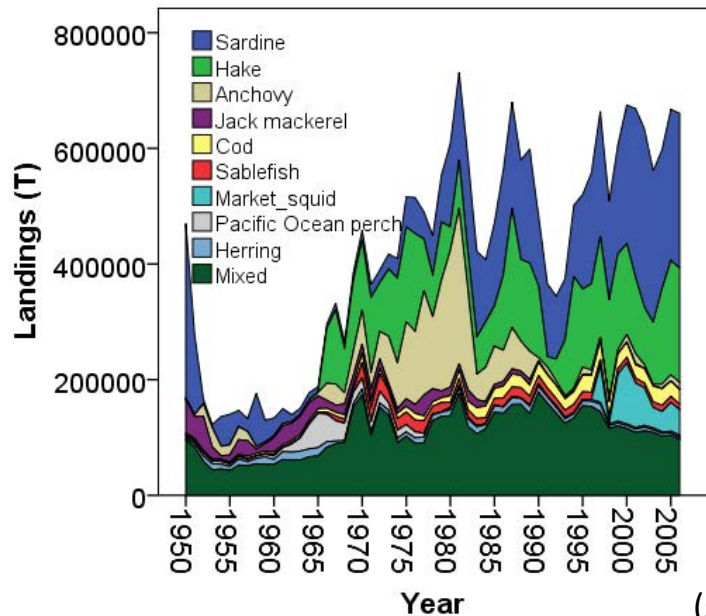

(source: SAUP)

- California Current landings: stable since ~1980 with interannual variability
- Changes to individual species:
  - Decline of anchovy & increase of sardine since ~1978 (climate)
  - Decline of POP post-60s (fishing)
  - Increase in market squid
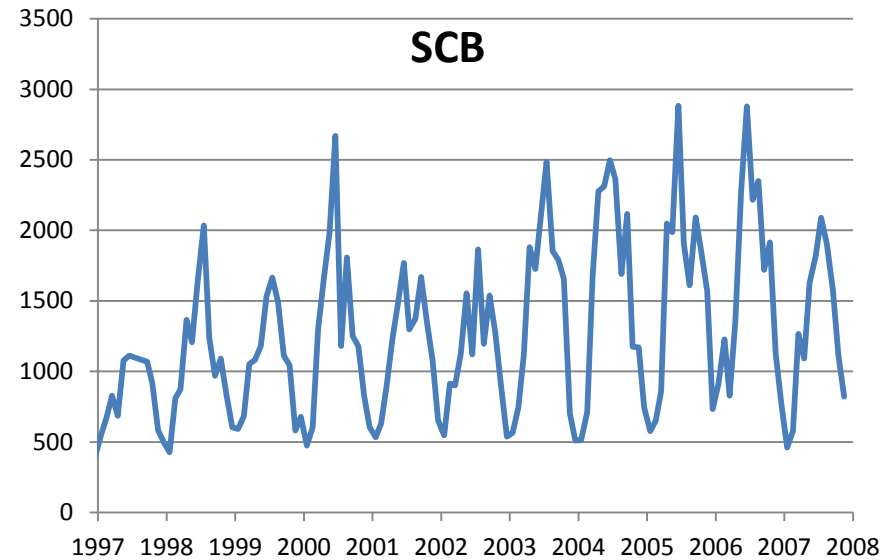 - Fluctuating hake & sardine

Why sample fish communities?

- Simple indices of ocean environment (e.g. chl, primary production) fail to capture major shifts in LMEs
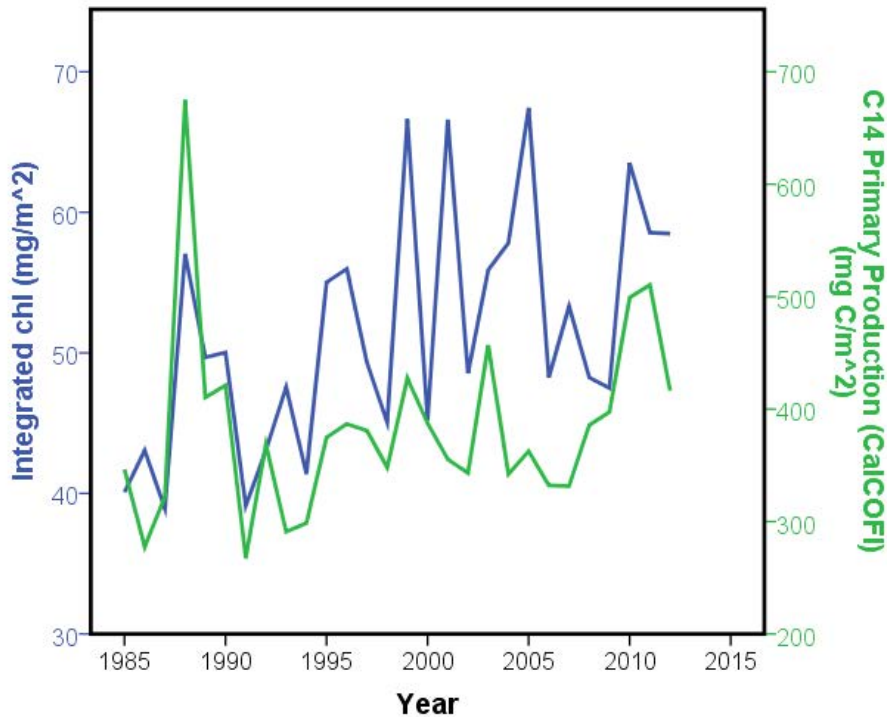
CalCOFI mean annual integrated chl & primary production (C-14)

Increasing trends

Primary production in Southern California Bight (SCB) from satellite chl+ algorithm (Kahru, pers commn)

Significant increasing trend in seasonal maxima

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_2, chl
  - Oblique net tows to 210 m depth, fish eggs/larvae removed, identified, enumerated (~500 taxa)
  - Rare species removed (0 > 50% of years), leaving 86 taxa
  - Annual means over consistently sampled region provide proxies for spawning biomass

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

  - PCA carried out on both time series
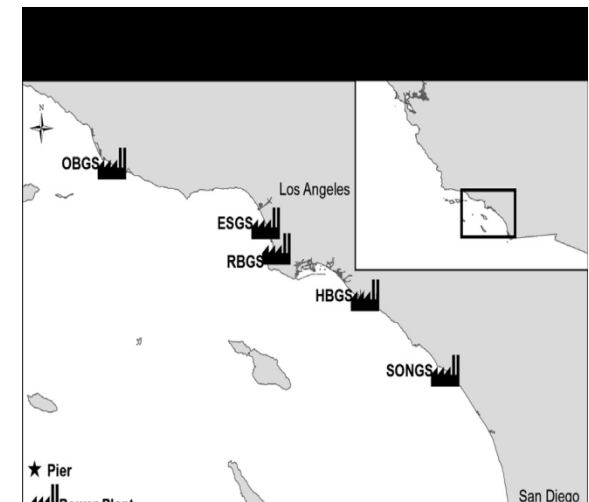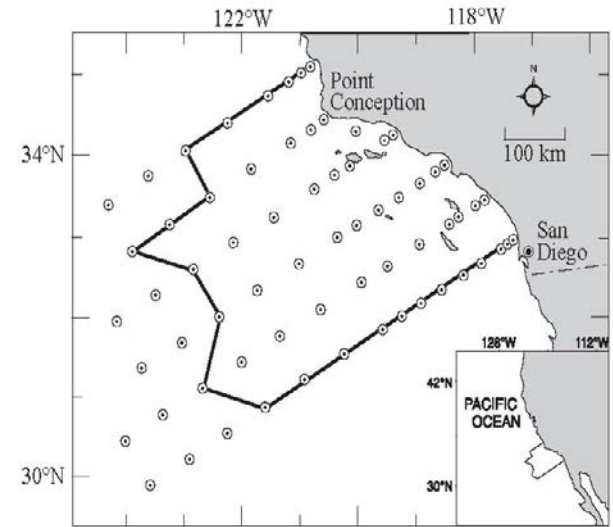
CalCOFI PC 1:
Mesopelagics and the impact of midwater O_2 concentration

PC 1 (20.5% var explained):

24/27 taxa with loadings $\geq$ 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

63% decline in abundance, 1951-65 & 1999-2008 vs 1966-99
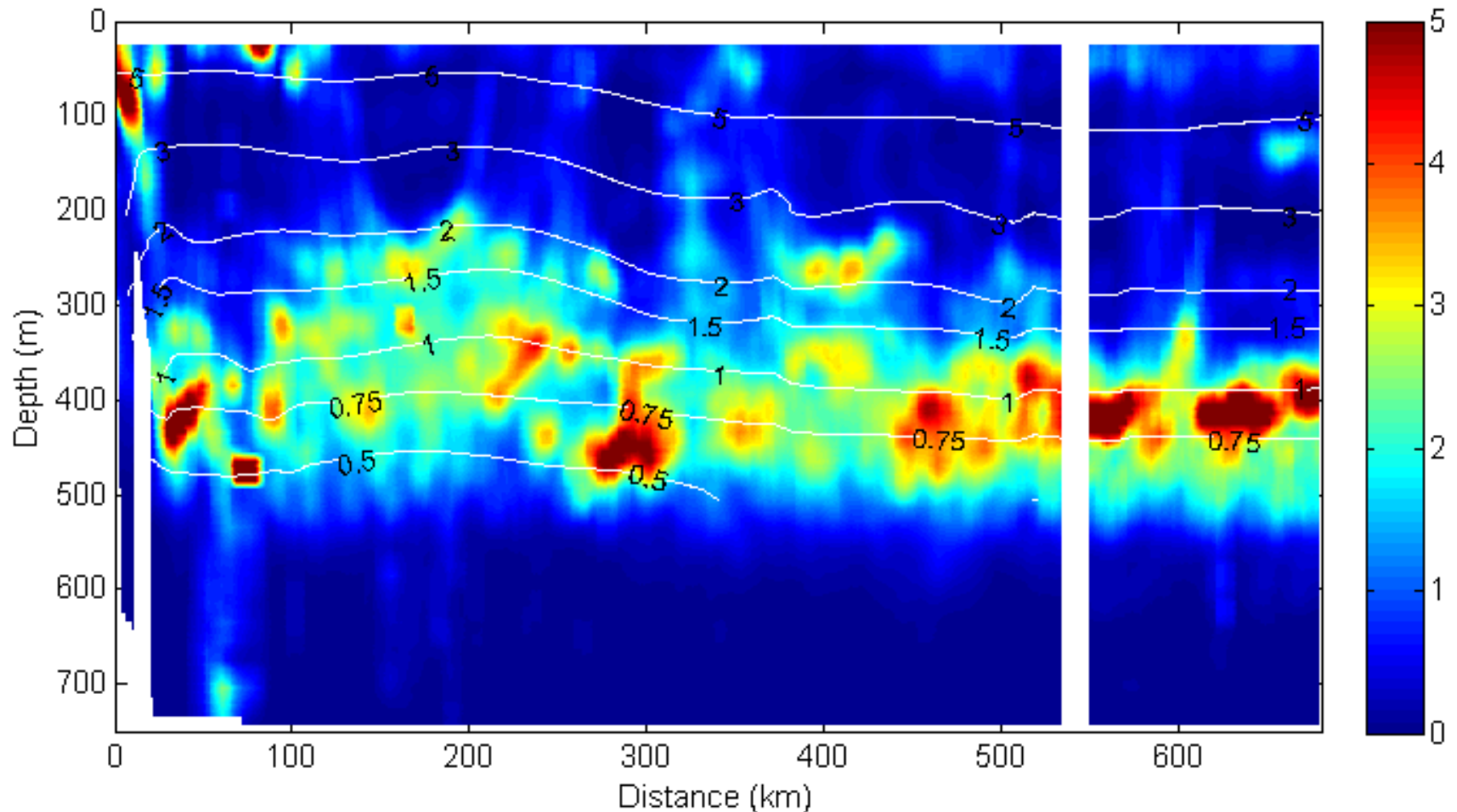Linked to midwater O_2 concentrations
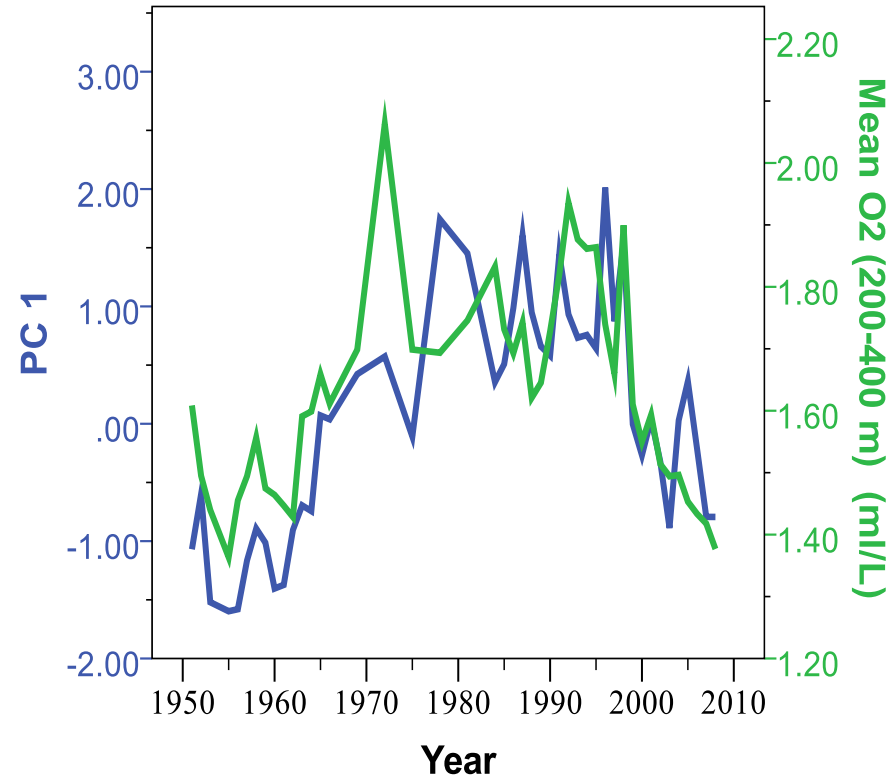
(Koslow et al 2011, MEPS)

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

The relative importance of the mesopelagic fauna

- Relative acoustic backscatter per ping, daytime averaged over 6 CalCOFI transects, January 2010
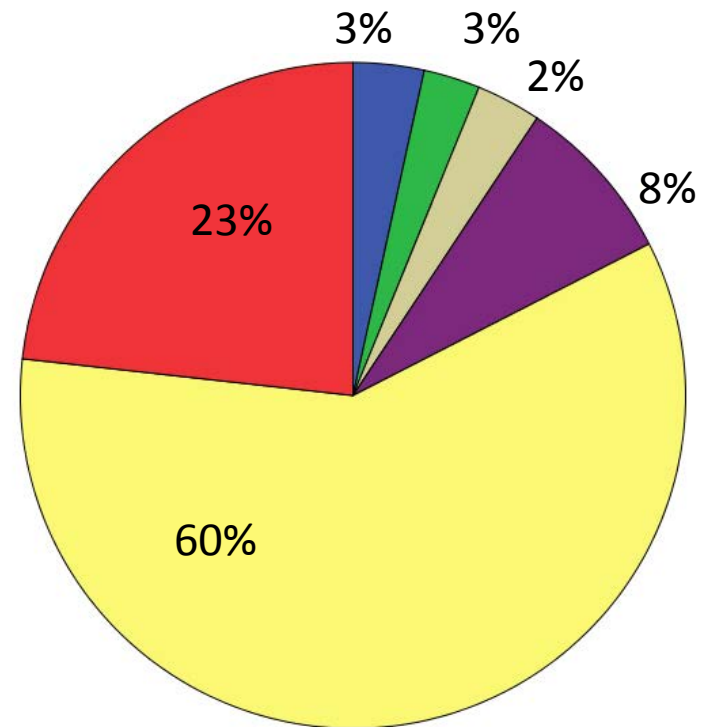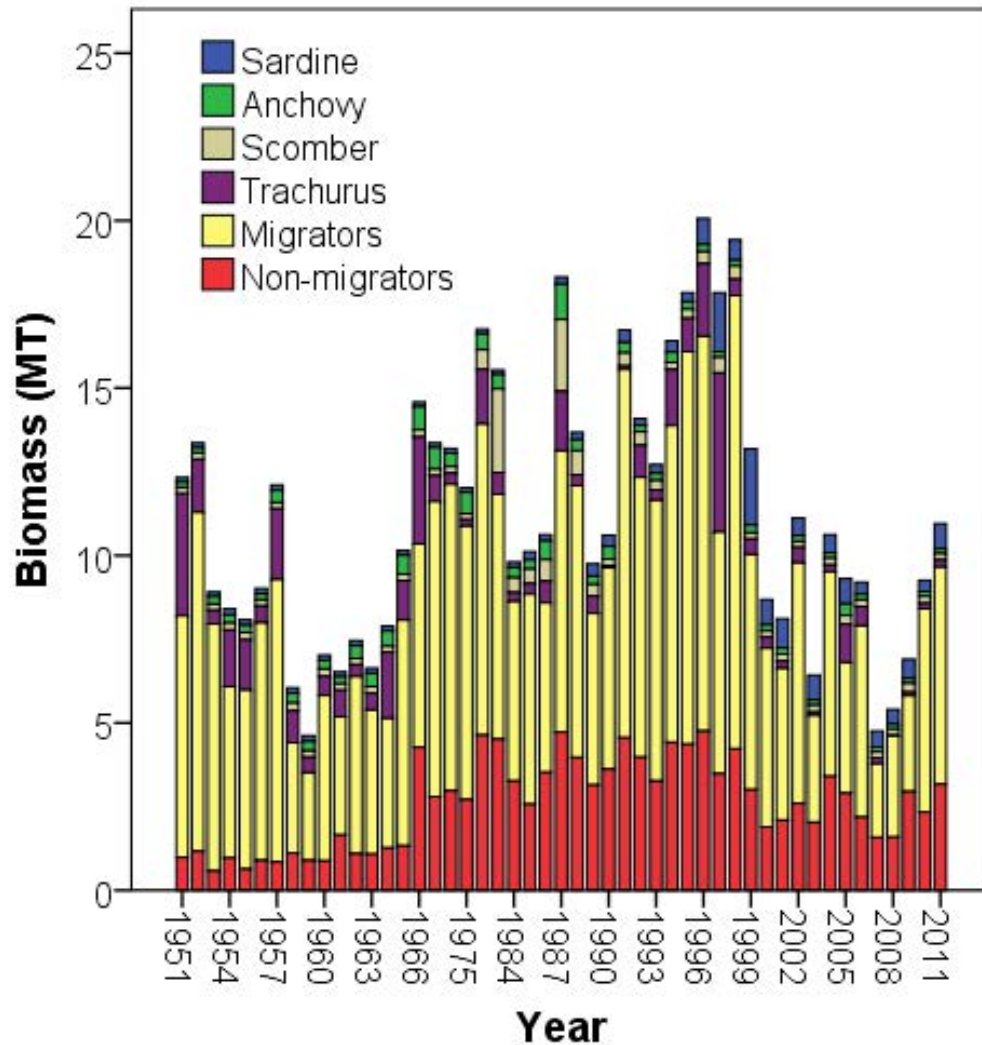- Pelagics dominant near coast, mesopelagics offshore

Planktivore larval abundance from CalCOFI surveys, 1951-2011
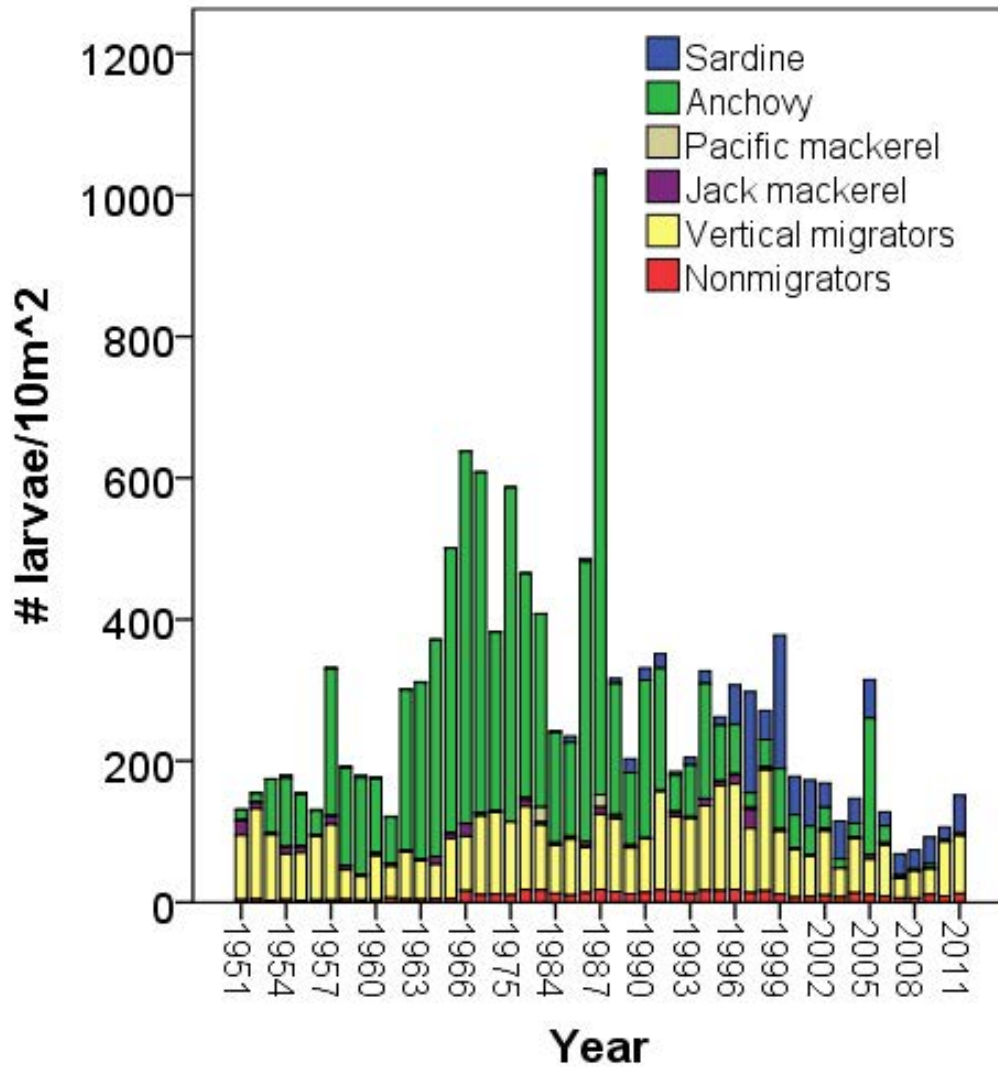
Planktivore biomass in the California Current

(Davison et al 2013, in press)

Mean biomass, 1951-2011 (MT)

Sardine:	0.38
Anchovy:	0.32
Scomber:	0.25
Trachurus:	0.91
Migrators:	6.61
Non-migrators:	2.59

Time series: dominant fishes, nearshore (power-plant intakes) & CalCOFI

- PC 2 (CalCOFI): explains 12.4% var, 6 of the 7 most abundant species in ichthyoplankton time series loaded highly (> 0.5):
    - Pacific hake, northern anchovy, rockfish (*Sebastes* spp.), 2 mesopelagics (myctophid (*Stenobrachius leucopsarus) &* bathylagid *(Leuroglossus stilbius)*) (+)
    - Pacific sardine (-)   (Koslow et al 2013)
- PPI : 78% decline in abundance of nearshore fishes (Miller & McGowan 2013)
- 76% decline in PC 2 (CalCOFI) larval fish abundance (83% without sardine included)
- 72% decline in overall CalCOFI larval fish abundance since 1969 (Koslow, Miller & McGowan, submitted)
- 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 or chl/primary prod indices*
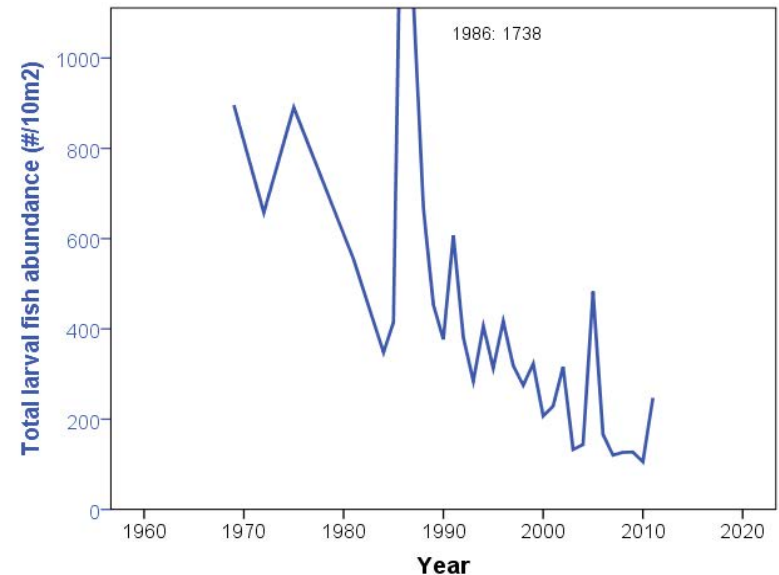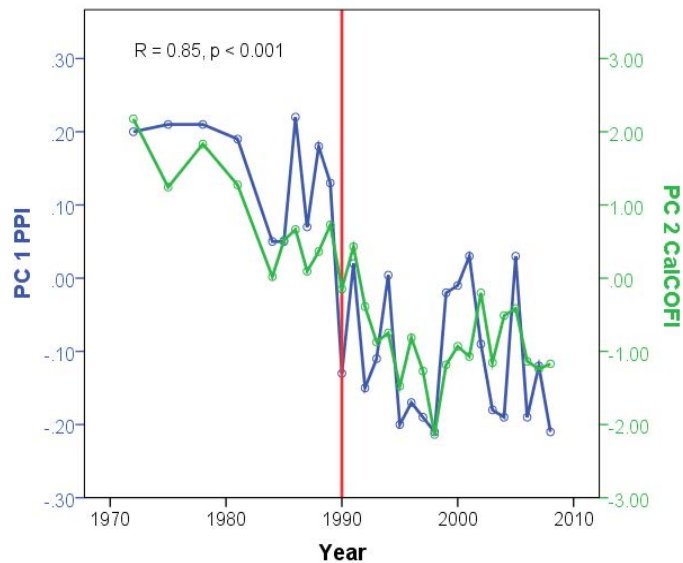
Declining fish in CC system: links to climate

- 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)

(Koslow, Miller & McGowan submitted)

	SST	Upwelling	SD SL	MEI	PDO	NPGO
PC 1 (PPI) (df)	-0.40* (27)	0.47** (29)	-0.45* (28)	-0.08† (27)	0.04† (27)	0.13† (27)
PC 2 (CalCOFI) (df)	-0.31† (26)	0.23† (31)	-0.58*** (28)	-0.02† (26)	-0.06† (26)	0.00† (26)

$Y = -45.16 + 0.032 X$
$R^2 = -0.19, p < 0.05$

$Y = 2723 - 1.25 X R2$
$= 0.16, p < 0.05$
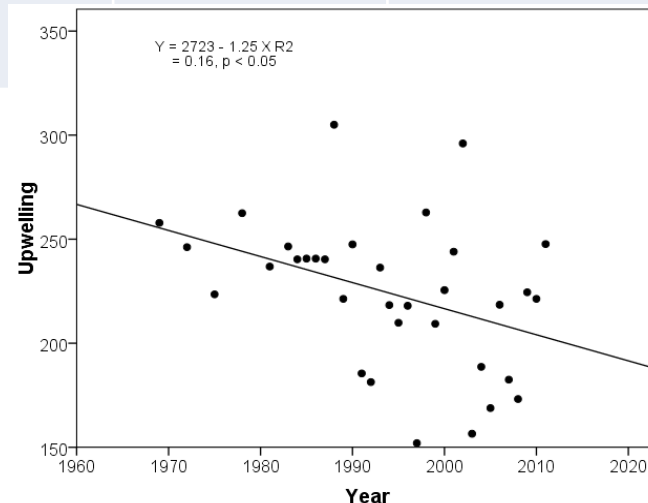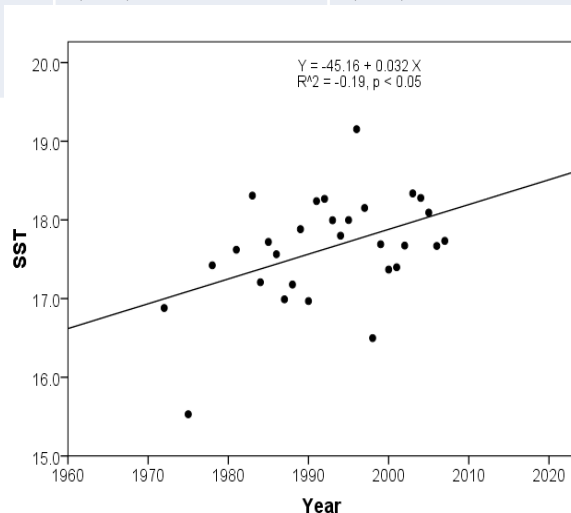
Critical role of fish time series in global observing systems

- Fish are EOVs readily sampled via the ichthyoplankton
- Fishery landings tell very little about underlying productivity and ecosystem status
  - Biases
  - Commercial species ~3% of a region's fish fauna
- Fishery independent time series critical to assess the status of fish communities
- Fish community time series provide a perspective on the state of marine systems potentially not seen from indices of chl/primary productivity
- The declines in the fish fauna of the CC system have not been reported elsewhere, but it is unlikely that these changes are occurring only there
- There is today a critical shortage of fish community time series

Are ship-based, species-level observations too difficult & costly?

- Longhurst: ~56 biogeographic provinces/66 LMEs in the world's oceans
- CalCOFI's cost: ~$5 million pa
- But is full egg survey grid (e.g. CalCOFI) required to capture patterns of change in key fish species and communities?

LONGHURST BIOGEOGRAPHICAL PROVINCES
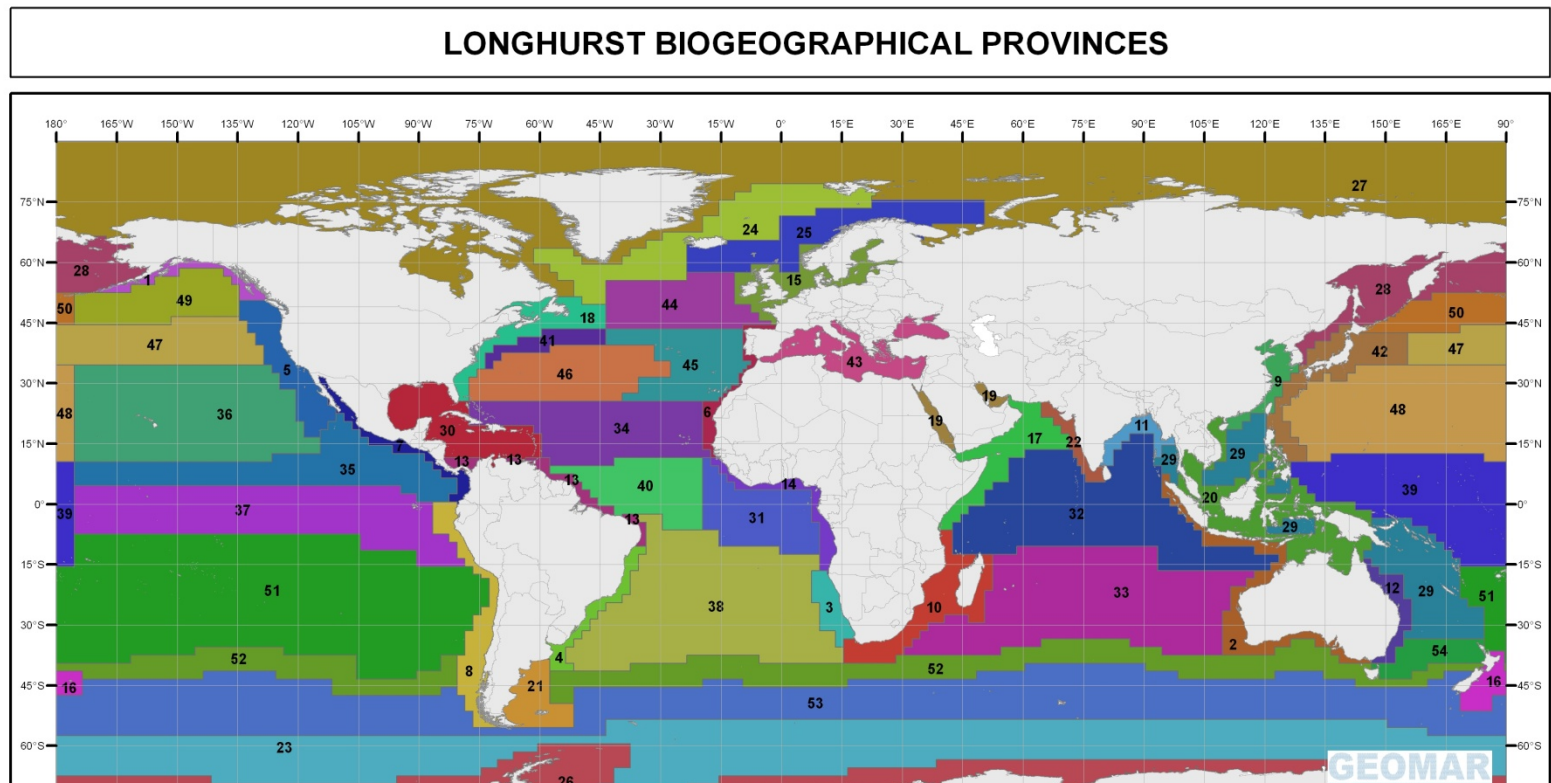
Proposed ichthyoplankton monitoring

- 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
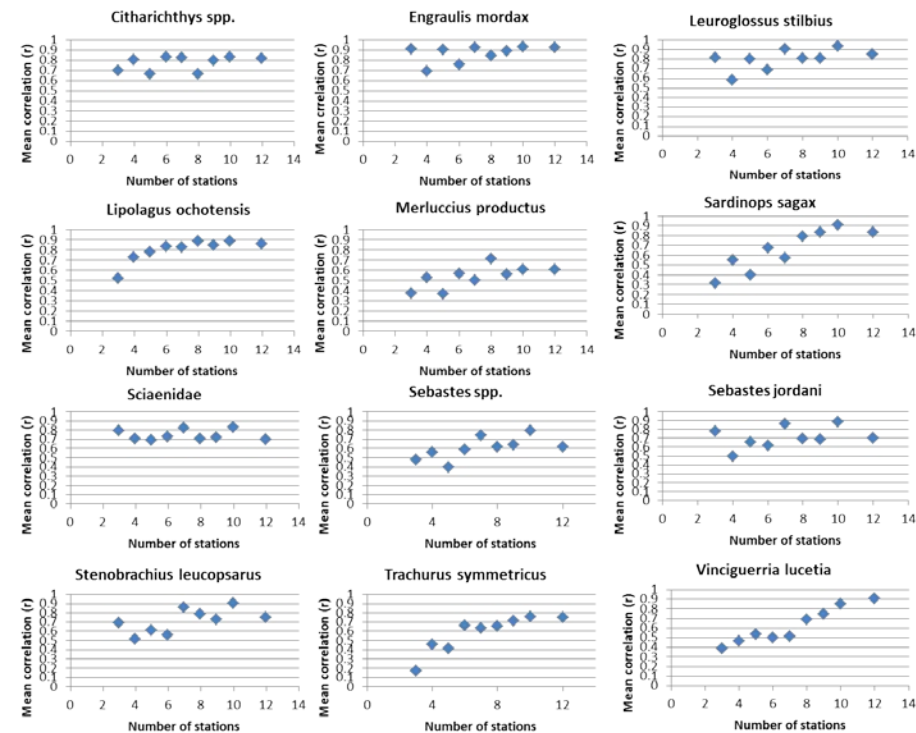

Figure 3. Correlations between the log-transformed abundance time series of the 12 most abundant taxa of the full CalCOFI data set and the abundance time series of those taxa for transects or fractions of transects. Mean correlation values were calculated for subsamples sharing the same number of sampling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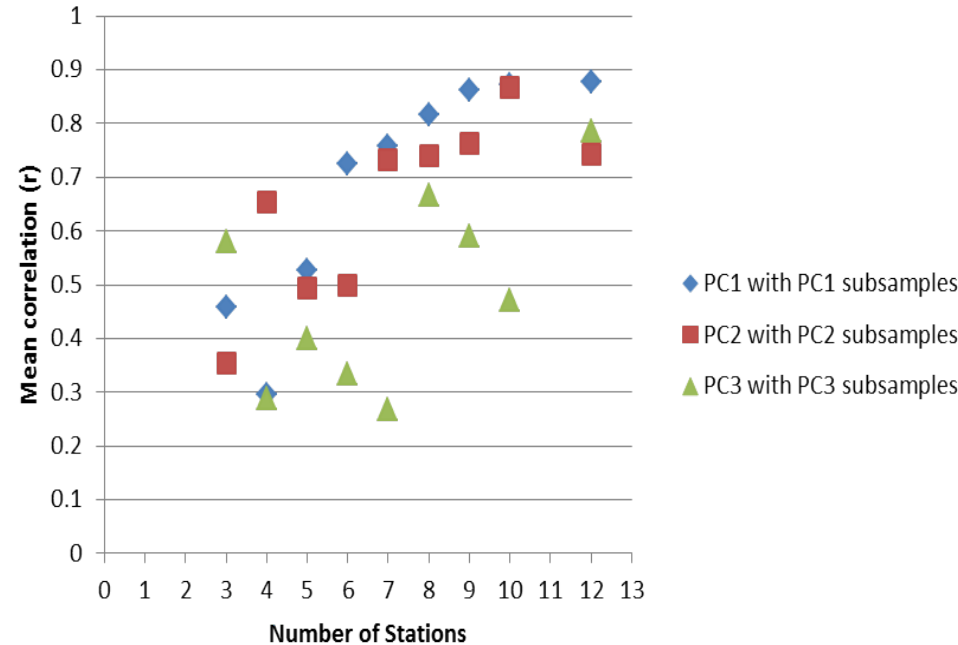

Figure 2. Correlation between the three significant PCs of the full data set with the respective PCs from the transect subsamples. Mean correlation values were calculated for subsamples sharing the same number of stations. Number of stations is defined as the number of stations from inshore to offshore on a single transect.

Effect of length of time series + number of stations

A greater number of stations and/or a longer time series is needed to capture the same trends for weaker PCs and less abundant, more patchily distributed species:
Either time series should be at least 20 years long or taxa should be sampled from more than 5 stations if the time series is 20 years or shorter
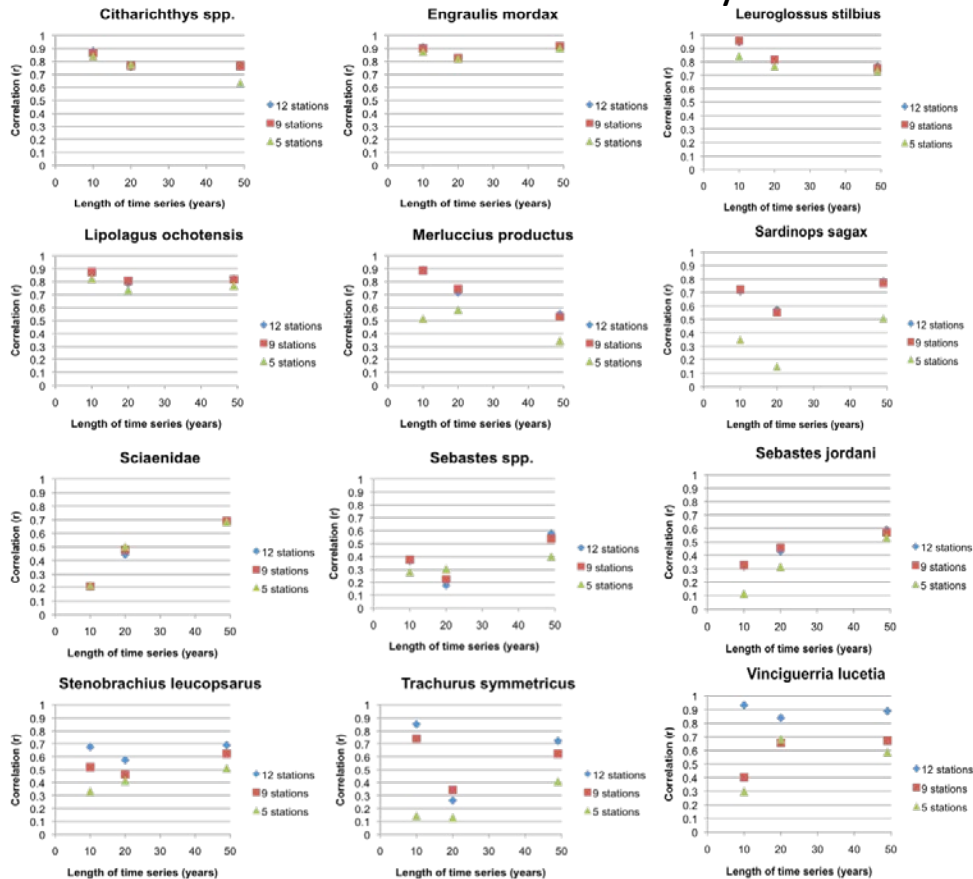

Figure 7. Correlations between the log-tranformed abundance time series of the 12 most abundant taxa of the full CalCOFI data set and the last 10, 20, or 49 years of the abundance time series of those taxa for transect 93, stations 60 and less on transect 93, and stations 40 and less on transect 93.
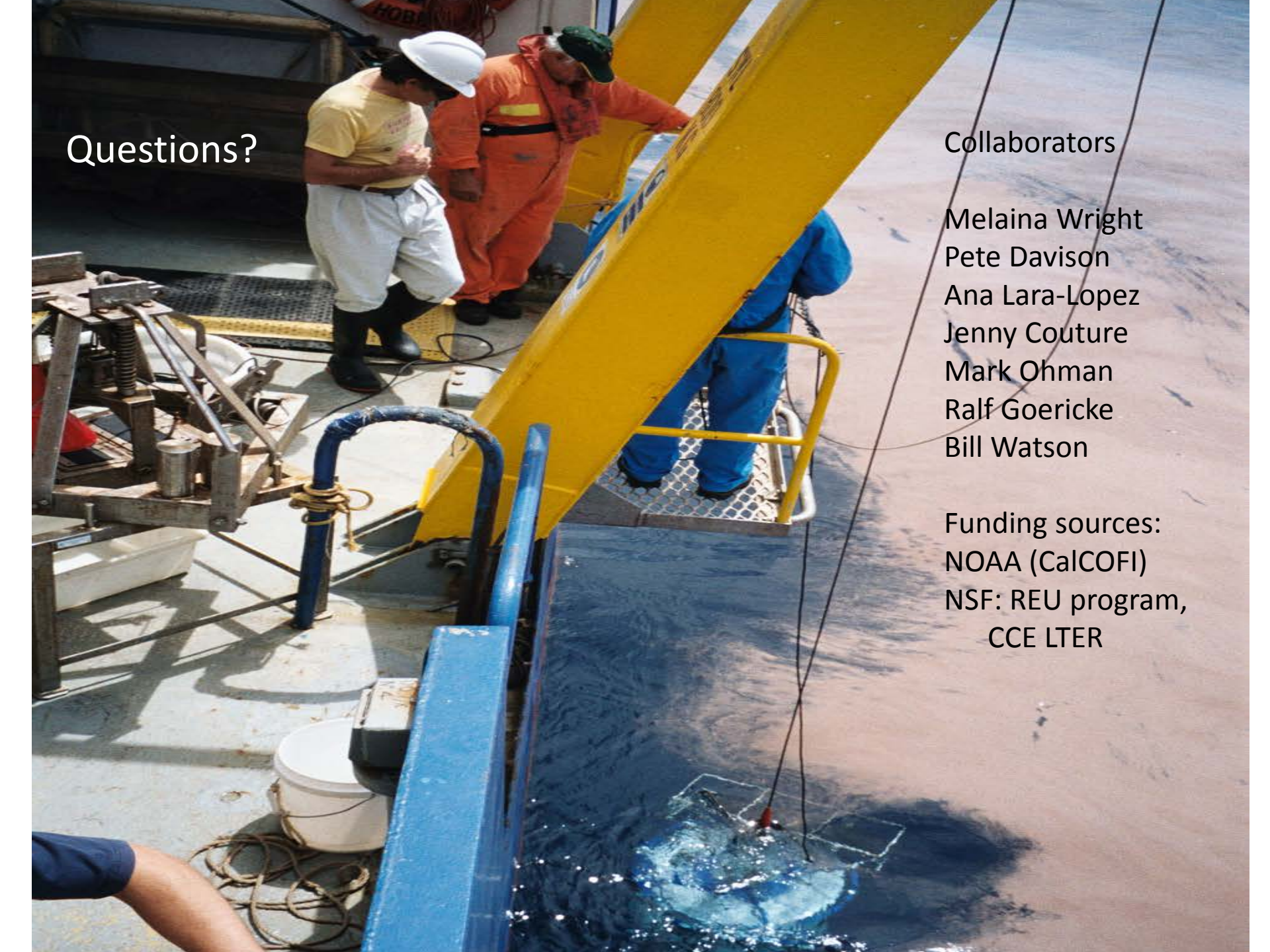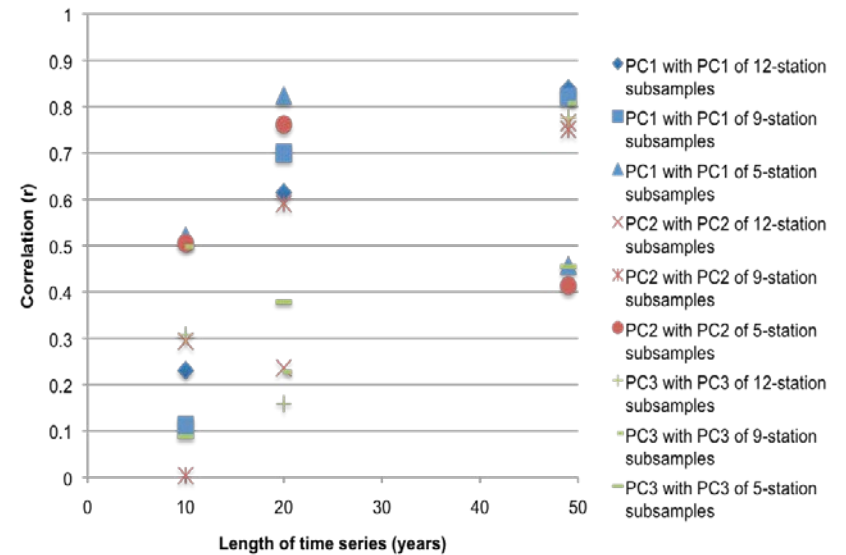
Figure 6. Correlation between the three significant PCs of the full data set with the respective PCs from the last 10, 20, or 49 years of the abundance time series of the 86 taxa surveyed on transect 93, stations 60 and less on transect 93, and stations 40 and less on transect 93 from 1951-2011.

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
- Trends in fish faunas of other LMES unknown: lack of time series
- 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
    - Link to fisheries enhances client support/sustainability of ocean obs programs
- Collaborative Oceanographic & Fisheries Investigations (COFI) as a GOOS initiative?

Questions?

Collaborators

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

Funding sources:
NOAA (CalCOFI)
NSF: REU program,
    CCE LTER