7.1: Incorporating Environment and Ecosystem into Assessments

NOAA FISHERIES

SWFSC

Theme 5, item d: *How well does the Center consider ecosystem and environmental factors affecting fish stocks and their assessments?*

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"When we try to pick out anything by itself, we find it hitched to everything else in the universe,"
- John Muir

Fishery stocks are "hitched" to the ecosystem.

How is the environment incorporated into stock assessment?

- environmental factors: implicitly included in all, specifically in some,
- ecosystem analysis: a ways to go.

As the previous talks have shown, there is a way to go before EBFM will be broadly implemented.

It's not from lack of interest, but lack of data and ecosystem models to properly capture the the necessary environmental scales.

Plus there is the necessary iterative process to implement new analyses into management decisions.

The SWFSC has always included environmental considerations in survey work leading to assessment. One could go further: the SWFSC has continually set standards for ecosystem monitoring and the relationship to stock assessment

*Should the Center be taking greater advantage of opportunities for collaboration in conducting fishery stock assessments and **related research**, including shared approaches with other Centers, regional academic partners, other government agency partners, and stakeholders (7d)?*

The SWFSC has a long history of collaboration with:

- other Centers: Groundfish, CPS (SAKE) and HMS,
- other government agency partners: CalCOFI, Central Valley Salmon
- regional academic partners: CalCOFI, salmon and many individual research projects,
- international collaboration: IATTC, WCPFC, ISC, Antarctic Marine Living Resources Program (AMLR).

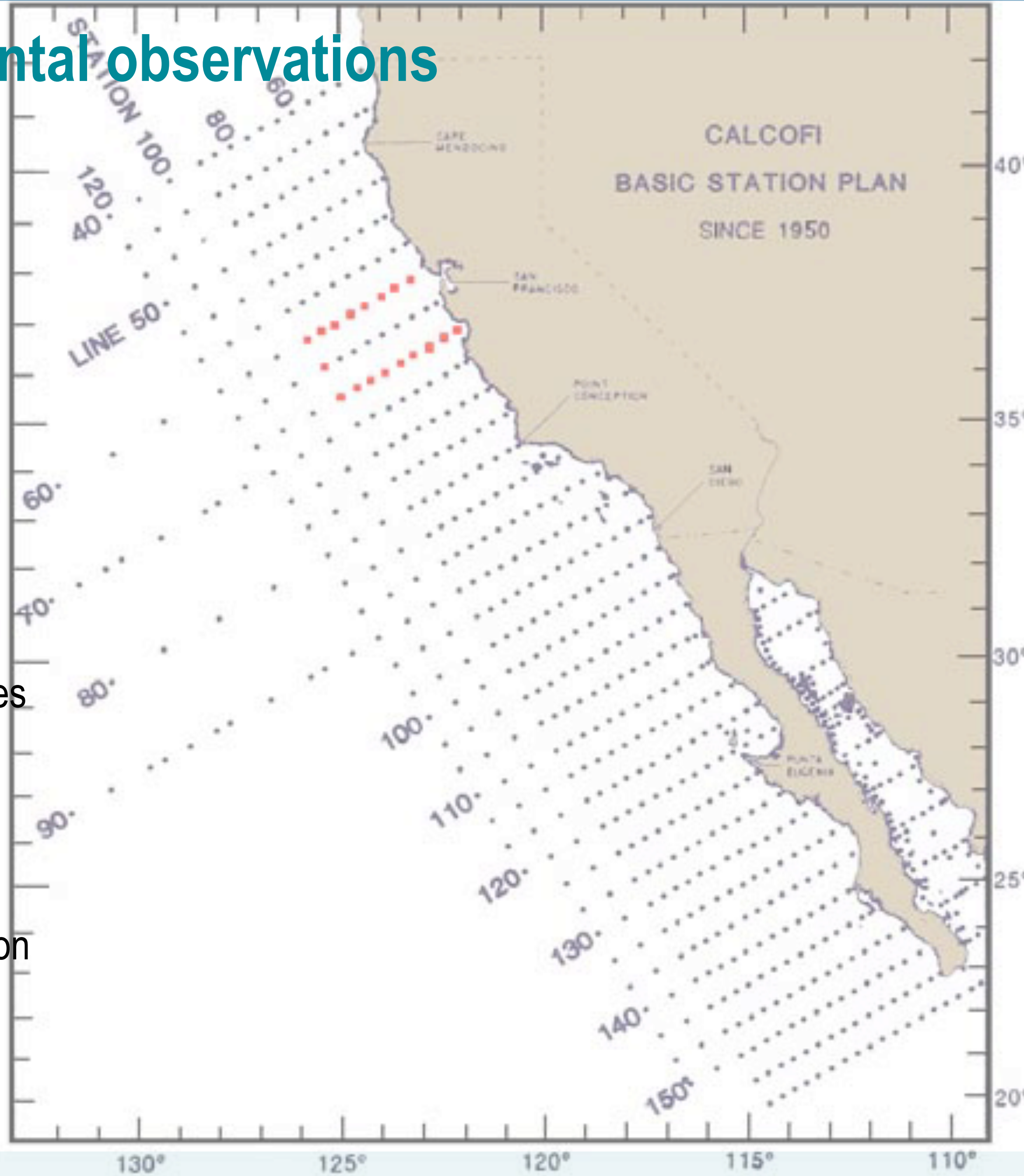
West coast environmental observations

The west coast driver for environmental monitoring was the 1946 sardine fishery collapse.

At 65 years, the California Cooperative Oceanic Fisheries Investigations (CalCOFI) collaborative program is the longest continuous oceanic ecosystem assessment program in the US.

At present there are 15 environmental parameters plus an additional 13 fisheries parameters collected during the four annual CalCOFI cruises.

Most data are now available online via SWFSC Environmental Research Division (ERD) servers (ERDDAP).



Environmental Observing isn't just CalCOFI

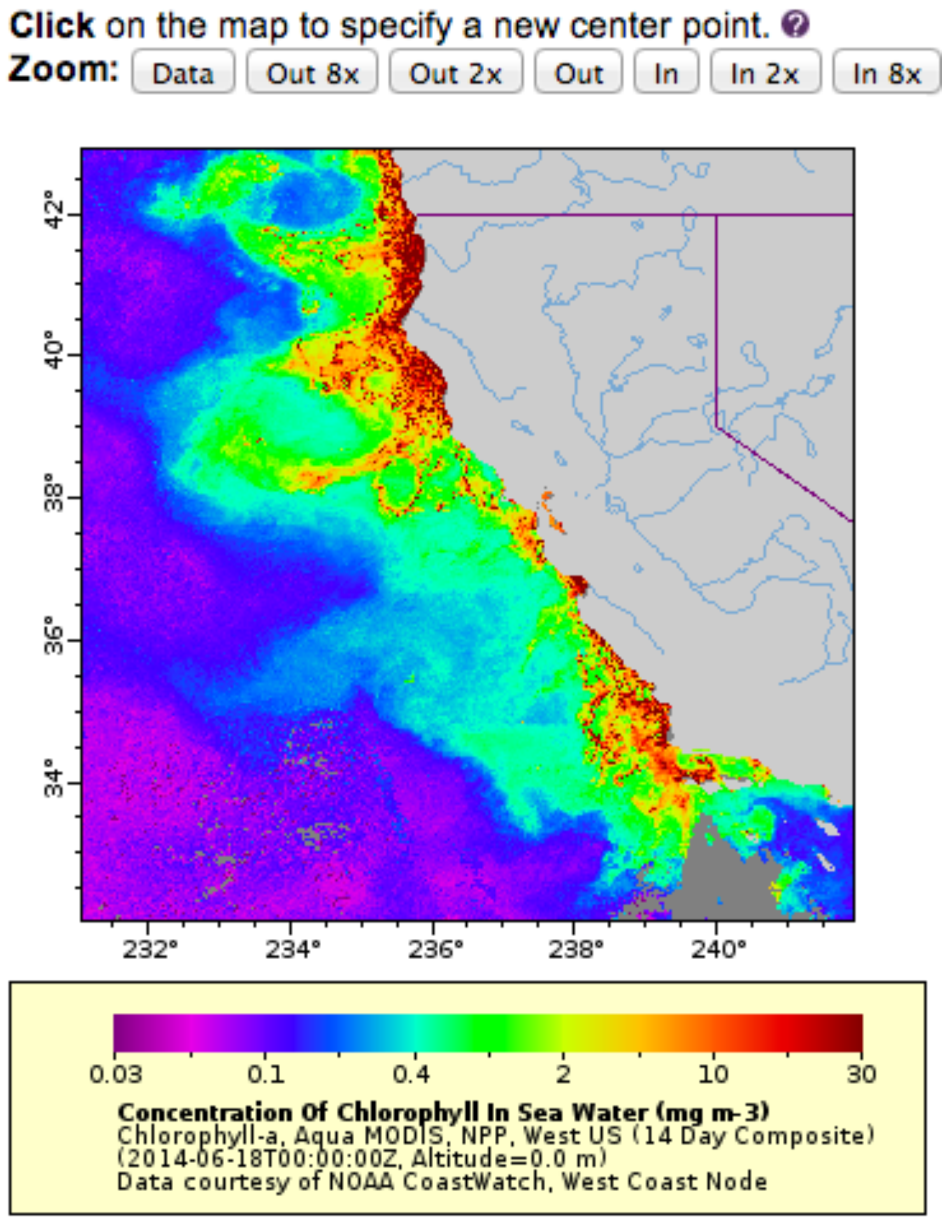
- Environmental data are collected on all groundfish and CPS cruises,
- Real time data from multiple sources are made accessible,
- Leverages off CalCOFI include:
  - Southern CA Long Term Ecological Research Program,
  - SIO glider lines along CalCOFI lines 66, 80 & 90,
  - Systematic coastal observations by IOOS regional associations,
- California HFR array for surface current measuring,
- Glider line off Trinidad being added.

Real time data includes satellite imagery, HF radar hourly estimates of surface currents, gliders and buoys.

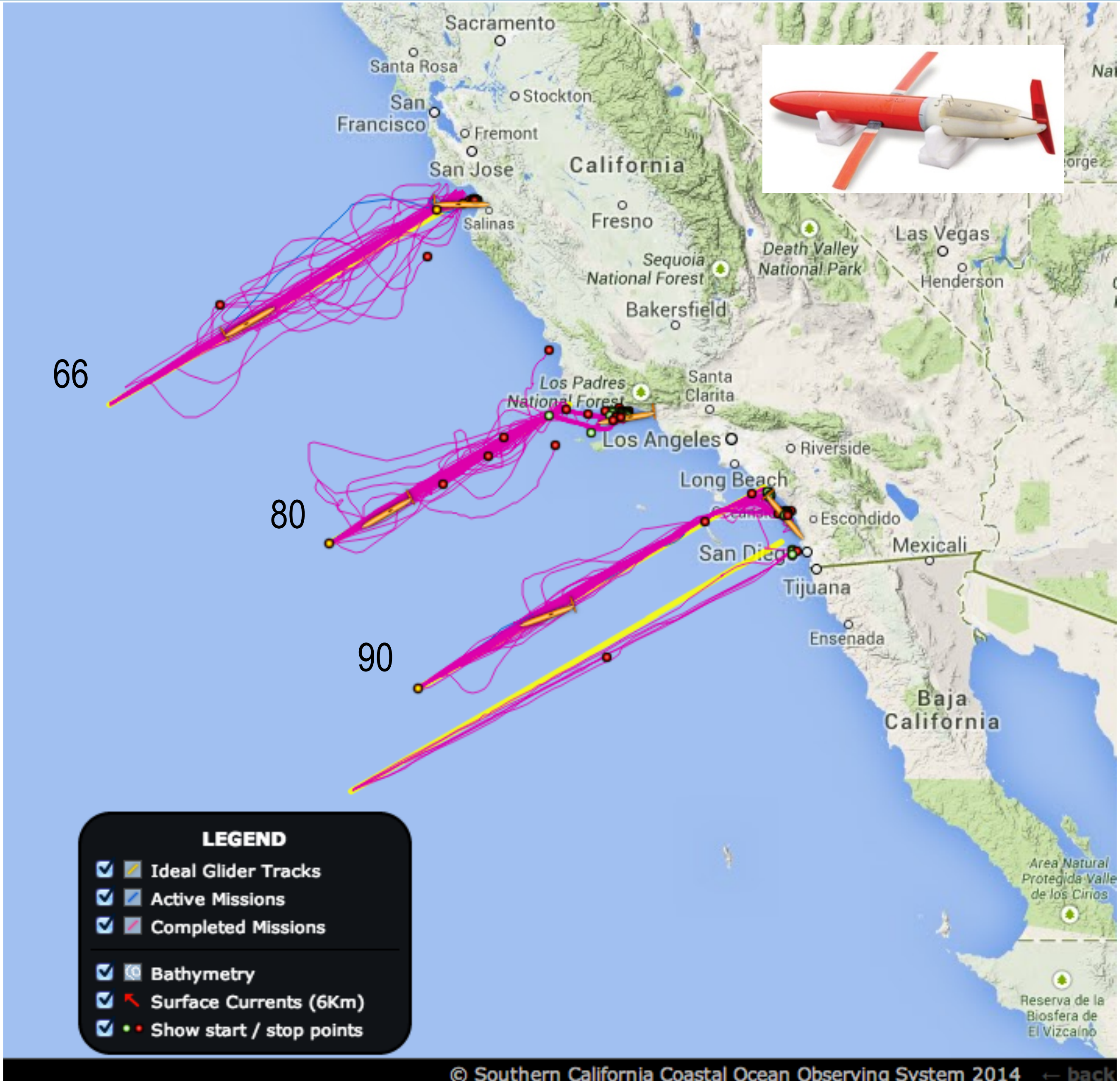
CoastWatch's colocation with SWFSC ERD led to many data sets being aggregated and web-accessible. ERDDAP allows data retrieval in multiple ways and multiple formats.

ERDDAP & CoastWatch host over 700 different data sets, including satellite imagery, cruise data, shore station data, AUVs, fisheries catch data, model output and derived products.

http://coastwatch.pfeg.noaa.gov/erddap/index.html



SIO Spray Glider Tracks along CalCOFI sampling lines (Rudnick)



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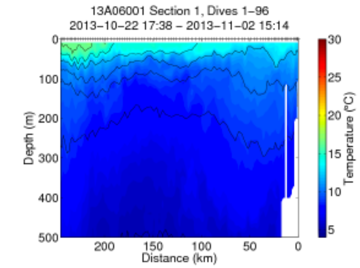

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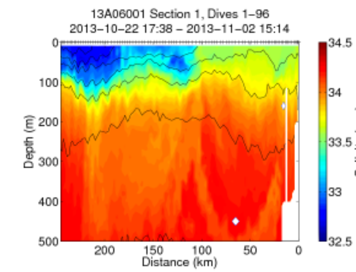

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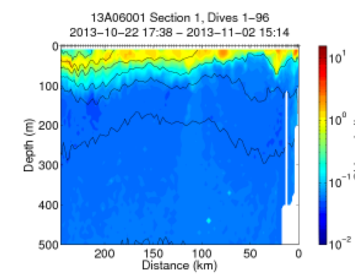

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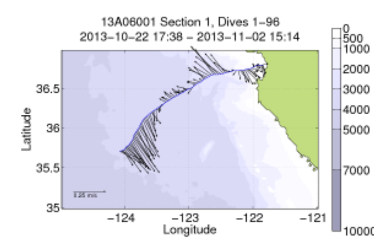
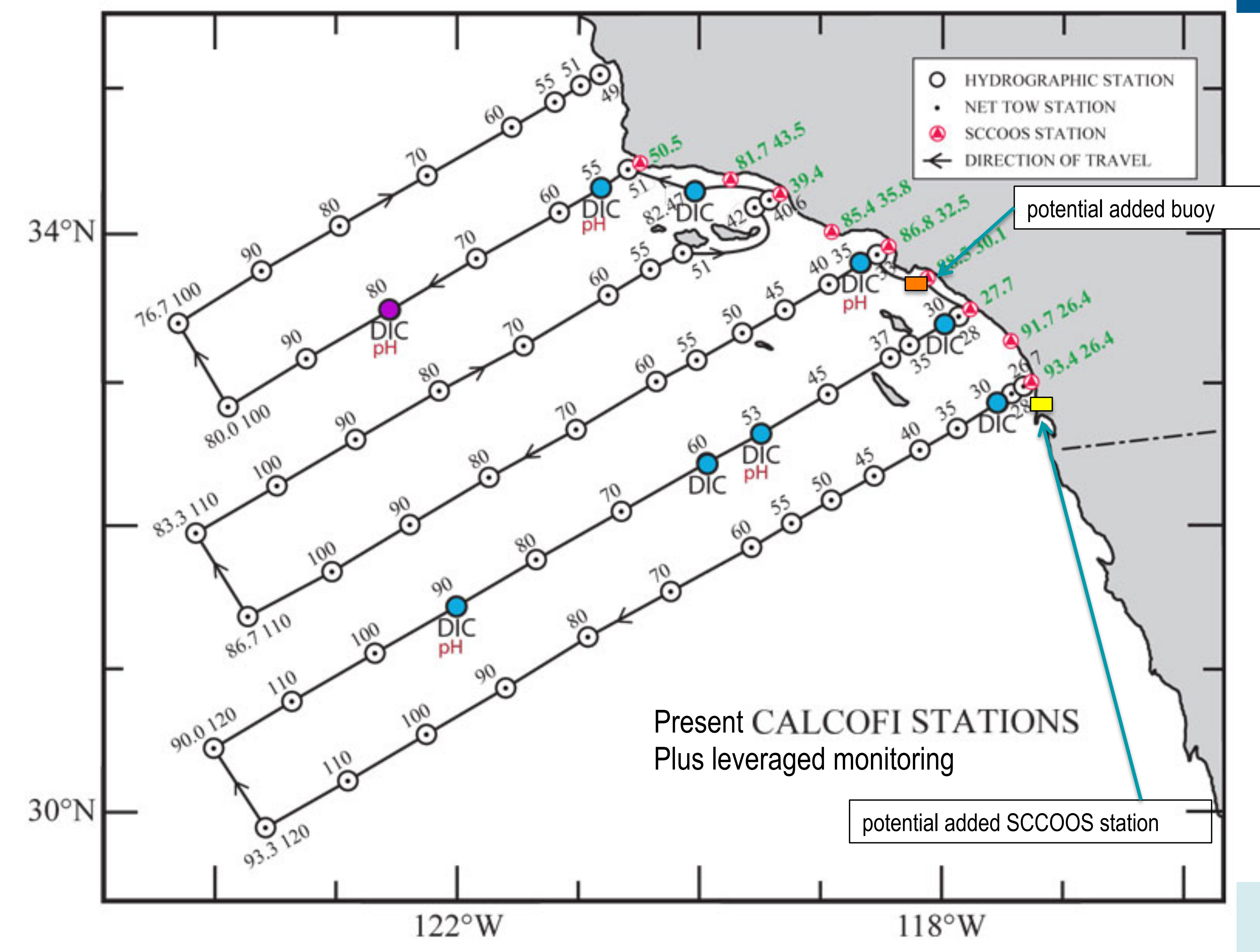
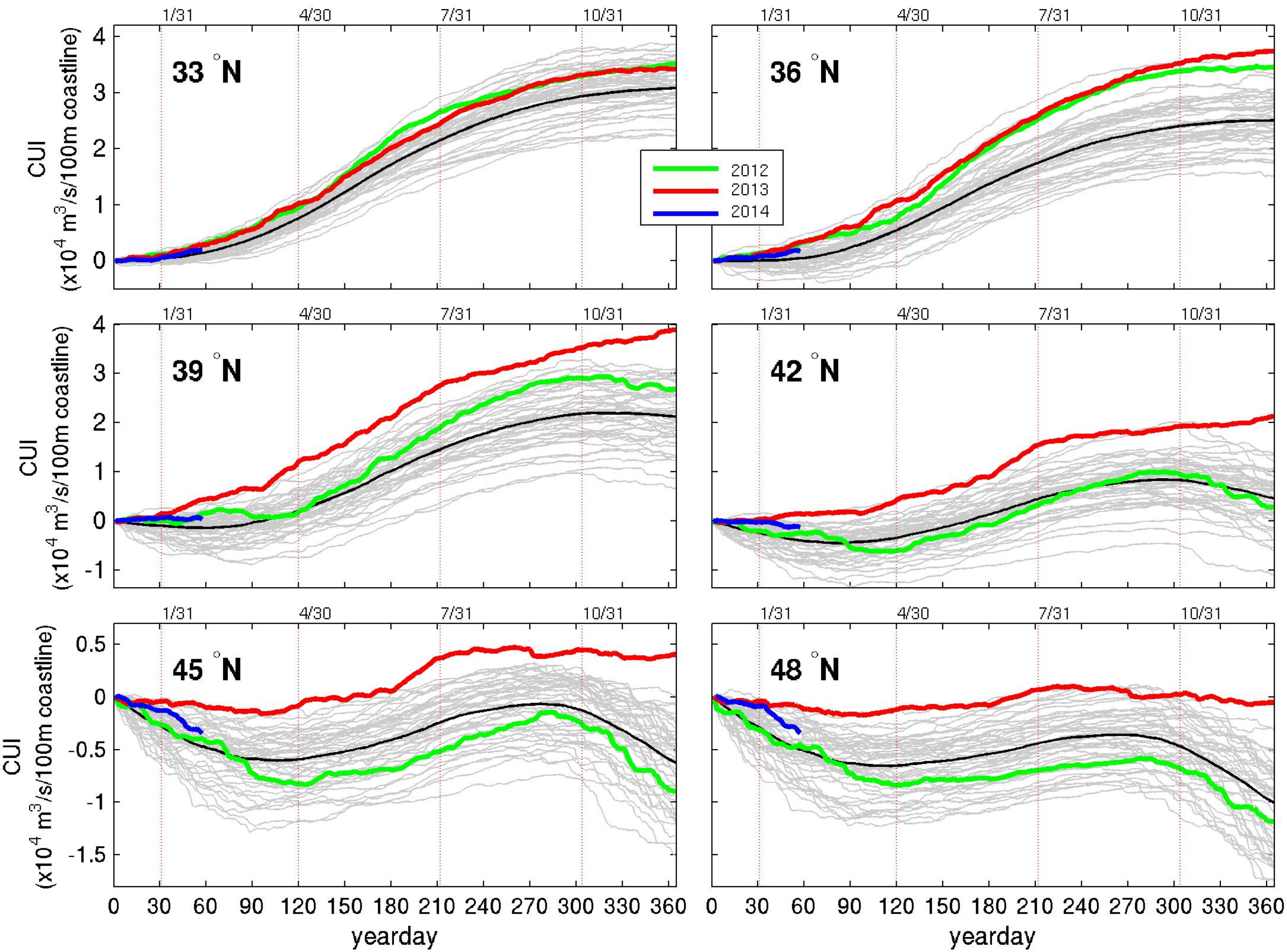



HYDROGRAPHIC STATION
NET TOW STATION
SCCOOS STATION
DIRECTION OF TRAVEL
potential added buoy
potential added SCCOOS station
Present CALCOFI STATIONS
Plus leveraged monitoring
76.7 100
80.0 100
83.3 110
86.7 110
90.0 120
93.3 120
DIC
pH
34°N
30°N
122°W
118°W

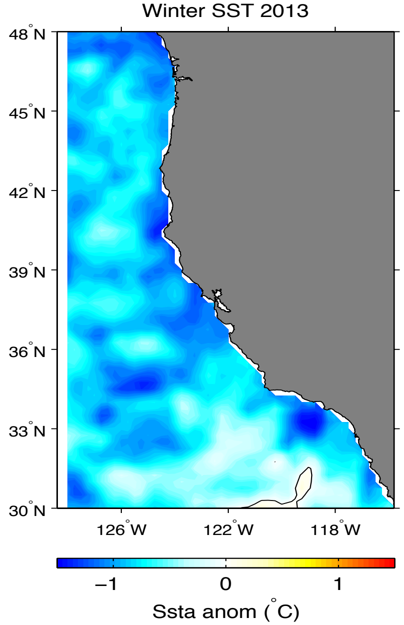
SWFSC environmental indicators

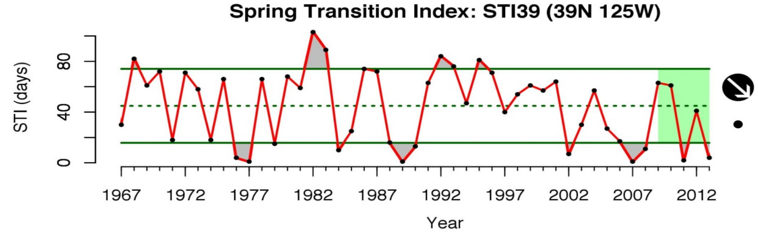
- 1973: Development of the Bakun Index of upwelling,
- Other important indices:
  - ENSO, MEI, PDO, & NPGO that capture the environment,
- The CalCOFI annual “State of the California Current” report,
- 2010: California Current Integrated Ecosystem Assessment (IEA) started (NWFSC & SWFSC collaboration).

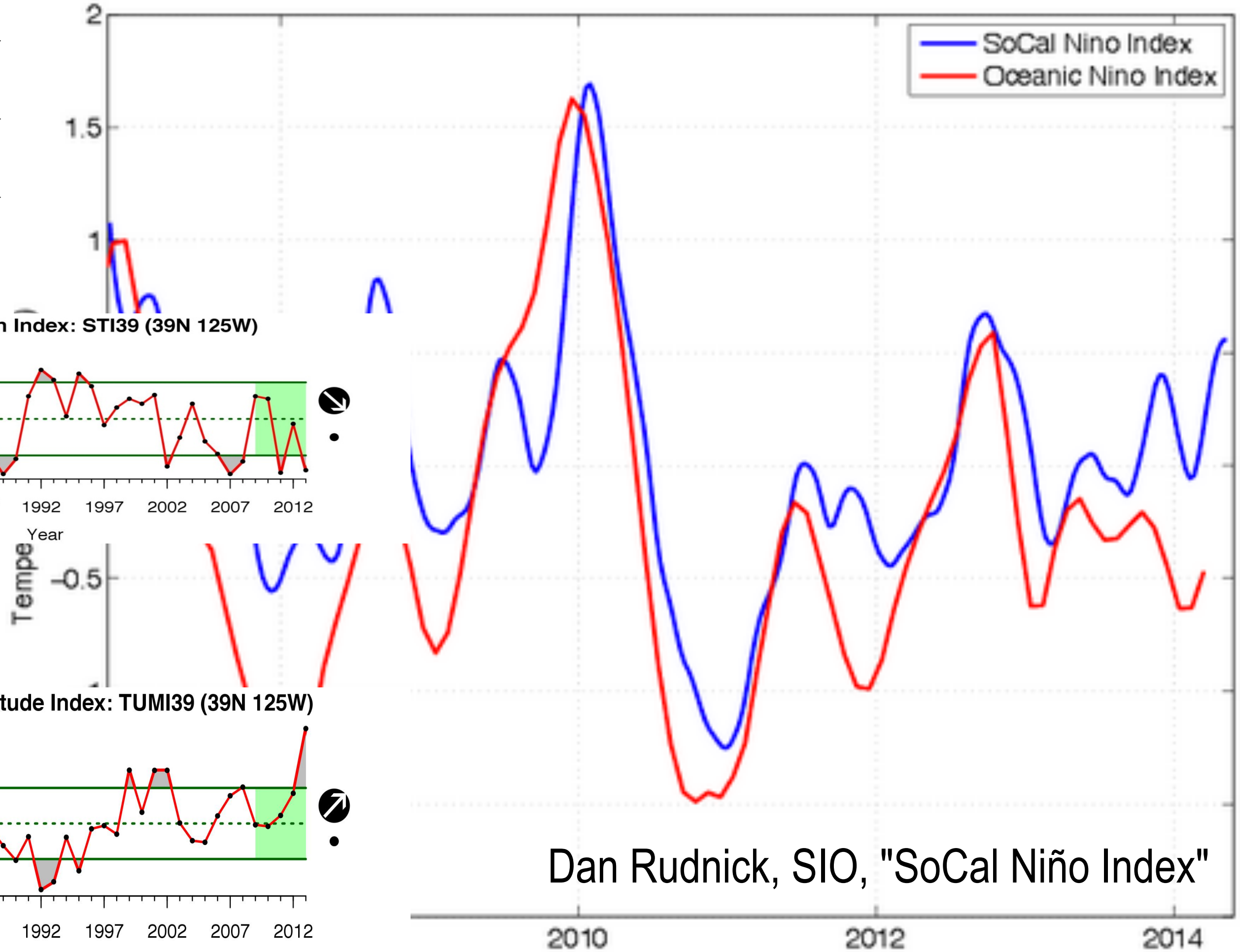
Cumulative Upwelling Index (CUI) as a function of latitude

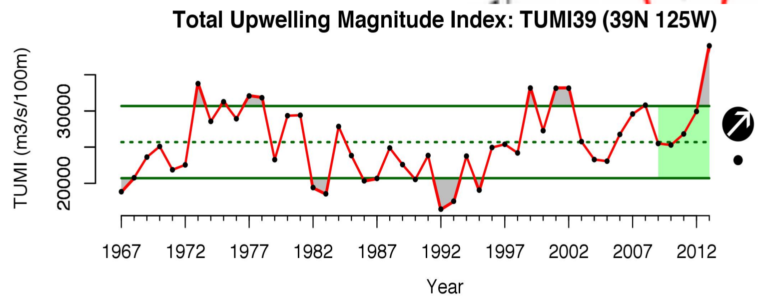


How are environmental data and indices included with Stock Assessments?









Examples of including environmental data in fish stock assessments?

The SWFSC is conducting research in the area of potential ecosystem and environmental factors that might affect fish stocks; there are not many examples of how this research has affected the stock assessments *per se*;

- Pacific sardines: temperature used in both stock assessment models and harvest control rules,
- Looking at the large scale indices and geography as sardine recruitment factors,
- Central Valley salmon recruitment modeled in terms of local environment and food source,
- Albacore tuna – oceanographic analysis was used to identify the appropriate areas and periods for the standardization,
- Striped marlin – oceanographic conditions used to inform population projections.

Example 1: Temperature in the Sardine Harvest Rule

- 1995-2004 SIO pier SST included in CANSAR (Catch-at-age Analysis for SARdine) assessment model to overcome data deficiency (per Deriso et al., 1996),
- 2000-2012 PFMC included SIO SST dependency in harvest control rule to determine E_{MSY} (Jacobson & MacCall, 1995),
- 2010 SIO SST no longer representative of temperature conditions in spawning region (McClatchie et al., 2010),
- 2014 new PFMC SSC guidelines implemented for using 5-15 m temperature from CalCOFI data in the harvest control rule (Lindegren & Checkley, 2012),
- Most recent Pacific sardine assessment used satellite SST to differentiate stock source for fish landed in southern California and northern Baja California (Demer & Zwolinski, 2014).

Example 2: Spatial and temporal scales are critical for using temperature in fisheries stock assessments. There exist multiple drivers for temperature variability, both local and large scale:

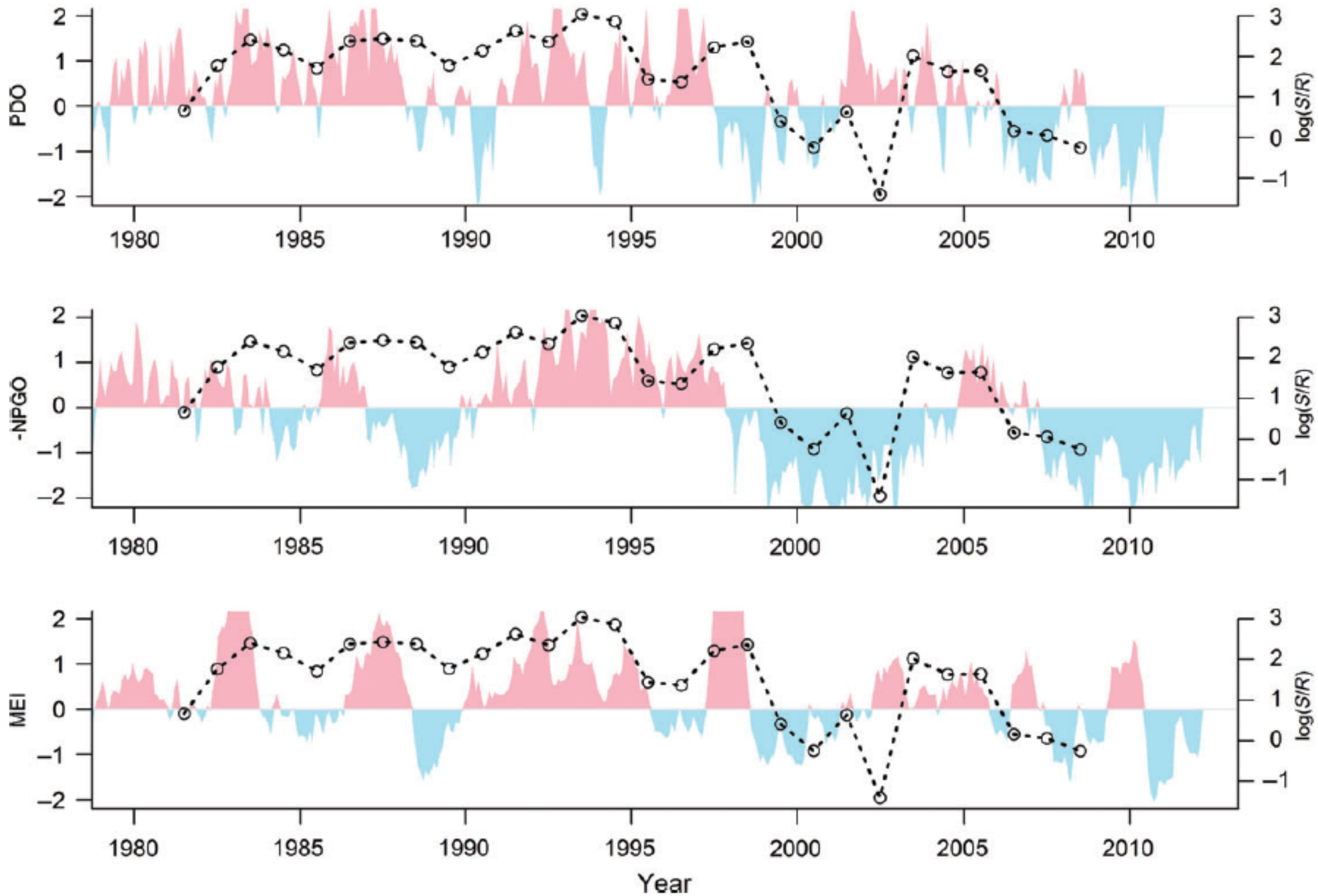
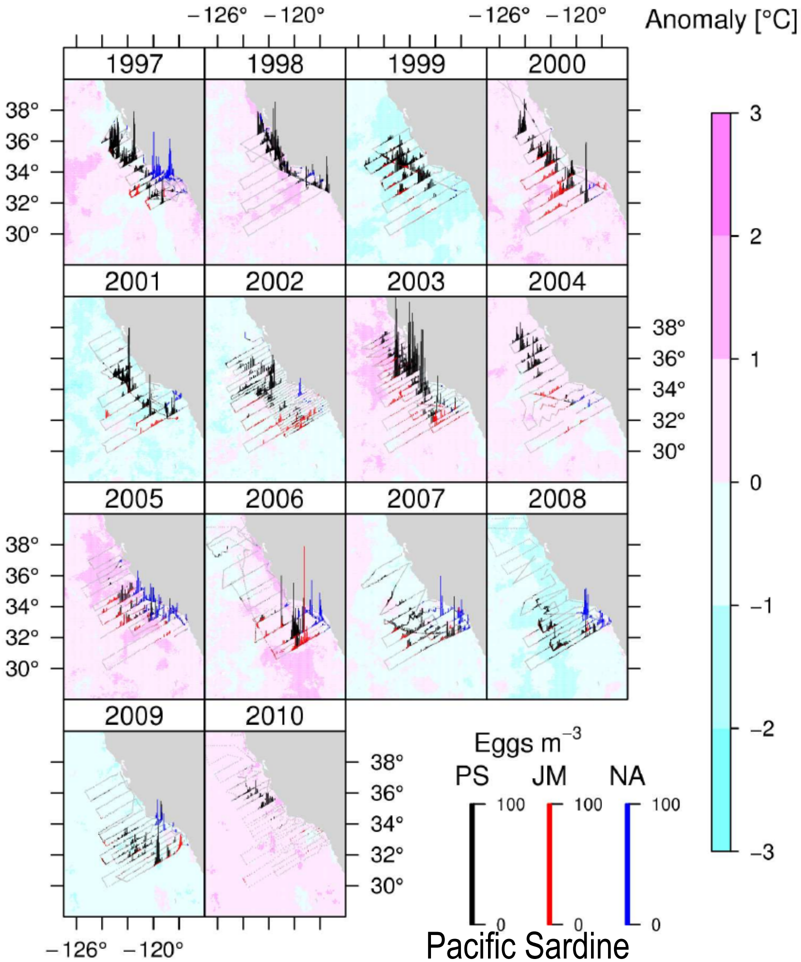


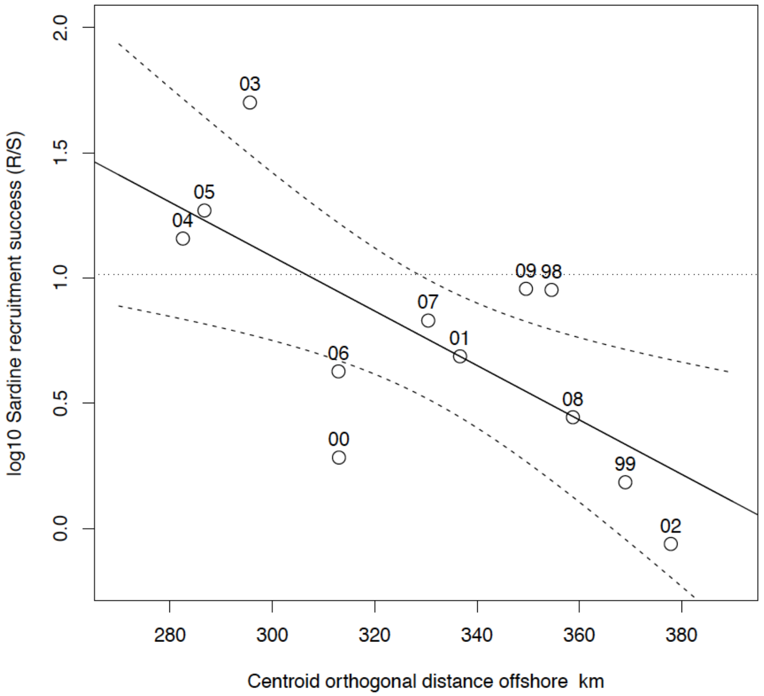
Figure 1. Logarithmic reproductive success (dashed line) from the 2010 assessment (Hill *et al.*, 2010), overlaid on the monthly values of large-scale oceanographic monthly PDO index; North Pacific Gyre Oscillation index (NPGO); and Multivariate ENSO Index (MEI).

Zwolinski & Demer (2013) found the highest correlation of Sardine stock recruitment when both the adult summer feeding season and the following spring spawning season are related to the PDO.

Example 3: Spawning Distance from Shore

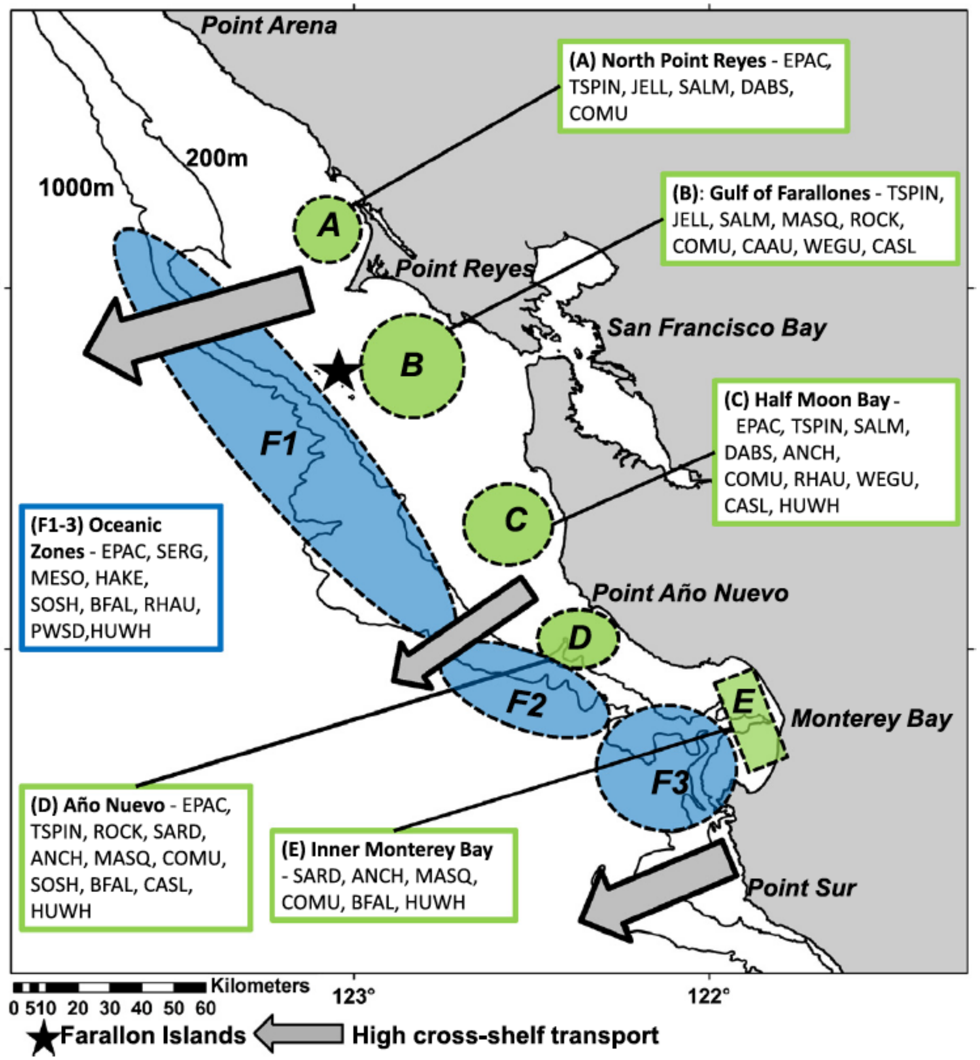


Pacific Sardine
Jack Mackerel
Northern Anchovy



Recruitment success (1998-2009) as a function of the predicted spawning centroid distance offshore, Nieto, et al., (JGR in review).

Example 4: Environmental Conditions



The combination of variability in upwelling winds, coastal geomorphology and abrupt bathymetry influences the geospatial variability of upwelling centers and ecosystem productivity.

Wells et al., 2013 modeled that the success of juvenile salmon depended on the zooplankton in the Gulf of Farallones.

Santora et al., 2012
Wells et al., 2013

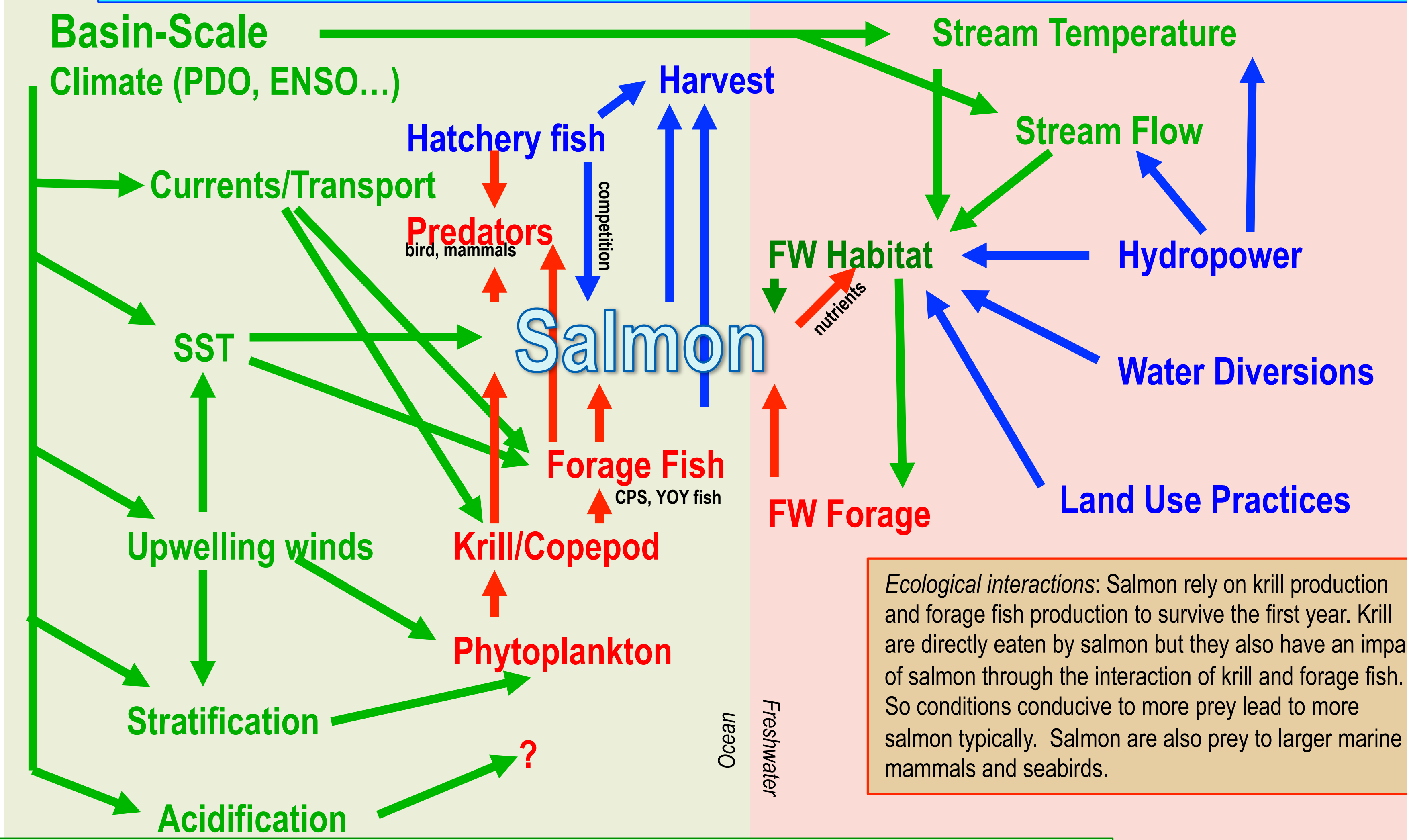
Fisheries and the Environment (FATE)

- Reinvigorating CalCOFI (2 FATE FTEs at SWFSC)
- Relating juvenile fish abundance to climate signals & (de)coupling to adult populations,
- Climate impacts on growth and fecundity of rockfish (e.g., sea surface height as an indicator of CC variability),
- Environmental variables into Klamath River fall Chinook forecast,
- Chilipepper recruitment assessment includes time-varying growth and the PDO state,
- Combined climate- and prey-mediated range expansion of Humboldt squid in the California Current System,
- Coupled ROMS-biology modeling (e.g., NEMURO, IBM, EwE),
- Inclusion of freshwater environment variability in Starry flounder stock assessment,
- Pacific bluefin tuna "hot-spot index" uses state space modeling to combine biological and physical data, producing feeding success maps for future assessments,
- Incorporation of remotely sensed data into estimation of spawning area for CPS

Integrated Ecosystem Assessment (IEA)

- **California Current IEA** is the first undertaken by NOAA (2010)
- 50+ NWFSC and SWFSC scientists engaged (not funded), along with various partners at other labs & line offices
- Work to date has focused on:
  - Developing ecosystem indicators of status and trends for natural and human attributes
  - Assessing risk of indicators and attributes to stressors and pressures
  - Developing management scenarios and testing them to discern outcomes and tradeoffs
  - Public outreach
- Phase III is just completed (program will be reviewed 2014)
  http://www.noaa.gov/iea/regions/california-current-region/products/index.html

Human benefits: We benefit directly from the production of salmon for fisheries. Improved prediction based on ecosystem information can allow for precautionary management, thus, reducing the likelihood of boom and bust fisheries. However, we also rely on the aspects of the freshwater that can directly impact the production of salmon.



Ecological interactions: Salmon rely on krill production and forage fish production to survive the first year. Krill are directly eaten by salmon but they also have an impact of salmon through the interaction of krill and forage fish. So conditions conducive to more prey lead to more salmon typically. Salmon are also prey to larger marine mammals and seabirds.

Environmental drivers: Ocean drivers are largely dependent on basin-scale forcing such as PDO state. Specifically, basin-scale conditions are the forces that ultimately translate to local production. There is also a need to consider regional drivers such as local upwelling and wind dynamics which correspond to water column characteristics and forage dynamics. Freshwater habitat, and the factors related to it, relate to the production of salmon entering the ocean.

Wells, et al, 2014

Incorporating the Environment:

- Strengths
  - The PFMC Pacific Coast Fishery Ecosystem Plan calls for an annual State of the ecosystem report as a PFMC reference input,
  - The PFMC's individual FMPs call for information on environmental effects on managed species,
  - The new La Jolla laboratory facility has capabilities for controlled experiments at different life stages,
  - CalCOFI and other monitoring programs continue and most data are available online,
  - FATE program providing ecosystem analyses and index development,
  - Modeling studies are linking biophysical parameters (e.g. ROMS with NEMURO or EwE)
  - Multiple collaborators and partners, both within and external to NOAA.

- Challenges
  - MSA doesn't directly mandate ecosystem approach (framework is there),
    - PFMC has interpreted the MSA mandates of optimal yield while protecting species as essentially requiring an ecosystem-based approach,
  - Bringing data down to the scale of the fisheries,
  - Forage biomass needed to sustain ecosystem and protected species,
  - Developing environmental models with the necessary multiple space and time scales,
  - Some basic physiological data on even well studied species (and stages) vital rates vs environmental conditions (e.g. growth as a function of temperature) are still not well known,
  - FTE limited to extend the scope of environmental research and analyses.

Incorporating the Environment:

- Strategies
  - Encourage basic research on managed species vital rates vs environmental drivers,
  - Continue the development of multi-component models,
  - International collaboration (ISC, PICES) on climate variability effects on pelagic fish/fisheries
  - Determine the ecosystem knowledge essential for managing both short- and long-lived species,
  - Work with other NOAA lines to broaden “Environmental Intelligence,” perhaps through drawing attention to emerging issues impacting beyond just fishery stocks
    - Climate Change
    - Hypoxia and Ocean Acidification
    - Plastics and marine debris

- **Questions?**