# Integrating Plankton Survey Observations in the California Current Large Marine Ecosystem- Workshop of Summary From September 25-26, 2006 Meeting

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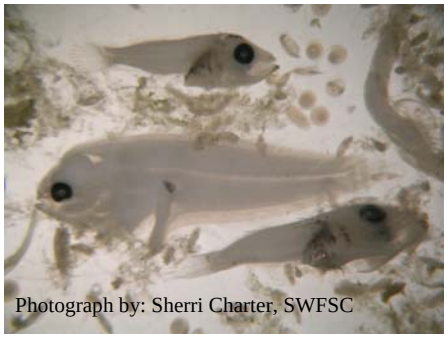

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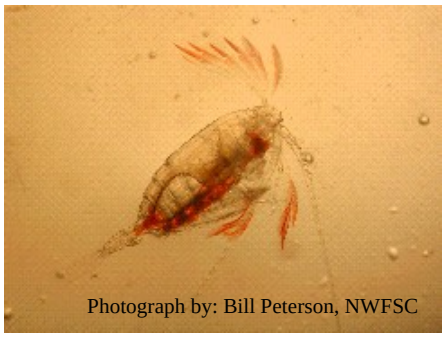

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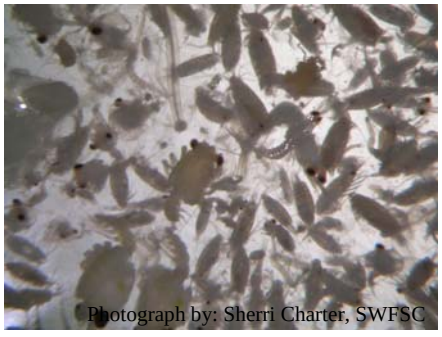

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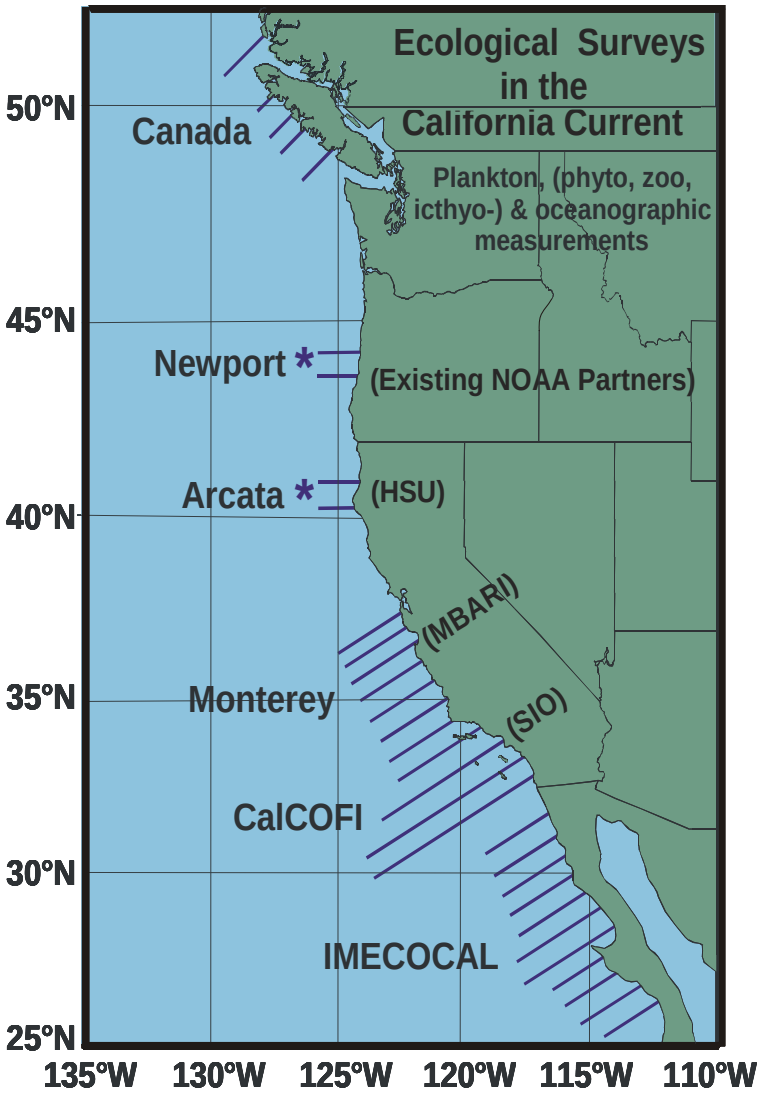

# Preamble

The PaCOOS* Board of Governors requested that the PaCOOS staff execute a workshop involving the principal investigators of the five (5) long-term plankton surveys conducted in the California Current: (1) the Canadian Line (DFO*, Canada); PaCOOS Newport Line (NOAA Fisheries*/OSU*, USA); PaCOOS- Humboldt Line (NOAA Fisheries/ HSU*); PaCOOS-Monterey Line (NOAA Fisheries/MBARI/USCS* ); CalCOFI (NOAA Fisheries/SIO*/California DF&G*); and (5) IMMECOCAL (CICESE*). A September 2006 workshop was held at the Scripps Institution of Oceanography and developed the following products: a summary of the existing surveys including net type, depth, oceanographic parameters and acoustic measurements; proposed sentinel plankton species in the California Current LME that can indicate climatic regime changes; "best practices" for zooplankton sampling; recommended parameters in the development of new plankton survey lines and action items to raise the profile of plankton surveys and to enhance the existing collaboration between researchers.

This report can be cited as:
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*__PaCOOS__: Pacific Coast Ocean Observing System. Summaries and action items from the Board of Governor's meeting can be found on the PaCOOS website (www.pacoos.org).
**NOAA Fisheries**: NOAA's National Marine Fisheries Service
**DFO**: Department of Fisheries and Oceans, Canada
**OSU** Oregon State University, USA
**HSU** Humboldt State University, USA
**MBARI** Monterey Bay Area Research Institute, USA
**UCSC**: University of California, Santa Cruz, USA
**DF&G**: California State Department of Fish and Game
**SIO** University of California, San Diego-Scripps Institution of Oceanography, USA
**CICESE** Centro de Investigación Científica y de Educación Superior de Ensenada, Mexico

# Integrating Plankton Survey Observations in the California Current Large Marine Ecosystem

**September 25-26, 2006**
**Scripps Institution of Oceanography**

*HOSTED BY PACOOS- THE PACIFIC COAST OCEAN OBSERVING SYSTEM*

1) **Executive Summary**. The focus of the meeting was on integration of existing data collection and observations (Table 1a & 1b) of plankton-based hydrographic surveys in the California Current Large Marine Ecosystem (CC LME) including: Baja, California Mexico (IMECOCAL), Southern California Bight (CalCOFI and CA LTER), Central and Northern California (e.g. PaCOOS Monterey and Humboldt Lines), Newport, OR, (PaCOOS Newport Line) and the West Coast Canadian surveys (Figure 1). Participants representing the major West Coast Plankton surveys summarized existing sampling protocols and identified sampling gaps. While icthyoplankton and phytoplankton were discussed, the major focus was zooplankton protocols and observations. Standardization of protocols between surveys was discussed and action items and recommendations developed. Emerging bioacoustic technology for surveying zooplankton was also covered. The meeting developed baseline tables and summaries of existing California Current-wide surveys.

**Actions and Recommendations.**

- **Existing plankton surveys along the California Current regional ecosystem were established to answer specific questions and differences in sampling methods reflect those origins.**
    i. **No consensus on standardizing nets between surveys was accomplished because of the differences in survey objectives.**
    ii. **Improved collaborations[1] between existing plankton surveys will advance the scientific understanding of the system and likely detect and possibly predict climate changes effects on the California Current ecosystem.**
    iii. **Instituting "best practices" for surveys should be a priority for existing and new plankton surveys. (Table 2 and Appendix 1)**
- **Raising the profile of zooplankton surveys requires developing useful products by:**
    i. **Highlighting the presence of "sentinel species" that are indicative of ecosystem changes, including climate change. (Table 3).**
    ii. **Including zooplankton synthesis coastwide for the annual CalCOFI Report.**
- **New acoustic technologies application should be a priority for zooplankton surveys including:**
    i. **Adding ship based acoustic measurements at 38 and 120 kHz frequencies (at a minimum) should be implemented to measure zooplankton biomass.**
    **ii. Work with researchers developing Autonomous Underwater Vehicles (AUV) and gliders that can accommodate acoustic technology.**
    iii. **Protocols for acoustic sampling and training program(s) are needed to be developed through NOAA and/or acoustic vendors.**
    **iv. Acoustic technology application to marine environments is at its infancy and needs better theoretical basis that could be part of the National and Regional Sea Grant's portfolio.**
- **Investigators need to incorporate DMAC[2] data management techniques to eventually make survey data accessible from the web.**
- **Acknowledgment of long term data sets (e.g. CalCOFI, IMECOCAL) in publications is very important to demonstrate importance to government funding.**
- **The reduction of IMECOCAL surveys from 4 times a year to 2 times a year is contrary to the Global Ocean Observing System (GOOS) development worldwide sponsored by the IOC, UNEP, WMO and ICSU.**
    **i. IMECOCAL surveys are the first to document the ecological effects of an El Nino along the entire California Current.**
    ii. **Participants are strongly encouraged to raise the importance of IMECOCAL data results in reports and talks.**

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[1] Mackas, D.L., W.T. Peterson, M.D. Ohman and B.E. Lavaniegos. (2006). Zooplankton anomalies in the California Current system before and during the warm ocean conditions of 2005. *Geo Res Lett;* **33(L22S07)**. doi: 10.1029/2006GL027930.
[2] DMAC-Data Management and Communication protocols can be found at http://dmac.ocean.us/dacsc/imp_plan.jsp
[3] PaCOOS- Pacific Coast Ocean Observing System- is developing the ecological observing system along the California Current LME (www.pacoos.org)

- **PaCOOS[3] should develop the following items:**
    i. **An online distribution listserv on ecological phenomenon on the CA Current.**
    ii. **A workshop on acoustic sampling methods for plankton and other ecological needs.**
    iii. **Solicit participants on the need to standardize protocols between surveys to allow for direct comparisons.**
    iv. **Support a pilot project analyzing existing acoustic data to demonstrate efficacy of technique in survey work. A recommended candidate species is euphausiids.**

Participants at PaCOOS Plankton Survey Integration Workshop.

| | | | |
|---|---|---|---|
| **Tim Baumgartner** | Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE) | **Andy Leising** | NOAA Fisheries –Southwest Fisheries Science Center |
| **Eric Bjorkstedt** | NOAA Fisheries –Southwest Fisheries Science Center | **Dave Mackas** | Institute of Oceans and Fisheries (Canada) |
| **Steven Bograd** | NOAA Fisheries –Southwest Fisheries Science Center | **Baldo Marinovic** | University of California, Santa Cruz |
| **Rich Charter** | NOAA Fisheries –Southwest Fisheries Science Center | **Cheryl Morgan** | Oregon State University |
| **Francisco Chavez** | Monterey Bay Area Research Institute (MBARI) | **Todd O'Brien** | NOAA Fisheries- Science and Technology (HQ) |
| **Dave Checkley** | UCSD, Scripps Institution of Oceanography | **Mark Ohman** | UCSD, Scripps Institution of Oceanography |
| **Ralf Goericke** | UCSD, Scripps Institution of Oceanography | **Bill Peterson** | NOAA Fisheries –Northwest Fisheries Science Center |
| **Sarah Goldthwaith** | Humboldt State University | **Jay Peterson** | NOAA Fisheries –Northwest Fisheries Science Center |
| **Dave Griffith** | NOAA Fisheries –Southwest Fisheries Science Center | **Jonathan Phinney** | NOAA Fisheries –Southwest Fisheries Science Center |
| **Roger Hewitt** | NOAA Fisheries –Southwest Fisheries Science Center | **Ryan Rykaczewski** | UCSD, Scripps Institution of Oceanography |
| **John Hunter** | NOAA Fisheries –Southwest Fisheries Science Center (retired) | **William Watson** | NOAA Fisheries –Southwest Fisheries Science Center |
| **Bertha Lavaniegos** | Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE) | **Jim Wilkinson** | UCSD, Scripps Institution of Oceanography |

**List of Figures and Tables:**

Figure 1. Existing and plankton surveys in the California Current Large Marine Ecosystem.

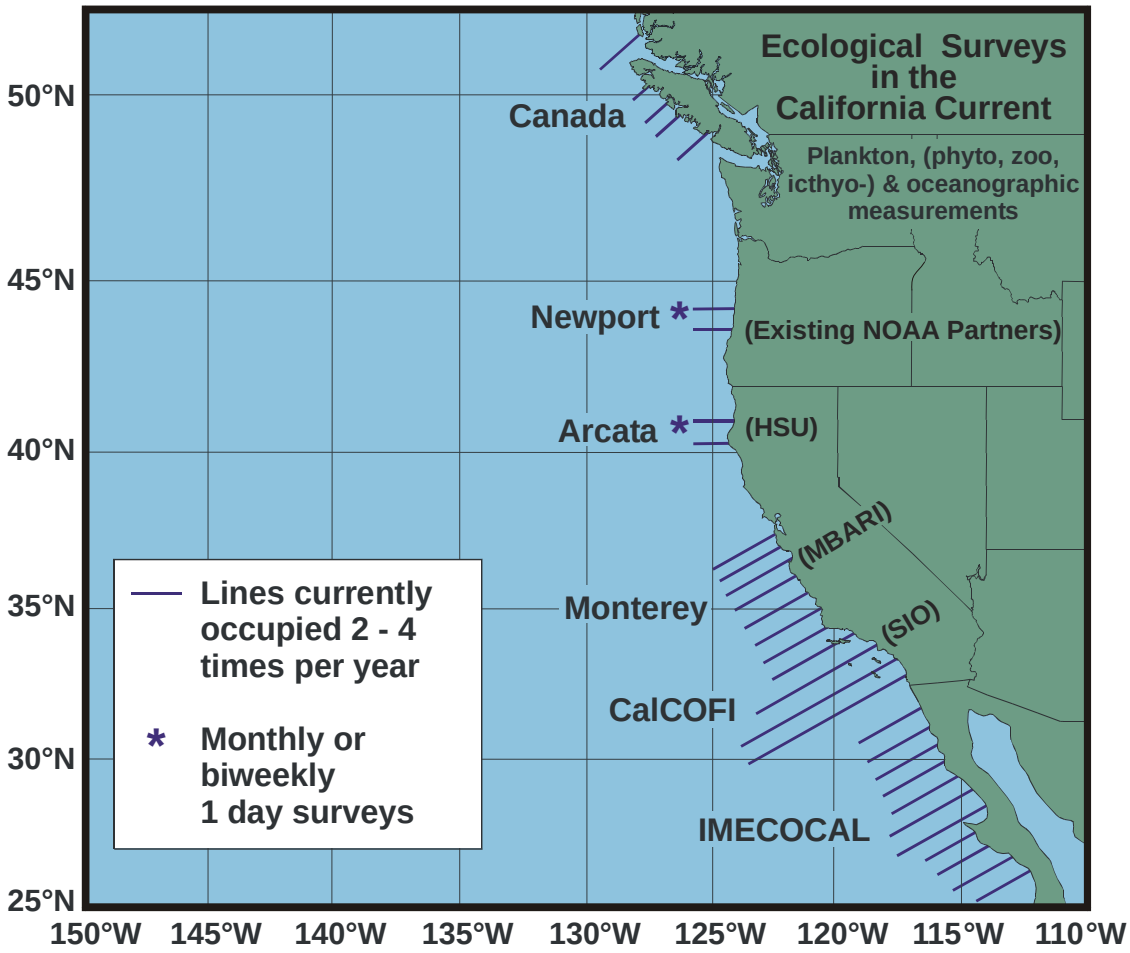


**Table 1a. Existing plankton surveys in the California Current Large Marine Ecosystem**

| Survey Name/ Organization | Region | Annual Frequency | Date | Chlorophyll/ Flouresence | Nutrients | Plankton tows | CTD | DO | Other Parameters |
|---|---|---|---|---|---|---|---|---|---|
| **IMECOCAL- Investigaciones Mexicanas de la Corriente de California-CICESE, UABC, CIBNOR** | Northern-Central Baja California (~112°-119°W, ~24.5°-32°N) | Total 4 15-22 days/cruise at quarterly intervals; Winter: (January-February); Spring (April), Summer (July), Fall (October) | 1997-present | Casts: a) associated to CTD standard cast (0, 10, 20, 50, 100, 150, 200 m); b) productivity casts (depths in function of euphotic layer) up to 20 depths since 1984; flow-through fluorescence at 3 m) | Nitrate, nitrite, phosphate, (same depths as Chlorophyll); 20 depths to 520 m, since 1984 | Bongo, Oblique tow, (71 cm diameter, 0.505 mm 200 m depth) | 1000 m | | ADCP |
| | | | | | | Pairovet vertical tow, (25 cm diameter, 150 m, 70 m depth) (all stations in 1997-2005; since Oct 2005 selected stations some times) | | | Primary Production |
| | | | | | | Manta -horizontal surface tow, (15.5 cm x 86 cm; .333 mm mesh Surface ~15 cm; only one shallow station per transect) | | | Secchi |
| | | | | | | CUFES (Continuous Underway Fish Egg Sampler). Water pumped through ship's hull from approx. 3 m depth. Mesh size = .505 mm. Sampling during all four quarters beginning in Jan. 2000 | | | PAR |
| **CalCOFI- California Cooperative Oceanic Fisheries Investigation-SIO, NOAA, CA Dept Fish & Game** | Southern-Central California (~116'-124'W, ~30'-38'N) winter and spring quarters, southern California (~30-35$^0$ N) summer and autumn quarters | Total 4 15-30 days/cruise at quarterly intervals; Winter (January); Spring (April); Summer (July); Fall (November) | 1951-present | Underway or < than 200m | Nitrate, nitrite, phosphate, silicates 1-515 m/Basins | Bongo, Oblique tow, (71 cm diameter, 212m depth) (all cruises) Starboard net 0.505 mm mesh, formalin-preserved sample; Port net 0.505 or 0.333 mm mesh, ethanol preserved sample | 515m; exceptions Santa Barbara & Santa Monica Basins: 10m off bottom | 515m + Basins | ADCP |

| Survey Name/ Organization | Region | Annual Frequency | Date | Chlorophyll/ Flouresence | Nutrients | Plankton tows | CTD | DO | Other Parameters |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Pairovet vertical tow, 25cm diameter, 0.150mm mesh, 70m depth) (Paired Vertical Egg Tow) (all cruises) | | | Primary Production |
| | | | | | | Manta -horizontal surface tow , 15.5 cm x 86 cm, 0.505 mm mesh, Surface ~15 cm) (all cruises) | | | Acoustics (EK500 transitioning to EK60) on all cruises or only april? |
| | | | | | | CUFES (Continuous Underway Fish Egg sampler) horizontal tow~ 3 m depth) (Spring quarter only; winter quarter added in 2006) 0.505 mm mesh | | | Secchi |
| **Humboldt Line-NOAA and HSU** | 60 nm transect ($41^0$ 3.4' N; $124^0$ 12.5' W to $125^0$ 32.0' W) | (4) 36 hour cruises time to coincide with CalCOFI cruises; anticipate extending cruise duration and frequency as funding allows. | 2006-present | fFow-through fluorescence & CTD fluorescence (currently uncalibrated by chl a measurements) | None yet; anticipate adding on next cruise | CalBOBL/Bongo (210 m; oblique; 505 µm); Manta (505 µm); Pairovet (70 m; vertical; 202 µm); 1 m Multiple-Net/Opening-Closing Tucker Trawl (505 µm; 75-35 m & 35 m-surface typical) | Casts to 500 m or bottom minus 15 m; Seabird 19plus; fluorescence, transmissivity, PAR (Biospherical), DO (Seabird 43); | YES | PAR; minor weather observations |
| **Line 67 -NOAA, MBARI, UCSC** | Central California, CalCOFI Line 67 | Quarterly cruises, 4-8 day each | 1988-present, some interruptions | Underway, CTD profiles, bottle profiles | Macronutrients, 0-1000 m | Oblique bongos, 333 or 505 µm; 200 m | 0-1000 m | | CTD profiles, 0-1000m; occasional bottle samples |
| | | | | | | | | | Meteorological |
| | | | | | | | | | Secchi |
| | | | | | | | | | PAR |
| | | | | | | | | | Primary prod, total - C14 |
| | | | | | | | | | Primary Prod, new and |

| Survey Name/ Organization | Region | Annual Frequency | Date | Chlorophyll/ Flouresence | Nutrients | Plankton tows | CTD | DO | Other Parameters |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | recycled - N15 |
| | | | | | | | | | POC, HPLC, FCM, A*, surface |
| | | | | | | | | | ADCP, most ships |
| | | | | | | | | | pCO2, surface |
| **Juvenile Rockfish Trawl NOAA, PRBO, and MBARI** | San Diego (33°N) to Cape Mendocino (40°N) from nearshore to 60 km offshore | Once per year during May-June | 1983-present | Underway, CTD | | Midwater trawl (micronekton) | 0-500 m | | ADCP, EK-500, birds & marine mammals (PRBO), krill & squid (UCSC) |
| **PRBO (Point Reyes Bird Observatory)** | Central/Northern California, SE Farallon to Cordell Bank | Bimonthly, 3-4 day each | 2004 – present | CUDLS T/S/F, CTD casts at 9 stations | Samples in 2006 | Tucker trawls for euphausiids, started in 2005; hoop nets 2004 – present | 0 – 200 m, some to near 1000 m | | Seabirds and marine mammals observations; 7 transect lines; |
| **Newport Line Biweekly Sampling (NOAA, OSU)** | Newport Line 44° 40'N from 124° 06'W to 124°39'W;stations 1, 3, 5,10, 15, 20 and 25 nautical miles from shore. Newport Line 44° 40'N from 124° 06'W to 124°39'W; stations 1, 3, 5,10, 15, 20 and 25 nautical miles from shore. Historical data available ~biweekly from June 1969-August 1972, May-September 1973, July-August 1977, May-September 1983, February-September 1990, summer 1991 and 1992 | Bi-weekly; usually get in 25-28 cruises per year | 1996-present | Surface bucket for chl at all stations. < 10 µm Nitex size fraction at NH 5, 15, 25. As of March 2006, we use 5 µm Nucleopore filters | Surface bucket at NH 5, 15 and 25, for silicate, phosphate, nitrite, nitrate, ammonia | Vertical (50 cm diameter, 202 µm) from 5 m off the sea floor or from 100 m in water deeper than 105 m. TSK flowmeter. Bongo (60 cm mouth, 333 µm mesh, black nets). Oblique tow from ~ 20 m to the surface: tow at 2 knots, pay out 60 m wire then retrieve | Seabird 19 since March 1997; with Wetstar fluorometer since June 2004; with Seabird 43 Oxygen since August 2005 | YES | Secchi Depth; presence/ absence of seabirds; presence of whales. Measurement of copepod egg production rates; done year around, since 2001. Focus on *Calanus marshallae, C. pacificus, Centropages abdominalis, Acartia longiremis*. *Incubate Epilabidocera, Tortanus, Eucalanus, Mesocalanus* and *Clausocalanus* when available. Set-up at-sea incubations of euphausiid molting rates of juvenile and/or adults, and brood size of adult females |

| Survey Name/ Organization | Region | Annual Frequency | Date | Chlorophyll/ Flouresence | Nutrients | Plankton tows | CTD | DO | Other Parameters |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | when available, since 2001. |
| **PaCOOS/GLOBEC L-TOP Lines (NOAA and OSU)** | Grays Harbor (47°N); Columbia River (46°11'N), Newport (44°40'N, Heceta Head (44°), Crescent City (41°54') and if time, Eureka (40°502'N) and Point Arena. From 1 to 85 miles from shore. Historical salinity, temperature and oxygen (from Nansen bottles, reversing thermometers, and titrations) data available from 1960s from Astoria, Newport and Brookings (30 miles north of Crescent City), 1-85 miles from shore. | Whenever we can get a NOAA ship which is not very often! Data from May 2004, Setpember 2004, November 2004, May 2005, November 2005, and May 2006 | LTOP 1998-2003; NOAA ship requests submitted for cruises in February, May, July, September and November | 3 m chlorophyll at all stations; 12 bottle depths at all Newport Line stations. CTD has fluorometer | Same effort as with chlorophyll. Same species as above | Vertical tow (50 cm diameter, 202 µm) from 5 m off the sea floor or from 100 m in water deeper than 105 m. TSK flow meter. Bongo (70 cm mouth, 333 µm mesh, black nets). On Newport Line at Night: Oblique tow from ~ 20 m to the surface: tow at 2 knots, pay out 60 m wire then retrieve. All other stations, regardless of day or night, double oblique to 100 m. | Yes | Yes | Bird and mammal observation during the day; either from Point Reyes or NMFS observers on all other occasions. Living zooplankton saved and sorted for incubations of copepods. Target species same as listed above. At night, at all stations, focus is collect purple female euphausiids and incubate if available; also set up at least two molting rate experiments each night. |

| Survey Name/ Organization | Region | Annual Frequency | Date | Chlorophyll/ Flouresence | Nutrients | Plankton tows | CTD | DO | Other Parameters |
|---|---|---|---|---|---|---|---|---|---|
| **PaCOOS Biweekly Hydrography, Zooplankton and Trawlable Fish (NOAA and OSU)** | Willapa Bay (46°39'N) and Columbia River (46° 11'N) | Biweekly from late April through early September | 1998-present | Same as juvenile. salmonid project | Same as juvenile salmonid project | Same as juvenile salmonid project | Same as juvenile. salmonid project | Beginning in 2007 | Secchi. No birds or mammals |
| **Dept of Fisheries and Oceans, Canada** | Southwest coast of Vancouver Island (48-49.5°N), 12-18 stns at standard locations, covering the continental shelf (12) and continental slope | 4-6 surveys per year, mostly April-October | 1979-present (since 1985 on present station grid) | Fluorometer mounted on CTD rosette | Nitrate, phosphate, silicate, sometimes ammonium, 2-4 surveys per year | vertical (occasionally oblique) tows, near -bottom to surface or 250m to surface, flowmeter 0.5 $m^2$ bongo, black frame and black 0.23 mm mesh. Catch from one side preserved in formalin, other side usually frozen | CTD cast at all stations, | Yes | |
| **Dept of Fisheries and Oceans, Canada** | Northwest coast of Vancouver Island (49.5-51.5°N), 12-20 stns at standard locations covering the shelf (10) and continental slope (up to 10) | 3-5 surveys per year, mostly March-October | 1990-present, but best coverage is 1997-present | Fluorometer mounted on CTD rosette | nitrate, phosphate, silicate, sometimes ammonia, 2 surveys per year | vertical (occasionally oblique) tows, near -bottom to surface or 250m to surface, flowmeter 0.5 m2 bongo, black frame and black 0.23 mm mesh. Catch from one side preserved in formalin, other side usually frozen | CTD cast at all stations | Yes | |

| Table 1b. Oceanographic parameters and Acoustic measurements for plankton surveys along the California Current LME. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **A. Oceanographic** | Maximum CTD & PAR depth | | Chlorophyll Filter Size | | | Primary Production | Nutrients | Dissolved Oxygen | pCO2 |
| | | GFF | 1 μm | 5 μm | 10 μm | | | | |
| IMECOCAL | 1000 m | X | | | | X | X | X | X |
| CalCOFI | 515 m | X | X | 3 μm, 8 μm | 20 μm | X | X | X | X |
| Line 67 | 1000 m | X | | X | | X | X | Sensor on CTD | X |
| Rockfish surveys | 520 m | X | | | | | X | | |
| PRBO | | | | | | | | | |
| Humboldt Line | 520 m | X | | | | | X | | |
| PaCOOS (Newport) Lines | 550 m (1000m) | X | | X | | | X | | |
| Salmonids Oregon-Washington | 100 m | X | | | | | X | | |
| DFO Canada | 1000 m | X | | | | | X | X | |
| DFO Canada Line P | 4000 m (bottom) | | | | | X | X | X | X |
| | | | | | | | | | |
| **B. Acoustic Measurements** | | | | | | | | | |
| | ADCP | Multi-frequency | 38 kHz | 120 kHz | 200 kHz | 18 kHz | | | |
| IMECOCAL | X | | | | | | | | |
| CalCOFI | X | X(Winter, Spring) | X | X | X | | | | |
| Monterey Line (CalCOFI 67) | X | X | X | X | X | | | | |
| Rockfish surveys | X | X | X | X | X | | | | |
| PRBO | | | | | | | | | |
| Humboldt | | | | | | | | | |
| Newport surveys | | X | X | X | X | X | | | |
| Salmonids Oregon-Washington | X | | | | | | | | |
| Canada | X | X | X | X | X | | | | |
| Line P | X | | | | | | | | |

| Table 1c. Net tow, type and mesh size for plankton sampling in the California Current LME. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bongo 505μm | Bongo 333μm | Bongo 230μm | Vertical 202μm | Vertical 150μm | Vertical 230μm | Tucker 333μm | Tucker 505μm | Manta 505μm | Manta 333μm | Bioness 230μm | Midwater trawl | CUFES |
| IMECOCAL | X | | | | X | | | | | X | | | X |
| CalCOFI | X | X | | X | X | | | | X | | | | X |
| Monterey Line (CalCOFI 67) | X | X | | X | | | X | | | | | | |
| Rockfish surveys | X | X | | | | | | | | | | X | |
| PRBO | | | | | | | | | | | | | |
| Humboldt | X | X | | X | X | | | X | X | | | | |
| PaCOOS (Newport) Lines | | X | | X | | | X | | | | | | |
| Salmonids Oregon-Washington | | X | | X | | | | | | | | | |
| Canada | | | X | | | | | | | | X | | |
| Line P | | | X | | | | | | | | | | |

| Table 2. “Best Practices” for Zooplankton Sampling for California Current LME. | | |
|---|---|---|
| **Objective. Assess spatial, seasonal, and interannual variations in:** | **Sampling Gear** | **Sampling Processing Methodology** |
| 1. Total mesozooplankton biomass;<br>2. Abundance of “sentinel zooplankton species” (Table 3). | Vertically hauled 202-µm mesh nets, minimum diameter 0.5 m, dyed black or dark blue; sampling to 200 m depth, bottom-depth permitting; otherwise to within 10 m of the bottom.<br><br>**Acceptable alternatives:** 0.75 – 1.0 m diameter nets.<br><br>Obliquely hauled bongo frame, 0.71-m diameter, with one 333-µm mesh mesh and one 505-µm mesh, dyed black or dark blue; sampling to 200 m depth as above - LOPC (Laser Optical Particle Counter) mounted in mouth of 333 net for vertical distribution information<br><br>**Acceptable alternatives:** 0.61-m diameter bongo and omitting LOPC if cost prohibitive. | Size-based reconstruction of biomass from microscopic enumerations of taxa within size categories; conversion to carbon biomass using appropriate Length-Carbon regressions.<br><br>**Acceptable alternatives:** Probably optical scanning (e.g., Zooscan) measures of size and abundance; remains to be validated. |
| 1. Total euphausiid biomass;<br>2. Assess California Current-wide coherence and alongshore continuity of regionally measured properties of the zooplankton assemblage | Obliquely hauled bongo frame, 0.71-m diameter, with one 333-µm mesh mesh and one 505-µm mesh, dyed black or dark blue; sampling to 200 m depth as above - LOPC (Laser Optical Particle Counter) mounted in mouth of 333 net for vertical distribution information.<br><br>**Acceptable alternatives:** 0.61-m diameter bongo omitting LOPC if cost prohibitive.<br><br>Multi-frequency hydroacoustic system for acoustic backscatter, principally to assess fine-scale vertical and horizontal spatial distribution of euphausiid-sized organisms (number and specific frequencies of transducers to be determined and standardized; (its essential that transducers be regularly calibrated).<br><br>**Acceptable alternatives:** unclear; needs to be reviewed by competent bioacousticians | Enumerations of total euphausiid abundance by microscopy and size-based reconstruction of biomass from Length-Carbon regressions.<br><br>**Acceptable alternatives:** Possibly optical scanning (e.g., Zooscan) measures of size and abundance; remains to be validated.<br><br>Standardized processing techniques for hydroacoustic surveys agreed to by experts in krill and fisheries bioacoustics.<br><br>**Acceptable alternatives:** None.<br><br>Microscopic identification of particular taxa with known merit as sentinel species. |

**Table 3. Proposed sentinel plankton species in the California Current LME that can indicate climatic regime changes. Presence or absence indicates "warm": southern species dominated or "cool", northern species dominated periods.**

| **Cosmopolitan throughout the California Current System** | **Northern CCS (British Columbia and Oregon)** |
|---|---|
| **Copepods –** | **Copepods** |
| *Calanus pacificus* | *Acartia danae* |
| *Metridia* cf. *pacifica* | *Acartia longiremis* |
| *Paracalanus parvus* | *Acartia tonsa* |
| **Euphausiids –** | *Calanus marshallae* |
| *Thysanoessa spinifera* | *Calocalanus styliremis* |
| *Euphausia pacifica* | *Clausocalanus pergens* |
| Pteropods - | *Corycaeus anglicus* |
| *Limacina helicina* | *Ctenocalanus vanus* |
| **Salps** | *Ctenocalanus vanus* |
| *Salpa fusiformis* | *Eucalanus bungii* |
| **Doliolids -** | *Eucalanus californicus* |
| *Dolioletta gegenbauri* | *Mesocalanus tenuicornis* |
| **Medusae -** | *Neocalanus cristatus* |
| *Chrysaora fuscescens* | *Neocalanus plumchrus* |
| **Icthyoplankton** | *Paracalanus parvus* |
| Pacific Sardine, *Sardinops sagax* | *Pseudocalanus mimus* |
| Northern Anchovy, *Engraulis mordax* | *Rhincalanus nasutus* |
| Market Squid, *Loligo opalescens* | **Euphausiids** |
| Pacific Hake (Pacific Whiting), *Merluccius productus* | *Euphausia pacifica* |
| **CalCOFI region (Central California to Baja Mexico)** | *Thysanoessa inspinata* |
| **Copepods** | *Thysanoessa spinifera* |
| *Pareucalanus attenuatus* | **Chaetognaths** |
| *Euchaeta media* | *Eukrohnia hamata* |
| *Neocalanus robustior* | *Sagitta decipiens* |
| *Pleuromamma gracilis* | *Sagitta elegans* |
| **Euphausiids** | *Sagitta euneritica* |
| *Euphausia eximia* | *Sagitta minima* |
| *Euphausia gibboides* | *Sagitta scrippsae* |
| *Euphausia pacifica* | **Salps** |
| *Euphausia recurva* | *Salpa aspera* |
| *Nyctiphanes simplex* | **Icthyoplankton** |
| *Thysanoessa spinifera* | Sablefish ,*Anoplopoma fimbria* |
| **Doliolids** | Northern Flashlightfish, *Protomyctophum thompsoni* |
| *Doliolum denticulatum* | Robust Blacksmelt, *Pseudobathylagus milleri* |
| **Salps** | |
| *Cyclosalpa affinis* | |
| *Cyclosalpa bakeri* | |
| *Pegea socia* | |
| *Salpa maxima* | |
| **Decapods** | |
| *Pleuroncodes planipes* | |
| **Ichthyoplankton** | |
| Mexican lampfish, *Triphoturus mexicanus* | |

**Appendix 1. Recommended parameters in the development of a new plankton survey line in the California Current System. The Humboldt Line was highlighted as a case study.**

**Goal:** Develop the Humboldt Line for the California Current ecological observing system, for PaCOOS.
**Limitations:** Modest resources including a 60-foot R/V *Coral Sea*, which limits offshore surveys to within 60 nm of the coast in this area.
**Needs:** A hierarchy of sampling metrics with a core set of measurements.

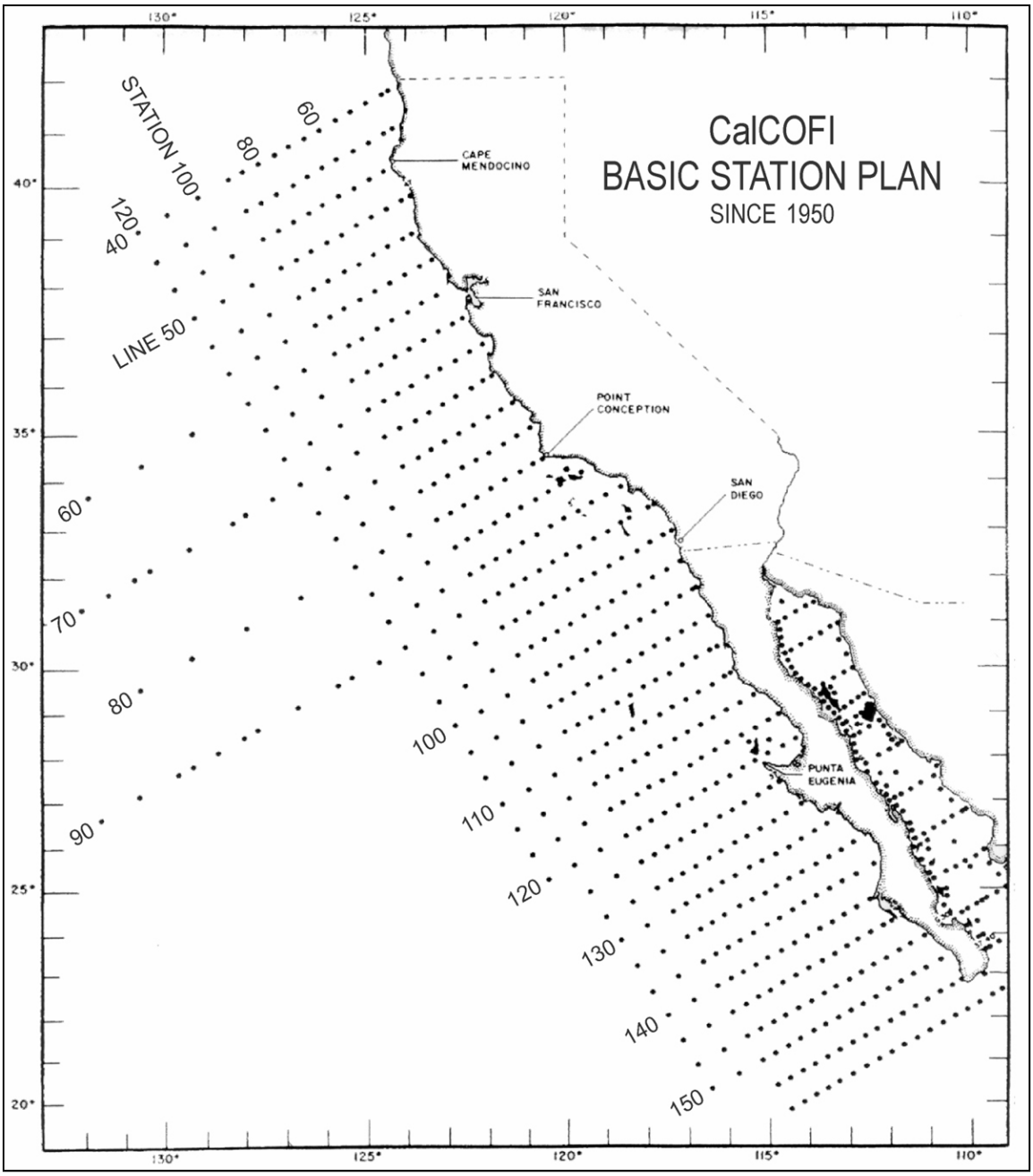
- Recommended survey location.
  - Transit offshore on one line, Trinidad Head, to limit of vessel (60 nm for the R/V *Coral Sea*).
  - Return to shore on adjoining historical CalCOFI line (approximately 30 nm south; see Appendix ?) so to be able to compare present samples with archived samples.

- Recommended station number.
  - Three to four (3-4) stations over the continental shelf (approximately 20 miles off shore in this area)
  - Three (3) offshore or more as weather permits.

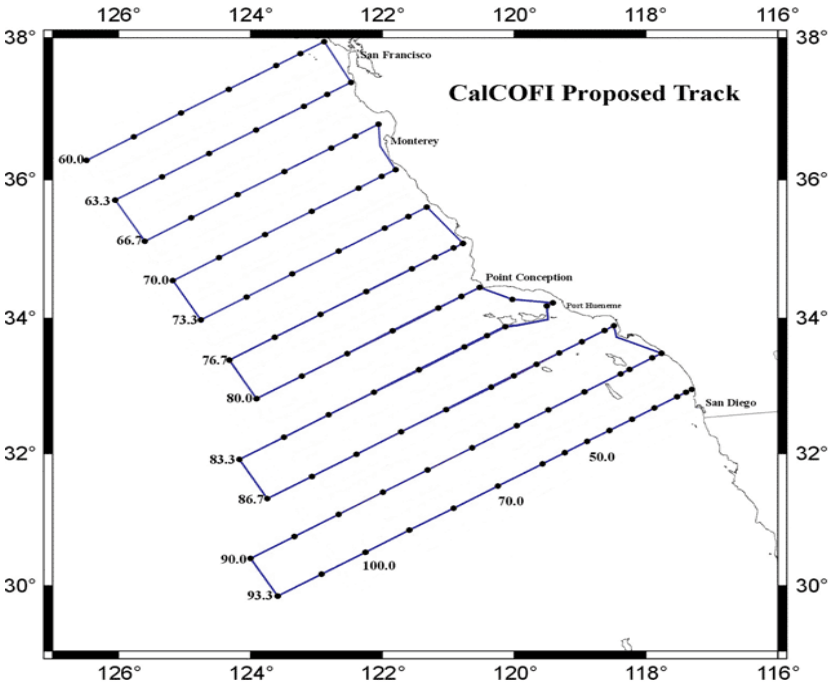
- Core survey parameters. Standard techniques are:
  - Oceanographic measurements
    - Surface chlorophyll
    - CTD (Conductivity, Temperature and Density)
    - Nutrients (nitrate, nitrite, ammonium, phosphate, silicate)
    - Primary production

  - Plankton measurements (see photos at http://www.calcofi.org)
    - Displacement volumes for zooplankton and icthyoplankton
    - Bongo net with 505 μm , 333 μm mesh nets to 200 meters or less over continental shelf
    - Surface (manta) tow
    - CUFES system over side to give spawning biomass estimates
    - Acoustics for estimating biomass mounted to the ship's hull or to a pole over side of vessel. ADCP is not recommended because of problems with calibration.
      - Minimum frequencies: 38 and 120 kHz for measuring micronekton and fish
  - Plankton species identification (See Table 4). Voucher specimens are required for each species). The following individuals are experts who are willing to help in identification:
    - Ichthyoplankton (Bill Watson)
    - Zooplankton (Copepods) (Bill Peterson)
    - Krill (Mark Ohman)
  - Reporting of data should be aligned with the Integrated Ocean Observing System's Data Management And Communication (DMAC) system. (http://dmac.ocean.us/dacsc/imp_plan.jsp)

Appendix 2. Historical CalCOFI survey lines along the coasts of California and Baja, California, Mexico.



Appendix 3. Present (2006) CalCOFI Survey Lines. (A) Winter and Spring sampling grid (101 stations) and (B) Summer and Fall sampling grid (66 stations).



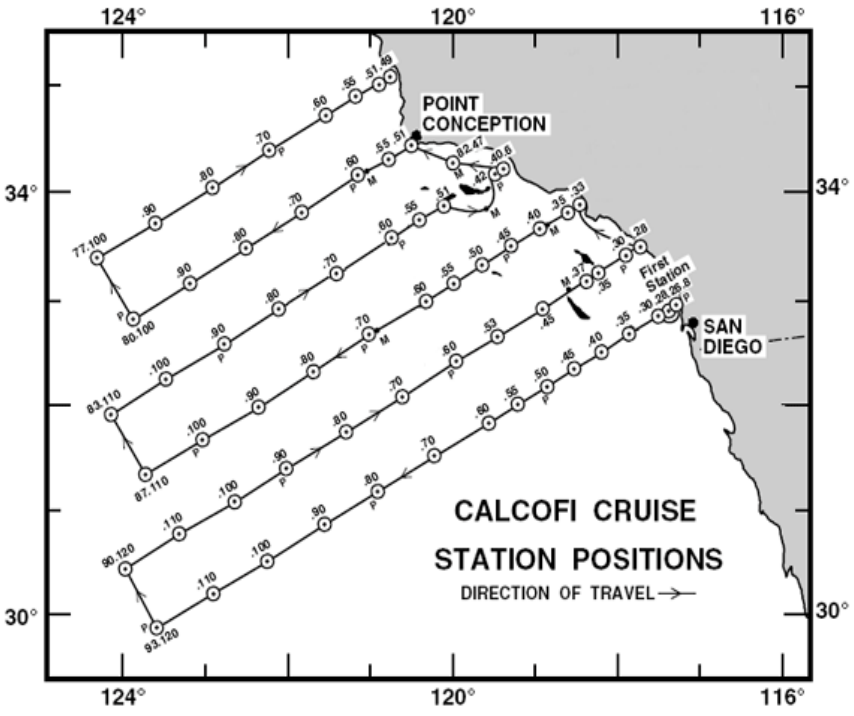




FIGURE 1

Appendix 4

**INTEGRATING PLANKTON SURVEY OBSERVATIONS IN THE CALIFORNIA CURRENT LARGE MARINE ECOSYSTEM**
**September 25-26, 2006**
**Scripps Institution of Oceanography**

# Agenda

**MONDAY, SEPTEMBER 25**

1:00 PM Welcome and Introduction, Co-Chairs Hunter and Chavez

1:15 PM **Assess compatibility of measurements from existing surveys (meeting objective No. 1 ) using survey status forms and discussion and including: annual temporal coverage, zooplankton sampling, hydrographic, and other measurements**.

Discussion leaders: Hunter and Chavez

2:15 PM **Review Best Practices document and identify actions required to increase compatibility of key measurements among surveys and set priori**ties.

Discussion leader: Mark Ohman

3:15 PM Coffee Break

3:45 PM **Review NOAA's list of sentinel species (climate indicator species) for the California Current system. Identify critical gaps in taxa, new measurements required and candidate species that could be accomplished on plankton-based hydrographic surveys**.

Discussion leader: Bill Peterson

4:15 PM **Progress on California Current zooplankton synthesis. Presentation of the in-press paper "Zooplankton anomalies in the California Current system before and during the warm ocean conditions of 2005" by Mackas, Peterson, Ohman and Lavaniegos.**

Presentation: David Mackas

4:30 PM **Identify potential coast-wide indices of the dynamics of the California Current Ecosystem that might be generated from existing plankton-based hydrographic surveys.**

Discussion leader: John Hunter

5:30 PM **Assess compatibility of ichthyoplankton information among plankton-based hydrographic surveys in the California Current.**

Discussion leader: William Watson

6:00 PM Adjourn

**TUESDAY, SEPTEMBER 26**

| | |
|---|---|
| 8:30 AM | **Improving survey integration using bioacoustics.** |
| | Discussion leaders: Roger Hewitt |
| 10:00 AM | **Identify and describe projects that demonstrate the value of synthesis of data among existing plankton-based hydrographic surveys**. |
| | Discussion leader: Francisco Chavez |
| 10:30 AM | Coffee Break |
| 10:45 AM | **Continue discussion on previous agenda item.** |
| | Discussion leaders: John Hunter and Jonathan Phinney |
| **12:00** | **Lunch at T-29** |
| 1:00 PM | **Processing and reporting of California Current zooplankton survey data.** |
| | Discussion leader: Eric Bjorkstedt |
| 1:30 PM | **Action Items** |
| | Discussion Leader: Jonathan Phinney |
| **3:00 PM** | **Adjourn** |