

Demersal fish and benthic invertebrate biomass in relation to low oxygen off the U.S. west coast

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Introduction

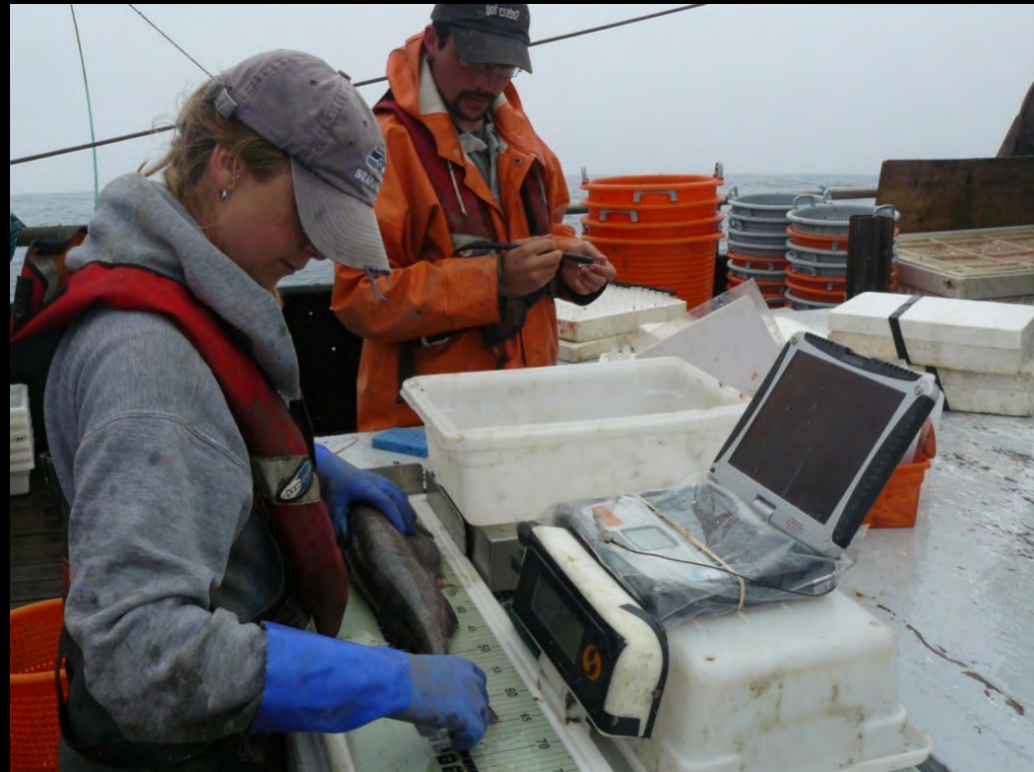


- Near bottom waters along the continental margin of the eastern North Pacific are naturally low in dissolved oxygen ($\text{DO} < 0.5 \text{ ml l}^{-1}$ or $22.3 \mu\text{mol kg}^{-1}$)
- In southern California Current System large decreases in DO observed from 1984 - 2006 (21% below the thermocline - Bograd et al. 2008)
- In the northern California Current System similar declines noted off WA and OR with seasonal hypoxia ($< 1.4 \text{ ml l}^{-1}$) observed annually since 2002 (Chan et al. 2009)
- Expansion and shoaling of these low DO waters lead to our examining the relationship between low DO and catch of near bottom organisms during the NWFSC's annual groundfish survey off the Pacific coast

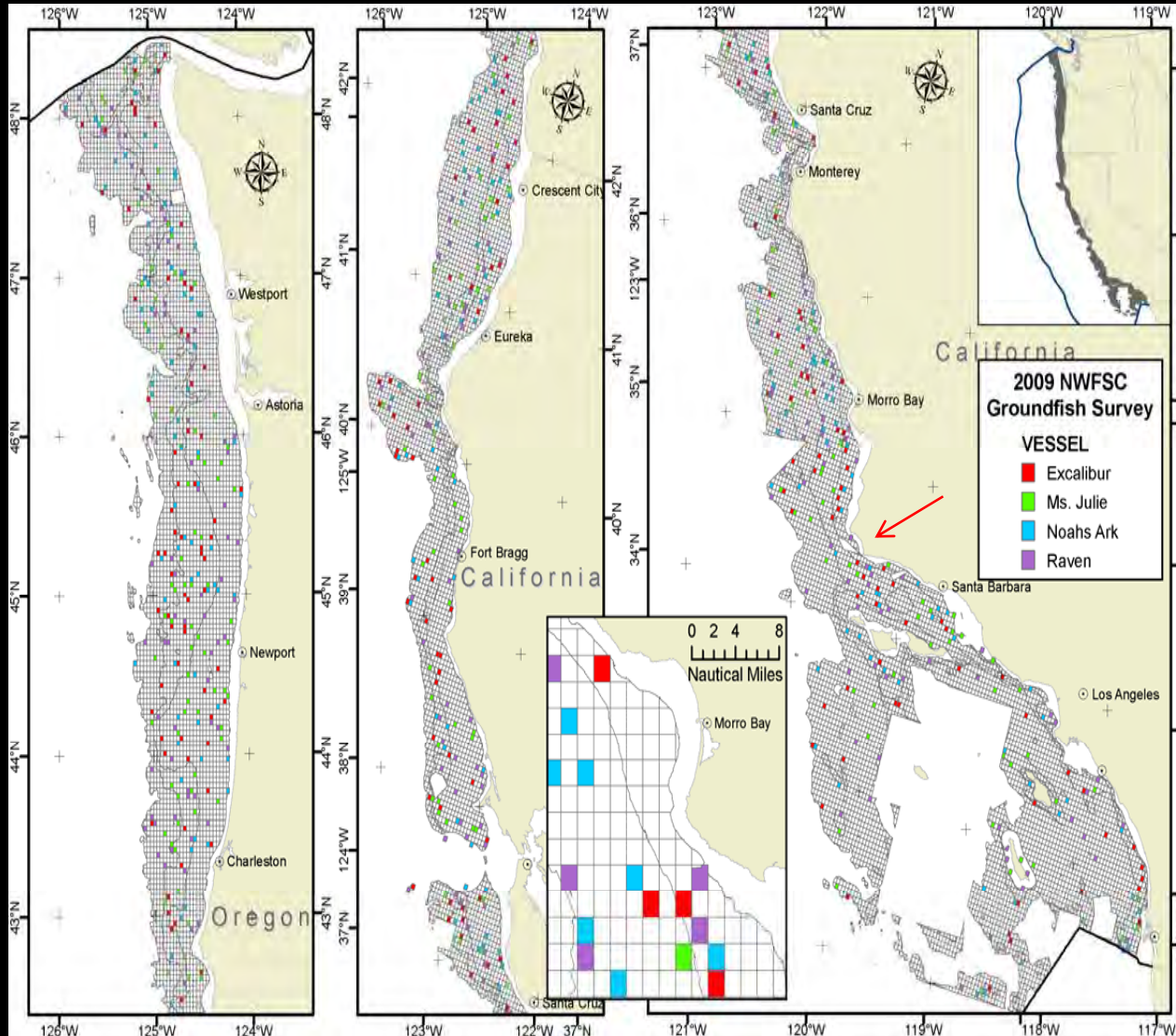
NWFSC West Coast Groundfish Bottom Trawl Survey

Mission: provide information for management of 90 commercial groundfish species

- Annually chartered 4 west coast fishing vessels, 65-96' (19.8-29.3 m)
- 2 passes down entire coast (mid-May – July; mid-Aug – Oct)
- Standardized fishing gear: four-panel Aberdeen 85/104' (25.9/31.7 m) bottom trawl
- Average 4-5 tows per day
- Fish at depths 55 -1,280 m
- Target tow speed 2.2 kt
- Target tow duration 15 minutes
- Fish during daylight hours
- 160 days at sea; ~760 tows yr⁻¹



Stratified-Random Sampling Design



- US Canadian border to US Mexican border
- Survey area sub-divided into >11,500 equally sized cells (1.5 X 2.0 nm)
- Each of 4 vessels randomly assigned a set of 188 cells, secondary and tertiary cells also assigned (not shown)
- 2 geographic strata: 80% N of Pt. Conception (34°30'N), 20% S
- 3 depth strata (55-183 m, 183-549 m; 550-1,280 m)
- Minimum 30 tows/stratum

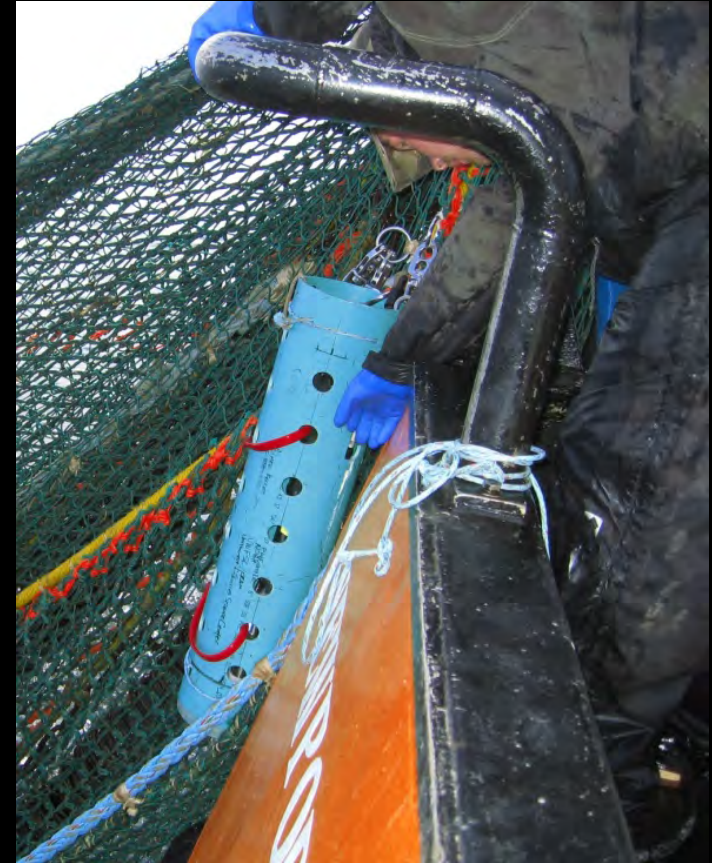
Methods

- All catch sorted, identified to species and weighed
- Selected species individually sexed and measured
- Stomachs, ovaries, age structures, DNA, tissue samples collected
- Wireless back deck with electronic scales, fish meter boards, bar code scanner
- Trawl data collected via sensors (net width, height, speed, door spread, distance fished, position of trawl transect, bottom contact, temperature, depth, salinity, DO, etc.)
- Trawl and catch data input via customized software



2007 – 2010 Bottom Oxygen Studies during the NWFSC Groundfish Survey

1. Hypoxia Studies offshore Oregon (annually since 2007) with some coverage back to 2003
2. Southern California basin study (2008)
3. Coast wide near-bottom oxygen measurements from US Canada to US Mexico (two vessels May – Oct. 2009; four vessels May – Oct. 2010) as part of groundfish survey



Annual Hypoxia Surveys Offshore Oregon

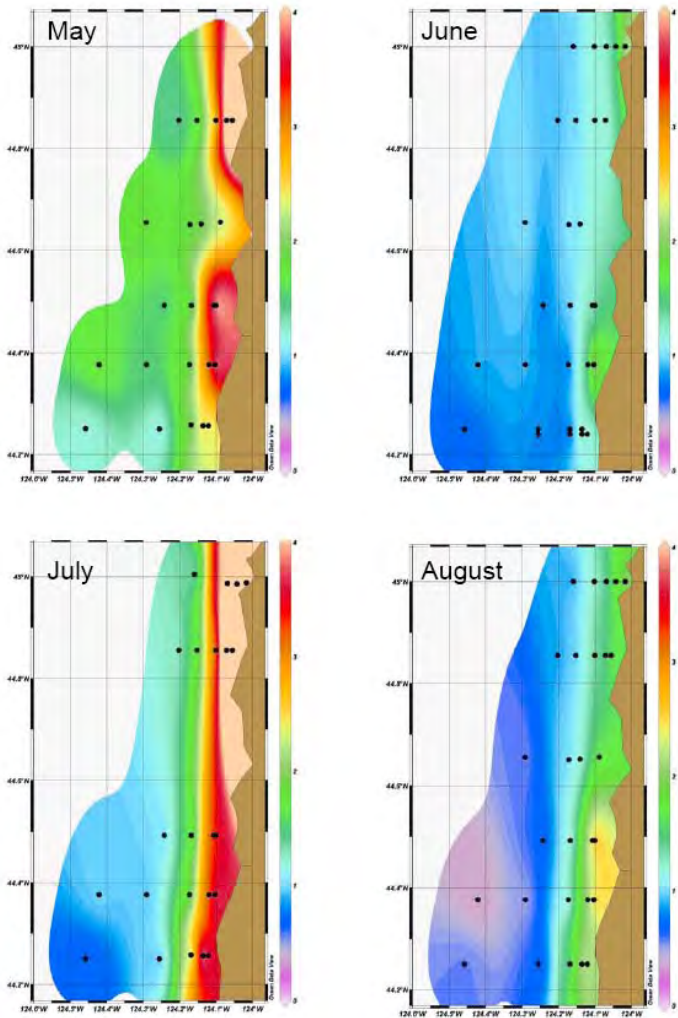
- 13 – 17 stations per year
- 2 – 3 days per year
 - Aug. 30 – 31, 2007
 - Sept. 7 – 8, 2008
 - Aug. 22 – 24, 2009
 - Sept. 2 – 3, 2010
- Cells selected along 2 depth contours each year (55 to 80 m)
- Sample dates and depths determined each year from DO monitoring data supplied by Oregon State University colleagues



2007 Bottom DO (ml l⁻¹)

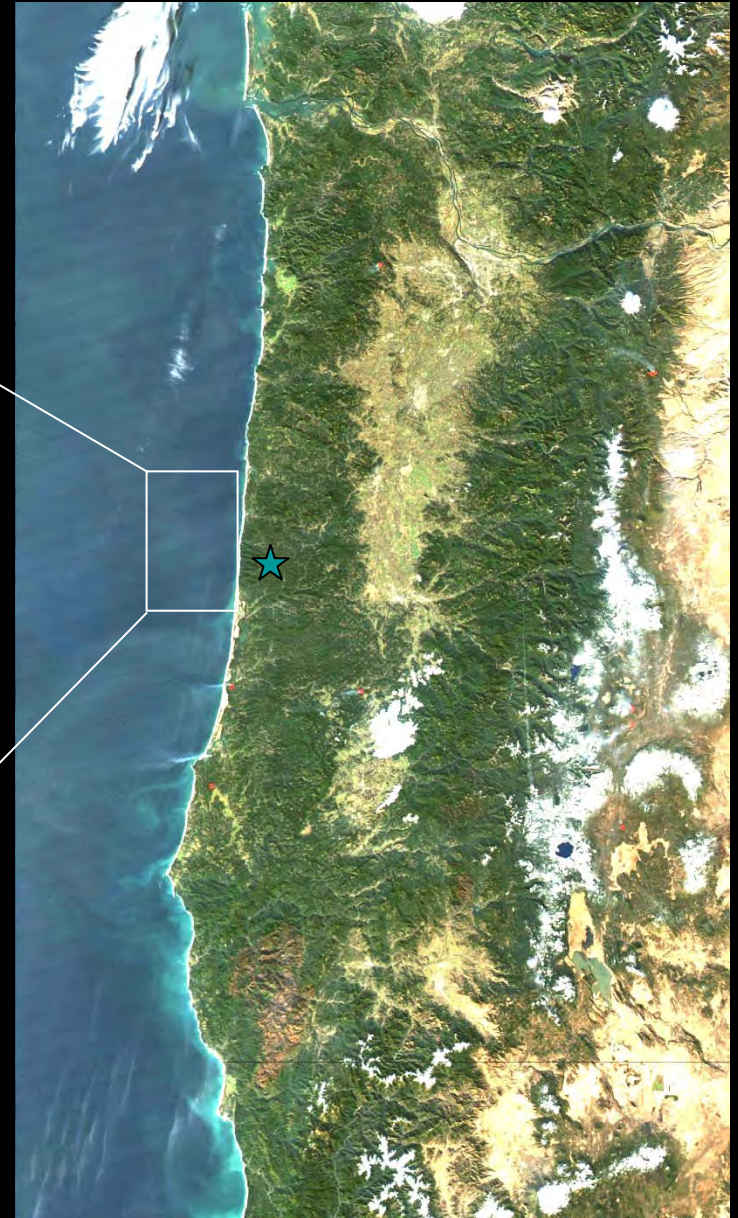
2007

bottom dissolved oxygen (ml l⁻¹)



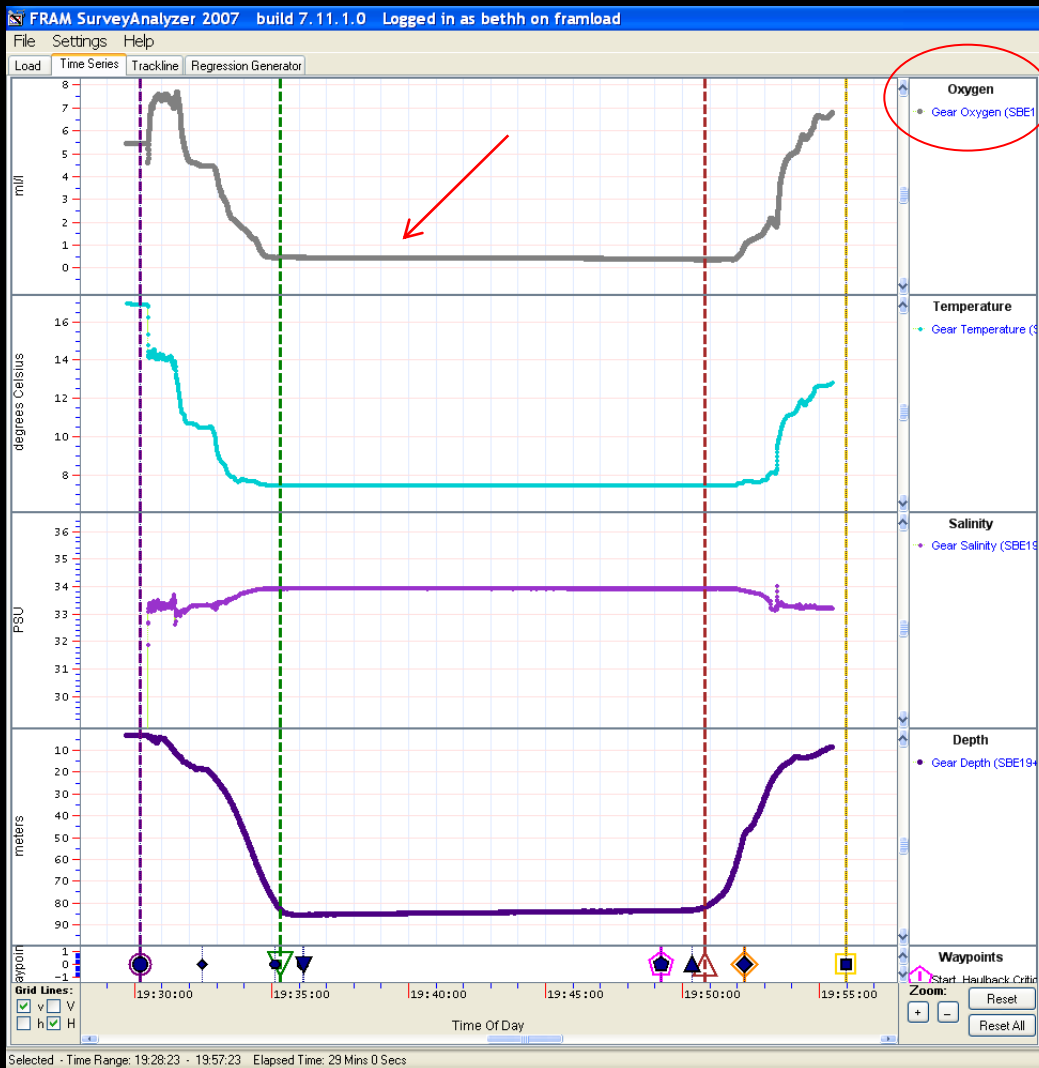
1.4 ml l⁻¹

0.5 ml l⁻¹



DO data from OSU: Francis Chan & Jack Barth

Seabird SB19+: used to collect near bottom oxygen, temperature, salinity and depth during the trawl operation

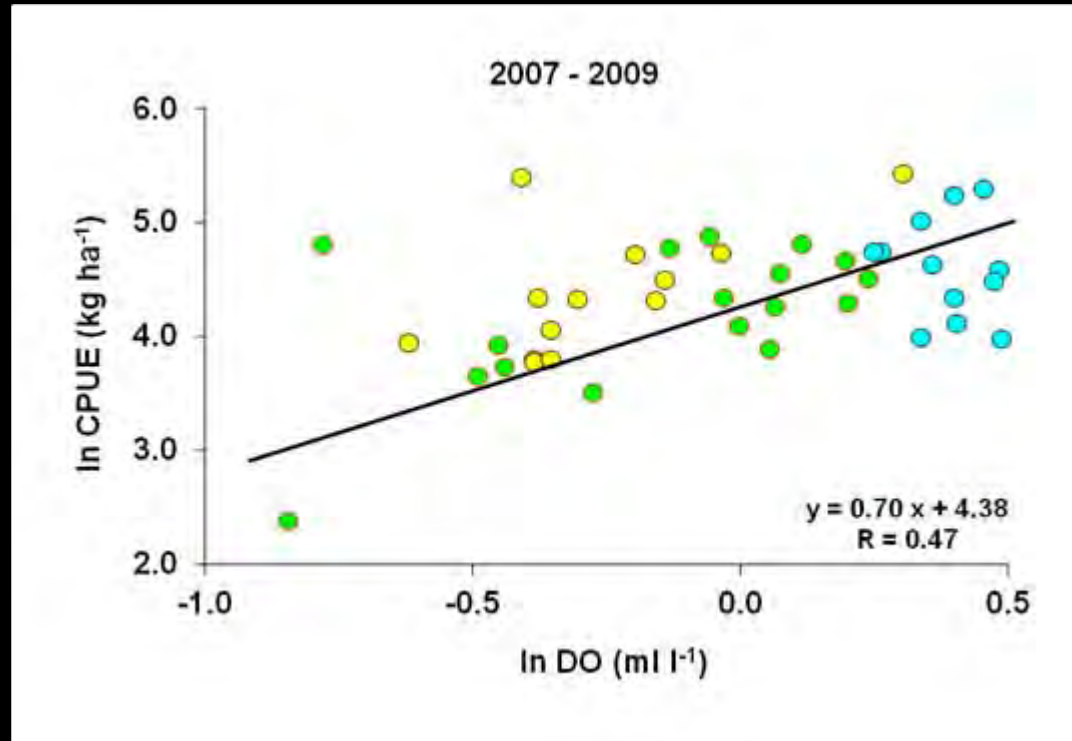


Summary of Hypoxia Sampling 2007 - 2010

Year	tows n	casts n	DO min ml l ⁻¹	DO max ml l ⁻¹	Depth Contours m
2007	17	13	0.43	1.27	60, 70
2008	13	14	1.37	1.87	50, 70
2009	14	31	0.55	1.48	55, 75
2010	15	12	0.77	1.92	70, 80

Hypoxia Studies (2007 – 2009)

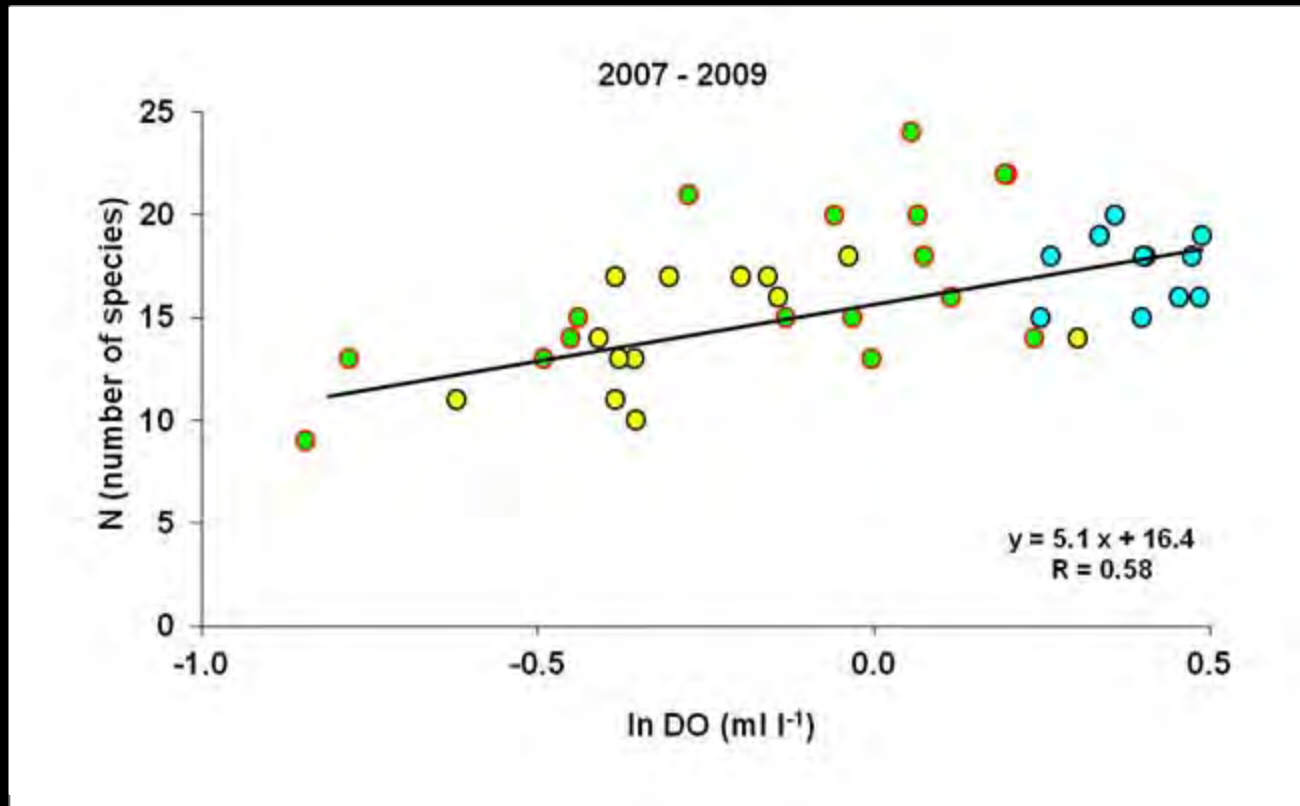
Total CPUE versus average bottom DO



$\text{CPUE (kg ha}^{-1}\text{)} = \text{Catch (kg)} / \text{Area Swept (ha)}$

Hypoxia Studies (2007 – 2009)

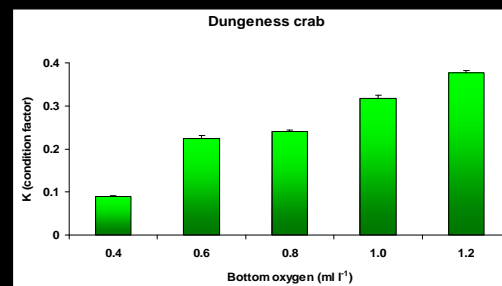
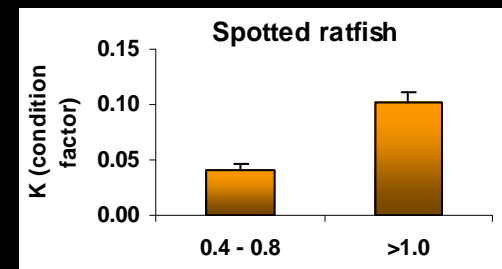
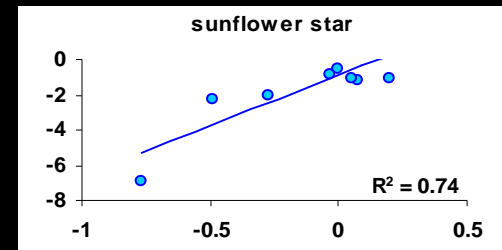
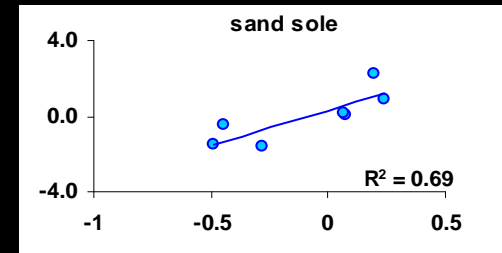
Number of species per tow versus Average bottom DO along the tow tract



Includes: demersal fish and benthic invertebrates

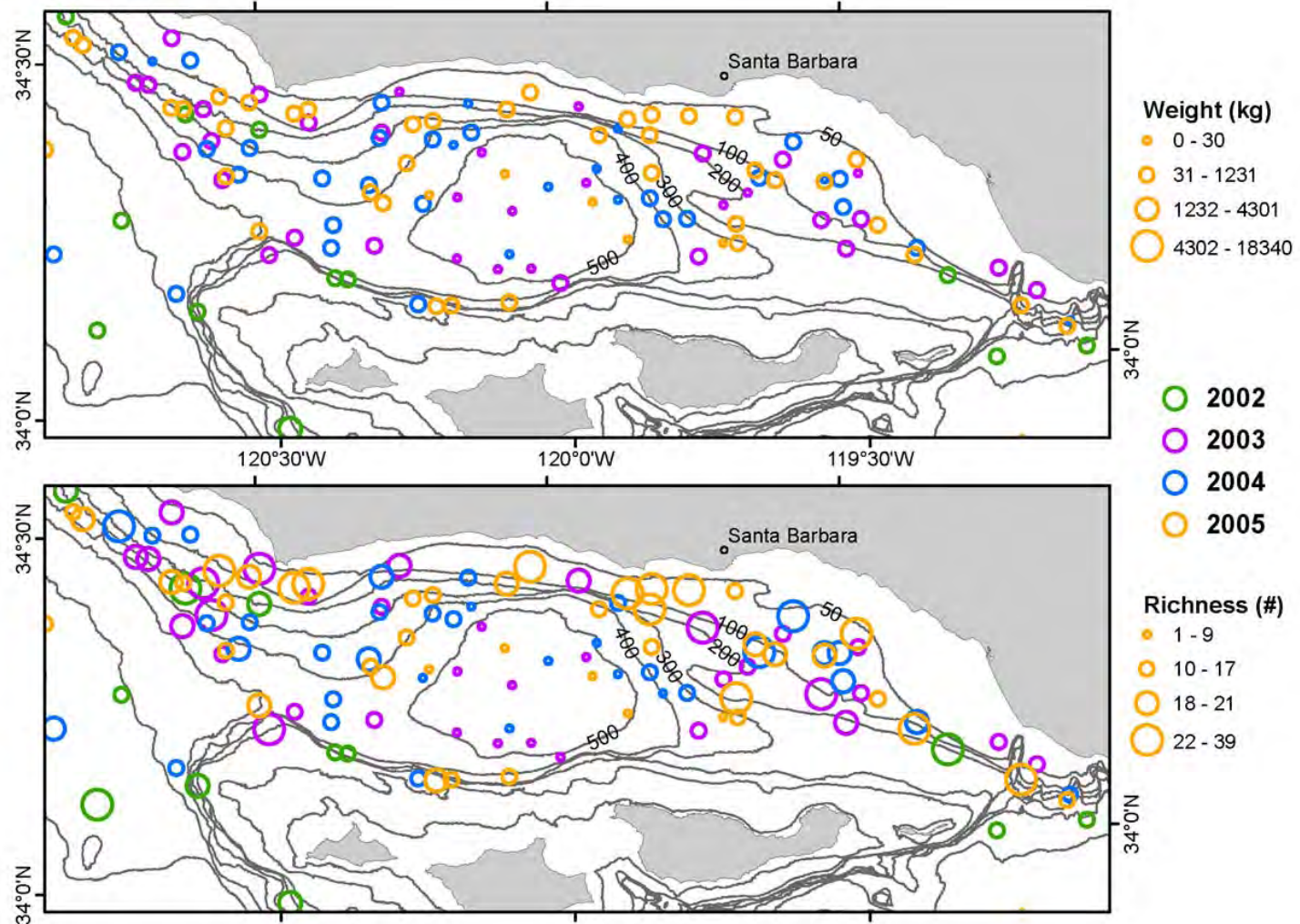
Summary of other results in hypoxic bottom water off Oregon for 2007

- CPUE (\ln , kg ha^{-1}) for 11 of 17 groundfish species significantly related to near bottom DO (\ln , mg l^{-1}) concentration
- CPUE (\ln , kg ha^{-1}) for 5 of 8 benthic invertebrate species significantly related to near bottom DO (\ln , mg l^{-1}) concentration
- condition factors for 5 of 6 groundfish species increased significantly at higher oxygen levels (mg l^{-1}) within the hypoxic region (except Dover sole)
- condition factors for Dungeness crab increased significantly with increased oxygen levels (mg l^{-1}) within the hypoxic zone

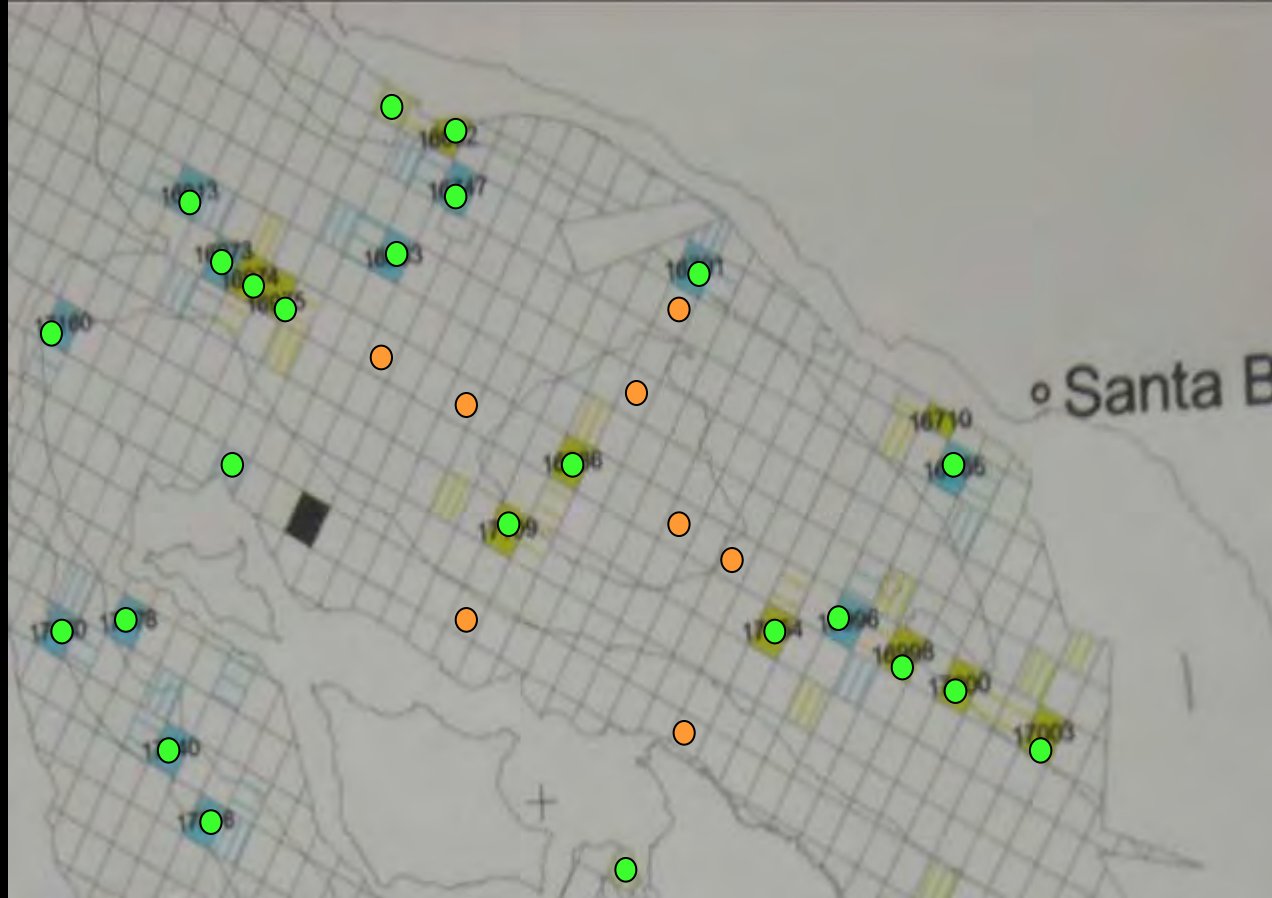


2008 Southern California Basin Study

Background Survey Data 2002 - 2005



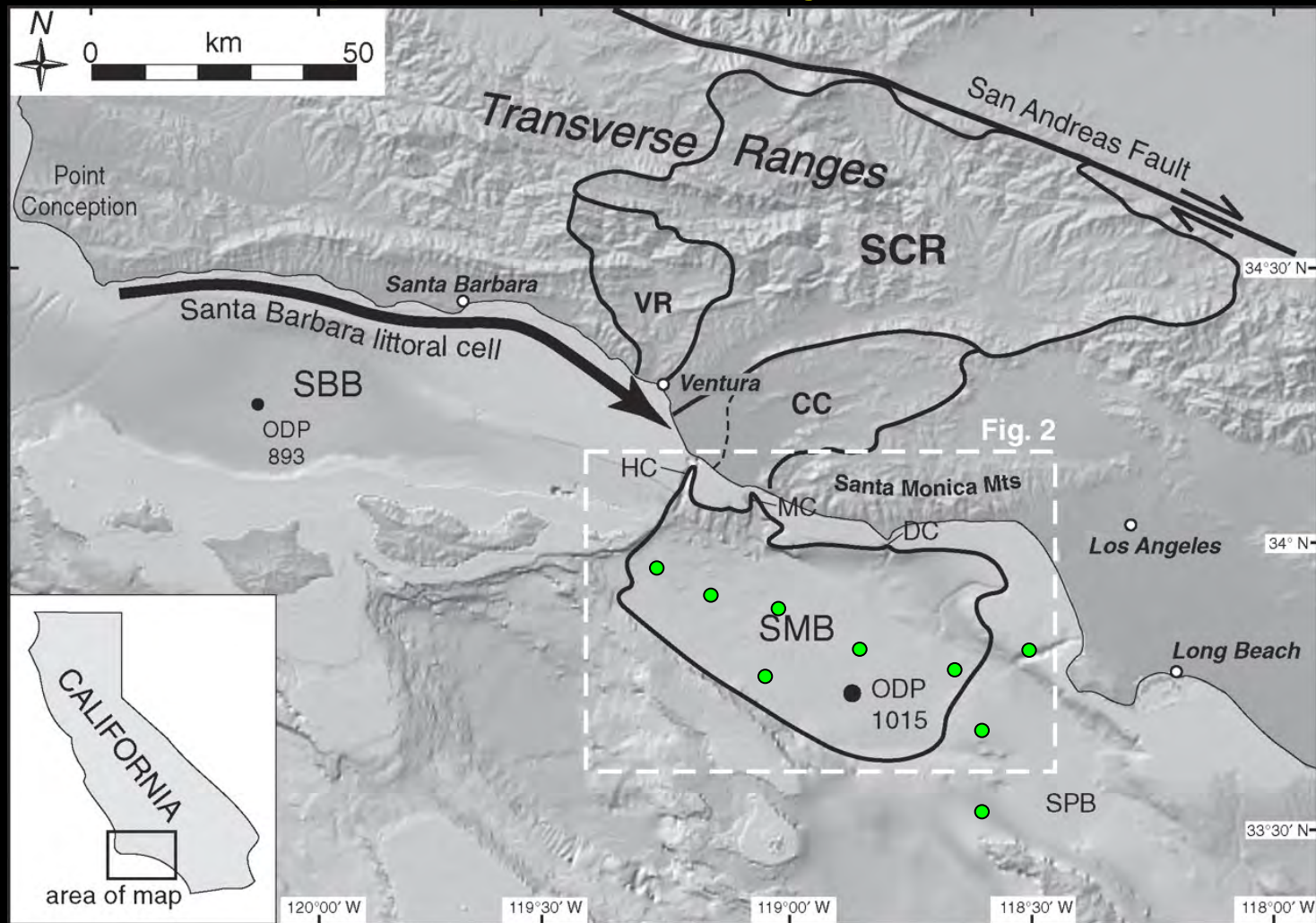
Southern California Basin Study – 2008



Sample Sites

- Designated Sites
- Extra Stations

Santa Barbara Basin (SBB), Santa Monica Basin (SMB) and adjacent areas

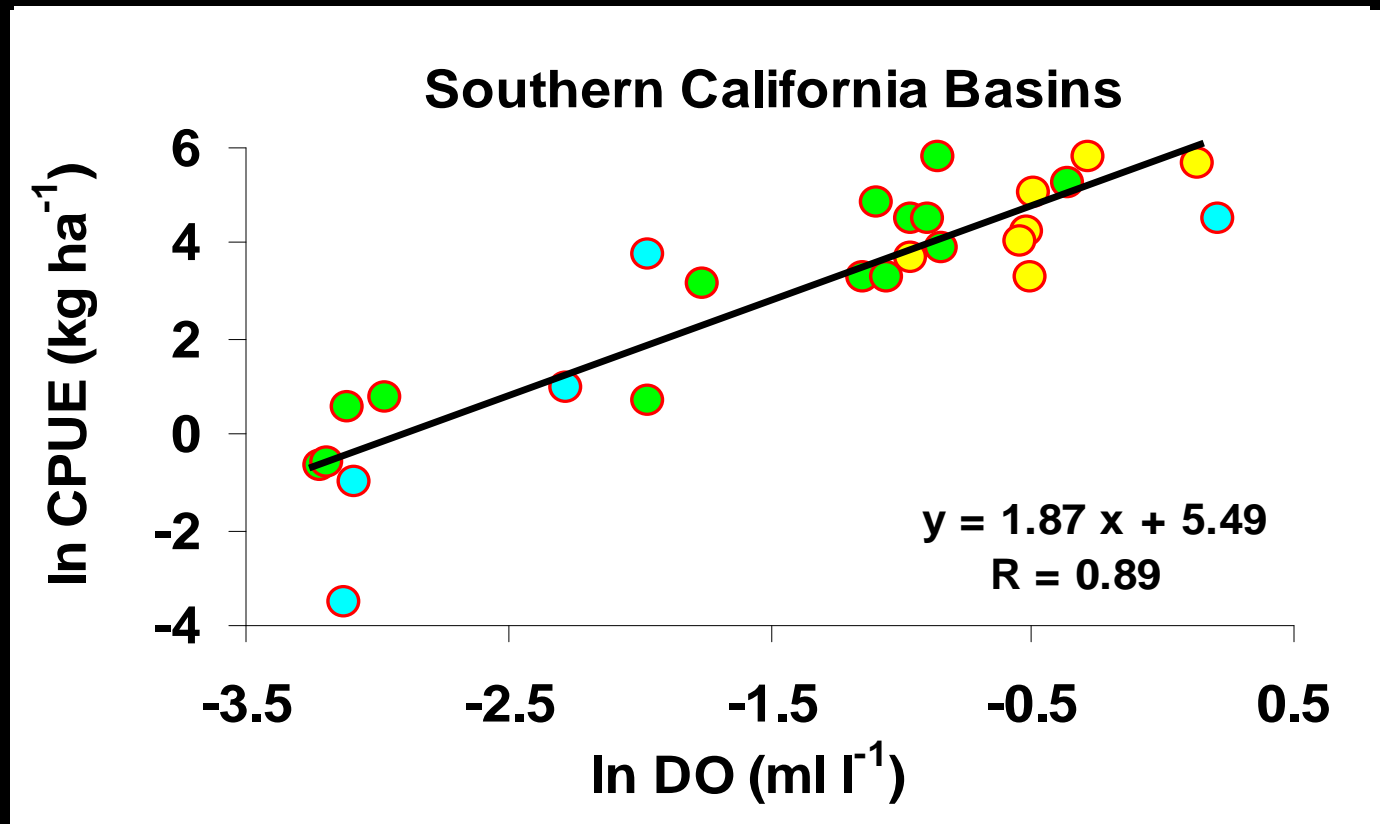


2008 Southern California Basin Study

- 39 stations sampled
 - 19 in Santa Barbara Basin
 - 9 in Santa Monica Basin
 - 11 in adjacent areas
- Depth range: 59 – 1,100 m
- Near Bottom DO range: 0.04 – 4.22 ml l⁻¹
or 1.8 – 188.2 $\mu\text{mol kg}^{-1}$
- Hypoxic: 26 of 39 stations
 - 14 of 19 in Santa Barbara Basin
 - 6 of 9 in Santa Monica Basin
 - 7 of 11 in adjacent areas

California Basin Study - 2008

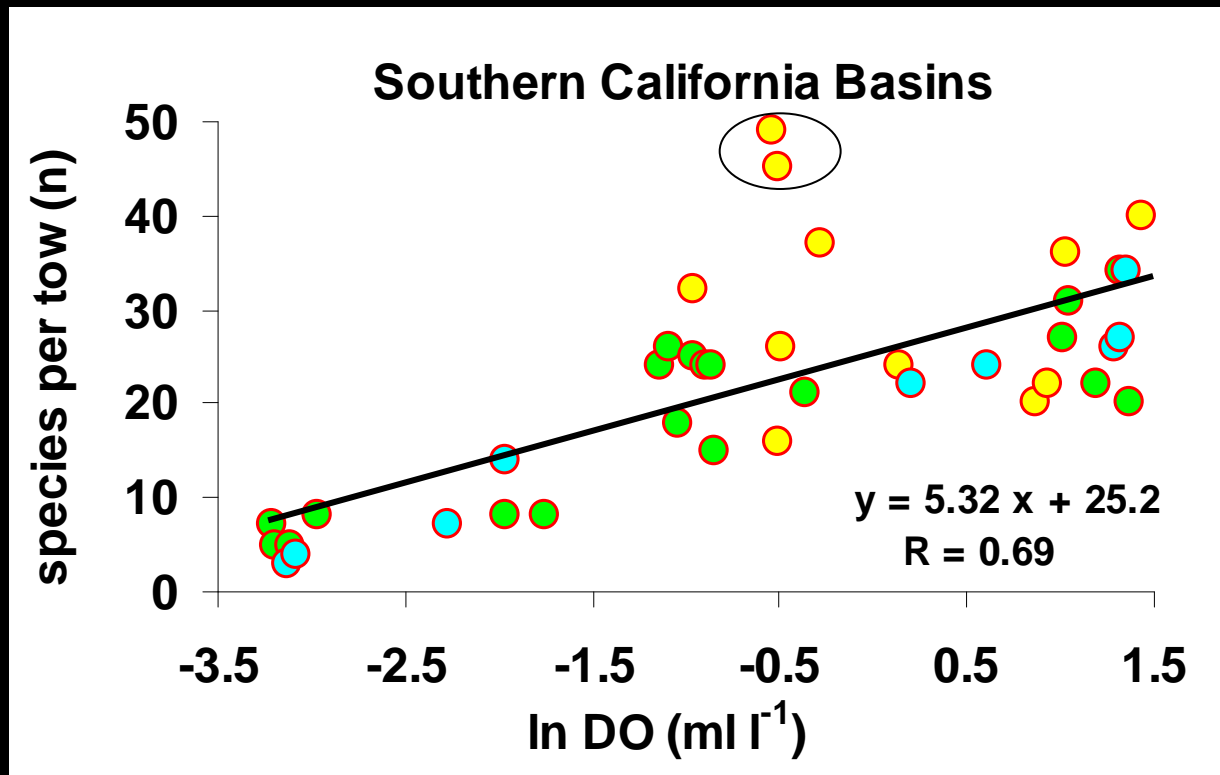
Total CPUE versus average bottom DO Hypoxic Stations



$$\text{CPUE (kg ha}^{-1}\text{)} = \text{Catch (kg)} / \text{Area Swept (ha)}$$

California Basin Study - 2008

Number of species per tow versus
Average bottom DO along the tow tract



Includes: demersal fish and benthic invertebrate

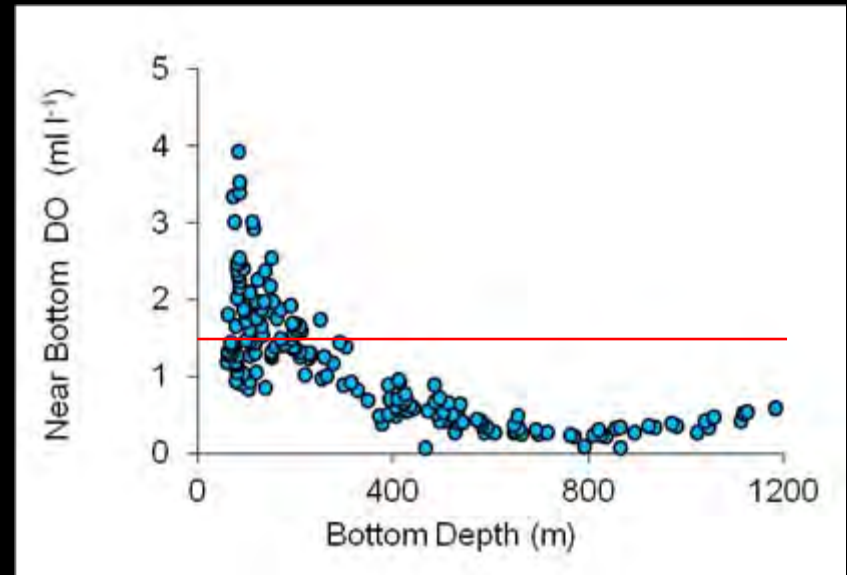
Coast Wide Study – 2009



- 360 stations sampled
- Depth range: 59 – 1,204 m
- Near Bottom DO: 0.08 – 4.25 ml l⁻¹
- Hypoxic stations (DO < 1.43 ml l⁻¹)

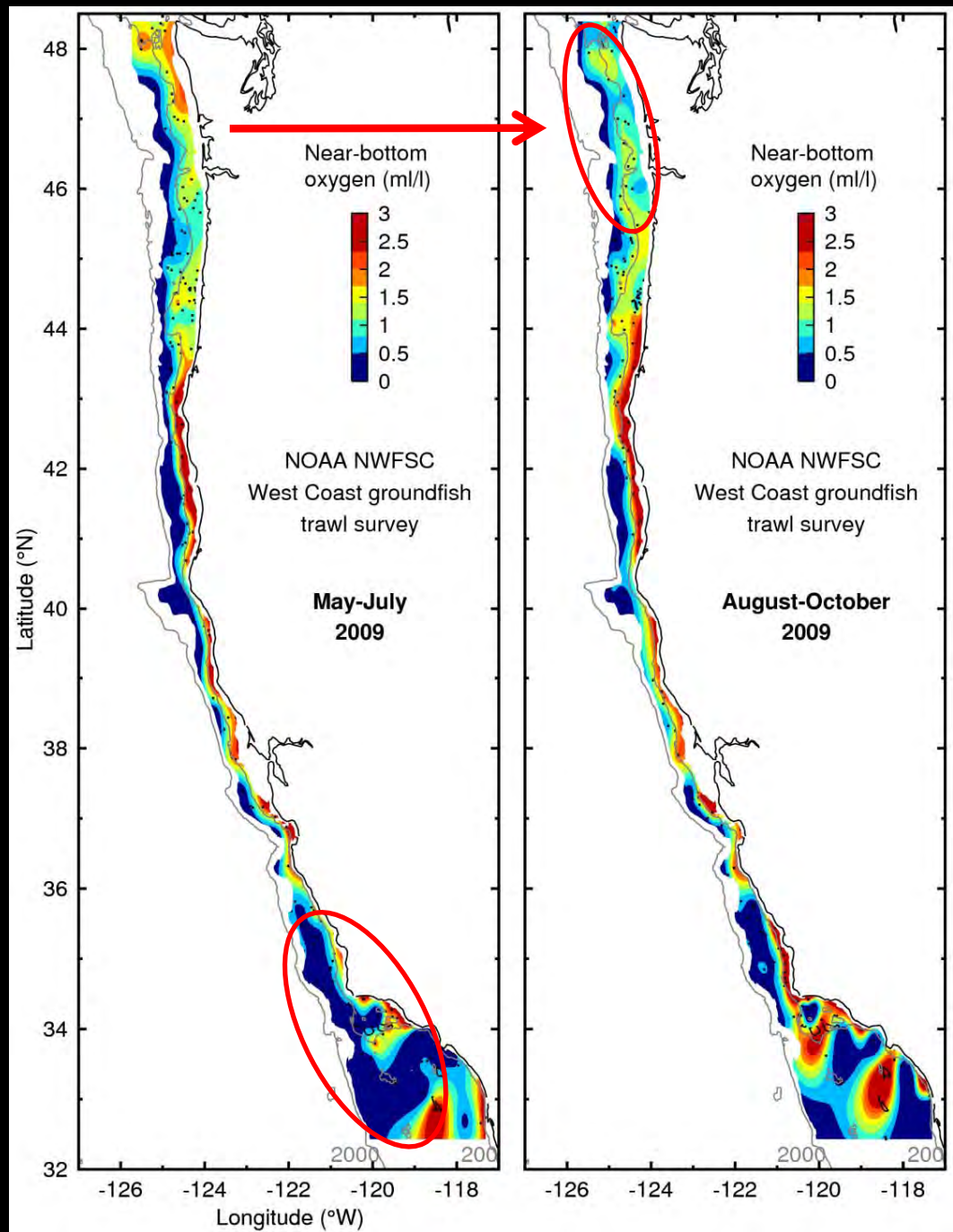
Pass 1: 117 of 176 stations

Pass 2: 123 of 184 stations

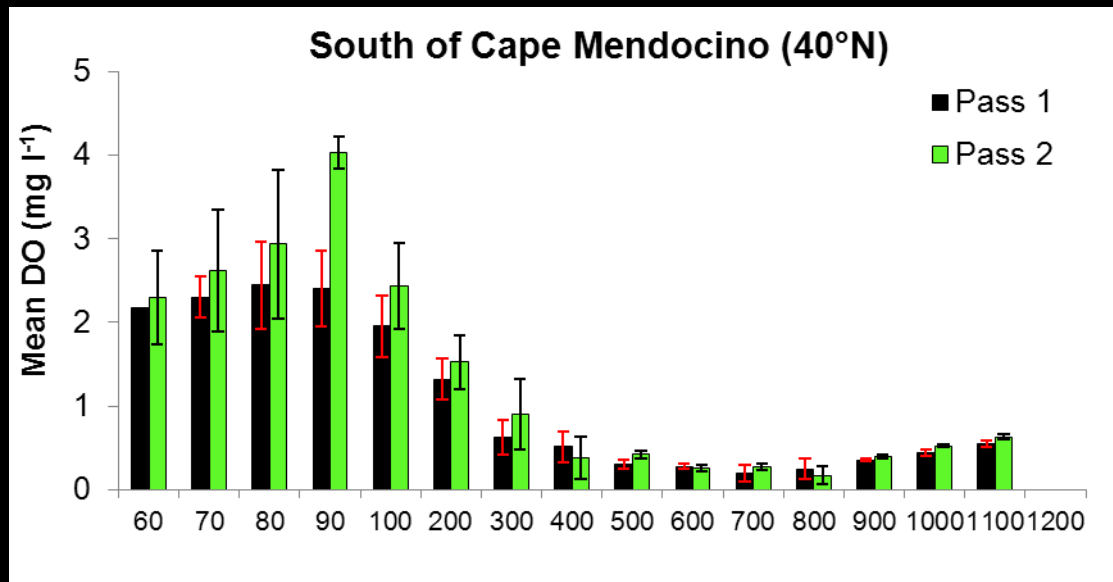
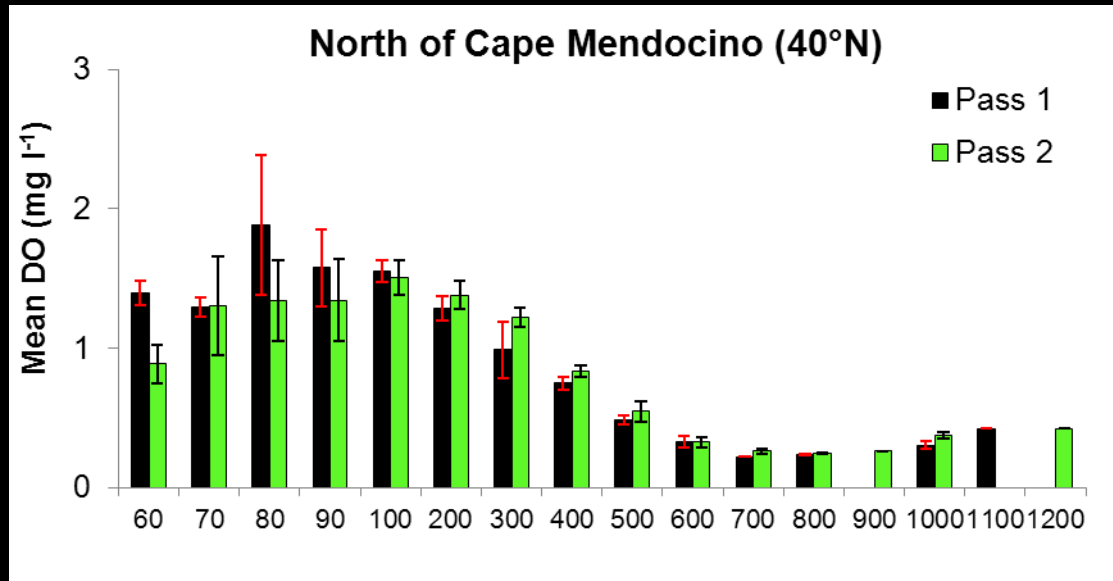


Coast Wide Study 2009

Thanks to S. Pierce

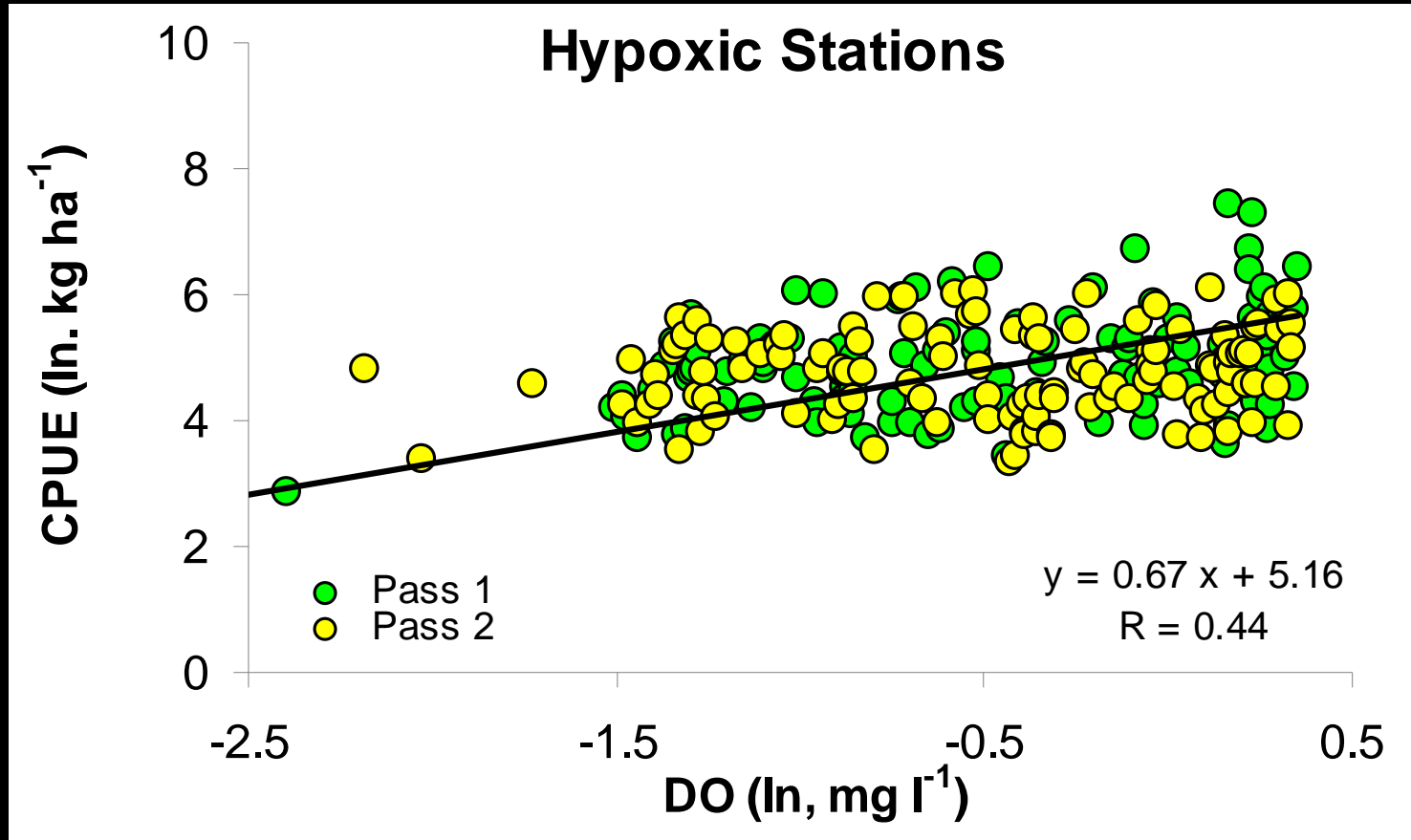


2009 Coast Wide Study



2009 Coast Wide Study

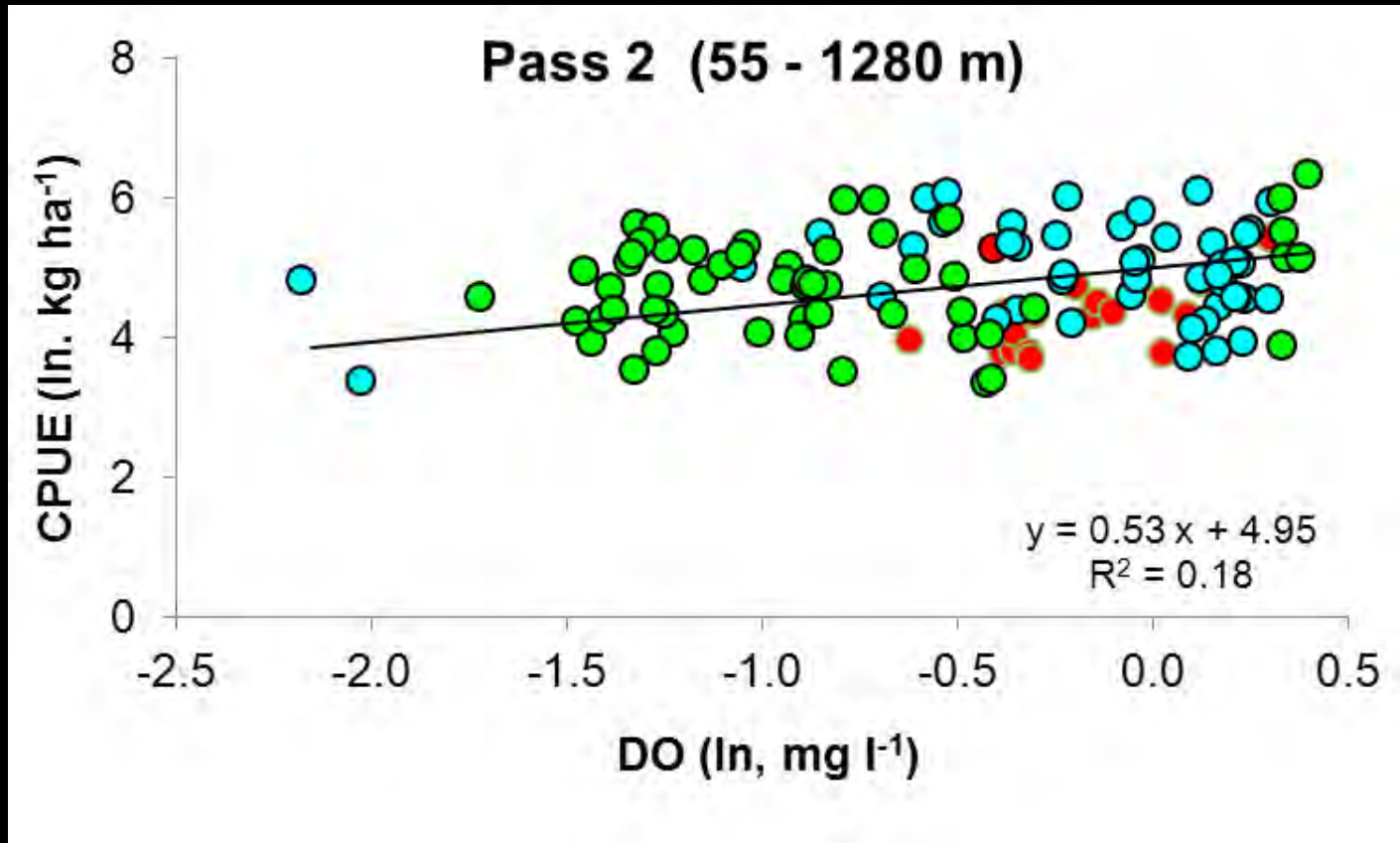
Total CPUE versus average bottom DO



Hypoxic Stations: DF = 239, F = 59.7, P<0.0001

All Stations: DF = 356, F = 3.6, NS

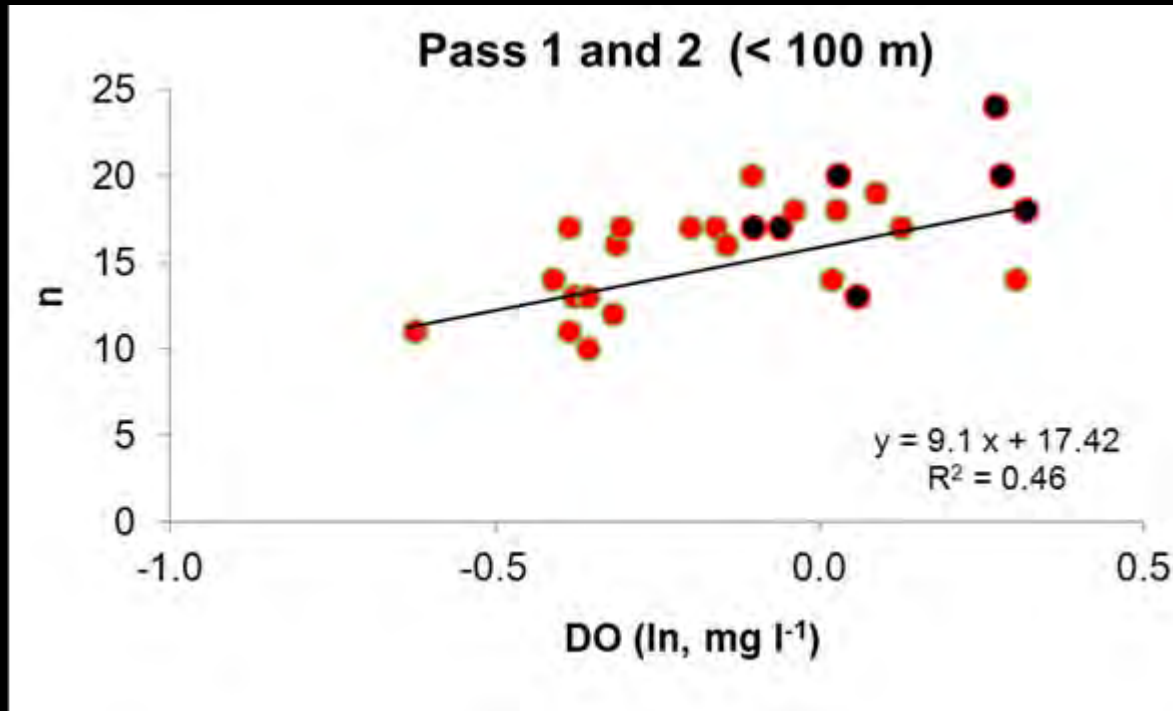
2009 Coast Wide Study – Pass 2



**Total CPUE versus average bottom DO
by depth**

2009 Coast Wide Study

species richness



Depth	Hypoxic stations
<100 m	DF = 35, F = 25.6, P<0.0001
100 – 500 m	DF = 107, F = 2.1, NS
>500 m	DF = 95, F = 2.9, NS



Conclusions

- mean oxygen levels varied from oxic to severely hypoxic among stations but little along individual tow tracts ($\leq 0.2 \text{ ml l}^{-1}$)
- CPUE (fish and invertebrate catch) varied significantly and positively with bottom oxygen concentration within hypoxic areas regardless of year or geographic area - depth may influence variability
- Species richness (fish and invertebrates) varied significantly and positively with bottom oxygen concentration within hypoxic areas –both depth and/or geographic areas may influence these relationships
- In the northern California Current System low DO moved shoreward as the sampling season progressed (May through September)
- In the southern California Current System low DO was more widespread in July (pass 1) than Oct (pass 2) with the geographic distribution of low DO waters variable between passes