Environmental sampling, hypoxia and the Northwest Fisheries Science Center's Cooperative U. S. West Coast Groundfish Bottom Trawl Survey

Aimee Keller[1], W. Waldo Wakefield[2], Victor Simon[1], John (Jack) A. Barth[3] and Stephen D. Pierce[3]

[1]NOAA, NMFS, Northwest Fisheries Science Center, Seattle, WA
[2]NOAA, NMFS, Northwest Fisheries Science Center, Newport, OR
[3]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR

NOAA Northwest Fisheries Science Center
NOAA Fisheries Service

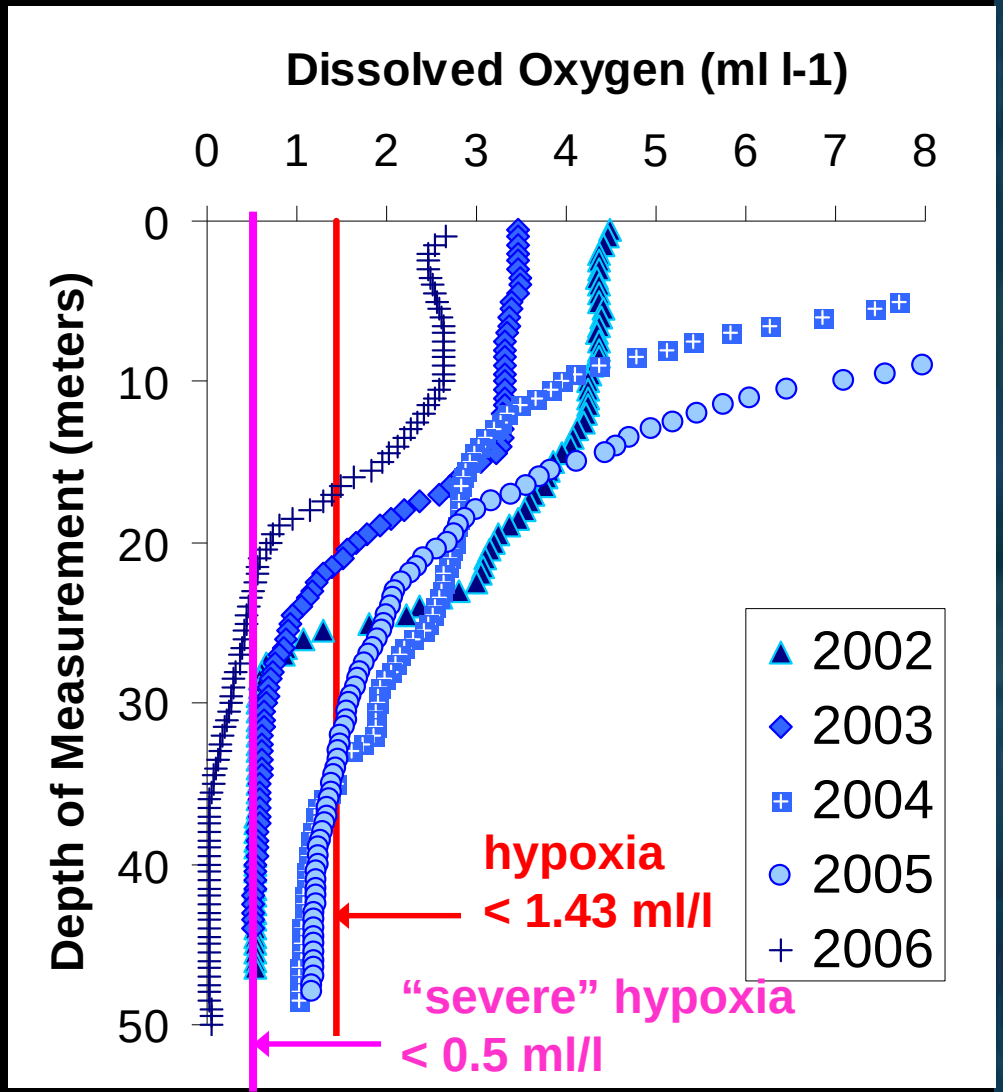
Oregon State University OSU College of Earth, Ocean, and Atmospheric Sciences

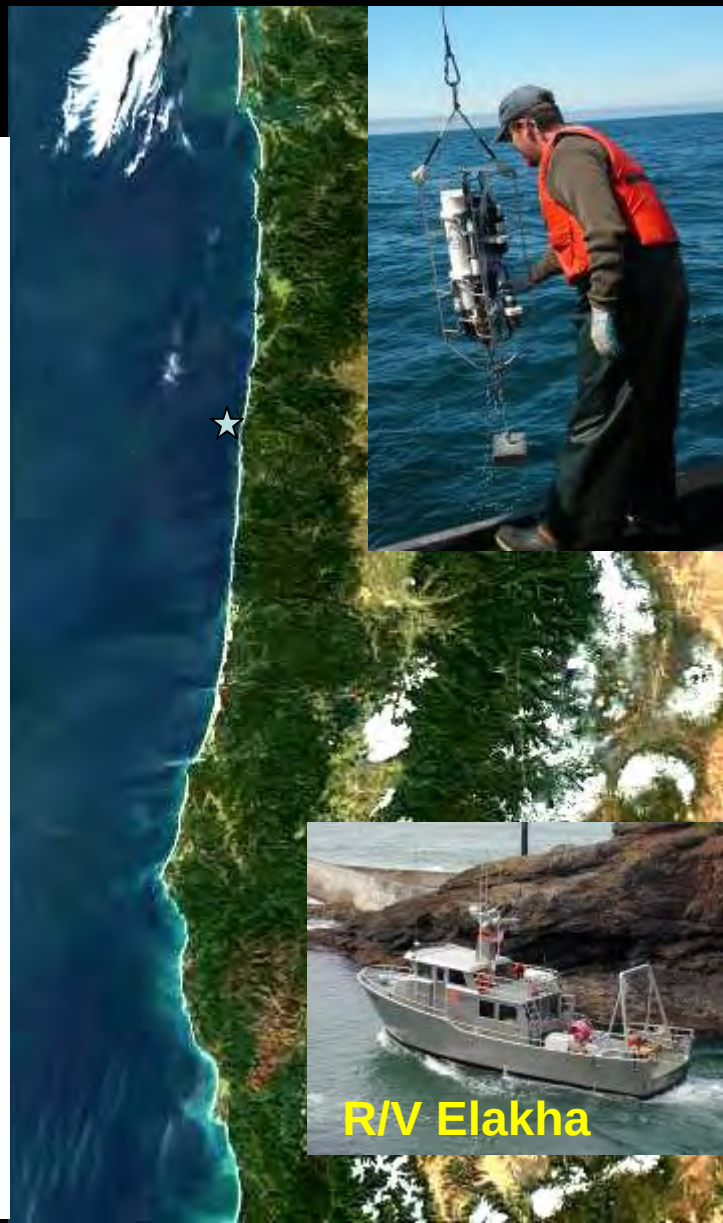
Outline

- Near bottom waters along the continental slope of the eastern North Pacific are naturally low in dissolved oxygen
- These waters are upwelled onto the continental shelf during summer, potentially affecting the shelf ecosystem
- Observed decline in source water dissolved oxygen all along west coast of North America
- Is there a way to exploit annual fish surveys to
  - learn more about dissolved oxygen distributions
  - examine the relationship between low DO and catch of near bottom organisms
- NWFSC's annual groundfish survey off the Pacific coast
- NWFSC targeted trawls in & out of hypoxic zone off Oregon

Hypoxia off Oregon detected by ship-based CTD sampling

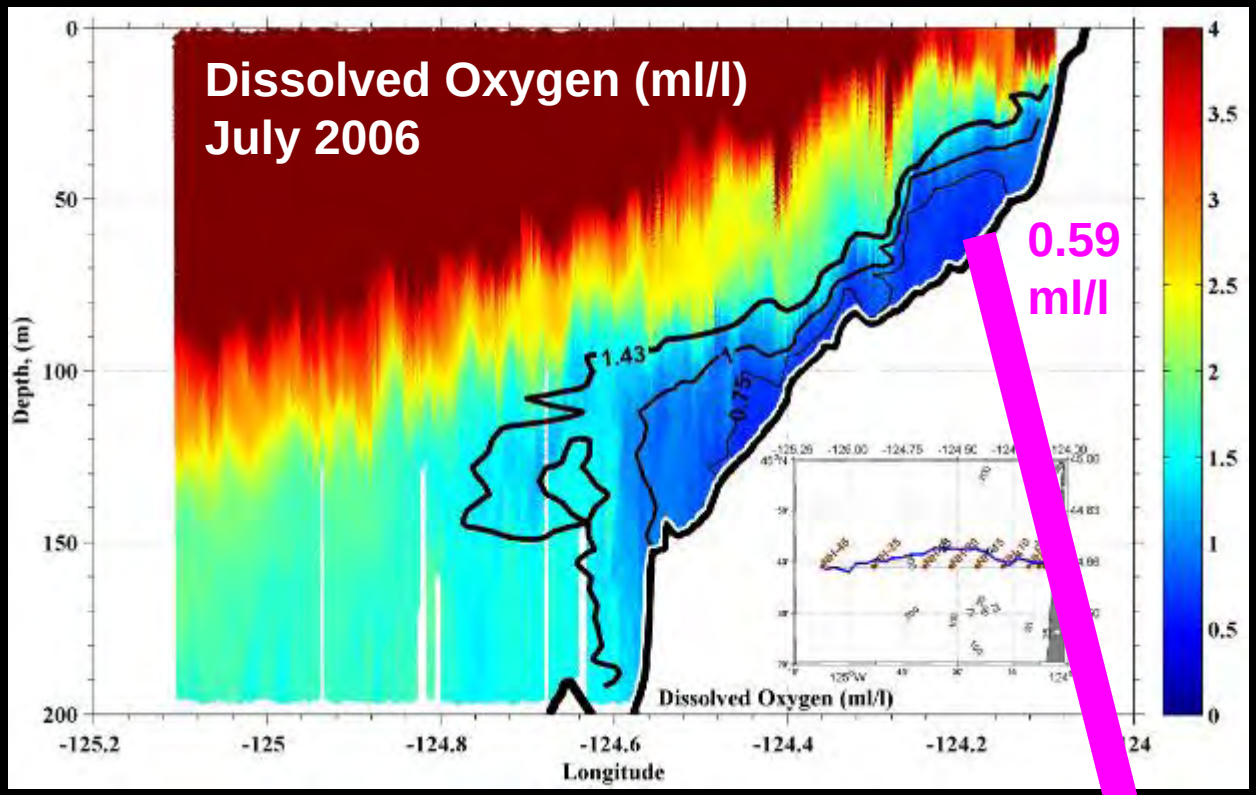
Grantham et al. (2004)





Cross-shelf structure from autonomous underwater gliders

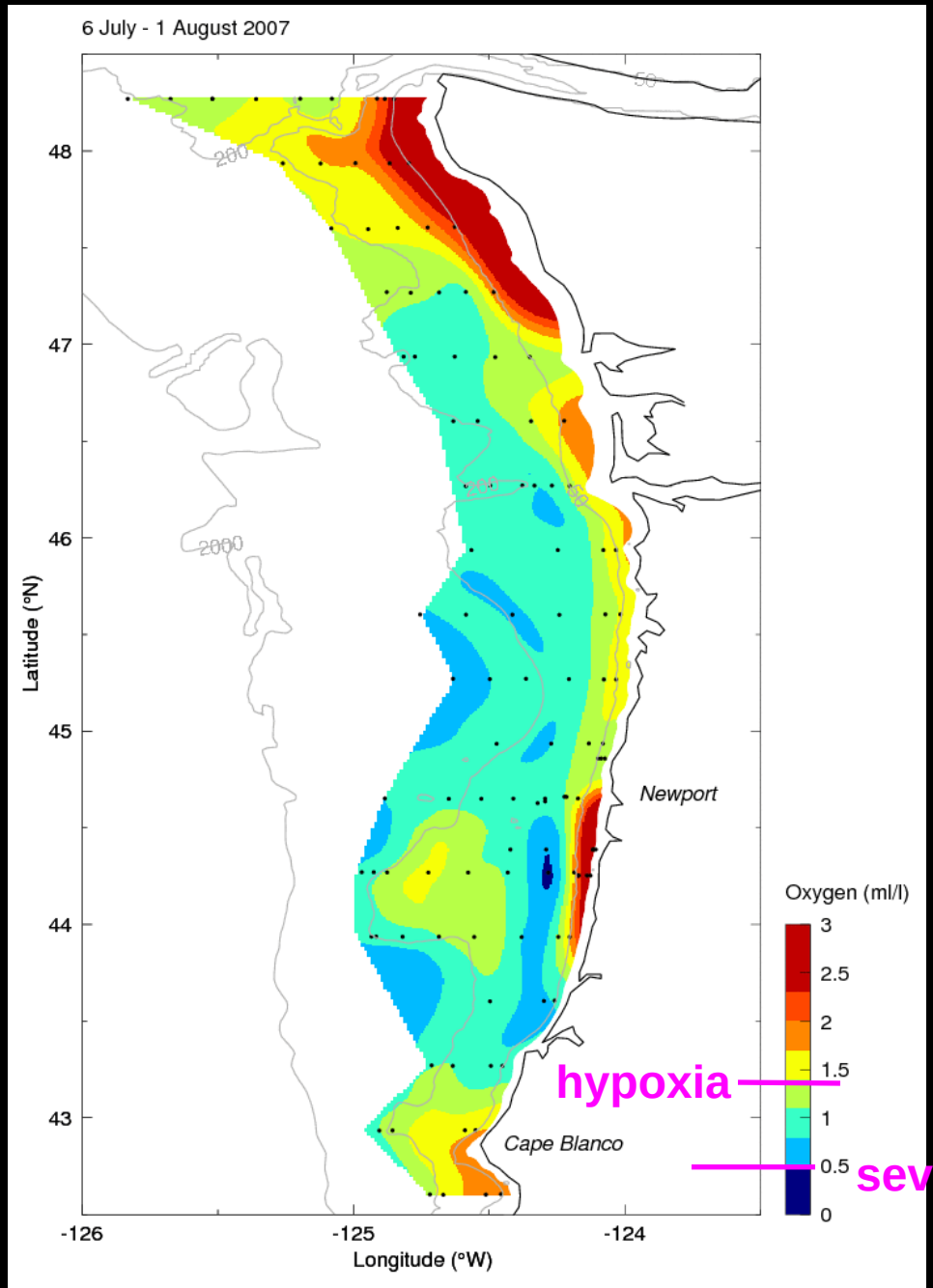
Great coverage, but specialized instrument



temperature, salinity, pressure
dissolved oxygen
chlorophyll fluorescence
colored organic matter fluorescence
light backscatter
velocity (depth-averaged, shear)

OREGON Fish & Wildlife

Near-bottom hypoxia over the PNW continental shelf



July 2007

Data from:

- PISCO
- Newport-line glider
- NOAA NWFSC hake survey

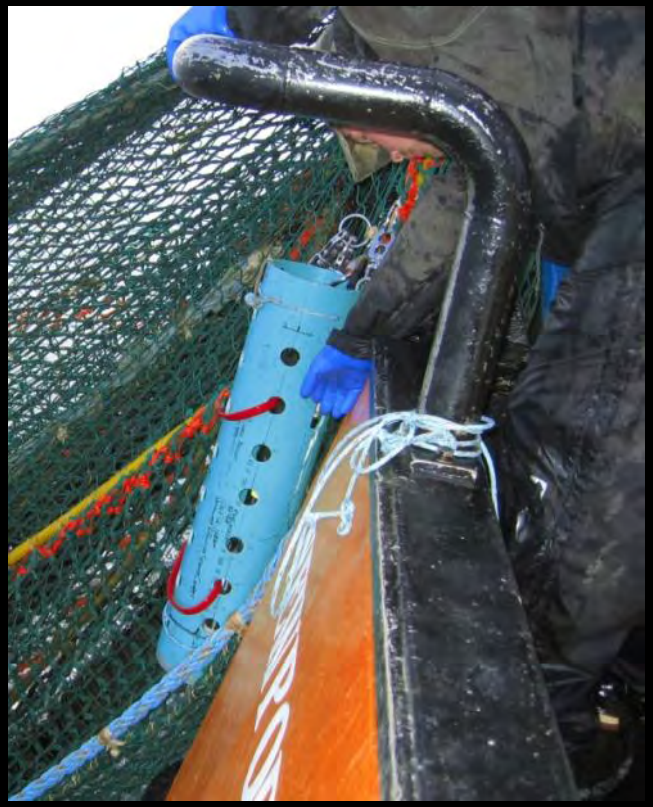
  (Steve Pierce did CTDs at night)

17,800 km² < 1.4 ml/l
(inshore of 200-m isobath)

68% of shelf inshore of 200-m isobath is hypoxic

But how about measuring all along the US west coast on a regular basis at relatively low cost?

Measure environmental parameters from rugged sensor package on fish trawl

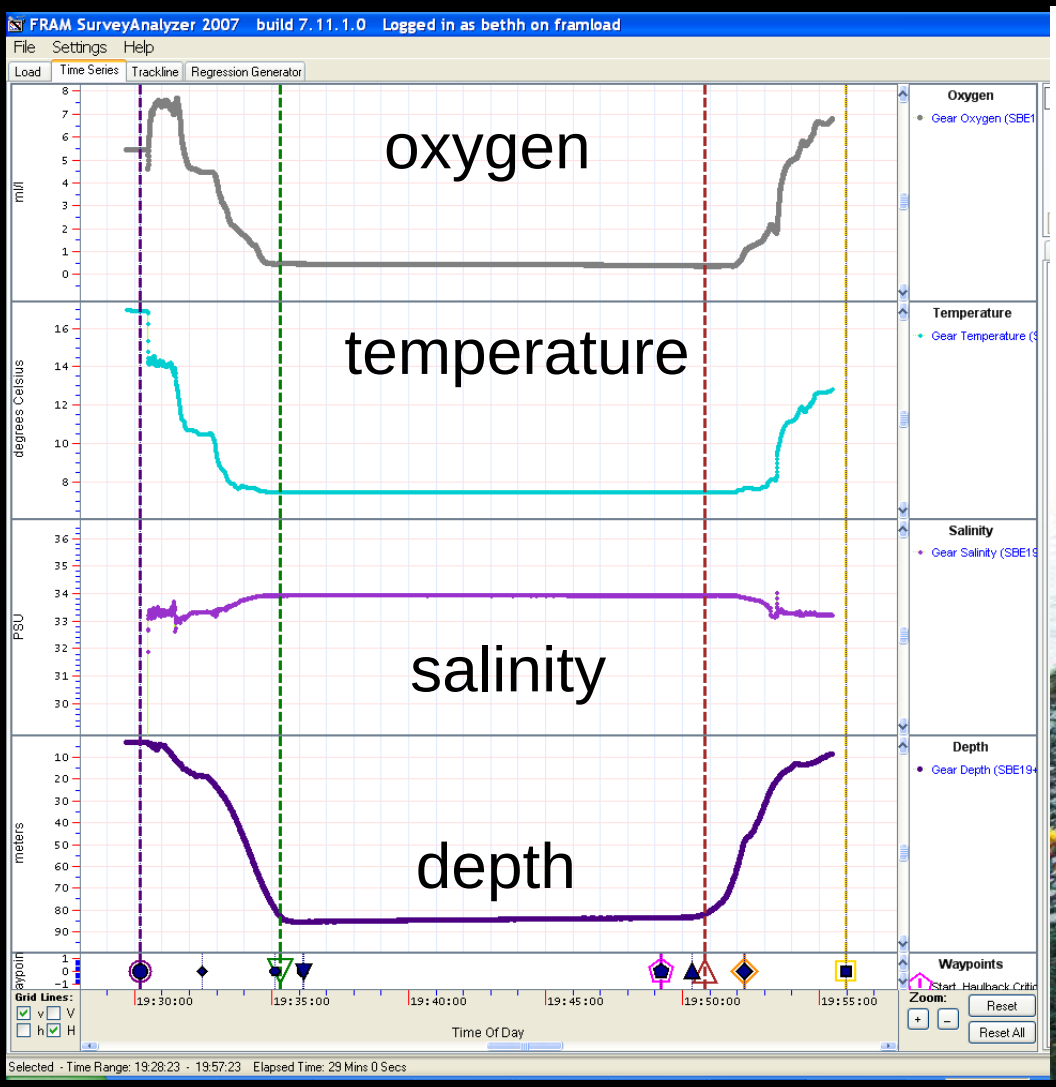


Sea-Bird 19+ CTD

- **Temperature**
- **Salinity**
- **Pressure**
- **Dissolved oxygen**
  - **SBE43**
  - **[also Aanderaa optode]**
- **Chlorophyll fluorescence**
- **Turbidity**
- **light**

~$33,000

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



Chartered fishing vessels, 2008-2011

F/V Excalibur
F/V Ms. Julie
F/V Noah's Ark
F/V Raven

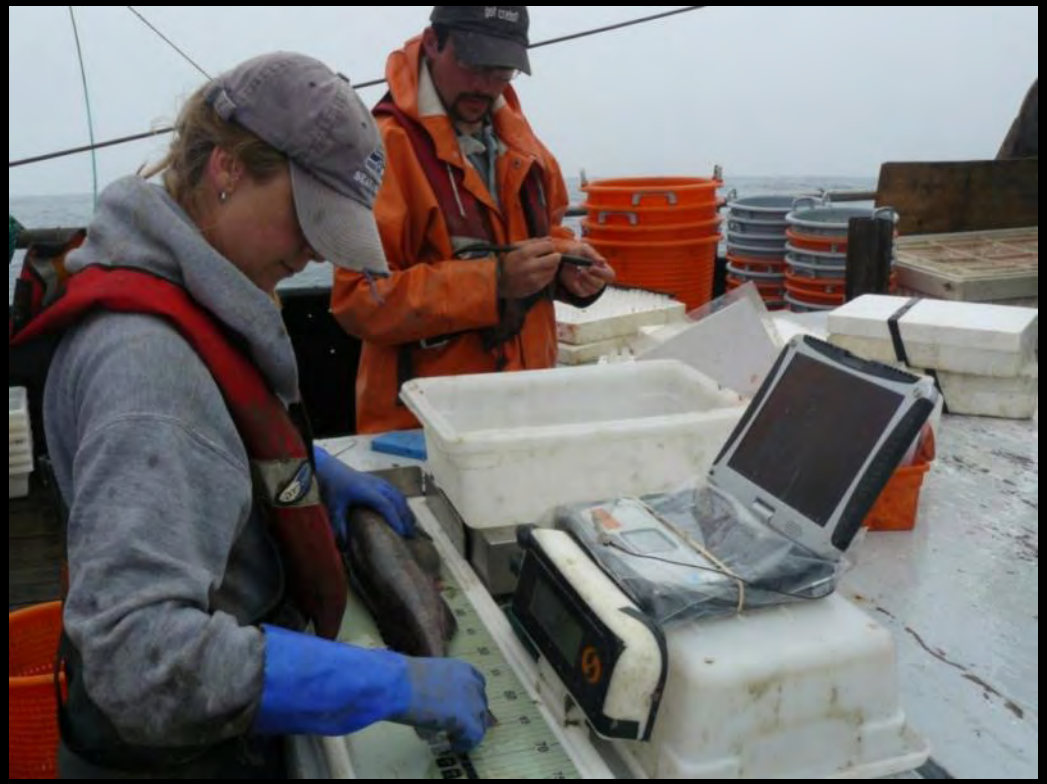
of stations per year

2008	58
2009	371
2010	648
2011	642

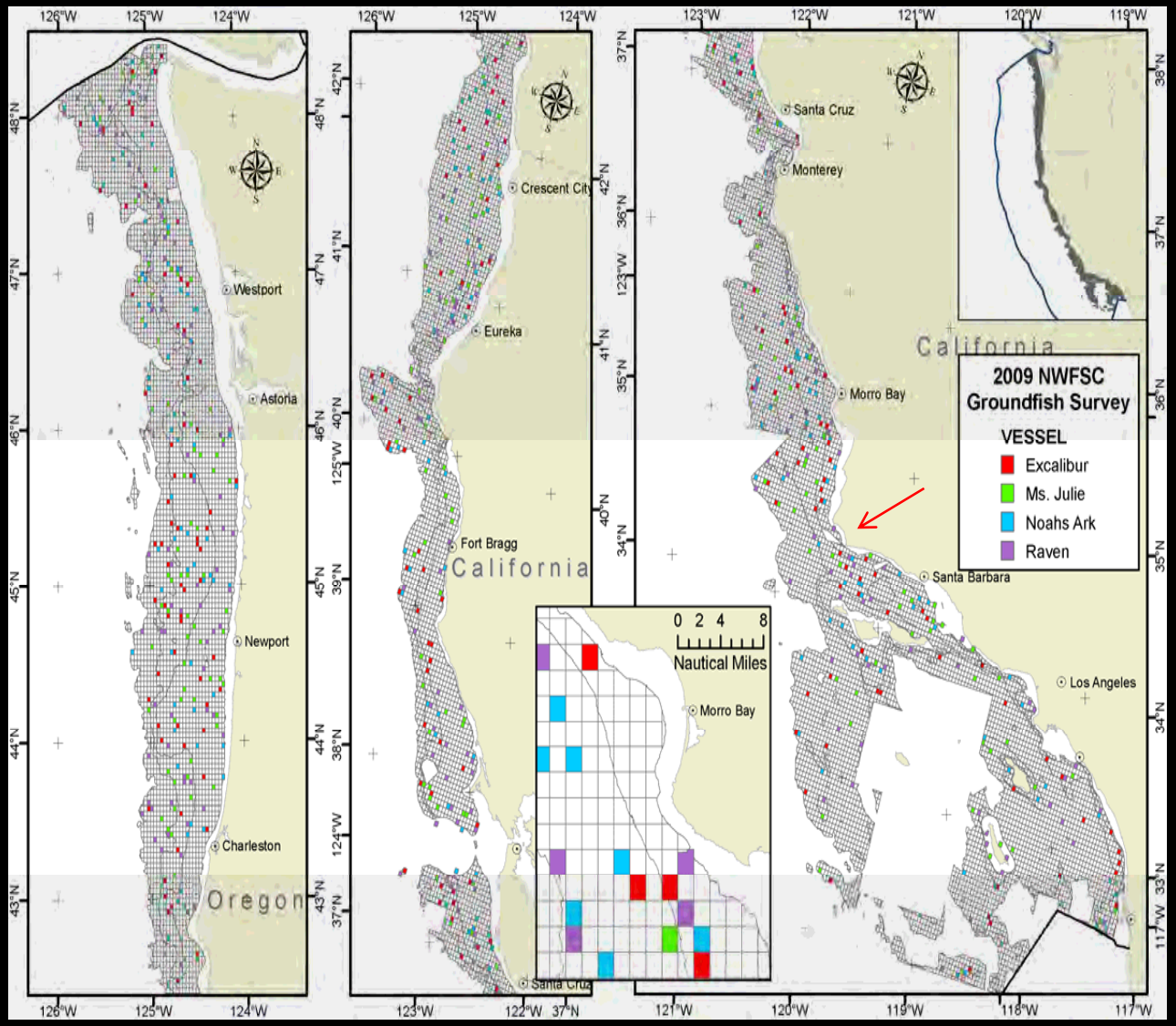
NWFSC West Coast Groundfish Bottom Trawl Survey

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



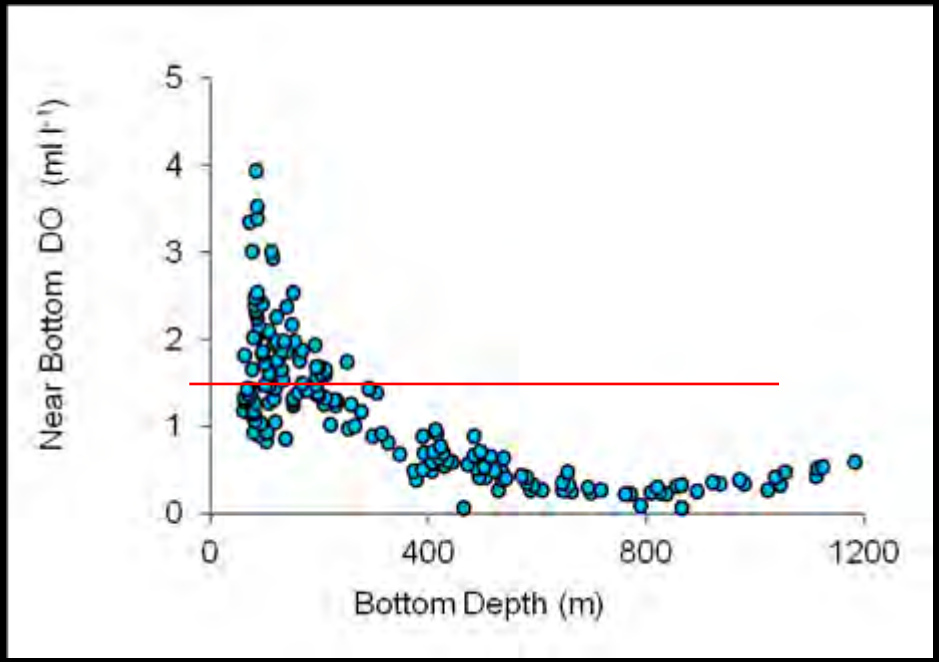
- US Canadian border to US Mexican border
- Survey area sub-divided into >11,500 equally sized cells (1.5 X 2.0 nm)
- Each of 4 vessels randomly assigned a set of 188 cells, secondary and tertiary cells also assigned (not shown)
- 2 geographic strata: 80% N of Pt. Conception (34°30'N), 20% S
- 3 depth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

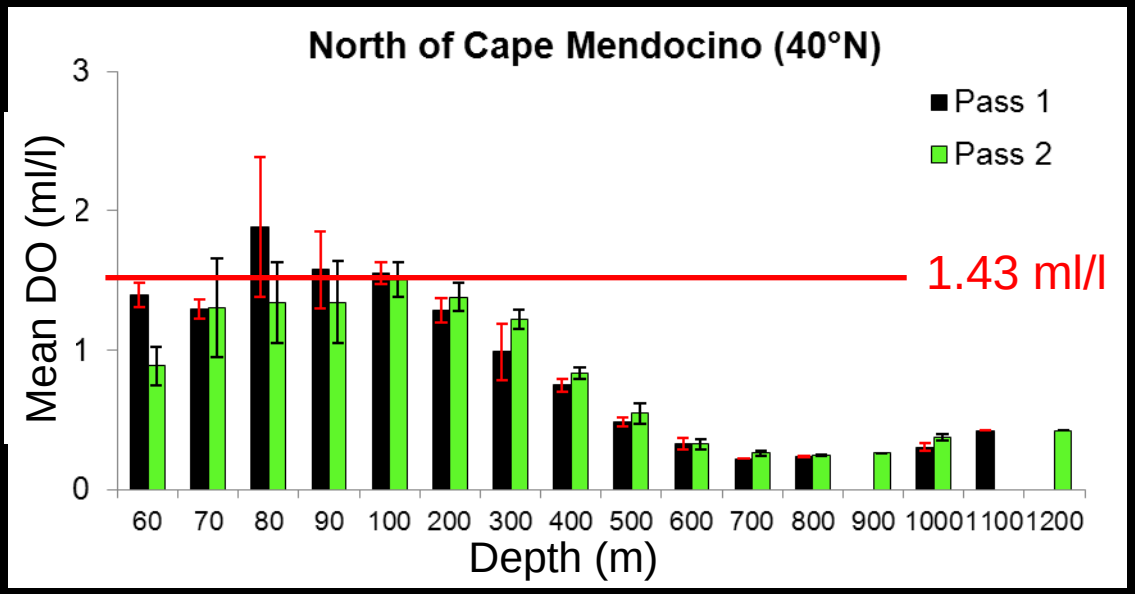
Coast Wide Study – 2009

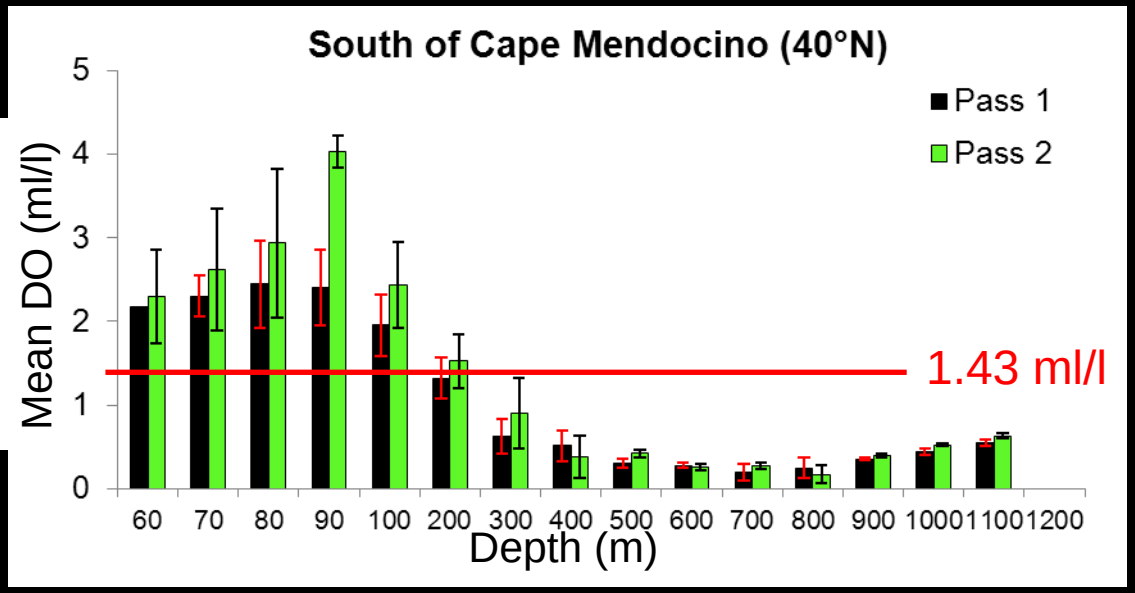
- 371 stations sampled
- Depth range: 59 – 1,204 m
- Near Bottom DO: 0.08 – 4.25 ml l^{-1}
- Hypoxic stations (DO < 1.43 ml l^{-1})
  - Pass 1: 117 of 176 stations
  - Pass 2: 123 of 184 stations



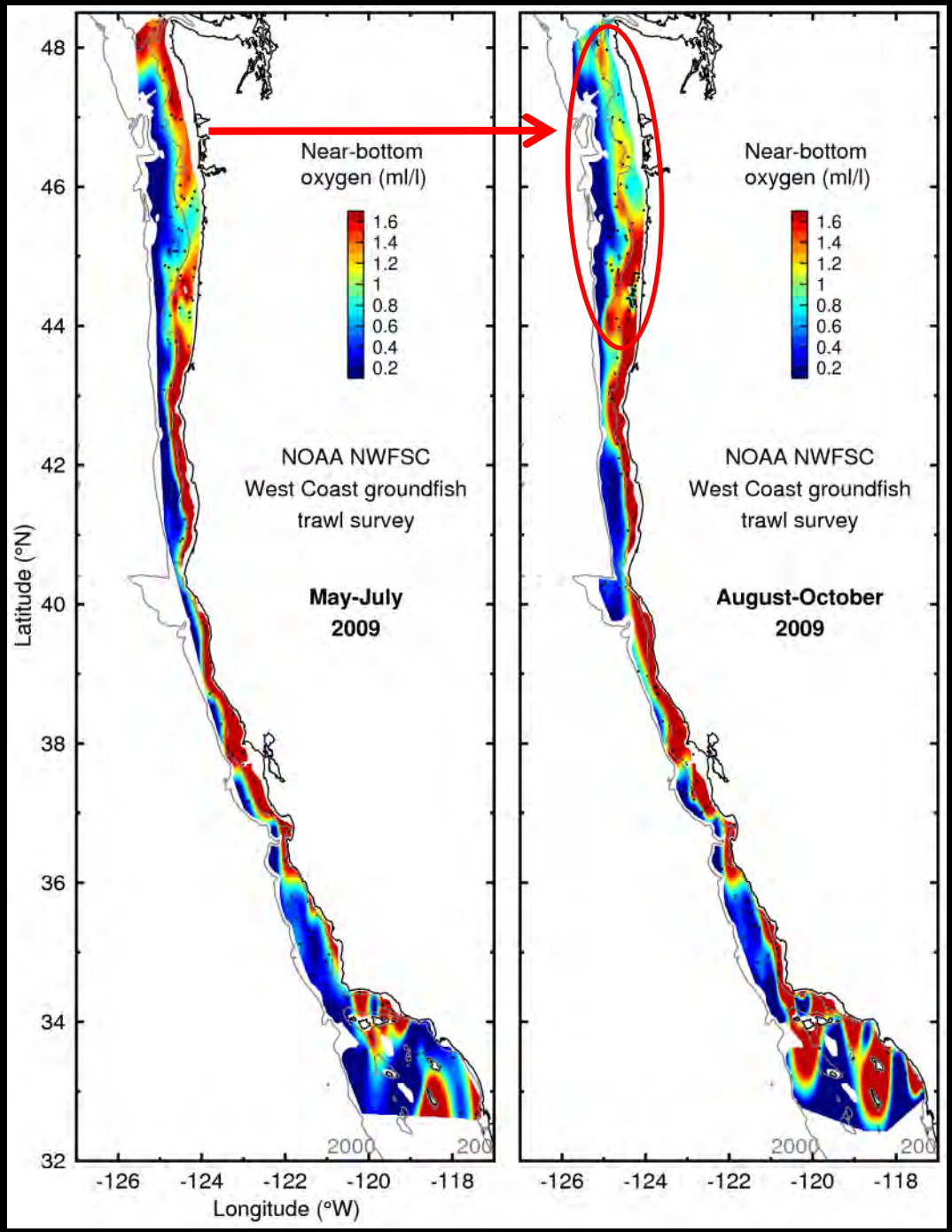
funding: NOAA's Office of Ocean Exploration & Research through West Coast & Polar Regions Undersea Research Center

2009 Coast Wide Study



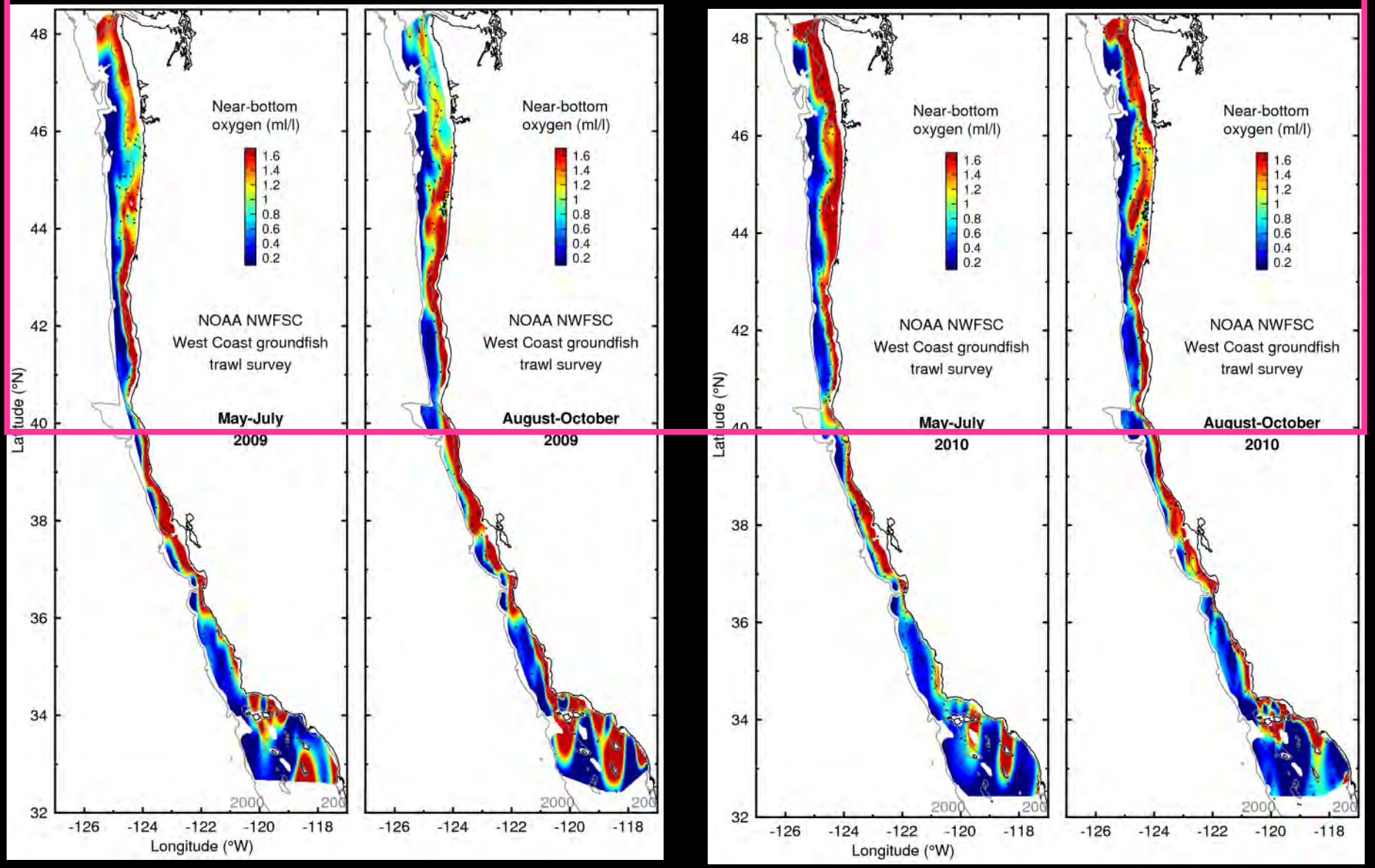


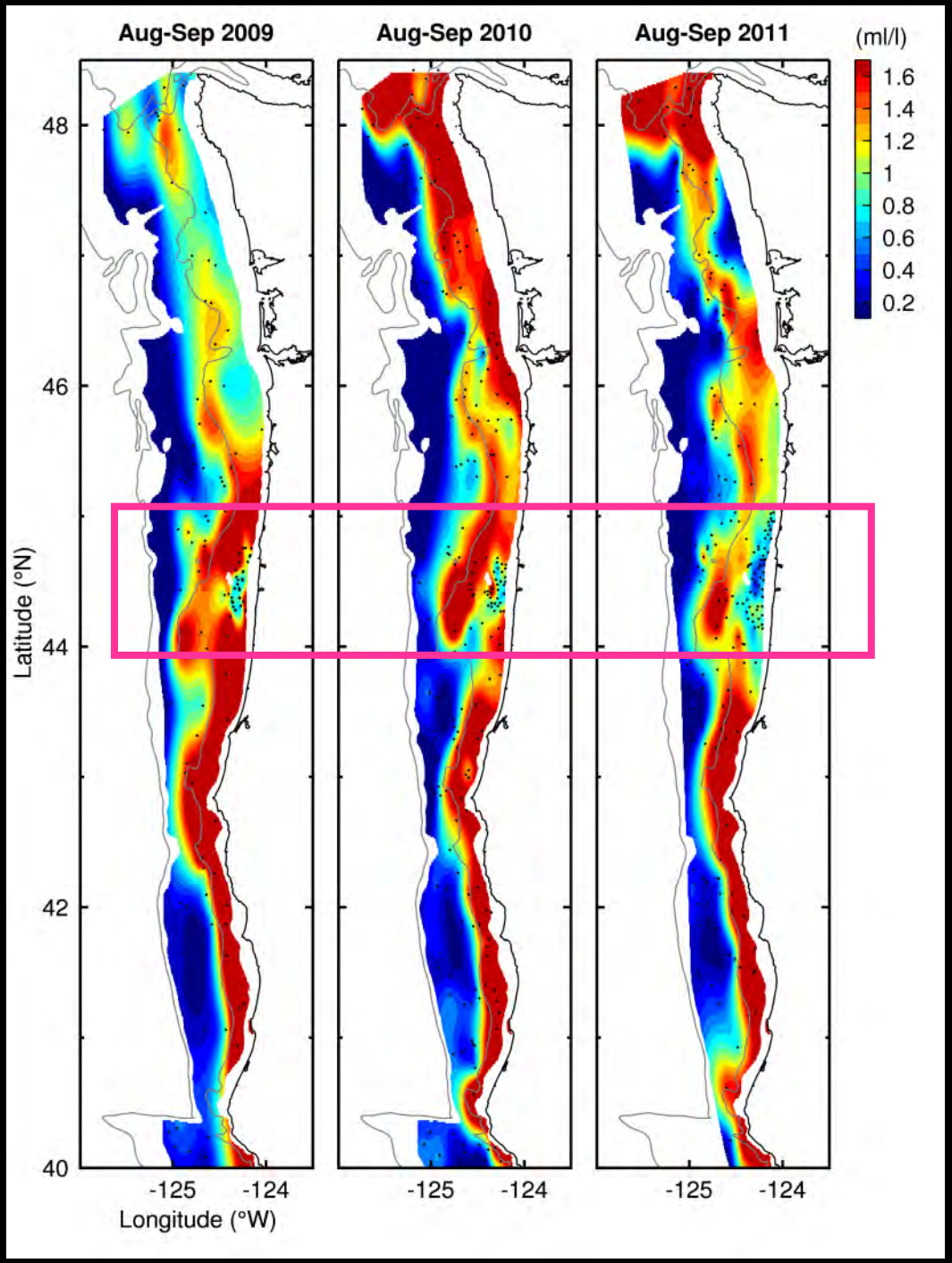
Coast Wide Study 2009 (371 stations)



2009
371 stations

2010
648 stations

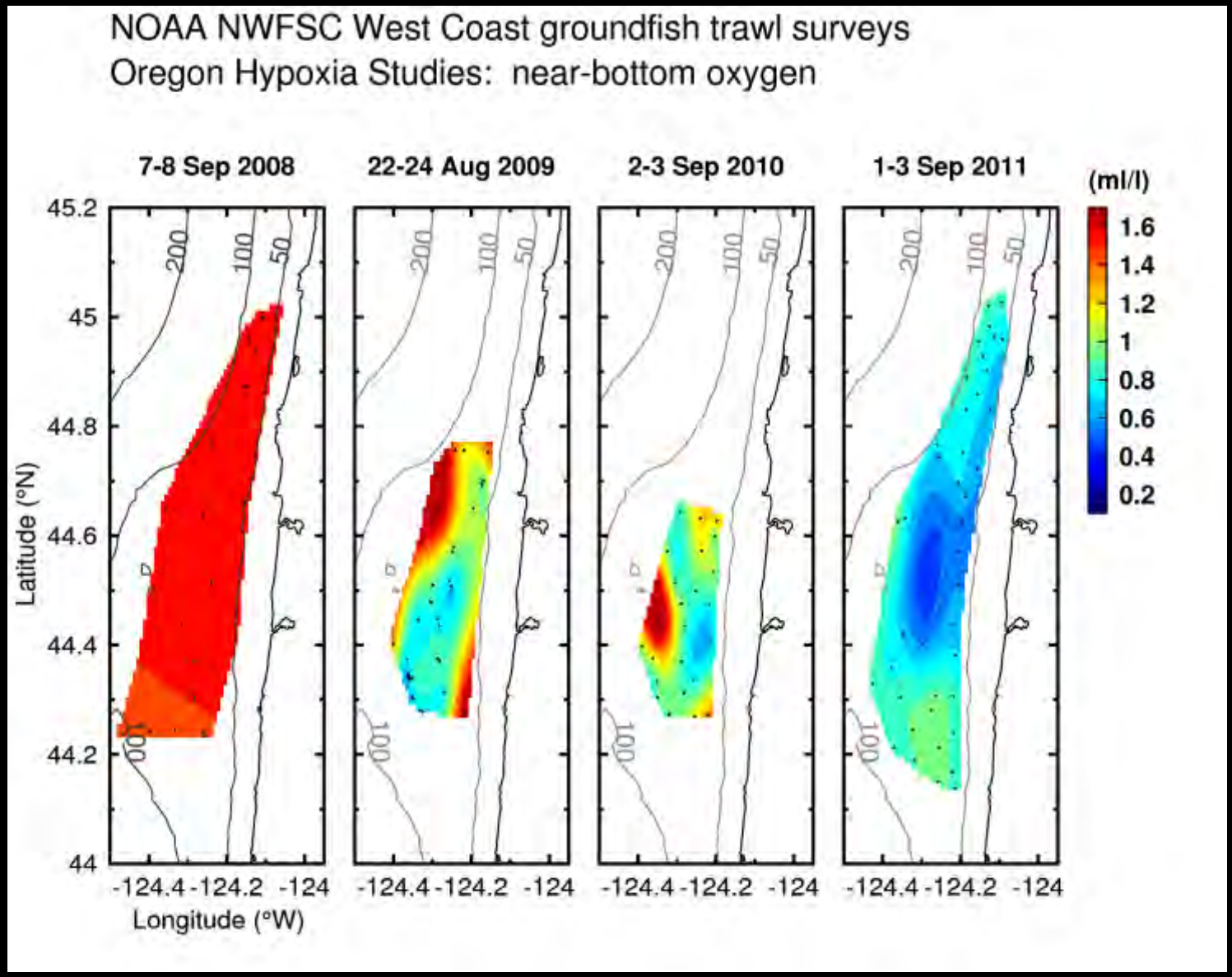




North of Cape Mendocino

2009
2010
2011

Near-bottom dissolved oxygen off central Oregon



Annual Hypoxia Surveys Offshore Oregon

- 13 – 17 stations per year

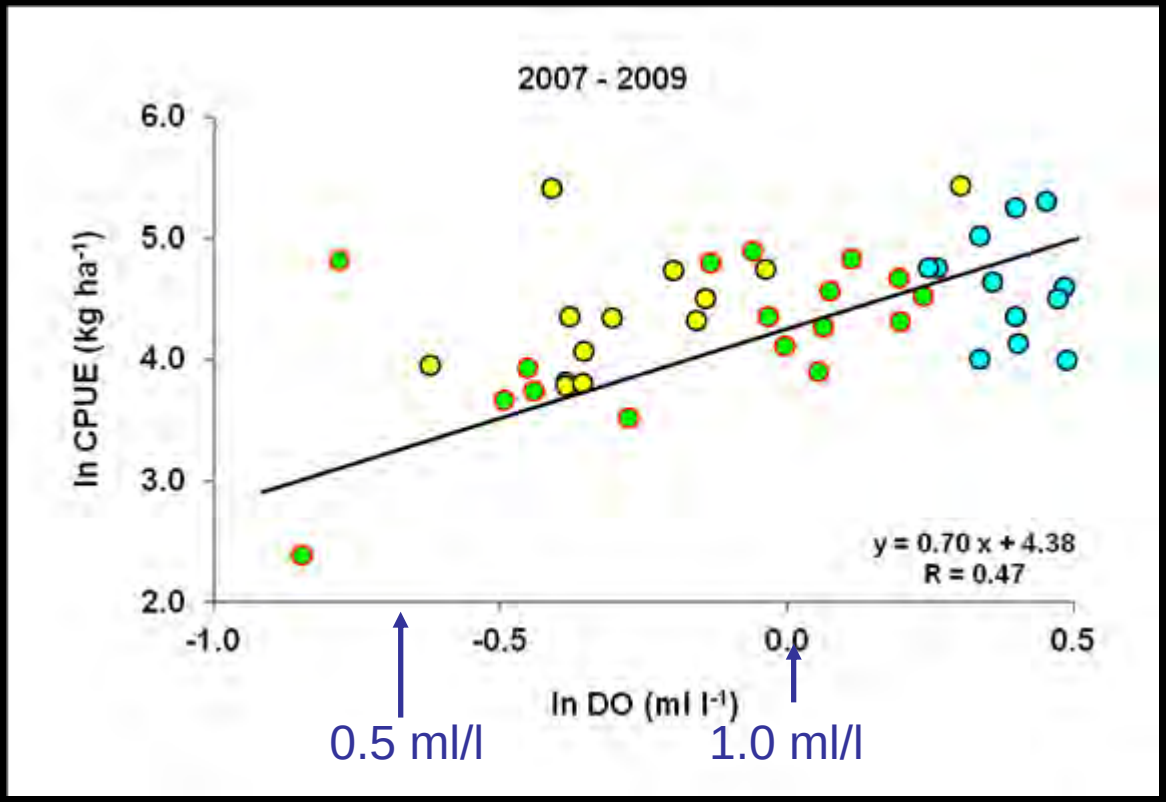
- 2 – 3 days per year
  - Aug. 30 – 31, 2007
  - Sept. 7 – 8, 2008
  - Aug. 22 – 24, 2009
  - Sept. 2 – 3, 2010
  - Sept. 1 – 3, 2011

- Cells selected along 2 depth contours each year (55 to 80 m)

- Sample dates and depths determined each year form DO monitoring data supplied by Oregon State University colleagues

Hypoxia Studies (2007 – 2009)

Total CPUE versus average bottom DO



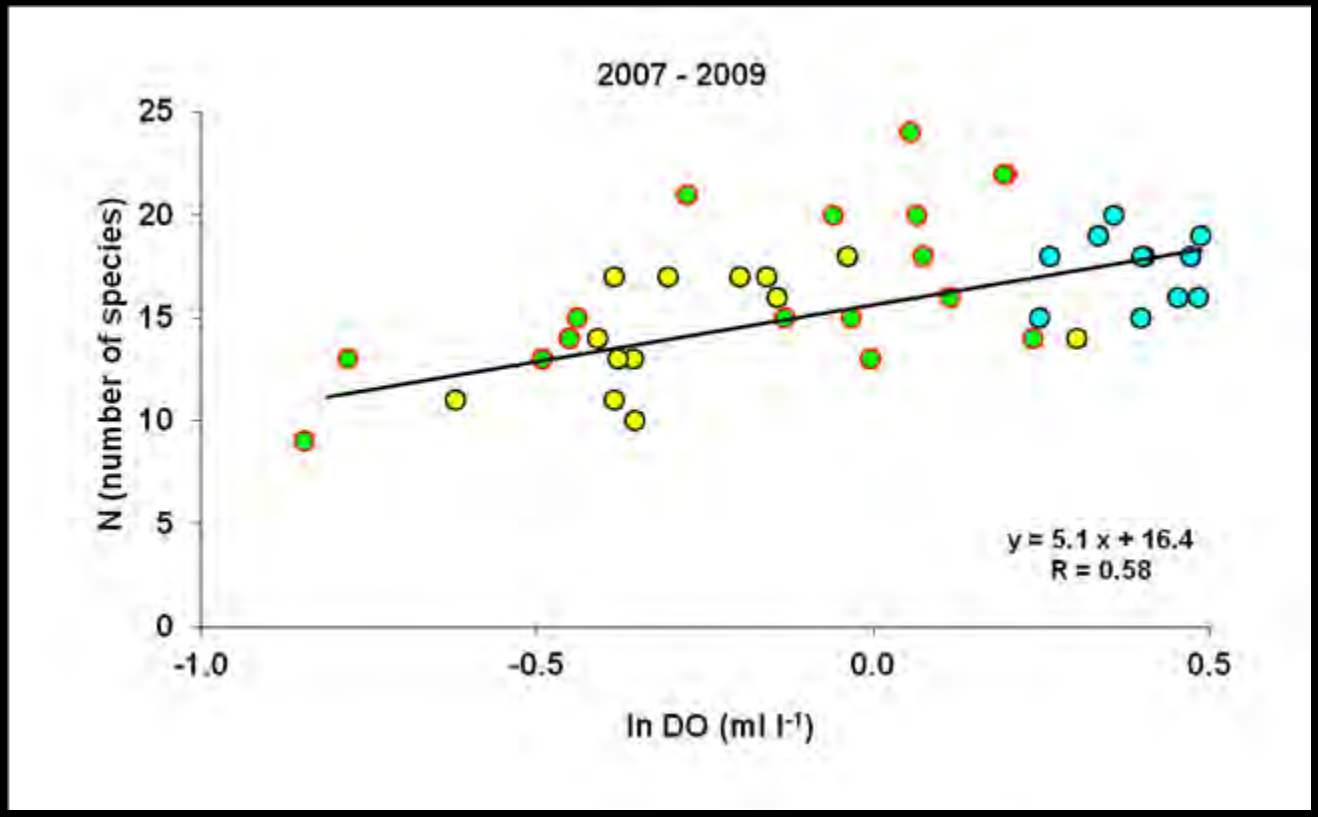
CPUE (kg ha^{-1}) = Catch (kg) /Area Swept (ha)

Includes: demersal fish and benthic invertebrates

(Keller et al., 2010 reported on 2007 data)

Hypoxia Studies (2007 – 2009)

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



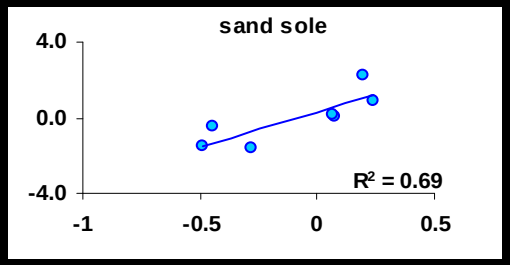
Includes: demersal fish and benthic invertebrates

(Keller et al., 2010 reported on 2007 data)

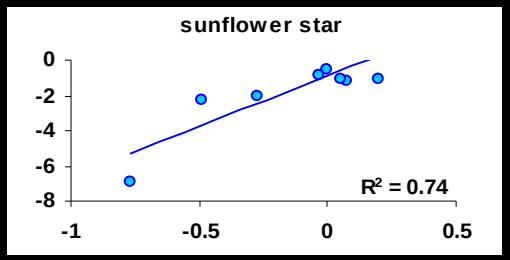
Summary of other results in hypoxic bottom water off Oregon for 2007

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

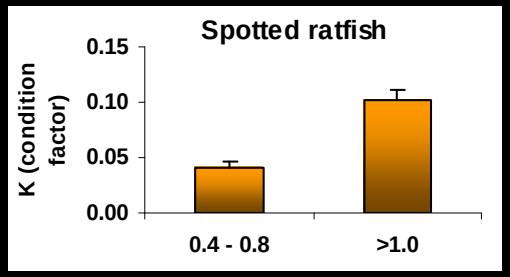
(Keller et al., 2010)



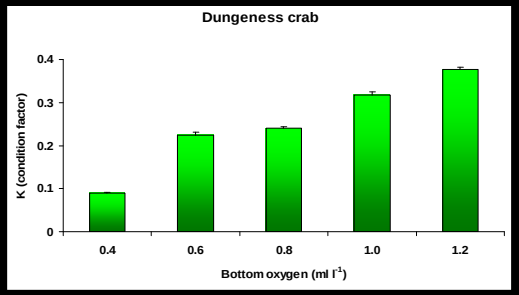
sand sole



sun-flower star



spotted ratfish



Dungeness crab

Conclusions

- Benefit of NOAA annual groundfish surveys to obtain environmental data over entire U.S. west coast
- Ruggedized trawl sensor package
- Collaboration of NOAA and university scientists
- CPUE (fish and invertebrate catch) varied significantly and positively with bottom oxygen within hypoxic areas regardless of year or geographic area
- Species richness (fish and invertebrates) varied significantly and positively with bottom oxygen within hypoxic areas – both depth and/or geographic areas may influence these relationships