Plankton and sediment respiration on the LA Continental Shelf: implications for hypoxia

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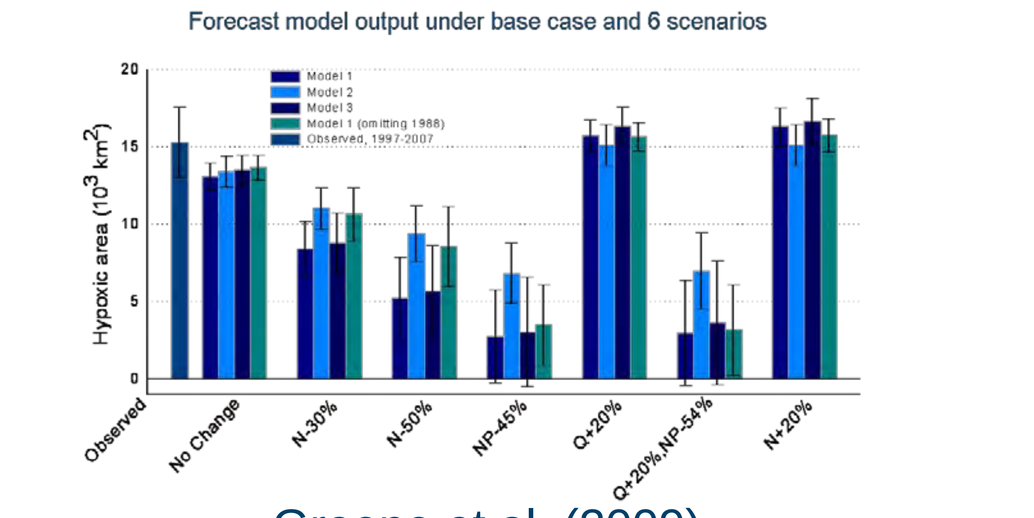
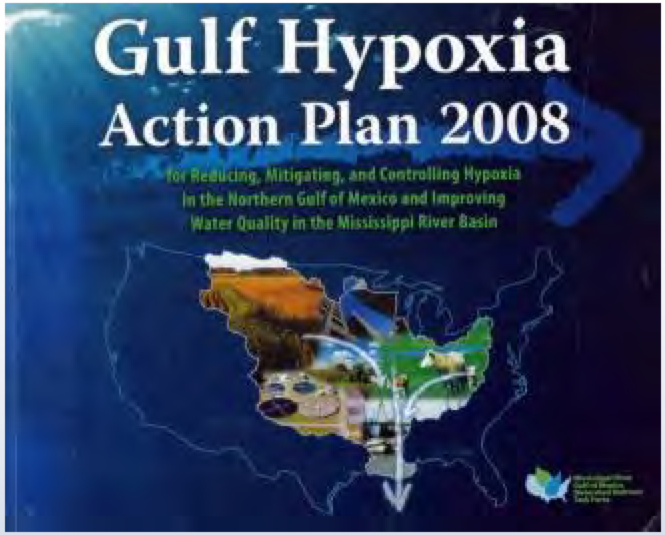
Thanks to GED's hypoxia research staff (and many others)

Project Overview

- **Addresses scientific priorities identified by EPA's Science Advisory Board and the Gulf Hypoxia Task Force.**
- **Project evolution**
  - Shelf wide monitoring to support modeling (2002-05)
  - Emphasis on process rate measurements: production, respiration, and nutrient cycling rates (2006-08)
  - Modeling and analyses, sediment biogeochemistry (2009-present)
- **Technical support to EPA Office of Water and Task Force during Action Plan reassessment**



Greene et al. (2009)



Hypoxia Task Force
(MRGOMWNTF)

- –Federal Agencies
  - USEPA, USDA, USGS, NOAA, USACOE
- –States Agencies
  - LA, MS, MO, OH, IL, TN, MN, IA, WI, AR
- –GOAL: To reduce areal extent of hypoxia to <5000 km^2 by the year 2015 via reductions in N and P
- –Reassess progress every 5 years (2008 >>2013)

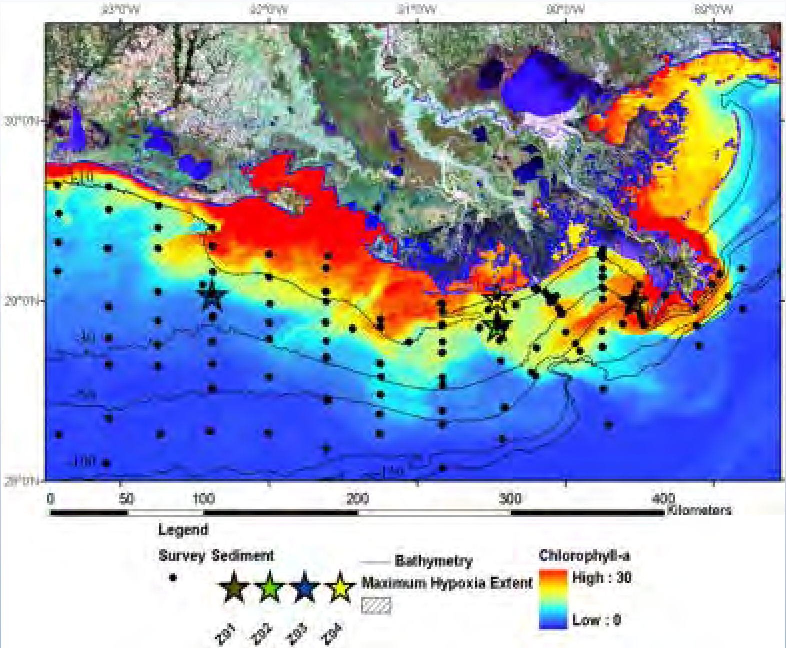
EPA's Science Advisory Board Report (2007)

- Among over 90 recommendations
  - –Advance understanding of biogeochemical and transport processes
  - –Develop a suite of models to integrate physics and biogeochemistry
  - –Improve models characterizing onset, volume, extent, and duration of the hypoxic zone

EPA research cruises

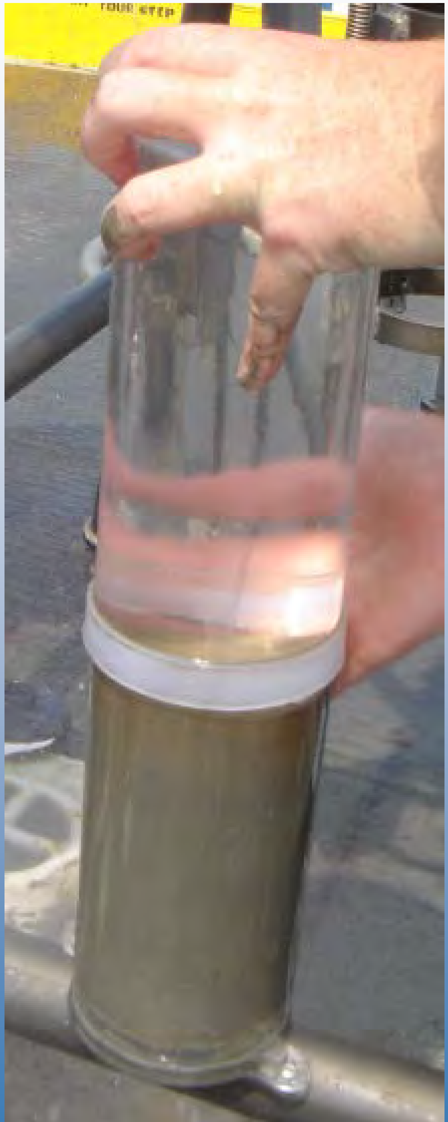
		# of stations		
Surveys	Vessels	CTD	Water	Sediment
2-15 Dec ’02	*OSV Anderson*	36	19	0
17-31 Mar ’03	*OSV Anderson*	65	36	6
9-23 Jun ’03	*OSV Anderson*	51	25	7
5-19 Nov ’03	*OSV Anderson*	70	42	9
2-7 Apr ’04	*OSV Anderson*	22	22	4
21-31 Mar ’05	R/V Longhorn	66	42	10
26 Sep-9 Oct ’05	*OSV Bold*	65	50	0
23 Mar-6 Apr ’06	*OSV Bold*	131	98	3
6-22 Jun ’06	*OSV Bold*	125	95	3
5-19 Sep ’06	*OSV Bold*	125	95	3
24 Apr-8 May ’07	*OSV Bold*	125	95	3
18 Aug-1 Sep ’07	*OSV Bold*	125	95	3
25 Sep-9 Oct ‘10	*OSV Bold*	12	12	12
Total				
13	*3*	*1018*	*726*	*63*

EPA's Field Program 2002-2010

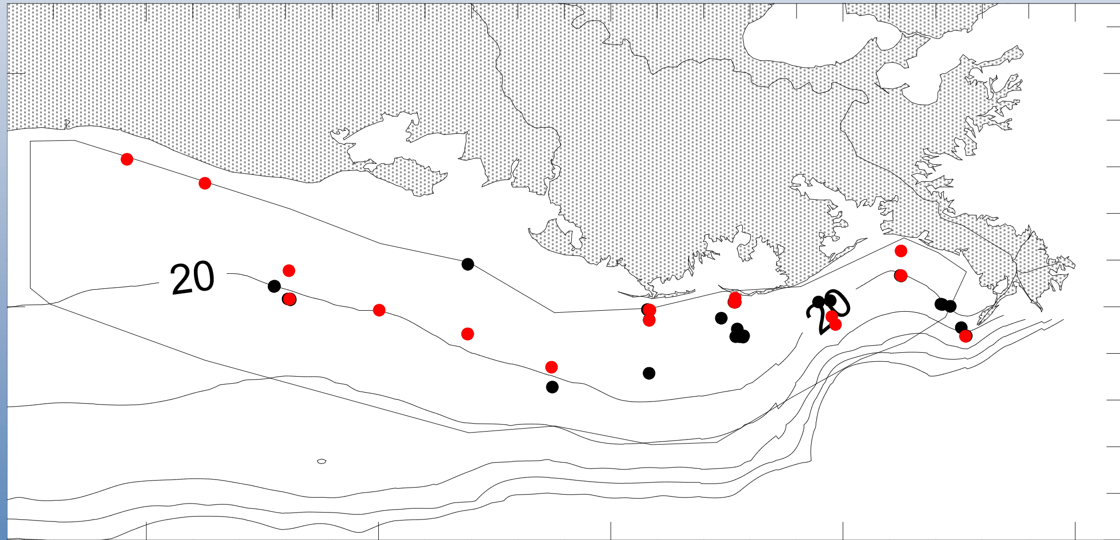


State and Process	Water	Sediment
Inorganic: NO_x, PO_4, NH_4, Si	X	
Particulate C, N, P	X	X
Total Dissolved N, P	X	
DOC	X	
Total Suspended solids	X	
Chlorophyll a	X	X
PAR attenuation	X	
Dissolved oxygen	X	
T, S, turbidity, in vivo fluorescence	X	
Phytoplankton species composition	X	
Primary productivity rates	X	
Plankton Respiration rates	X	
Bacterioplankton production rates	X	
O_2, DIC, and nutrient flux rates		X
Denitrification rates		X
Sulfate, Fe, Mn reduction rates		X
Grain size, Bulk density, porosity, % water		X
Pore water Fe, Mn, SO_4, NH_4, DIC, TN, TP		X
Solid phase Fe, C, N, P		X
Stable Isotope $\delta^{13}C$, $\delta^{15}N$		X

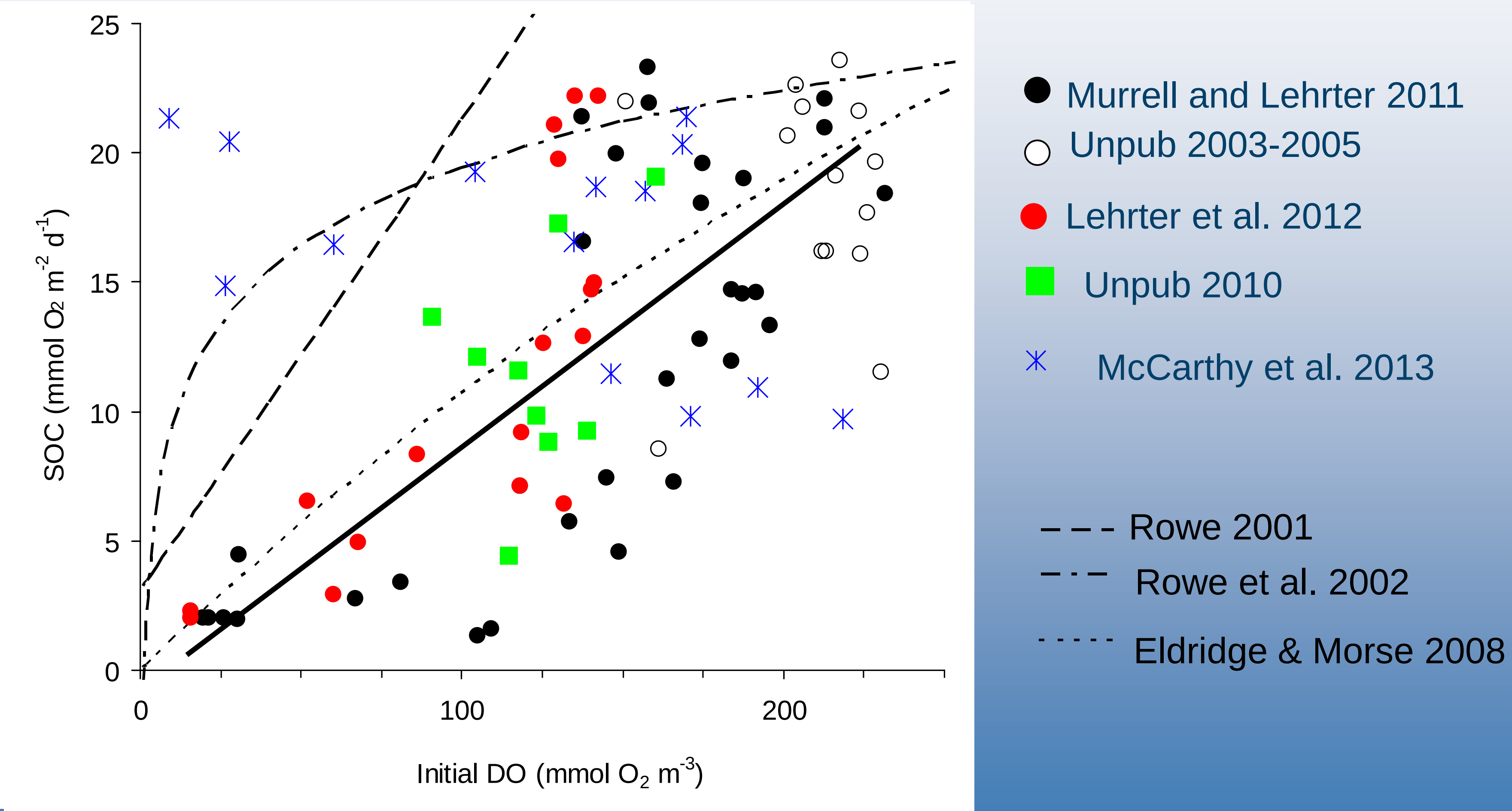
Sediment Oxygen Consumption



- 8 Cruises, 50 stations
- O_2 fluxes via static cores and DO probe
  - ***Range 0-35 mmol O_2 m^{-2} d^{-1}***
- Murrell & Lehrter 2011 *Estuaries and Coasts*

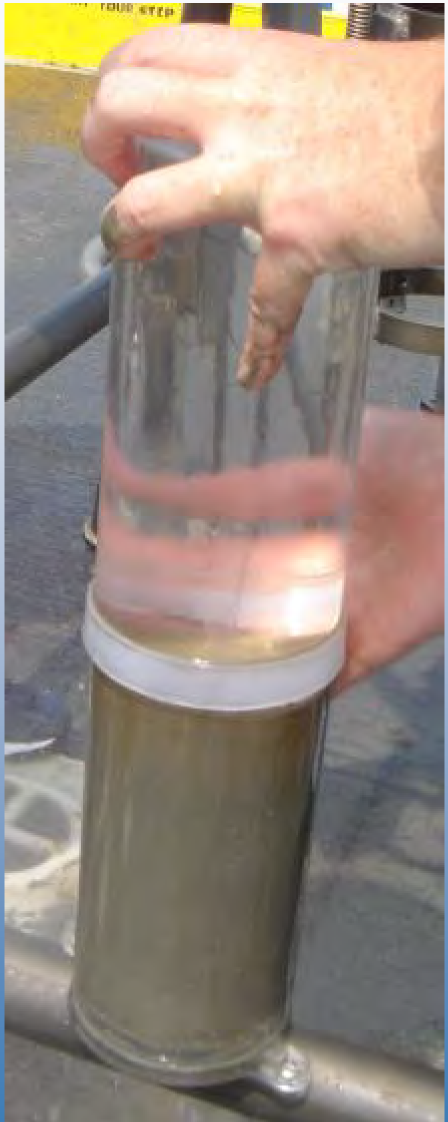


Does overlying water O_2 control SOC?

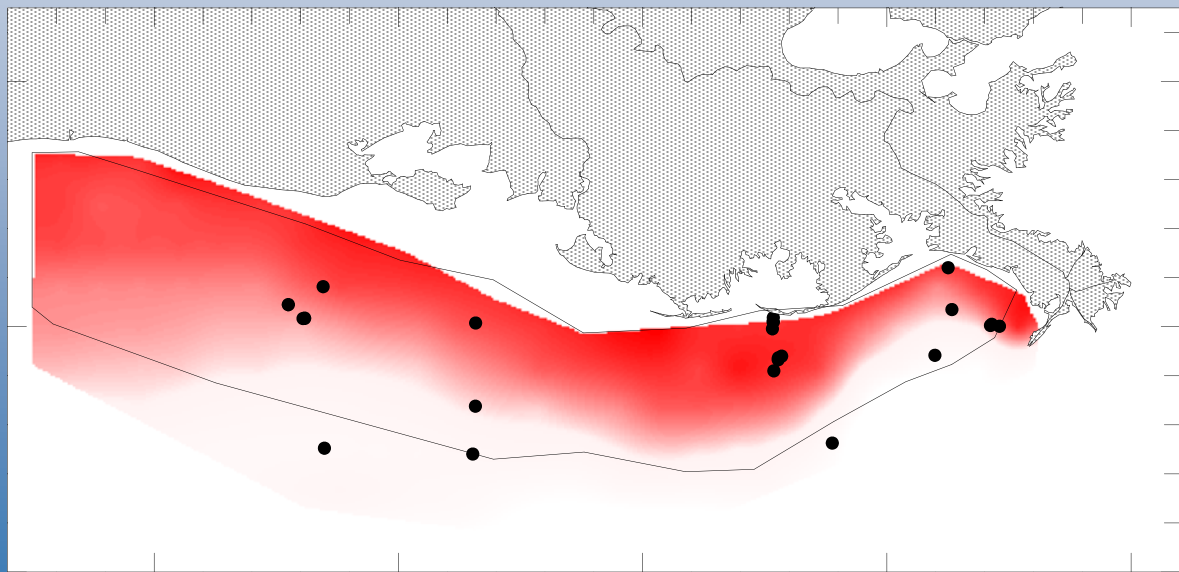


SOC = 0.094 * DO – 1.35

Total Benthic Respiration



- 6 Cruises, 28 stations
- DIC fluxes – aerobic + anaerobic
  - ***Range 8-34 mmol m^{-2} d^{-1}***
- O_2 fluxes (via MIMS)
  - ***Range 3-27 mmol m^{-2} d^{-1}***
- Lehrter et al. 2012 *Biogeochemistry*



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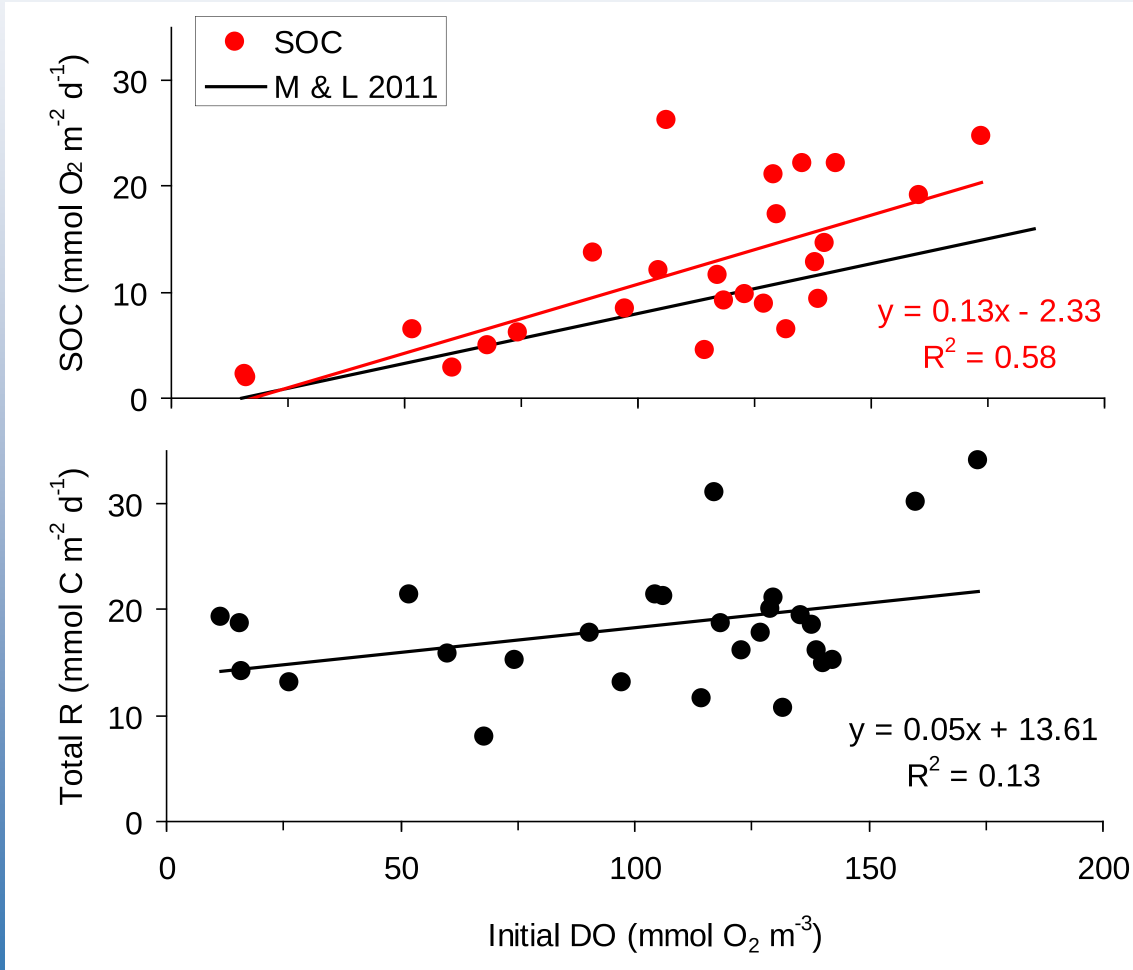
Overlying O_2 conc. relationship with SOC and Total R (aerobic + anaerobic)



Paired O_2 and DIC flux measurements from 2005-2010

n= 28

Lehrter et al. 2012 + unpublished data

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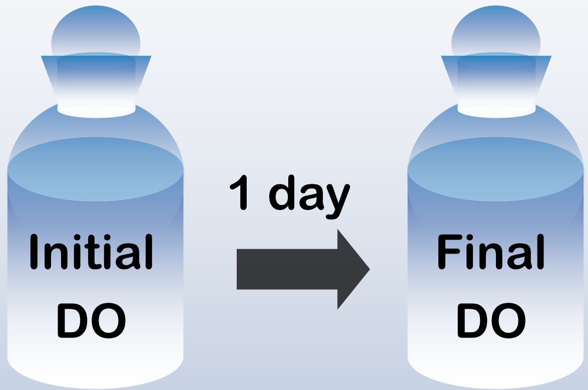
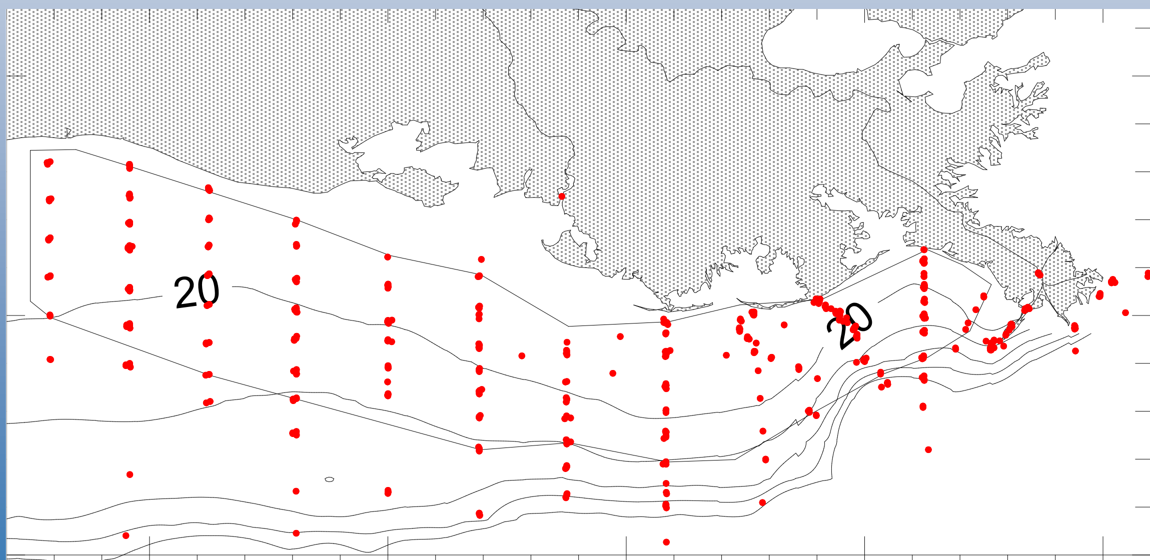
Plankton Community Respiration

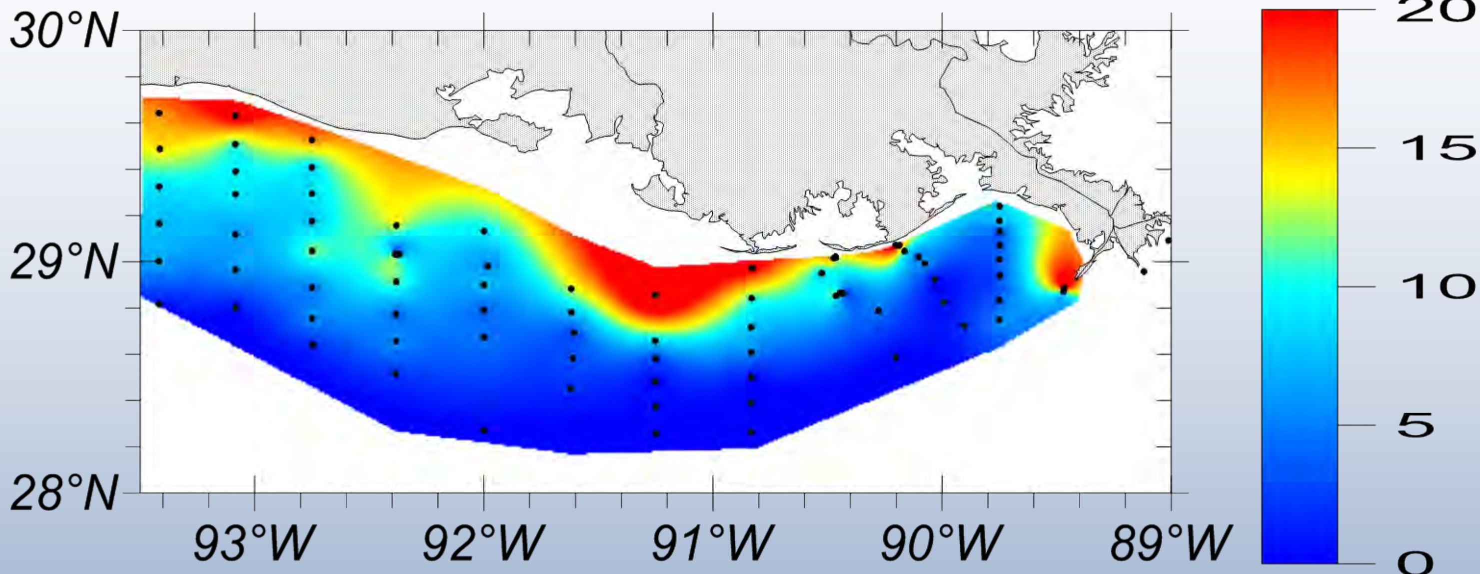
- 10 Cruises, shelfwide coverage
- Mar-Sept
- Surface layer and bottom layer
- >1200 measurements
- Murrell et al. 2013, *Cont. Shelf. Res.*



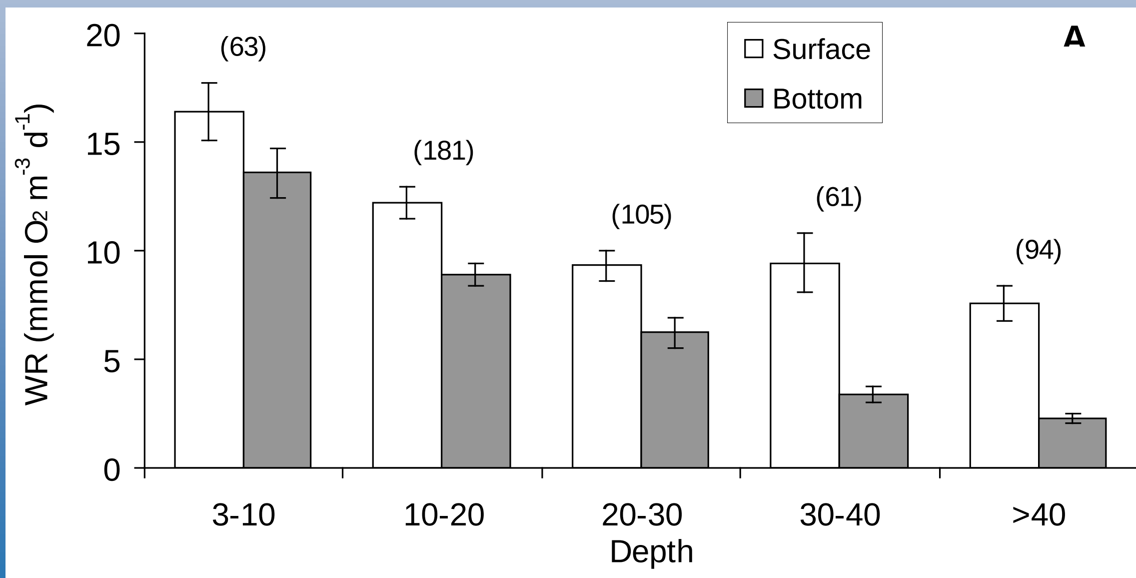


Plankton respiration has strong inshore-offshore gradient

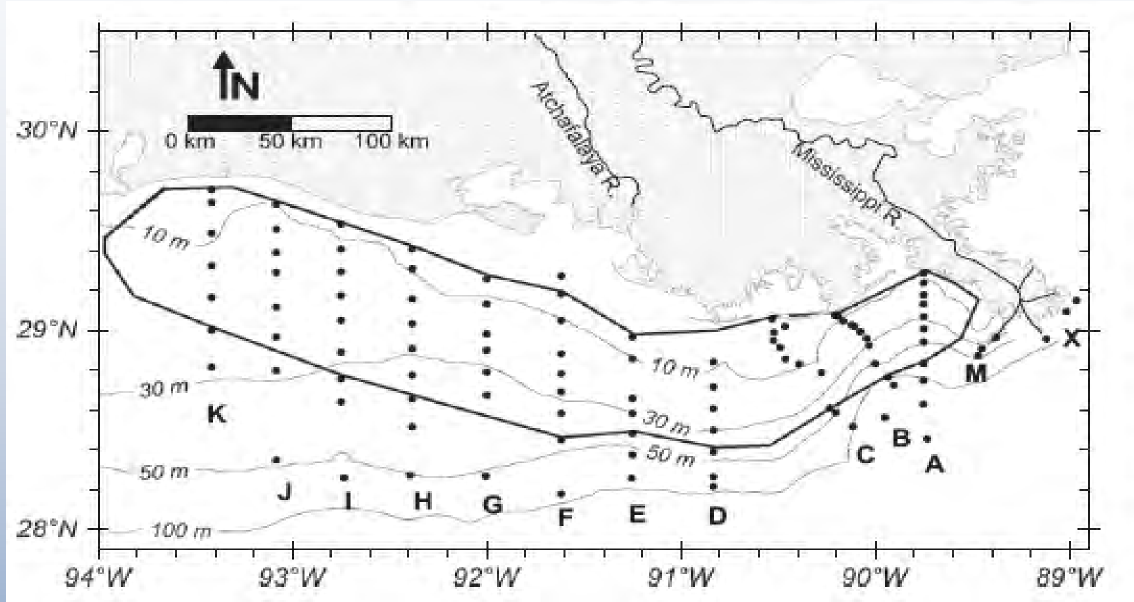
Aug 2007

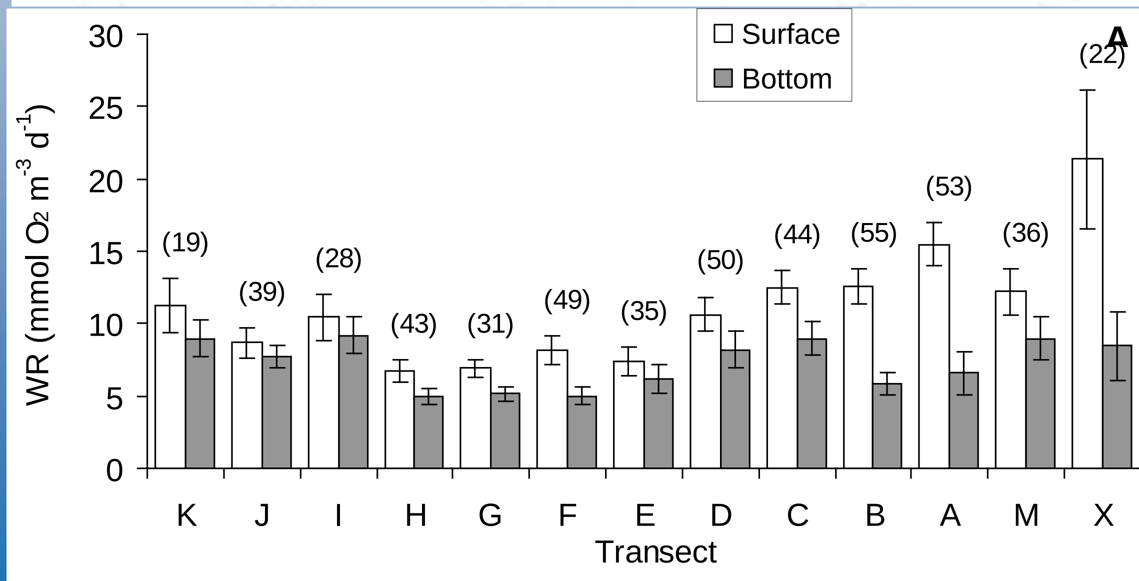


All Data



Plankton respiration has subtle alongshore gradient





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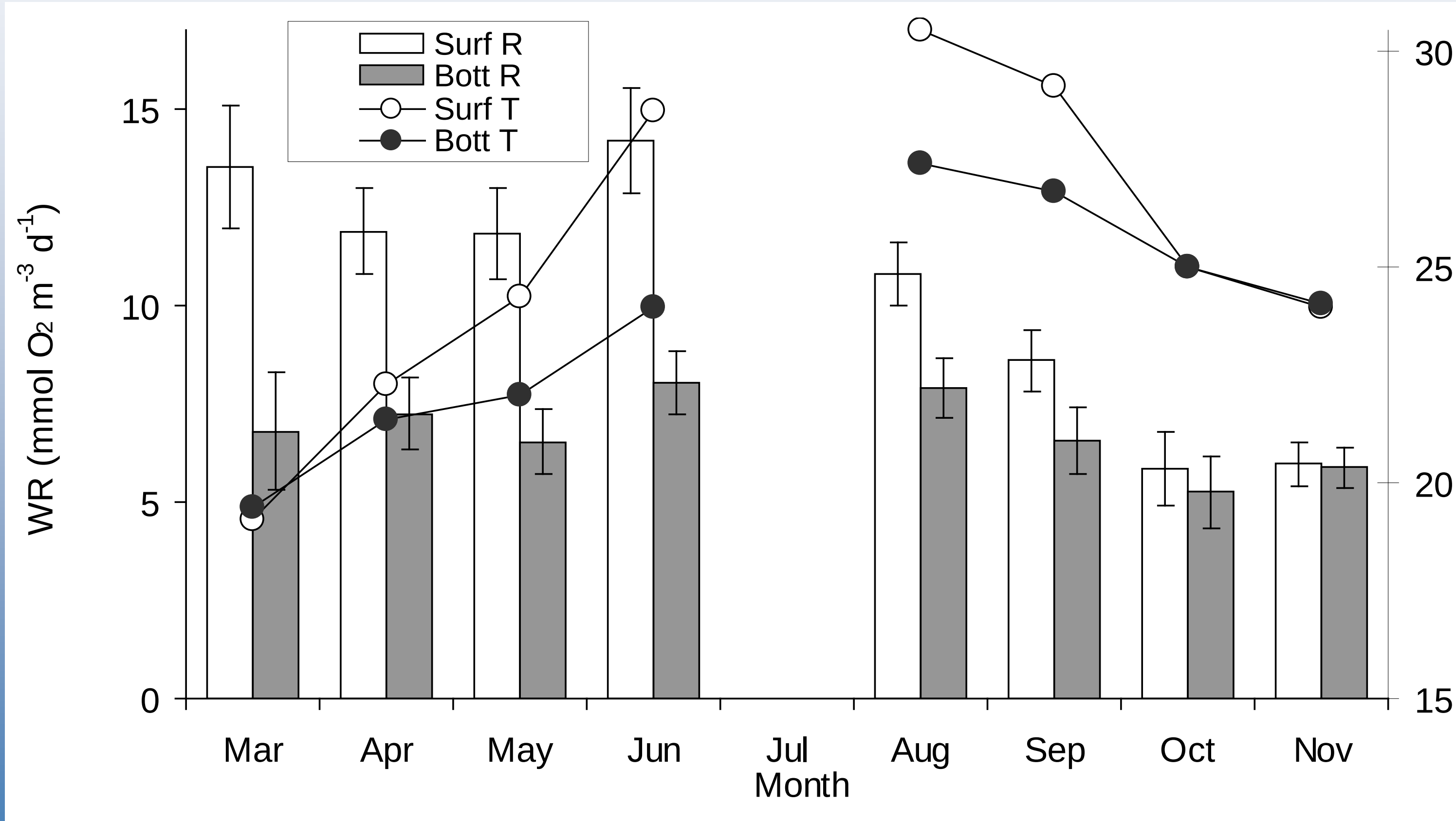
Plankton respiration shows seasonality



Summary / Conclusions

- **Sediment Respiration**
  - SOC dependant on overlying O_2 concentration
  - Total R not so much
- **Plankton Respiration**
  - Bottom waters lower than surface waters
  - Inshore-offshore gradient
  - Alongshore gradient more subtle
    - Higher near plume
  - Seasonality – Temperature-dependence?

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Future Plans

- **No field work currently planned**
- **Most process data are now published**
- **Continued collaboration with modelers to help better constrain biogeochemical processes**
- **Future research should focus on critical controls of respiratory processes**
  - O_2 limitation of SOC (but not Total R)
  - Temperature (Q_{10})
  - pCO2/pH effects
  - OM quantity/quality

Contributions to Date

- Eldridge, P. and D. Roelke. 2010. Origins and scales of hypoxia on the Louisiana shelf: importance of seasonal plankton dynamics and river nutrients and discharge. Ecological Modeling 221:1028-1042
- Greene, R.M., Lehrter, J.C., Hagy, J.D., III, 2009. Multiple regression models for hindcasting and forecasting midsummer hypoxia in the Gulf of Mexico. Ecological Applications 19, 1161-1175.
- Lehrter, J.C., Murrell, M.C., Kurtz, J.C., 2009. Interactions between Mississippi River inputs, light, and phytoplankton biomass and phytoplankton production on the Louisiana continental shelf. Continental Shelf Research 29, 1861-1872.
- Lehrter, J.C., Beddick, D.L., Jr., Devereux, R., Yates, D.F., Murrell, M.C., 2012. Sediment-water fluxes of dissolved inorganic carbon, O2, nutrients, and N2 from the hypoxic region of the Louisiana continental shelf. Biogeochemistry 109, 233-252.
- Murrell, M.C., Lehrter, J.C., 2011. Sediment and lower water column oxygen consumption in the seasonally hypoxic region of the Louisiana continental shelf. Estuaries and Coasts 34, 912-924.
- Murrell, M.C., Stanley, R.S., Lehrter, J.C., Hagy, J.D., 2013. Plankton community respiration, net ecosystem metabolism, and oxygen dynamics on the Louisiana continental shelf: implications for hypoxia. Continental Shelf Research 52, 27-38.
- Schaeffer, B.A., Sinclare, G.A., Lehrter, J.C., Murrell, M.C., Kurtz, J.C., Gould, R.W., Jr, 2011. An analysis of diffuse light attenuation in the northern Gulf of Mexico hypoxic zone using the SeaWiFS satellite data record. Remote Sensing of Environment.
- Schaeffer, B.A., Conmy, R.N., Aukamp, J., Craven, G., Ferer, E., 2011. Organic and inorganic matter in Louisiana coastal waters: Vermilion, Atchafalaya, Terrebonne, Barataria, and Mississippi regions. Marine Pollution Bulletin 62, 415-422.

Thank You!

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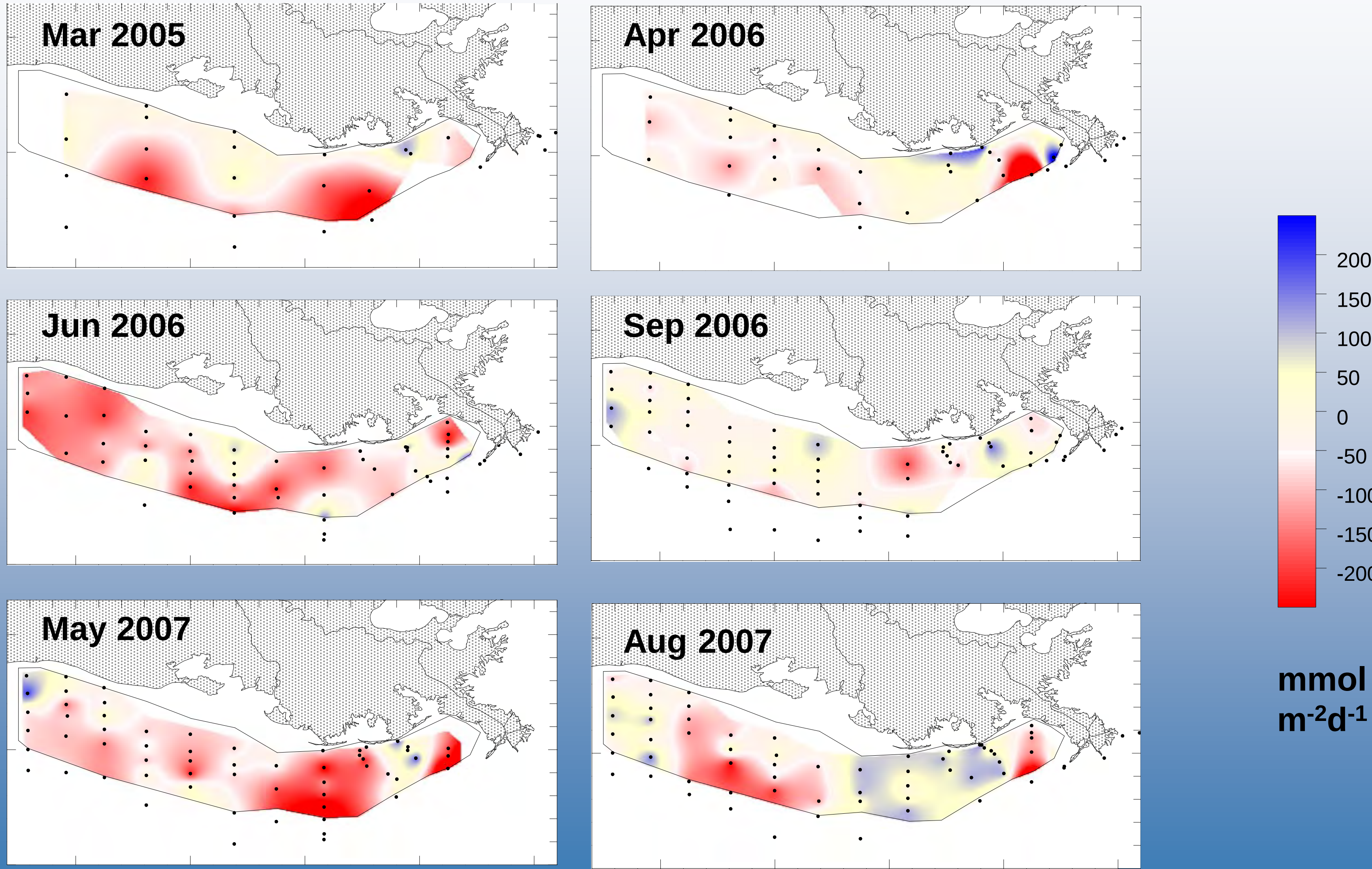
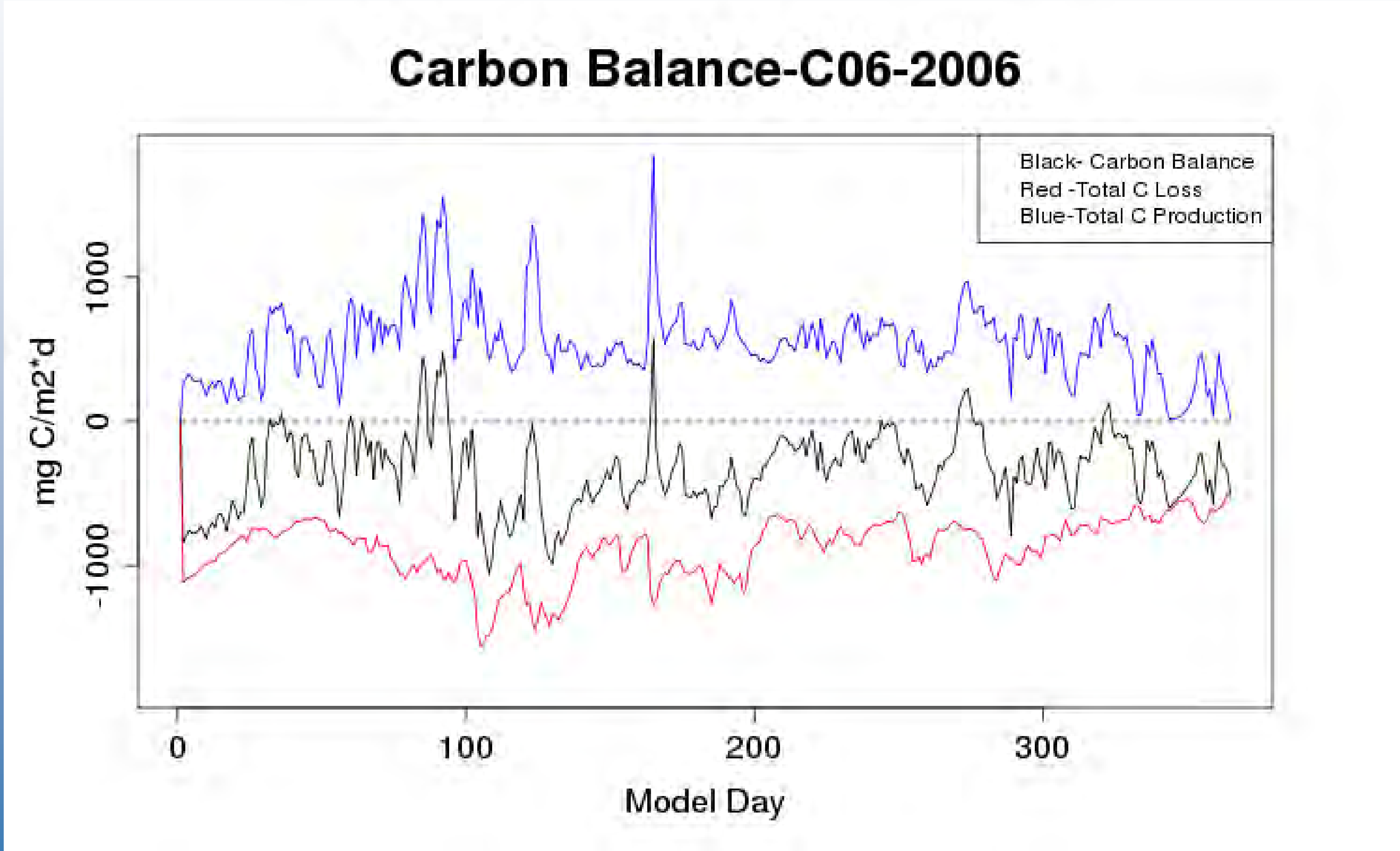
Net Metabolism



Eutrophication model produces similar patterns



Feist et al. (in prep)

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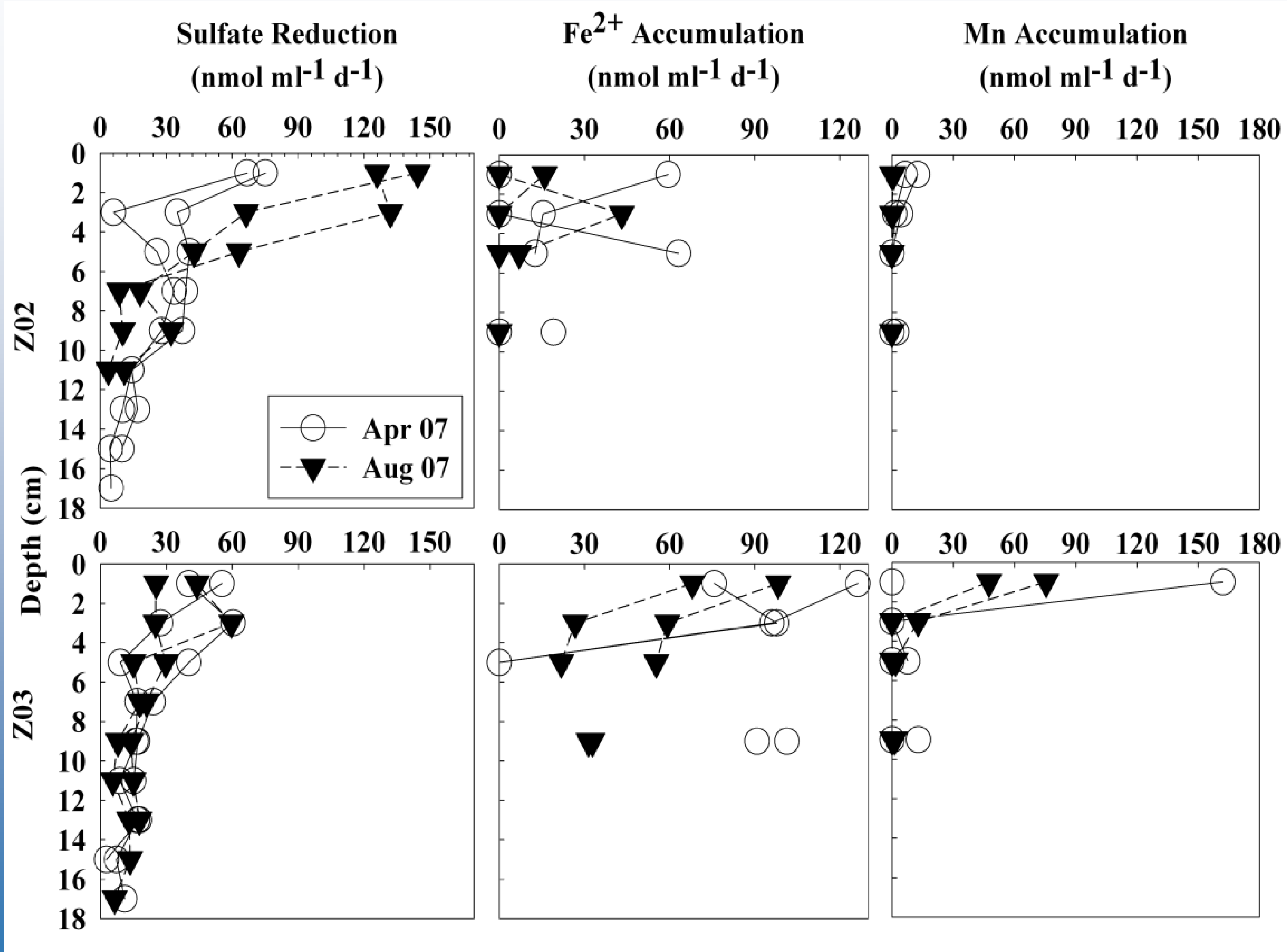
Carbon Sources

Cruise	Primary Production *in situ*	River TOC	Subsidy
Mar 2005	58%	19%	23%
Apr 2006	75%	19%	6%
Jun 2006	50%	13%	37%
Sept 2006	92%	6%	2%
May 2007	51%	17%	32%
Aug 2007	87%	10%	3%
Average	69%	14%	17%

Primary production is major source of C to shelfwide metabolism

- **Shelfwide average PP**
  - 114 mmol C m^{-2} d^{-1}
- **Shelfwide respiration**
  - 171 mmol C d^{-1}
- **PP contribution to C demand (P:R)**
  - 114 /171 = 66%

Anaerobic Processes
(end-products contribute to sediment O2 demand)



Devereux et al. (In Review)

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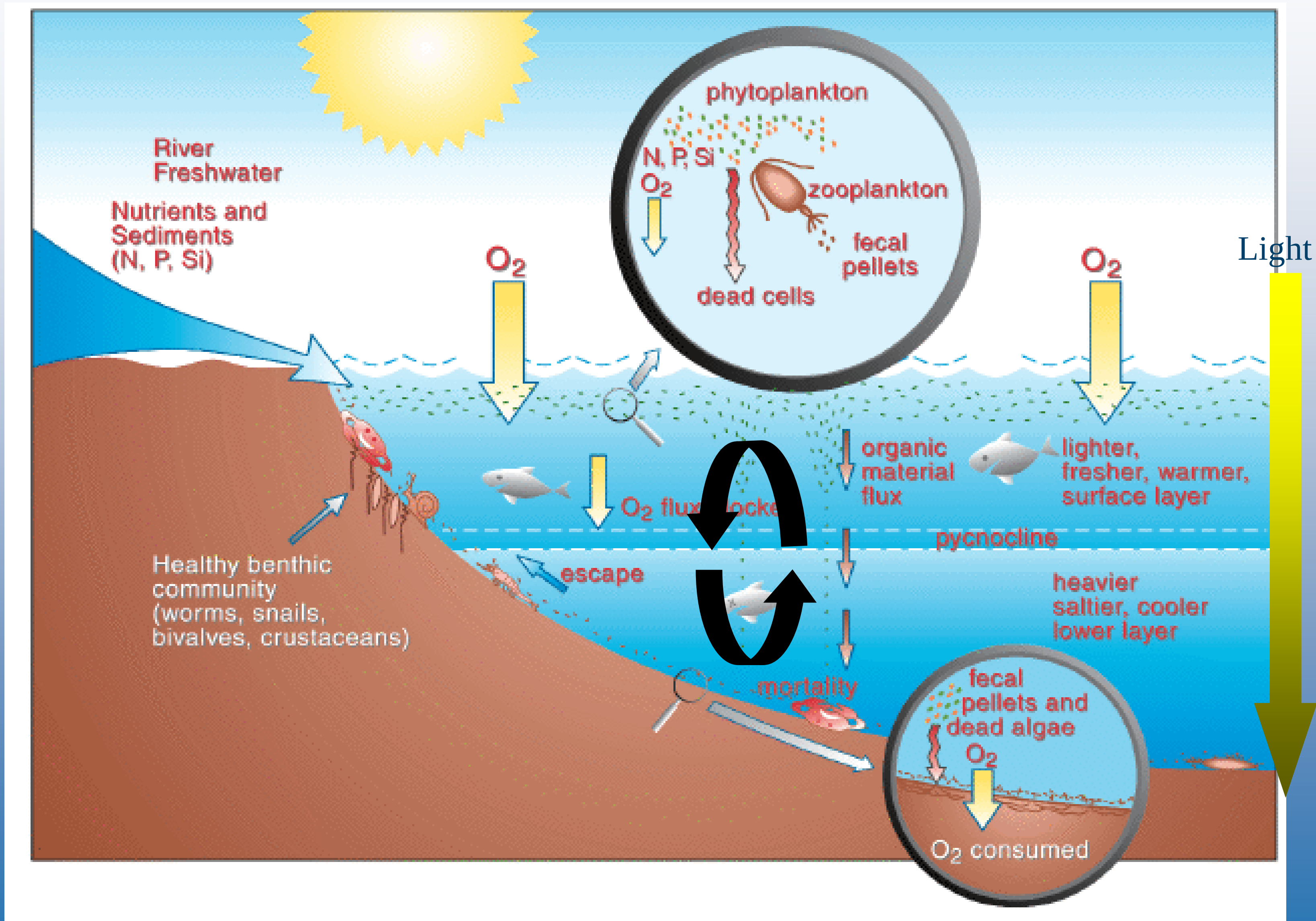
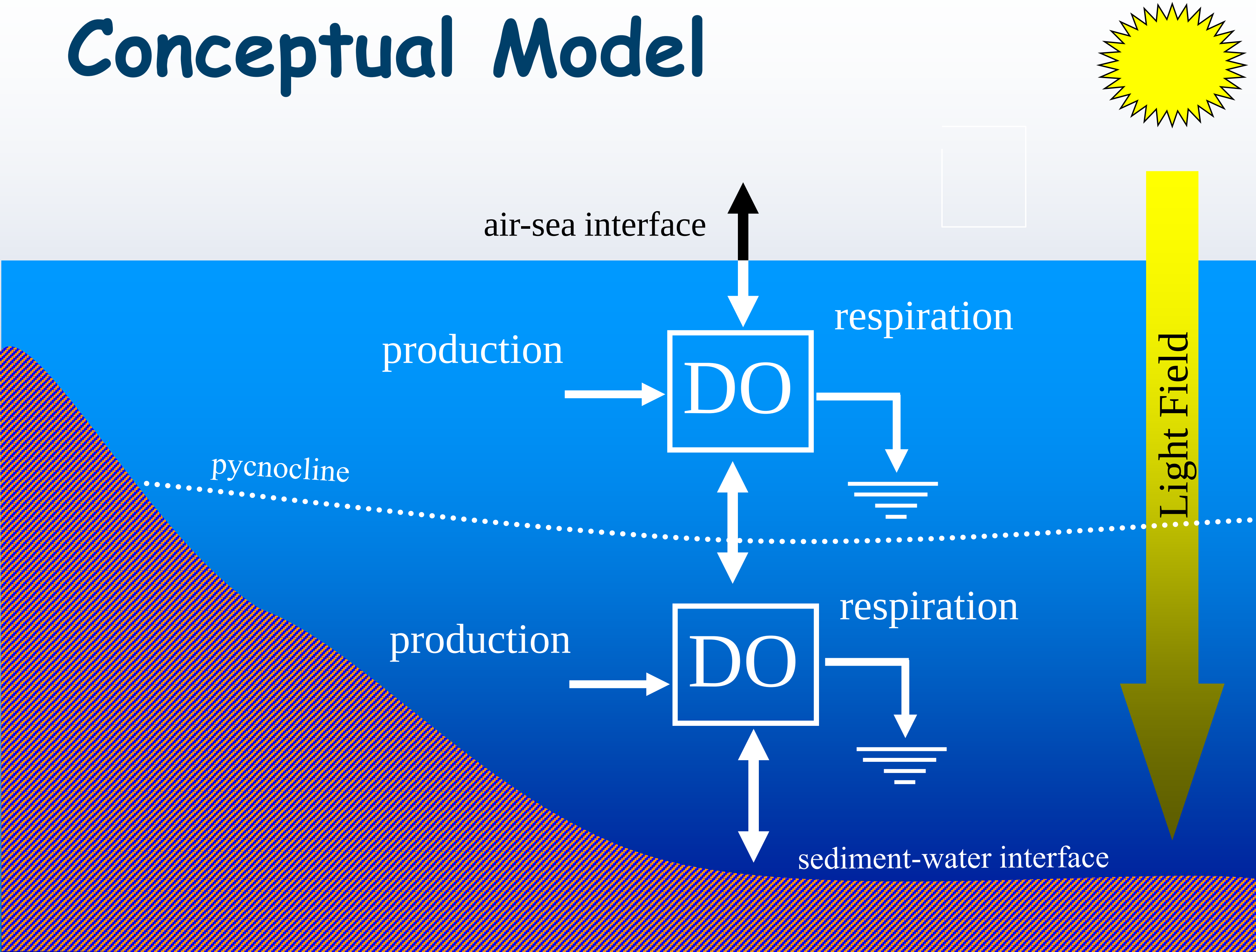
Eutrophication-Hypoxia Paradigm



Conceptual Model



Questions

- **Do current nutrient loads cause accumulation of organic matter on the Louisiana Shelf?**
  - Net autotrophic? Production exceeds respiration
  - Contributes to Legacy effect?
    - (e.g., Turner et al. 2006, 2008, 2012)
  - Lag time between nutrient reductions and observable changes in hypoxia (e.g., Greene et al. 2009)

- **What is the role of terrestrial- and phytoplankton-OM supporting observed respiration?**
  - Benthic and water column respiration
    - Murrell and Lehrter 2011, Lehrter et al. 2012, Murrell et al. 2013

Summary of Production & Respiration

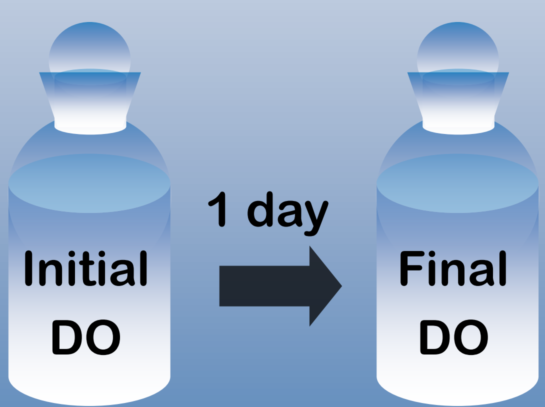
Cruise	Prod *(mmol $m^{-2}d^{-1}$)*	WC+Benth Resp *(mmol $m^{-2}d^{-1}$)*	Net *(mmol $m^{-2}d^{-1}$)*	*P:R*
Mar 2005	124	212	-88	0.58
Sept 2005	62	120	-59	0.51
Apr 2006	116	154	-38	0.75
Jun 2006	89	178	-89	0.50
Sept 2006	138	150	-12	0.92
May 2007	98	193	-94	0.51
Aug 2007	168	193	-25	0.87
Average	114	171	-58	0.66

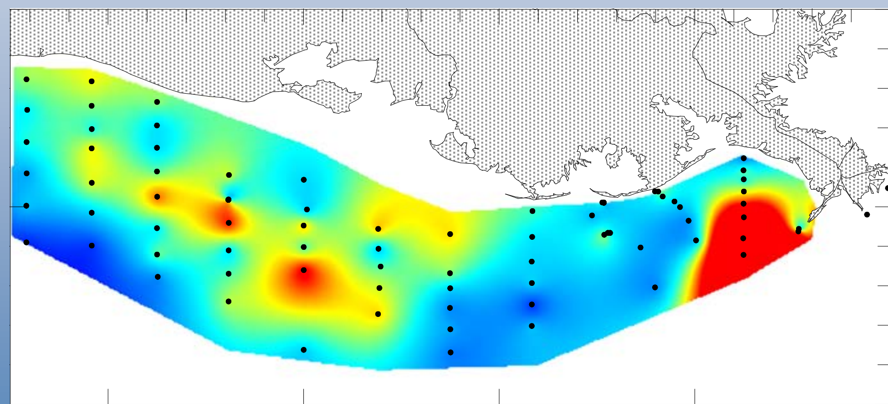
Turnover times of freshwater and TOC

Cruise	T_{FW} (d)	T_{TOC} (d)	Ratio
Mar 2005	32	6.1	0.19
Apr 2006	24	4.5	0.19
Jun 2006	35	4.5	0.13
Sept 2006	124	7.2	0.06
May 2007	22	3.7	0.17
Aug 2007	58	5.8	0.10
Average	49	5.3	0.14

Plankton Community Respiration

- 10 Cruises, shelfwide coverage
- Mar-Sept
- Surface layer and bottom layer
- >1200 measurements
- Murrell et al. 2013, *Cont. Shelf. Res.*





Aug 2007

175 mmol $m^{-2}d^{-1}$