CSCOR NGOMEX: The Effects and Impacts of Hypoxia on Production Potential of Ecologically and Commercially Important Living Resources in the Northern Gulf of Mexico

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NGOMEX – Spatially-explicit, High-resolution Mapping and Modeling to Quantify Hypoxia Effects on the Living Resources of the Northern Gulf of Mexico

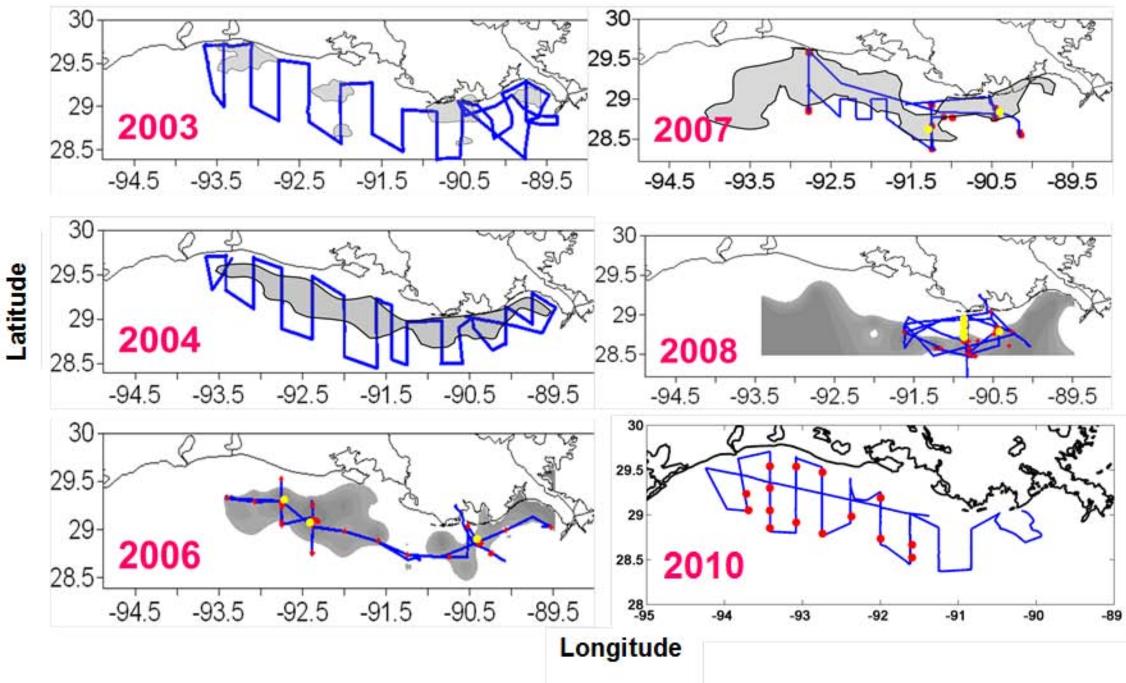
PROJECT OBJECTIVES:

1. Conduct high resolution mapping of NGOMEX pelagic food web in relation of hypoxia.

2. Integrate our ecosystem measurements through a variety of models designed to assess the effects of hypoxia on pelagic food webs and production.

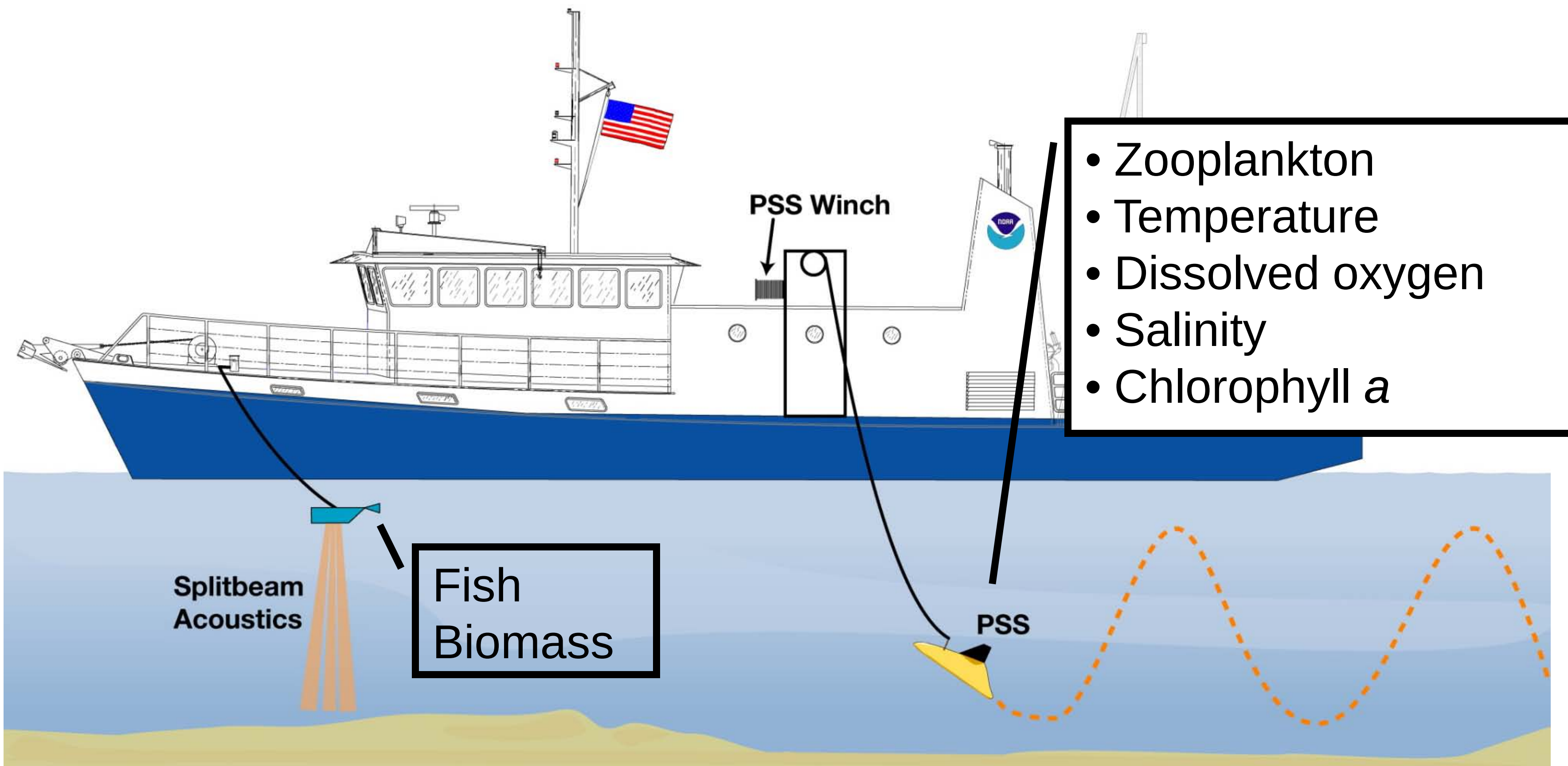
3. Quantify habitat suitability for economically important fishes.

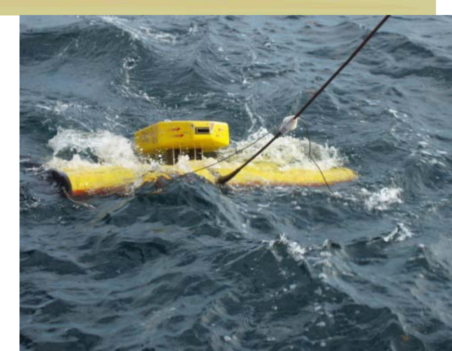
4. Provide tools to forecast food-web interactions, habitat suitability and fish production in relation to hypoxia.

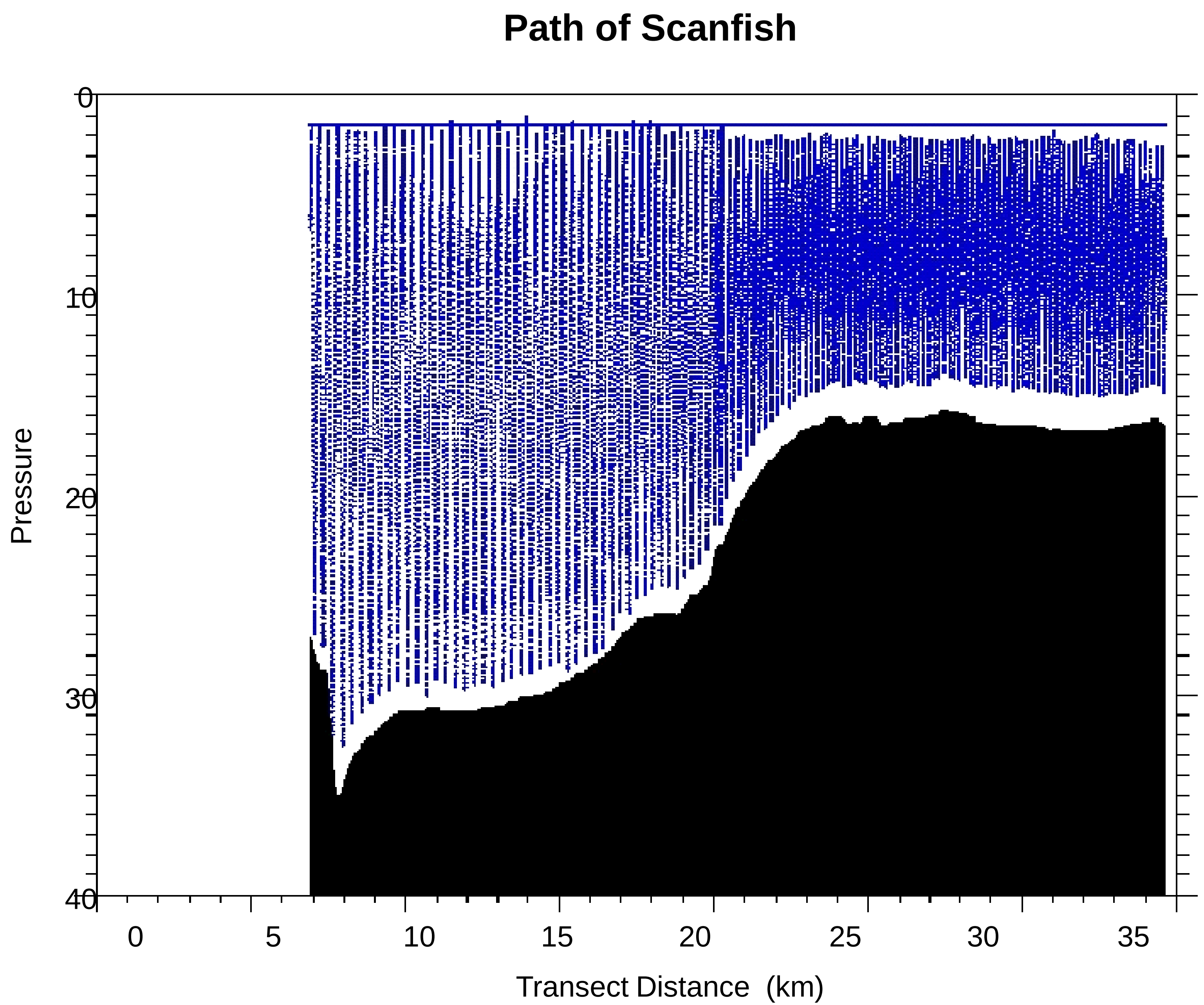


2003
2007
2004
2008
2006
2010
30
29.5
29
28.5
28
-94.5
-93.5
-92.5
-91.5
-90.5
-89.5
-95
-94
-93
-92
-91
-90
-89
Latitude
Longitude

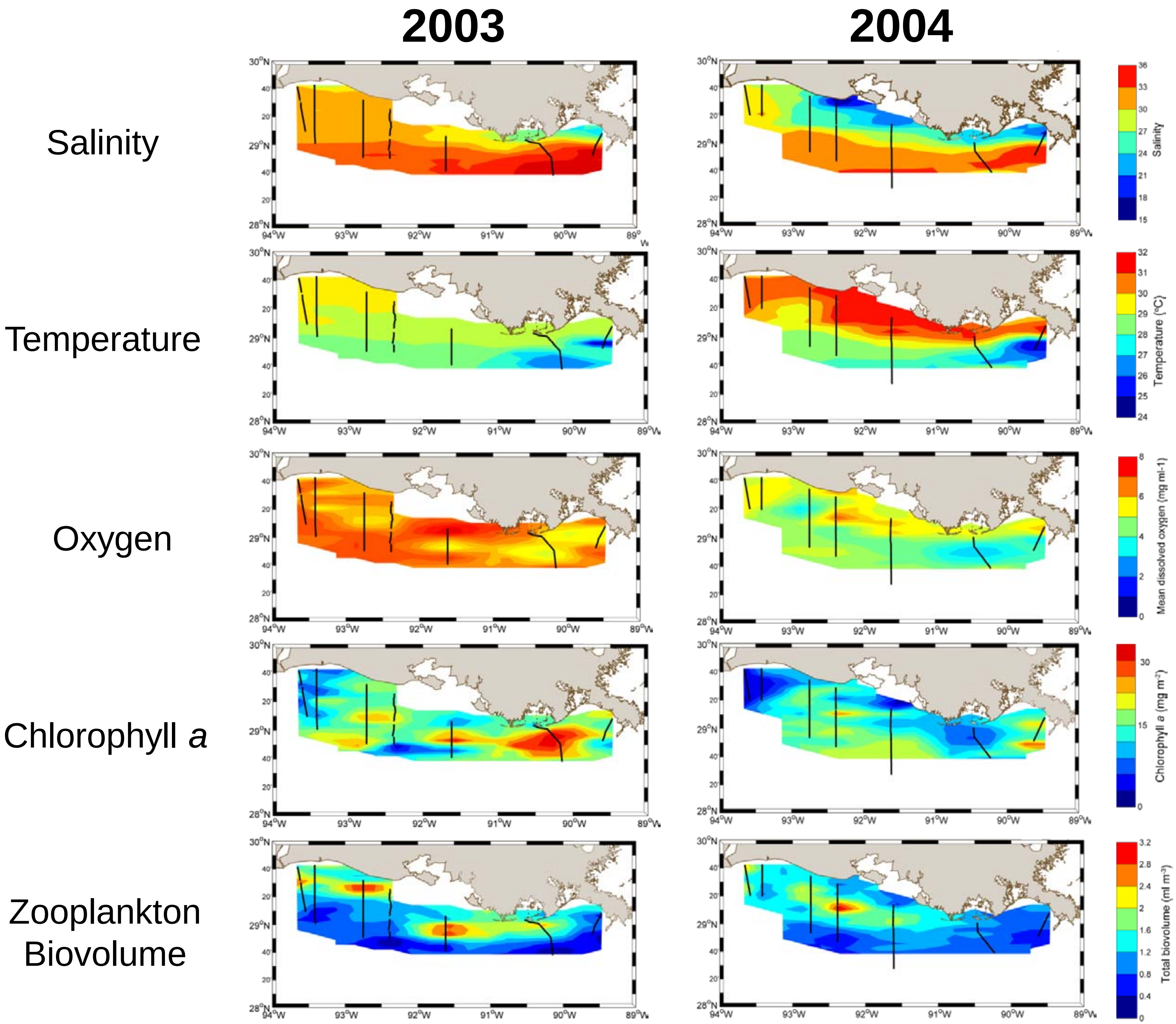
Baseline Field Sampling






Path of Scanfish
Pressure
0
10
20
30
40
0
5
10
15
20
25
30
35
Transect Distance (km)

Gear	EcosystemComponent	03	04	06	07	08	10
CTD	Temp,DO,Salinity,Chla,PAR	15	15	67	59	77	32
ADCP	Currents		X		X	X	X
FlowCytometry	Microbialfood web			X	X	X	
ZPPump	Mesozooplankton	X	X	X	X	X	
TAPS	Mesozooplankton	X	X	X	X	X	X
Scanfish/CTD/OPC	Mesozooplankton,Temp,DO, Salinity,Chla	X	X	X	X	X	X
Acoustics	PelagicFish	X	X	42h	85h	107h	X
BottomTrawl	BenthicFish			67	40	31	X[1]
MidwaterTrawl	PelagicFish			X	X	X	X[1]
DIDSON	Pelagic&BenthicFish					22h	


2003
2004
Salinity
Temperature
Oxygen
Chlorophyll a
Zooplankton Biovolume
Salinity
Temperature (°C)
Mean dissolved oxygen (mg ml-1)
Chlorophyll a (mg m-2)
Total biovolume (ml m-3)
94°W
93°W
92°W
91°W
90°W
89°W
30°N
29°N
28°N

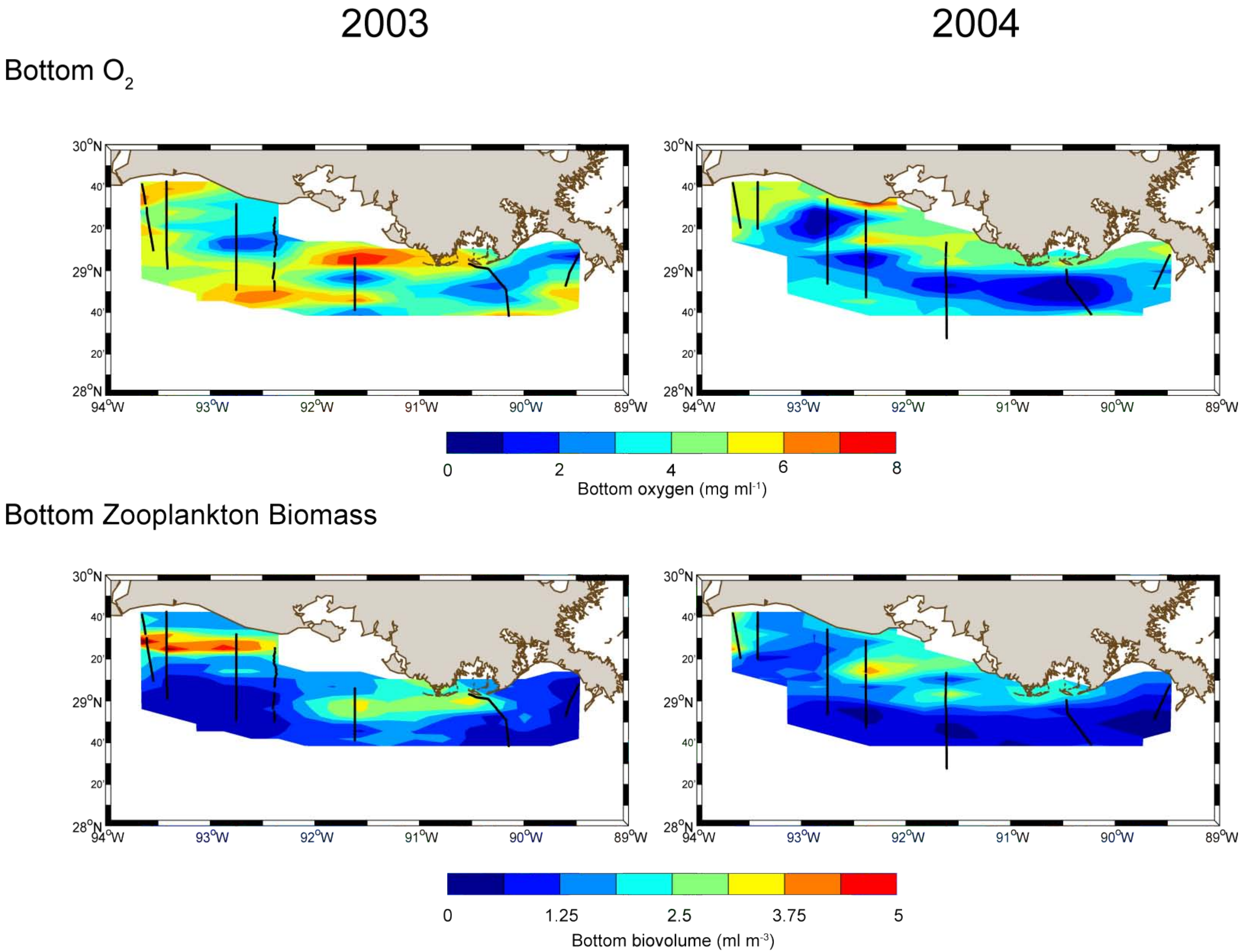
Potential effects of hypoxia on coastal zooplankton

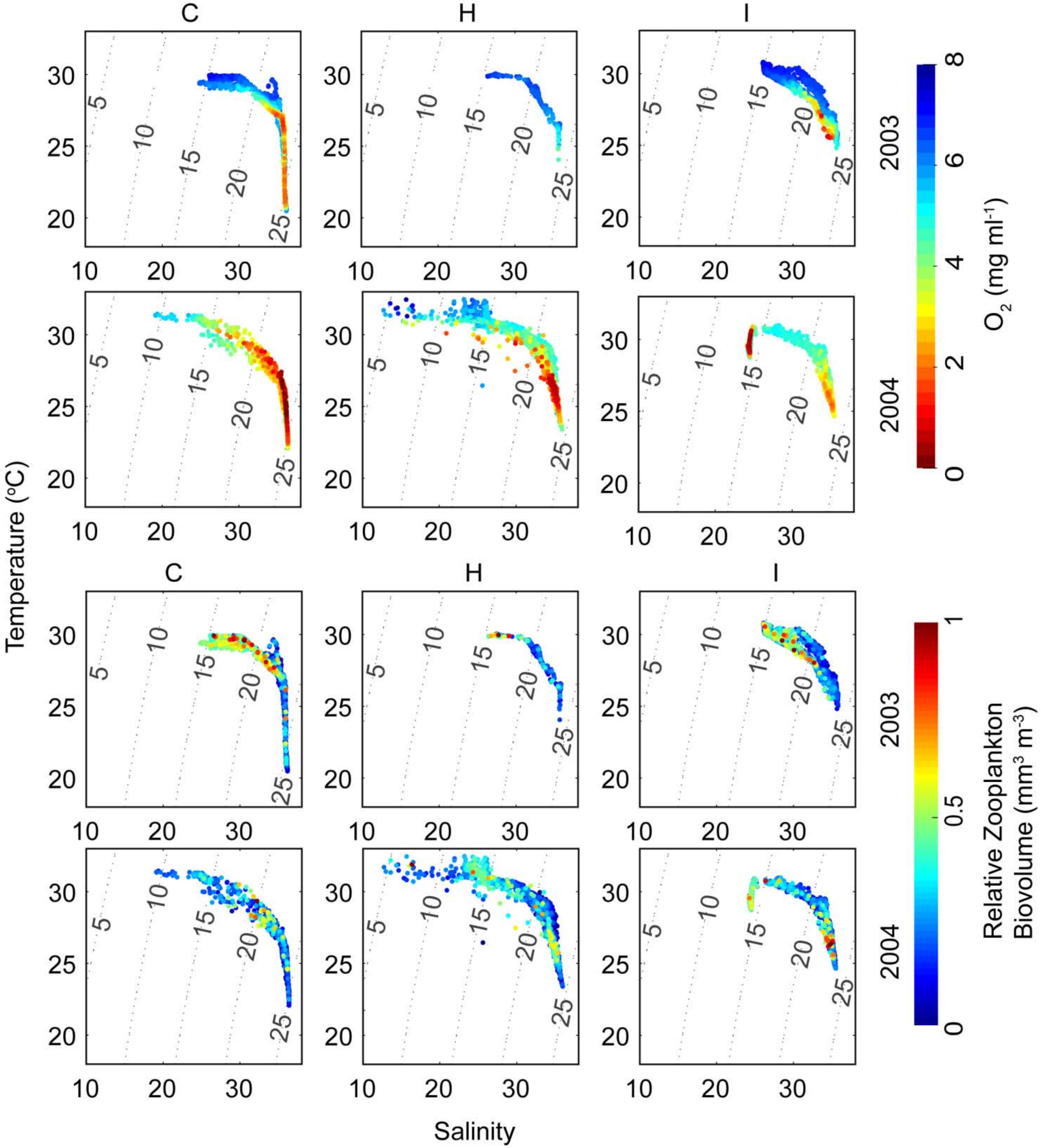
Deleterious

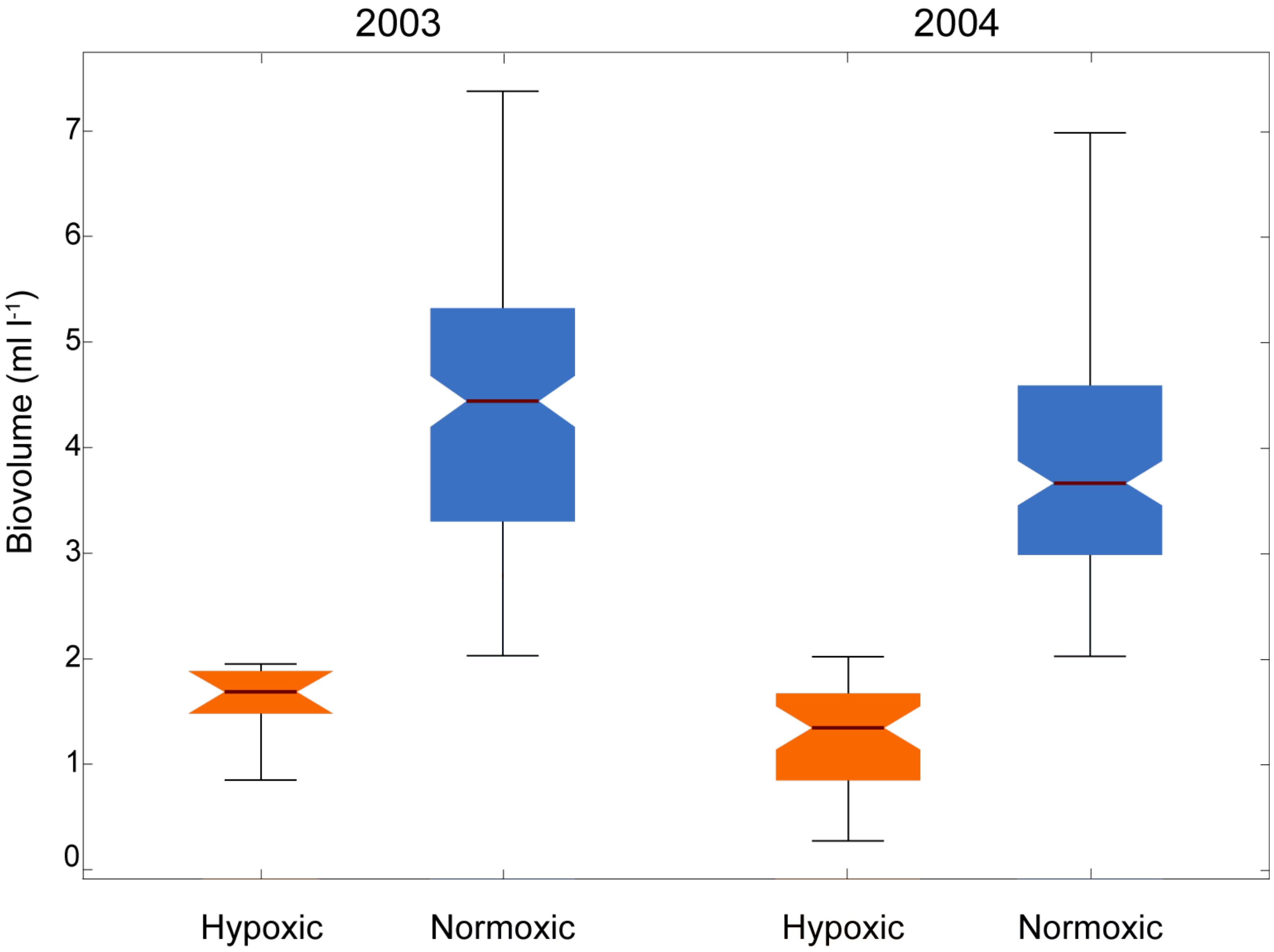
- Direct
  - Lethal
  - Sub-lethal, e.g.
    - Slowed development
    - Reduced reproductive success
- Indirect
  - Habitat reduction
  - Trophic interactions altered

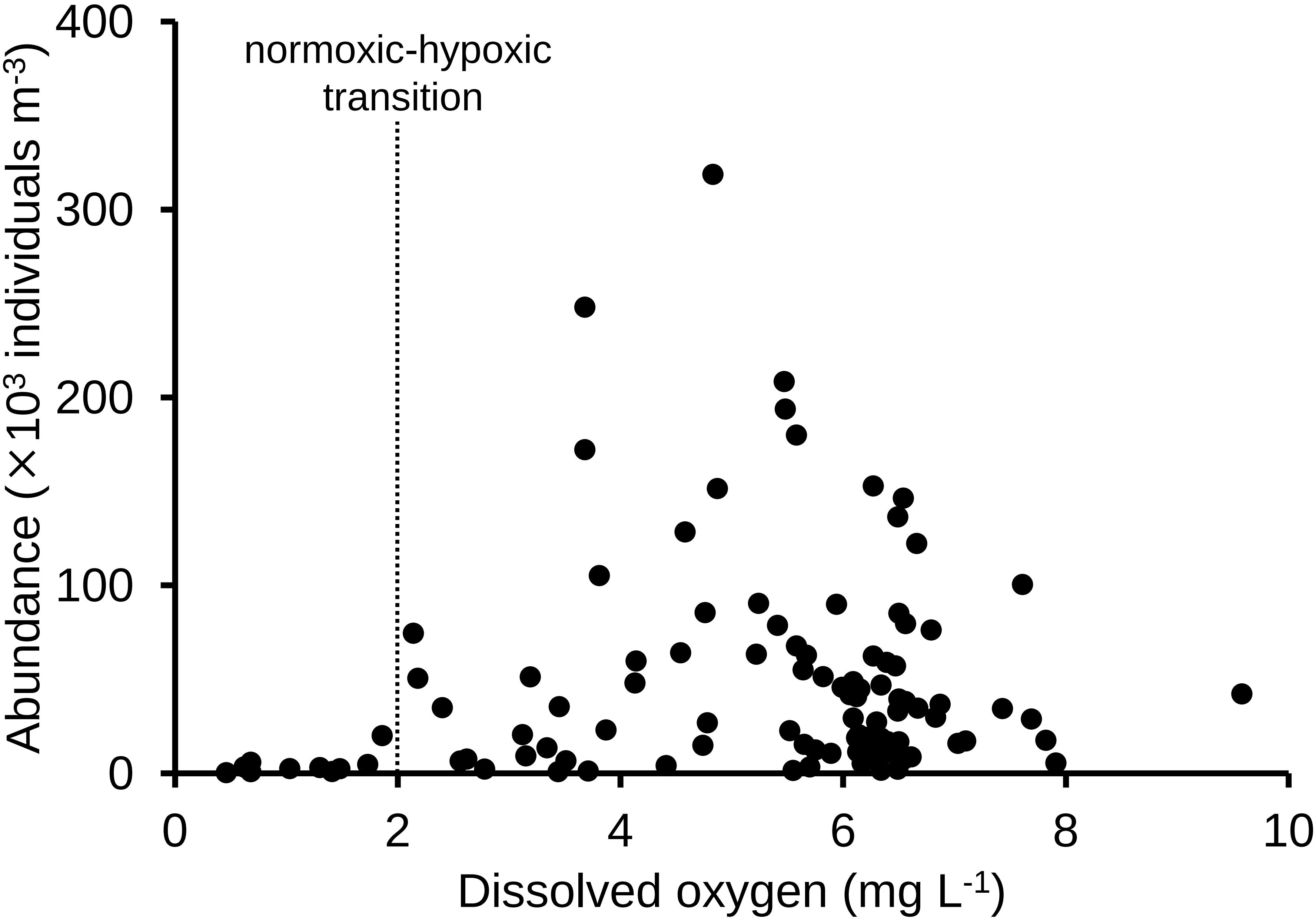
Beneficial

- Refuge from less tolerant predators
- Habitat reduction could enhance prey encounter rates
- Selection for some species

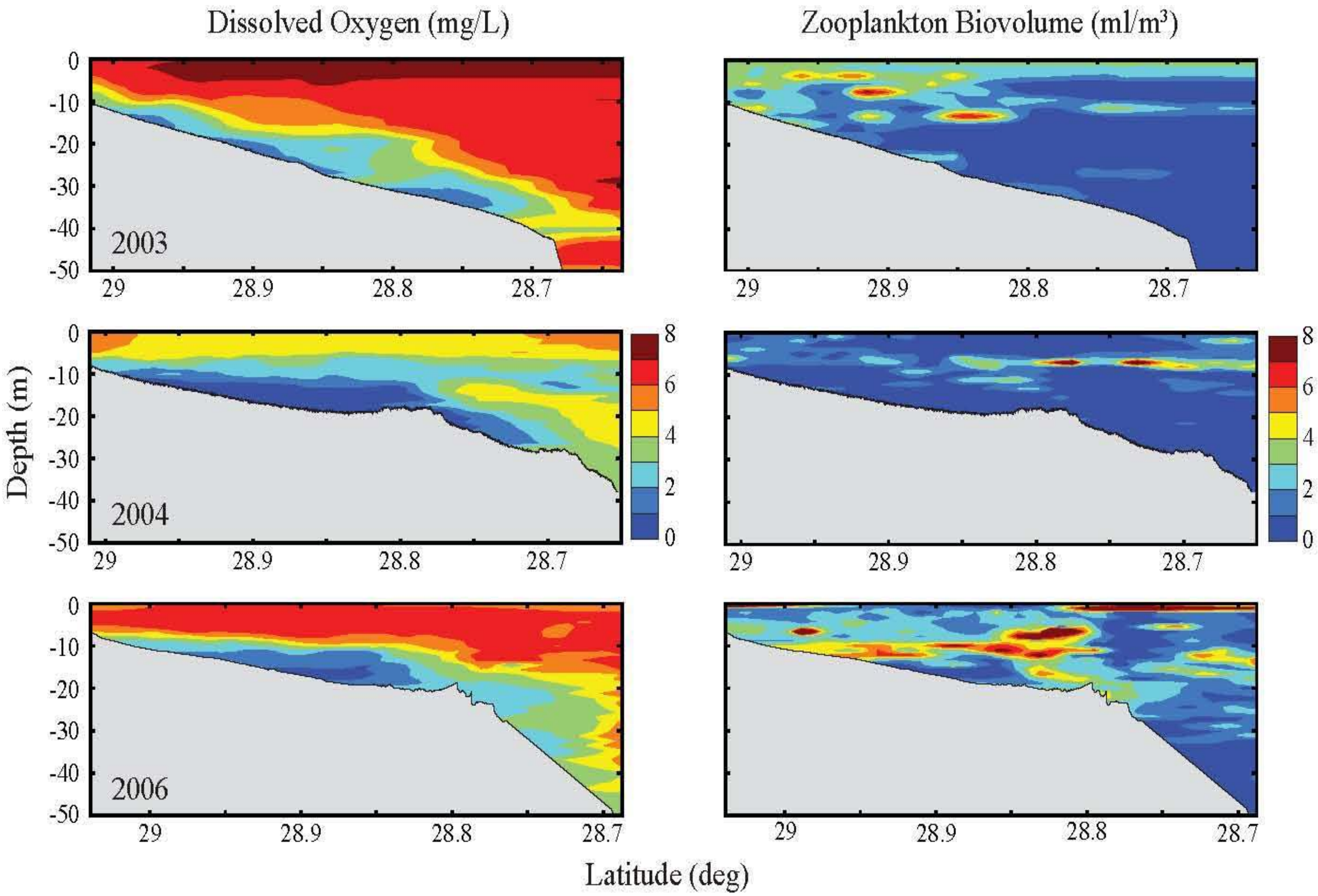

2003
2004
Bottom O2
30°N
40'
20'
29°N
40'
20'
28°N
94°W
93°W
92°W
91°W
90°W
89°W
0
2
4
6
8
Bottom oxygen (mg ml-1)
Bottom Zooplankton Biomass
0
1.25
2.5
3.75
5
Bottom biovolume (ml m-3)


C
H
I
2003
2004
O$_2$ (mg ml^{-1})
Relative Zooplankton Biovolume (mm^3 m^{-3})
Temperature (°C)
Salinity

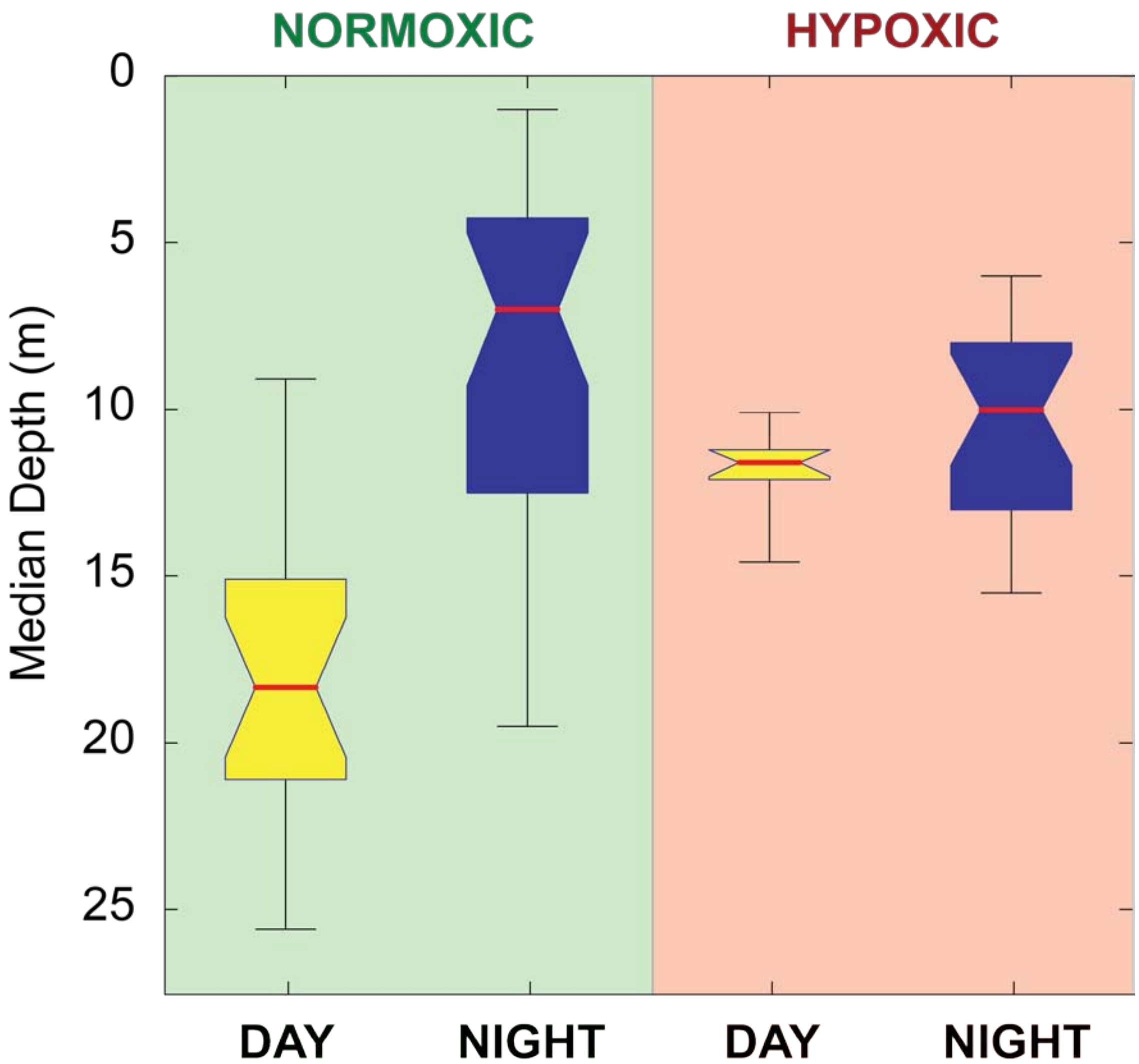

2003
2004
Biovolume (ml l-1)
0
1
2
3
4
5
6
7
Hypoxic
Normoxic
Hypoxic
Normoxic



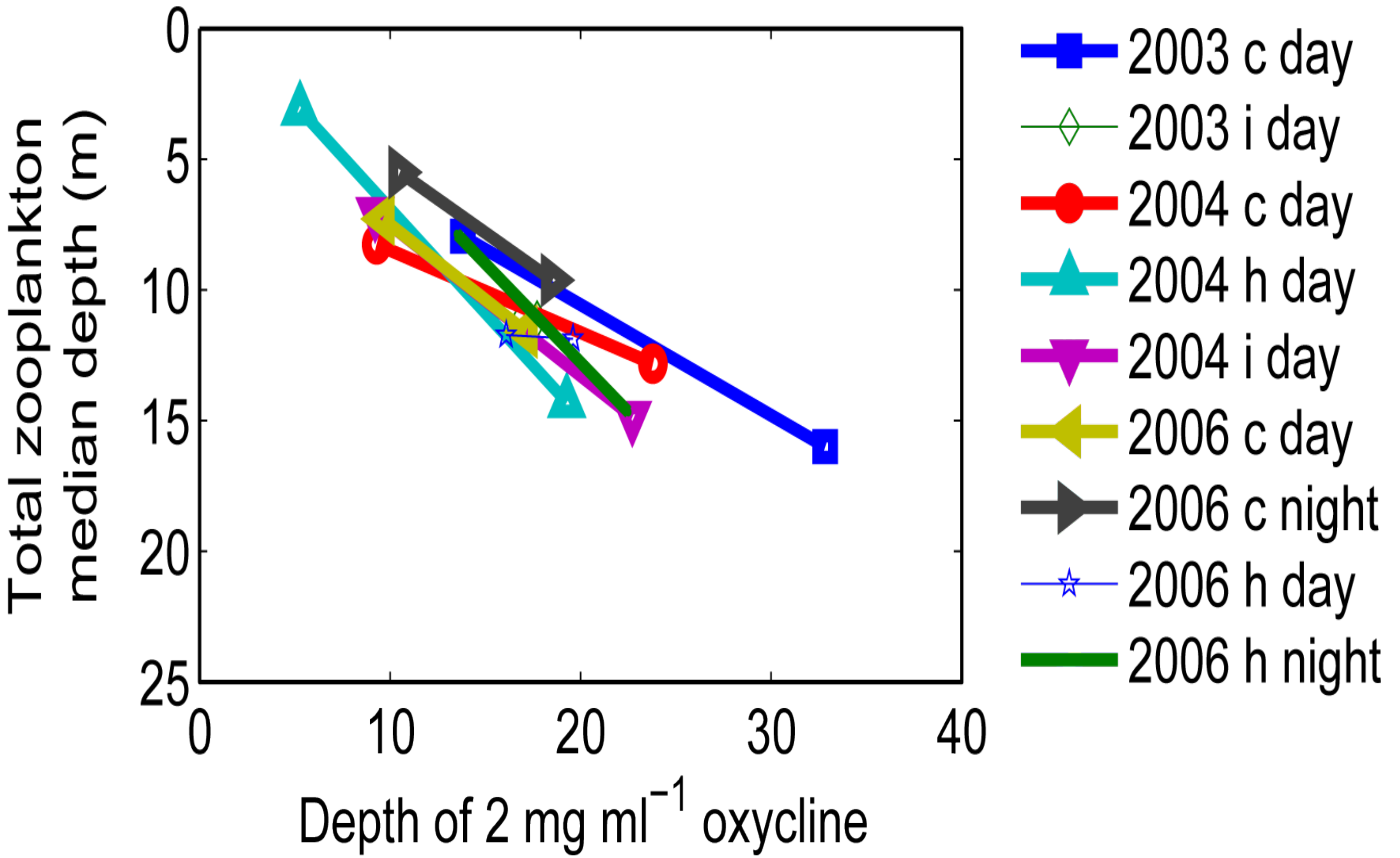
400
300
200
100
0
Abundance (×10³ individuals m⁻³)
normoxic-hypoxic
transition
0
2
4
6
8
10
Dissolved oxygen (mg L⁻¹)
NGOMEX

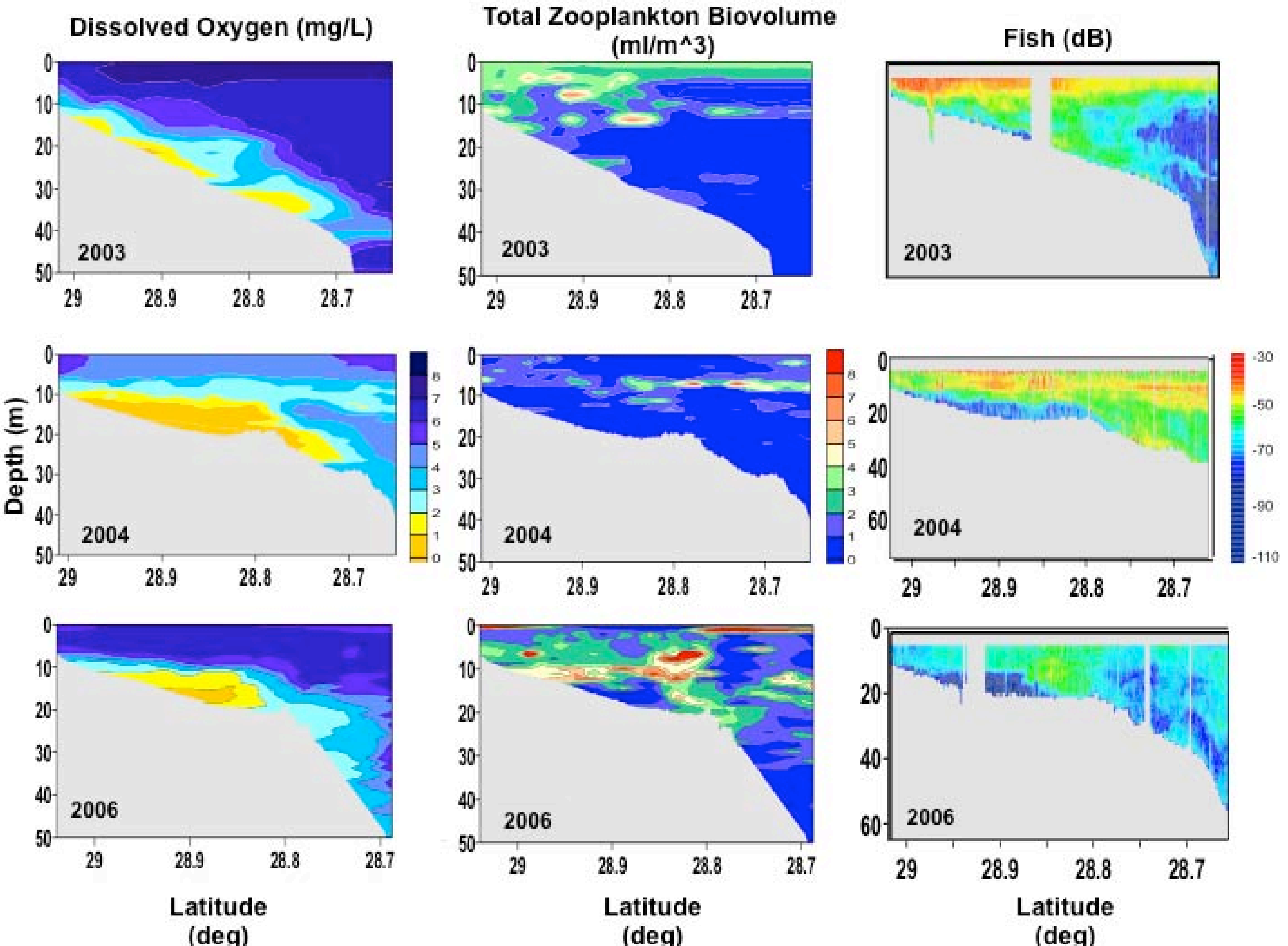


Dissolved Oxygen (mg/L)
Zooplankton Biovolume (ml/m³)
Depth (m)
2003
2004
2006
0
-10
-20
-30
-40
-50
29
28.9
28.8
28.7
8
6
4
2
0
Latitude (deg)


NORMOXIC
HYPOXIC
Median Depth (m)
0
5
10
15
20
25
DAY
NIGHT
DAY
NIGHT

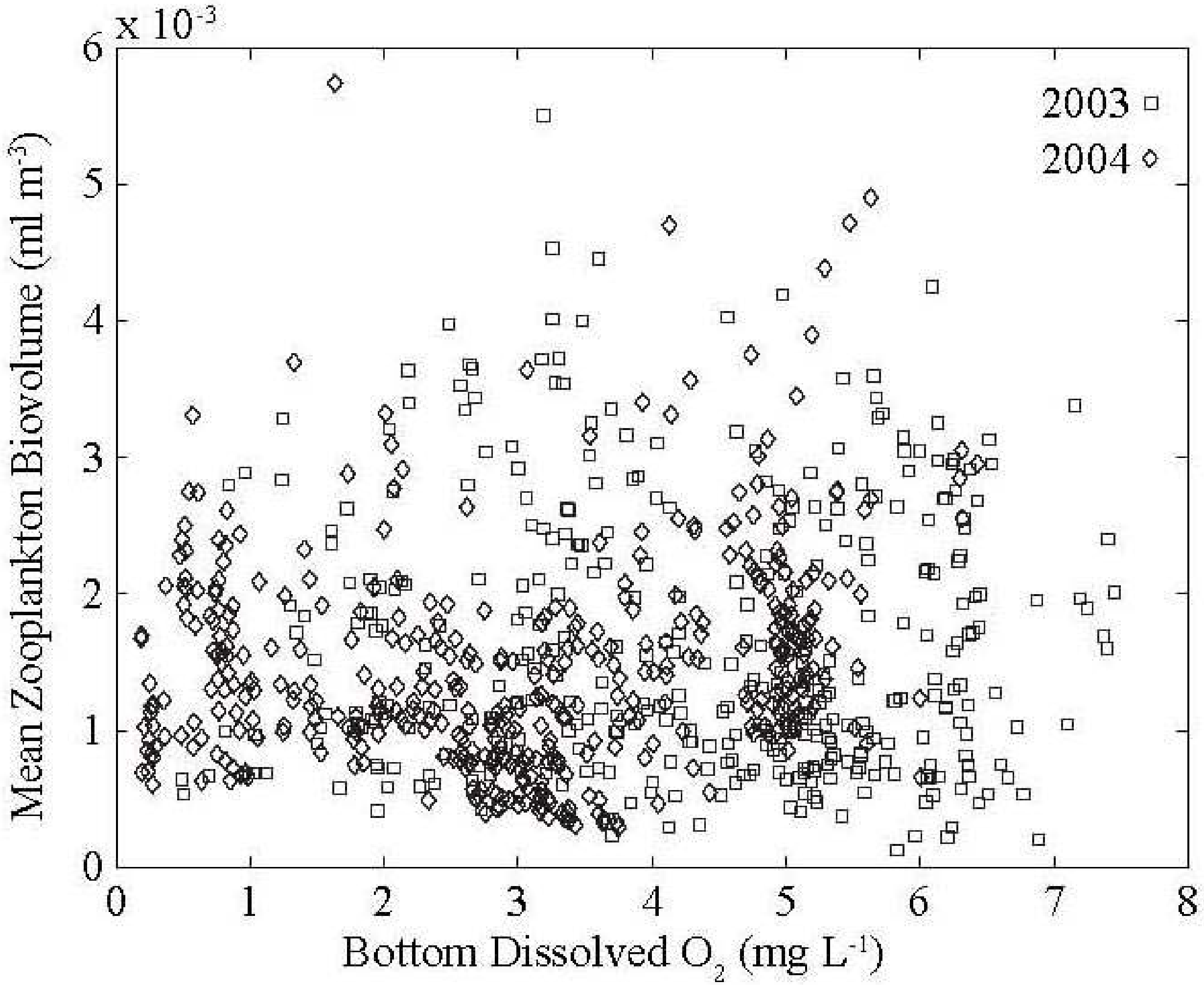
NGOMEX: Relationship between zooplankton median depth and depth of the 2 mg ml^{-1} oxycline.



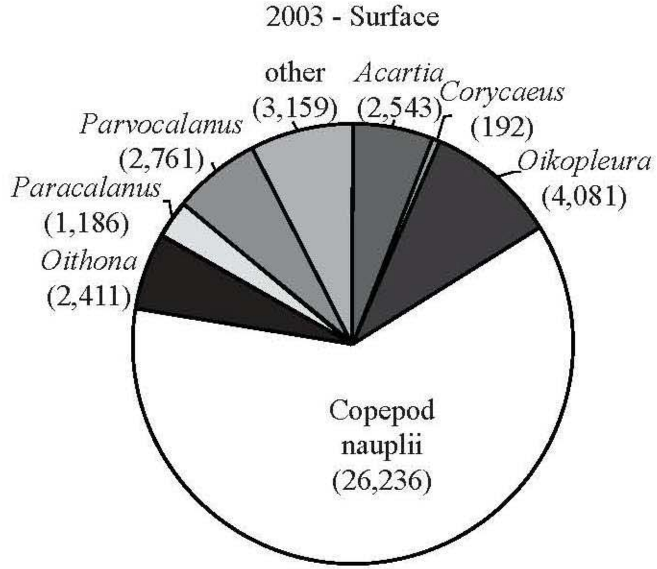

Dissolved Oxygen (mg/L)
Total Zooplankton Biovolume (ml/m^3)
Fish (dB)
Depth (m)
2003
2004
2006
Latitude (deg)
0
10
20
30
40
50
60
29
28.9
28.8
28.7
8
7
6
5
4
3
2
1
0
-30
-50
-70
-90
-110

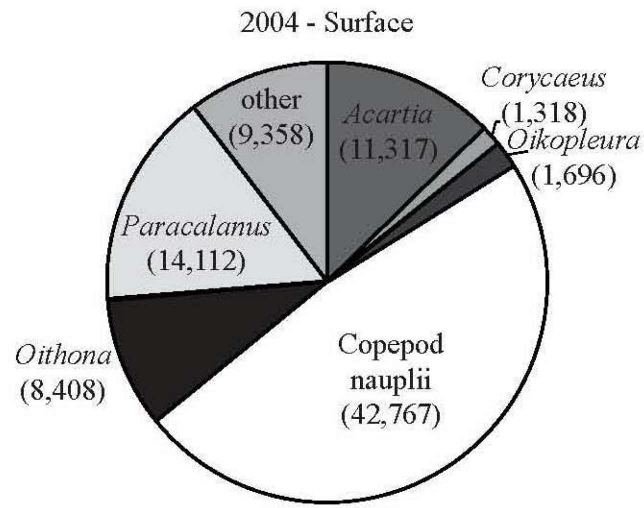
NGOMEX SURVEY COMPARISONS

	2003	2004
Area Mapped (km2)	28,697	28,746
Hypoxic Area (km2)	1,807	10,172
Mean Zooplankton (mg C m-3)		
250-500µm ESD	0.77	0.98
500-1000µm ESD	1.34	1.39
1000-1500µm ESD	1.01	0.77
1500-2000µm ESD	0.71	0.54
2000-2500µm ESD	1.00	0.71
TOTAL	4.84	4.39

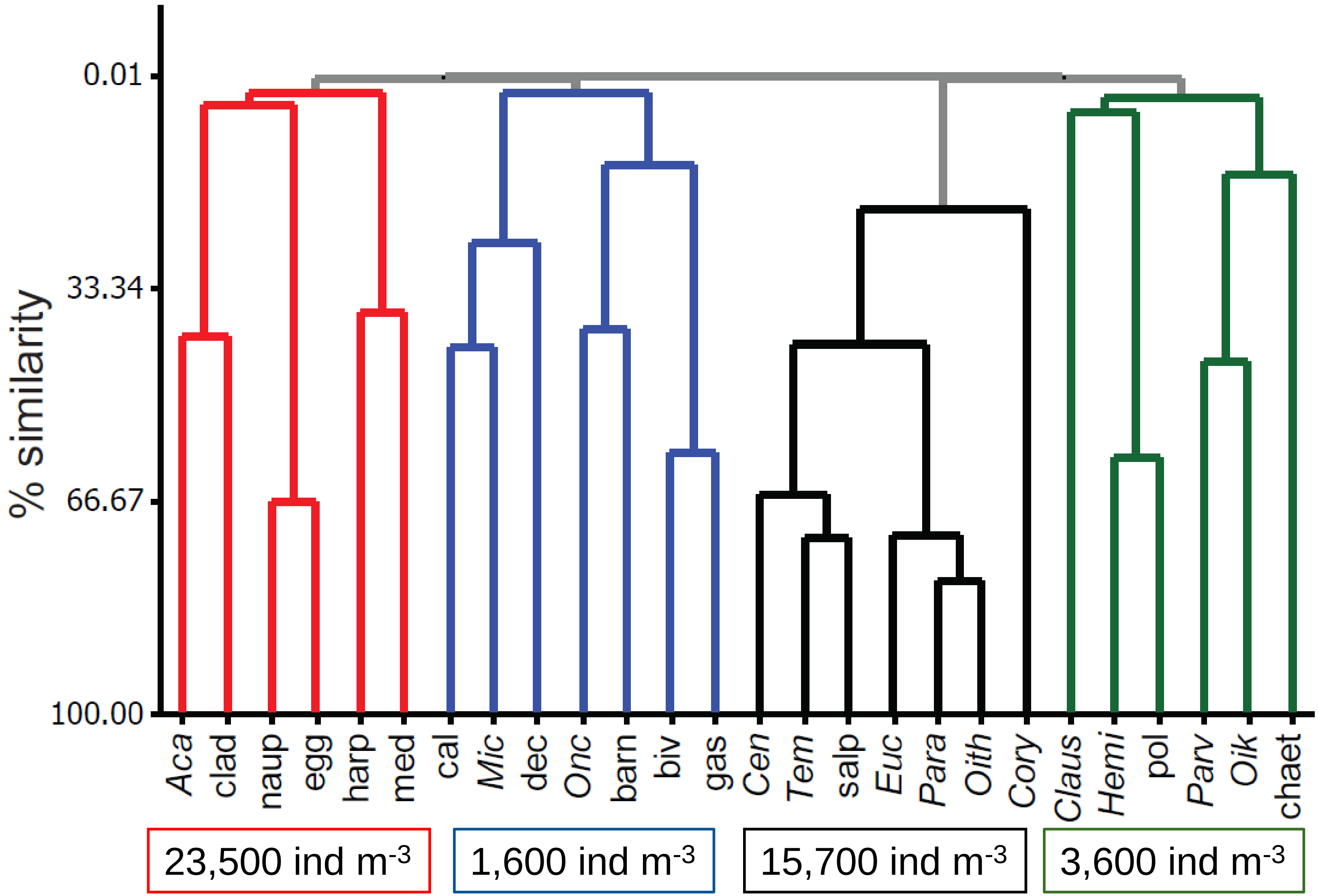


x 10^-3
6
5
4
3
2
1
0
Mean Zooplankton Biovolume (ml m^-3)
2003
2004
0
1
2
3
4
5
6
7
8
Bottom Dissolved O2 (mg L^-1)

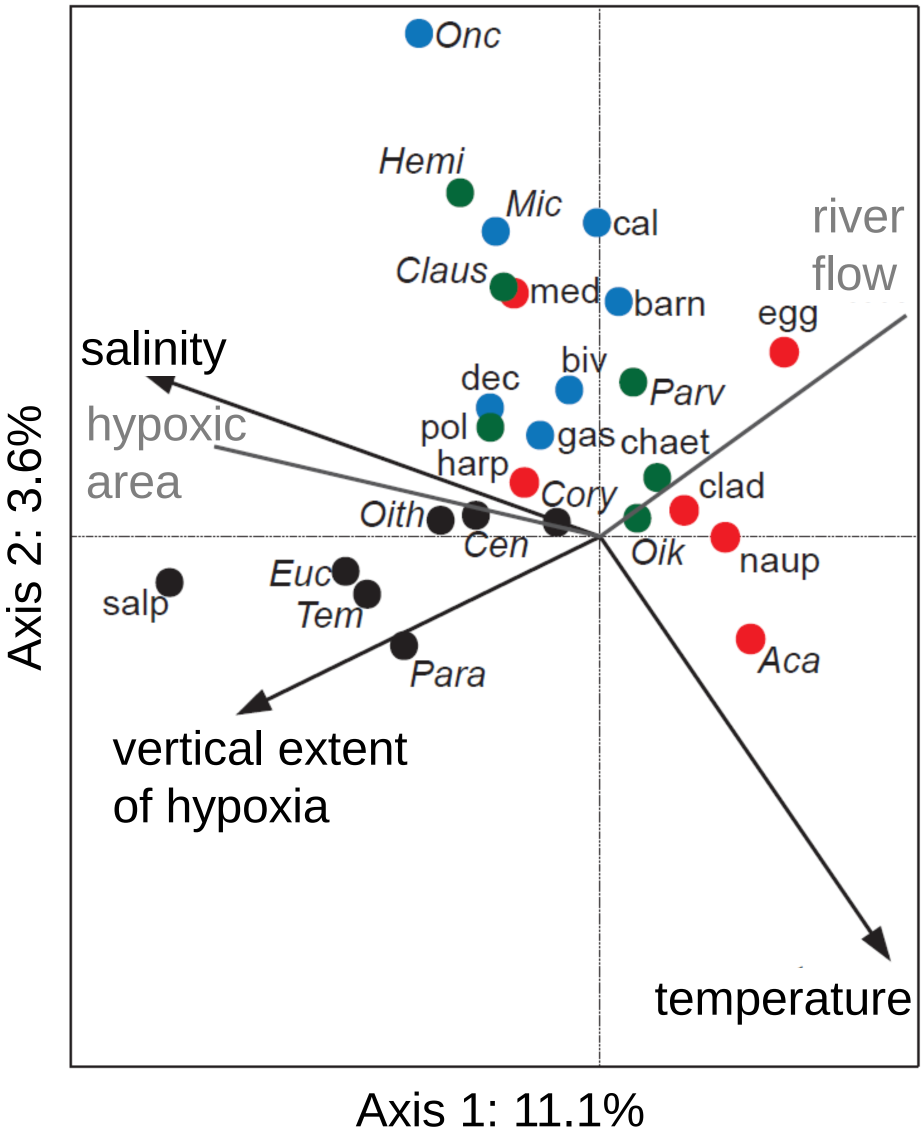

2003 - Surface
other
(3,159)
Acartia
(2,543)
Corycaeus
(192)
Oikopleura
(4,081)
Parvocalanus
(2,761)
Paracalanus
(1,186)
Oithona
(2,411)
Copepod
nauplii
(26,236)


2004 - Surface
other
(9,358)
Acartia
(11,317)
Corycaeus
(1,318)
Oikopleura
(1,696)
Paracalanus
(14,112)
Oithona
(8,408)
Copepod
nauplii
(42,767)

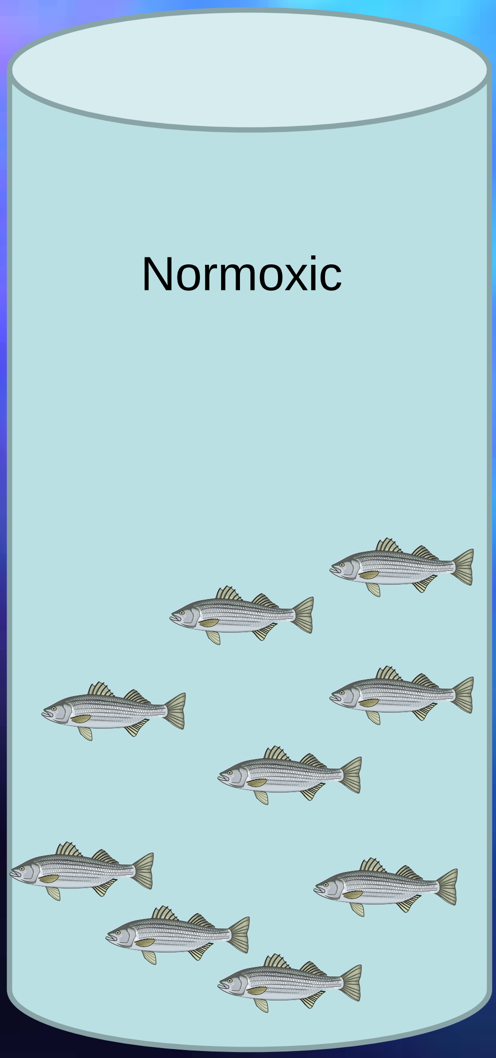
Taxonomic composition



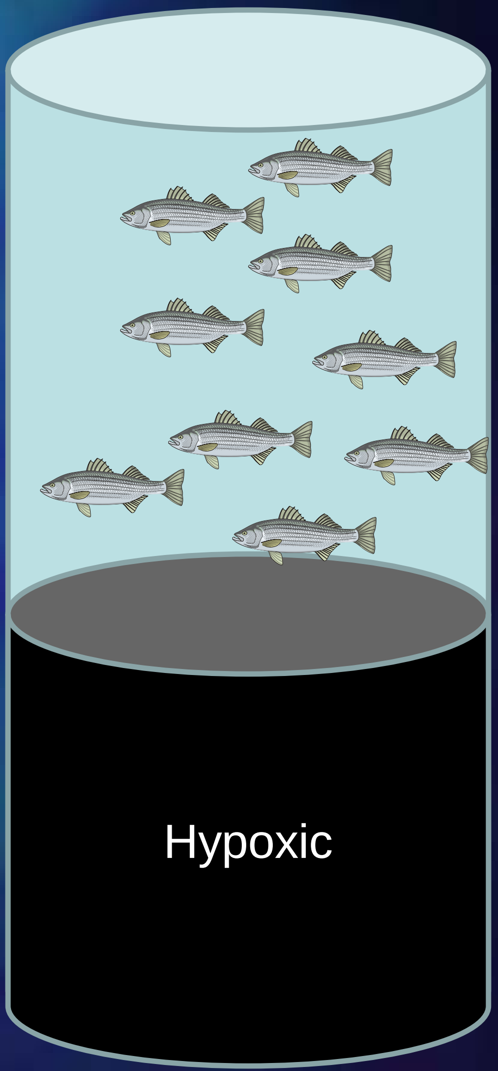
Zooplankton-environment relationship



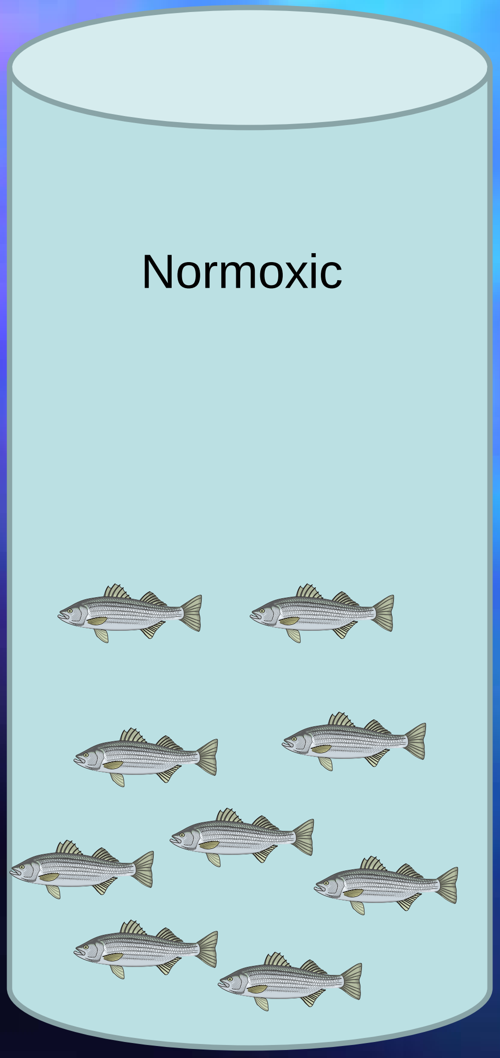
Hypoxia and Pelagic Fish



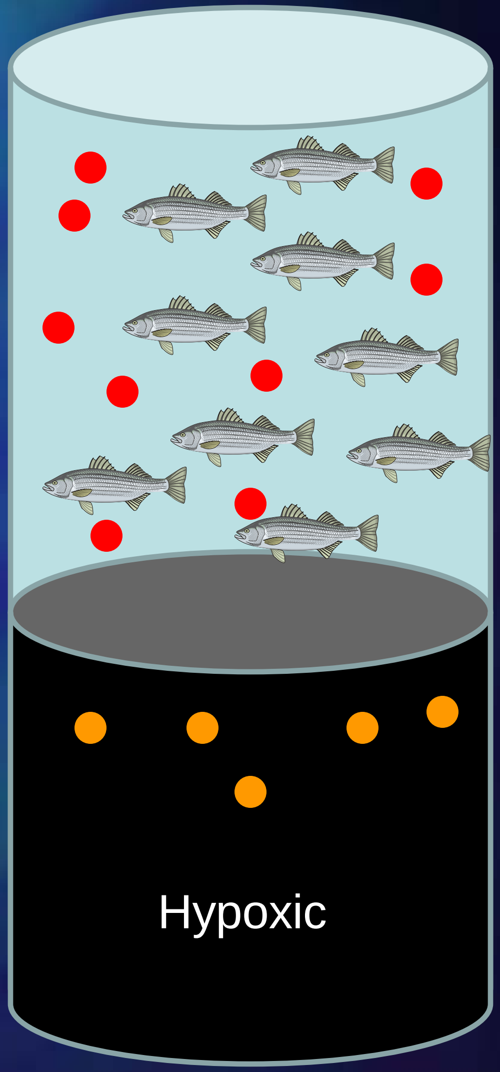
- Alter spatial distribution
- Restrict vertical migrations
- Move to areas of poorer habitat quality (e.g. less food, change in temperature)
- Increased predator concentration
- Increased vulnerability to predation (e.g. increased light?)



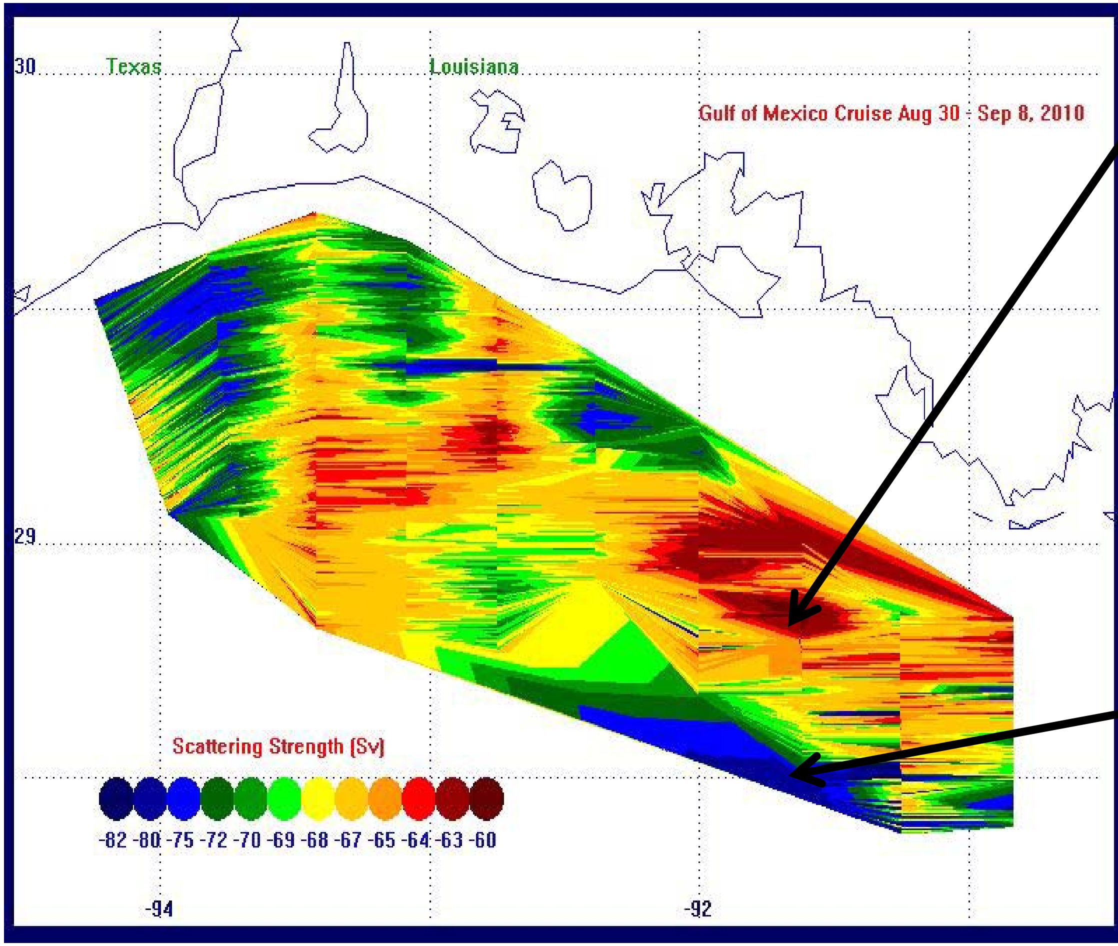
Hypoxia and Pelagic Fish

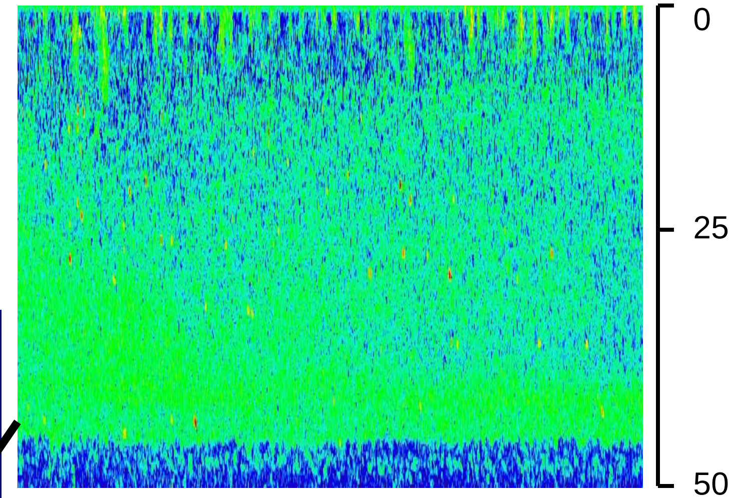


- Increase prey concentration?
- Increase prey vulnerability (e.g. light)
- Better overall habitat conditions (e.g. growth)
- Can hypoxia be used as a refuge?
- Are there edge effects?

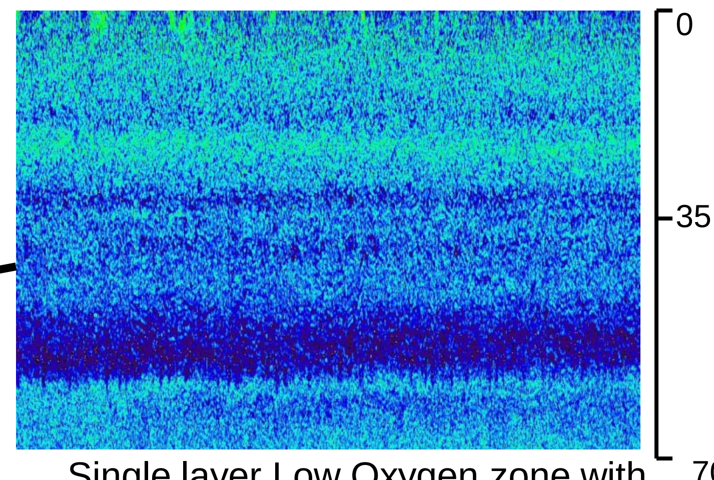


Transect F



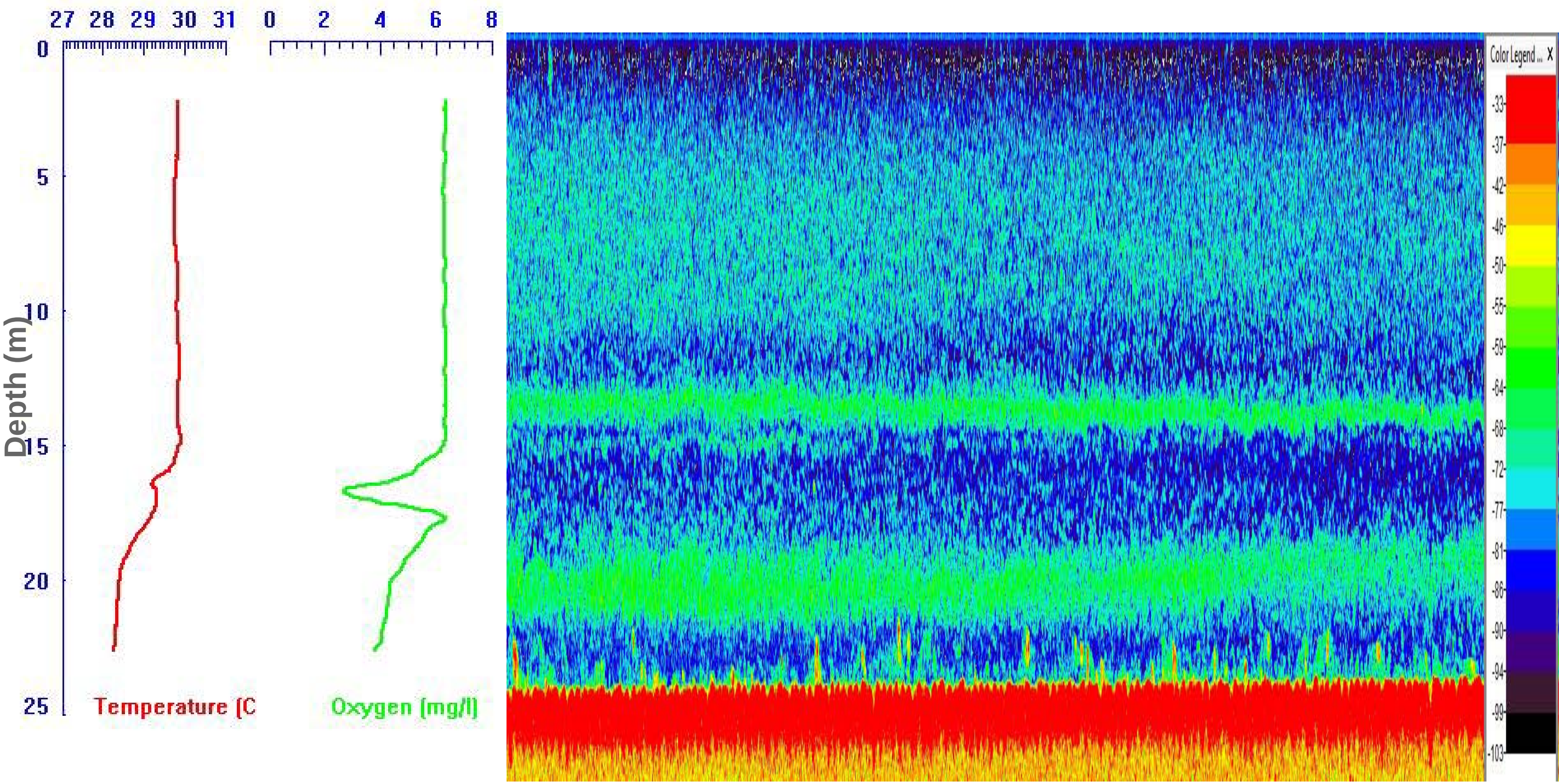


Targets throughout the layer with the exception of the very bottom (Sv = -62)

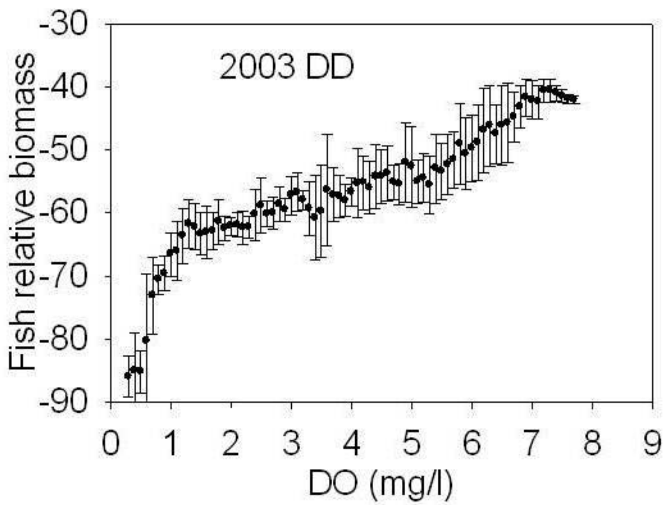


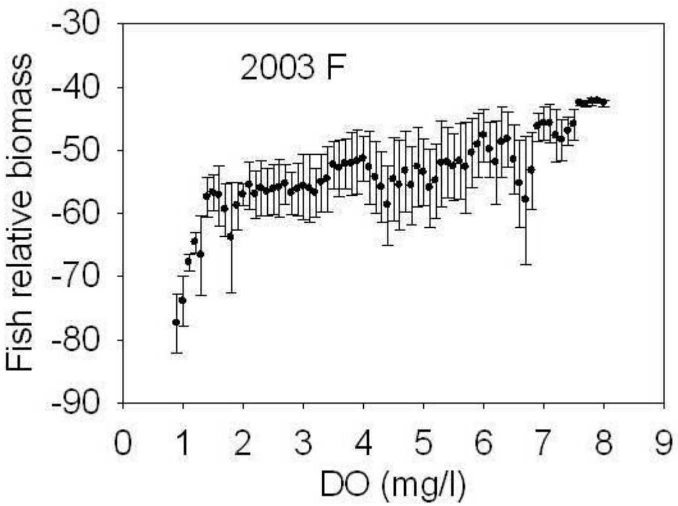
Single layer Low Oxygen zone with little target activity (Sv = -74)

Gulf of Mexico—H Transect
Double Hypoxia Layer

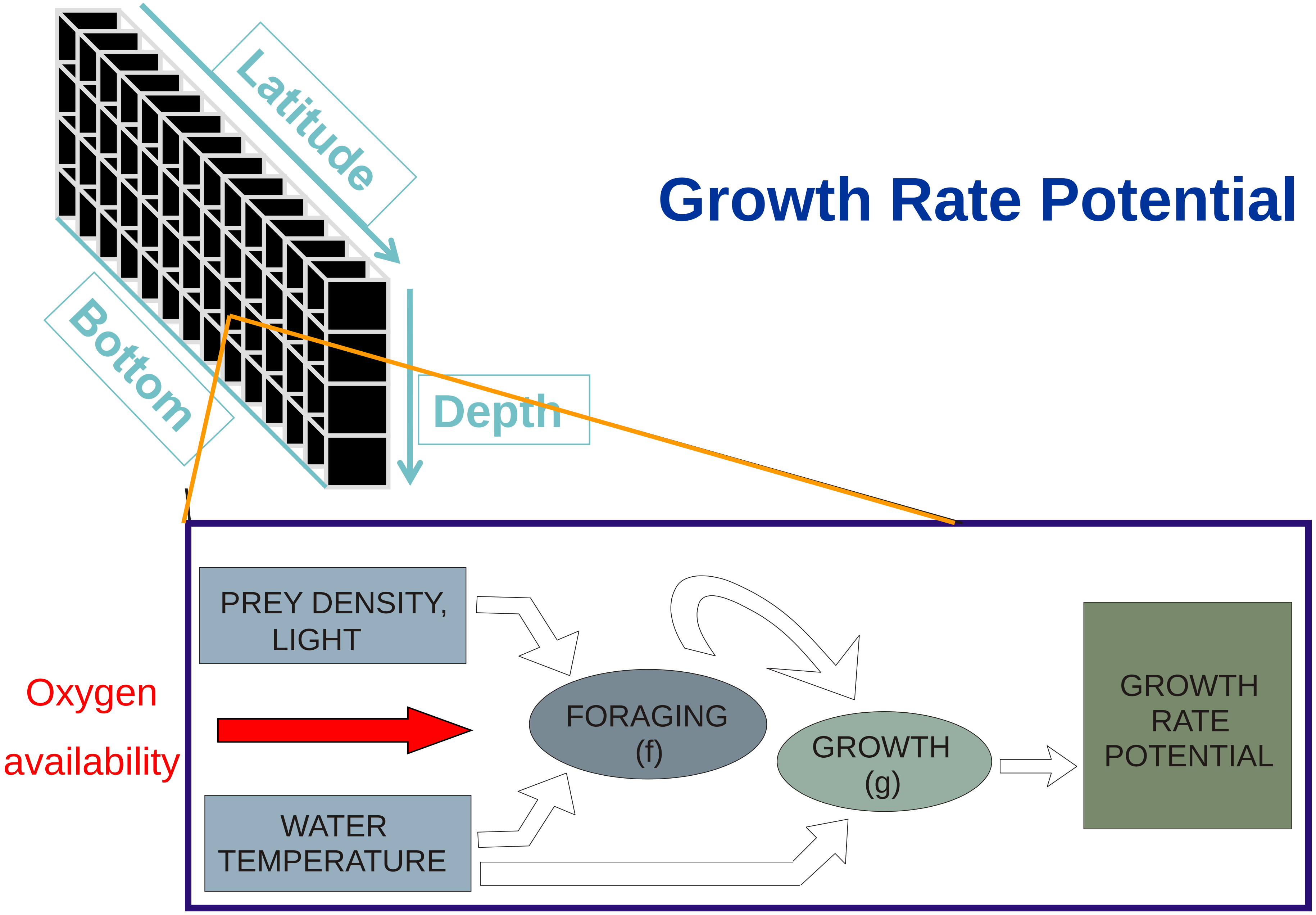


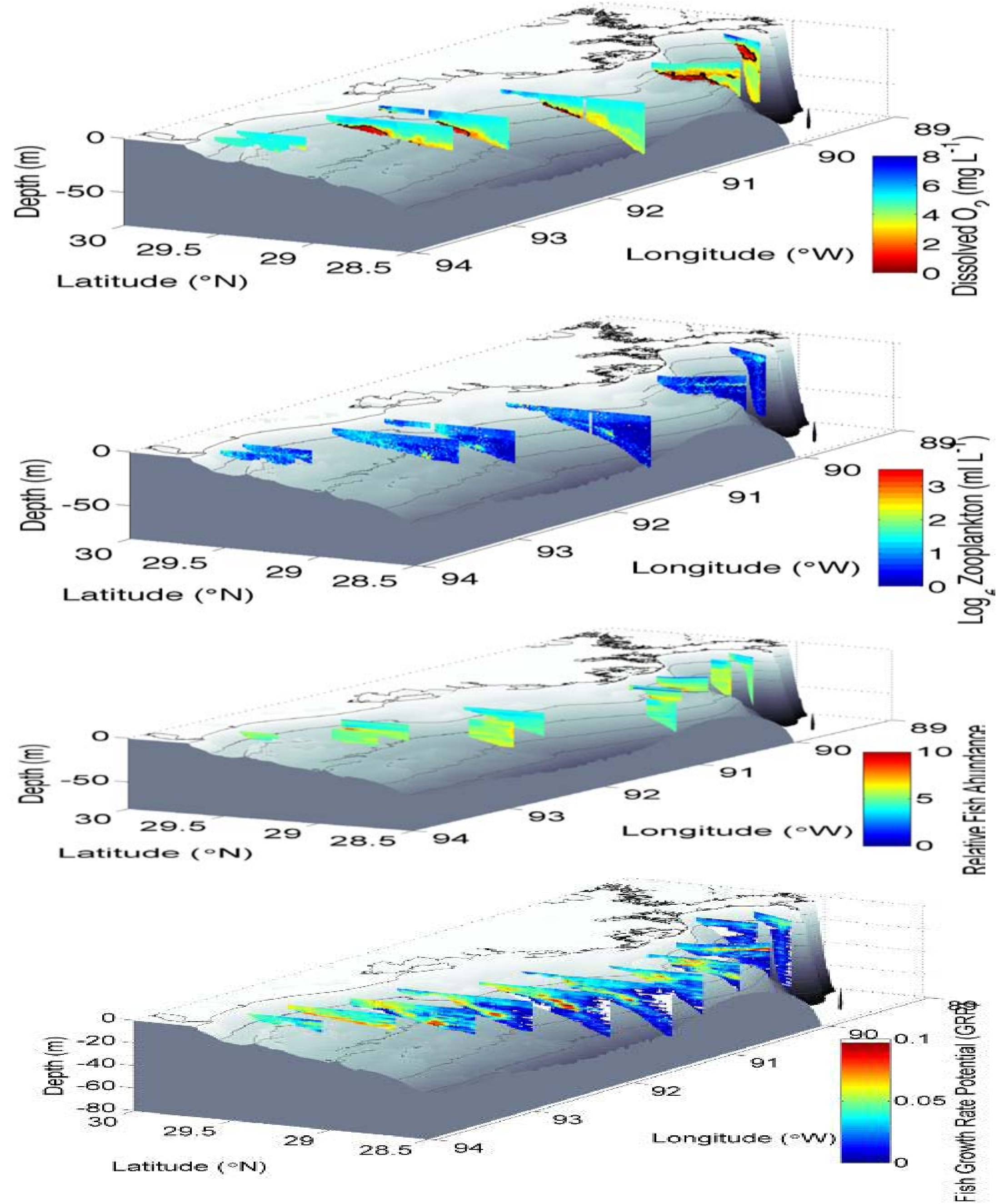
Fish Density and Oxygen levels





Growth Rate Potential





Depth (m)
0
-50
30
29.5
29
28.5
Latitude (°N)
94
93
92
91
90
89
Longitude (°W)
Dissolved O$_2$ (mg L^{-1})
0
2
4
6
8
Depth (m)
0
-50
30
29.5
29
28.5
Latitude (°N)
94
93
92
91
90
89
Longitude (°W)
Log$_4$ Zooplankton (ml L^{-1})
0
1
2
3
Depth (m)
0
-50
30
29.5
29
28.5
Latitude (°N)
94
93
92
91
90
89
Longitude (°W)
Relative Fish Abundance
0
5
10
Depth (m)
0
-20
-40
-60
-80
30
29.5
29
28.5
Latitude (°N)
94
93
92
91
90
Longitude (°W)
Fish Growth Rate Potential
0
0.05
0.1

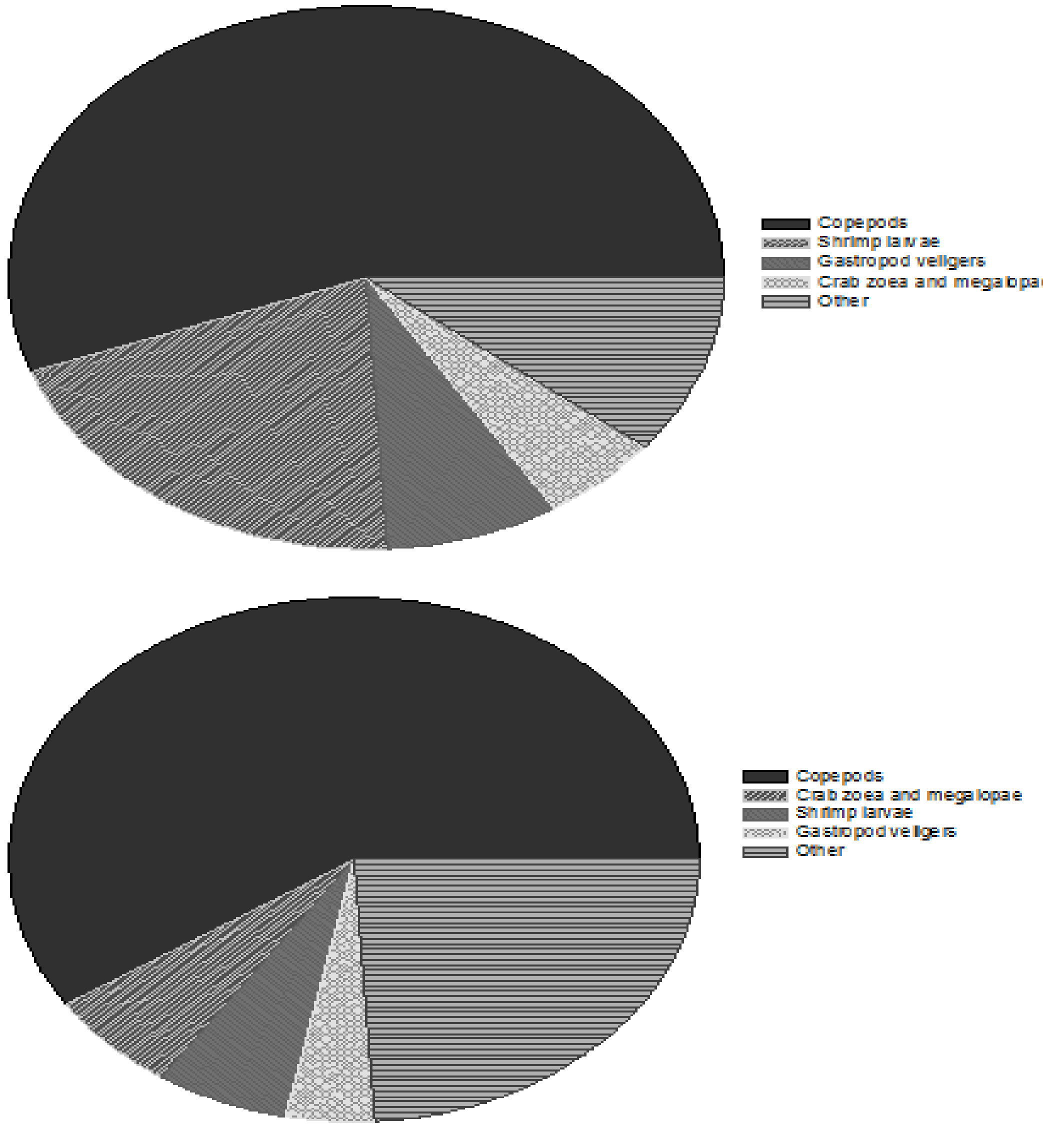
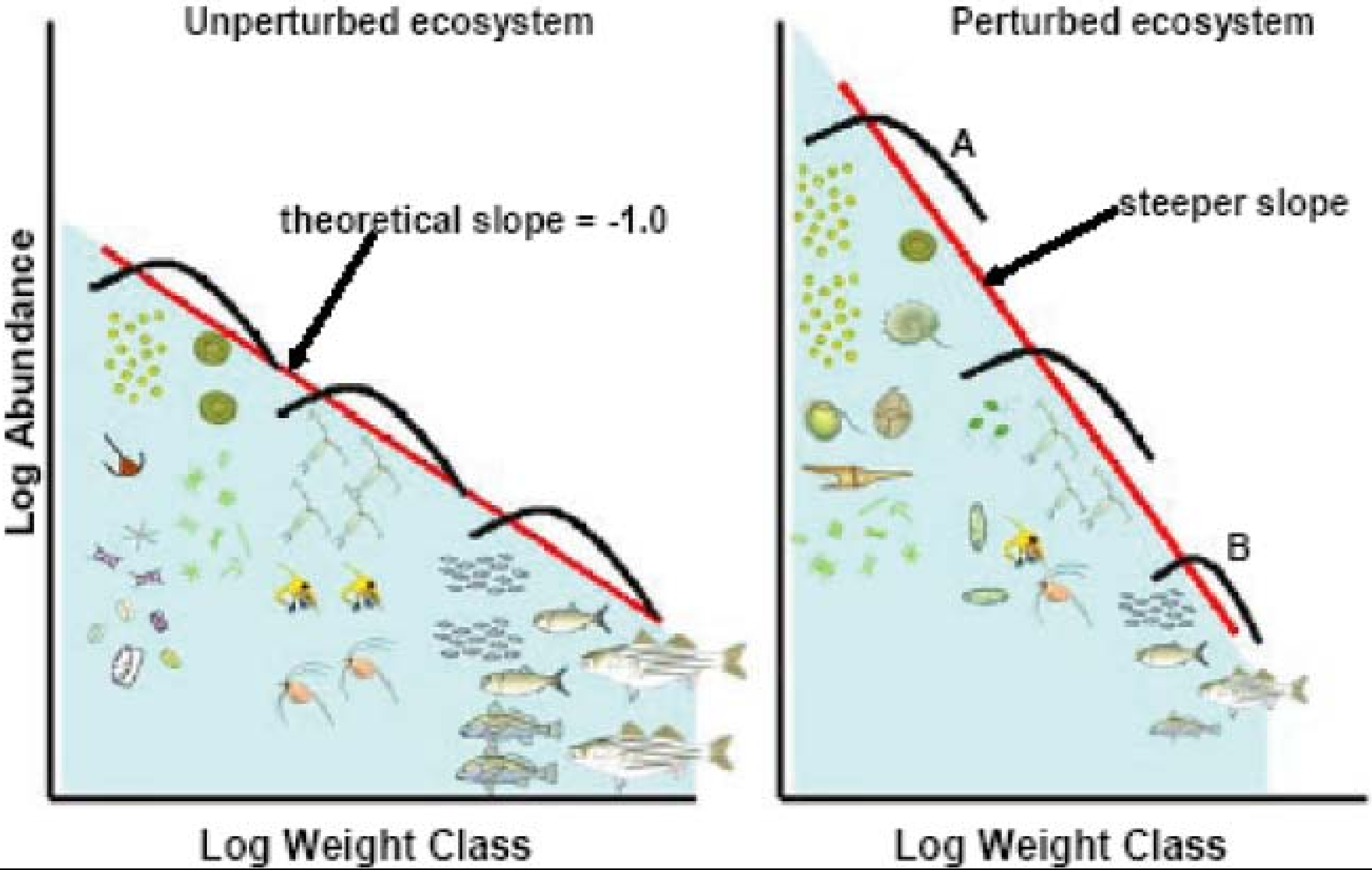
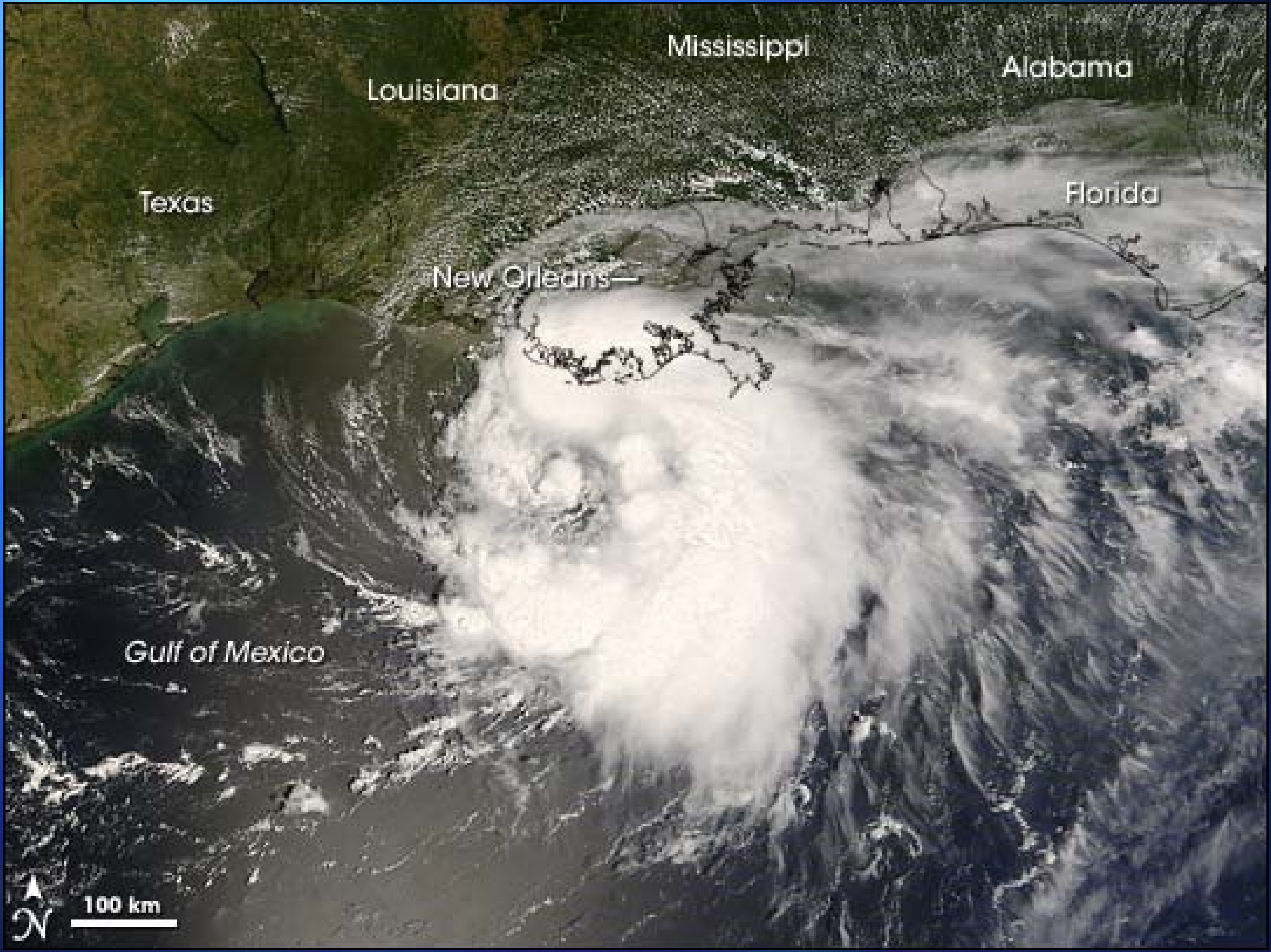


Figure 6 – Stomach contents from Atlantic bumper (top, n = 497) and striped anchovy (bottom, n=411).

Biomass Size Spectra as Indicators of Ecosystem Status



Tropical Storm Edouard



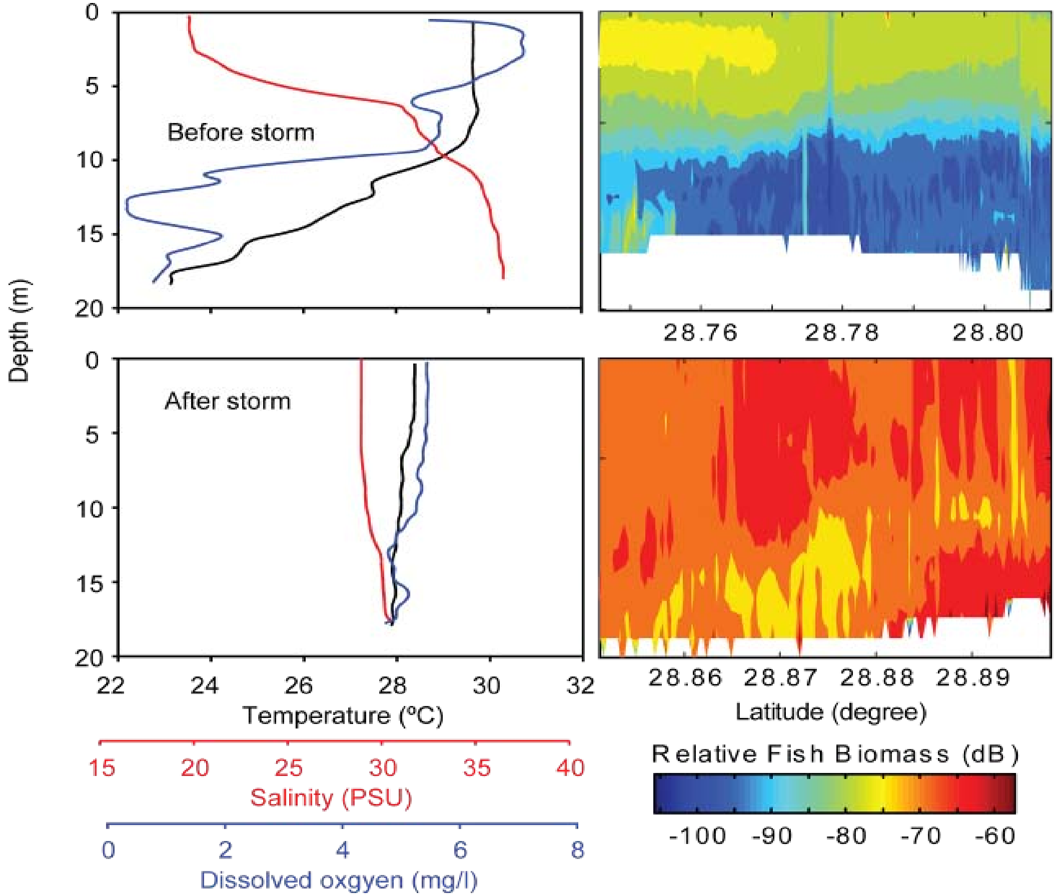
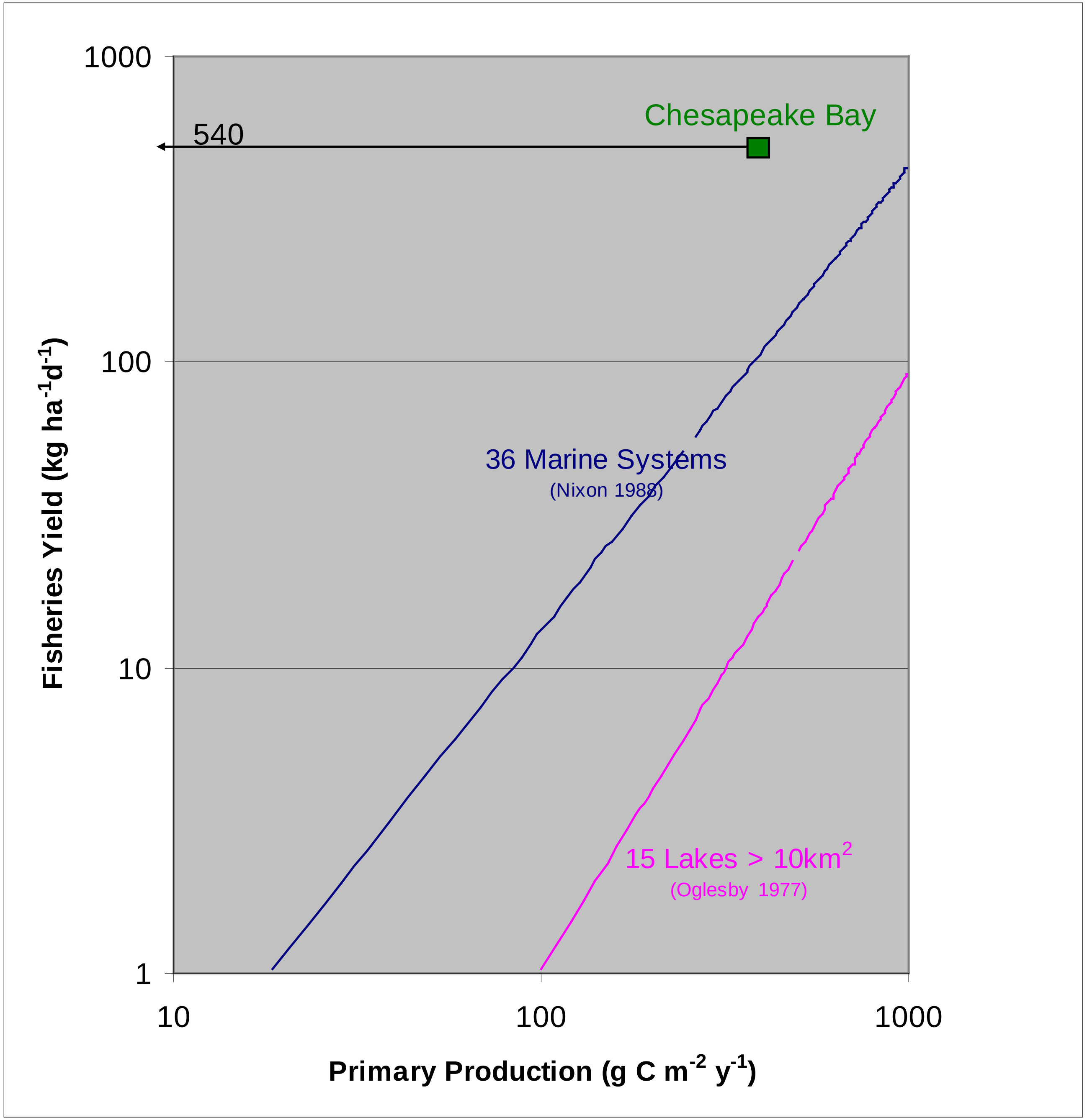


Figure 9 – CTD profiles (left panels) and relative fish biomass (right panels) before (top panels) and after (bottom panels) a hurricane in August 2008.


1000
100
10
1
540
Chesapeake Bay
36 Marine Systems
(Nixon 1988)
15 Lakes > 10km2
(Oglesby 1977)
Fisheries Yield (kg ha-1d-1)
10
100
1000
Primary Production (g C m-2 y-1)

WE WILL USE MULTIPLE MODELS TO EVALUATE:

What is the effect of the spatial extent and seasonal timing of hypoxia on fish growth, recruitment and production potential?

How does hypoxia affect food web interactions in the pelagic zone? Specifically:

How will hypoxia affect the spatial distribution and predator-prey interactions of mobile organisms and zooplankton?

How does hypoxia affect habitat quality and suitability for economically and ecologically important fishes?

How will management decisions on nutrient loadings affect fisheries through its impact on the timing and extent of hypoxia?

What is the potential of strong wind events (and their relationship to climate change) to re-aerate the water column and alter the interactions of fish and their prey?

What are the most effective tools to forecast food-web interactions, habitat suitability, and fish production in relation to hypoxia?

NGOMEX PUBLICATIONS TO DATE:

Brandt, S.B., M. Gerkin, K. Hartman, and E. Demers. 2009. Effects of hypoxia on food consumption and growth of juvenile striped bass (*Morone saxatilis*). Journal of Experimental Marine Biology and Ecology. 381:S143-S149

Kidwell, D.M., A.J. Lewitus, E.B. Jewett, S. B. Brandt and D.M. Mason. 2009. Ecological impacts of hypoxia on living resources. Journal of Experimental Marine Biology and Ecology. 381:S1-S3.

Kimmel, D.G., W.C. Boicourt, J.J. Pierson, M.R. Roman, and X. Zhang. 2009. A comparison of the mesozooplankton response to hypoxia in Chesapeake Bay and the northern Gulf of Mexico using the biomass size spectrum. Journal of Experimental Marine Biology and Ecology. 381: S65-S73.

Kimmel, D.G., Boicourt, W.C., Pierson, J.J., Roman, M.R., Zhang, X. 2010. The vertical distribution and diel variability of mesozooplankton biomass, abundance and size in response to hypoxia in the northern Gulf of Mexico USA. Journal of Plankton Research. *Advance Access published on January 9, 2010 doi:10.1093/plankt/fbp136*

Lewitus, A.J., D.M. Kidwell, E.B. Jewett, S. B. Brandt and D.M. Mason (Editors). 2009. Ecological Impacts of Hypoxia on Living Resources. Special Supplement of the Journal of Experimental Marine Biology and Ecology. 381: 215 pages.

Ludsin, S.A., X. Zhang, S.B. Brandt, M.R. Roman, W.C. Boicourt, D.M. Mason, and M. Costantini. 2009. Hypoxia-avoidance by planktivorous fish in Chesapeake Bay: Implications for food web interactions and fish recruitment. Journal of Experimental Marine Biology and Ecology. 381:S121-S131.

Nor, R., M. Nesternko, and P.J. Lavrentyev. 2010. Oxybuoy: Constructing a Real-Time Inexpensive Hypoxia Monitoring Platform. *In*: Ad Hoc Networks, First International Conference, Niagara Falls, Canada, September 22-25, 2009, Revised Selected Papers. Springer Berlin Heidelberg, Germany. 28:795-804. doi: 10.1007/978-3-642-11723-7_54

Pierson, J.J., M.R. Roman, D.G. Kimmel, W.C. Boicourt, and X. Zhang. 2009. Quantifying changes in the vertical distribution of mesozooplankton in response to hypoxic bottom waters. Journal of Experimental Marine Biology and Ecology. 381:S74-79.

Walker, J. T., C. A. Stow, and C. Geron. 2010. Nitrous Oxide Emissions from the Gulf of Mexico Hypoxic Zone. Environ. Sci. Technol. 44: 1617–1623.

Zhang, H., S. Ludsin, M. Roman, W. Boicourt, X. Zhang, D. Kimmel, A. Adamack, D. Mason and S. B. Brandt. 2009. Hypoxia-driven changes in the behavior and spatial distribution of pelagic fish and zooplankton in the northern Gulf of Mexico. Journal of Experimental Marine Biology and Ecology. 381:S80-S91.

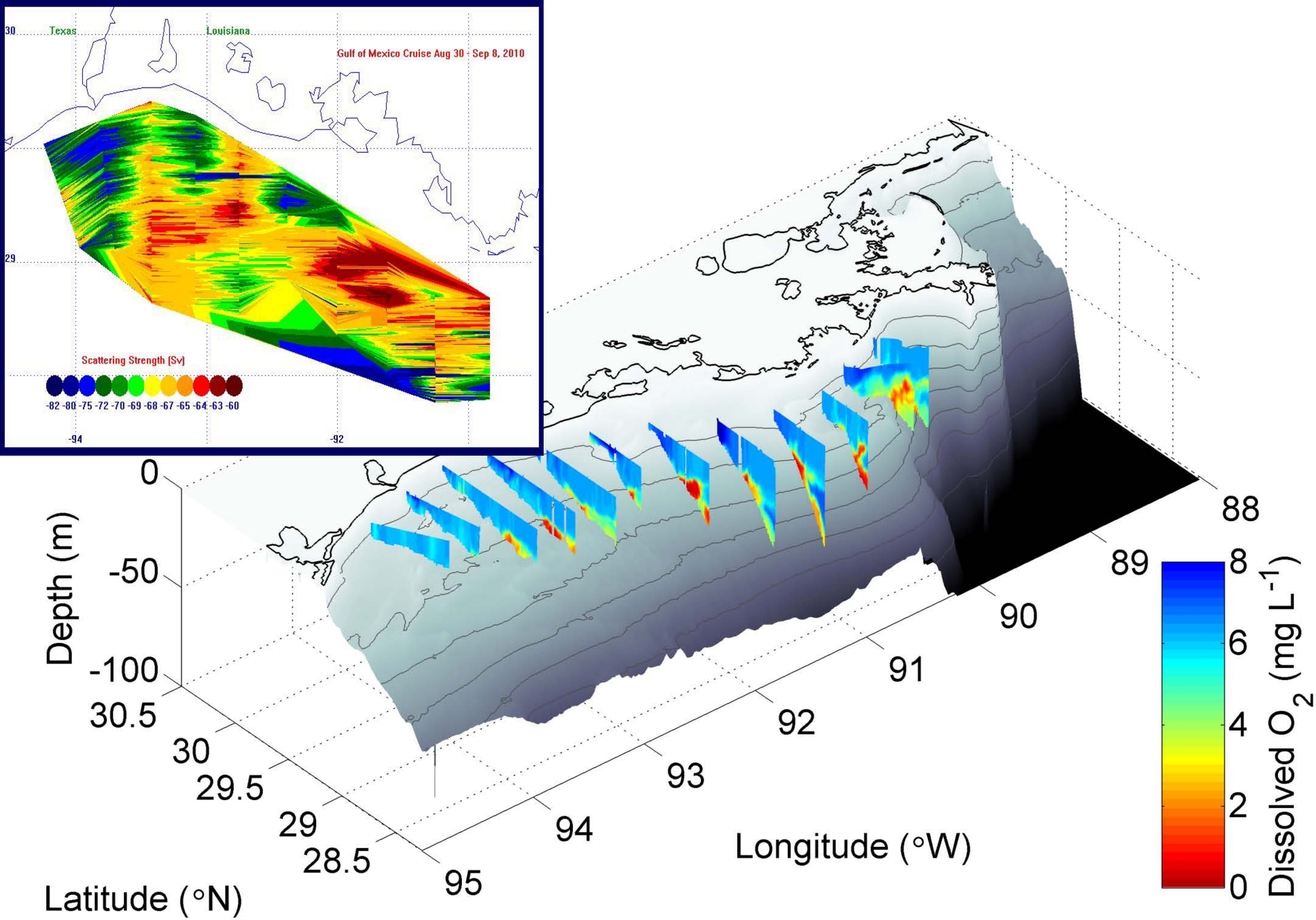
HANGING CHADS

Clouse, M., A. Adamack, S. Ludsin, H. Zhang, D. Mason, and S. Brandt. Summer feeding habits of Atlantic bumper in the northern Gulf of Mexico. drafted.

Clouse, M., A. Adamack, S. Ludsin, D. Mason, S. Brandt, and H. Zhang. Feeding habits and trophic relationships of fish species in the northern Gulf of Mexico during summer hypoxic events. drafted.

Roman, M.R, J.J. Pierson, D.G. Kimmel, W.C. Boicourt and X. Zhang. 2011. Spatial patterns in hypoxia and zooplankton in the northern Gulf of Mexico. Estuaries and Coasts, In Review

Zhang, H., D. M. Mason, S. A. Ludsin, S. B. Brandt, C. A. Stow, A. T. Adamack, M. R. Roman and W. C. Boicourt. Hypoxia, habitat quality and the spatial distribution of pelagic fishes in the northern Gulf of Mexico. drafted.



Texas
Louisiana
Gulf of Mexico Cruise Aug 30 - Sep 8, 2010
Scattering Strength (Sv)
-82 -80 -75 -72 -70 -69 -68 -67 -65 -64 -63 -60
30
29
-94
-92
Depth (m)
0
-50
-100
Latitude (°N)
30.5
30
29.5
29
28.5
Longitude (°W)
95
94
93
92
91
90
89
88
Dissolved O2 (mg L-1)
0
2
4
6
8