IMPACT OF HYPOXIA ON HABITAT QUALITY OF PELAGIC FISHES IN THE NORTHERN GULF OF MEXICO

Hongyan Zhang[1], Doran M. Mason[2], Craig A. Stow[2], Aaron T. Adamack[3], Stephen B. Brandt[4], Xinsheng Zhang[5], David G. Kimmel[6], Michael R. Roman[7], William C. Boicourt[7], and Stuart A. Ludsin[8]

CILER Cooperative Institute for Limnology and Ecosystems Research

1.Cooperative Institute for Limnology and Ecosystems Research, University of Michigan, Ann Arbor, MI 48108, USA.; 2. NOAA Great Lakes Environmental Research Laboratory, Ann Arbor, MI 48108, USA.; 3. Bruce, ACT from Canberra, NSW, Australia ; 4. Oregon Sea Grant, Oregon State University, Corvallis, OR 97331, USA.; 5. NOAA/NMFS/SEFSC/SFD, Panama City, FL 32408; 6.Department of Biology/Institute for Coastal Science and Policy, East Carolina University, Greenville, NC 27858, USA.; 7. Horn Point Laboratory, University of Maryland Center for Environmental Science, Cambridge, MD, 21613, USA ; 8. Aquatic Ecology Laboratory, Department of Evolution, Ecology, and Organismal Biology, The Ohio State University, Columbus, OH 43212

INTRODUCTION

The northern Gulf of Mexico experiences one the world's largest anthropogenically-driven, seasonal hypoxia zone, potentially subjecting both pelagic and benthic fishes to a suboptimal physical environment, insufficient food resources, and enhanced encounter rates with predators. The impacts on pelagic fishes are especially complicated, and differ according to fish species and the spatial and temporal scale. While hypoxia-induced fish displacement in the northern Gulf of Mexico has been documented using trawl-based and acoustics-based sampling, the importance of hypoxia in this displacement relative to other habitat factors (e.g., temperature and prey availability) has not been fully evaluated, particularly for pelagic fishes. Our overall objective was to quantify the effect of hypoxia on habitat quality for two common species of pelagic fishes using the spatially-explicit Growth Rate Potential model. We hypothesized that bottom hypoxia would reduce habitat quality for bay anchovy during the peak hypoxic period by reducing access to zooplankton prey, but would have less of an affect on menhaden habitat quality as Gulf menhaden mainly inhabit the surface layer of the water column, and phytoplankton are not affected by bottom layer hypoxia.

METHODS

GRP model We developed spatially-explicit GRP models for age-1+ bay anchovy and age-0 Gulf menhaden. The model is a combined foraging model and bioenergetics model that requires spatial measures of prey density (zooplankton and phytoplankton), water temperature, and DO. Positive GRP indicates "high" quality habitat (HQH), and negative GRP indicates "low" quality habitat (LQH). Our models are based on data collected during three research cruises conducted between late July and early August in 2003, 2004, and 2006 (Fig. 1).

Simulations and analyses The fraction of LQH in each transect was calculated (F_{-GRP}) and compared to the fraction of LQH in non-hypoxia water ($F_{(-GRP,>2)}$) to show the importance of hypoxia in determining overall habitat quality. Linear regressions between Diff (difference between F_{-GRP} and $F_{(-GRP,>2)}$) and $F_{hypoxia}$ (fraction of water column being hypoxic) were conducted for transects within and across years to test whether the importance of hypoxia in habitat quality would increase with the increase in areas of hypoxic zones.

Drivers of habitat quality To assess the independent influence of each environmental variable on habitat quality, we ran each GRP model using combinations of different levels of observed temperature, prey availability (ZP for bay anchovy and CHL for Gulf menhaden), and DO in the region.

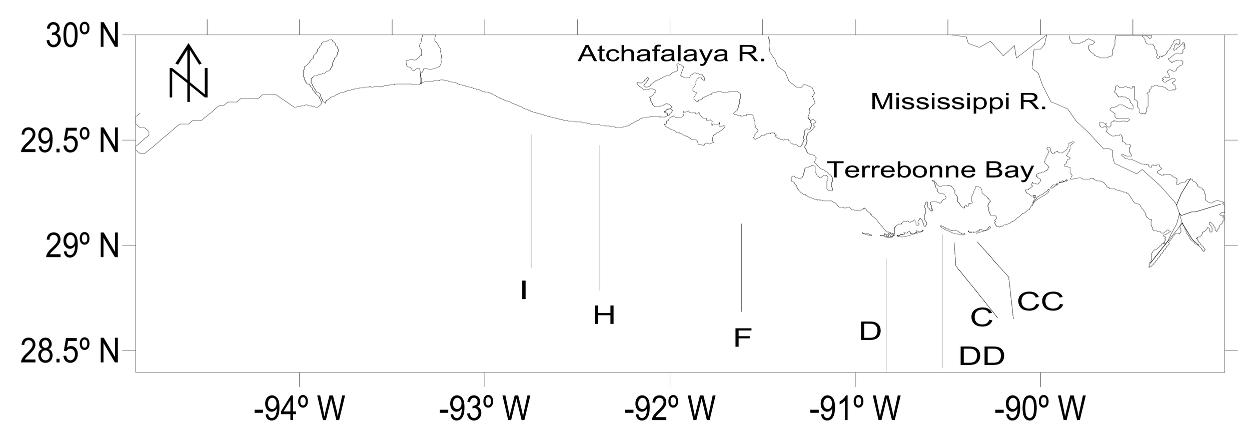

Fig. 1. Sampling transects in the northern Gulf of Mexico during 2003, 2004, and 2006. Letters are the names of transects that were sampled: CC, DD, D, and F in 2003; C, F, H, and I in 2004; and C and H in 2006.

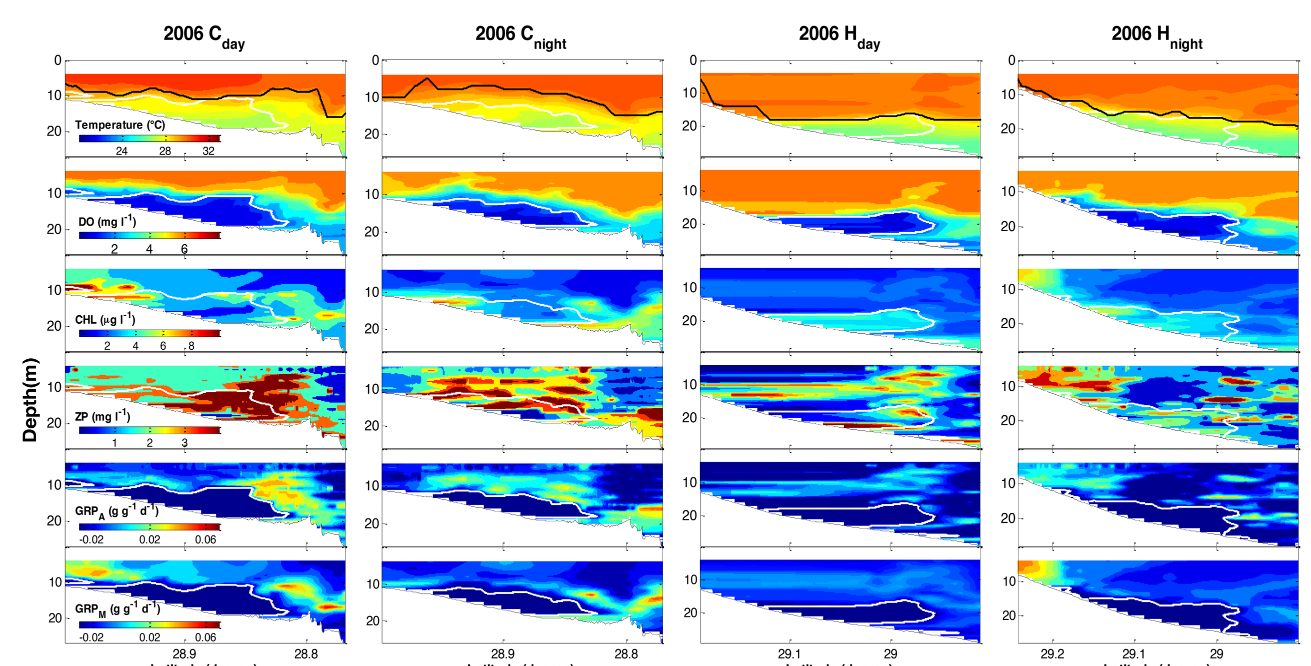

Fig. 2. Spatial distributions of environmental variables and growth rate potential of bay anchovy and Gulf menhaden during 2006, which had the strongest hypoxia among the three sampling years. White line is oxycline (2 mg O_2 l^{-1}). Note the different scales on the y-axis, with water surface (0 m) at the top.

Year	Transect	F_{-GRP}	$F_{(-GRP,>2)}$	Diff	$F_{hypoxia}$	r^2
Bay anchovy						0.7359**/
2003	C	0.69	0.68	0.01	0.03	
	DD	0.32	0.28	0.04	0.06	
	D	0.47	0.43	0.04	0.07	
	F	0.37	0.34	0.03	0.04	
	Mean	0.46	0.43	0.03	0.05	0.8167*
2006	Cday	0.64	0.51	0.13	0.26	
	Cnight	0.63	0.55	0.08	0.16	
	Hday	0.82	0.79	0.03	0.15	
	Hnight	0.78	0.73	0.05	0.17	
	Mean	0.72	0.65	0.07	0.19	0.8102*
Gulf menhaden						0.3839**
2003	C	0.18	0.16	0.02	0.03	
	DD	0.11	0.06	0.05	0.06	
	D	0.18	0.12	0.06	0.07	
	F	0.28	0.25	0.03	0.04	
	Meane	0.19	0.15	0.04	0.05	1.0*
2006	Cday	0.61	0.47	0.14	0.26	
	Cnight	0.79	0.75	0.04	0.16	
	Hday	1.00	1.00	0.00	0.15	
	Hnight	0.89	0.87	0.02	0.17	
	Mean	0.82	0.77	0.05	0.19	0.9492*
Overall mean		0.55	0.50	0.05	0.12	

Table 1. The spatial fraction of the water column with a negative growth rate potential (F_{-GRP}), spatial fraction of oxygenated water column (> 2 mg O_2 l^{-1}) with a negative growth rate potential ($F_{(-GRP,>2)}$), the difference between F_{-GRP} and $F_{(-GRP,>2)}$ – Diff, the spatial fraction of the water column having hypoxia for each transect $F_{hypoxia}$, and the r^2 for the linear regressions between Diff and $F_{hypoxia}$ for individual year (indicated by *) and for 2003 and 2006 combined (indicated by **).

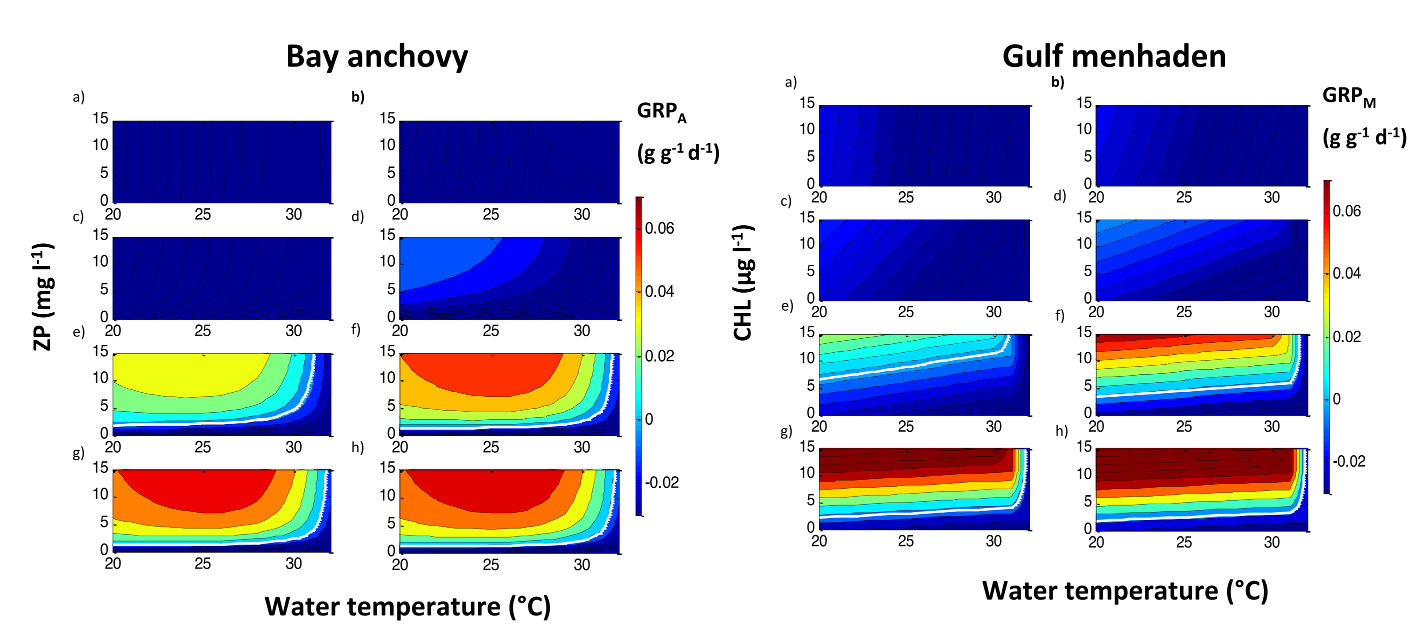

Fig. 3. The effect of water temperature, food concentration, and DO on GRP (g g^{-1} d^{-1}). DO concentration (mg l^{-1}) accrued by 0.5 mg l^{-1} from 0.5 mg l^{-1} in panel a) to 4.0 mg l^{-1} in h). The thick white lines indicate the contour line of GRP = 0 g g^{-1} d

RESULTS & DISCUSSION

Hypoxic zones were always low quality habitats (LQH, i.e., negative GRP values) for both bay anchovy and menhaden (Fig. 2), even though portions of these areas had high prey concentrations and suitable temperatures. The percentage of HQH in the hypoxic zones was zero for both species.

Across years and transects, the average proportion of the water column that was hypoxic ($F_{hypoxia}$) was 12% (Table 1), whereas the average proportion of the water column that was considered LQH (F_{-GRP}) for a species was 55%. Generally, the percent of LQH of oxygenated water column (> 2 mg O_2 l^{-1}; $F_{(-GRP,>2)}$) was not much different than that of the entire water column, which indicated that DO had little effect on the overall habitat quality. A strong positive relationship between Diff and $F_{hypoxia}$ indicated that the impacts of hypoxia on habitat quality increased with increases in the areas of hypoxic zones.

GRP predictions for both species were negative when DO <2.0 mg l^{-1}, regardless the levels of water temperature and food concentrations, indicating that the habitat quality was poor, and DO was the major controlling factor (Fig. 3). Under normoxic conditions, ZP concentrations as low as 1.1 mg l^{-1} and CHL above 6.5µg l^{-1} can result in positive GRP over the range of observed water temperature in the region during our sampling season. GRP became negative at temperatures above 32°C regardless of prey and DO concentrations.

Our results with Gulf menhaden are consistent with the results observed for Atlantic menhaden in the Chesapeake Bay, i.e., habitat quality was a function of phytoplankton concentration, and hypoxia has only a minimal effect, if any at all. In contrast to results for the Chesapeake Bay, habitat quality for bay anchovy in the northern Gulf of Mexico was strongly influenced by zooplankton concentration and only minimally affected by hypoxia. However, the impacts of hypoxia on habitat quality increased with the increases in the areas of hypoxic zones. Thus, the discrepancy between ecosystems is likely due to the vertical extent of hypoxia in the northern Gulf of Mexico compared to Chesapeake Bay.

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- Title: Impact of hypoxia on habitat quality of pelagic fishes in the northern Gulf of Mexico
  Presenter: Hongyan Zhang
  Session: SCI-075P1 — Ecology of Coasts and Estuaries: Ecosystems (POSTERS)
  Session Date/Time: November 4, 2013 from 5:00 PM to 7:00 PM
  Room: Grand Hall
  Poster Position: E45
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