Climate change in the shallows – interacting effects of diel-cycling hypoxia and acidification*

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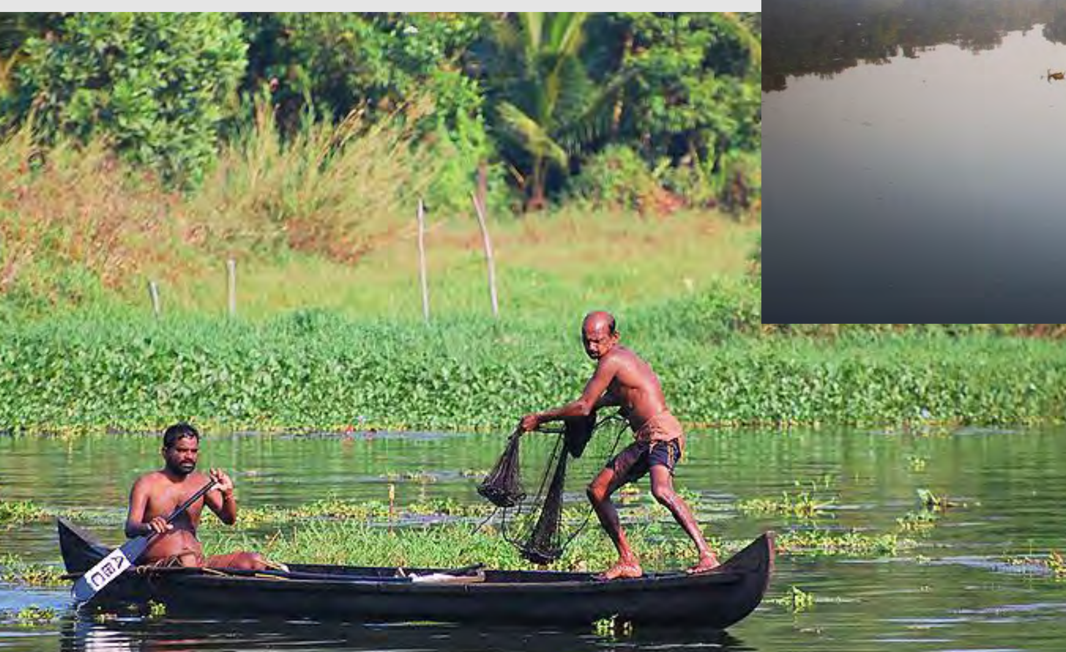
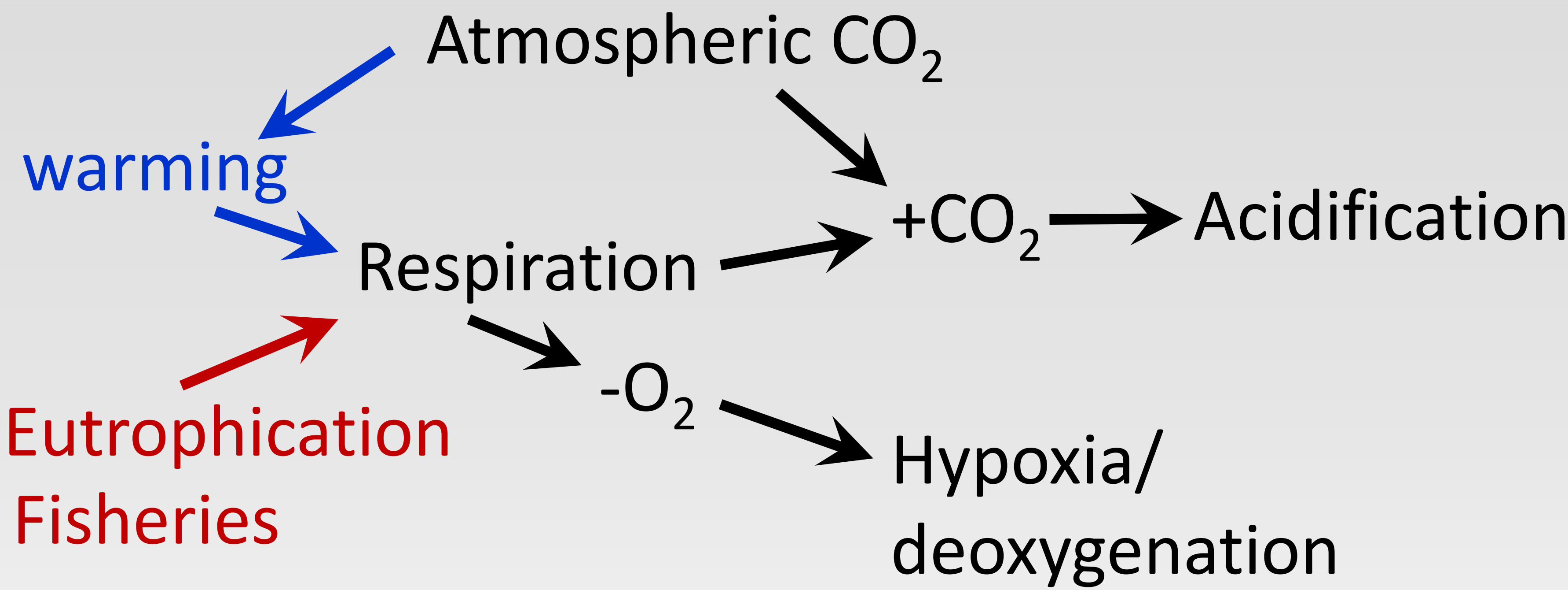


*unpublished student data removed from presentation

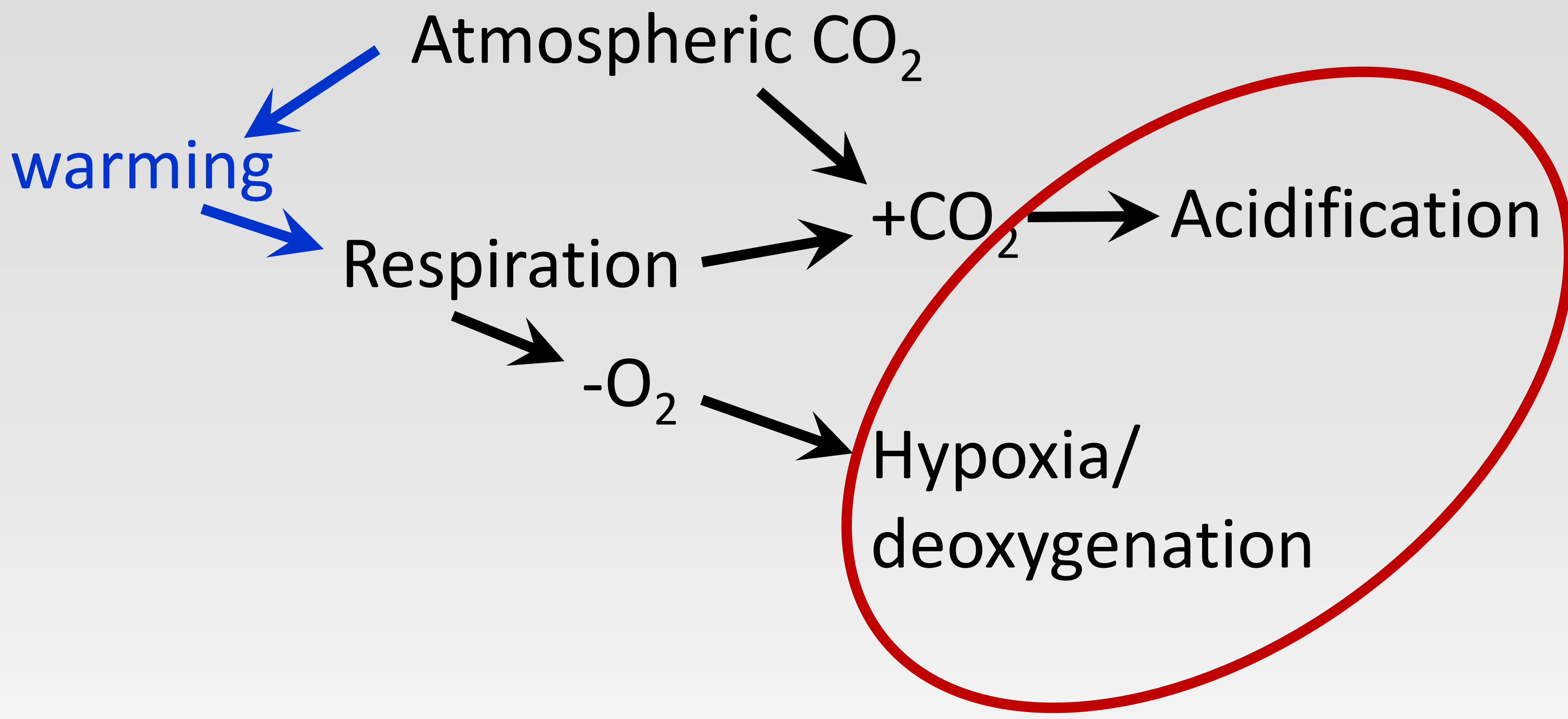
Smithsonian Institution

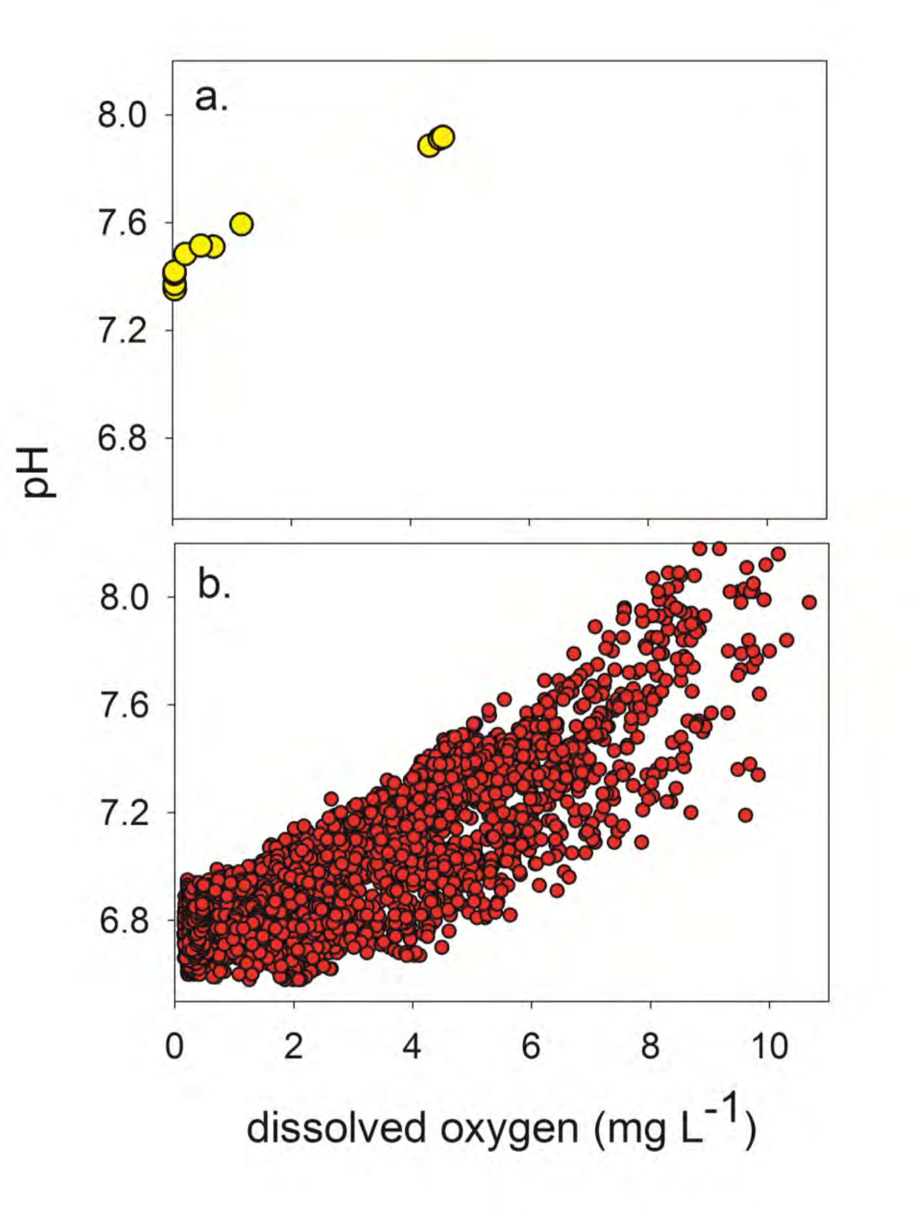
Center for Sponsored Coastal Ocean Research

Multiple stressors – management, understanding



Multiple stressors – management, understanding

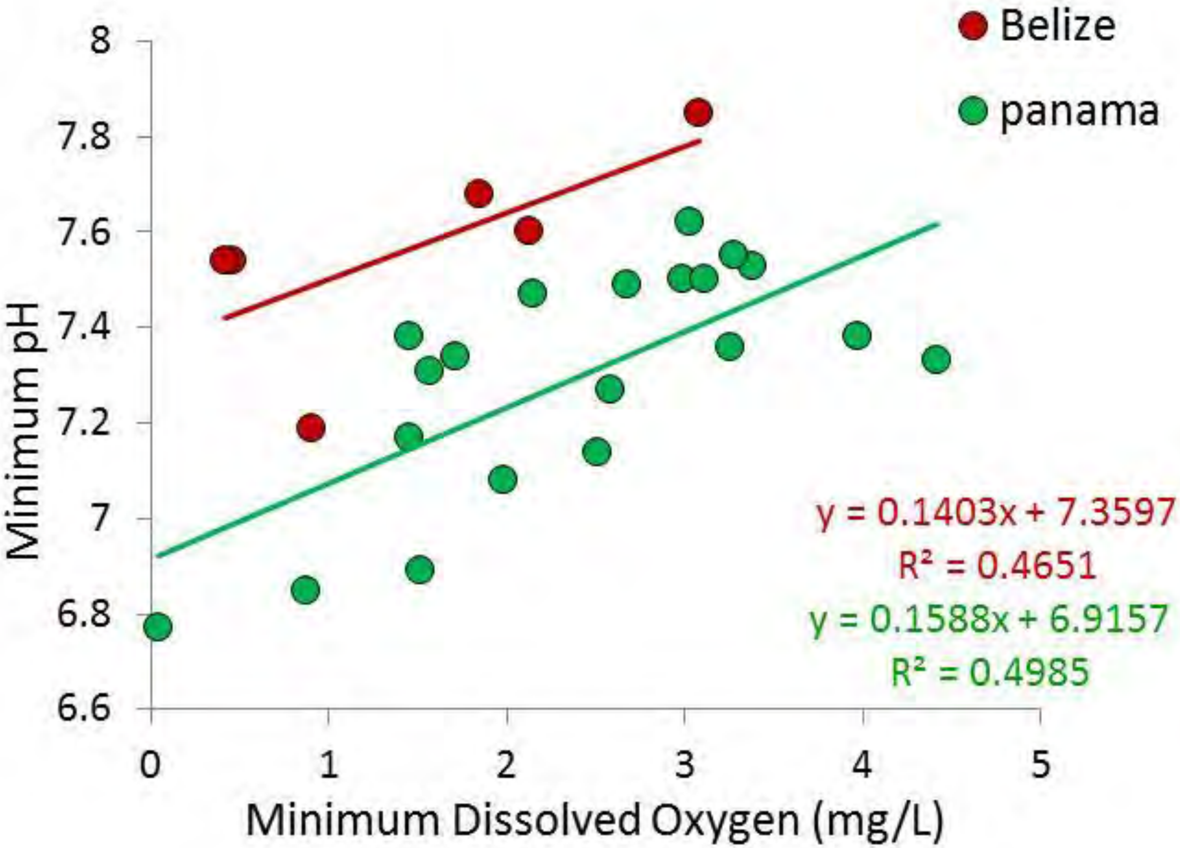


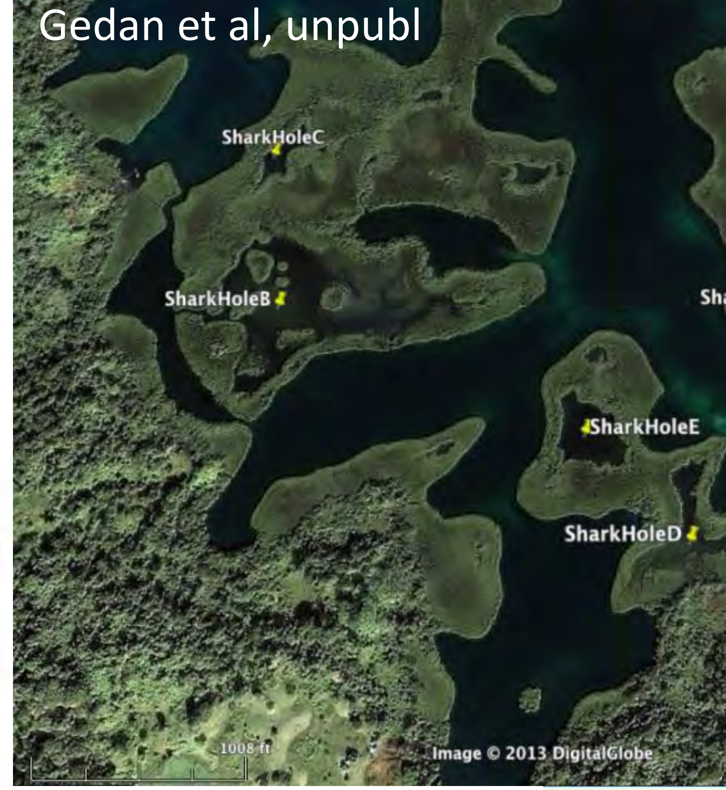


Costa Rica Dome
0-1000 m

Estuarine salt marsh
1 m

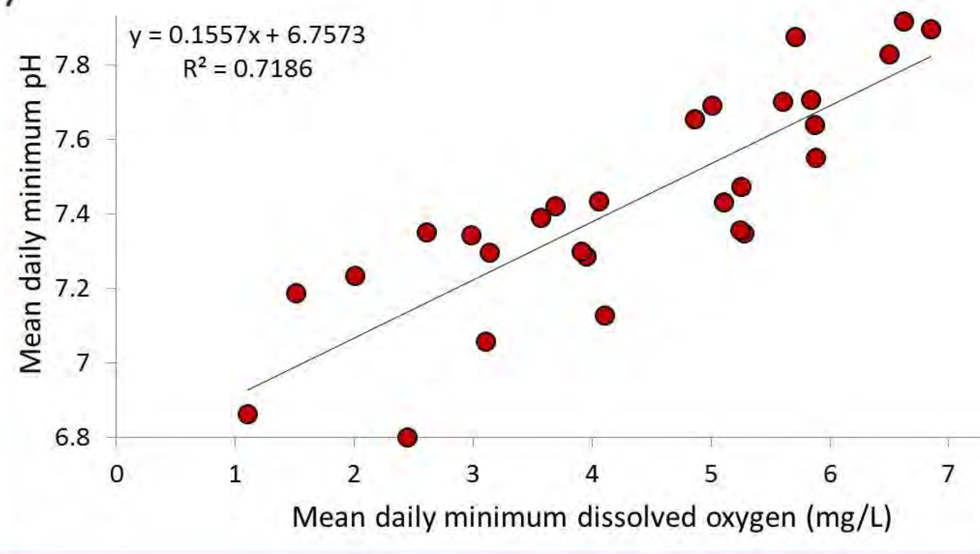
Breitburg et al., in press; data from Maas et al. 2014, Breitburg et al., unpublished





Chesapeake Bay

Breitburg et al., 2015



Shallow Chesapeake Bay
high productivity
restricted circulation
nutrient enriched
high respiration

seasonal & diel-cycling hypoxia

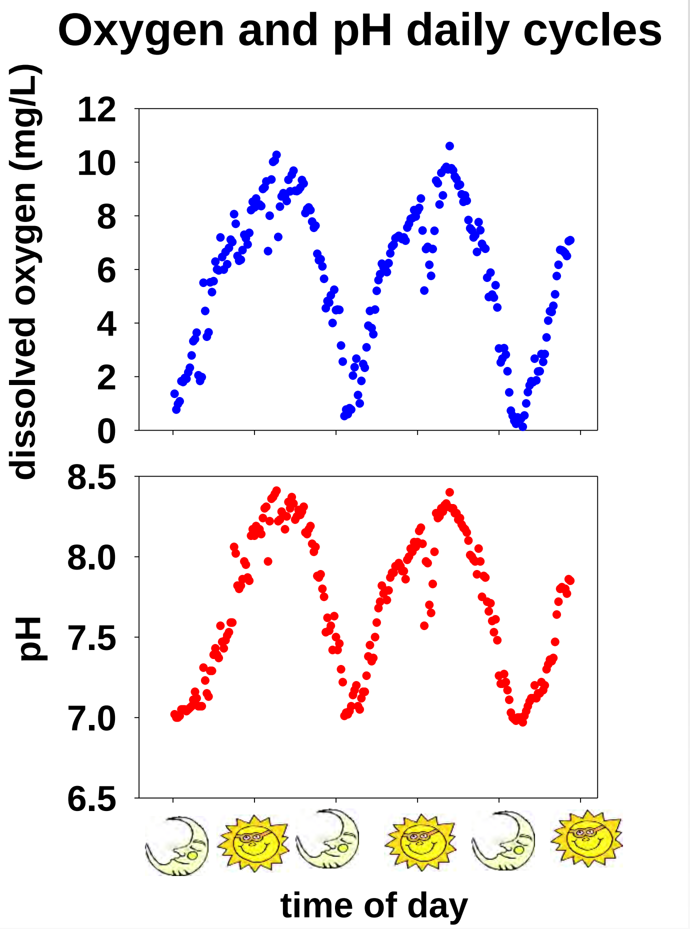
Diel-cycling hypoxia and acidification

- Patterns?
- Do diel-cycling acidification and hypoxia affect native species in spite of potential adaptation and daily periods of recovery? (Experiments with oysters & fish)

Contrasting patterns at 3 sites in Chesapeake Bay ,

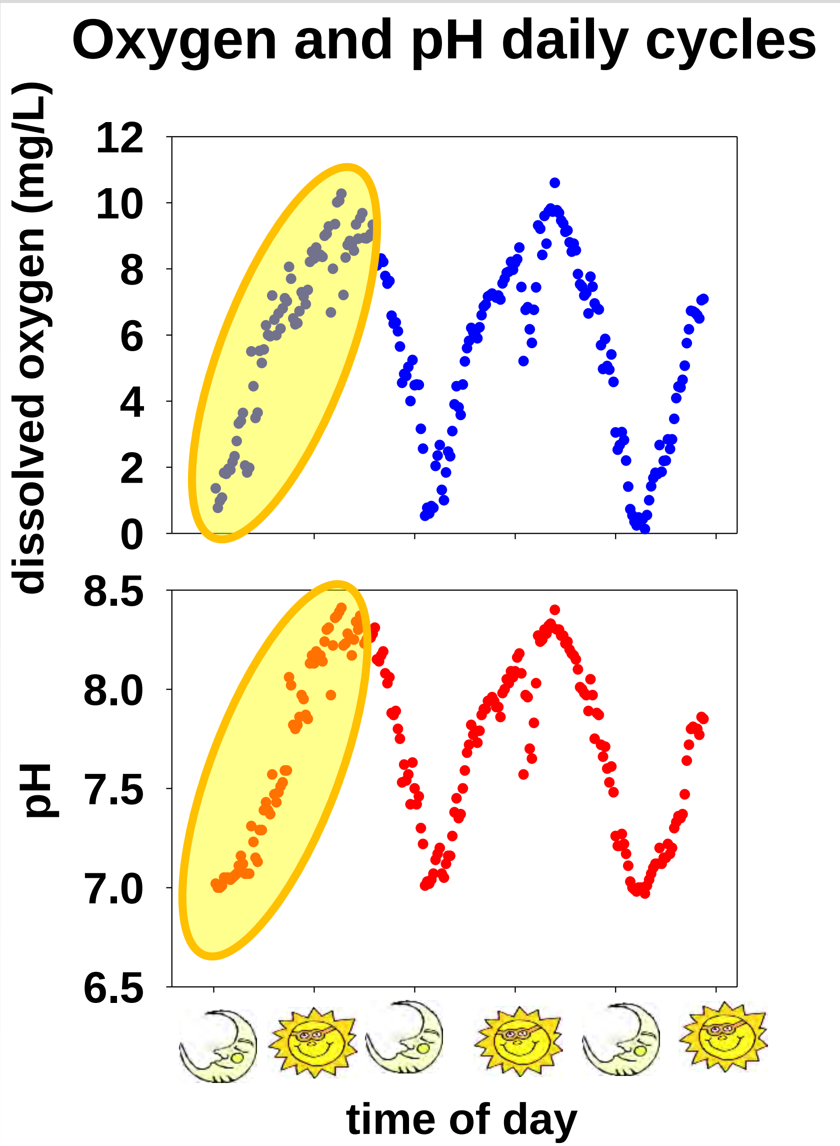
‘Classic’ diel cycling

Bear Creek



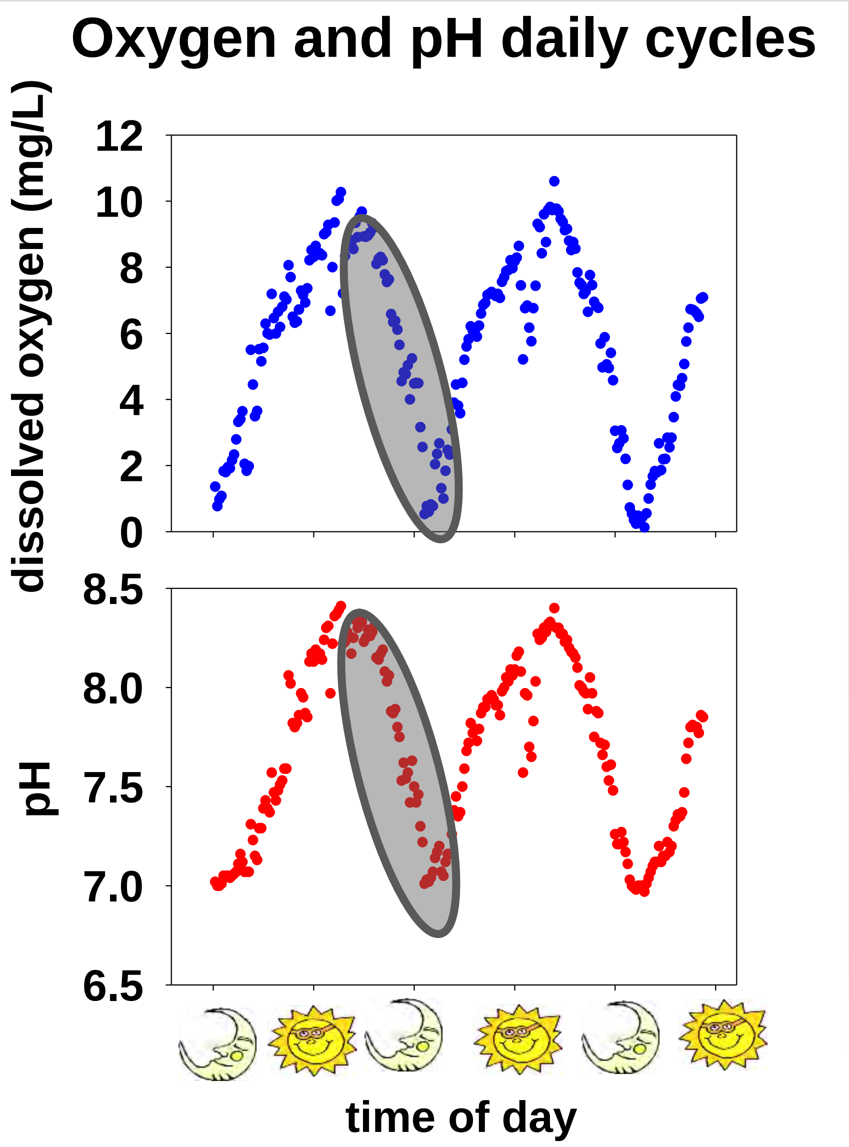
MD-DNR: eyesonthebay.net

‘Classic’ diel cycling



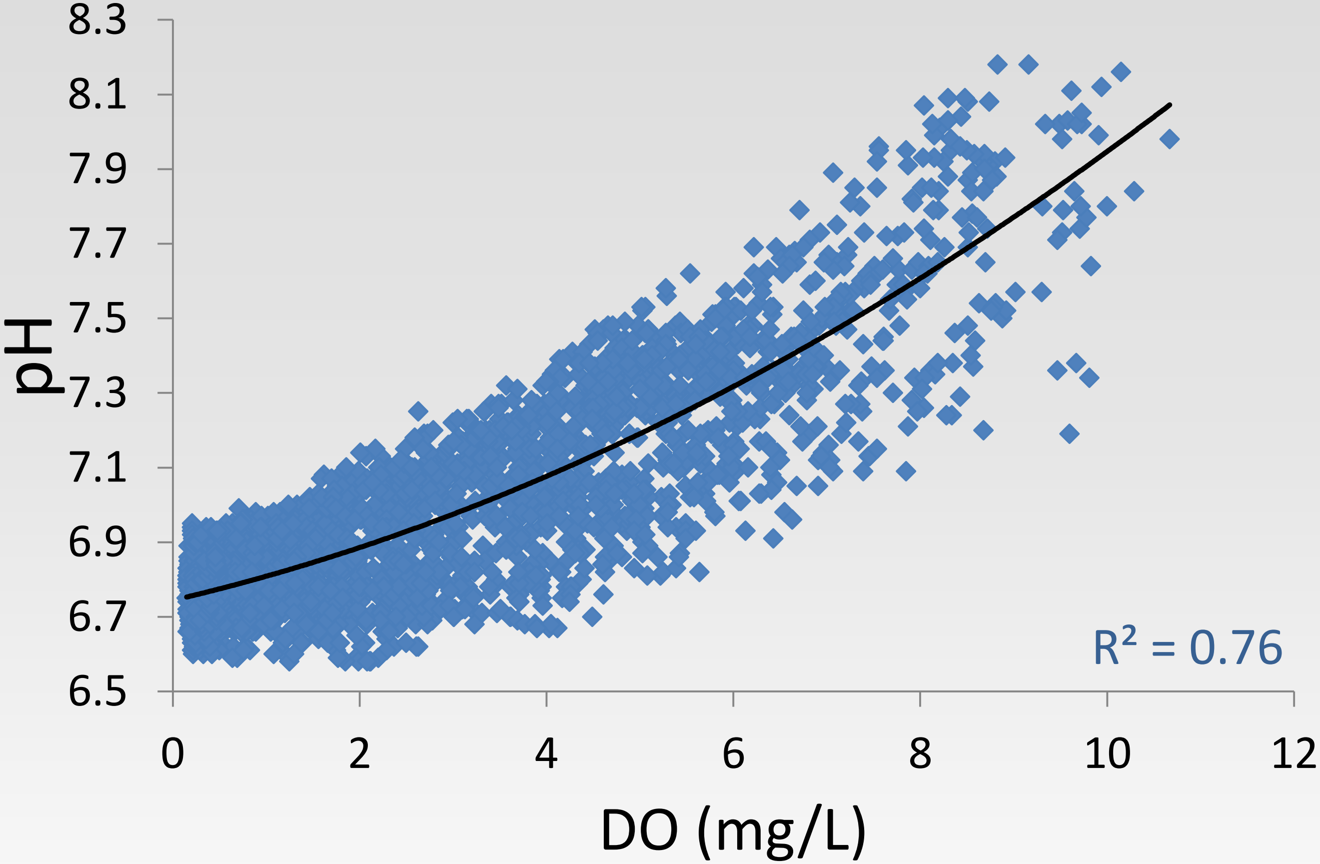
Daylight –
Photosynthesis dominates
+ oxygen, -CO_2

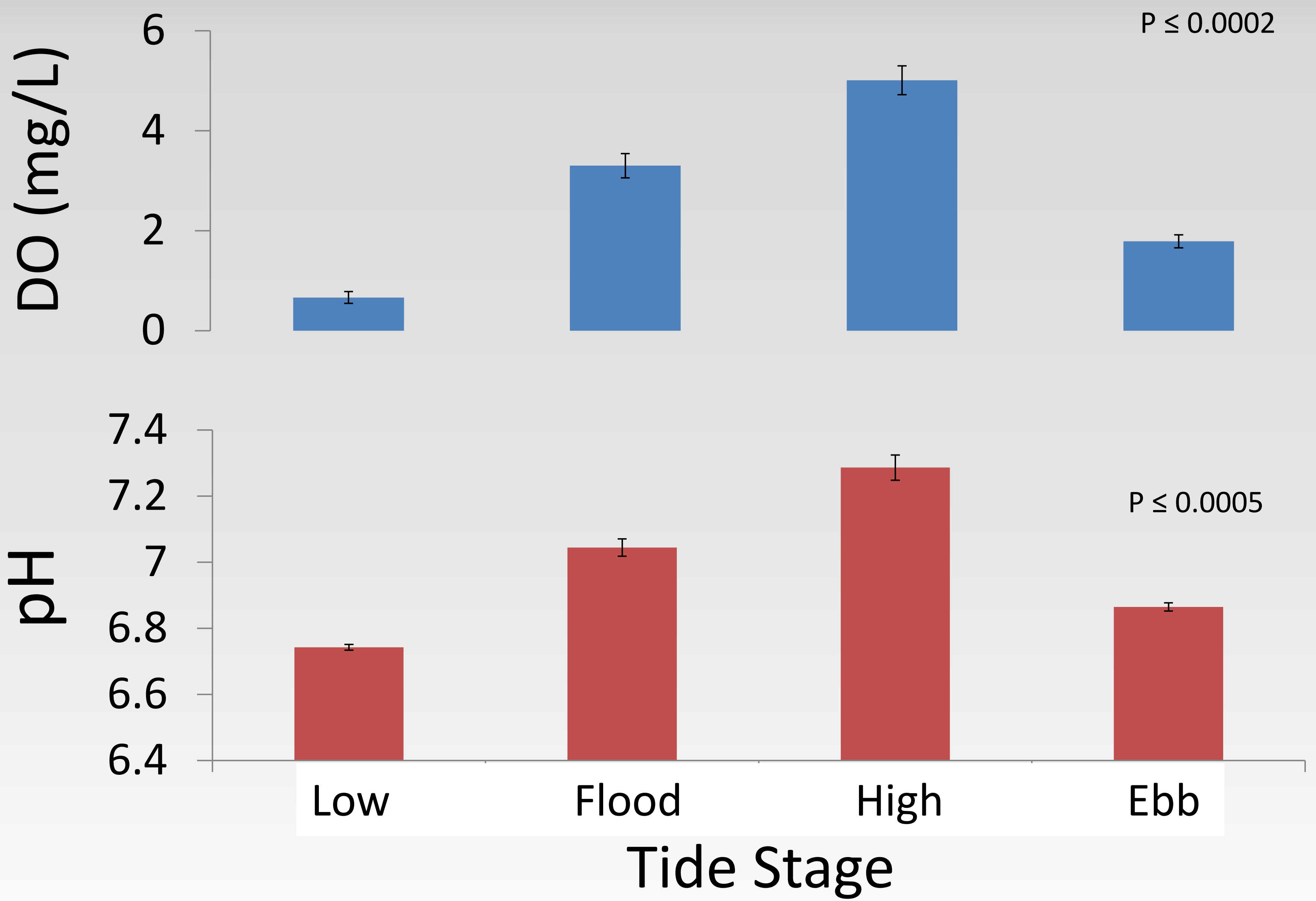
‘Classic’ diel cycling



Dark –
Respiration dominates
- oxygen, $+CO_2$

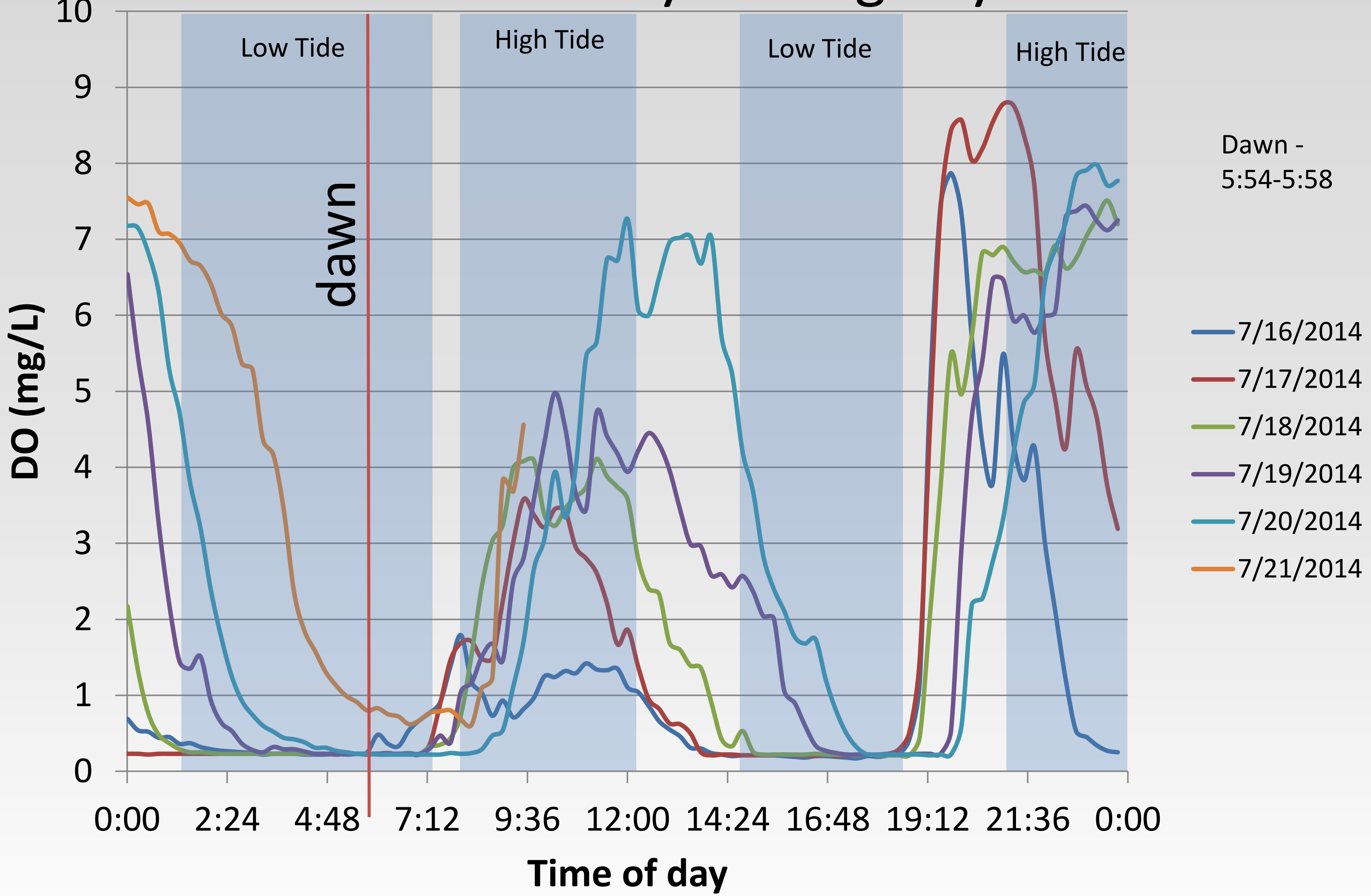
Salt marsh Creek
Rhode River, Chesapeake Bay
Strong tidal signal

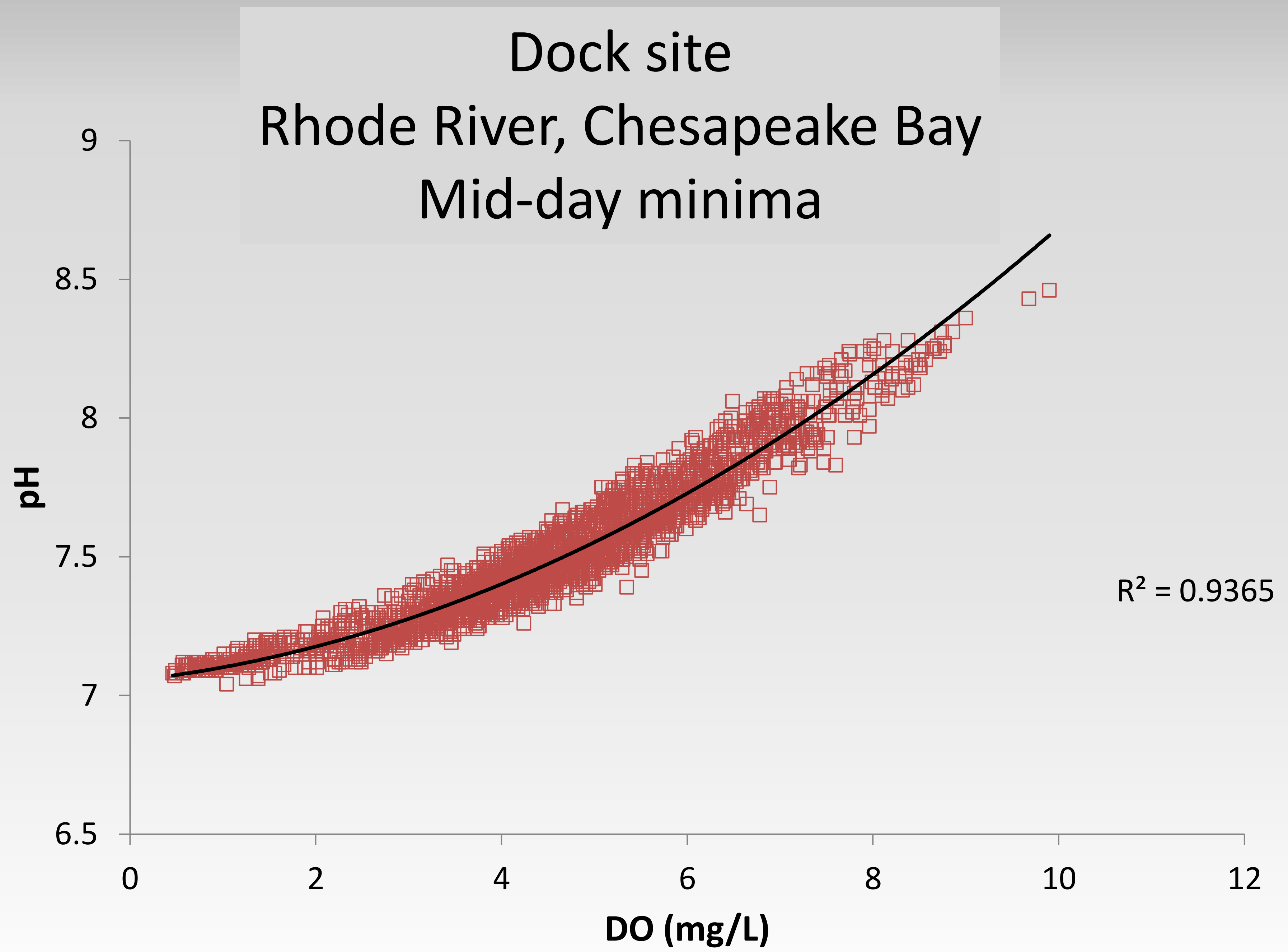




DO (mg/L)
6
4
2
0
P ≤ 0.0002
pH
7.4
7.2
7
6.8
6.6
6.4
P ≤ 0.0005
Low
Flood
High
Ebb
Tide Stage

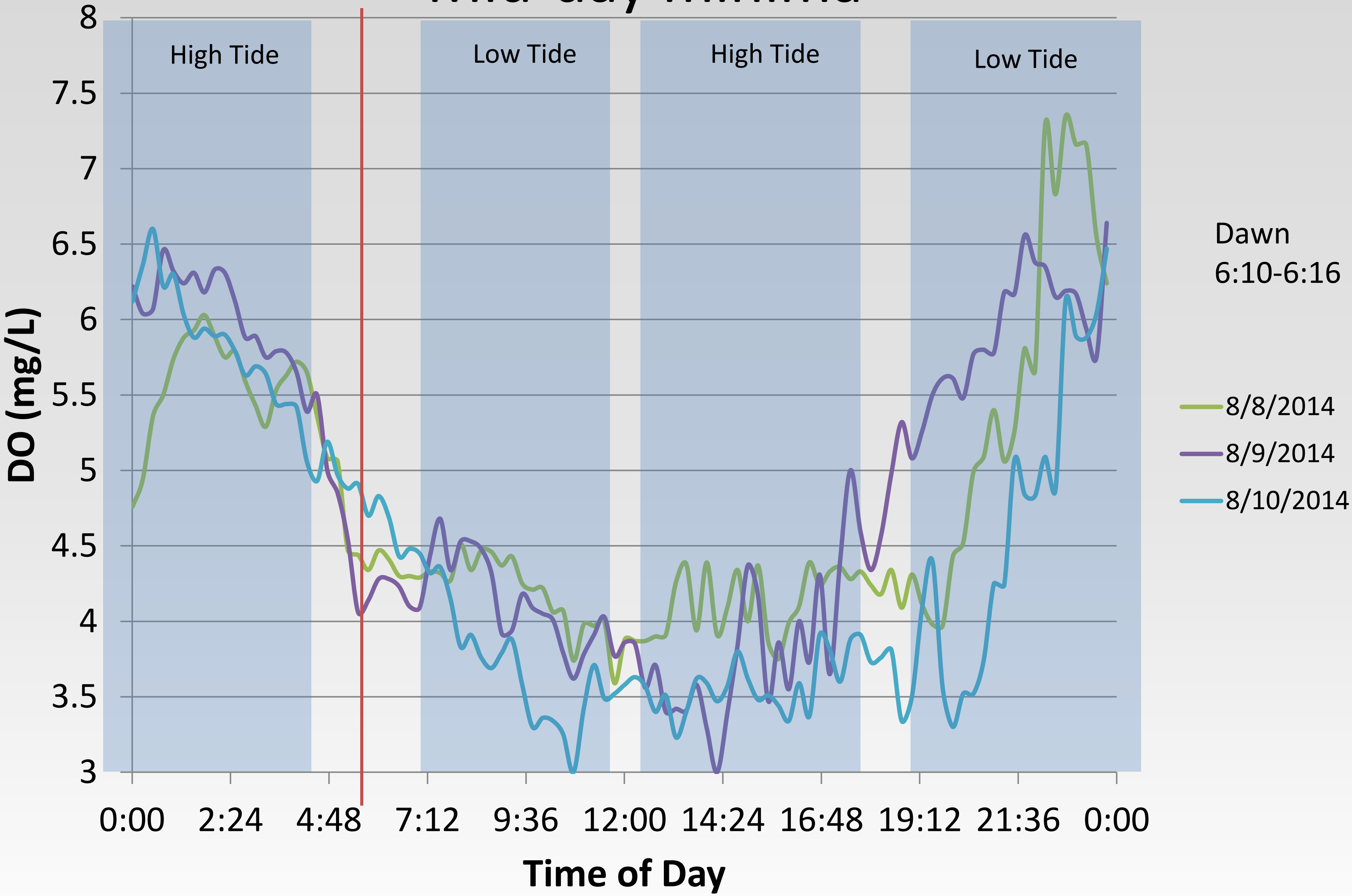
Tide-dominated pattern: timing of minima vary among days



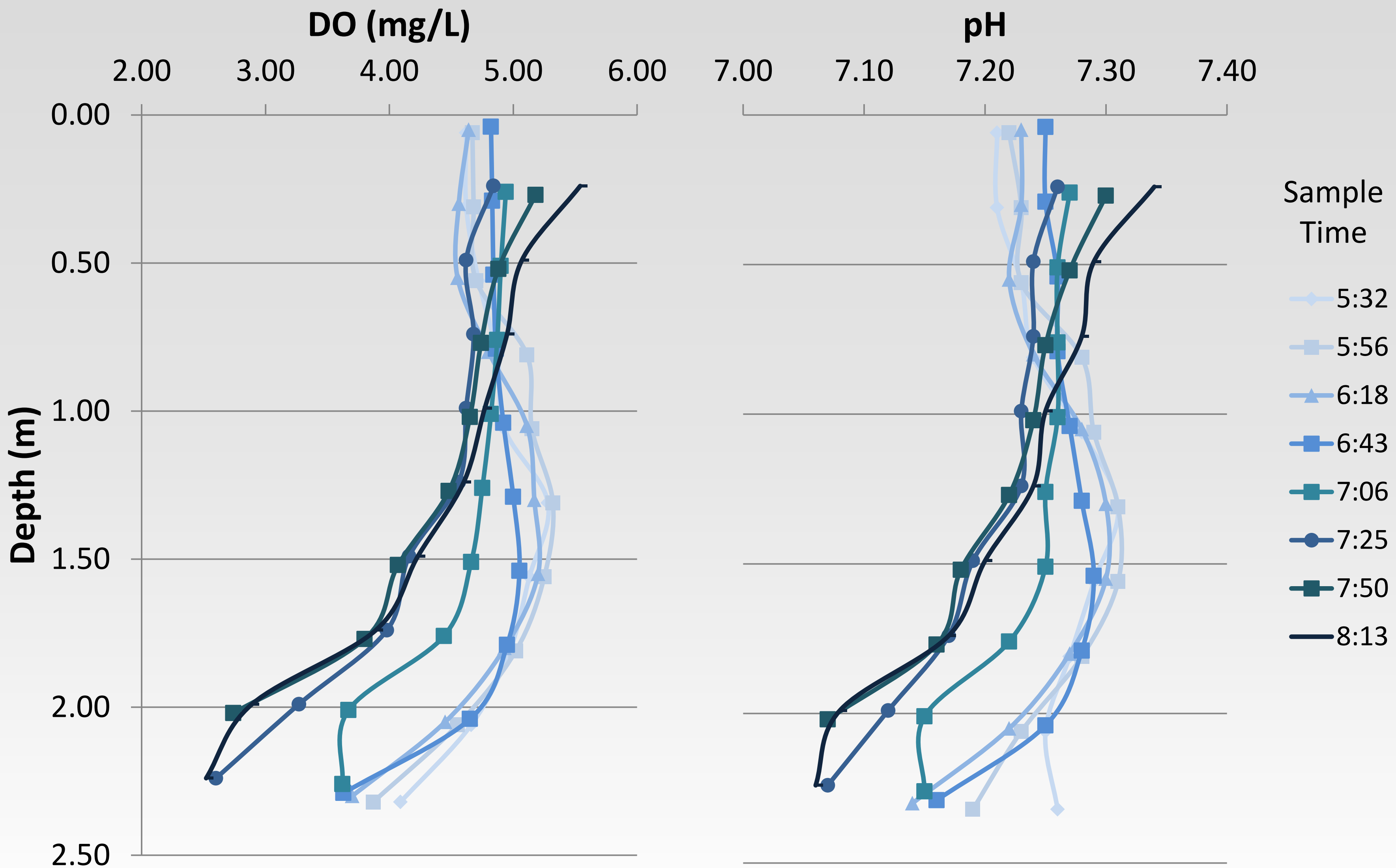


Dock site
Rhode River, Chesapeake Bay
Mid-day minima
pH
DO (mg/L)
R² = 0.9365
9
8.5
8
7.5
7
6.5
0
2
4
6
8
10
12

Stratification on sunny days – Mid-day minima



DO and pH at 2 m continue to decline after dawn



Shallow water cycles of dissolved oxygen and pH

Large spatial variation in timing and magnitude of cycles- different drivers dominate patterns

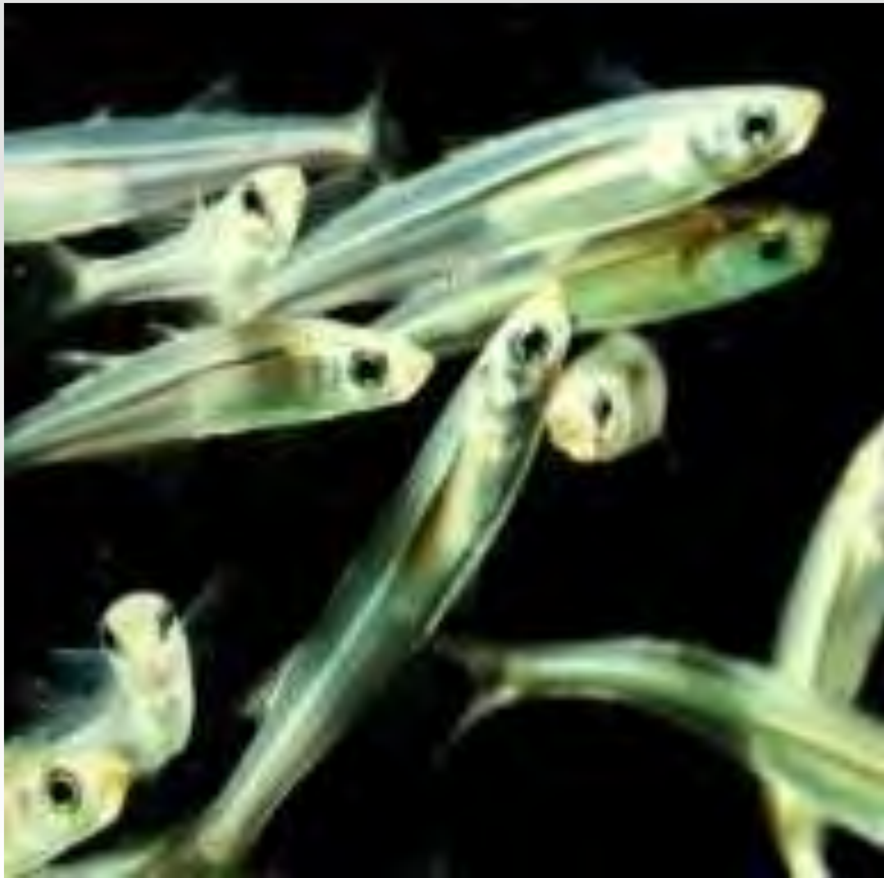
Spatial variation in ways hypoxia and acidification interact with diel patterns of behavior and physiology

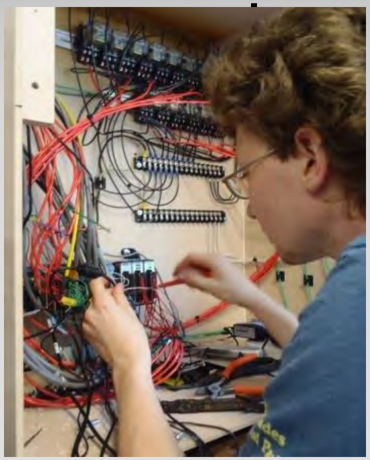
Eastern Oyster
(*Crassostrea virginica*)

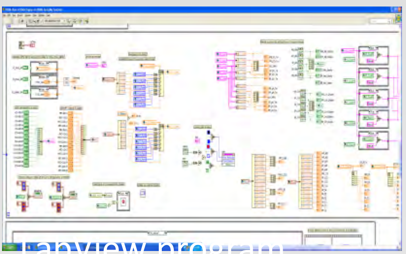
Disease
Growth

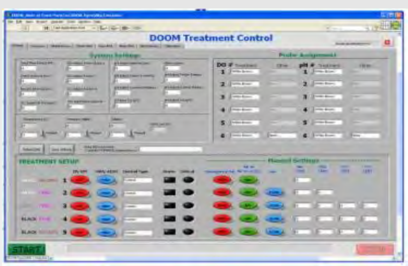
Atlantic & inland silversides
(*Menidia menidia & M. beryllina*)

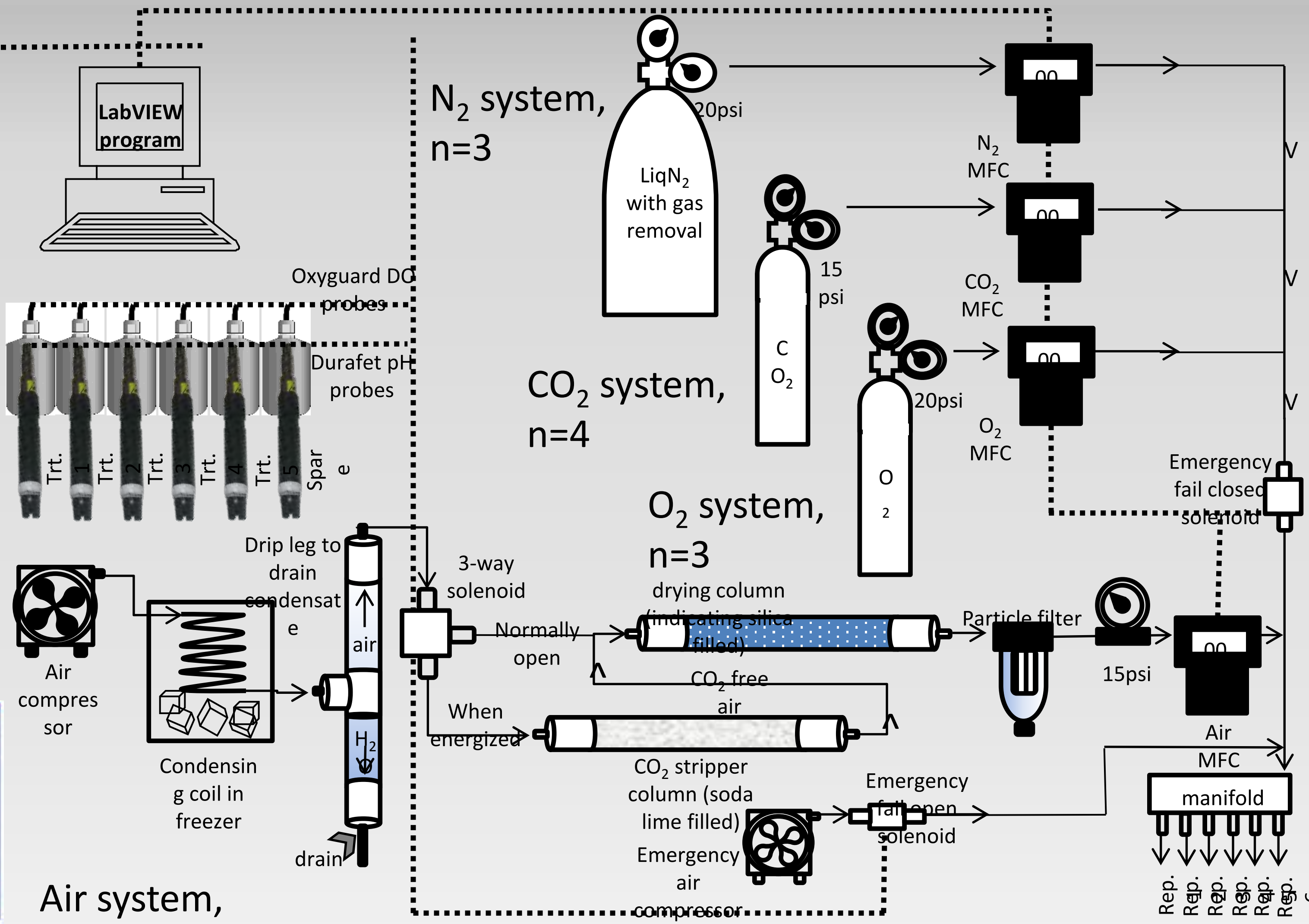
Growth
Sensitivity to hypoxia

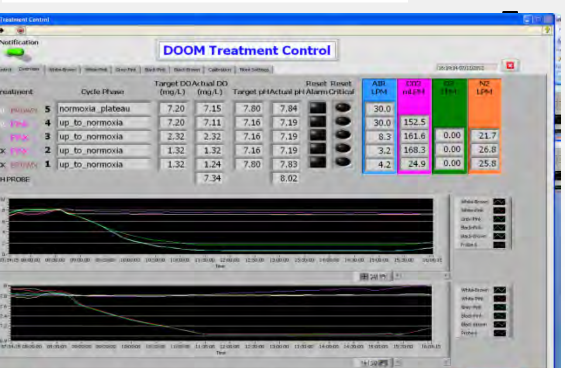




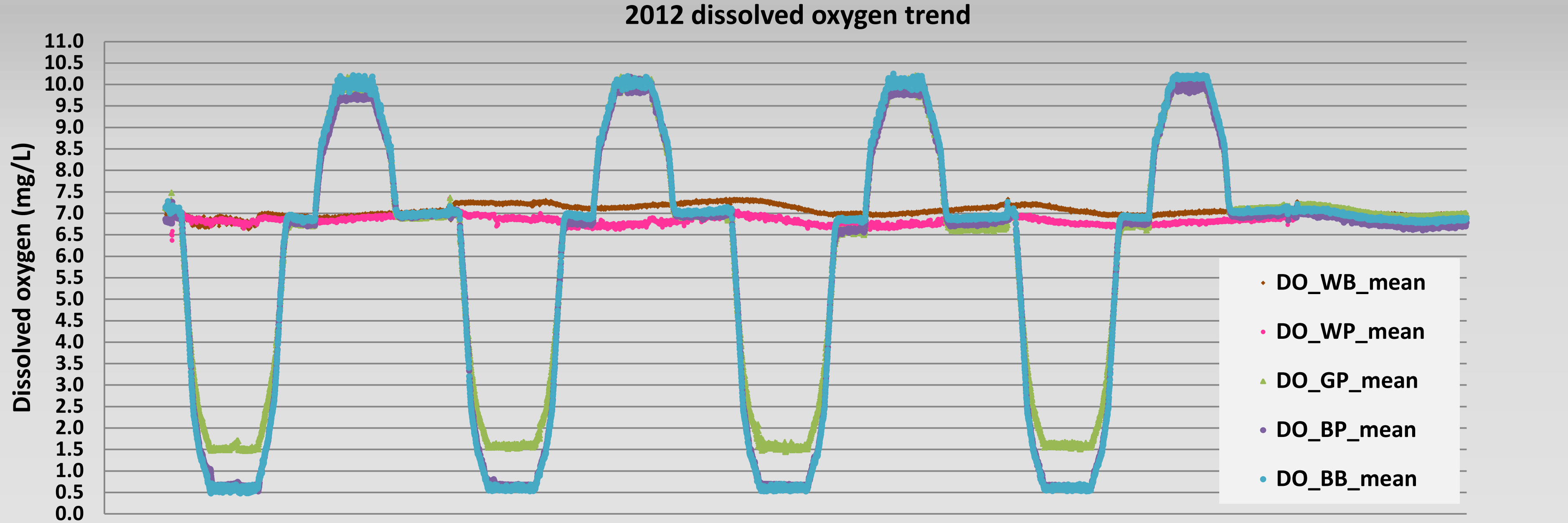




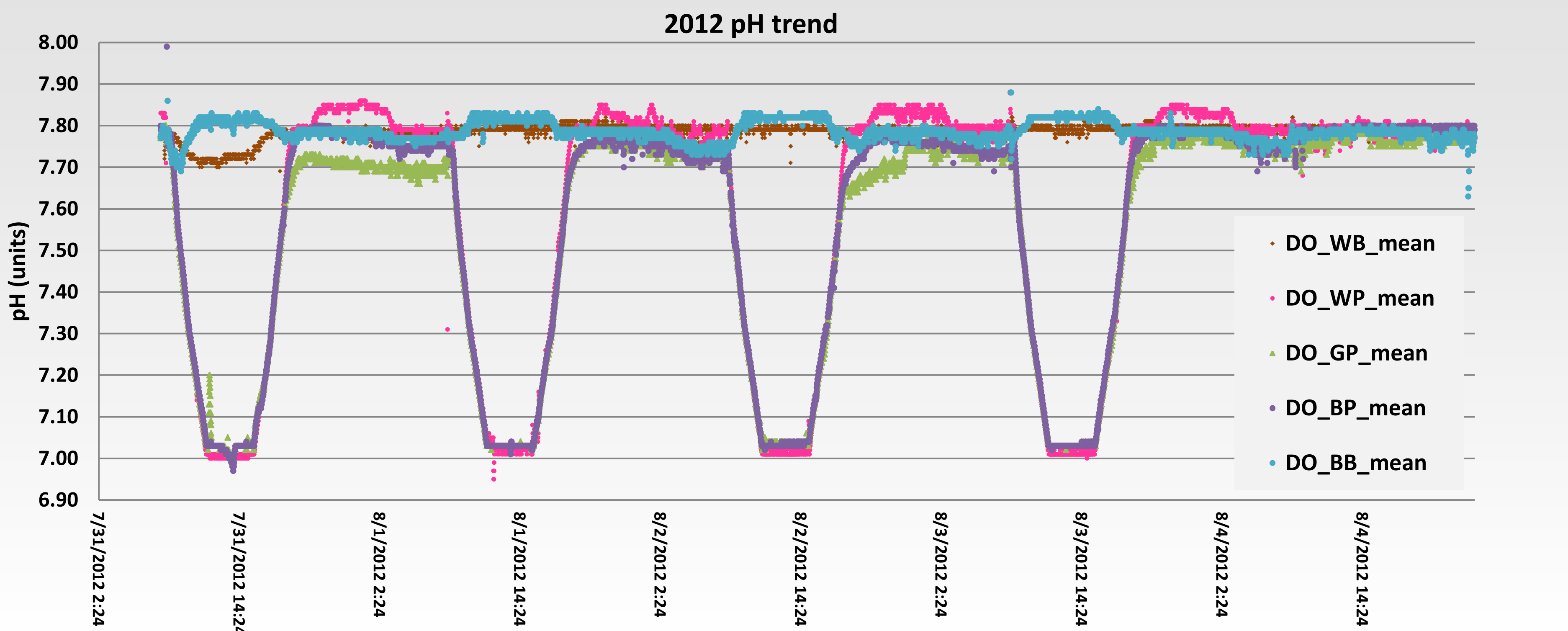




Burrell et al., accepted pending revision



2012 dissolved oxygen trend
Dissolved oxygen (mg/L)
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
DO_WB_mean
DO_WP_mean
DO_GP_mean
DO_BP_mean
DO_BB_mean



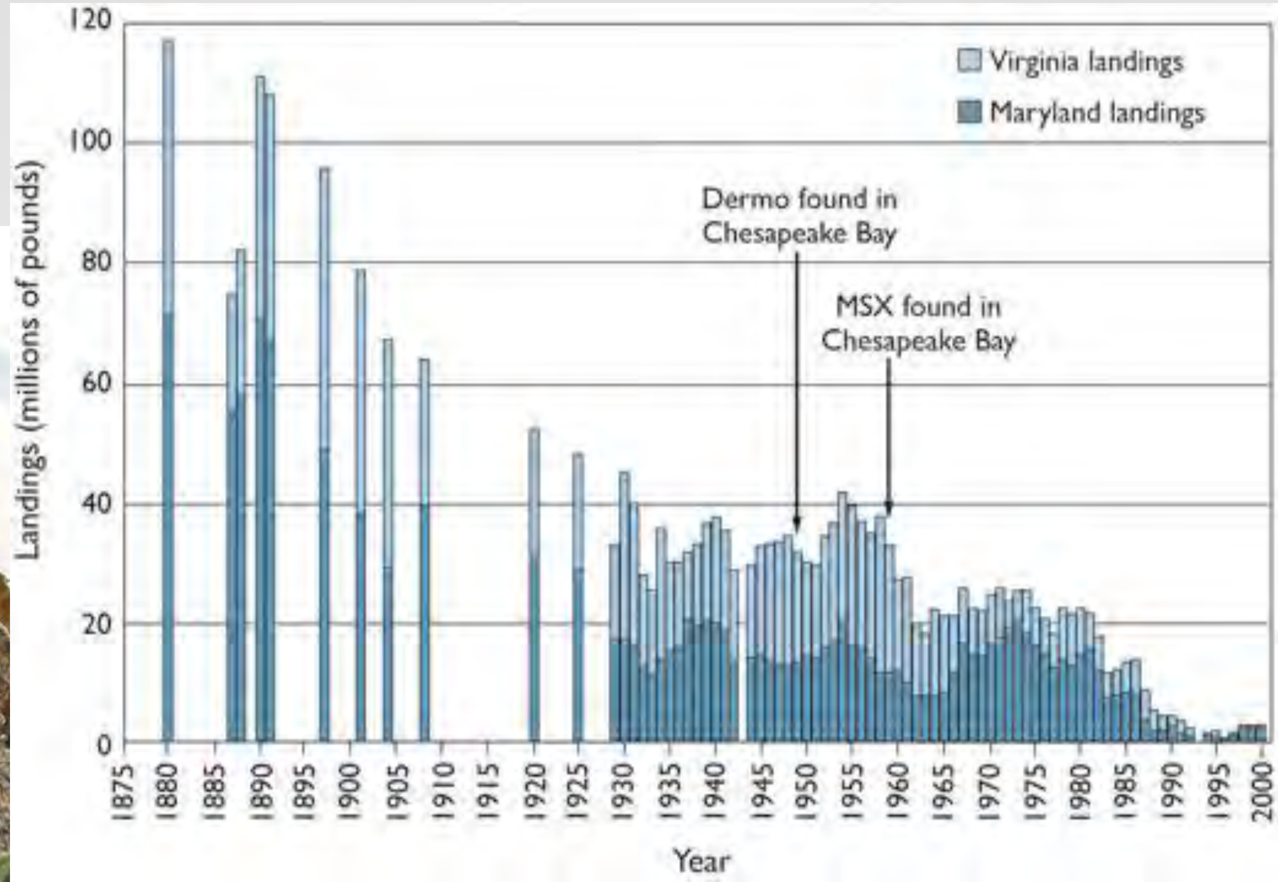
2012 pH trend
pH (units)
8.00
7.90
7.80
7.70
7.60
7.50
7.40
7.30
7.20
7.10
7.00
6.90
DO_WB_mean
DO_WP_mean
DO_GP_mean
DO_BP_mean
DO_BB_mean
7/31/2012 2:24
7/31/2012 14:24
8/1/2012 2:24
8/1/2012 14:24
8/2/2012 2:24
8/2/2012 14:24
8/3/2012 2:24
8/3/2012 14:24
8/4/2012 2:24
8/4/2012 14:24

Eastern Oyster (*Crassostrea virginica*)

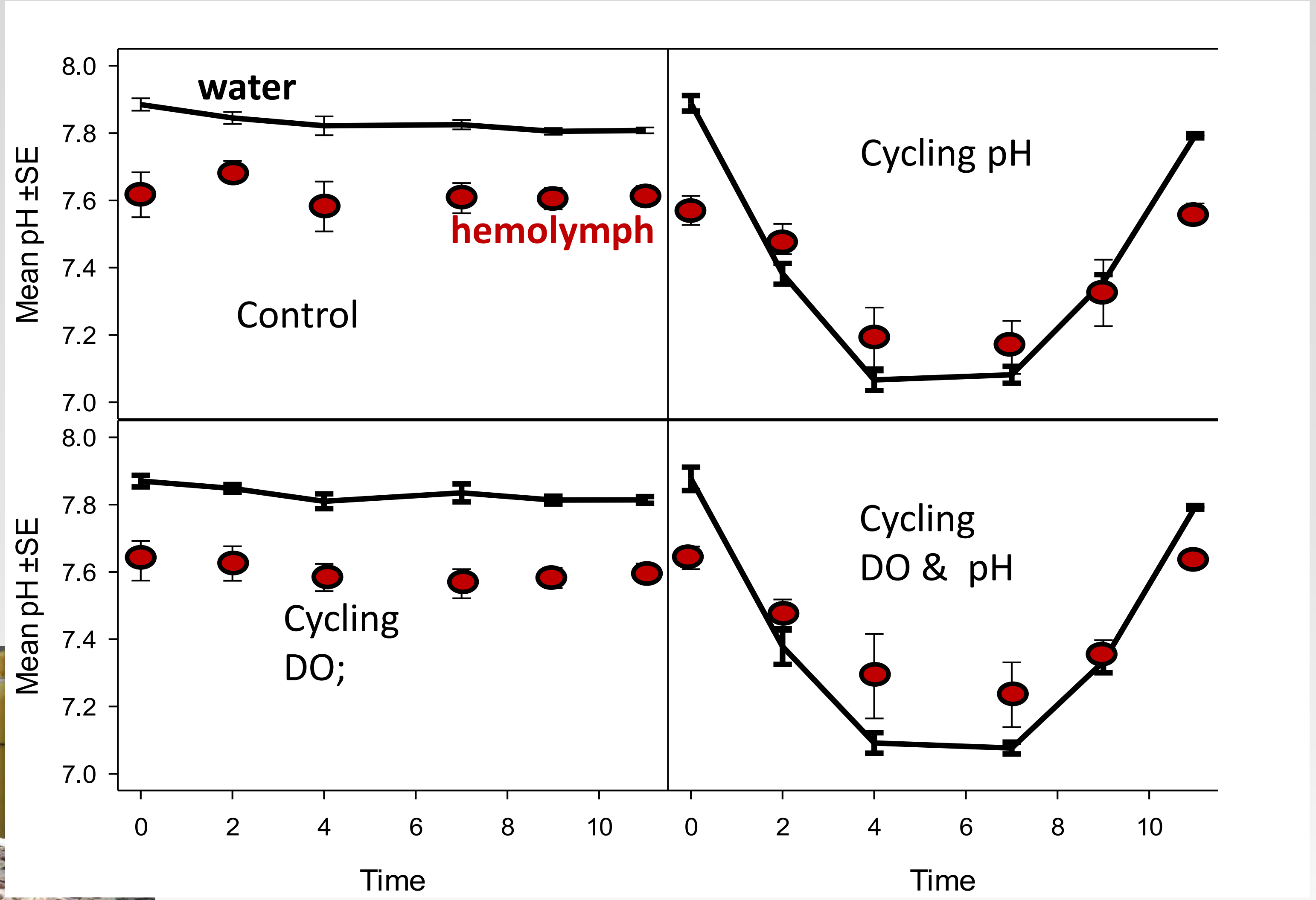
Immune response/disease (Dermo – *Perkinsus marinus)*

- hemolymph pH
- hemocyte function
- prevalence and intensity of infections

Juvenile growth



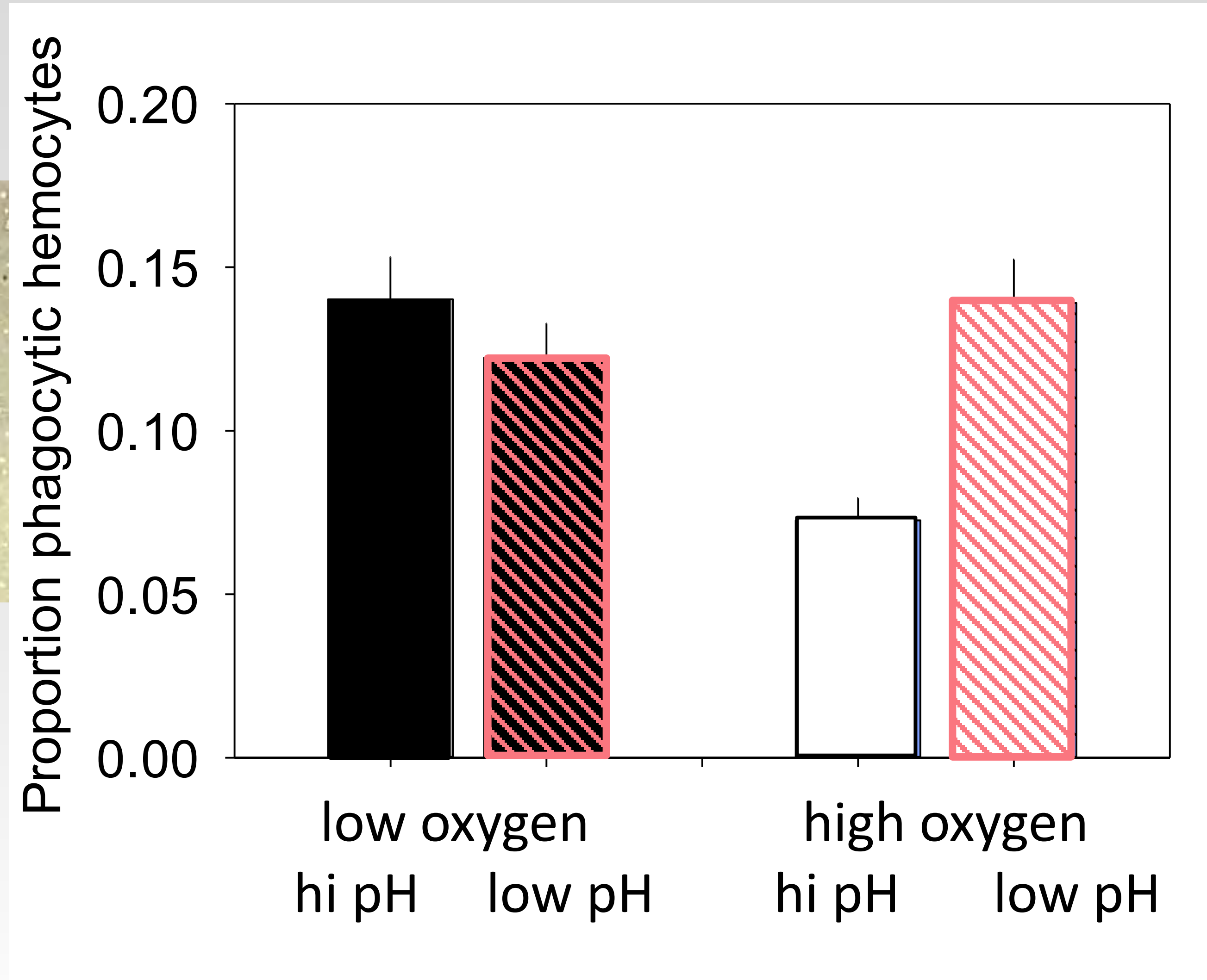
Hemolymph pH affected by water pH



Virginia Clark - 2014

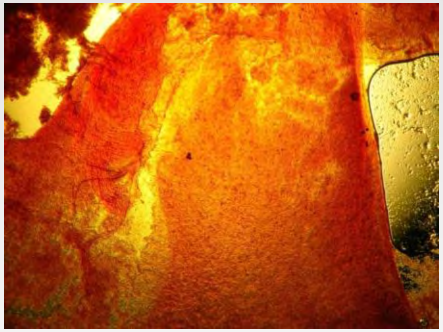
Cycling (DO, CO2, DO+CO2) stimulates hemocyte function

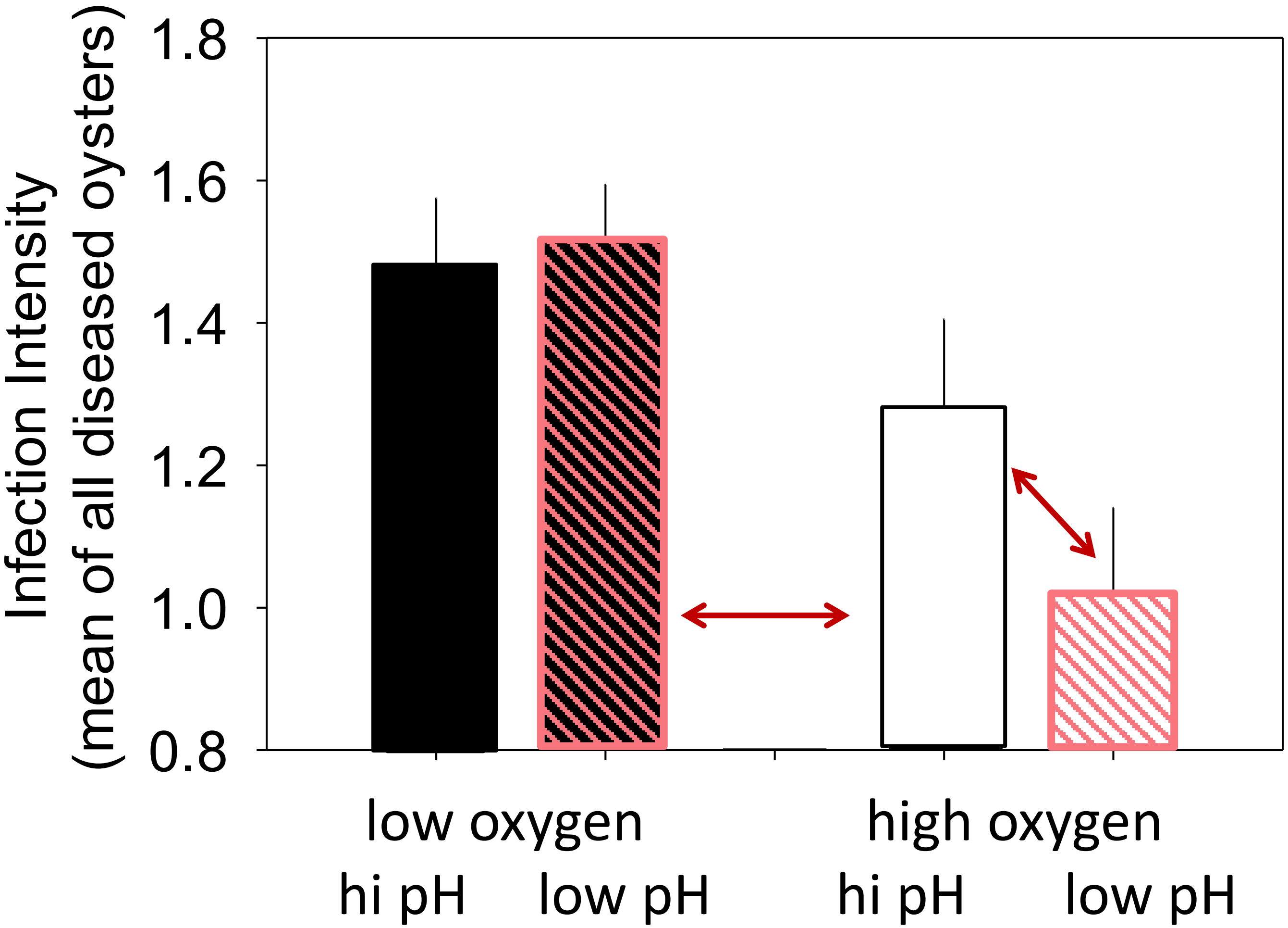
(cycling down to DO = 0.5, pH = 7.1)



Keppel et al., in review

Stimulation of hemocytes only tends to reduce infection progression when oxygen is high





Keppel et al., in review

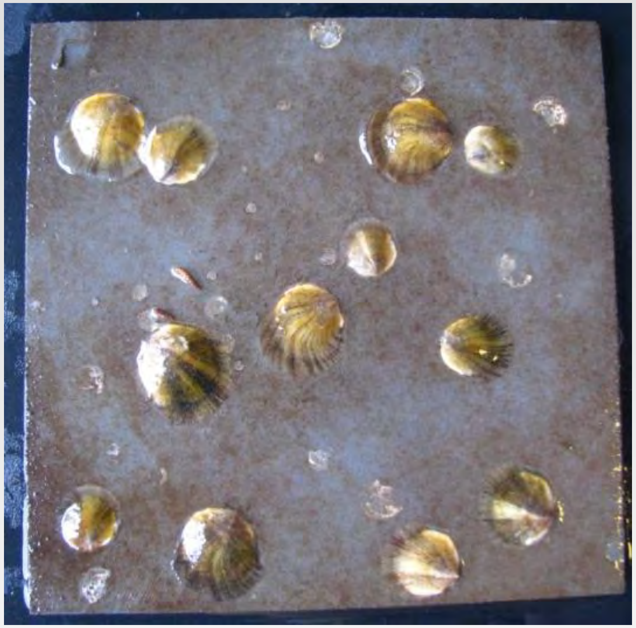
Juvenile growth

cycling down to

DO = 0.5, pH = 7.1

Low salinity year

$\Omega_{Calcite}$ =0.69



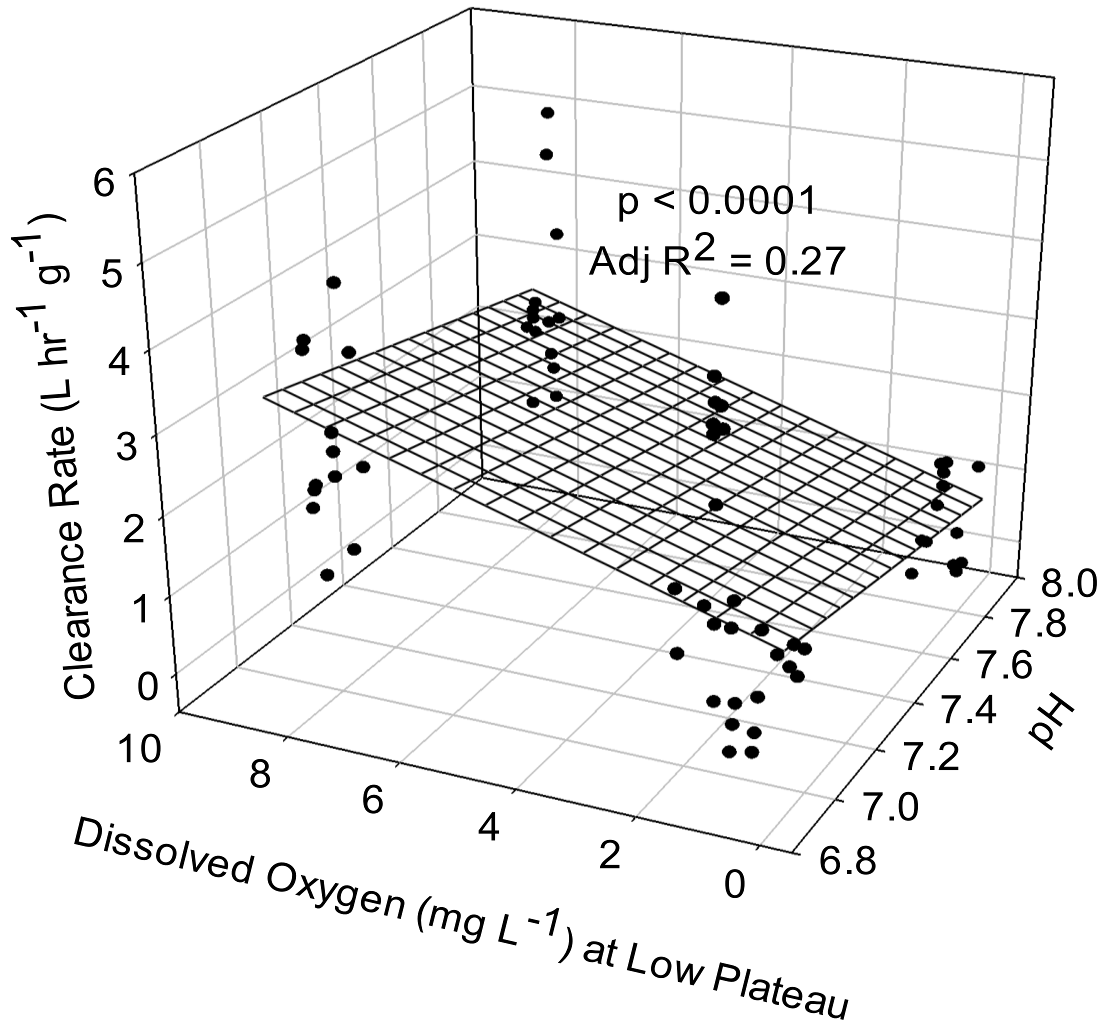
High salinity year

$\Omega_{Calcite}$ =1.87

Keppel 2014

The effect of diel-cycling pH differed in high and low salinity/ $\Omega_{Calcite}$ years

Low pH slightly increases oyster filtration rates



Clark 2014.

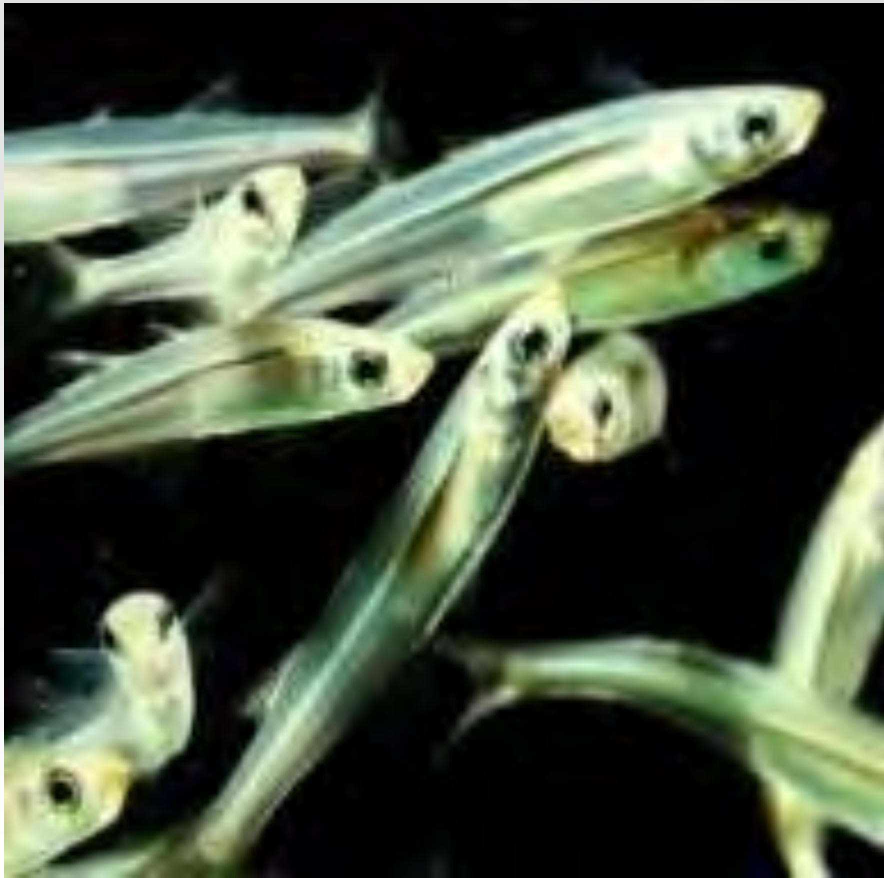
2 way ANOVA then Planar regression

Atlantic and inland Silversides- Growth, Aquatic Surface Respiration & Mortality

Growth of juvenile *Menidia beryllina* was lower relative to controls when fish were reared in diel-cycling dissolved oxygen or constant hypoxia conditions, but was not affected by cycling pH or constant low pH

Laboratory experiments indicated that simultaneous exposure to low pH can make fish more sensitive to low dissolved oxygen

Even brief daily exposures to acidification and hypoxia can negatively affect species that are native to systems with large natural fluctuations



So – Why worry about multiple stressors?

We can't predict consequences or manage effectively if we don't consider the full context in which organisms live

Individual stressors can either exacerbate or reduce effects of other stressors

For mobile species, co-occurrence with other stressors can determine exposure to acidification

- Almost all species tested behaviorally avoid low dissolved oxygen. Co-occurring hypoxia may therefore reduce exposure to respiration-driven acidification