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

Denise Breitburg
Andrew Keppel
Seth Miller
Rebecca Burrell

*unpublished student data removed from presentation
Multiple stressors – management, understanding

- Atmospheric CO$_2$
- Respiration
- +CO$_2$ → Acidification
- -O$_2$ → Hypoxia/deoxygenation

- warming
- Eutrophication
- Fisheries
Multiple stressors – management, understanding

- Warming
- Respiration
- Atmospheric CO$_2$
- +CO$_2$
- Acidification
- Hypoxia/deoxygenation
- -O$_2$
Breitburg et al., in press; data from Maas et al. 2014, Breitburg et al., unpublished

Costa Rica Dome
0-1000 m

Estuarine salt marsh
1 m
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

Oxygen and pH daily cycles

Daylight –
Photosynthesis dominates
+ oxygen, -CO₂
‘Classic’ diel cycling

Oxygen and pH daily cycles

- Oxygen, +CO₂

Dark –
Respiration dominates
Salt marsh Creek
Rhode River, Chesapeake Bay
Strong tidal signal

$R^2 = 0.76$

pH

6.5 6.7 6.9 7.1 7.3 7.5 7.7 7.9 8.1 8.3

DO (mg/L)

0 2 4 6 8 10 12
Tide-dominated pattern: timing of minima vary among days

Dawn - 5:54-5:58

DO (mg/L) vs Time of day

Low Tide
High Tide
Low Tide
High Tide

Dawn

Tide-dominated pattern: timing of minima vary among days.
Dock site
Rhode River, Chesapeake Bay
Mid-day minima

$R^2 = 0.9365$
Stratification on sunny days – Mid-day minima

DO (mg/L) vs Time of Day

- High Tide
- Low Tide

Dawn: 6:10-6:16

8/8/2014, 8/9/2014, 8/10/2014
DO and pH at 2 m continue to decline after dawn.

![Graph showing the decline of DO and pH at 2 m](image-url)
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
LabVIEW program

N$_2$ system, n=3
- LiqN$_2$ with gas removal

CO$_2$ system, n=4
- CO$_2$ MFC

O$_2$ system, n=3
- O$_2$ MFC

Air system,
- Air compressor
- Condensing coil in freezer
- Drip leg to drain condensate
- H$_2$O

Emergency fail open solenoid

Emergency air compressor
- Normally open
- When energized

Oxyguard pH probes
- Durafet pH probes

Trt. 1 Trt. 2 Trt. 3 Trt. 4 Trt. 5
Spar

Emergency fail closed solenoid

Burrell et al., accepted pending revision
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

Infection Intensity (mean of all diseased oysters)

Keppel et al., in review
Juvenile growth cycling down to DO = 0.5, pH = 7.1

Low salinity year
\[ \Omega_{\text{Calcite}} = 0.69 \]

High salinity year
\[ \Omega_{\text{Calcite}} = 1.87 \]

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

Keppel 2014
Low pH slightly increases oyster filtration rates

Clark 2014. 2 way ANOVA then Planar regression
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.