Tell it from the heart: Cardiac responses of Argopecten irradians to diel-cycling hypoxia

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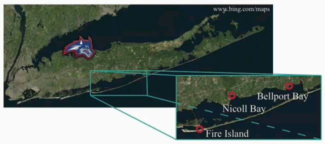

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Introduction

Non-lethal environmental stress may become a significant burden for benthic organisms affecting population growth and reproductive success. Periodic exposure to non-lethal stress may further reduce the ability to cope with acute stress events and thus constitute a precursor of mass mortalities. Due to the proximity to densely populated areas, estuaries are especially susceptible to multiple anthropogenic stressors. Hypoxia occurs when biological oxygen demand outweighs dissolved oxygen supply and is a common seasonal phenomenon in many temperate marine estuaries due to the combined effects of high summer temperatures, eutrophication-driven increased primary productivity and related increased oxygen consumption by respiration. It is clear that extended periods of hypoxia can have detrimental impacts on benthic communities and many efforts have been made to reduce the probability of extended hypoxic and anoxic periods (Diaz and Rosenberg 2008). Much less is known about the sub-lethal consequences of exposure to periodic stress of varied magnitude and frequency. If the repeated exposure to environmental stressors affects individual fitness, it will be critical to define the frequency and magnitude of thresholds that can cause sub-lethal harm to benthic species populations.

Materials

Cardiac activity of the bay scallop *Argopecten irradians* was measured with an infrared heartbeat rate sensing system (Burnett et al. 2013). The infrared sensors were adhered to the outside of shells. Data were recorded with a standalone 8 channel heart-beat amplifier and logger collecting data back-to-back from eight sensors over 1 minute intervals every 10 minutes.

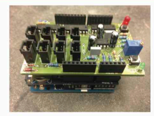
Methods

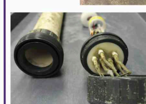
In-situ monitoring:

Cages of *A. irradians* affixed with heart beat monitoring infrared sensors were deployed for ~30 day periods at three south shore locations of Long Island (Fire Island, Nicoll Bay and Bellport Bay) that exhibit different patterns in diel-cycling dissolved oxygen concentrations to analyze the effects of temperature and dissolved oxygen to cardiac activity.

Post *in-situ* experiments:

A. irradians were returned from *in-situ* deployments to laboratory respiration chambers to measure the effects of temperature and oxygen availability to cardiac activity and rate of respiration.
A. irradians were exposed to temperatures between 17-28°C and lethal/sub-lethal durations of anoxia.





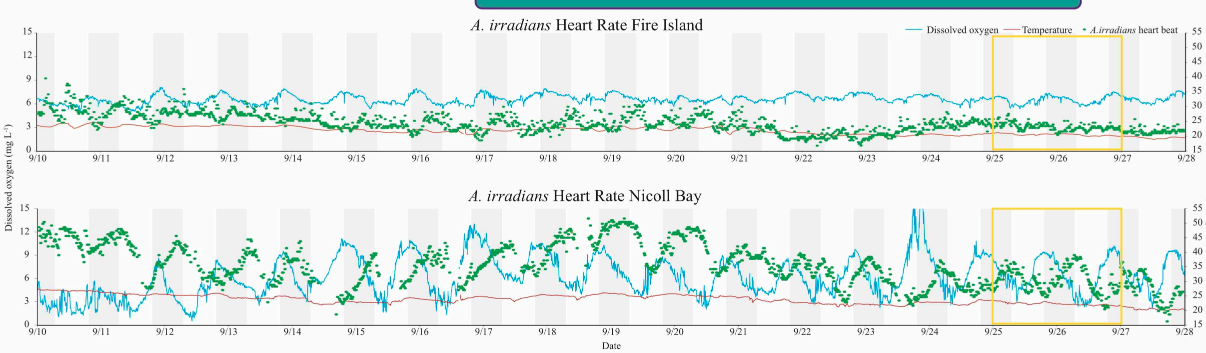
Hypothesis

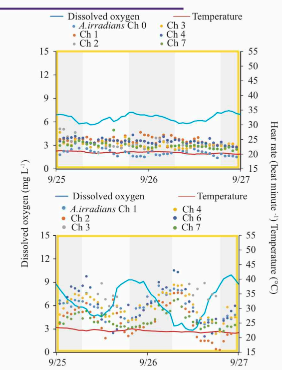
(1) Exposure to dynamic oxygen concentrations affects the metabolic acitivity of *Argopecten irradians*

(2) Periodic exposure to non-lethal stress affects the ability for *Argopecten irradians* to cope with acute stress events

(3) Periodic exposure to non-lethal stress affects the ability for *Argopecten irradians* to recover from short term anoxia

Results: diel cycling hypoxia and *in-situ* heart rate



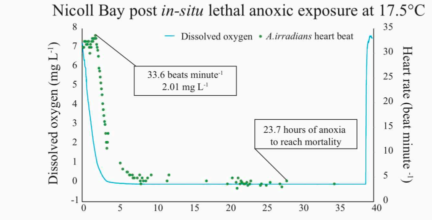


Results: post *in-situ* laboratory experiments

Lethal anoxic exposure

All *A. irradians* reached mortality after 23 - 32 hours of exposure to anoxic conditions. Maximum heart rate of 29.5 ± 3.5 beats minute^{-1} occurred during oxygen decline when concentrations fell to 2.25 ± 0.66 mg L^{-1}.

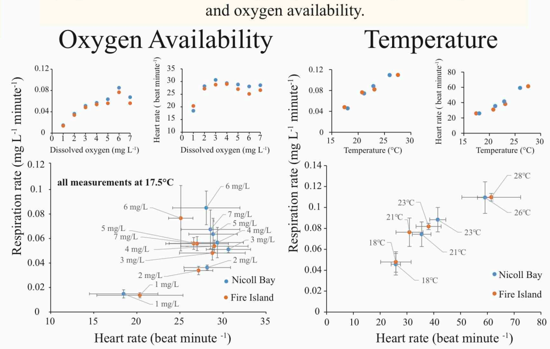
Nicoll Bay post *in-situ* lethal anoxic exposure at 17.5°C



Three *A. irradians* from the Fire Island and Nicoll Bay deployments were exposed to long-term anoxic conditons on arrival to the laboratory. Time of death was determined by the last approved heart rate measurement that proceeded at least three heart rates within the same hour.
Respiration and heart rate data from these trials are displayed in 'oxyen availabiliy'

Respiration trials

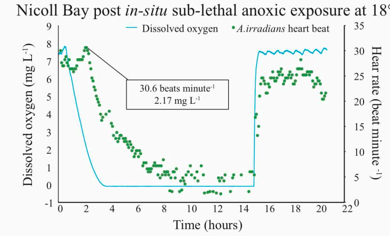
All *A. irradians* expressed similar metabolic (respiration and cardiac activity) responses to changes in temperature and oxygen availability.



Stress recovery

A. irradians can survive and promptly return to basal heart rate after 12 - 14 hours of exposure to anoxic conditions.

Nicoll Bay post *in-situ* sub-lethal anoxic exposure at 18°C



Three *A. irradians* from the Fire Island and Nicoll Bay deployments were exposed to 12 - 14 hours of anoxia to test the metabolic response to short-term stress. Stress recovery trials proceeded the 'temperature' ramp respiration trials.

Conclusions

(1) Exposure to dynamic *in-situ* oxygen concentrations causes maximum cardiac acitivity for *A. irradians* when oxygen concentrations fall below 5 mg L^{-1}. Further oxygen decline below 3 mg L^{-1} causes a decrease in metabolic activity.

(2,3) Exposure to contrasting patterns in diel-cycling hypoxia did not affect *A. irradians*' ability to survive and recover from periods of anoxia.

Future Work

Objective: Develop a thorough approach to measure the dynamic energy budget for *A. irradians* under exposure to multiple synergistic environmental and biological stressors.
Stressors: Hypoxia/anoxia, temperature, disease, acidification
Behavioral measurements: Add magnetic hall effect sensors to measure frequency and duration of valve gape opening as a proxy for active and inactive behaviors under stress events.
Immuno-regulatory response: Measure immune resilience to the syntergistic effects of disease and enviornmental stress by inoculating *A. irradians* with pathogenic algal and viral species.

Acknowledgements

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References

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