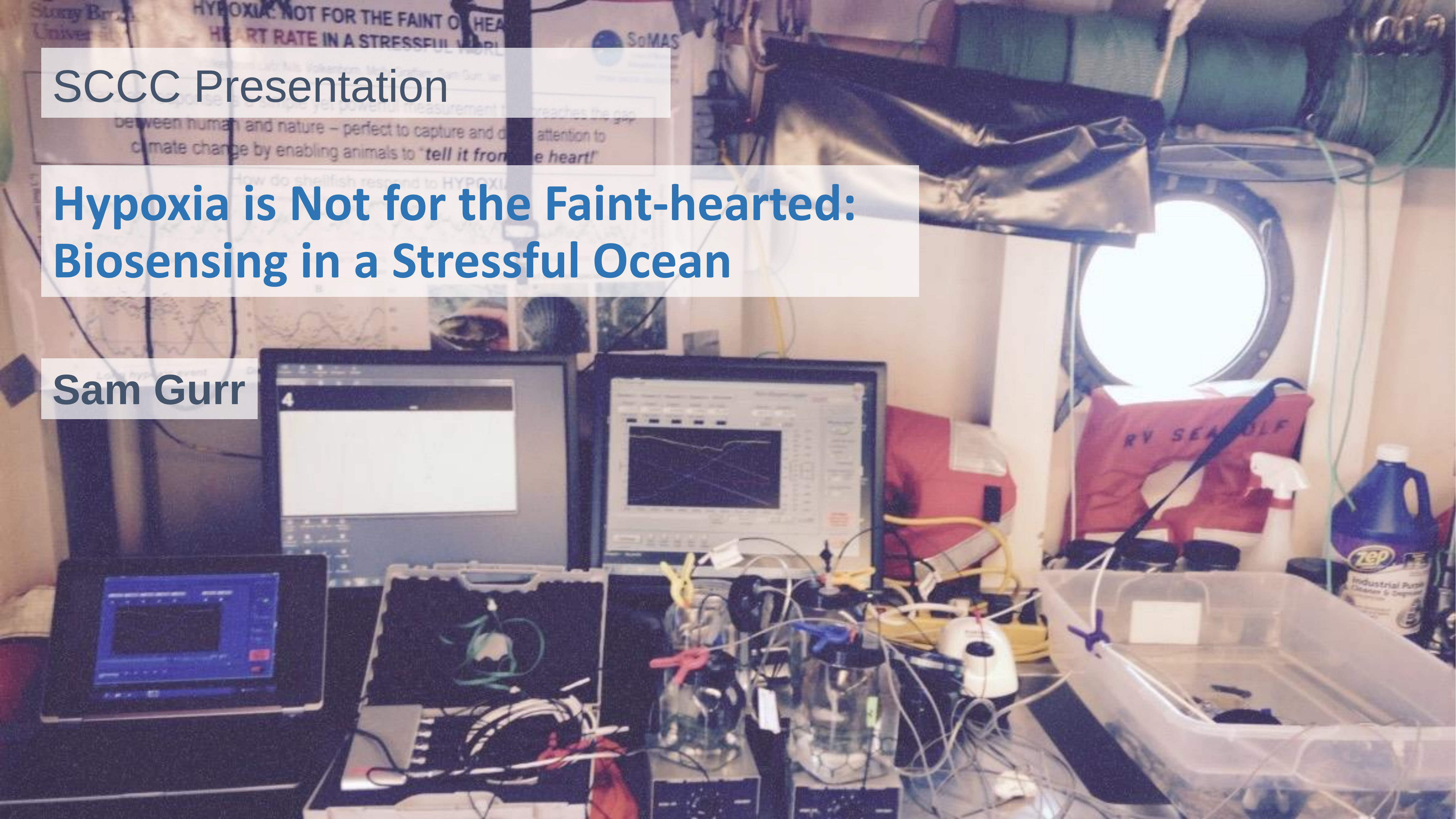
SCCC Presentation

Hypoxia is Not for the Faint-hearted: Biosensing in a Stressful Ocean

Sam Gurr

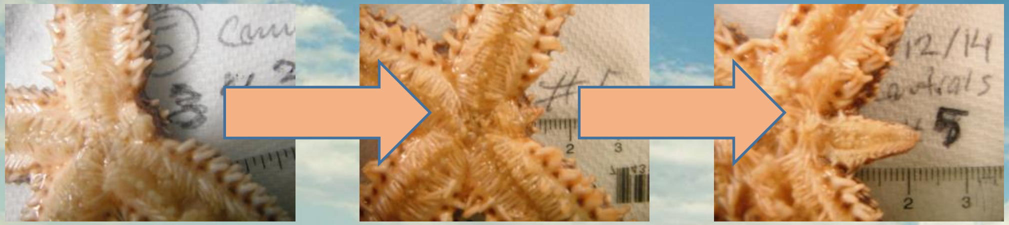



TAXI


SEATTLE

Lighthouse Point
New Haven, CT

UNH
UNIVERSITY OF
NEW HAVEN



Ecophysiology

Stony Brook
University

http://wshu.org/topic/connecticut-news#stream/0

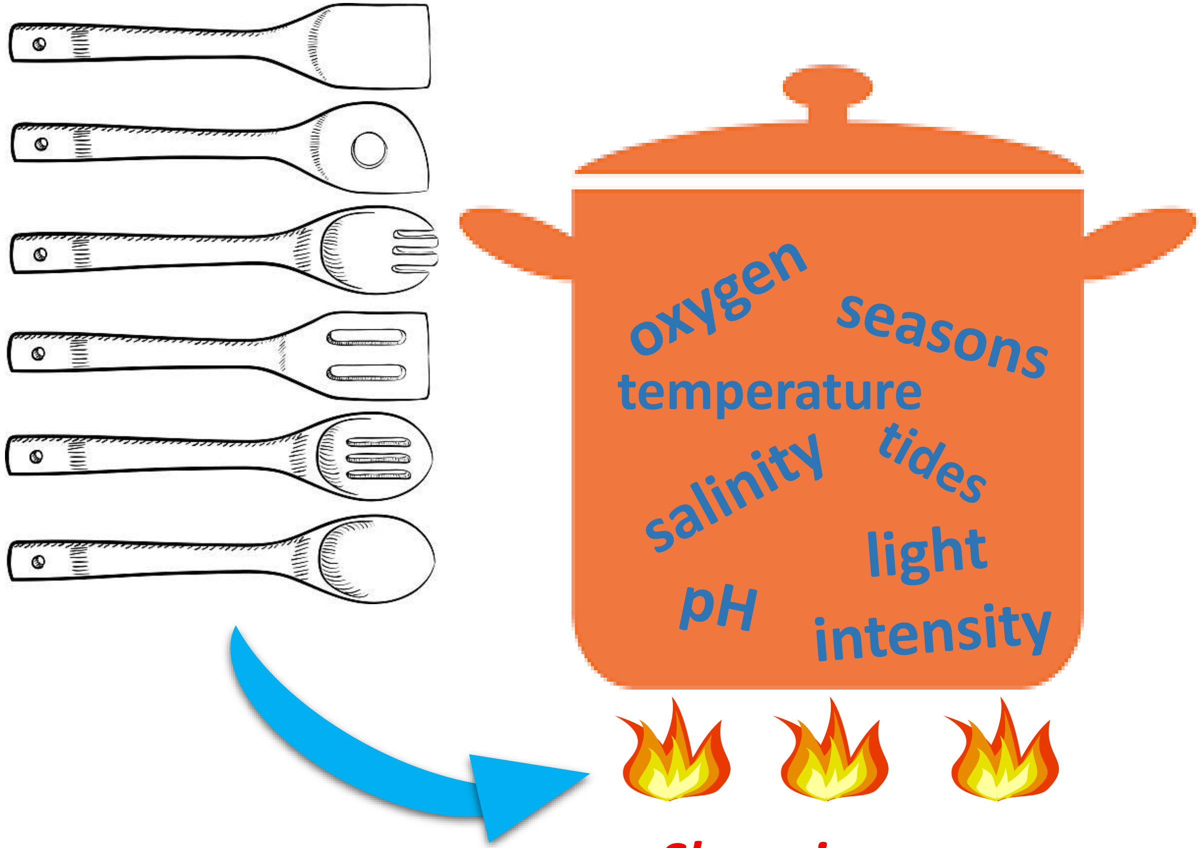
Environmental stressors

- Disturbances in the environment force life to adapt and cope

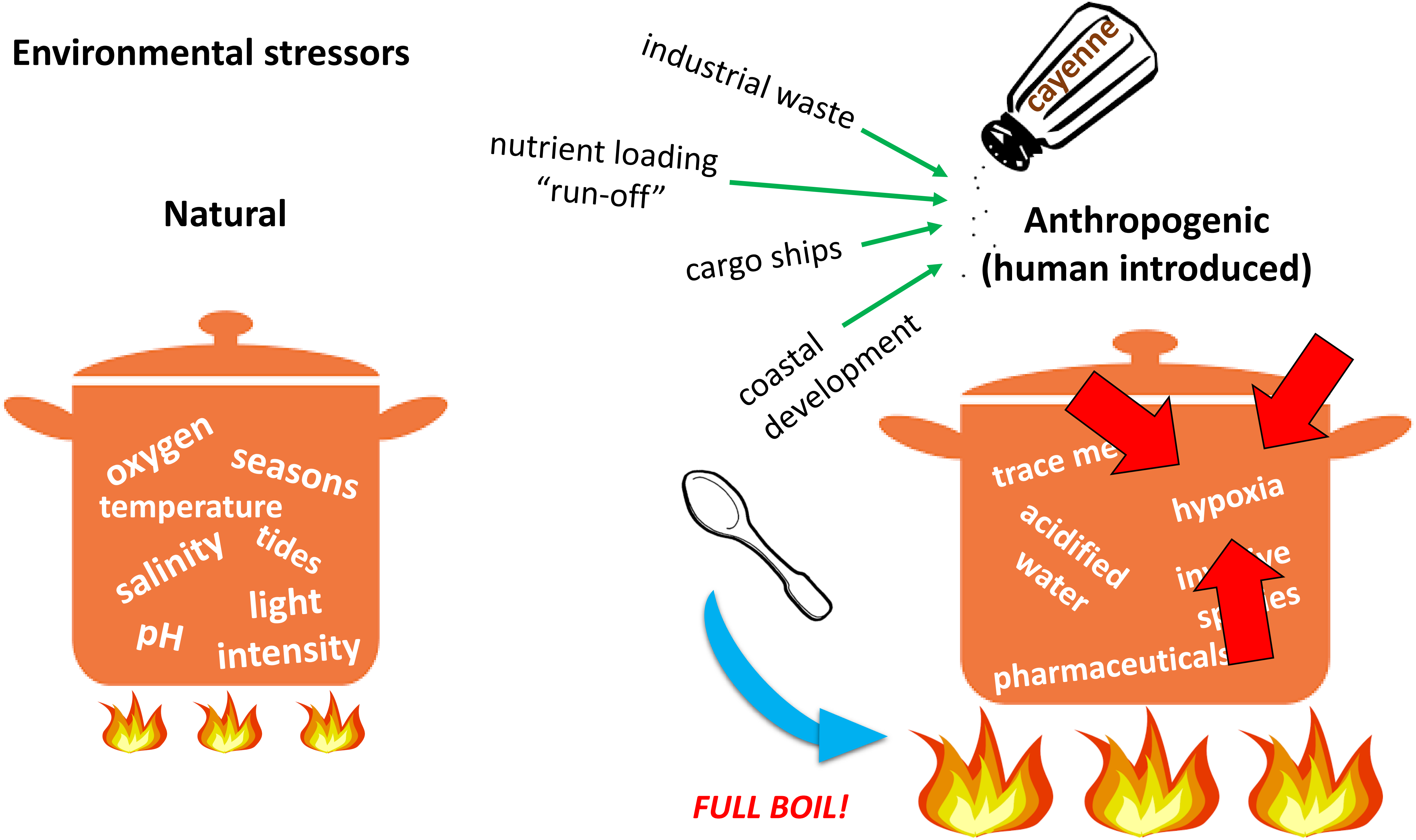
…eventually they find their niche

" Tools" of resilience

Natural



Slow simmer..

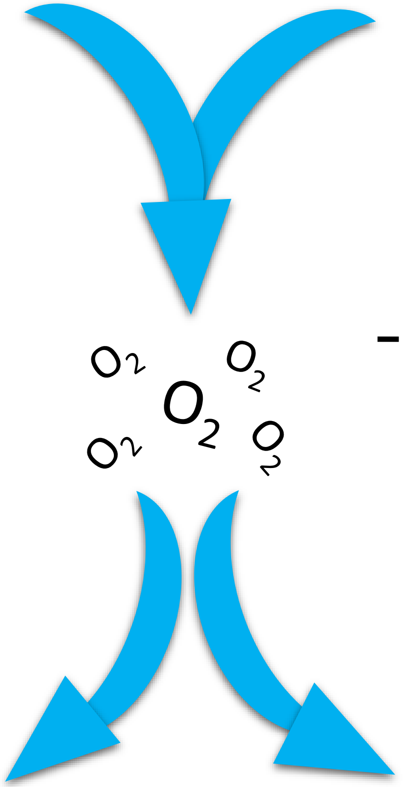

Environmental stressors
Natural
oxygen
seasons
temperature
salinity
tides
light
pH
intensity
industrial waste
nutrient loading
"run-off"
cargo ships
coastal
development
cayenne
Anthropogenic
(human introduced)
trace me
hypoxia
acidified
water
pharmaceuticals
FULL BOIL!

Hypoxia Recipe: Oxygen is the main ingredient

Supply

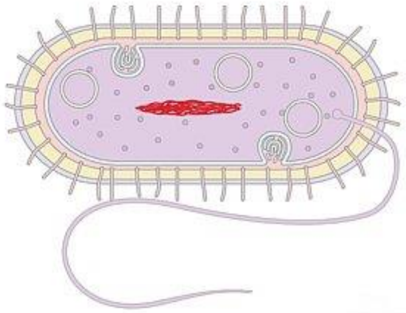
- Diffusion
- Surface agitation (waves)
- Rivers & streams

Photosynthesis



Respiration

Bacteria!

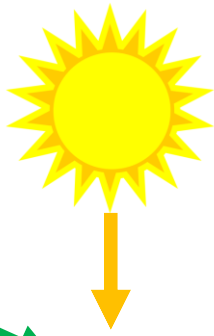


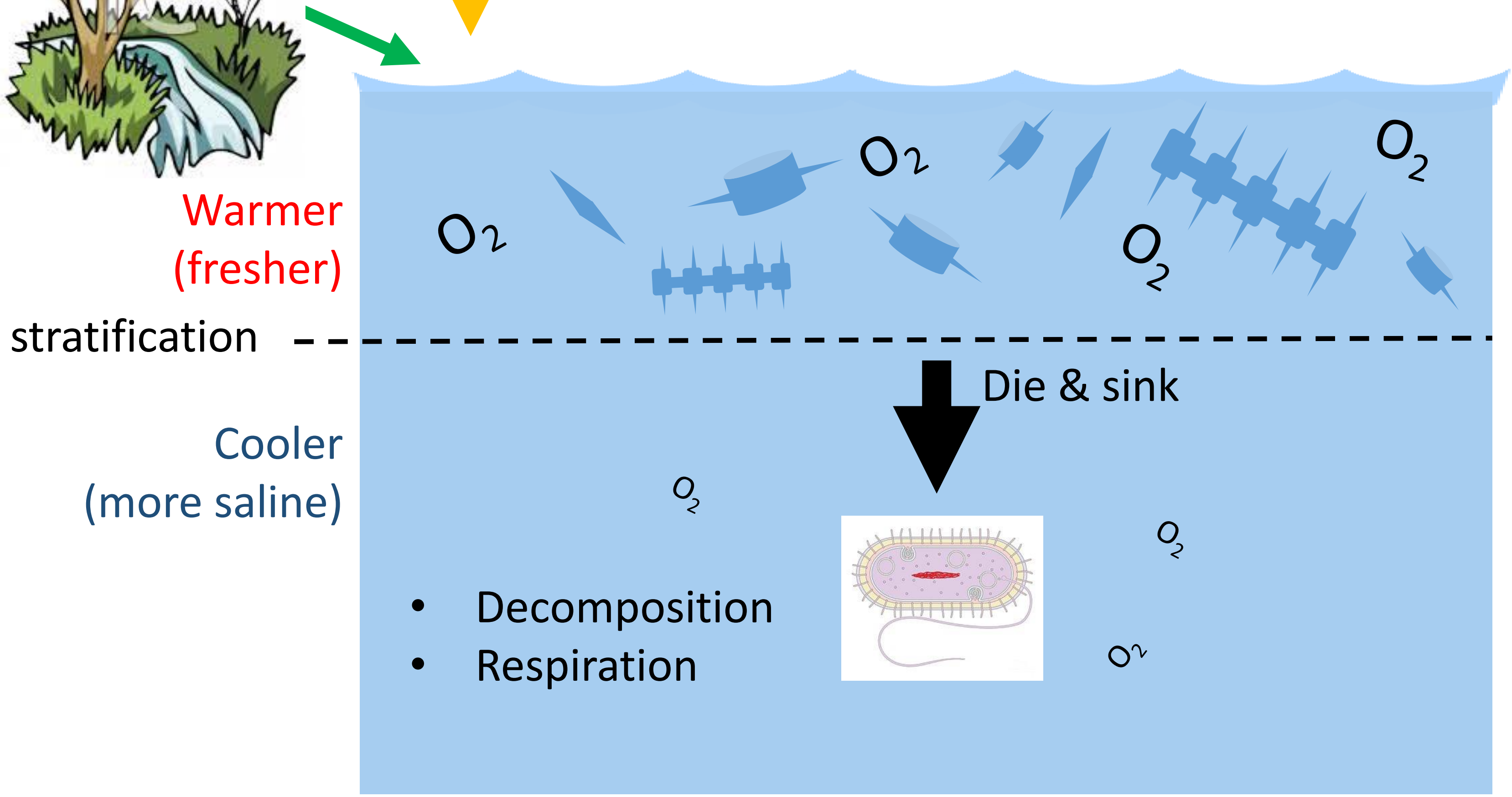
Demand

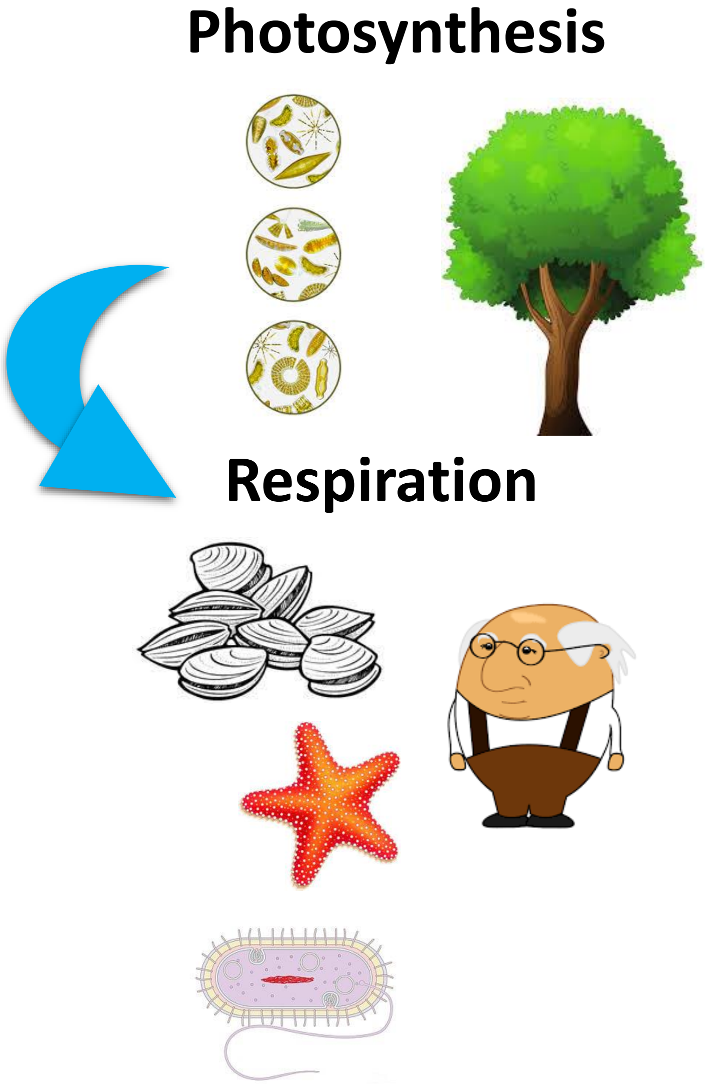
Hypoxia Recipe: Location & season!

Coastal enclosed estuaries in summer = most susceptible!

- Increase light intensity & water temperature
- Nutrients (run-off, pollutants, etc.)





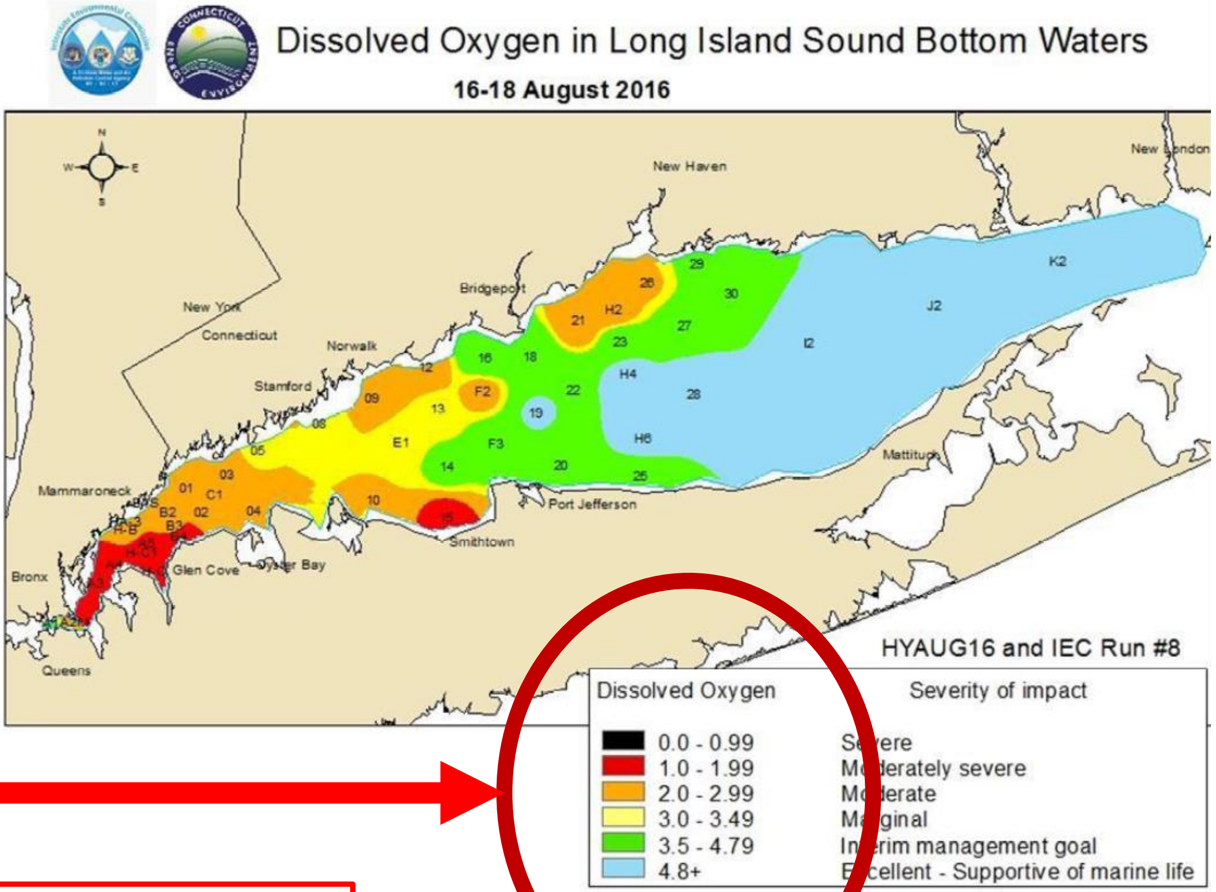


The stressor: Hypoxia

Hypoxia

- Low dissolved oxygen (DO)

<u>demand > supply</u>



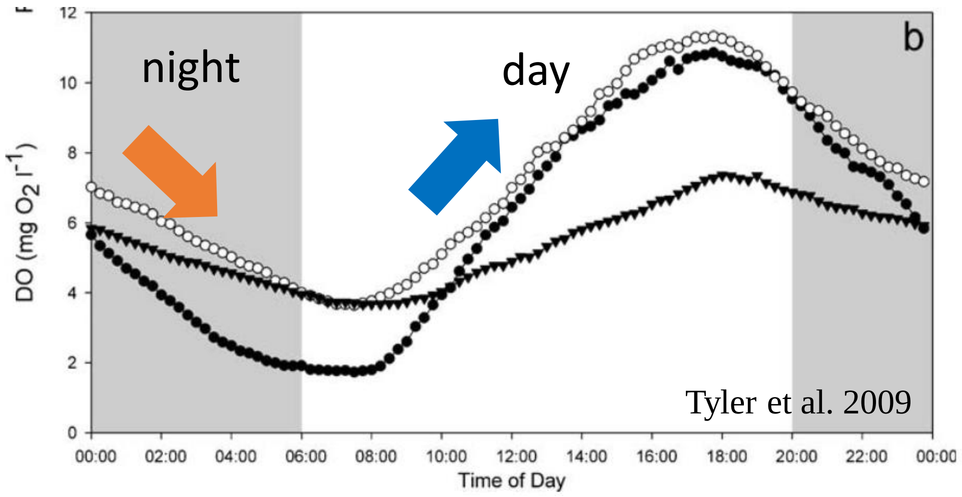
Thresholds of “marginal”, “moderate”, “severe”

Average oxygen concentration ***<u>only tells part of the the story</u>***

The stressor: Hypoxia

Respiration
(D > S)

Photosynthesis
(D < S)



Hypoxia

- Low dissolved oxygen (DO)

  demand > supply

Diel-cycling hypoxia

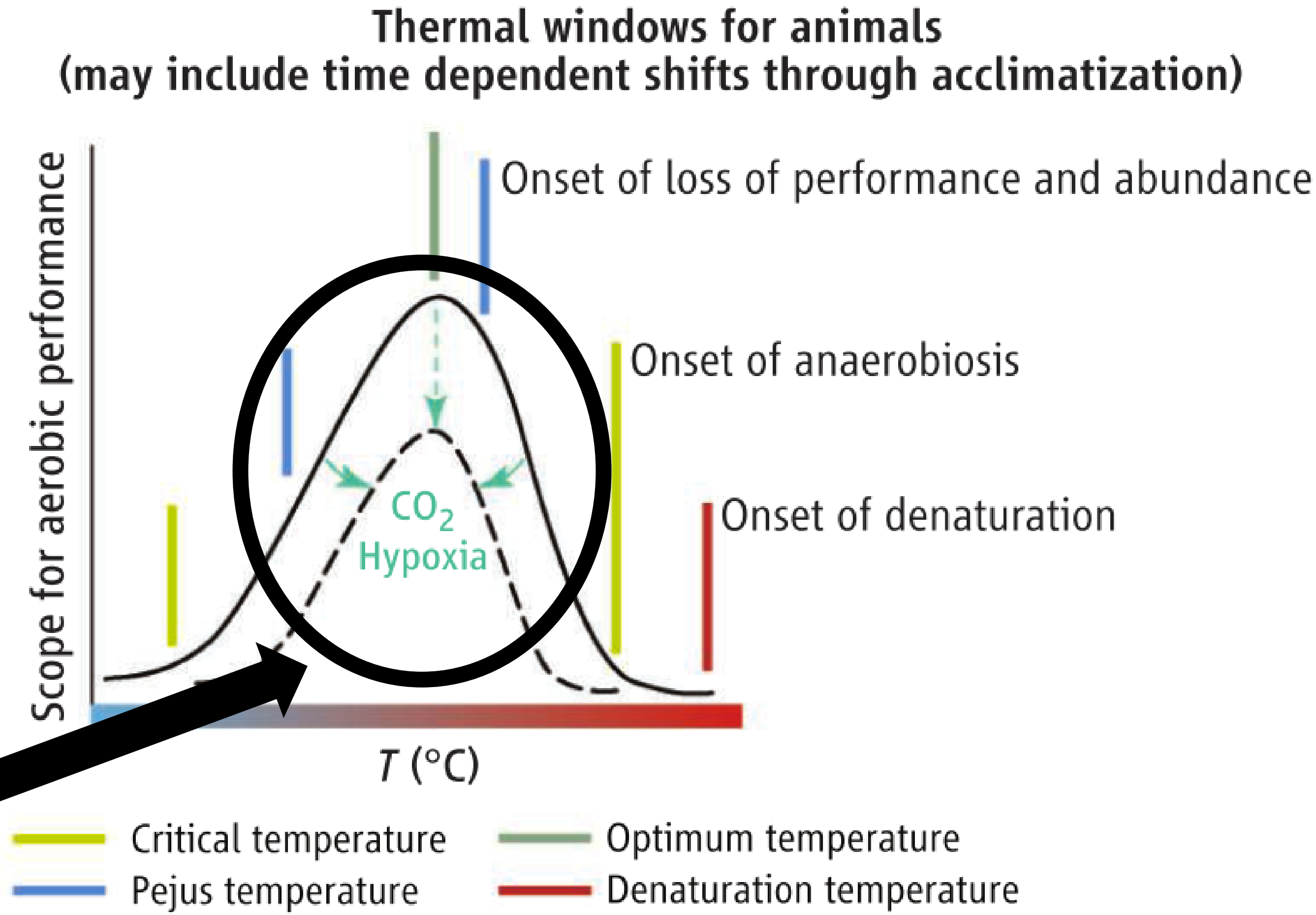
- Varies on a seasonal and **daily** time scale

Common effects of diel-cycling hypoxia

- mass mortality
- growth, calcification
- behavior
- early life stage development
- calcification
- immunoregulatory response

LIMITATION!
long time scales

Optimal "windows" for animals



This window can be **narrowed**
by environmental stressors

In other words…
Goldie locks gets <u>*even more*</u> picky

Pörtner and Farrell, 2008

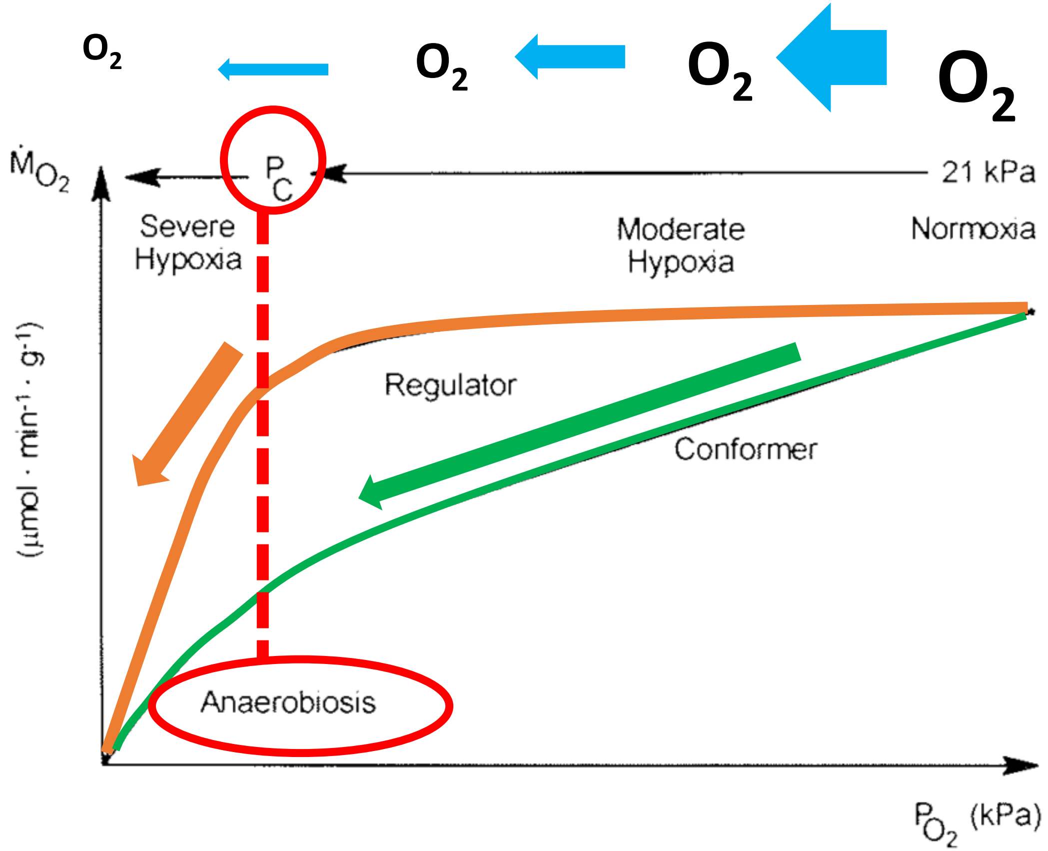
Respiration rate of marine invertebrates

Conformer VS **Regulator**

Conformer
- Linear dependence on oxygen availability

Regulator
- Non-linear response
- Hits a clear transition

Anaerobic metabolism
LESS or even NO OXYGEN UPTAKE!



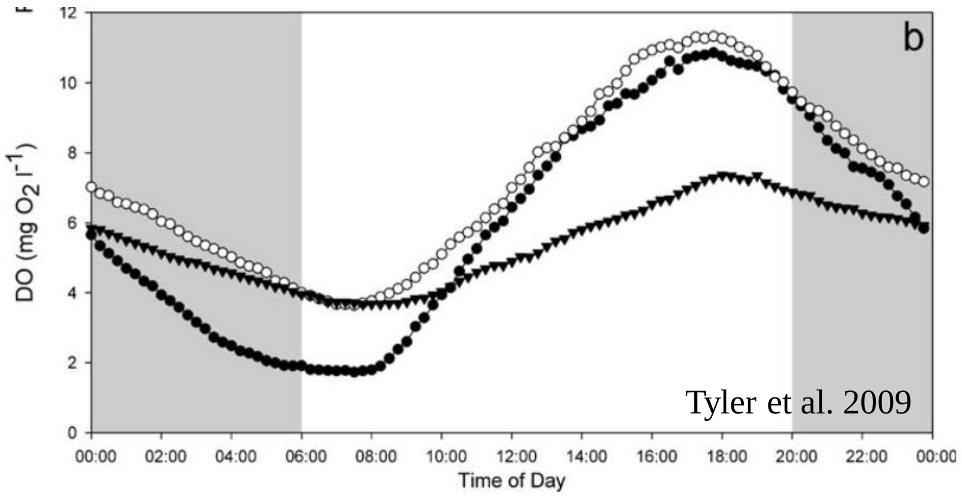
Less efficient + high energy cost = decrease in **growth, reproduction**, and **survival**

Greishaber et al. 1994

Rational

To understand and identify effects of
dynamic environmental stressors…

Need a dynamic response!!!



Heartbeat rate

Non-invasive
Infrared
sensors

Important **sub-lethal** physiological implications for whole animal metabolism

Rational

To understand and identify effects of ***dynamic environmental stressors***…

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Heartbeat rate

Non-invasive Infrared sensors

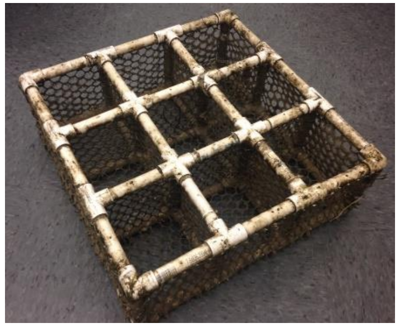
Common effects of diel-cycling hypoxia

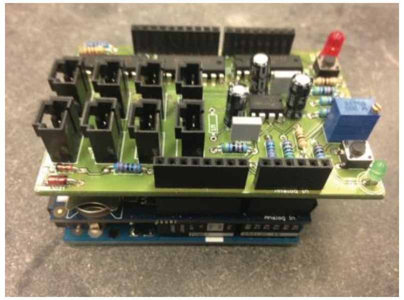
- mass mortality
- growth, calcification
- behavior
- early life stage development
- calcification
- immunoregulatory response

Important **sub-lethal** physiological implications for whole animal metabolism

Methods

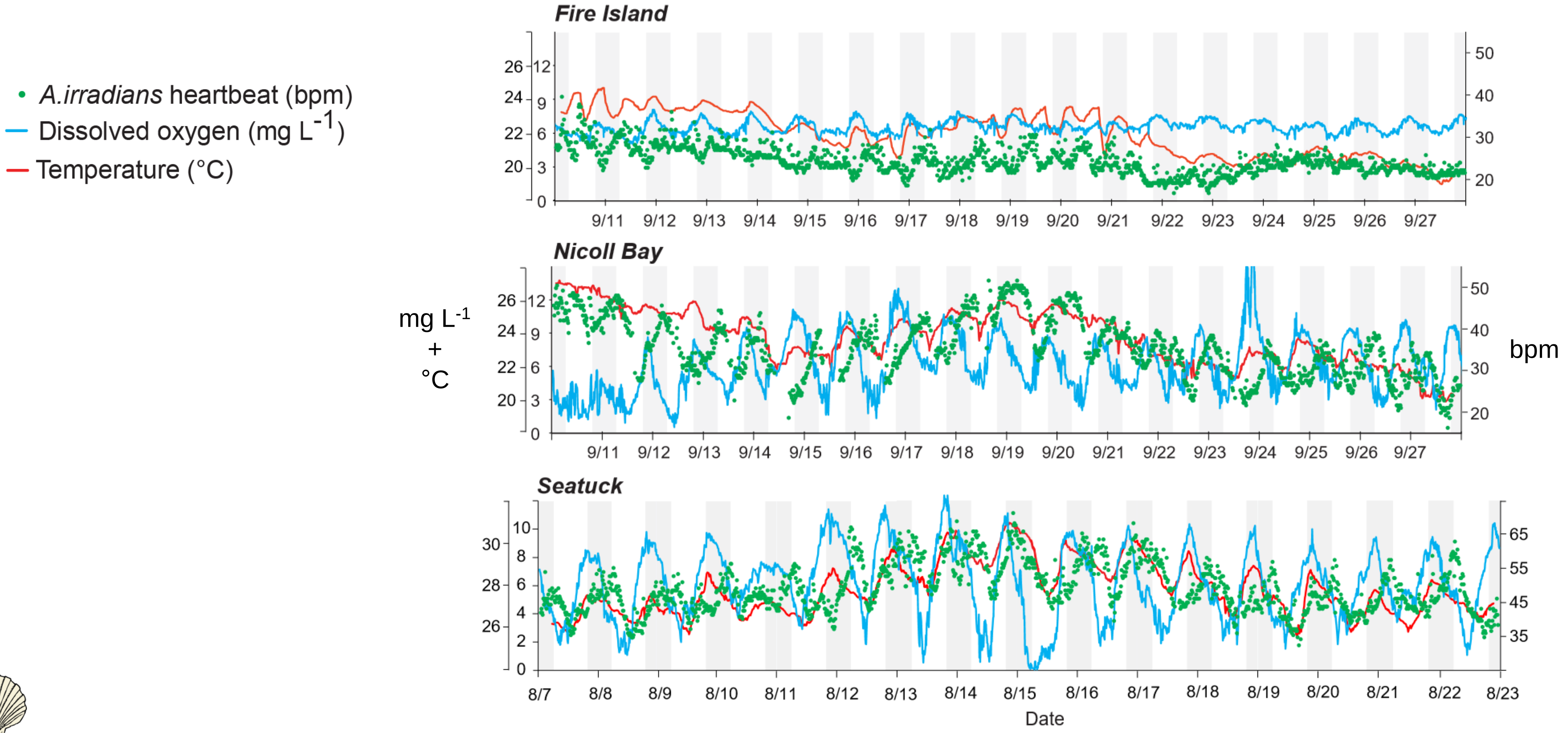
Bay scallops (*Argopecten irradians*) alter cardiac activity under exposure to *in-situ* diel-cycling dissolved oxygen



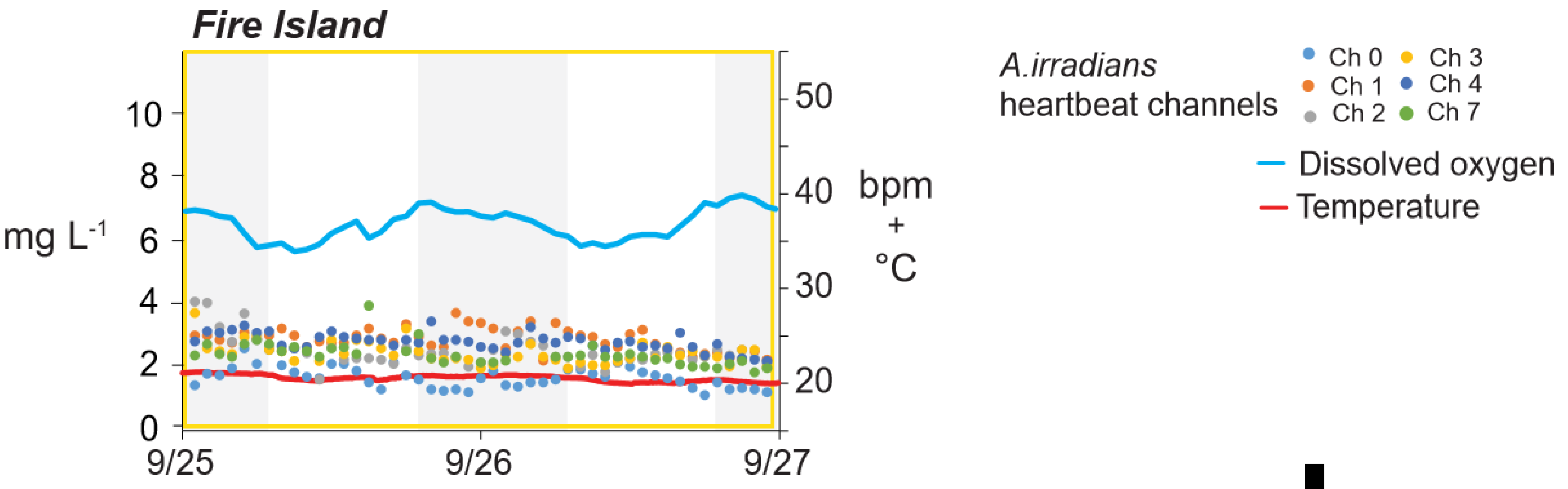


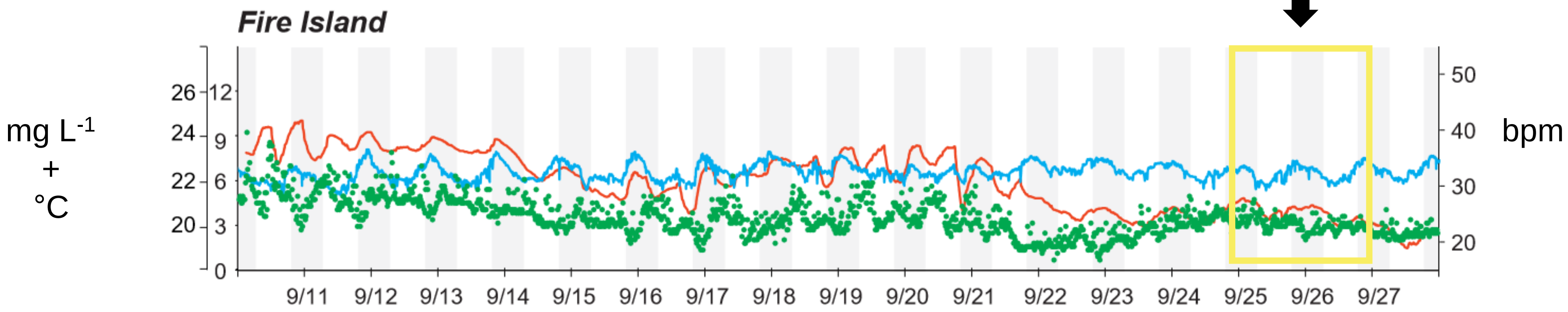

- 8 *A. irradians* per site
- 60 seconds of heartbeat data for each individual, cycle **repeated every 10 minutes**
- Dissolved oxygen and temperature recorded every 15 minutes with dockside sensors

In-situ Heartbeat Deployments



In-situ Cardiac Activity: **Normoxic VS. Hypoxic conditions**

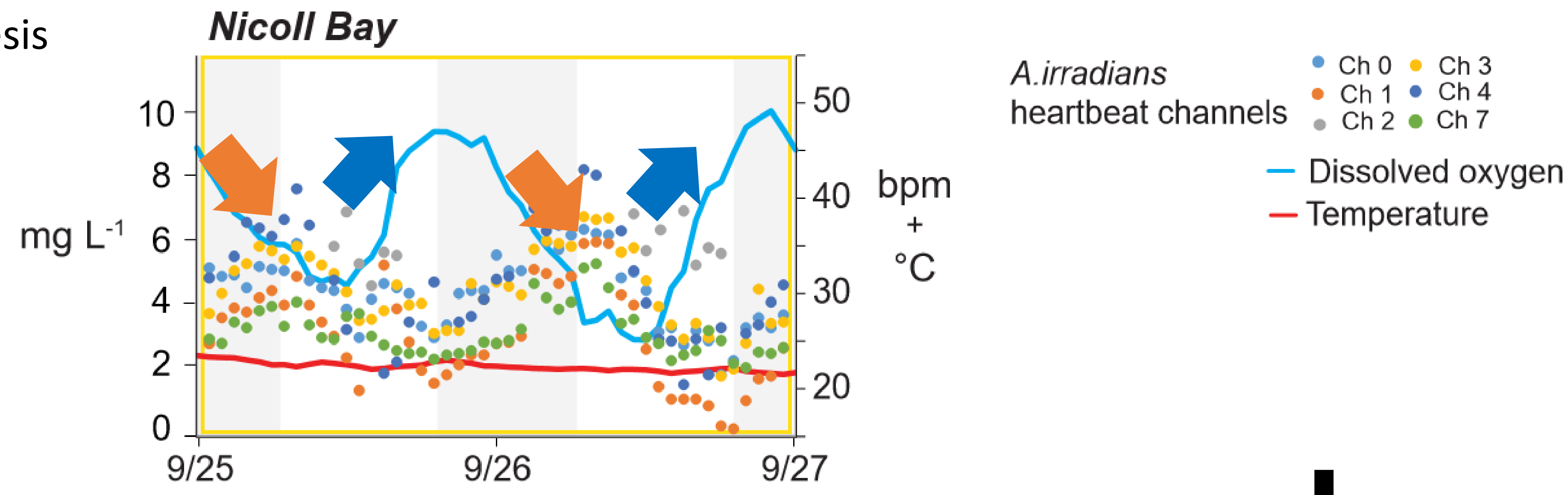




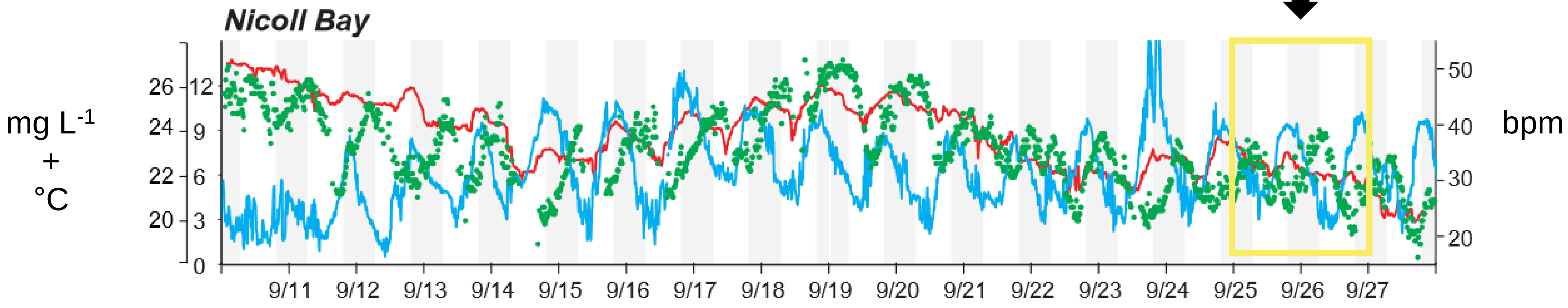
In-situ Cardiac Activity: **Normoxic VS. Hypoxic conditions**

Photosynthesis

Respiration

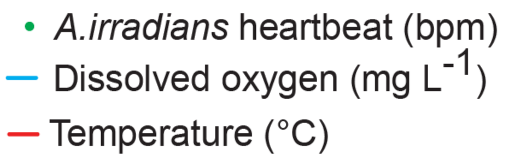


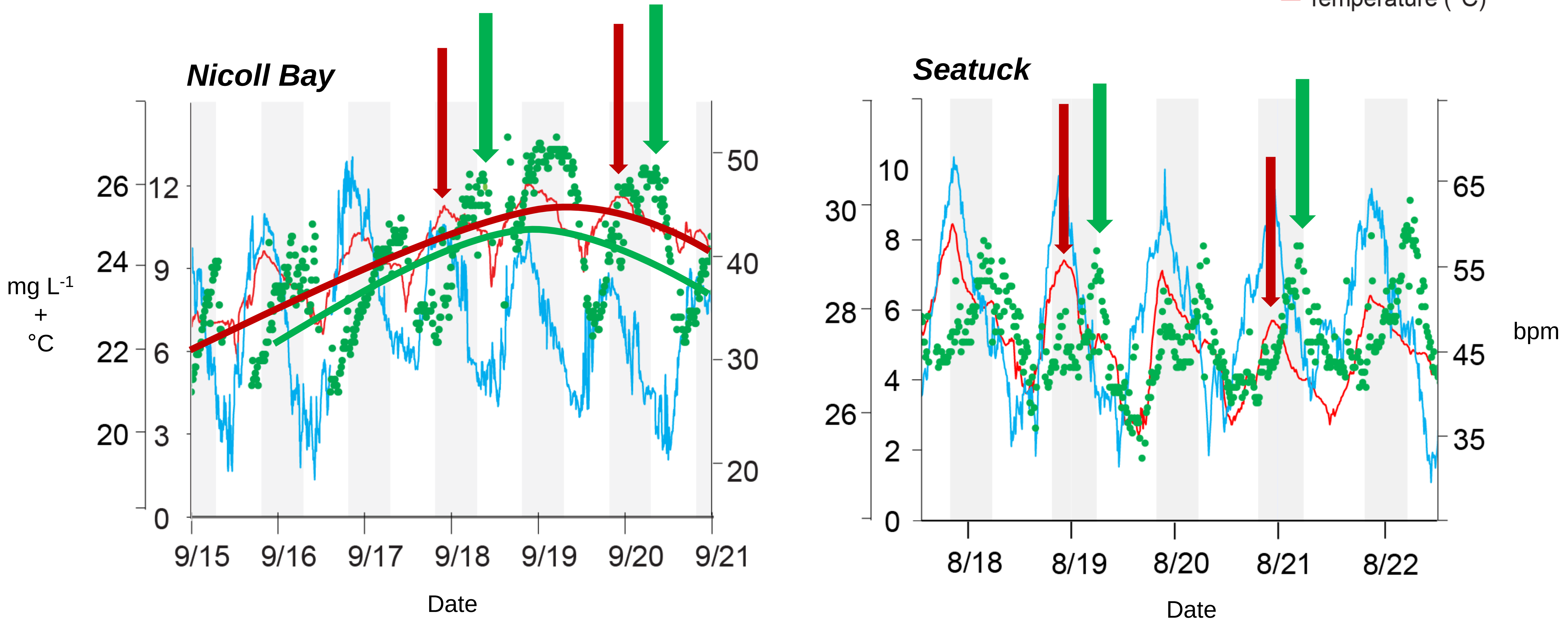
- **Heartbeat rate**: dynamic daily range of 20 bpm



In-situ Cardiac Activity: **Diel-cycling hypoxia**

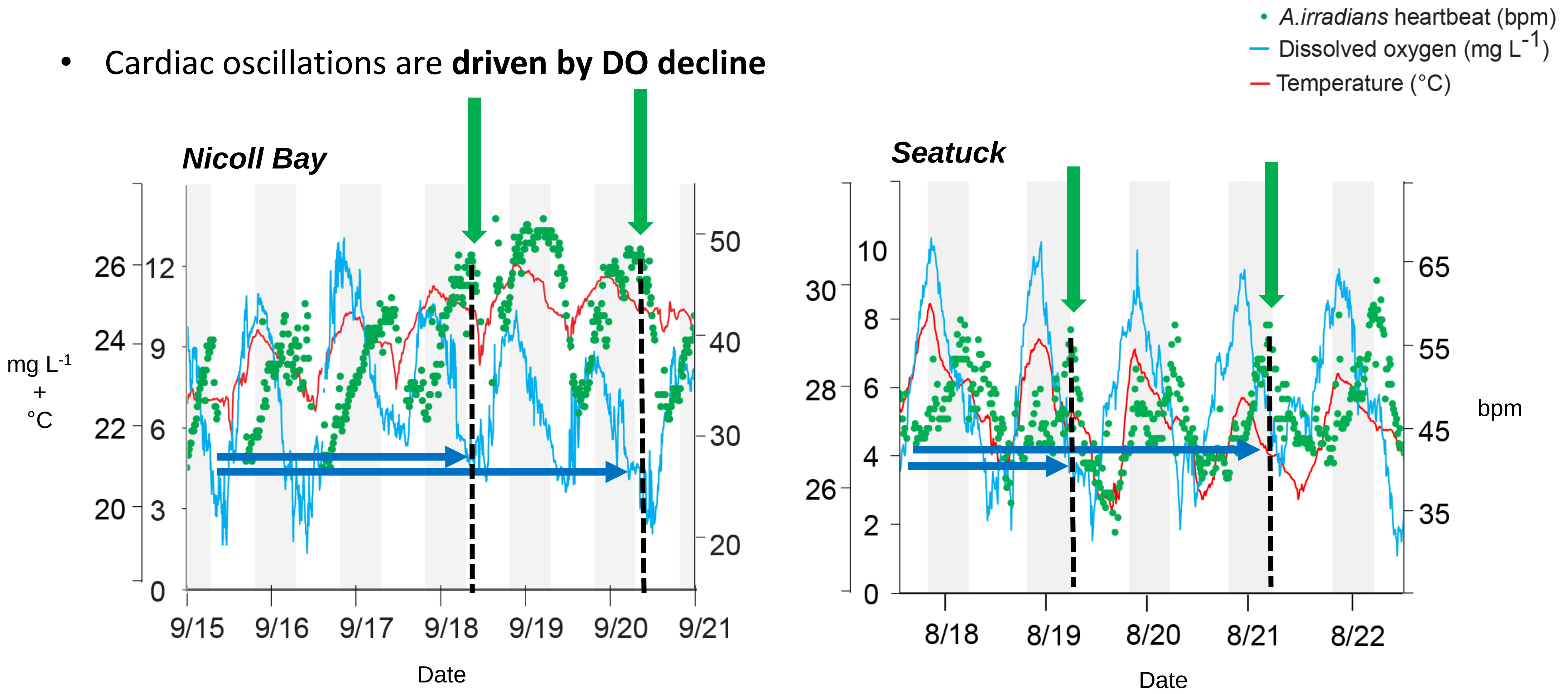
- Daily oscillations of activity are **not temperature driven**





In-situ Cardiac Activity: **Diel-cycling hypoxia**

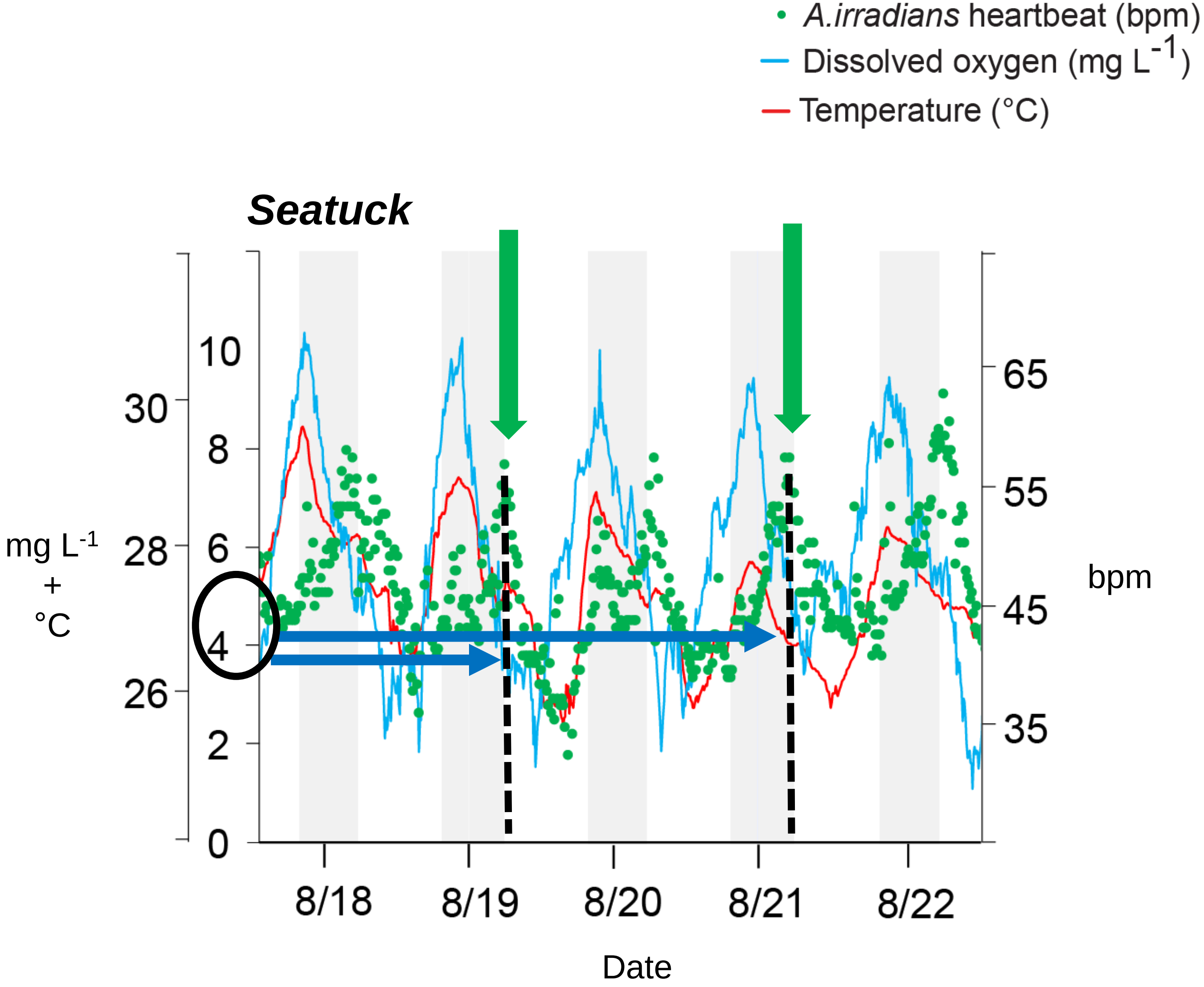
- Cardiac oscillations are **driven by DO decline**



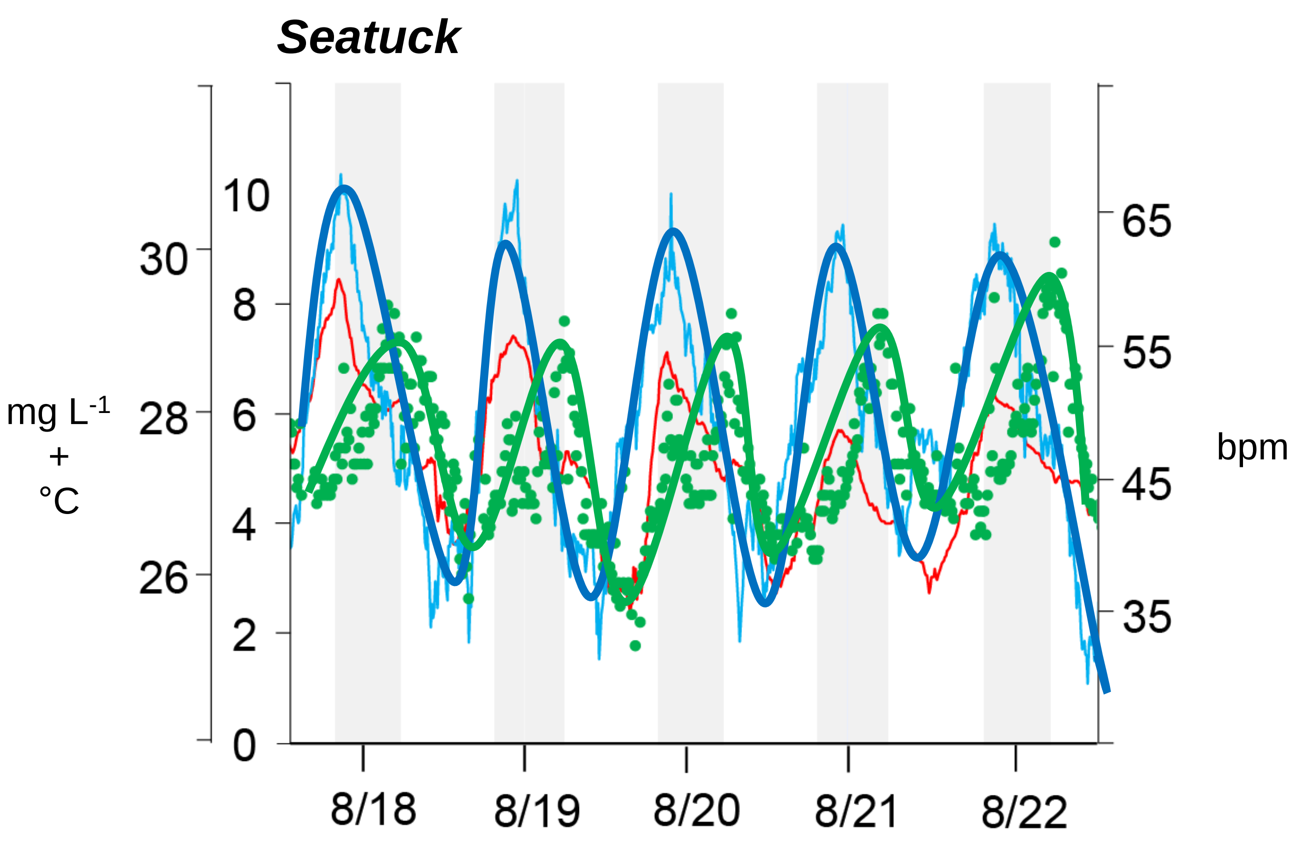
In-situ Cardiac Activity: **Diel-cycling hypoxia**

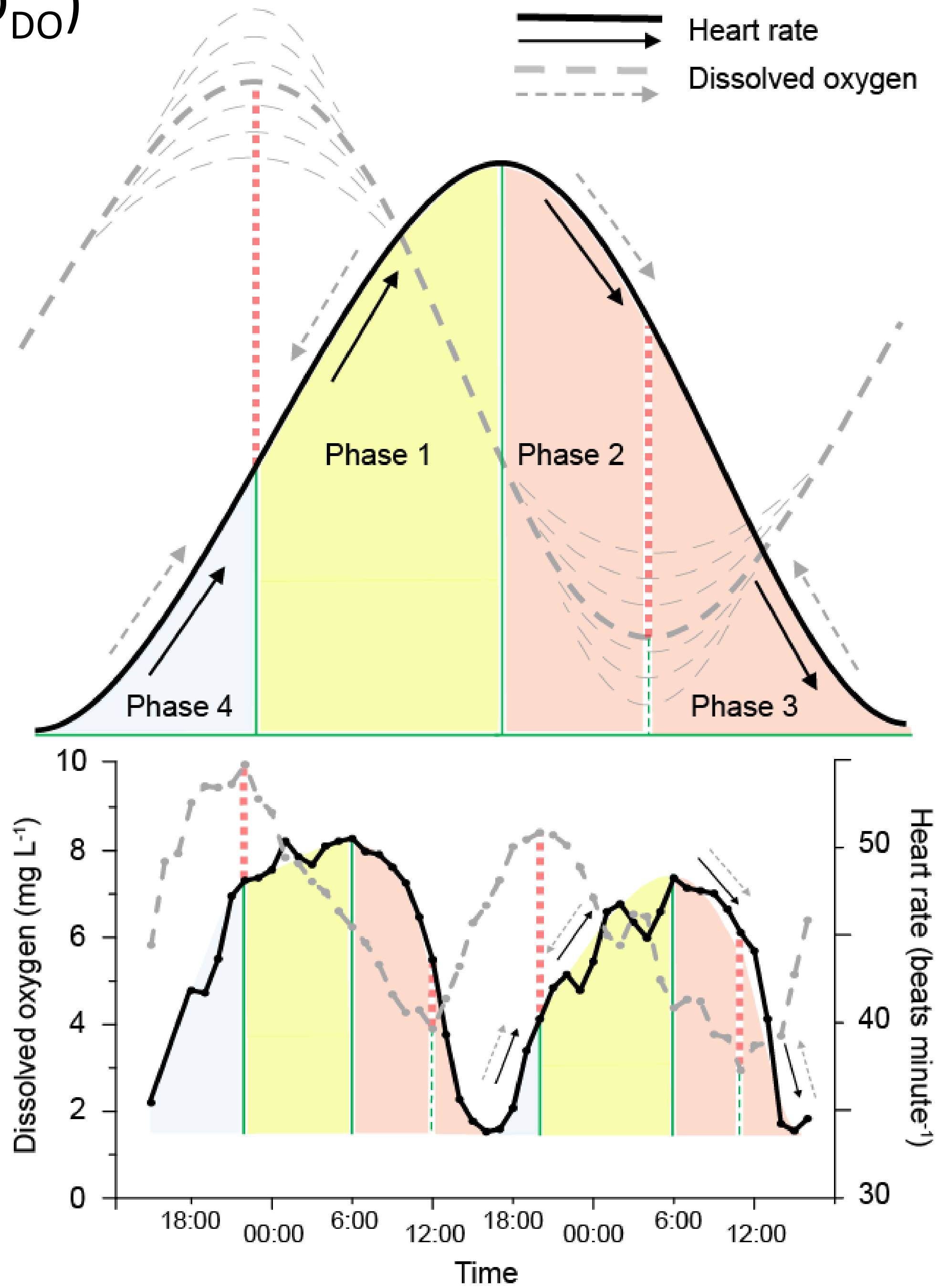
- Cardiac activity always peaked when DO decline to **5 mg L^{-1}** during early to late mornings

- Evidence of a potential onset of:
  - decline of aerobic function
  - transition to anaerobic metabolism



Cardiac response of diel-cycling dissolved oxygen (CRD_{DO})





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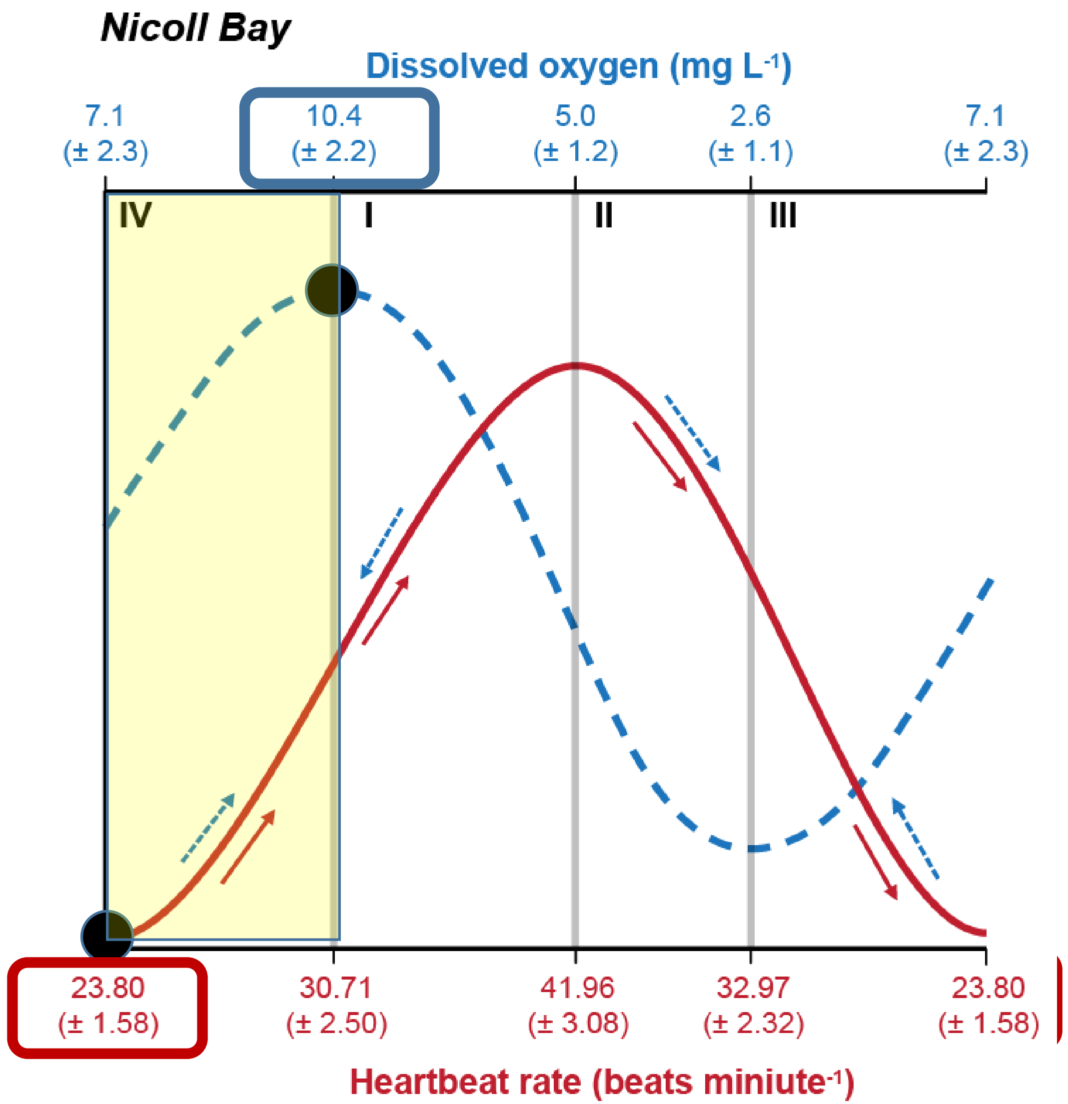
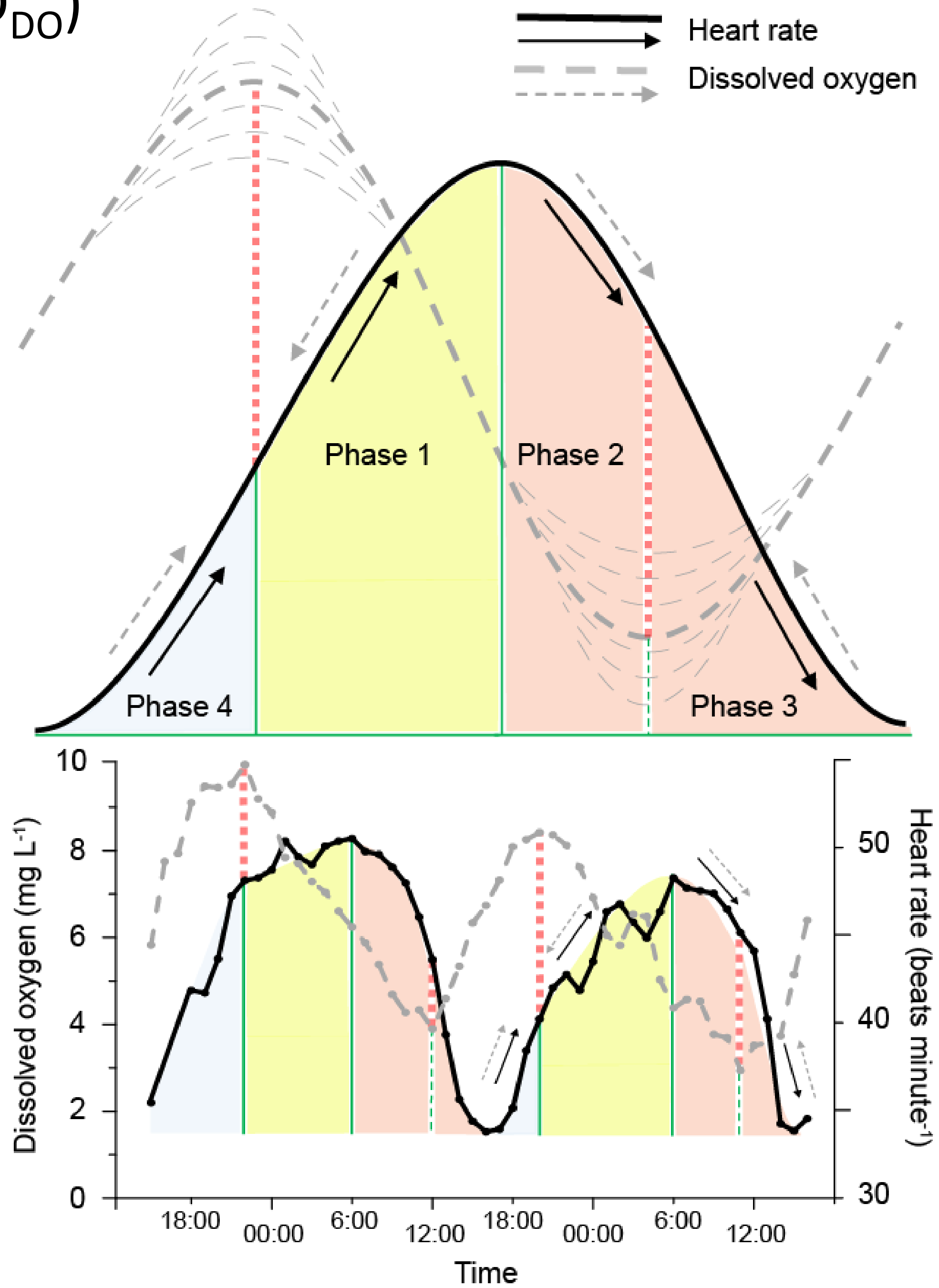




Cardiac response of diel-cycling dissolved oxygen (CRD_{DO})

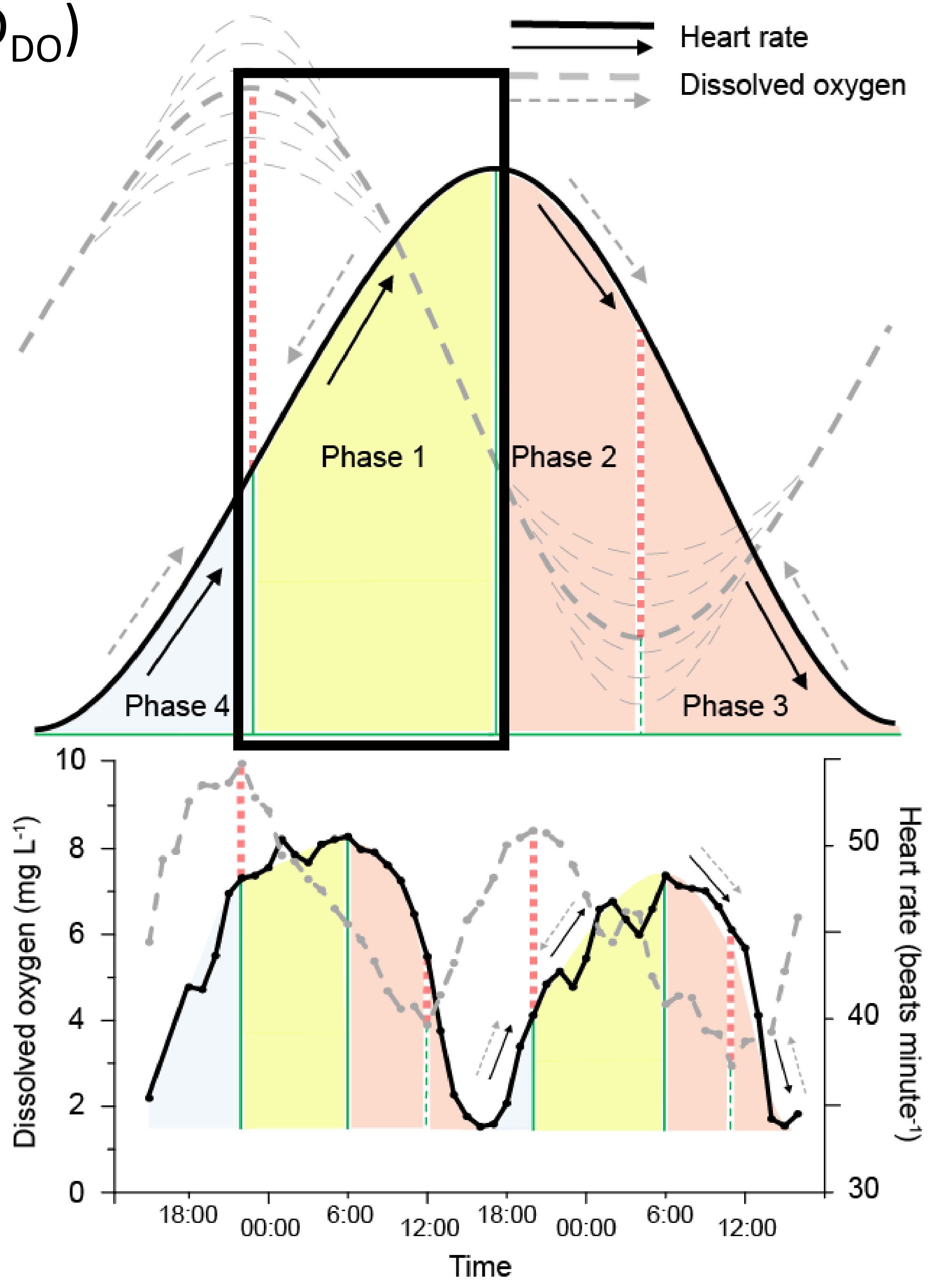
Phase 1 Heartbeat rate Dissolved oxygen

<u>Regulator</u> response

- maintain oxygen uptake and aerobic metabolism as DO becomes less available

Heartbeat rate change: +10 bpm

Duration: 8 – 10 hours (longest phase)



Cardiac response of diel-cycling dissolved oxygen (CRD_{DO})

Phase 2

Heartbeat rate

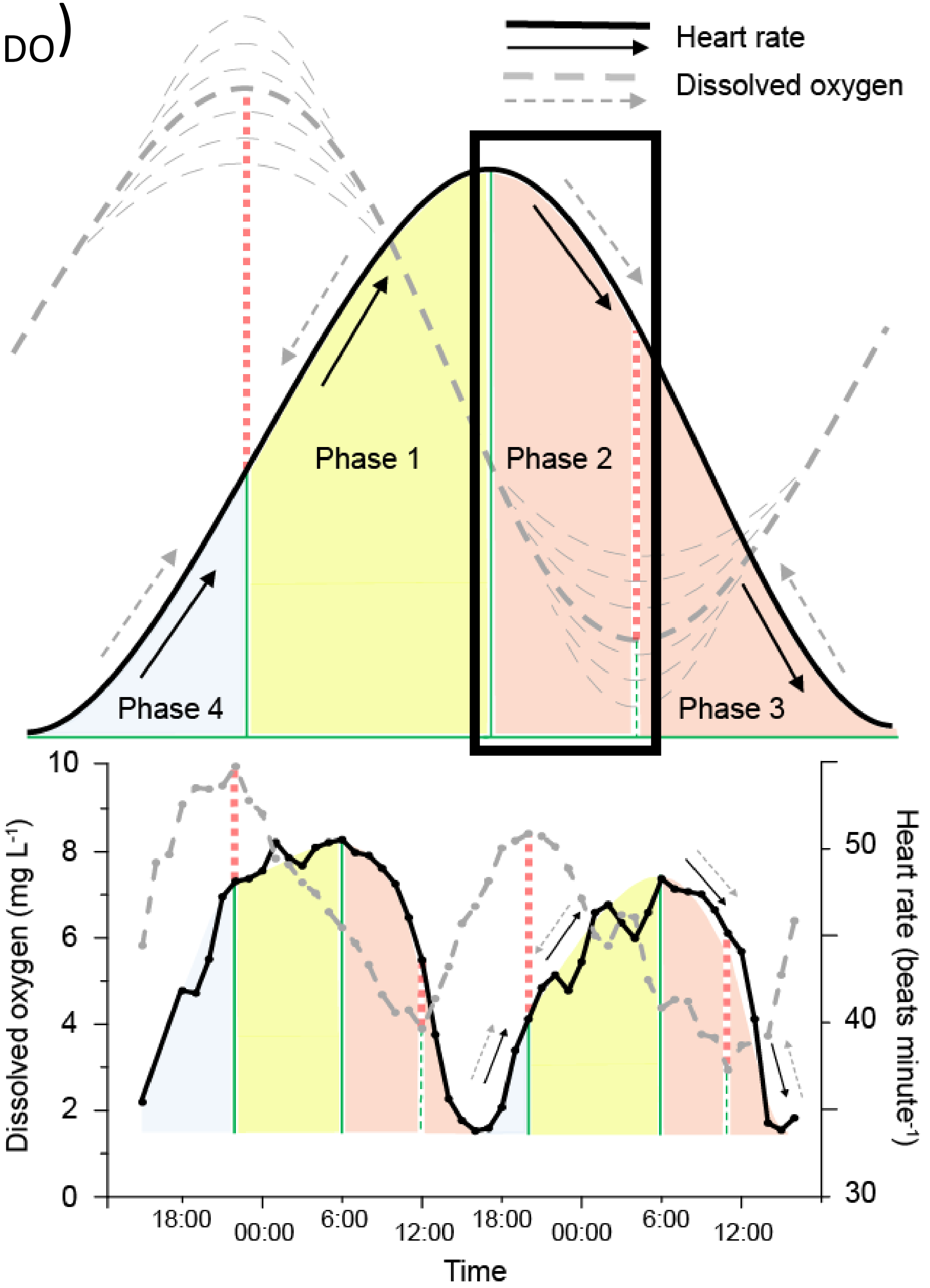
Dissolved oxygen

Transition to a **<u>conformer</u>** response

- **Peak heartbeat rate at 5 mg L^{-1}**
- May indicate an initiation of anaerobic metabolism

Heartbeat rate change: -10 bpm

Duration: 4 – 4.5 hours (shortest phase)



Cardiac response of diel-cycling dissolved oxygen (CRD_{DO})

Phase 3

Heartbeat rate

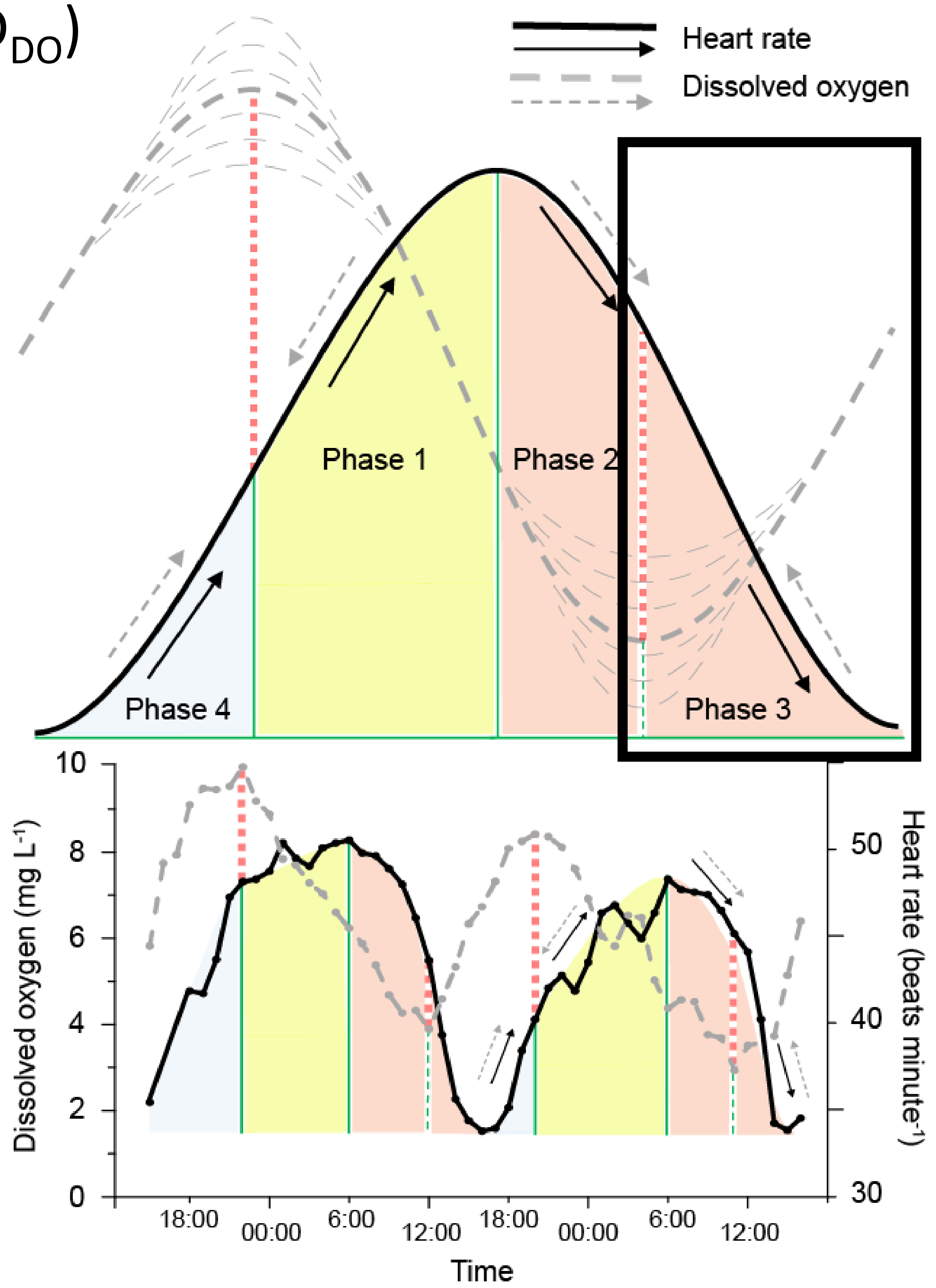
Dissolved oxygen

"Stress and rest" (still a **conformer** response)

- Cardiac activity continues to decline to a minimum rate although DO increases
- **Minimum heartbeat rate at 5 – 7 mg L^{-1}**

Heartbeat rate change: -10 bpm

Duration: 5 – 6 hours



Cardiac response of diel-cycling dissolved oxygen (CRD_{DO})

Phase 2 & 3

40 % each day

under anaerobic metabolism

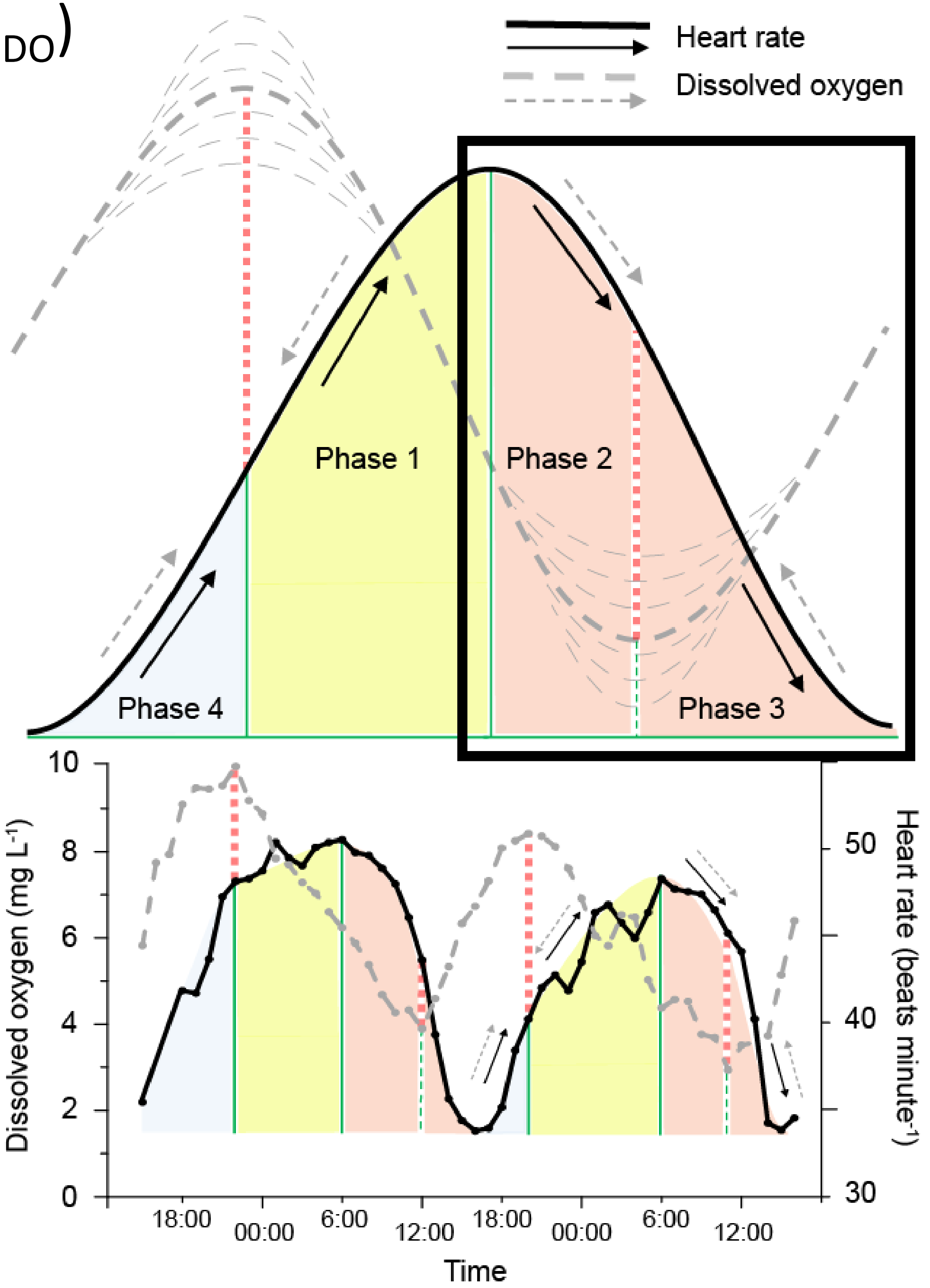
Does repeated exposure affect…

-Growth

-Reproduction

-Survival

?



Cardiac response of diel-cycling dissolved oxygen (CRD_{DO})

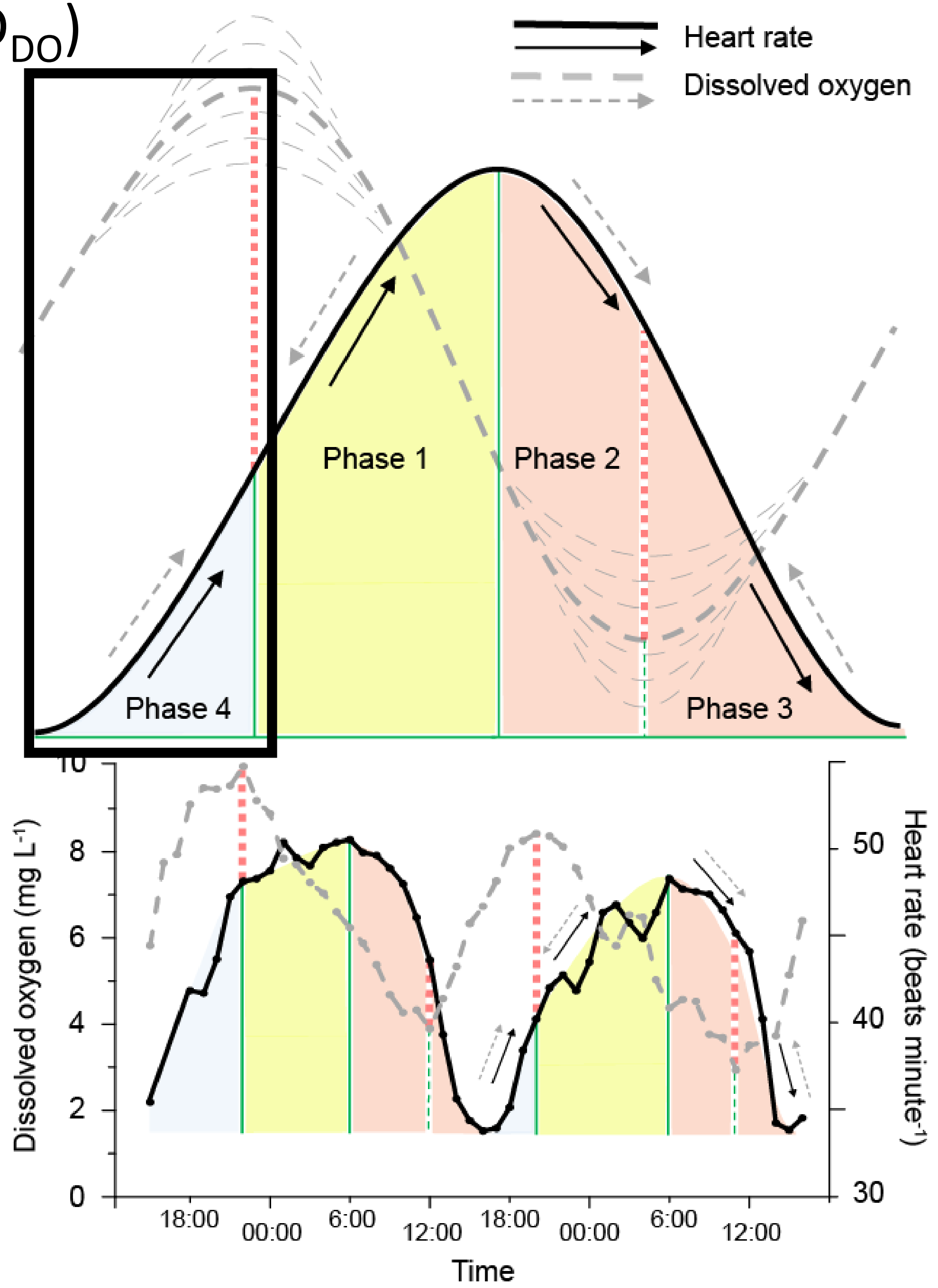
Phase 4 Heartbeat rate Dissolved oxygen

Cardiac and aerobic <u>recovery</u>

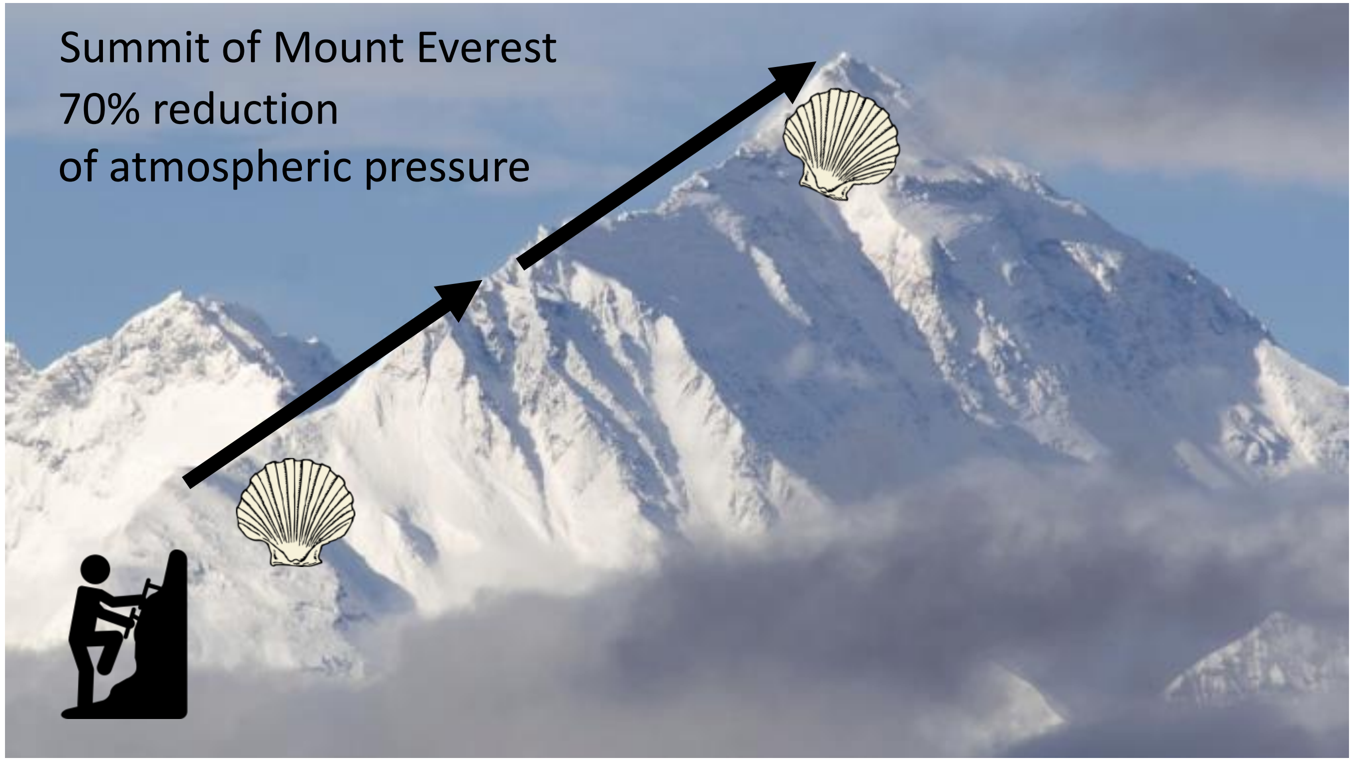
- Only phase when both heartbeat rate and DO **increase**
- Suggests an initial effort to restore aerobic function to "normal" heartbeat rates

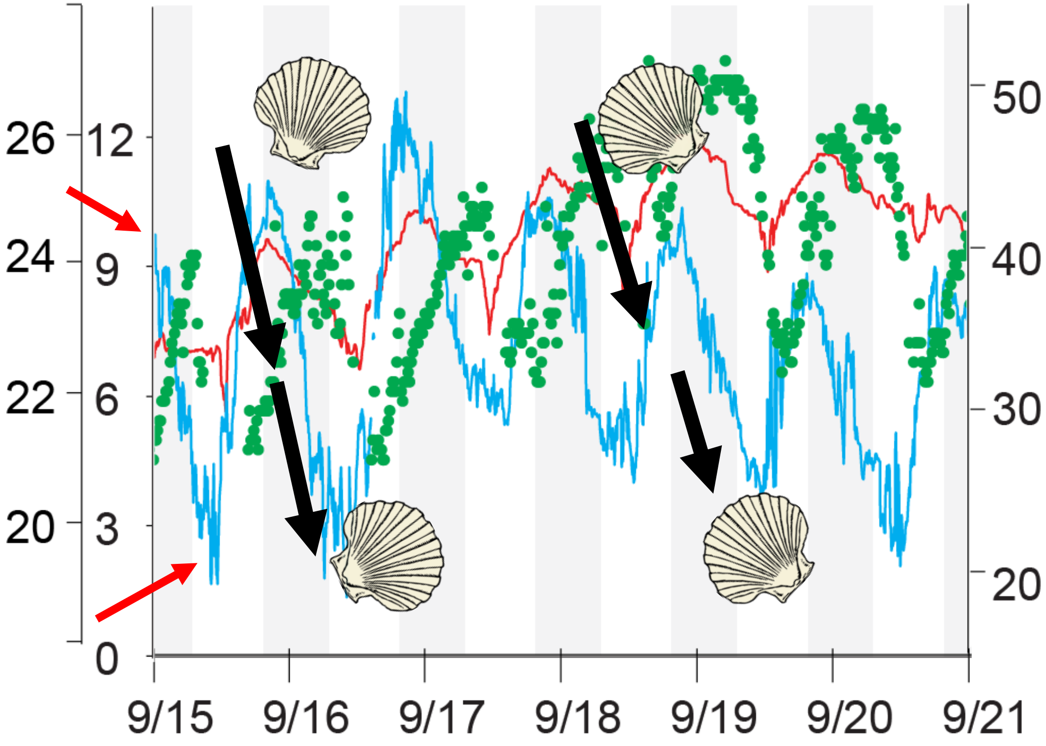
Heartbeat rate change: +10 bpm

Duration: 4 – 6 hours



In a metaphorical sense…





As if these scallops reach the summit of Mt. Everest
<u>every morning</u>

Summary & take home message

Yes.. scallops have hearts

- Bio-sensors give a **unique view** of ecosystem status unachievable by water quality sensors alone
- Help **determine specific thresholds** that can cause harm
- Offer a charismatic perspective to **inspire broad audiences** and spark change

Questions?


OPEN! QUICK!!!
That way he can’t apply a heartbeat sensor and deploy us to our doom!
ERRRGH! Yup. …he glued me shut.