Contribution of nuclear applications to study the effects of reduced oxygen in coastal environments

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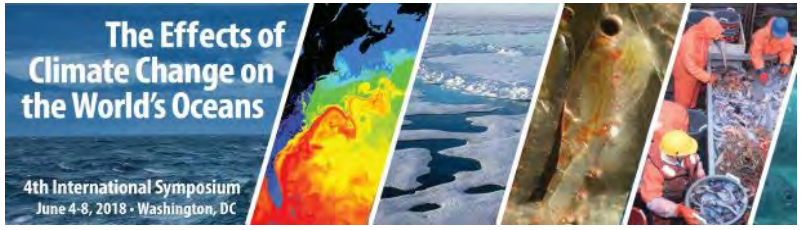

Global warming

- increase in mean global ocean temperature of 1-4° C by 2100
- greatest overall ocean warming in the Southern Hemisphere
- Polar regions = 2x the aver global warming rate
- Intensification and change in El Niño events (c Pacific)
- Changes in heat storage, heat transport, and currents

IPCC

CONTEXT

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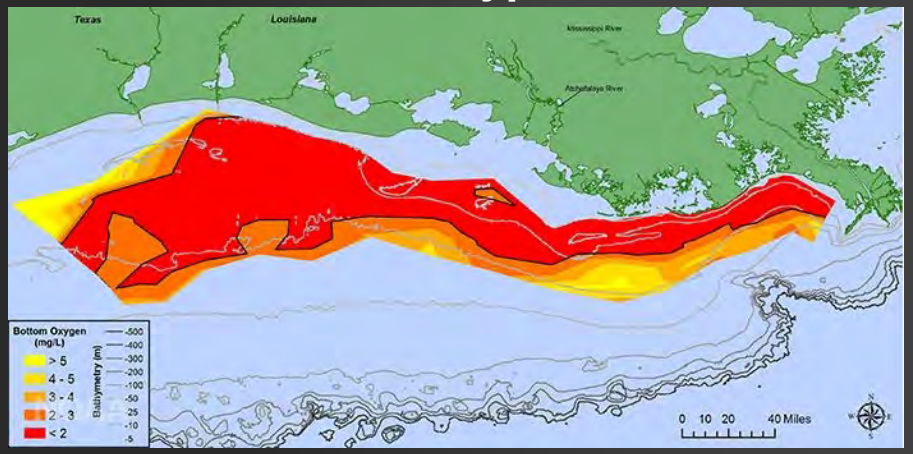
deoxygenation

- Reduced oxygen (O_2) solubility in warmer water.
- Reduced penetration of O_2 into deeper water due to enhanced stratification

2017 Gulf of Mexico Hypoxic Zone Size



Gulf of Oman world' largest Hypoxic Zone

CONTEXT

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deoxygenation

- Reduced oxygen (O_2) solubility in warmer water.
- Reduced penetration of O_2 into deeper water due to enhanced stratification

observed in much of the global ocean

OM respiration shifts to sp bacteria that use NO_3 rather than O_2 >> denitrification and N20 (300x)

More sinking particles reach the deep ocean >> air / sea CO_2 partitioning

Warmer water = incr O_2 demand

CONTEXT

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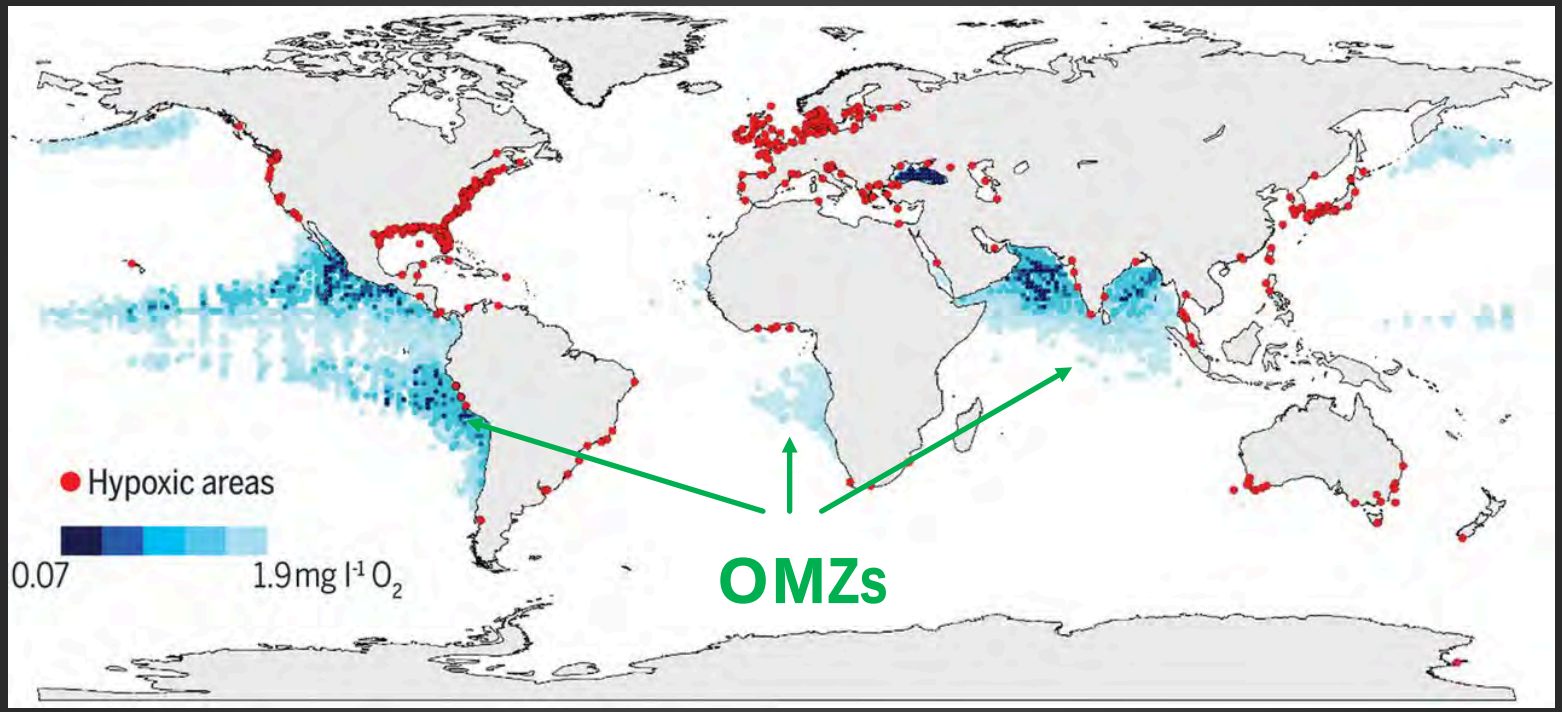
deoxygenation

increasing in number, volume, and intensity



<2 mg liter^{-1} (<63 µmol liter^{-1})

Denise Breitburg et al. Science 2018;359:eaam7240

Globally distributed

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deoxygenation

Potential consequences of ocean oxygen loss are profound:

- reduced biological productivity and diversity,
- altered animal behaviour,
- declines in fisheries, redistributions of communities,
- altered biogeochemical cycles, including
- environmental feedbacks (e.g., increased production of N_2O and CH_4.

consequences

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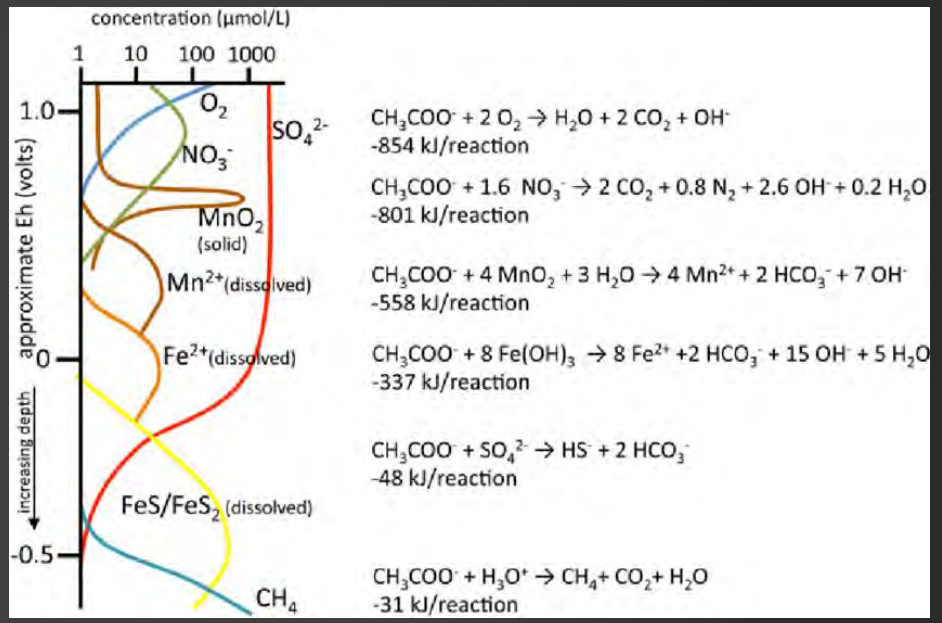
deoxygenation

O_2 plays a direct role in the biogeochemical cycling of carbon, nitrogen, and many other biogeochemically important elements: (P, Fe, Mn, etc.)

low O_2 effects on N and P cycling has global implications

Ideal redox sequence



Froelich et al (1979)

$NO_3^- \rightarrow NO_2^- \rightarrow N_2O \rightarrow N_2 \rightarrow NH_4^+$

Biogeochemical cycling

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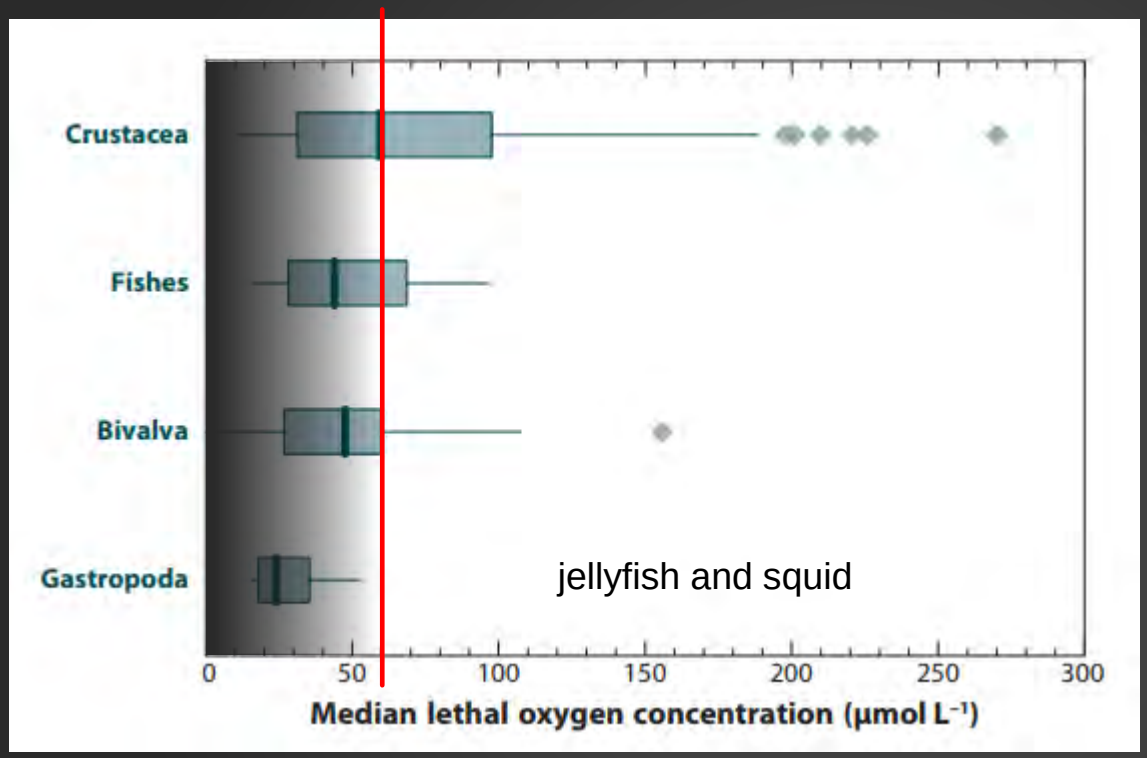
deoxygenation



Vaquer-Sunyer & Duarte 2008

O_2 is also fundamental for all aerobic life, including organisms living in the dark ocean interior.

sensitivity to low DO = non linear

Compounded by CO_2 and temperature

O_2 tolerance (LC_{50})

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Expansion of OMZs and habitat compression impacts commercial fisheries:

- In the tropical Atlantic, blue marlin/tuna have seen a 15% reduction in habitat between 1960-2010 (Stramma et al. 2011)
- Off the US West Coast, the Humboldt squid has greatly expanded its range, and the range expansion coincides strongly with areas of significant oxygen declines (Gilly et al. 2013).

Diversity impacts

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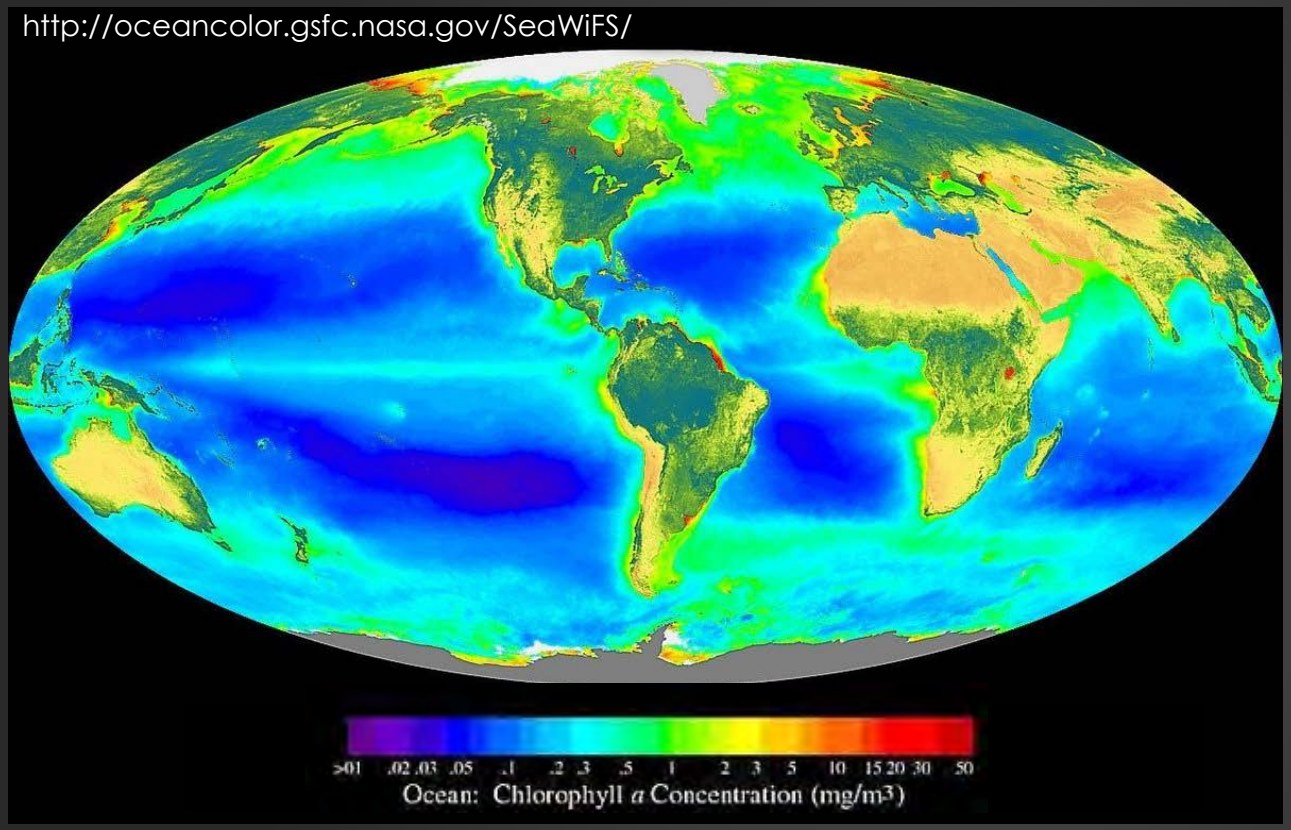

via photosynthesis and respiration

So a tracer of rate at which OM is produced, redistributed, and decomposed in the ocean >> biological pump

O_2 directly linked to carbon

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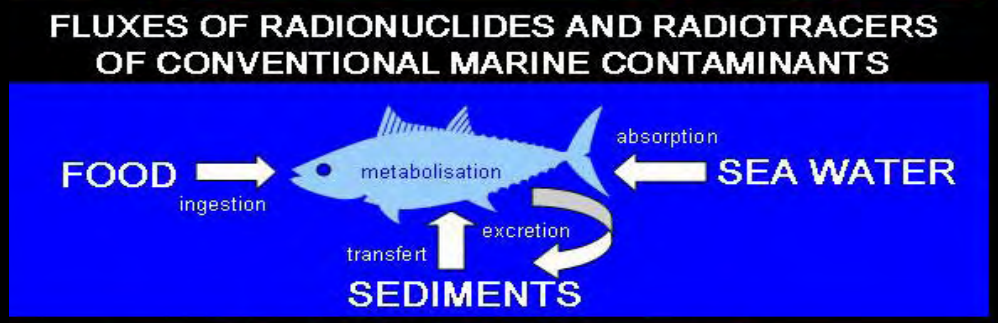
Contribution of nuclear applications to deoxygenation studies

RADIOTRACERS



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γ–emitters:

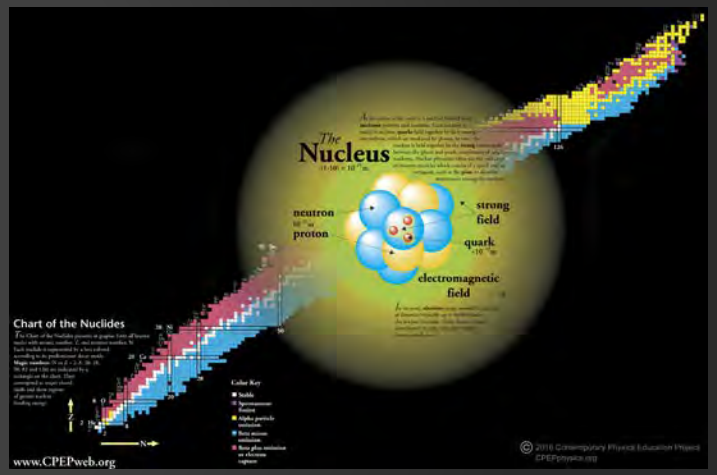
^{51}Cr, ^{54}Mn, ^{57}Co, ^{65}Zn, ^{73}As, ^{110m}Ag, ^{109}Cd, $^{134,137}Cs$, ^{203}Hg, ^{210}Pb…

β–emitters:

^{14}C, ^{3}H, ^{45}Ca, ^{63}Ni…

α–emitters:

^{210}Po…



to assess stress

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Contribution of nuclear applications to deoxygenation studies

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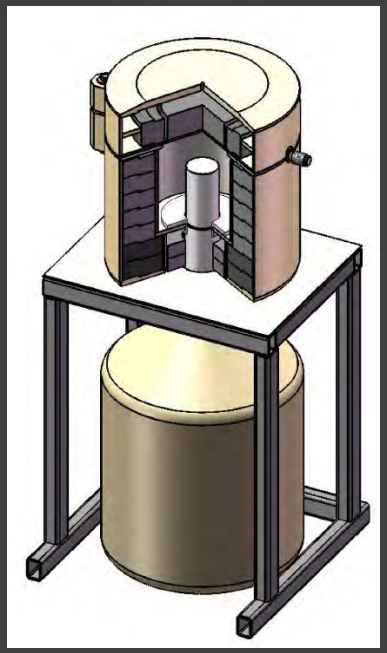
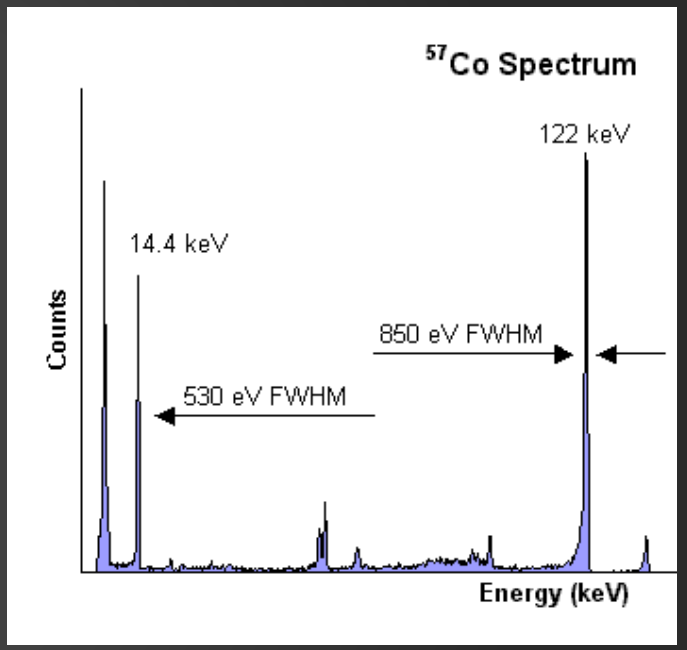
Exp. aquaria

HPGe detector



Gamma spectrum



to assess stress

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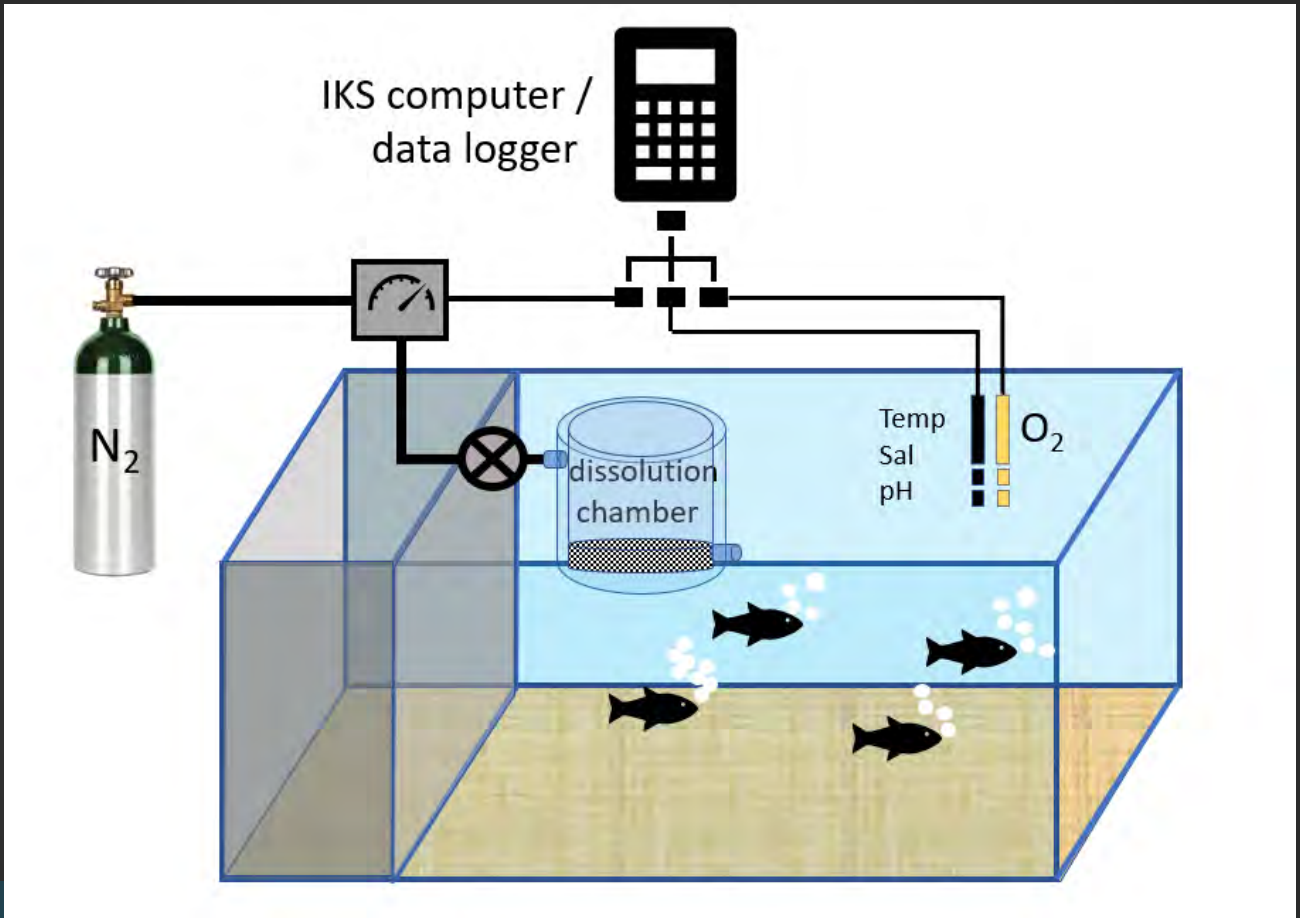
Regulating DO in experimental aquaria

RADIOTRACERS



to assess stress

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Regulating DO in experimental aquaria

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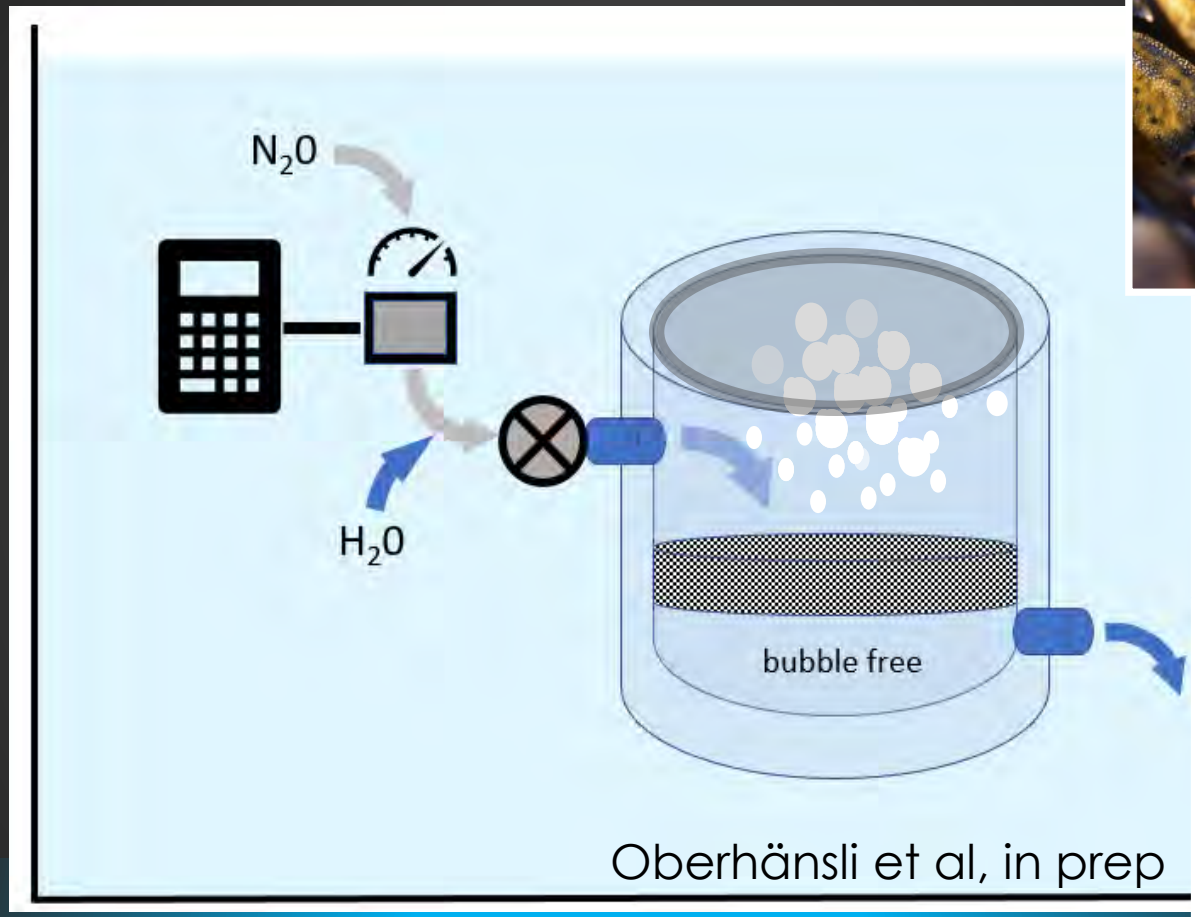

Oberhänsli et al, in prep

to assess s t r e s s

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Regulating DO in experimental aquaria

RADIOTRACERS

- Able to assess stress at environmental levels
- Very high sensitivity & specificity (multiple isotopes)
- Ability to count live organisms (adjust on the fly)
- Real-time data
- Ability to assess multi-stressor effects
- Cost-effective and easy

advantages

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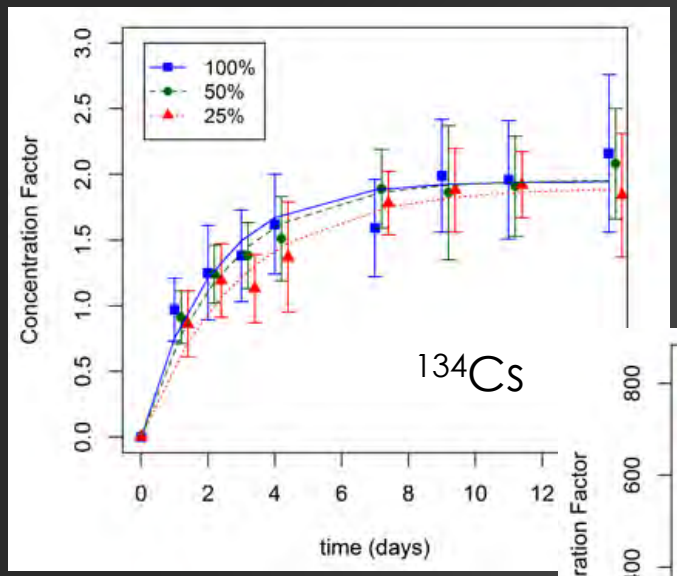
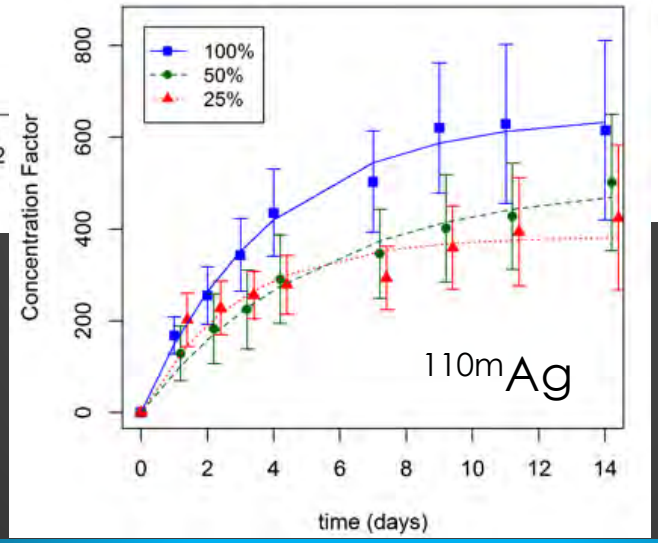
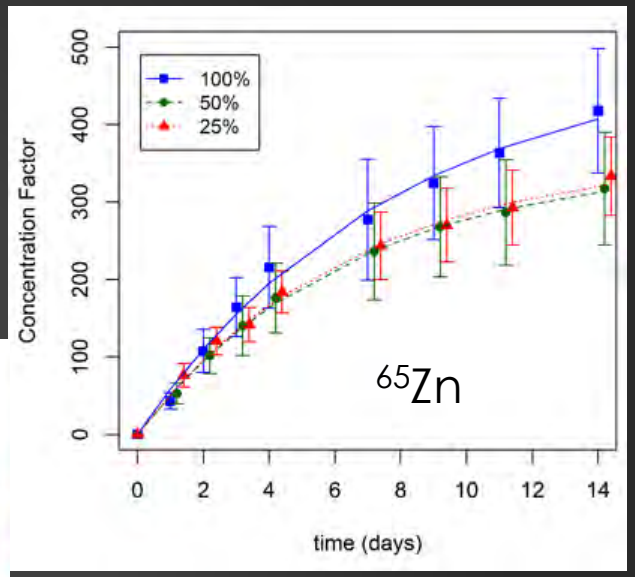
Bioconcentration of Zn, Ag, and Cs in mussel (Mytilus edulis)







Low DO on mussels

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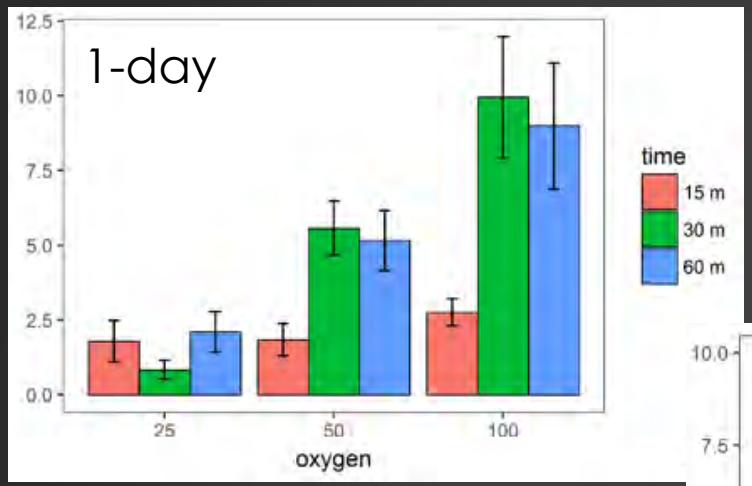
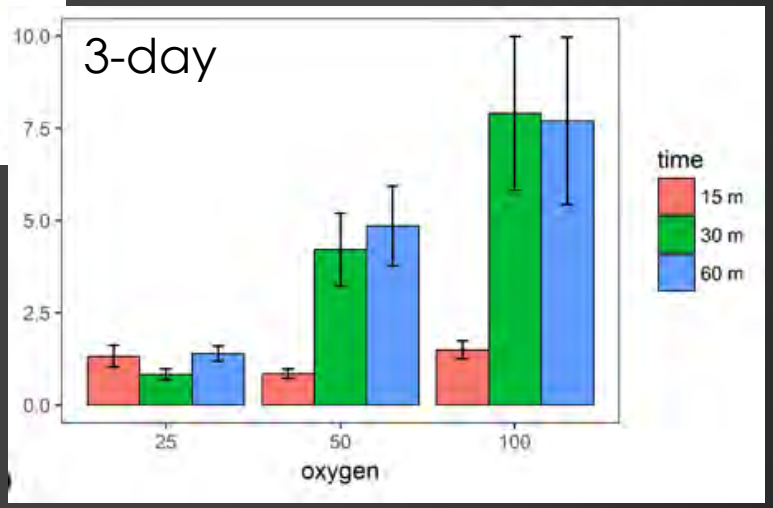
Filtration rate (L g^{-1} hr^{-1}) in mussel (Mytilus edulis)



Ability to feed is reduced with lowered DO



Low DO on mussels

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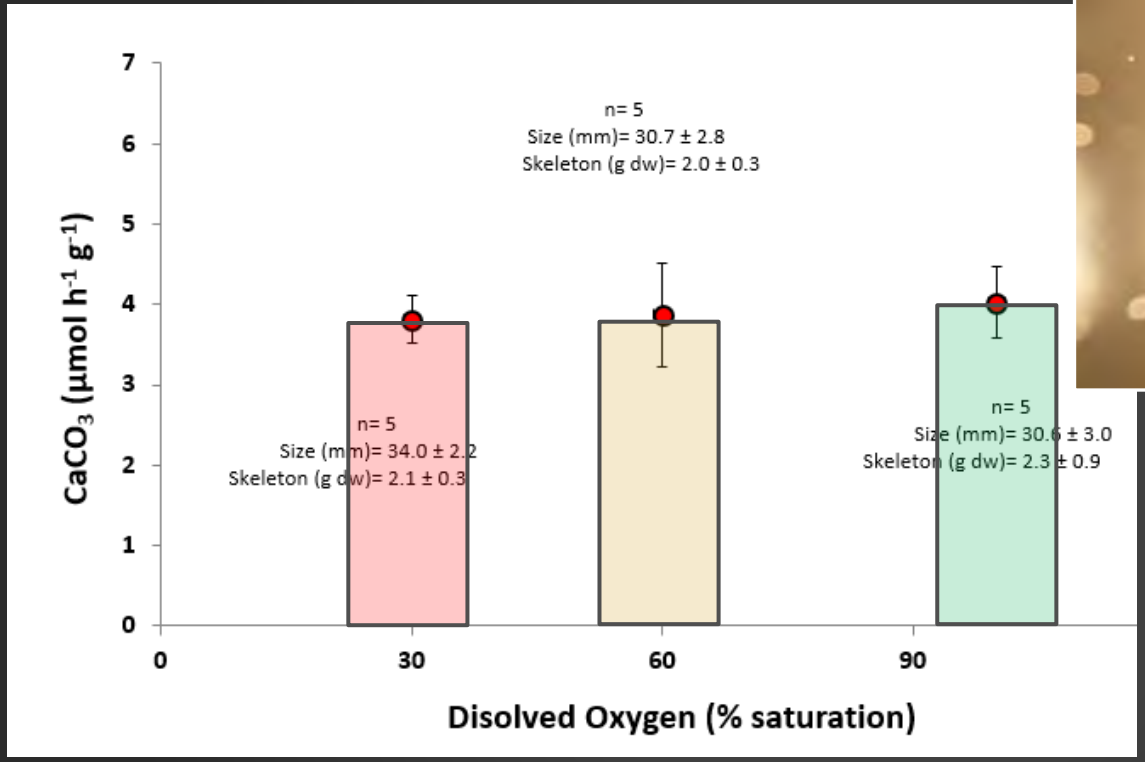
Regulating DO in experimental aquaria



6-d, non-preconditioned experiments show no change in the gross calcification rate w/ a change in DO

^{45}Ca-derived gross calcification rates

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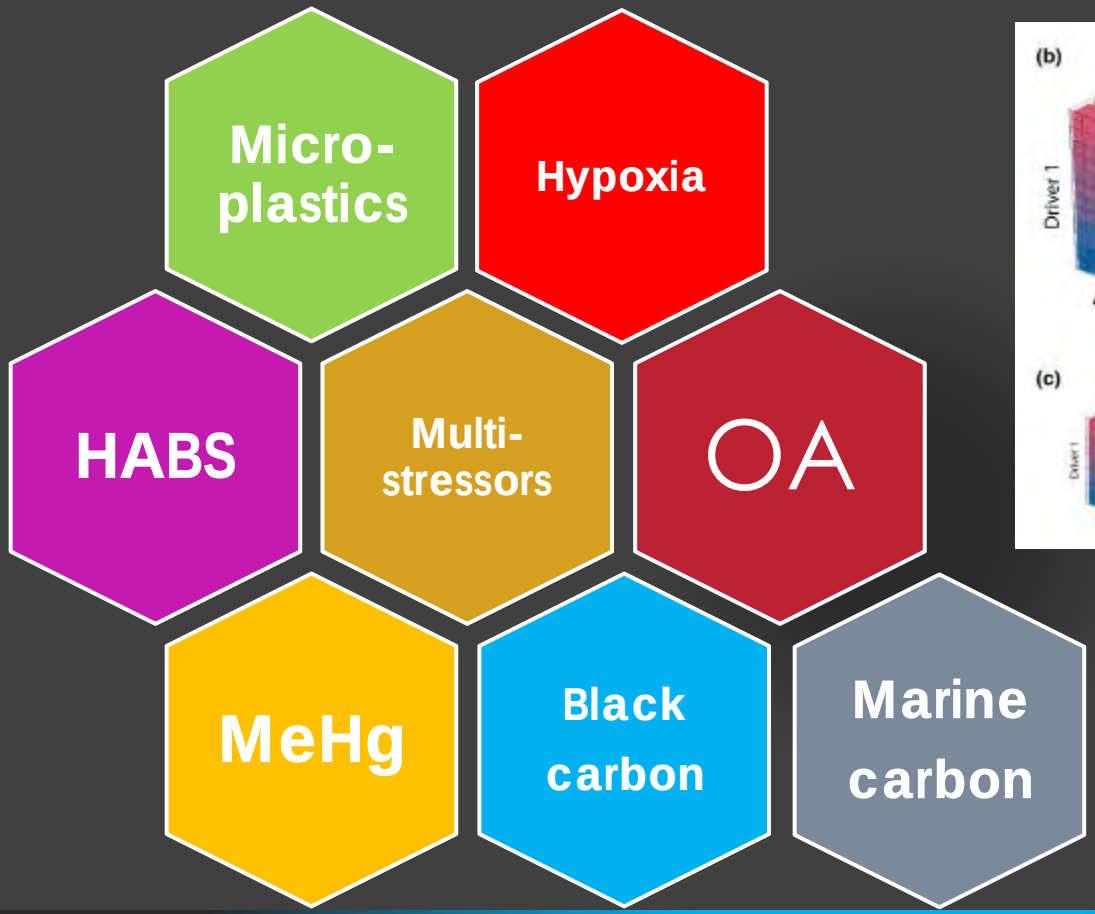

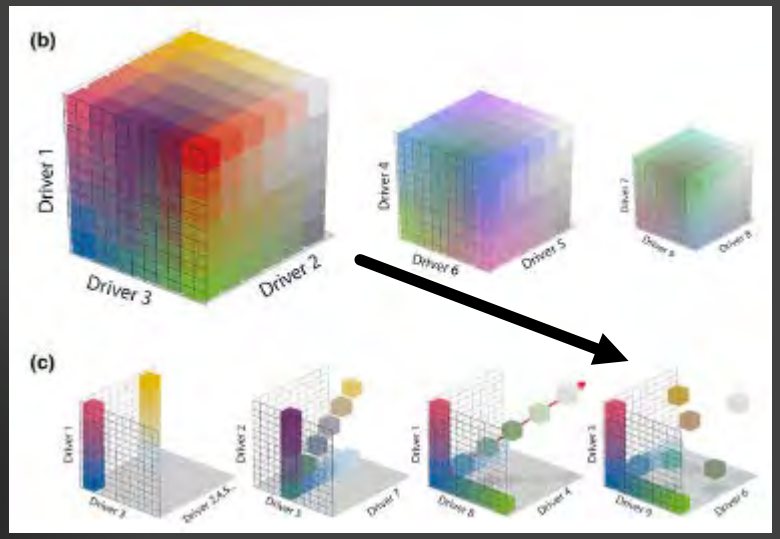

Boyd et al 2017

Current projects

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THANK YOU
Questions ?

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deoxygenation

The realization that future global warming might significantly impact ocean O2 distributions is still very new…

…so the science of ocean deoxygenation is still in its infancy

conclusions

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