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Is hypoxia's influence restricted to the deep? Evaluation of nearshore community composition in Hood Canal, Washington, a seasonally hypoxic estuary

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Is hypoxia restricted to the deep?

Spatial & temporal variation in nearshore community structure in a seasonally hypoxic estuary

Halley E. Froehlich¹, Shannon Hennessey¹, Anne H. Beaudreau¹, Timothy E. Essington¹, Phillip S. Levin²

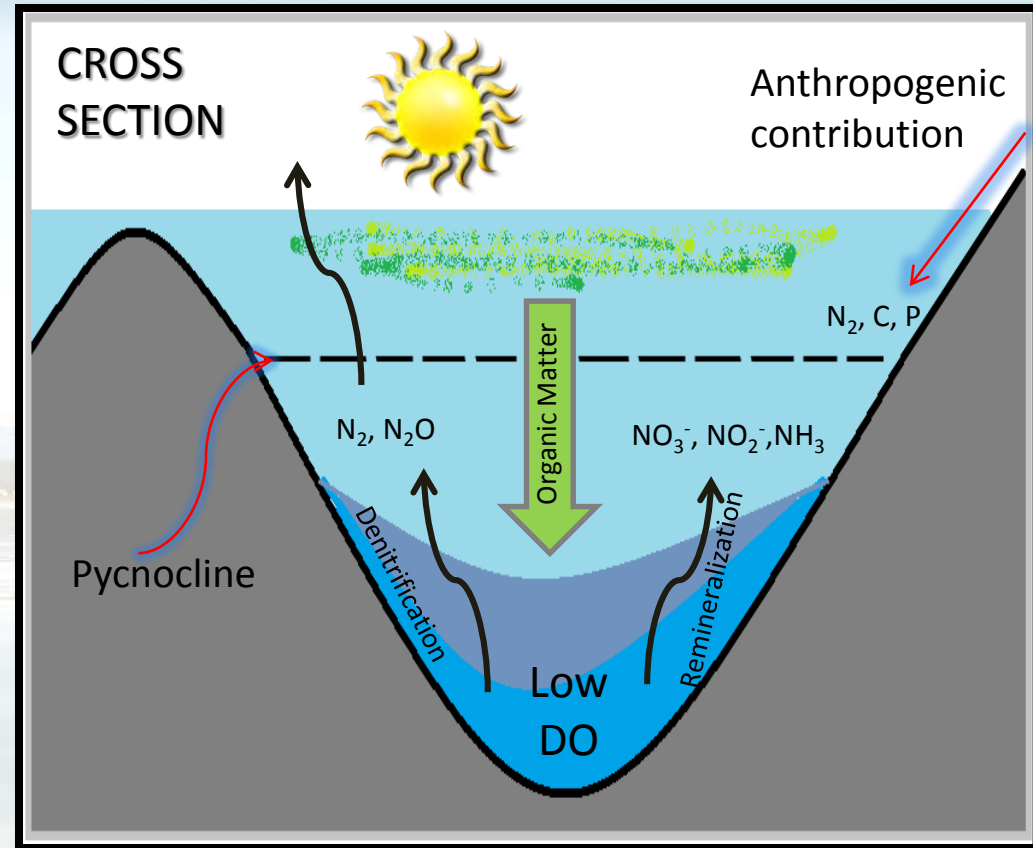
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Salish Sea Ecosystem Conference 2014

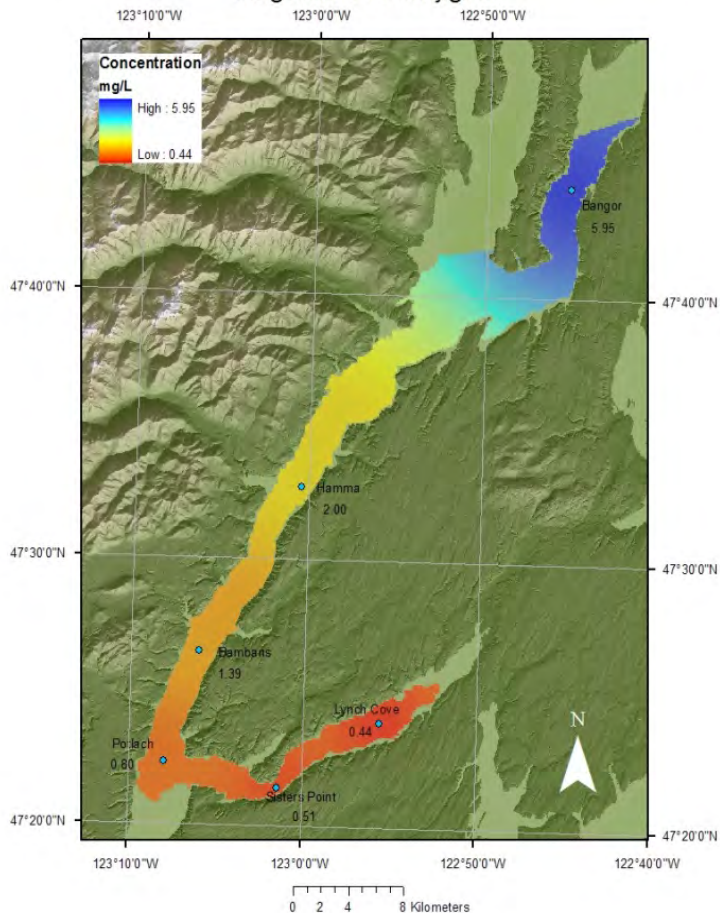
Hypoxia

- Dissolved oxygen concentration “ $<2\text{mg L}^{-1}$ ”
- Worldwide
- Pulse disturbance
- Anthropogenic

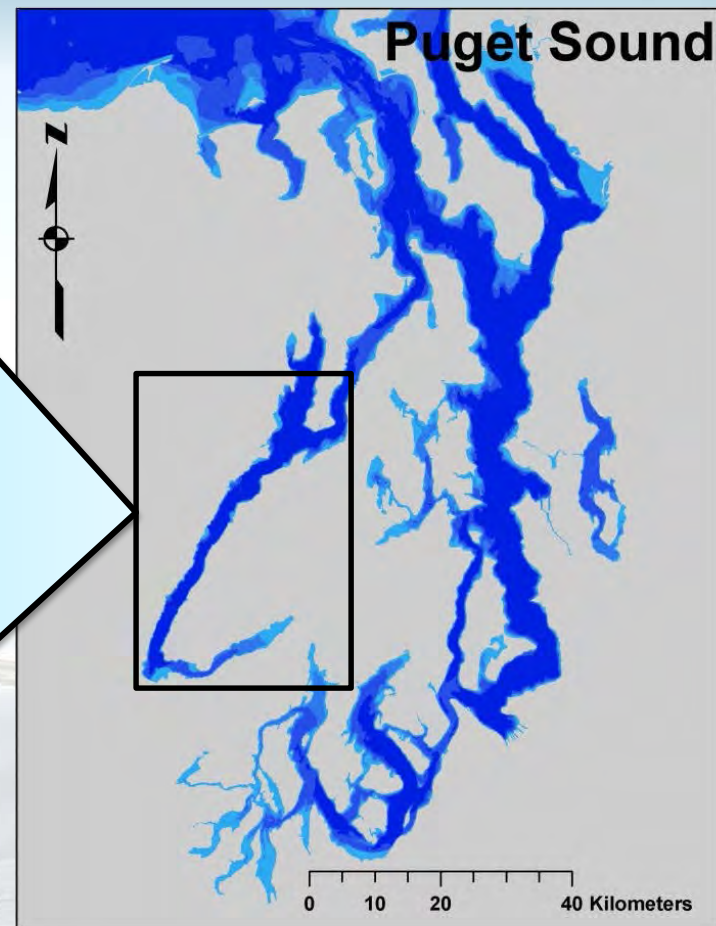


Hood Canal, Washington

Measured and Interpolated O₂
August 2006 Oxygen



Seasonal hypoxia
High productivity
Slow turnover
Deep bathymetry



Biological Impacts

1. Mortality



2. Sub-lethal effects

Originally published Tuesday, September 21, 2010 at 10:01 PM

Scientists worry Hood Canal may suffer extensive fish kill

Scientists have been warning for weeks that poor flush of ocean water may set the stage for substantial fish kills that conditions are right on the edge, with hundreds of fish deaths in Hood Canal.

Fish deaths in Hood Canal

Hundreds of fish and shrimp have suffocated in Hood Canal this week because of oxygen-starved water. Fear the worst may be yet to come.

The map shows the Hood Canal region with several callouts: 'By Tuesday, dead fish and shrimp were showing up north of Hoodsport.', 'A few hundred fish washed dead near Monday', 'Lilliwaup', 'Hoodsport', 'Tahuya', 'Potlatch State Park', 'Dobob Bay', 'Seab', and '101'. An inset map shows the location of Seattle, Washington, and the Olympic National Park area.

ON THE TRAIL OF BALLARD'S PORCH-CHAIR TH

Seattle Post-Intelligence

A HEARTY NEWSPAPER
DAILY.COM

HEALTH
Child's play: Eight tips for making it count
PAGE A10

HOME GROUND
LIFE AND ARTS BY

BOOKS
DEFINING OUR LANDSCAPE
How a dictionary/art book became a page turner
LIFE AND ARTS BY

MONDAY, OCTOBER 9, 2006

P-I SPECIAL REPORT THE SOUND OF BROKEN PROMISES

GRANNY, THE RESPECTED ELDER in her Northwest orca pod, has lived from the dawn of the automobile through the advent of the Internet.

In a six-part series starting today, the P-I chronicles her long life in the troubled waters of Puget Sound.

Over almost a century, the aged matriarch has been cursed at, shot at, netted by fortune hunters. Today, Granny and her pod are struggling to survive



perils unimaginable in her youth - the destruction of their food and habitat, an ever-rising tide of poisons, plastics and sewage, the threat of a massive oil spill.

Elected leaders have promised for decades to save the Sound. But weak regulations, spotty enforcement, political foot-dragging and a surge of new residents have led to little progress.

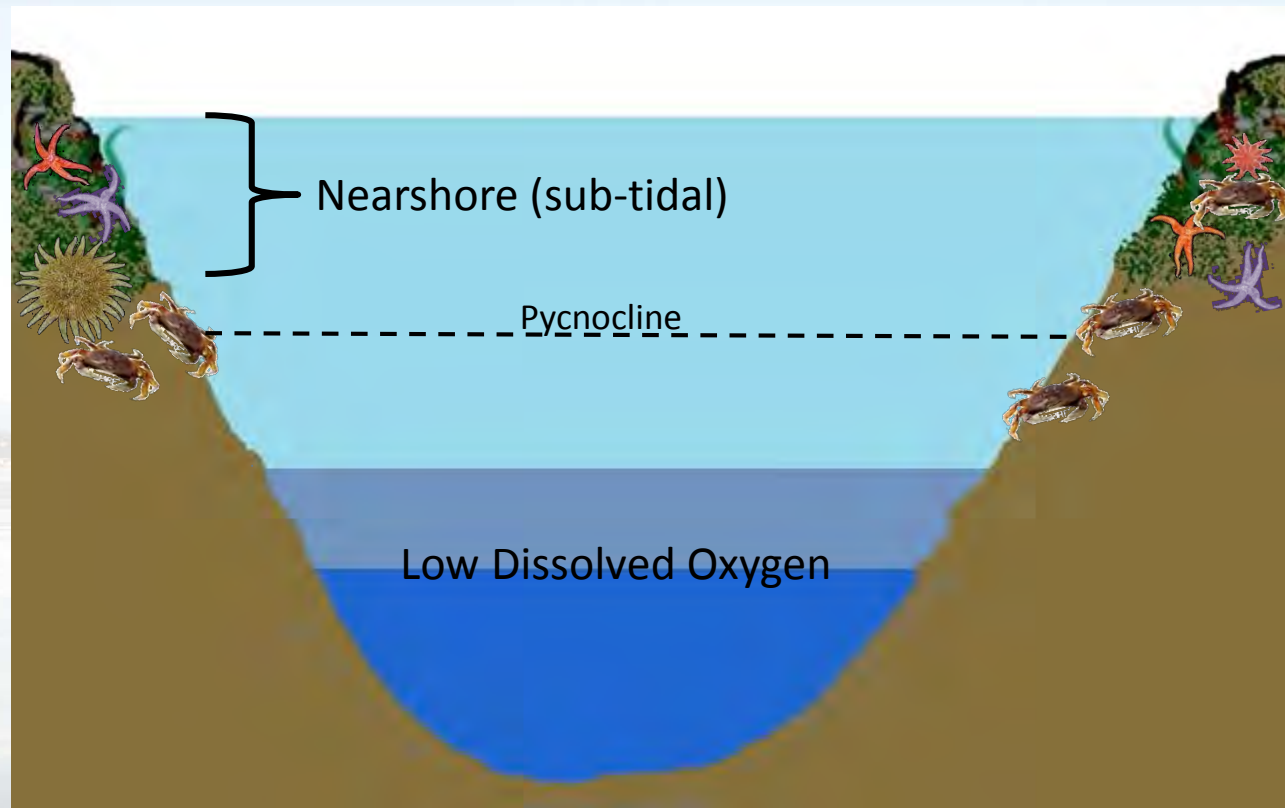
Will the recent adoption of Endangered Species Act protections for orcas and a pending plan to restore the Sound finally change that? Or will Granny and her pod continue swimming in a sea of broken promises?



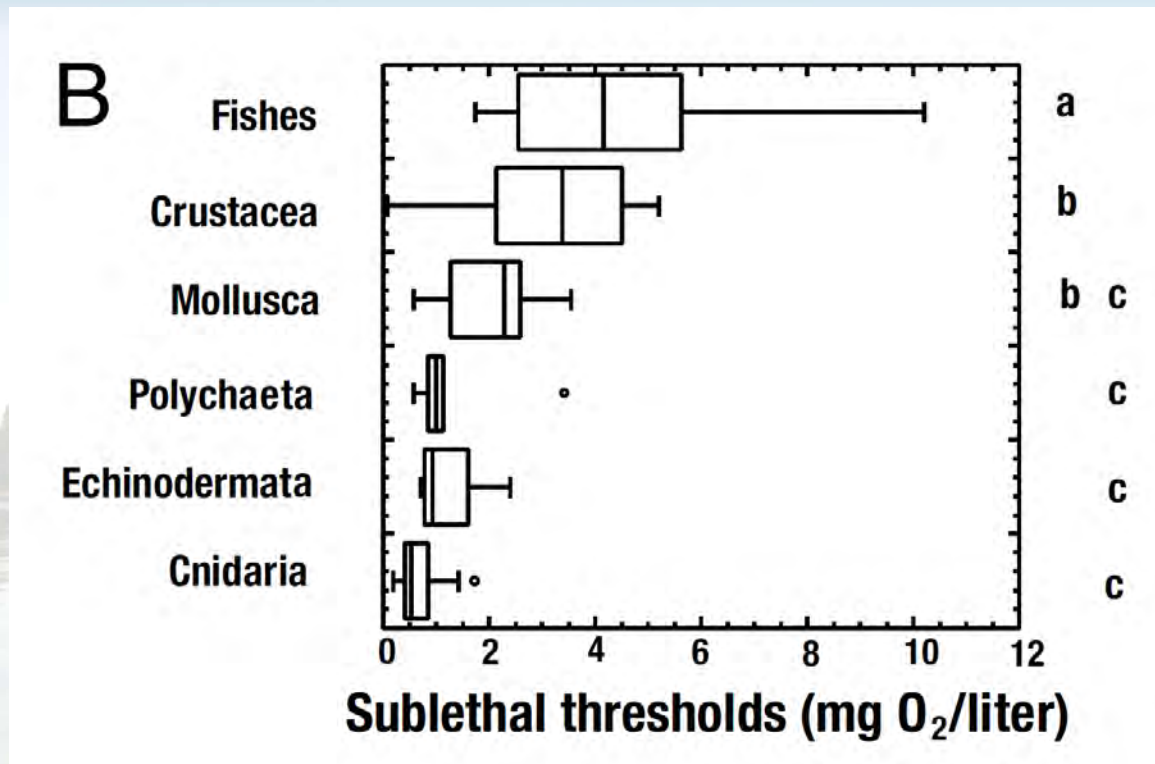
Hypoxic influence on the nearshore community?

Nearshore

- High productivity
- Nursery habitat
- Closer to human influence



Physiological driven patterns



Vaquer-sunyer and Duarte (2008)

Questions

1. Are there more hypoxia tolerant invertebrates and fewer fish species in the south?



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2. Does the southern community change temporally with the onset of hypoxia?
3. Is dissolved oxygen (DO) a main predictor for species presence and absence?

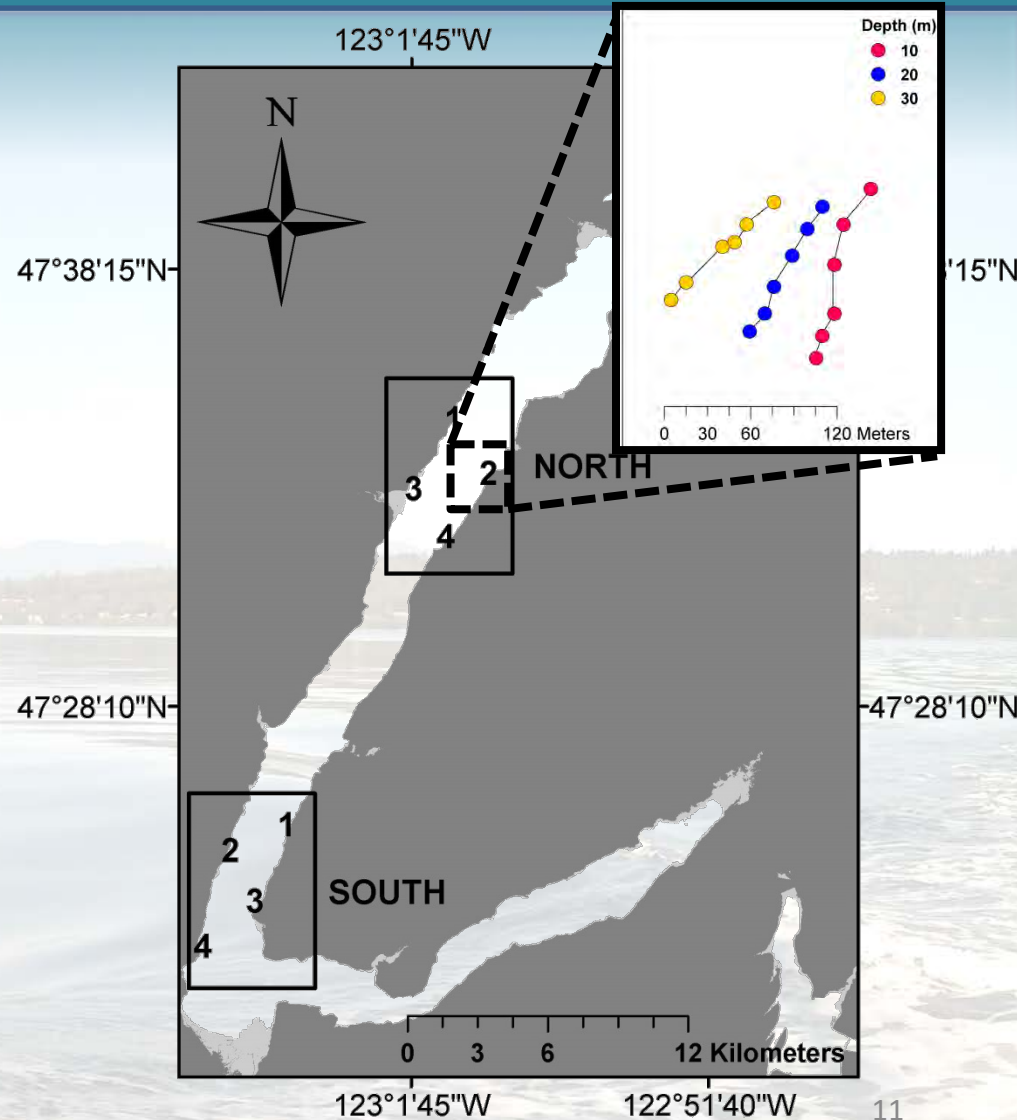
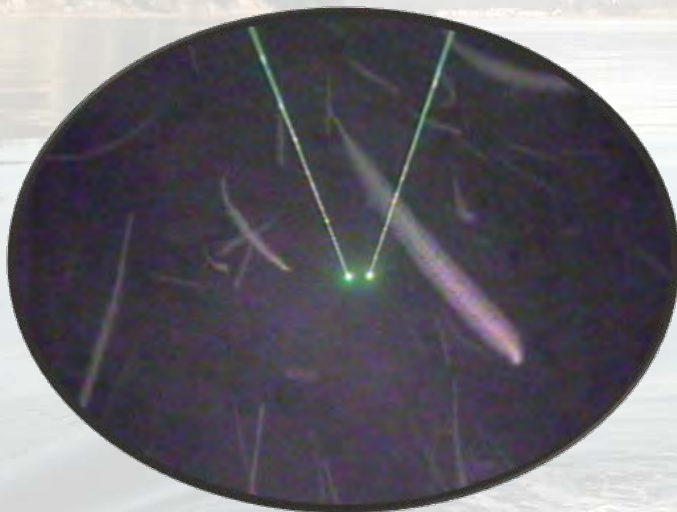
Questions

1. Are there more hypoxia tolerant invertebrates and fewer fish species in the south?
2. Does the southern community change temporally with the onset of hypoxia?
3. Is dissolved oxygen (DO) a main predictor for species presence and absence?
4. Do we detect distinct DO thresholds for 'sensitive' and 'tolerant' species?

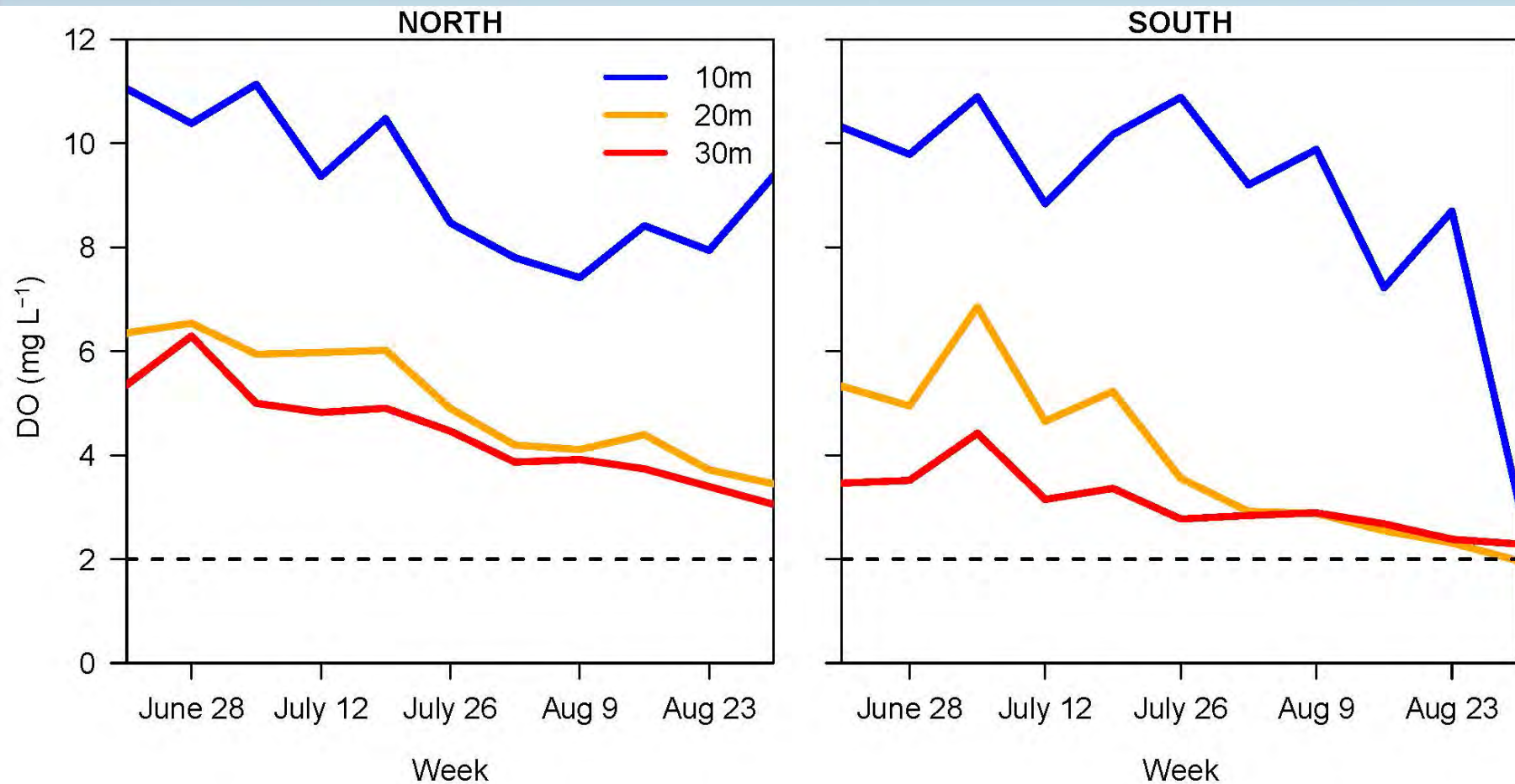
Drop-camera

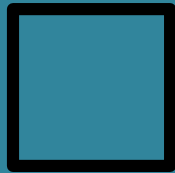
Paired study design

- June-Sept 2010
- Depths: 10, 20, 30m
- 5min transects
- Water quality data

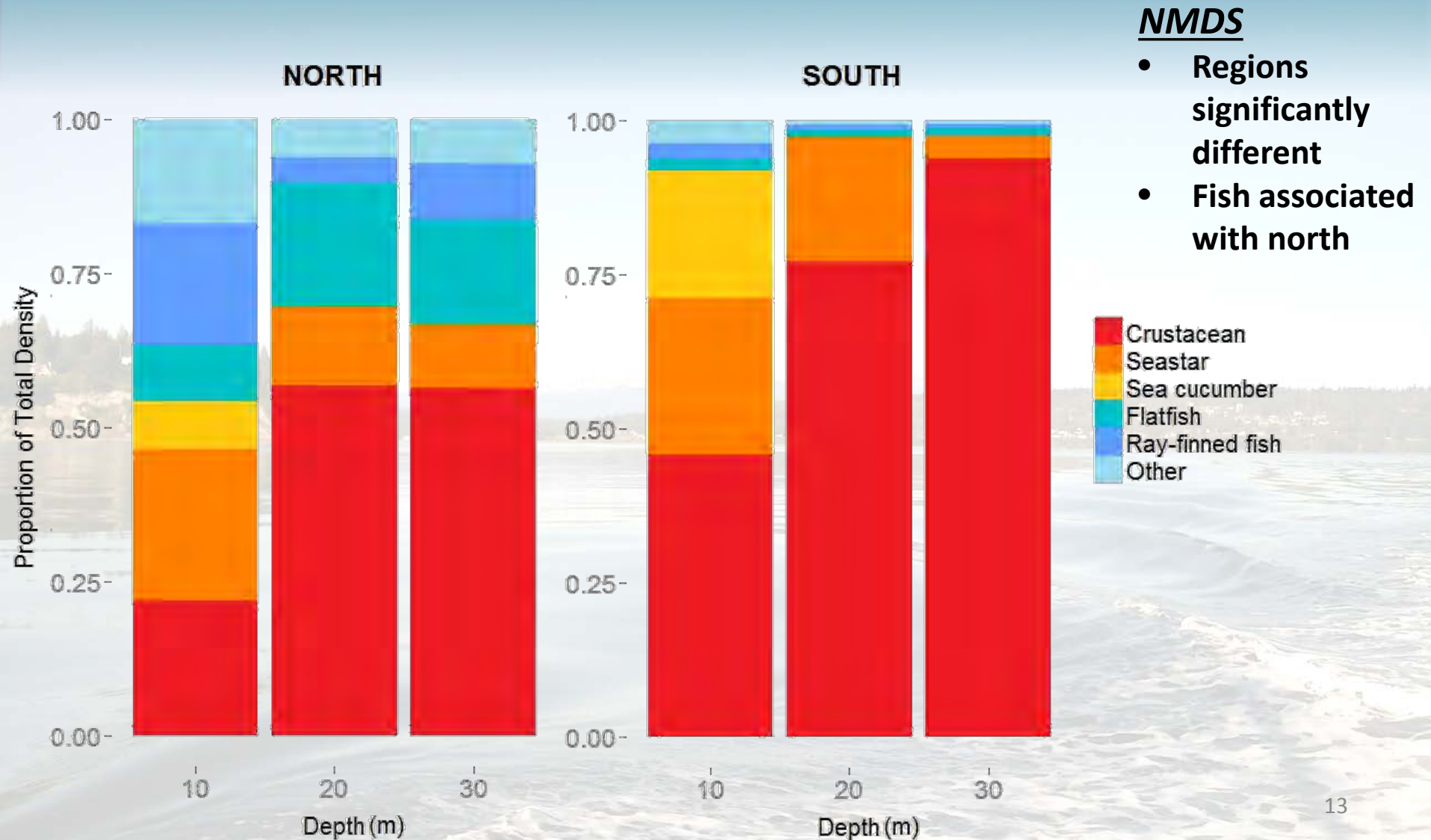


Water quality



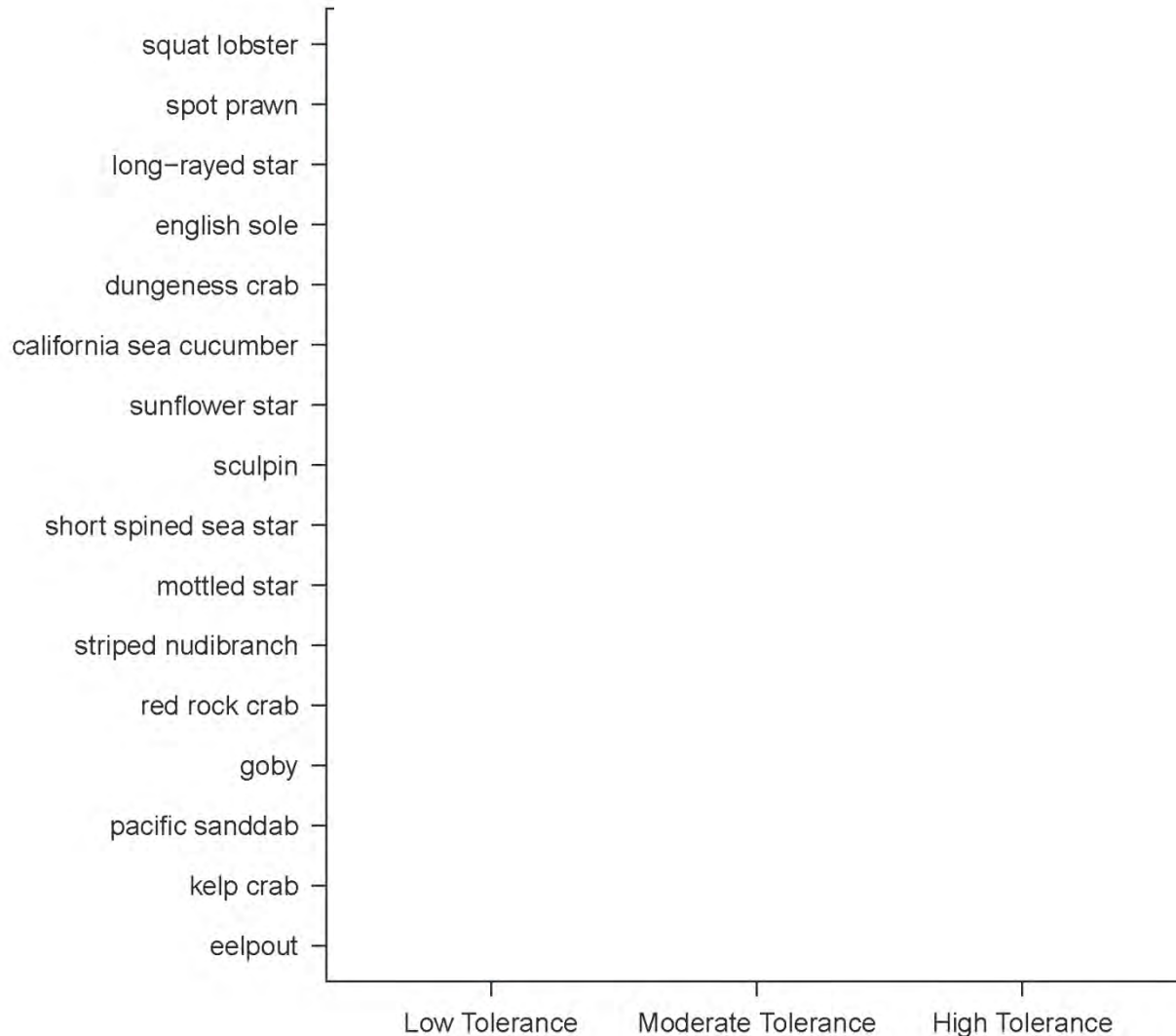


South composed of more hypoxia tolerant invertebrates and fewer fish species compared to the north?





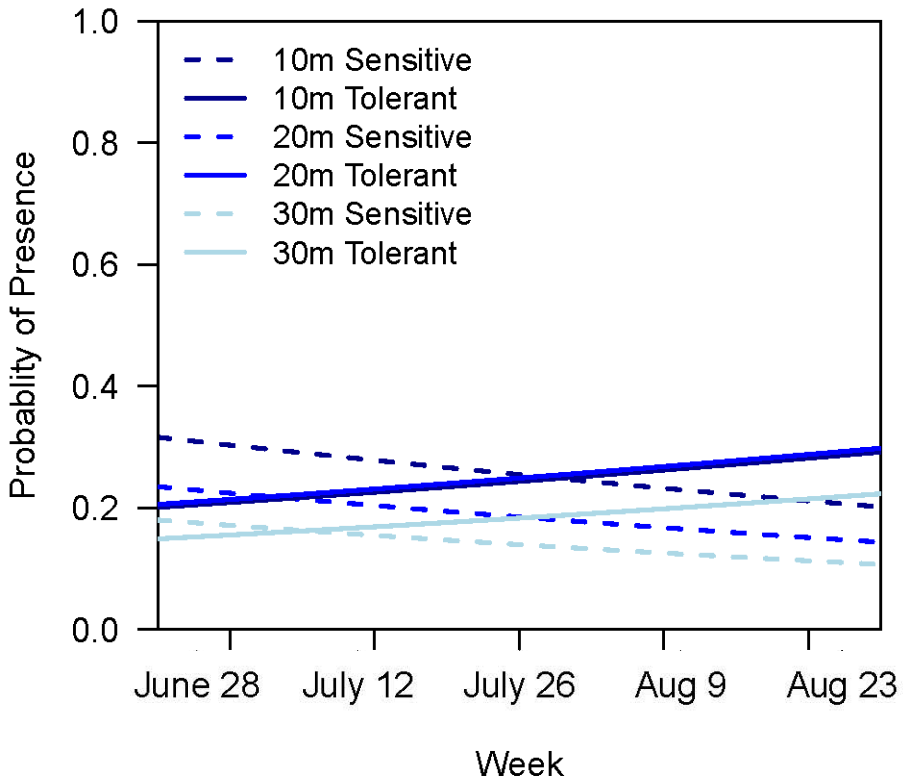
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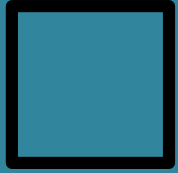




Southern community changes temporally with the onset of hypoxia?

NORTH

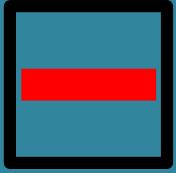




DO a main predictor for species presence-absence?

Rank predictor importance for each species (N=16):

Predictor	No. of times rank 1	Mean rank	No. times within top 5
Depth			
Region			
Temp			
Sample site			
DO			
Habitat			
Salinity			
Week			
Slope			
Side			



DO a main predictor for species presence-absence?

Rank predictor importance for each species (N=16):

Predictor	No. of times		Mean rank	No. times within top 5
	rank 1			
Depth	6		3.5	13
Region	3		3.8	11
Temp	2		3.8	13
Sample site	2		4.9	9
DO	2		5.1	9
Habitat	1		5.9	8
Salinity	0		5.6	8
Week	0		7.1	5
Slope	0		7.4	2
Side	0		8.0	2



Detect distinct DO thresholds for 'sensitive' and 'tolerant' species?

Broken-line analysis (GLM)

'Sensitive species' (n=7)

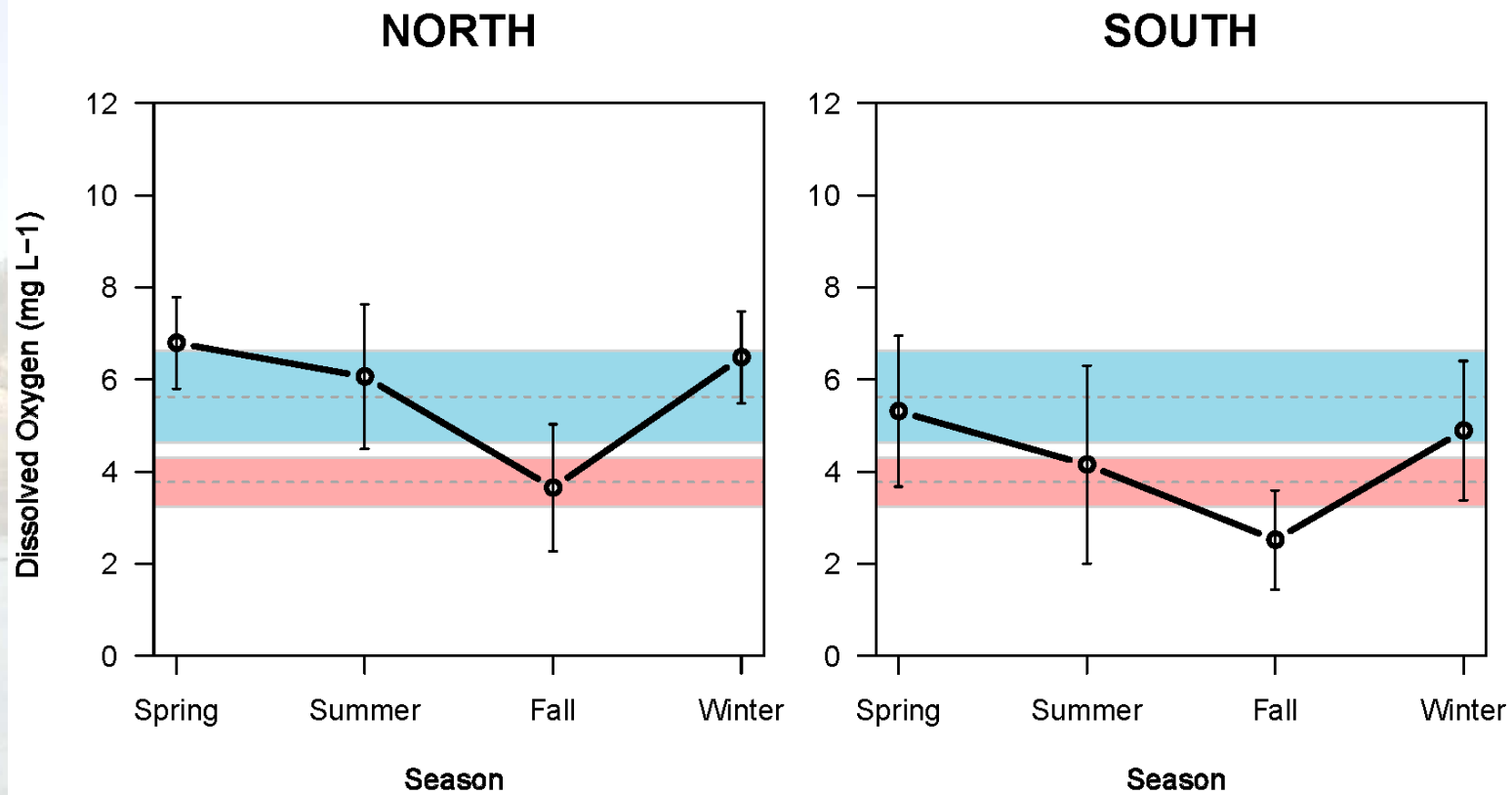
- **Breakpoint = 5.62mg L⁻¹ (SE ± 0.51)**

'Tolerant species' (n=9)

- **Breakpoint = 3.77 mg L⁻¹ (SE ± 0.27)**

Long-term implications?

6 years of shallow, cruise data



Summary

- I. Hypoxia influencing the nearshore community**
 - Synergistic/additive effects?

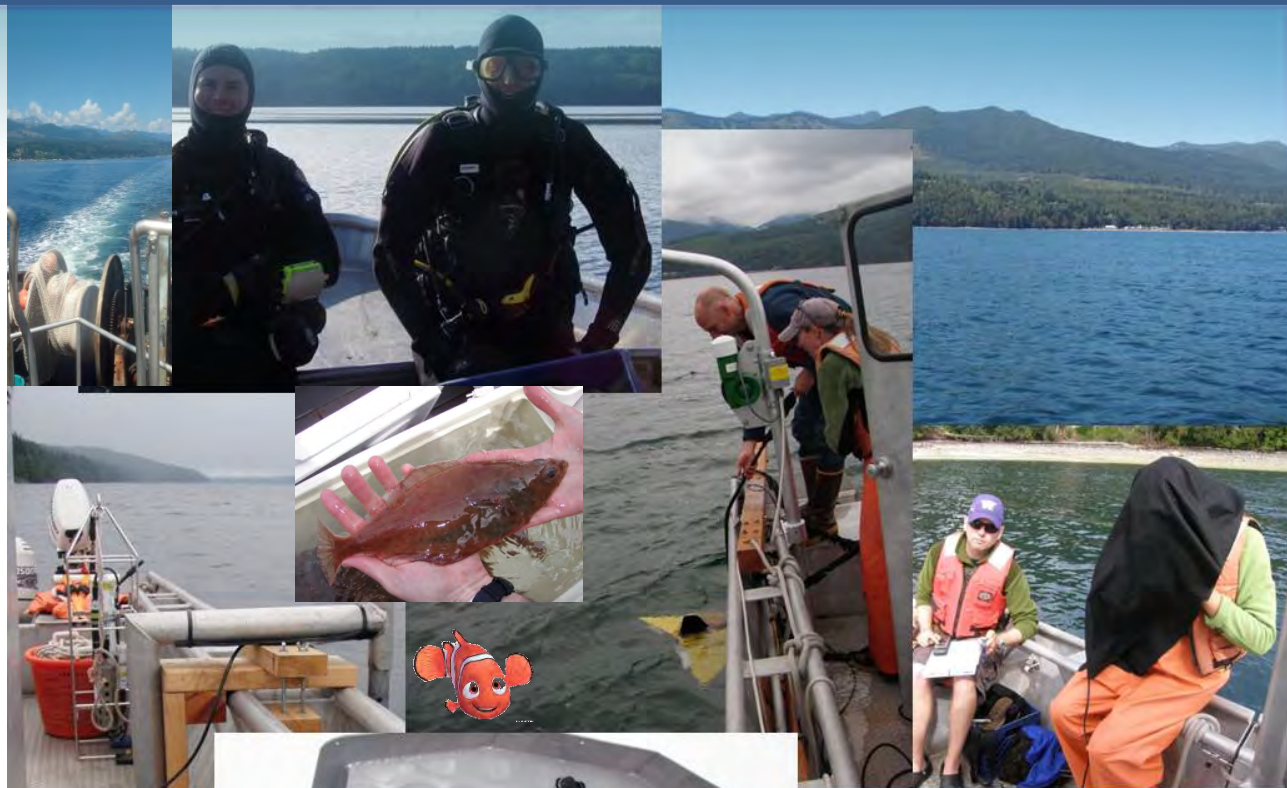
- II. More 'universal' hypoxia response level (3-4 mg L⁻¹)**

- III. More persistent low DO state in the south**
 - More vulnerable? Ecosystem function?

Acknowledgements

- **THANK YOU:**

- P. Sean McDonald
- Charles Simenstad
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- HCDOP
- NANOOS
- Essington lab



- **Funding:**



				Overall	Relative	Ordination
Common name	Scientific name	DO Range	DO Tolerance	Tolerance	Abundance (north; south)	Correlation Significance
Long-rayed star	Stylasterias forreri	0.5-6.6 ml/L ¹²	*more tolerant than fish & crustaceans ¹⁴	High?	1.3%; 3.1%	p < 0.01
Spot prawn	Pandalus platyceros	0.9-6.9 ml/L ¹²	minimum lethal ~1 ml/L ⁷ ; 3.5 to 4.0 mg/l (below this metabolism declines) ¹⁵	High	16.2%; 15%	p < 0.001
Squat lobster	Munida quadrispina	0.8-4.6 ml/L ¹²	0.1 to 0.15 ml/L, well adapted to hypoxia ⁴ ; exposed to < 0.5 mg/L ⁵ ; no association between density & DO ¹⁰	High	15%; 55.1%	p < 0.001
Dungeness crab	Metacarcinus /Cancer magister	4.9-6.6 mg/L ² ;2.6-7.5 ml/L ¹²	>3.3 mg/L ¹ ; 1.2 mg/L> DO > 0.6 mg/L ²	Moderate to high	3.2%; 3.4%	p < 0.01
Giant California sea cucumber	Parastichopus californicus	0.32 - 6.7 ml/L ¹²	*more tolerant than fish & crustaceans ¹⁴ ; > 3.2 mg/L ¹⁵ ; < 2.5 mg/L mortality ¹⁶	Moderate to high	3.1%; 4.0%	p < 0.001
English sole	Parophrys vetulus	1.1-6.6 ml/L ¹²	moderate degree of hypoxia tolerance (1.09 ml/L) ³ ; condition not sig. different btw 0.4-1.0 ml/L ⁸	Moderate to high	4.5%; 0.4%	p < 0.01
Sunflower star	Pycnopodia helianthoides	2.6-6.8 ml/L ¹²	more abundant >1 ml/L ⁸ ; least abundant < 0.5 ml/L ⁸ ; > 0.5 ml/L ¹³ ; present in hypoxic conditions ¹³	Moderate	9.8%; 5.3%	p < 0.001
Shortspined sea star	Pisaster brevispinus	3.9-6.6 ml/L ¹²	present in hypoxic conditions ⁶ ; *more tolerant than fish & crustaceans ¹⁴	Moderate	1.6%; 0.9%	p < 0.01
Sculpin spp.	Malacocottus kincaidii; Enophrys bison	1.0-6.6 ml/L ¹²	more abundant ≥1.3 ml/L ⁸ ; absent 0.6 ml/L ⁸	Low to moderate	4.5%; 0.6%	p < 0.001
Mottled star	Evasterias troschelii	3.0-7.3 ml/L ¹²	*more tolerant than fish & crustaceans ¹⁴	Low to moderate?	2.8%; 3.0%	p < 0.01
Striped nudibranch	Armina californica	2.4-6.5 ml/L ¹²	absent ≤ 0.8 ml/L ⁸	Low	3.6%; 0%	p < 0.01
Pacific sanddab	Citharichthys sordidus	2.6-5.5 ml/L ¹²	condition sig. better in DO > 1ml/L ⁸ ; can move off the bottom ⁹	Low	3.9%; 0.2%	p < 0.001
Eelpout spp.	Lycodopsis pacifica	2.3-5.5 ml/L ¹²		Low?	1.2%; 0.2%	p < 0.001
Goby spp.	Rhinogobiops nicholsii	3.3 - 6.4 ml/L ¹²		Low?	3.1%; 0.4%	p < 0.05
Kelp crab	Pugettia producta; Pugettia richii	6.6 ml/L ¹²		Low?	1.1%; 1.0%	p < 0.001
Red rock crab	Cancer productus	3.2-6.6 ml/L ¹²	Emersion (<12hrs) ¹¹	Low?	8.2%; 1.7%	p < 0.001

Habitat Type

cobble/sand/algae

cobble/sand/algae/seapens

cobble/sand/rock/algae

cobble/sand/rock/seawhips

cobble/sand/seawhips

cobble/sand/seawhips/algae

cobble/sand/seawhips/some algae

