ARC CENTRE OF EXCELLENCE
Coral Reef Studies

JAMES COOK
UNIVERSITY
AUSTRALIA

The future of coral reef fishes in a changing world

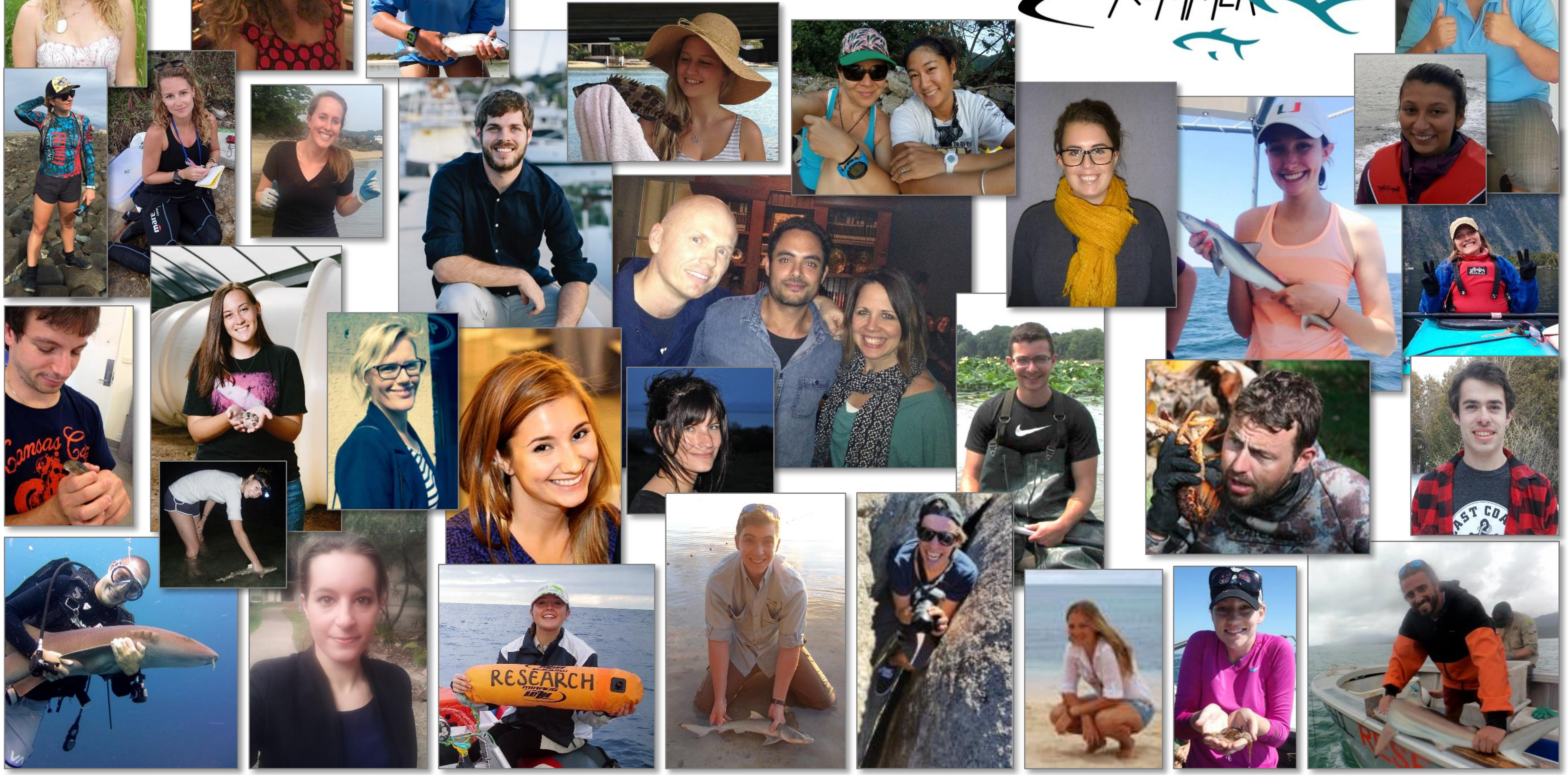
Jodie L. Rummer, Ph.D.

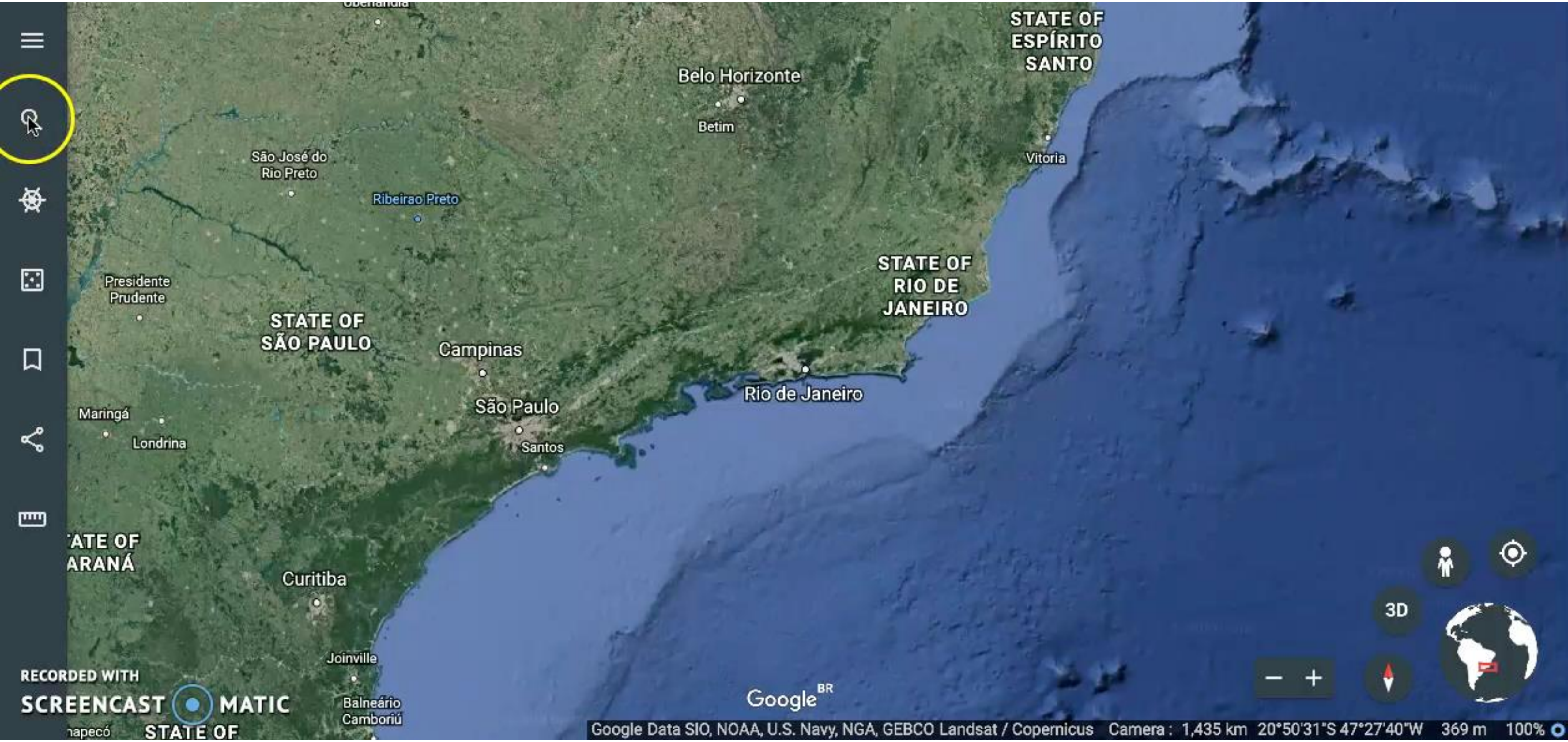
Reunião Magna 2019, Academia Brasileira de Ciencias, Rio de Janeiro

www.jodierummer.com @RummerLab @physioshark @physiologyfish www.coralcoe.org.au

Amazing team!

LAB RUMMER




STATE OF ESPÍRITO SANTO
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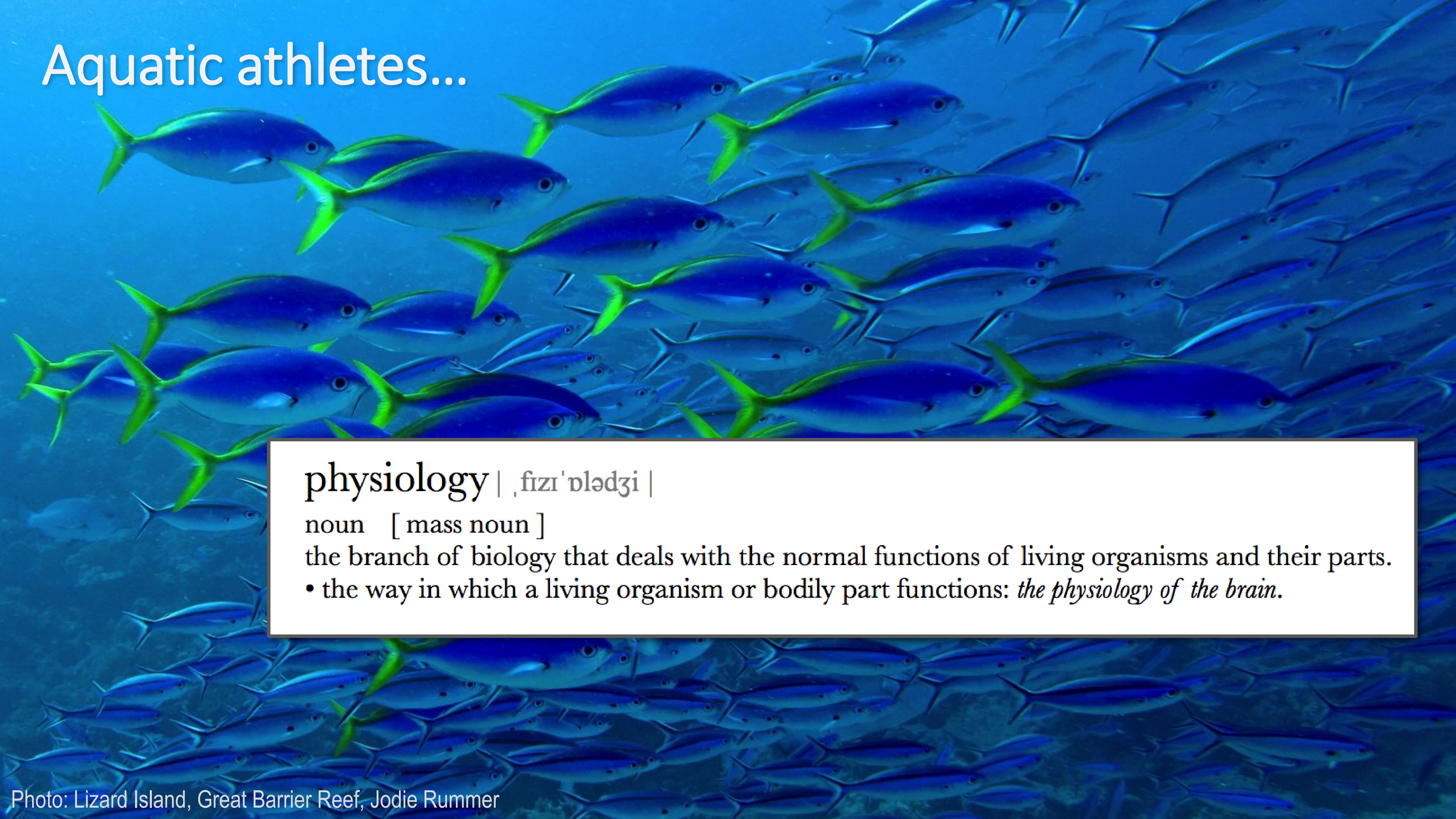
RECORDED WITH SCREENCAST MATIC
3D
Google BR
Google Data SIO, NOAA, U.S. Navy, NGA, GEBCO Landsat / Copernicus Camera : 1,435 km 20°50'31"S 47°27'40"W 369 m 100%

Aquatic athletes…



physiology | ˌfɪzɪˈɒlədʒi |

noun [mass noun]

the branch of biology that deals with the normal functions of living organisms and their parts.

• the way in which a living organism or bodily part functions: *the physiology of the brain*.

Photo: Lizard Island, Great Barrier Reef, Jodie Rummer

1. Why fish?
2. How do we measure/assess ‘athletic performance’ ???
3. What? Where? Why?
4. Three main areas of research
5. The future

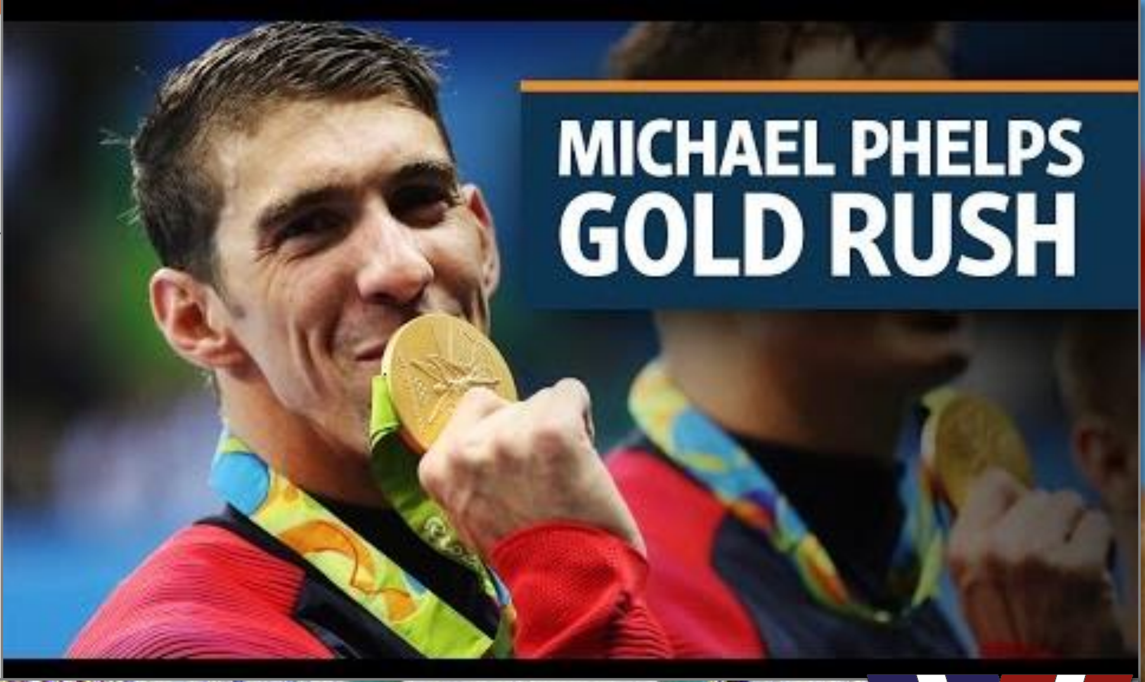
Photo: Lizard Island, Great Barrier Reef, Jodie Rummer

Why fish?

- >50% of all vertebrate species
- Almost every body of water on planet
    - Influenced by changes in water composition/quality
- Tremendous capacity for adaptation
- >400 million years – most successful vertebrates
- Success related to unique capacity for O_2 transport
- Acclimation & adaptation,
  contemporary issues,
  climate change

...but athletes?

Photo: Lizard Island, Great Barrier Reef, Jodie Rummer


MICHAEL PHELPS
GOLD RUSH


23!


PHELPS
PHELPS

True athletic performance

Usain Bolt

Avg. speed: 12.4m/s

Stride: 2.4m

5.09 BL/s

Eriksen et al (2009)

Cheetah

Avg. speed: 30.5m/s

Body Length: 1.5m

20 BL/s

Sharp (1997)

Michael Phelps

Avg. speed: 2.7m/s

Body Length: 1.93m

1.4 BL/s

O'Connor & Vozenilek (2011)

Sail Fish

Avg. speed: 30.5m/s

Body Length: 1.5m

20 BL/s

Sagong et al (2008)

Larval Reef Fish

Body Length: 9-35mm

12 to >20 BL/s

Fisher et al (2005)

The Washington Post

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Speaking of Science

Think Usain Bolt is fast? Scientists say fish are the world's best athletes

A 🖨 1

By Darryl Fears October 8 ✉ Follow @bydarrylfears

A woman swims near a swarm of fish in a cove off Portofino, Italy, on Sept. 9. (OLIVIER MORIN/AFP/Getty Images)

Science News

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The superfish challenge: Michael Phelps vs real fish

ABC Science by Dr Jodie Rummer

Posted Tue at 10:54am

1. Why fish?
2. How do we measure/assess ‘athletic performance’ ???

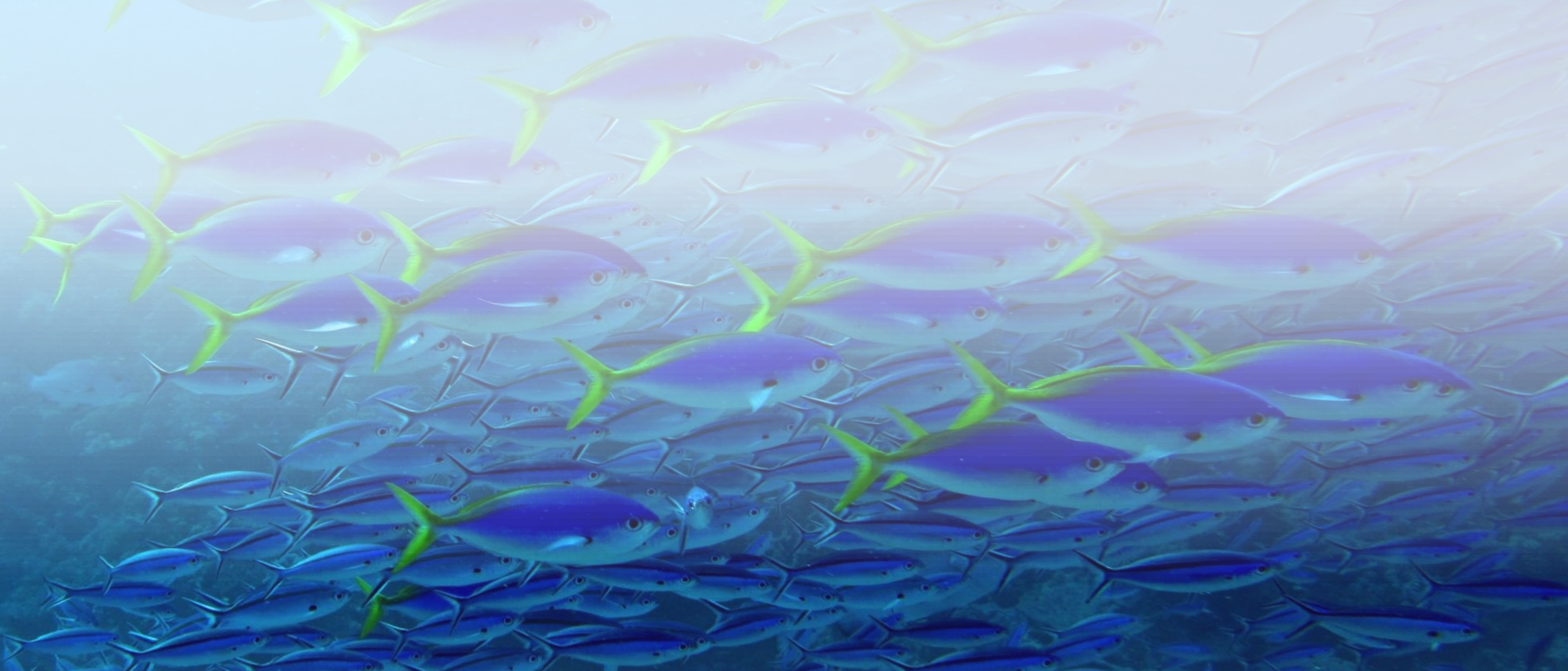


Photo: Lizard Island, Great Barrier Reef, Jodie Rummer

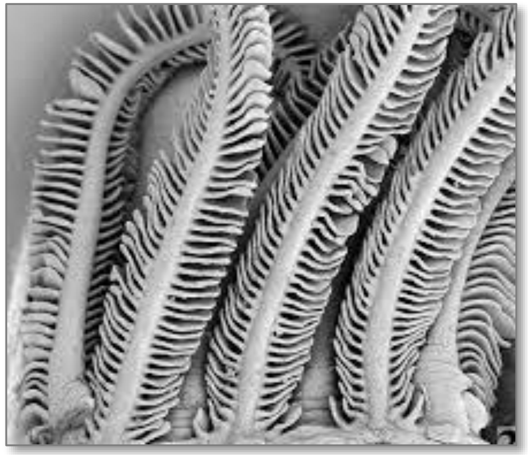
How do we measure/assess ‘athletic performance’ ???

- O_2 uptake
- Cost of transport
- Maximum swimming speed
- Optimal swimming speed
- Burst/escape responses
- Recovery time/cost

Video: Lizard Island Research Station, Jodie Rummer

How do we measure/assess ‘athletic performance’ ???

Getting O_2 into the body

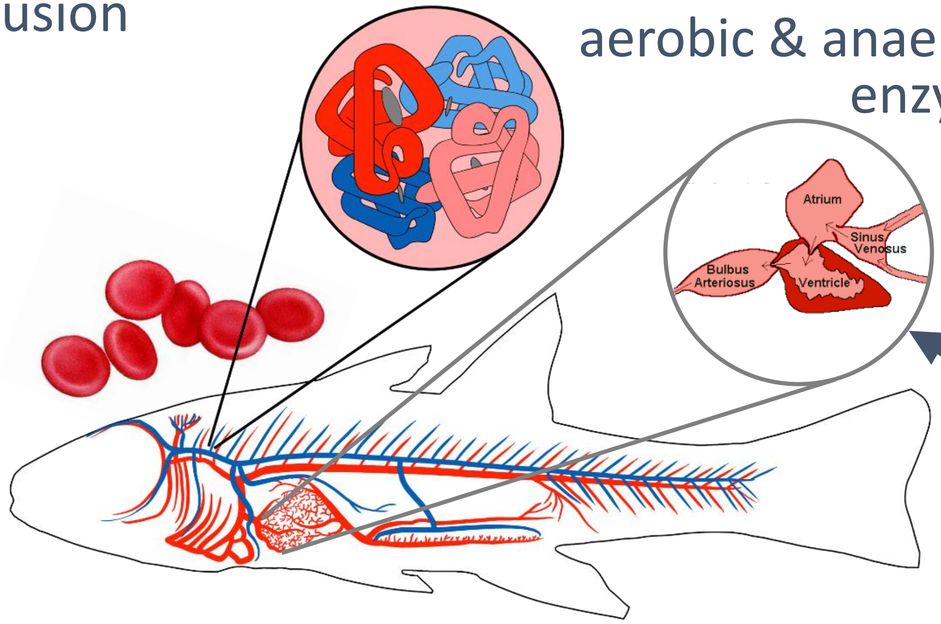


- morphology
- O_2 permeability
- ventilation rate/amplitude
- perfusion

GILLS

Getting O_2 around the body

- RBC counts
- Haemoglobin-O_2 affinity
- capillarity

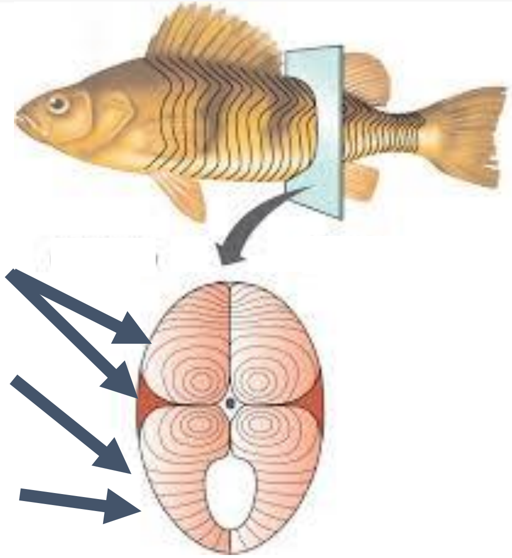


cardiac output

BLOOD & CIRCULATORY SYSTEM

Metabolic waste

FINS/MUSCULATURE



- red vs. white muscle
- mitochondrial function
- aerobic & anaerobic enzymes

Fuelling the tissues

**gene expression patterns at every step*

What? Where? Why?

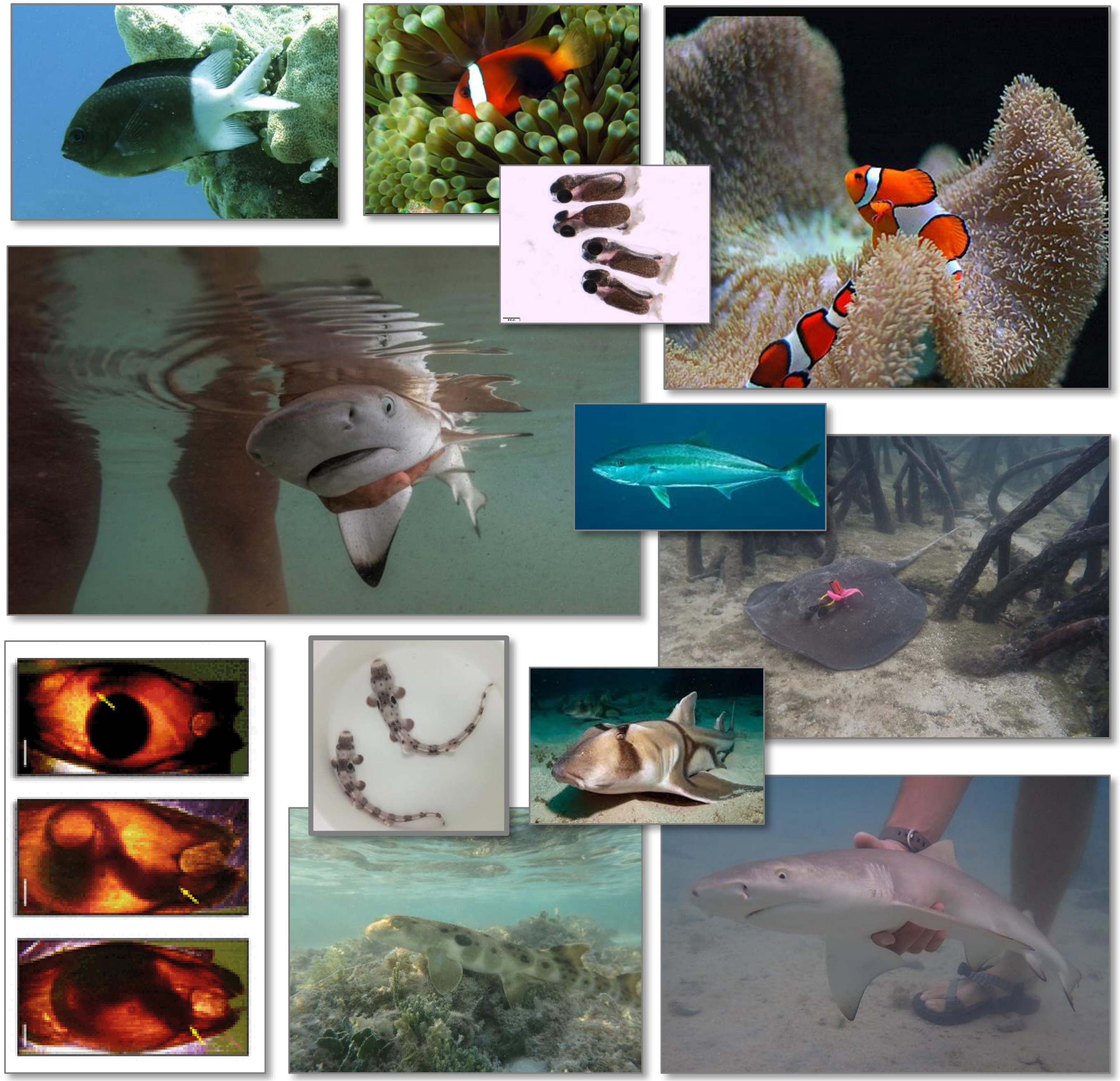
Photo: Lizard Island, Great Barrier Reef, Jodie Rummer

What? Where? Why?

- Fishes, bony & cartilaginous
- Fertilization, larval, juvenile, & adult stages

- Mangrove, lagoon, reef flat, pelagic
- Stable vs. dynamic habitats

- Basic science
- Cause-and-effect relationships
- Evidence base for conservation



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Conservation physiology

An integrative scientific discipline applying physiological concepts, tools, & knowledge to characterizing biological diversity & its ecological implications;

Understanding and predicting how organisms, populations, and ecosystems respond to environmental change and stressors; and

Solving conservation problems across a broad range of taxa

Conservation Physiology

Impact Factor
3.460
SI: Biodiversity Conservation
12 out of 53

Editor-in-Chief
Steven Cooke
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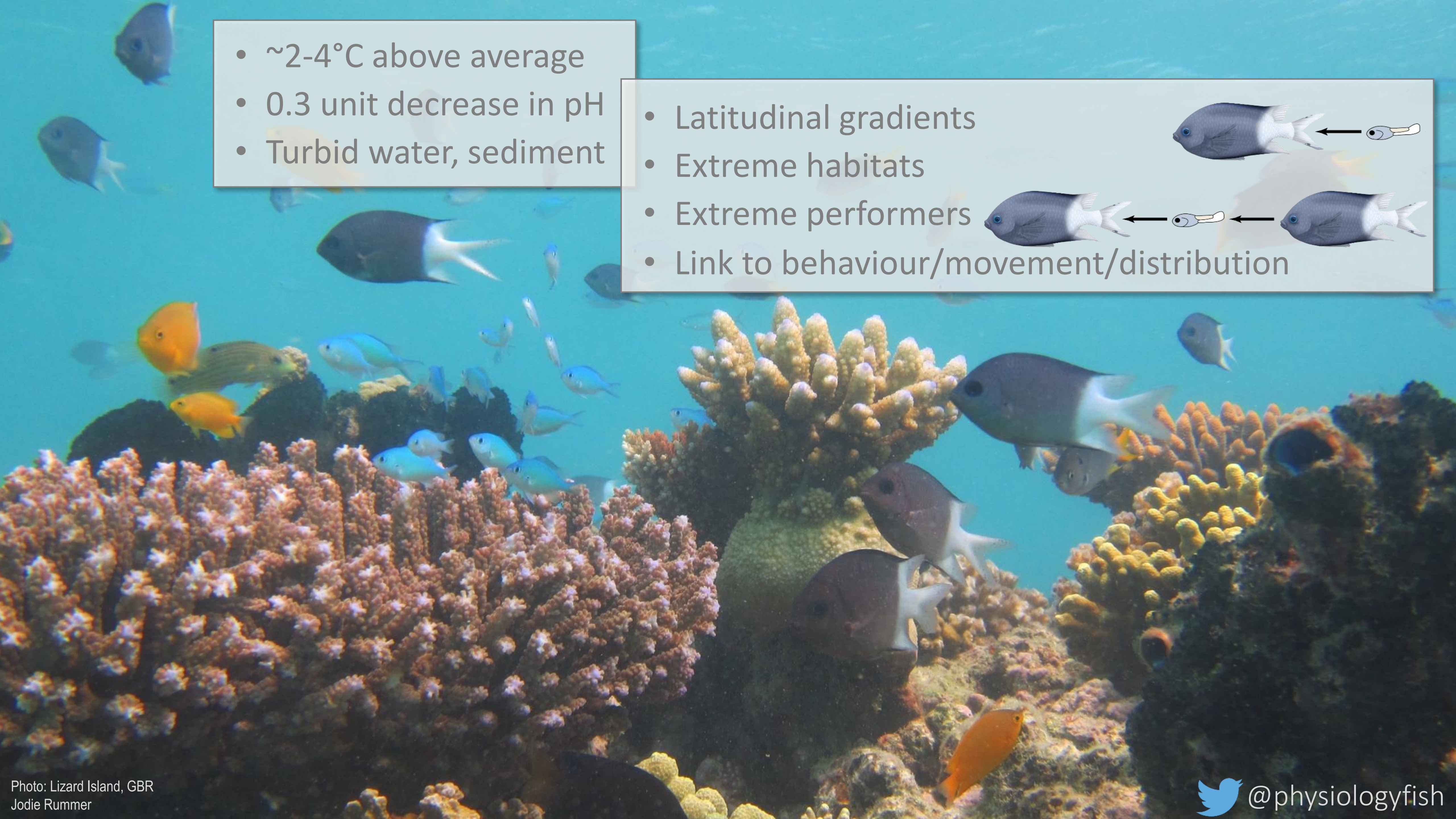
Photo: Lizard Island, Great Barrier Reef, Jodie Rummer

Cooke et al. 2013 Conservation Physiology

Global climate change

1. Ocean warming
2. Ocean acidification
3. Poor water quality

@physiologyfish


~2-4°C above average
0.3 unit decrease in pH
Turbid water, sediment
Latitudinal gradients
Extreme habitats
Extreme performers
Link to behaviour/movement/distribution
Photo: Lizard Island, GBR
Jodie Rummer
@physiologyfish

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Coral Reef Studies

The New York Times

ASIA PACIFIC

Climate-Related Death of Coral Around World Alarms Scientists

By MICHELLE INNIS APRIL 9, 2016

A turtle swimming over bleached coral near Heron Island, in the southern Great Barrier Reef.
XL Catlin Seaview Survey

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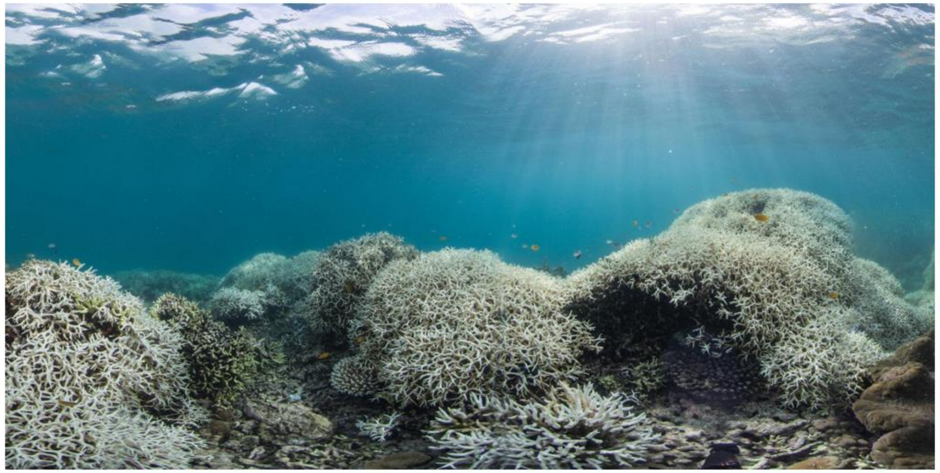
Corals Are Dying on the Great Barrier Reef

Australian government issues emergency response level and warns that bleaching may be linked to climate change.



This panoramic image reveals coral bleaching at Lizard Island on the Great Barrier Reef in March 2016.
PHOTOGRAPH BY XL CATLIN SEAVIEW SURVEY

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Just 7% of Australia's Great Barrier Reef escapes bleaching

20 April 2016 | Australia

Rising water temperatures cause corals to drive out the algae, called zooxanthellae, that gives them their colour

The Washington Post

Energy and Environment

‘And then we wept': Scientists say 93 percent of the Great Barrier Reef now bleached

By Chris Mooney Apri

NEWS

LOCATION:
Sydney, NSW Change

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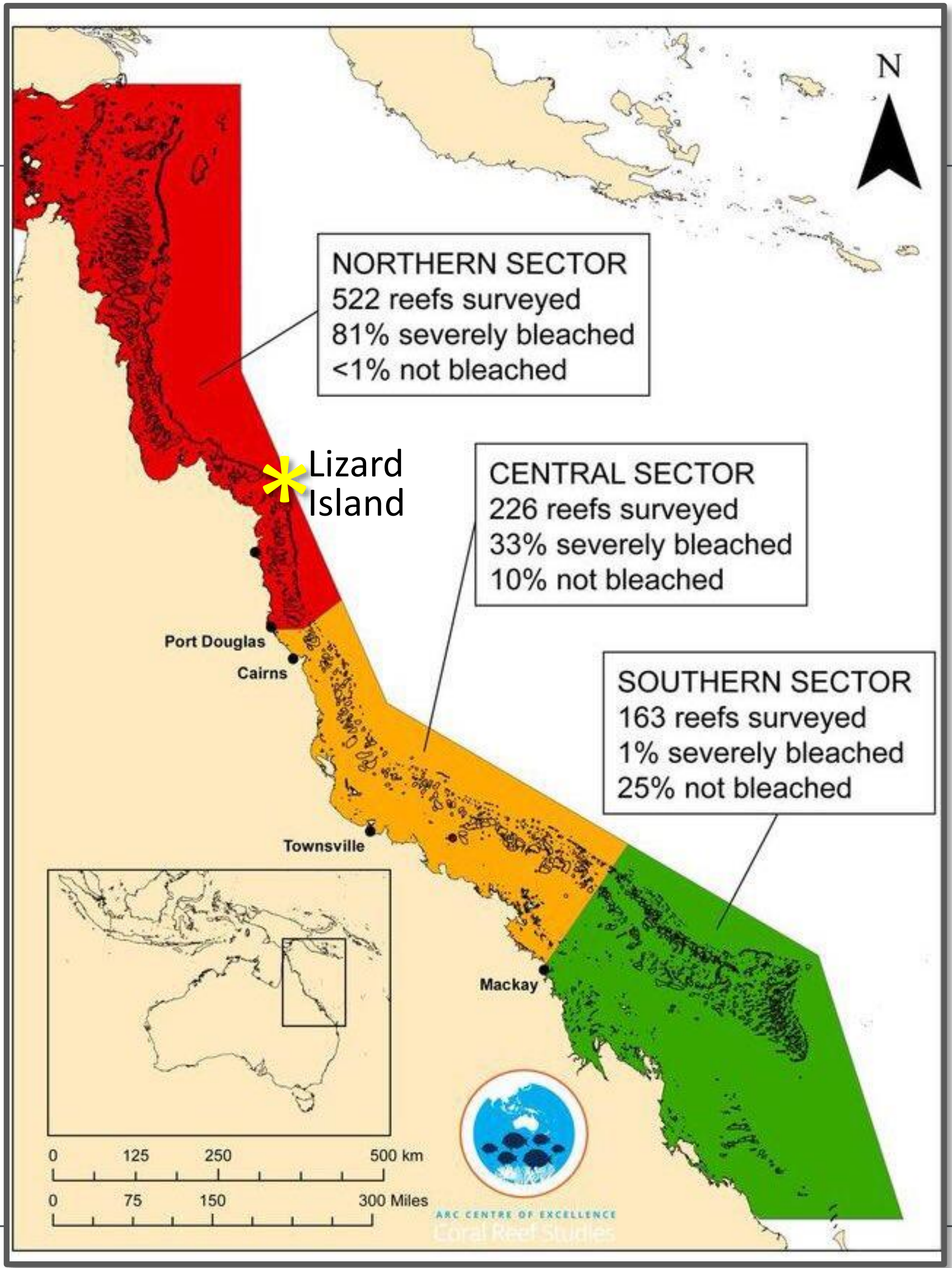
Great Barrier Reef coral bleaching will kill more than half reefs in northern section, federal officials say

By political reporter Francis Keany

Posted Thu at 11:14am


Photo: Lizard Island, GBR
Jodie Rummer
• '97/'98 & '02/'03 bleaching
• 1°C rise 2002-2011
• El Niño, 2016 & 2017 bleaching
ARC Centre of Excellence
Coral Reef Studies
AIMS
Australian Institute of Marine Science
CSIRO
NOAA
James Cook University Australia
The University of Queensland Australia
The University of Sydney
The University of Western Australia
Australian Government
Great Barrier Reef Marine Park Authority
Government of Western Australia
Parks and Wildlife
@physiologyfish
National Coral Bleaching Taskforce
Photo: Bridie Allan



Hughes et al., 2017 *Nature*; Hughes et al., 2018 *Science*

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Coral Reef Studies

- Aerial surveys (911 reefs) ground-truthed with underwater surveys
- Over entire GBR, only 7% of reefs completely escaped bleaching
- North the most damaged, with 81% of reefs severely bleached
- Back-to-back bleaching in 2016 & 2017
- >65% total mortality

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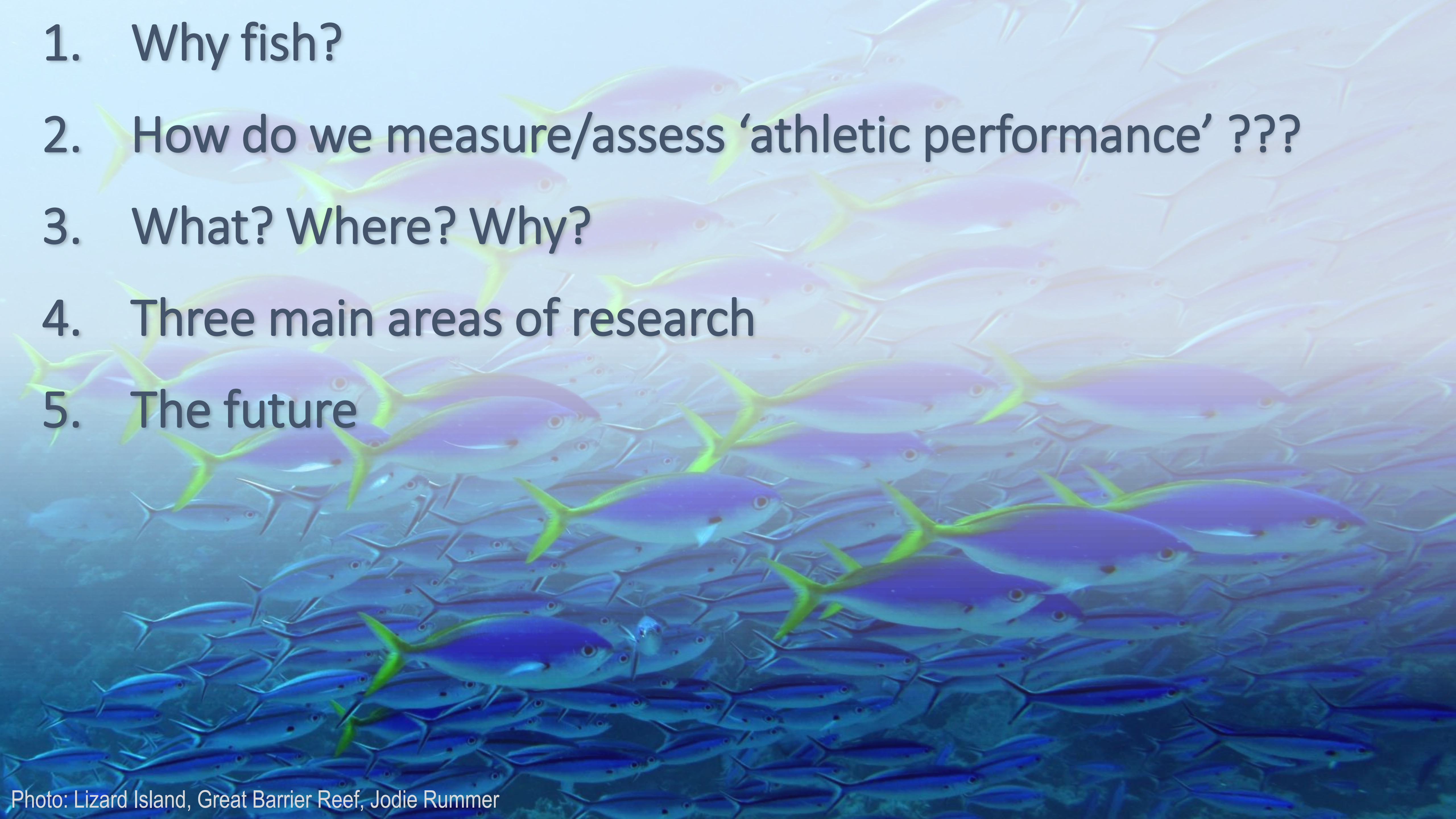


Photo: Lizard Island, Great Barrier Reef, Jodie Rummer

Three main areas of research

Mechanistic basis for tolerance/intolerance

- Basic science
- Identify physiological mechanisms
- Plasticity potential
- Relationship to environment
- Gene expression patterns

Early life history

- Understand development
- Predict windows of vulnerability
- Stress (e.g., climate change)
- Modelling performance/fitness
- Ecological connectivity

PhysioShark

- Predators
- K-selected species
- Hatch/newborn to adult
- Conservation/adaptation focus

Findings to date…

Mechanistic basis for tolerance/intolerance


Taryn Laubenstein


Kelly Hannan


Celia Schunter





Past RummerLab

- Changes in aerobic & anaerobic metabolism during acute heating events (e.g., bleaching)
- Evidence for maintained ‘athletic performance’ under elevated CO_2
- Tradeoffs between physiological & behavioural performance under elevated CO_2
- Identifying mechanism, target genes involved, changes over various time scales, ecological link

Findings to date…

- Decrease in length, weight, condition, bone size, survival, changes in reproduction
- Behavioural impairment
- Acid-base regulation
  - Increased energetic cost of pH/ion regulation
- But, increased oxygen release to select tissues/organs!
- Mixed O_2 transport/aerobic scope responses
  - Tradeoffs?

(Nilsson et al., 2012 *NCC*; Munday et al., 2014 *NCC*; Heuer & Grosell 2014 *AJP;* Lefevre 2016 *Cons. Physiol.*; Hannan & Rummer 2018; *JEB)*

Findings to date…

Early life history

Sybille Hess

Teish Prescott

Björn Illing

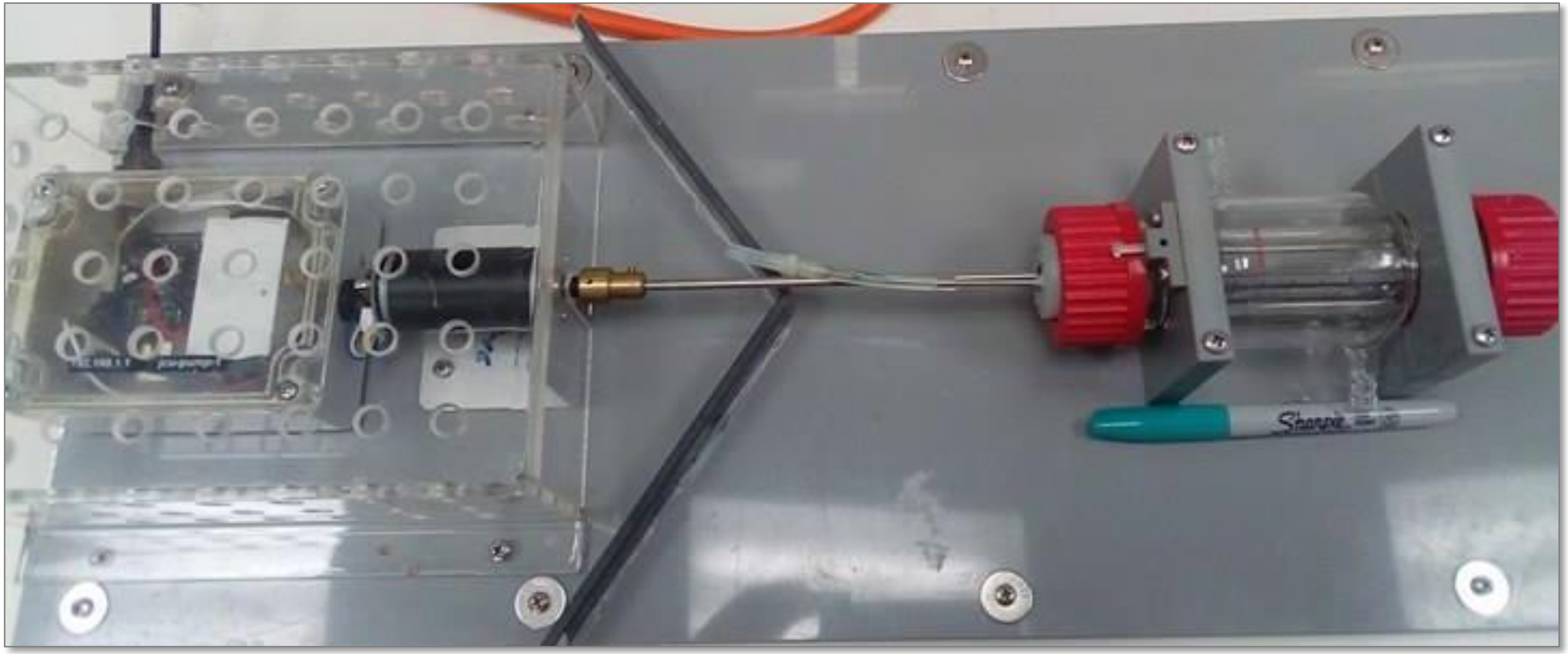
Bridie Allen

Adam Downie

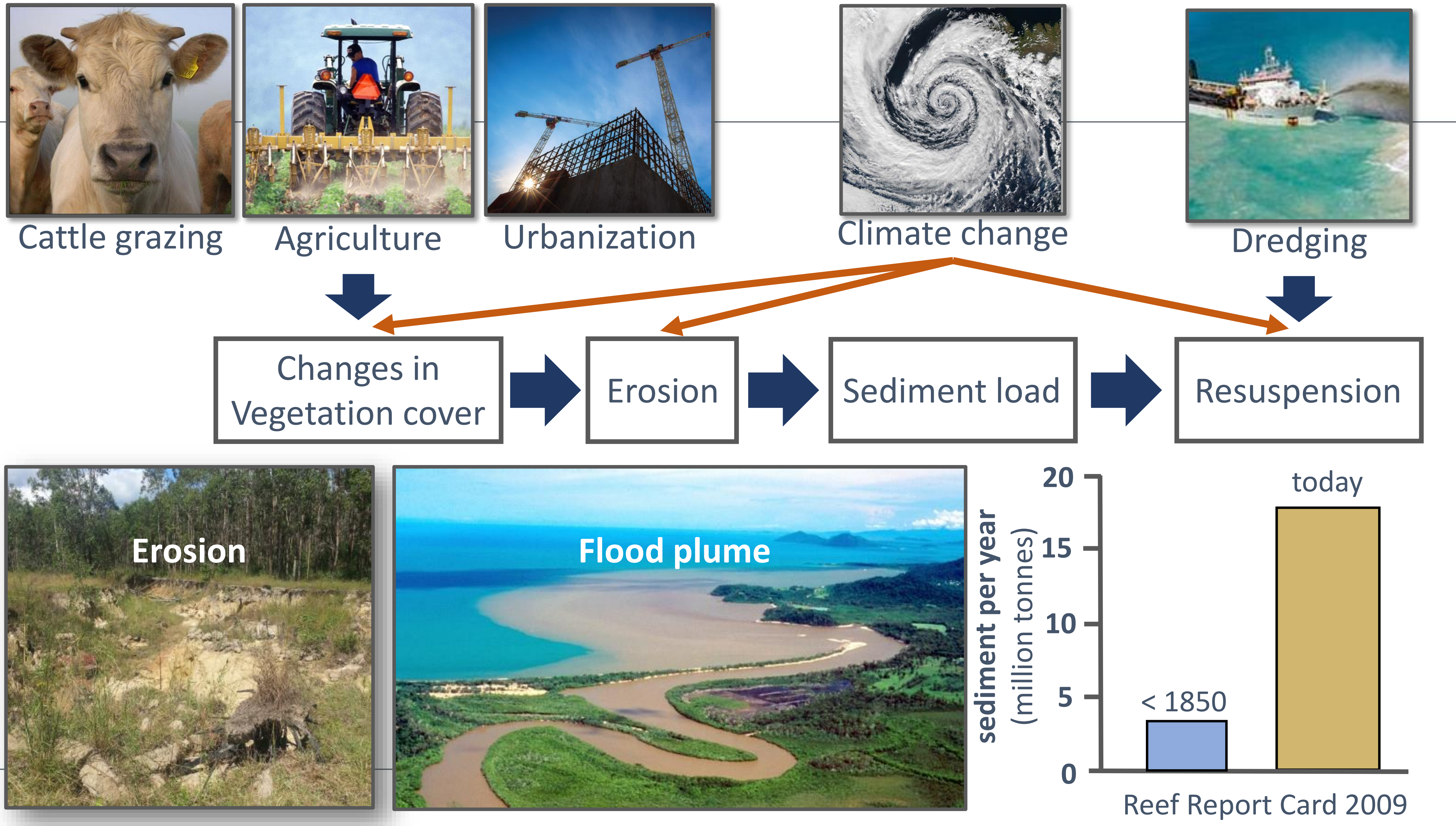
Sofia Jain-Schlaepfer

- Developmental milestones (e.g., heart, gill, swimming muscle formation & use)
- Stress (natural or anthropogenic) during certain developmental windows (i.e., pre vs. post hatch)
- Influence of multiple stressors
  - Warming, ocean acidification, hypoxia, turbidity, noise
- Implications toward ecosystem connectivity, modeling

Challenging miniature 'athletes'

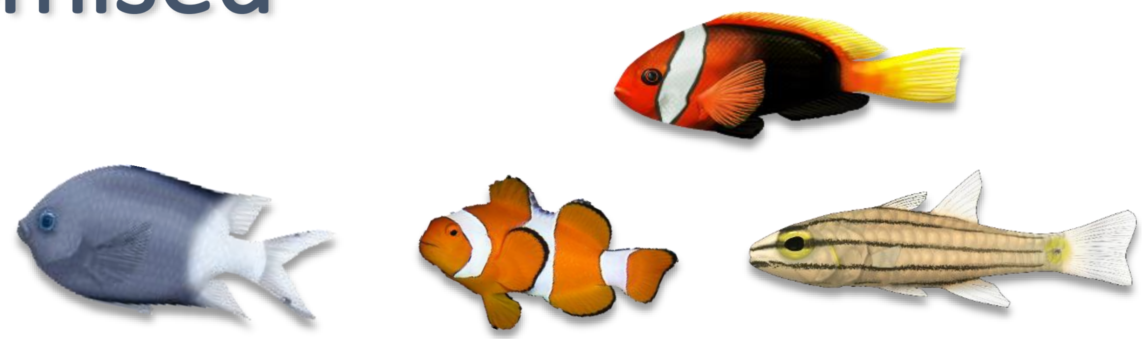


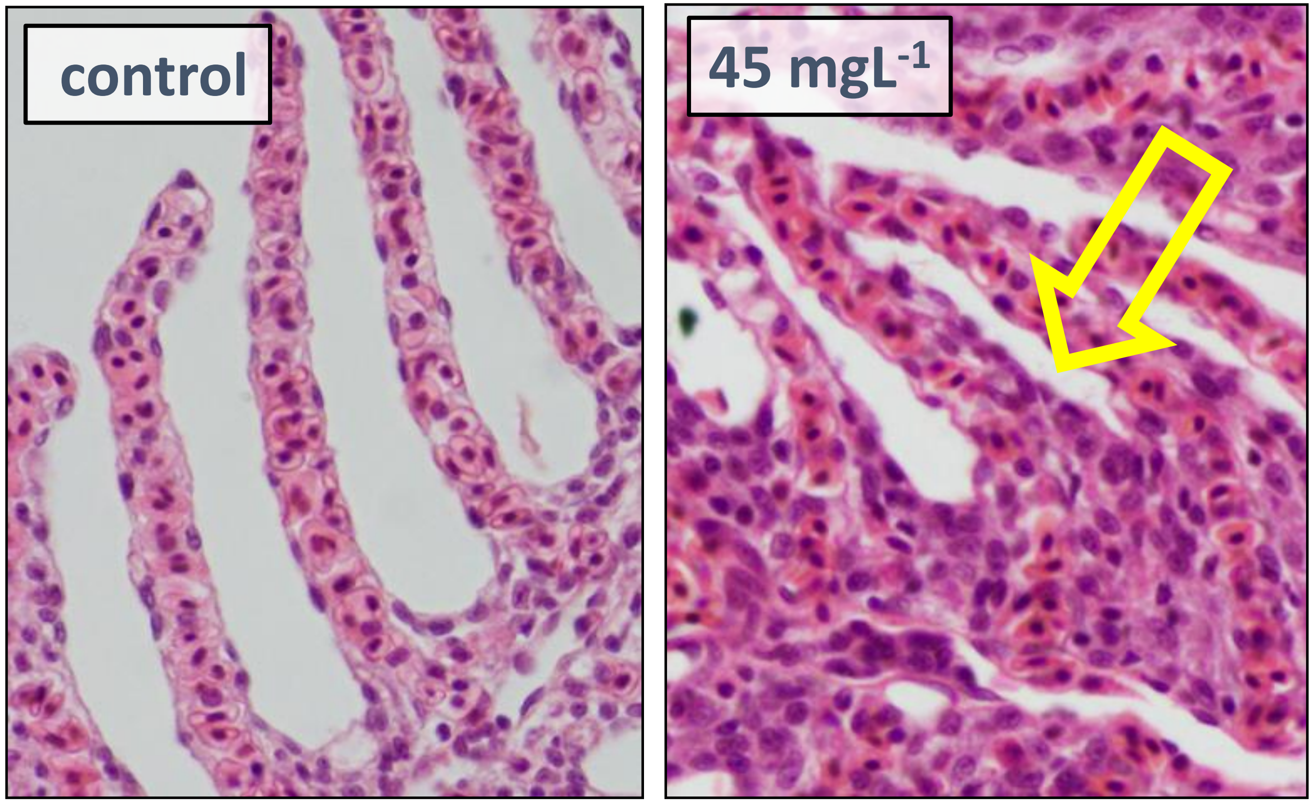
Downie et al., *in prep.*


Cattle grazing
Agriculture
Urbanization
Climate change
Dredging
Changes in Vegetation cover
Erosion
Sediment load
Resuspension
Erosion
Flood plume
sediment per year
(million tonnes)
20
15
10
5
0
< 1850
today
Reef Report Card 2009

Gills & performance compromised

- Sediment directly affects gills
- Affects energy required for rest
- Affects maximum performance
- Swimming & escape responses
- Interactions with elevated temperatures & water flow
- Species-specific, some more vulnerable than others
- Problems occurring at sediment levels common on inshore reefs!





@HessSybille Hess et al. 2015 *Scientific Reports* Hess et al. 2017 *Proc B* Hess et al., 2019 *Coral Reefs*

Findings to date…

- Physiological tolerance to climate change stressors

- Influence on development & performance


Ian Bouyoucos


Emily Higgins

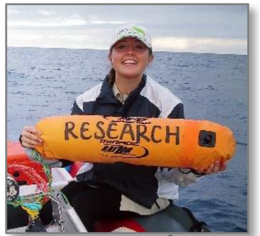

Carolyn Wheeler


Dennis Heinrich


Connor Gervais

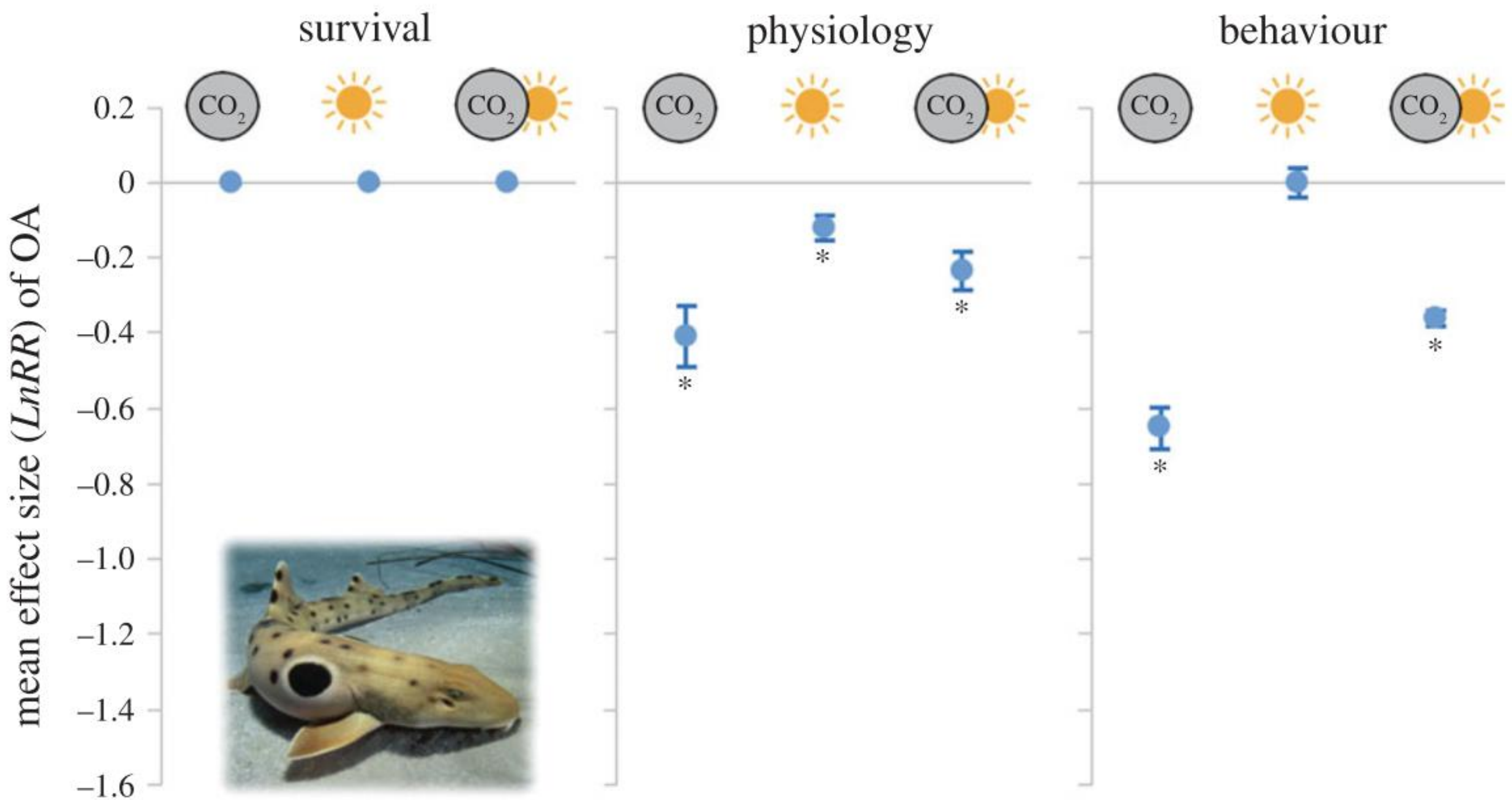
- Potential for adaptation?

- Implications toward management
    - MPAs
    - Shark sanctuaries



Past RummerLab

Is climate change a threat to sharks?

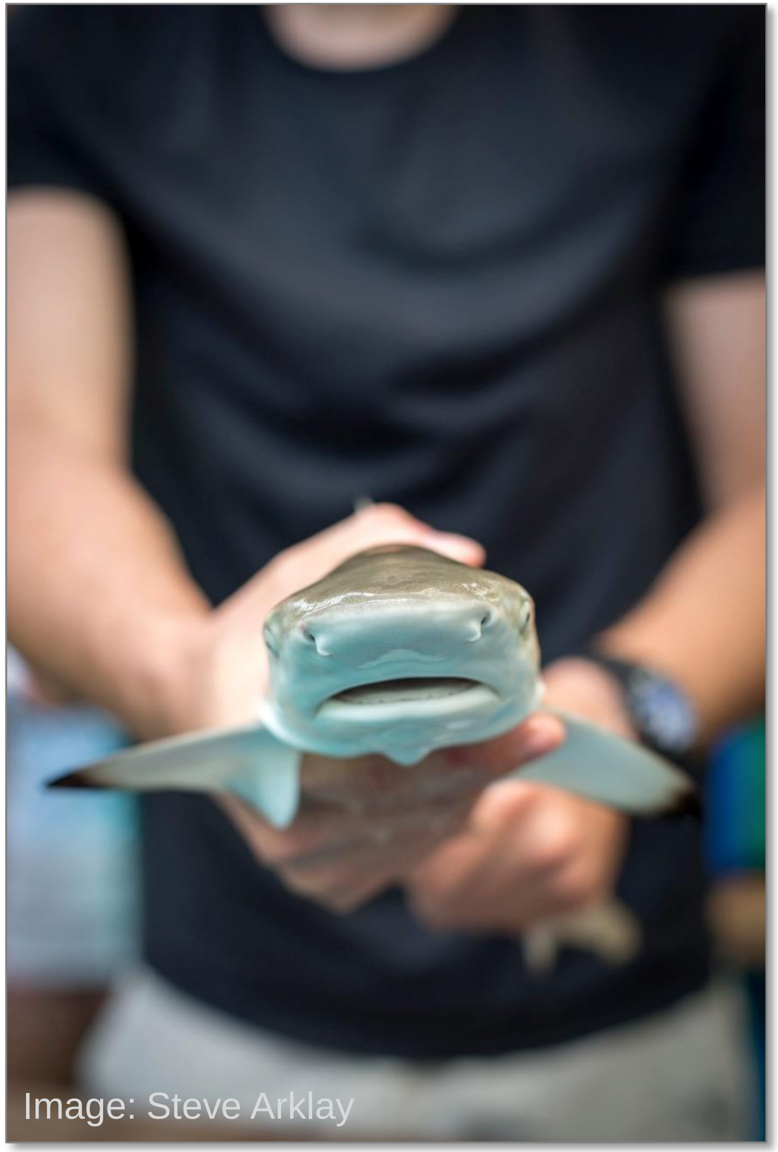


Rosa, Rummer, & Munday, 2017, *Biology Letters*

Newborn sharks also face “exhaustive challenges”

Images: Ian Bouyoucos

...and climate change conditions will only make things worse...



1. Recovery requires 3-9 hours!
2. No effects of temperature within their current range
3. No effects of elevated CO_2
4. Mortality likely after exercise at high temperatures (33°C)


OFFICIAL SELECTION
Barbados Independent Film Festival
2019
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RAW SCIENCE FILM FESTIVAL
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WILDLIFE CONSERVATION FILM FESTIVAL
2018
Cinematography Award
A Show For A Change Film Festival
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TOM VIERUS PRESENTS "INTRODUCING PHYSIOSHARK I BABY SHARKS & CLIMATE CHANGE"
FILMED ON MOOREA IN FRENCH POLYNESIA STARRING JODIE RUMMER & IAN BOUYOUCOS
SPECIAL THANKS CRIOBE RESEARCH STATION PRODUCED BY TOM VIERUS 2018
tomvierus.com
storytelling planet earth underwater

Research - *future*

Interactions

- Elevated temperature & (ocean acidification) CO_2 on key performance traits, e.g. swimming
- Other climate drivers, e.g., turbidity, sound pollution (increases heart rate of larval reef fish)

Mechanisms

- Maintained O_2 transport under stress
- Tradeoffs, e.g. athletic performance and behaviour

Environment

- Challenging micro-habitats
- Geographic gradients

Evolution & adaptation

- Genes involves, the future of reef fishes in the face of climate change

Physiology has the potential to contribute to identifying and solving complex conservation problems

What can we do?

- Engage practitioners & policy makers *(it's a two way street)*
- Be relevant! *(e.g., developing cause-and-effect relationships, predictive models, scaling from molecules to populations)*
- greater reporting (symposia, papers)

-

Finding clever ways to communicate research findings – beyond the journal article, reach large & diverse audiences, and convey passion & urgency has perhaps never been more important than it is today.


Obrigado & Thank you!
Photo: Lizard Island, GBR
Jodie Rummer
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