Fish Futures: Observation, Adaptation and Response to Climate Change

Kevin Weng, Gen Del Raye, Christina Comfort,
Gadea Perez-Andujar, Danielle Garcia

Pelagic Fisheries Research Program
JIMAR
University of Hawaii

What is future O2 concentration?

reach for the green bottle .....

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A

Phil. Trans. R. Soc. A (2011) **369**, 1980–1996
doi:10.1098/rsta.2011.0003

REVIEW

Warming up, turning sour, losing breath: ocean biogeochemistry under global change

BY NICOLAS GRUBER*

Biogeosciences, 10, 1849–1868, 2013
www.biogeosciences.net/10/1849/2013/
doi:10.5194/bg-10-1849-2013

Biogeosciences Open Access

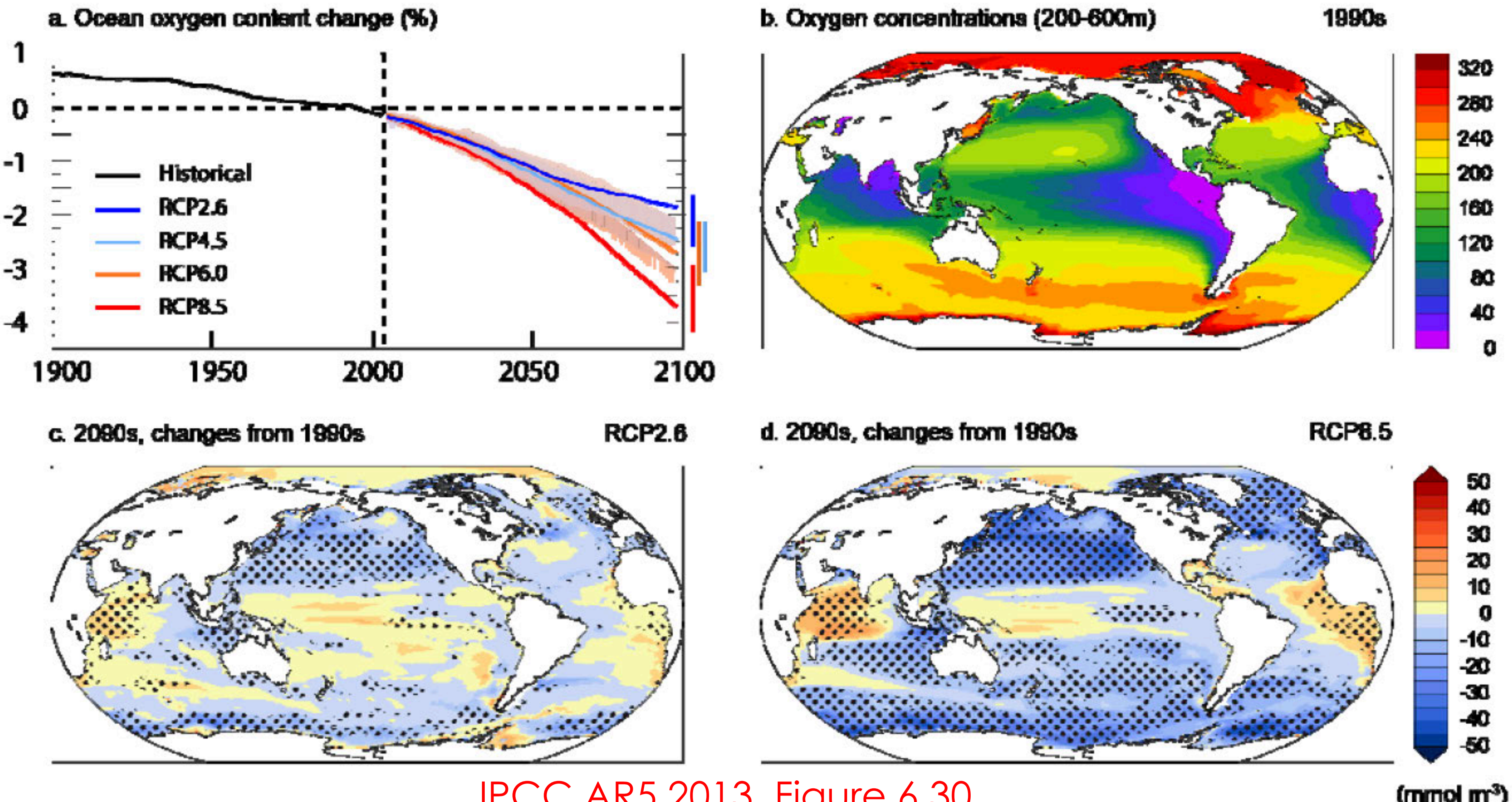
Oxygen and indicators of stress for marine life in multi-model global warming projections

V. Cocco[1,2], F. Joos[1,2], M. Steinacher[1,2], T. L. Frölicher[3], L. Bopp[4], J. Dunne[5], M. Gehlen[4], C. Heinze[6,7,8], J. Orr[4], A. Oschlies[9], B. Schneider[10], J. Segschneider[11], and J. Tjiputra[6,7,8]

the squeeze

- warming at surface (Trenberth, 2007)
- stratification (Steinacher et al., 2009)
- reduced gas solubility (Keeling et al., 2010)
- reduced ventilation (Keeling et al., 2010)
- deoxygenation at depth (changes in mid-depths are likely to exceed those at the surface (Hofmann and Schellnhuber, 2009)
- acidification expands the unfavorable zones even if O_2 remains constant (Brewer and Peltzer, 2009).

- It is *very likely* that global warming will lead to declines in dissolved O2 in the ocean interior – IPCC AR5 2013



IPCC AR5 2013, Figure 6.30

What does low O_2 mean?

imagine that you are a tuna .....

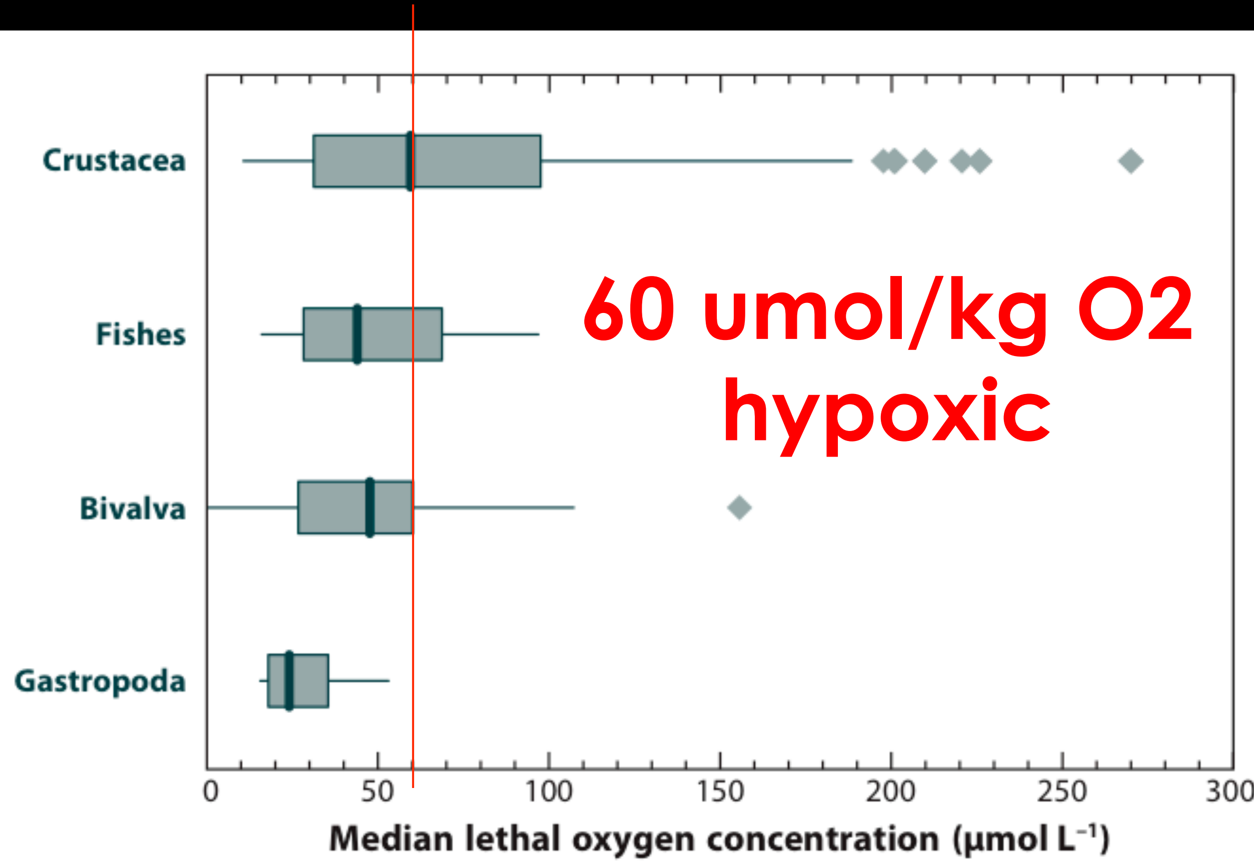
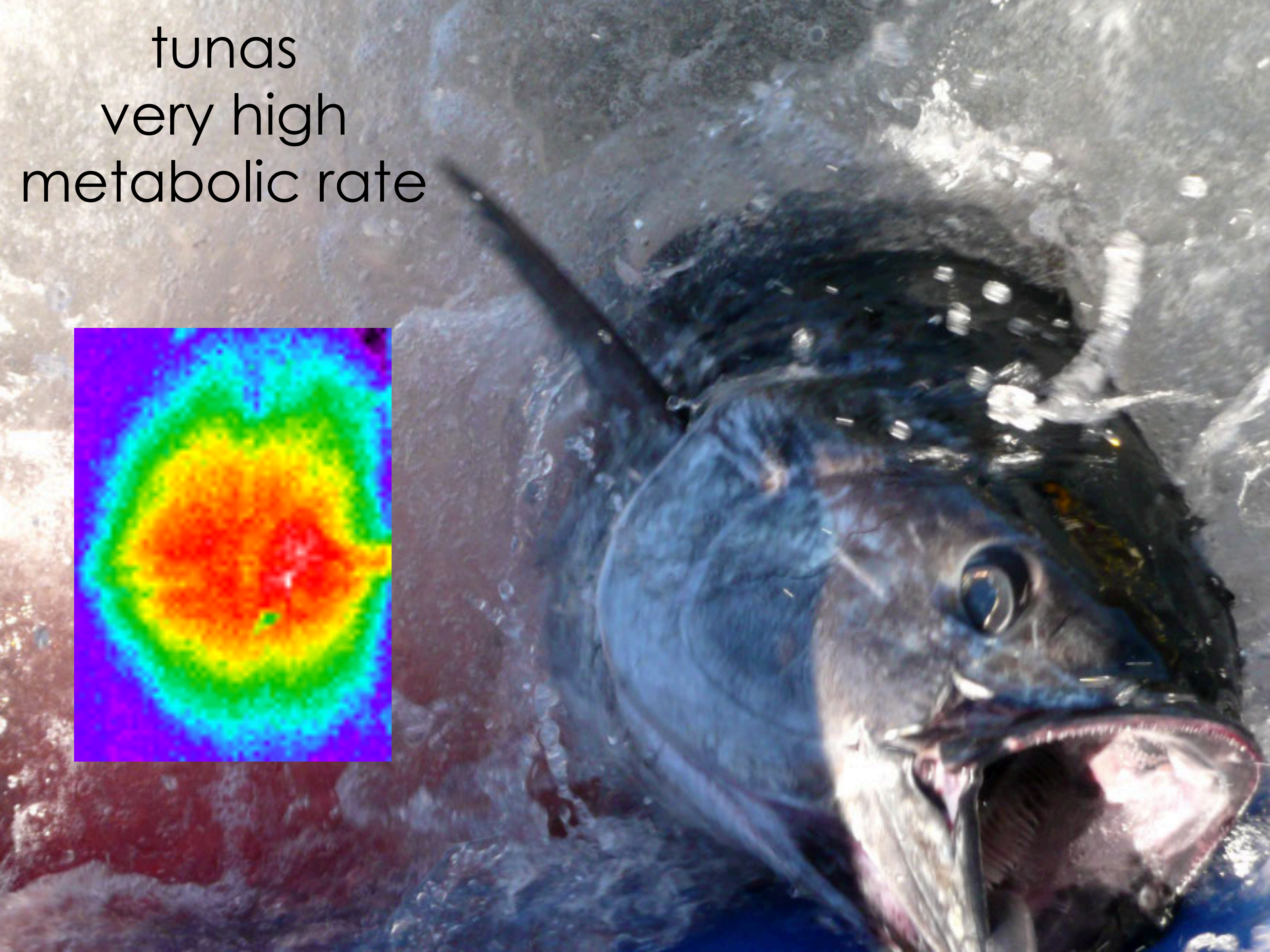


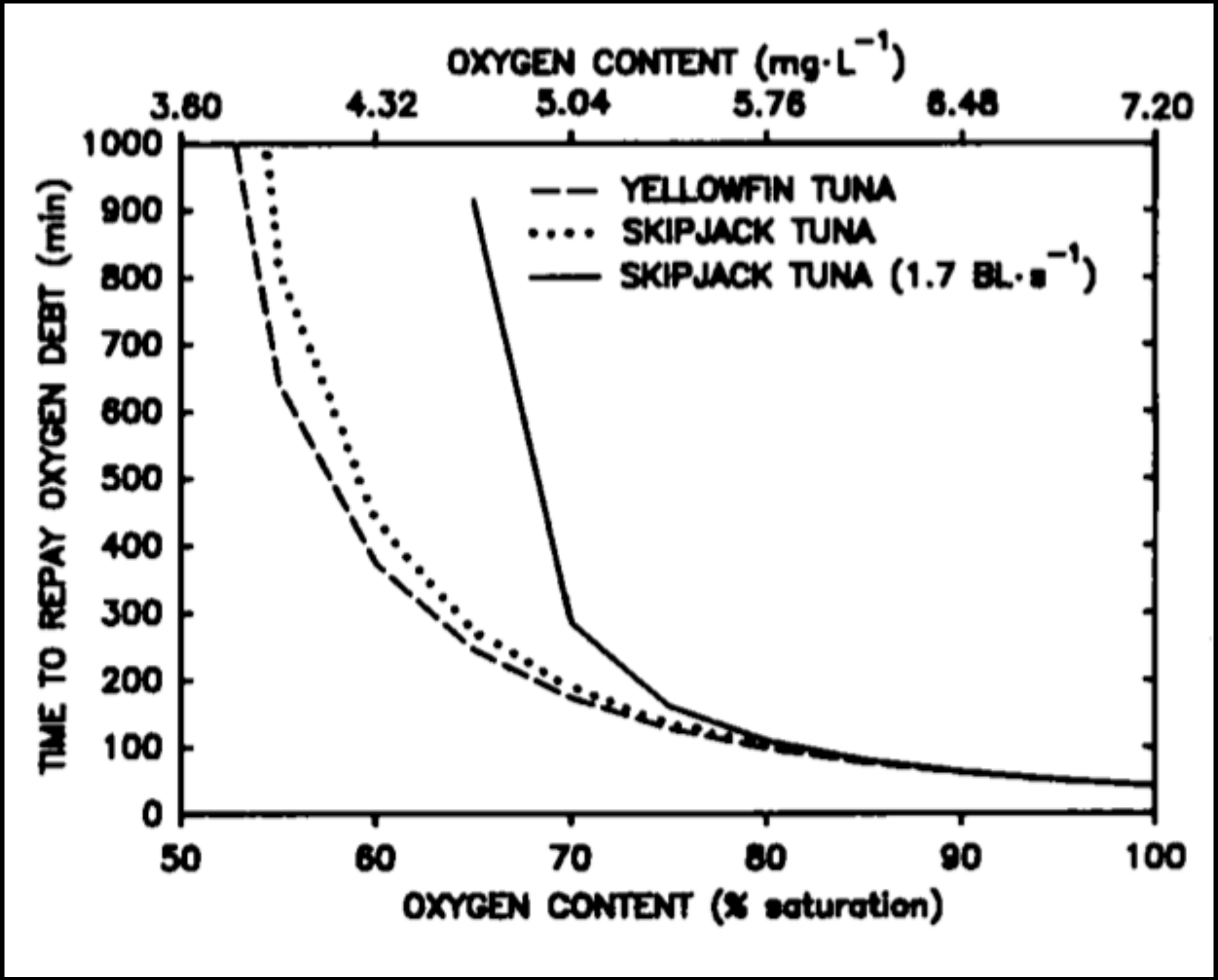
Figure 1

Median lethal oxygen concentration (LC_{50}, in µmol L^{-1}) among four different taxa. The box runs from the lower (Q_1, 25%) to the upper (Q_3, 75%) quartile and also includes the median (*thick vertical line*). The range of data points not considered outliers is defined as 1.5 times the difference between the quartiles (Q_3–Q_1), also known as interquartile range (IQR). The whiskers show the location of the lowest and highest datum within this range, i.e., 1.5 * IQR. Shaded diamonds are outliers as per this definition. Redrawn after Vaquer-Sunyer & Duarte (2008). Copyright (2008) National Academy of Sciences, U.S.A.


tunas
very high
metabolic rate

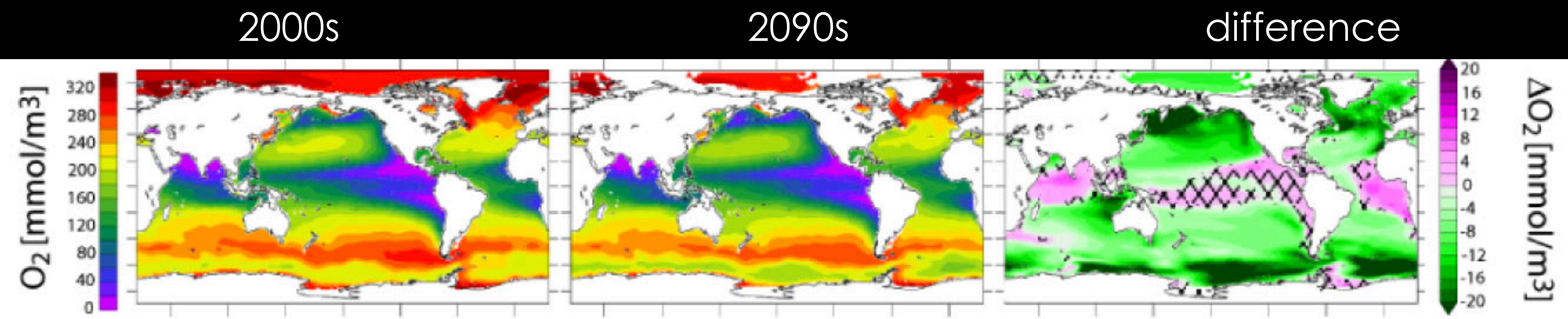
oxygen and tunas

60 umol/kg O_2



Brill 1994

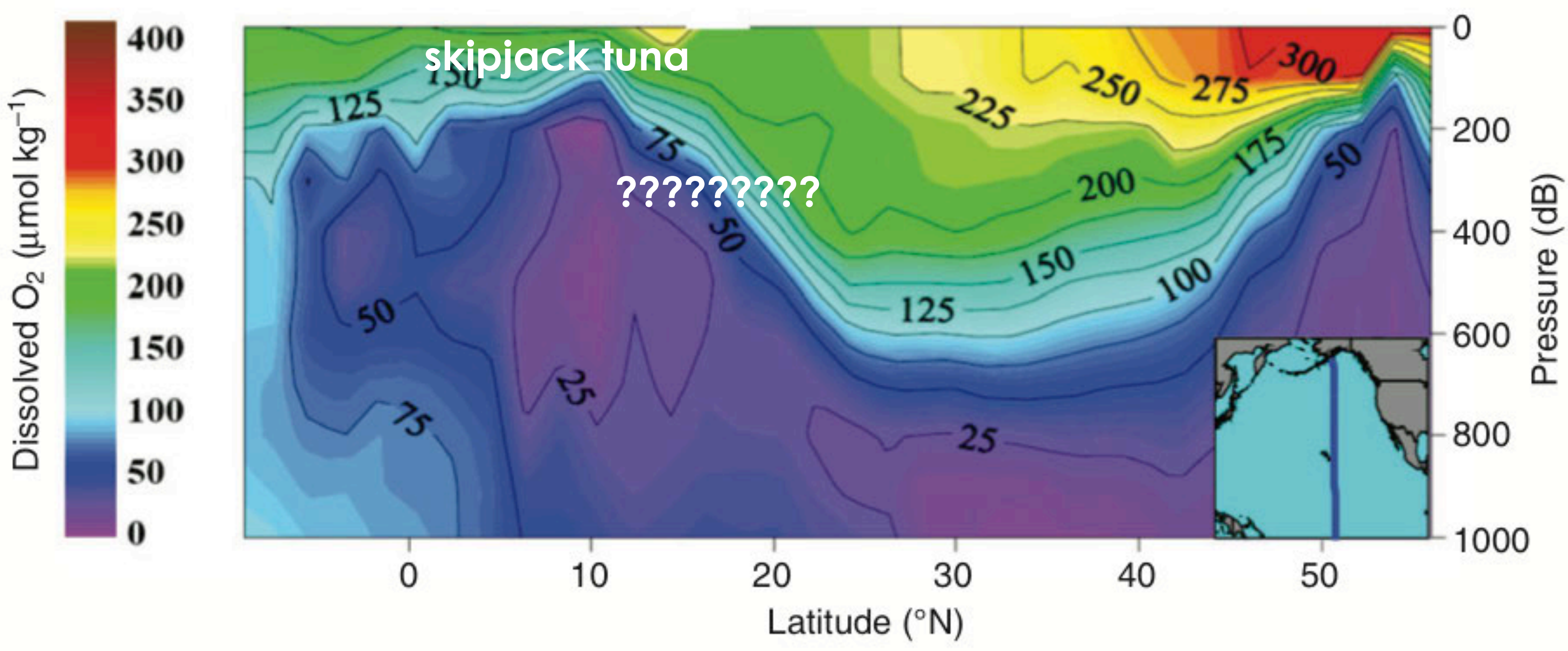
- [O2] decreasing in most regions



Oxygen in 100-600m layer: Cocco et al 2013, Biogeosciences

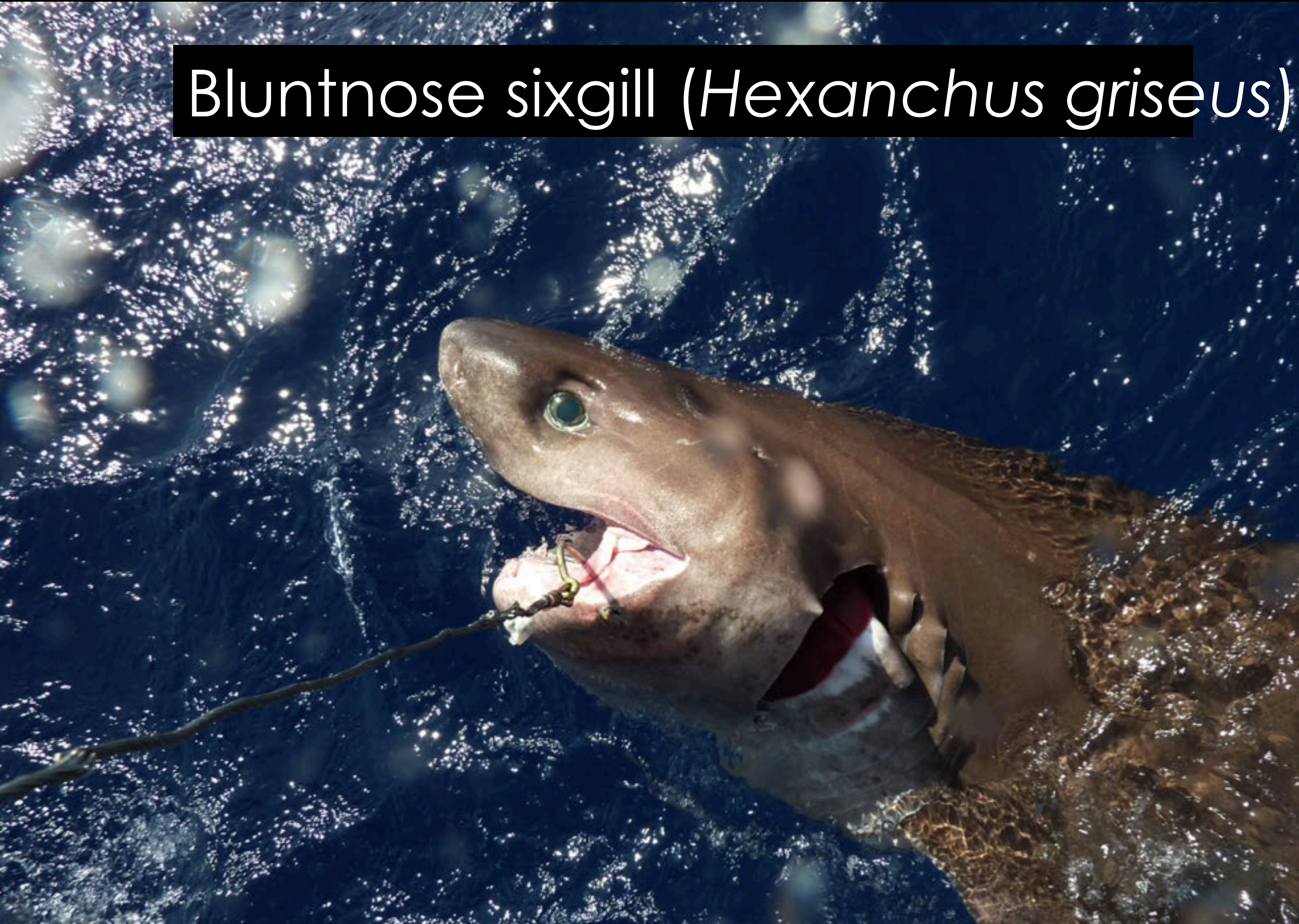
if volume of tuna habitat decreases,
who's habitat will increase?

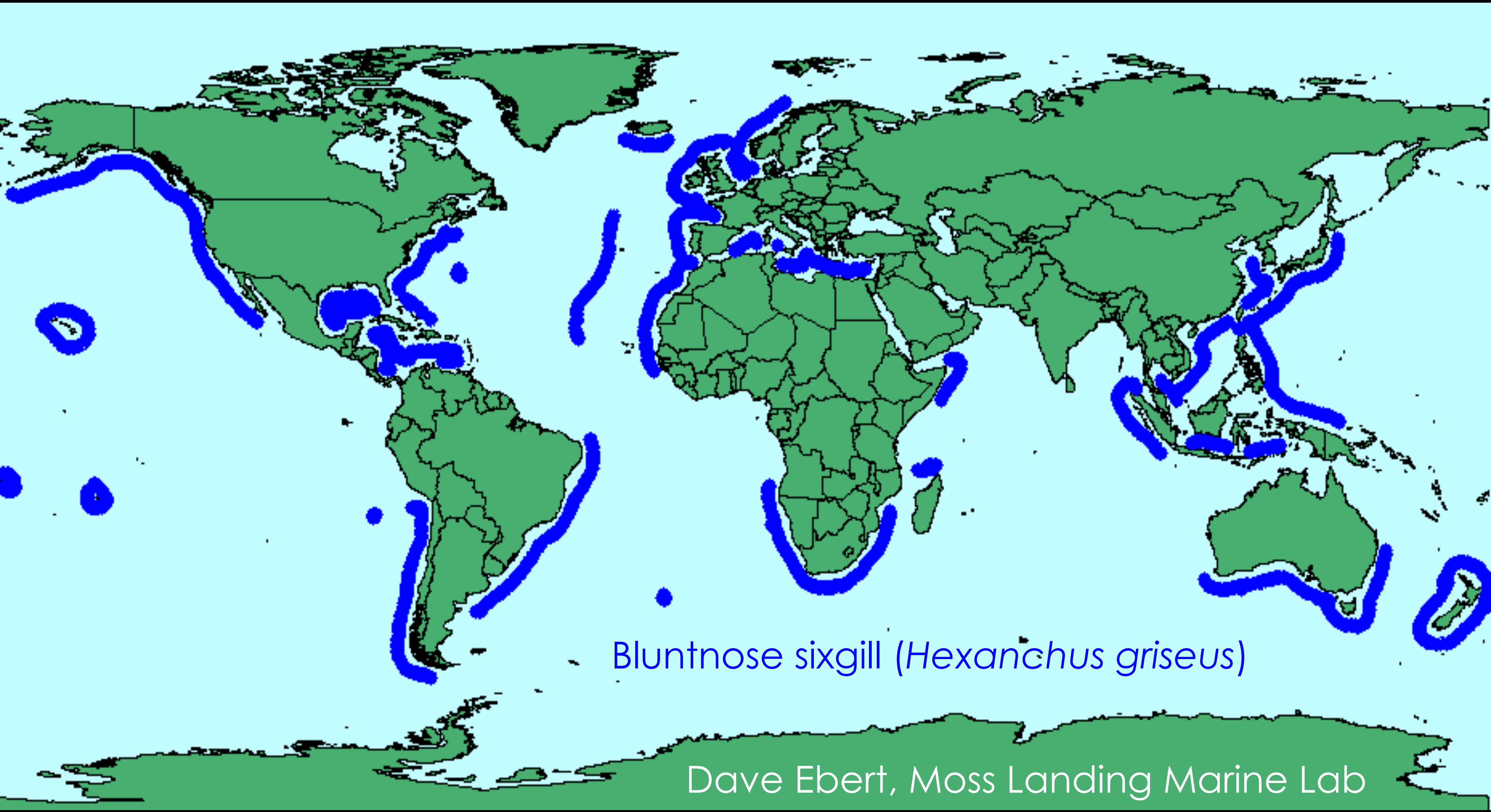
what high trophic level fishes are likely to intersect OML ?



Oxygen section from Seibel 2011

Bluntnose sixgill (*Hexanchus griseus*)





*Perhaps one of the most common shark species world-wide, from nearshore to 2,500 m.

Photo: David Slater

- **Comfort**, C., 2012, Spatial and trophic ecology of the bluntnose sixgill shark. MSc Dissertation, Oceanography, University of Hawaii at Manoa

- **Comfort**, C., and Weng, K. C., accepted, Vertical habitat and behavior of the bluntnose sixgill shark in Hawaii: Deep-Sea Research II

Photo: David Slater

- **Comfort**, C., 2012, Spatial and trophic ecology of the bluntnose sixgill shark. MSc Dissertation, Oceanography, University of Hawaii at Manoa

- **Comfort**, C., and Weng, K. C., accepted, Vertical habitat and behavior of the bluntnose sixgill shark in Hawaii: Deep-Sea Research II

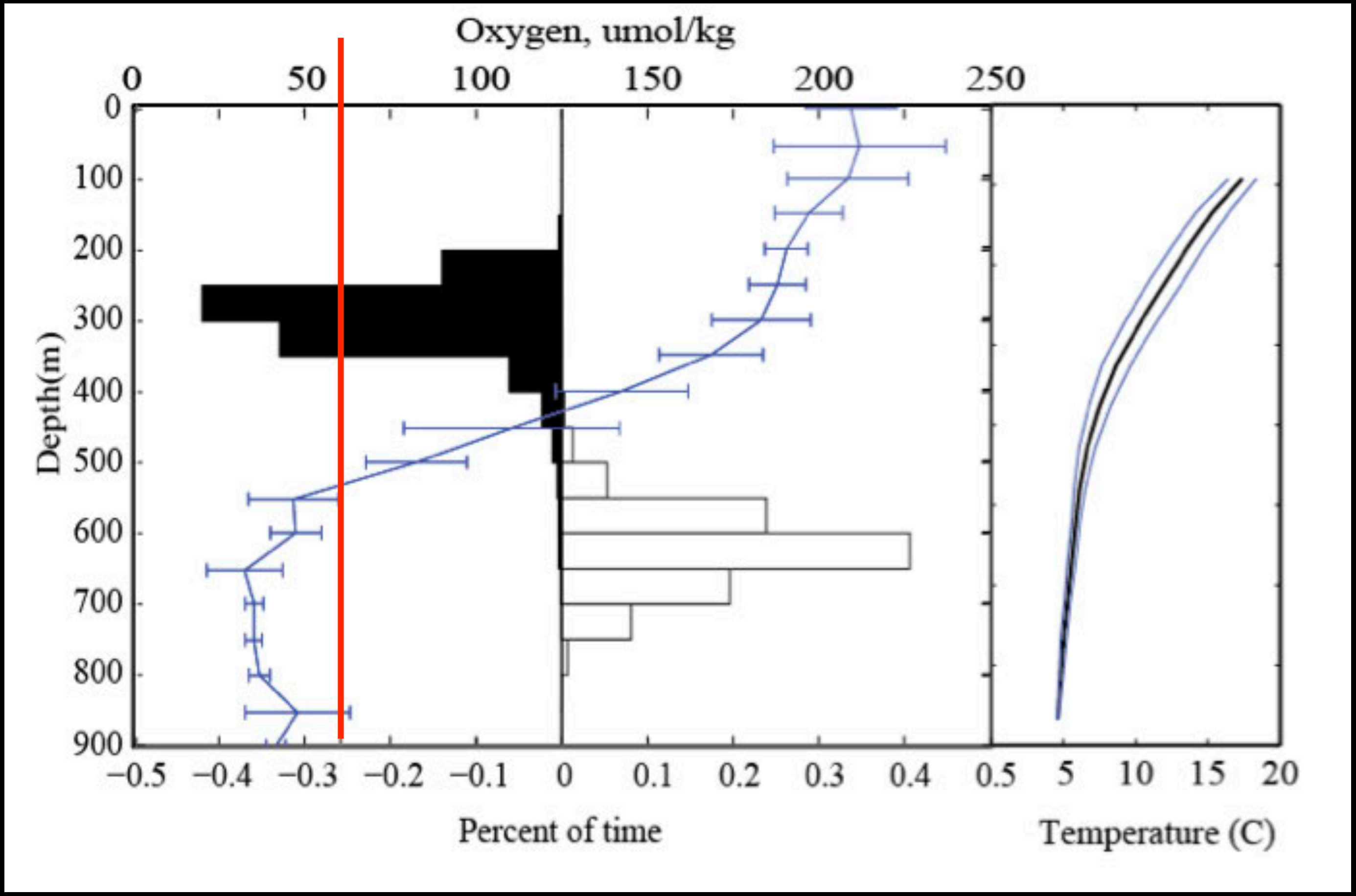
- **Garcia**, D., 2013, Enzyme Activity as an Indicator for Metabolic Rate. Honors Thesis, Department of Marine Biology, University of Hawaii

Photo: David Slater

all day spent in hypoxic water

Hexanchus griseus, July 26-31, 2011 (5 days). Oxygen contours from HOTS 233 (7/18-7/22 2011, Lance Fujieki).

- 39-41% of time in hypoxic waters



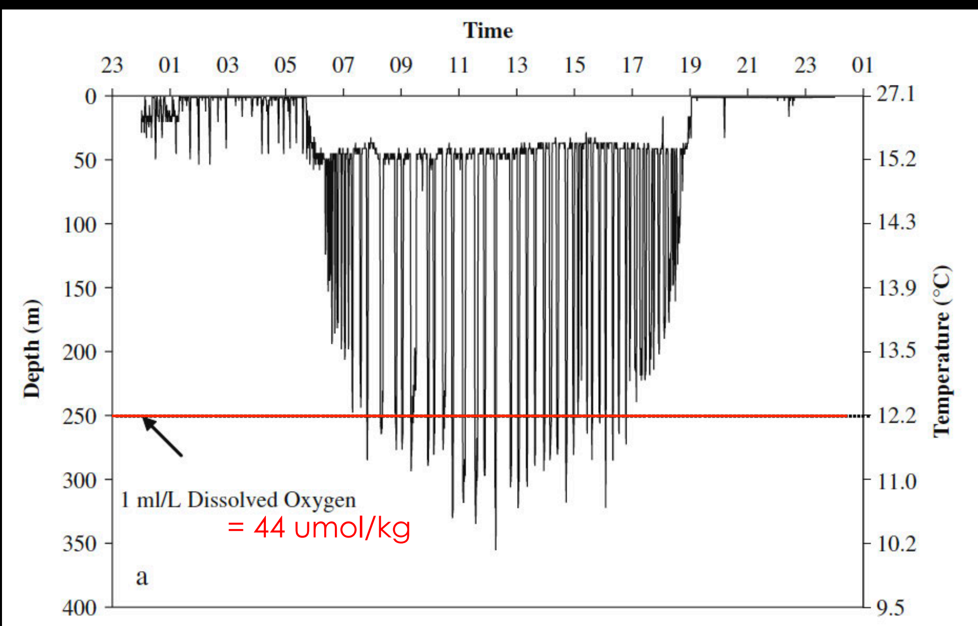
Comfort & Weng, accepted, DSRII

skipjack tuna

sixgill shark

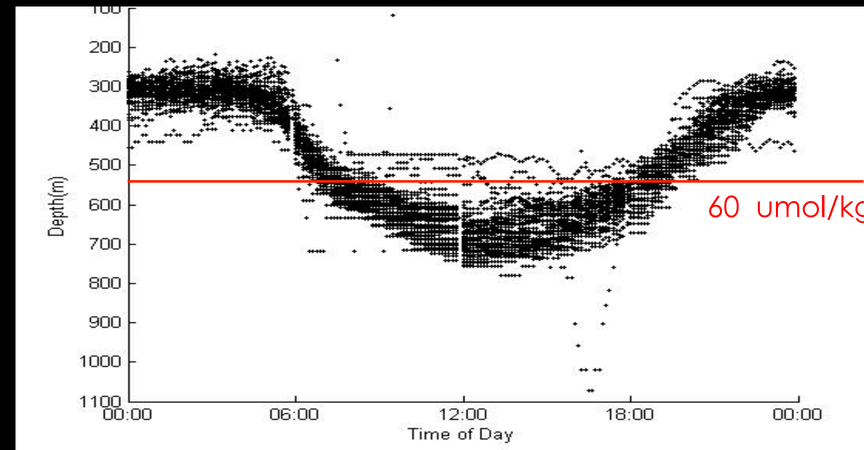
both species feed at 200-300m

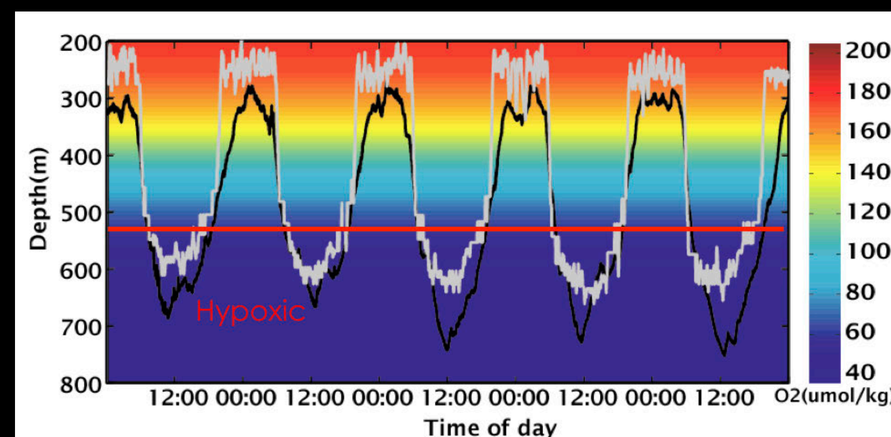
behavior and activity are very different



Kurt M. Schaefer, Daniel W. Fuller and Barbara A. Block

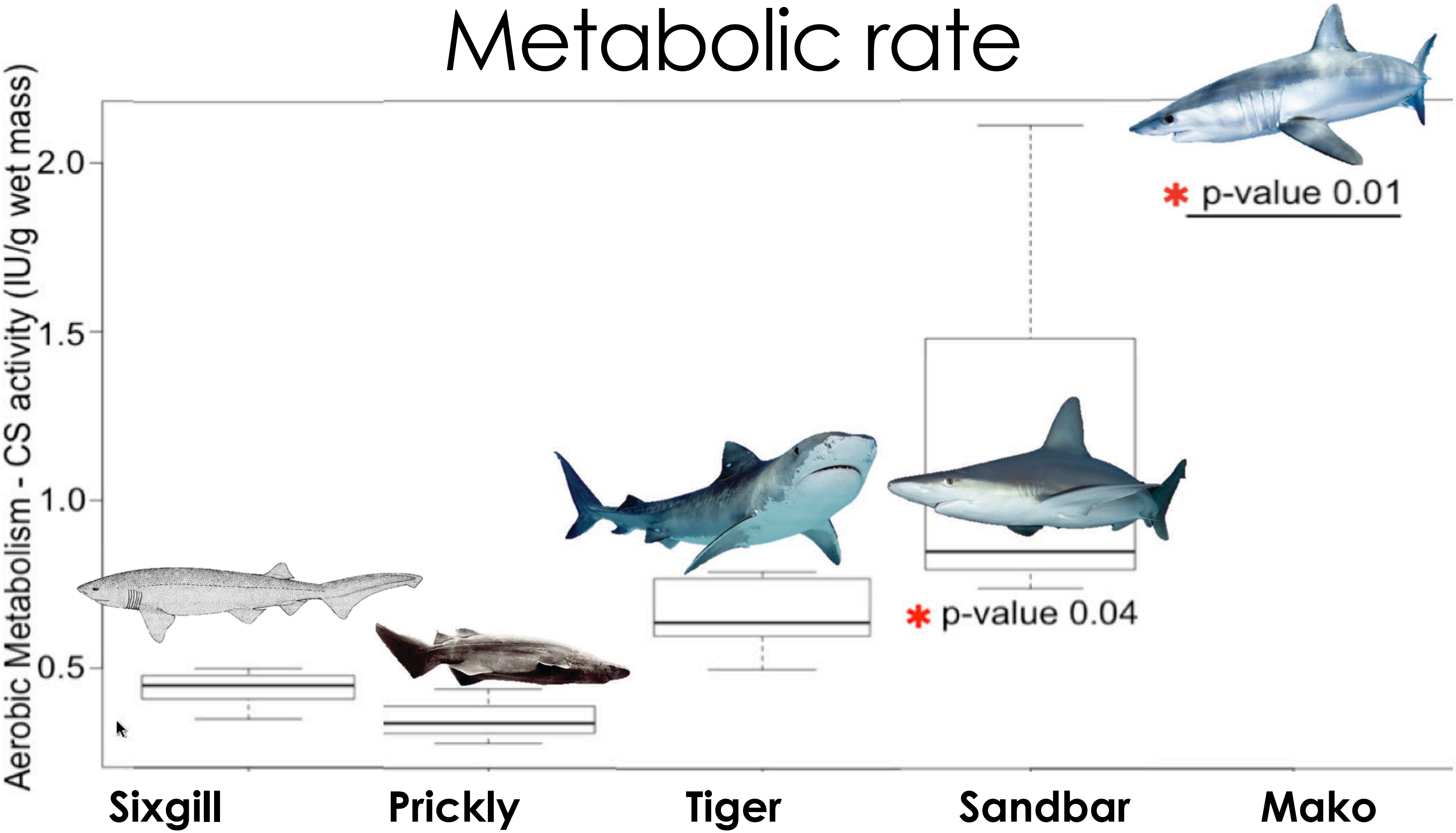
J.L. Nielsen et al. (eds.), *Tagging and Tracking of Marine Animals with Electronic Devices*,
Reviews: Methods and Technologies in Fish Biology and Fisheries 9,
DOI 10.1007/978-1-4020-9640-2_8, © Springer Science+Business Media B.V. 2009



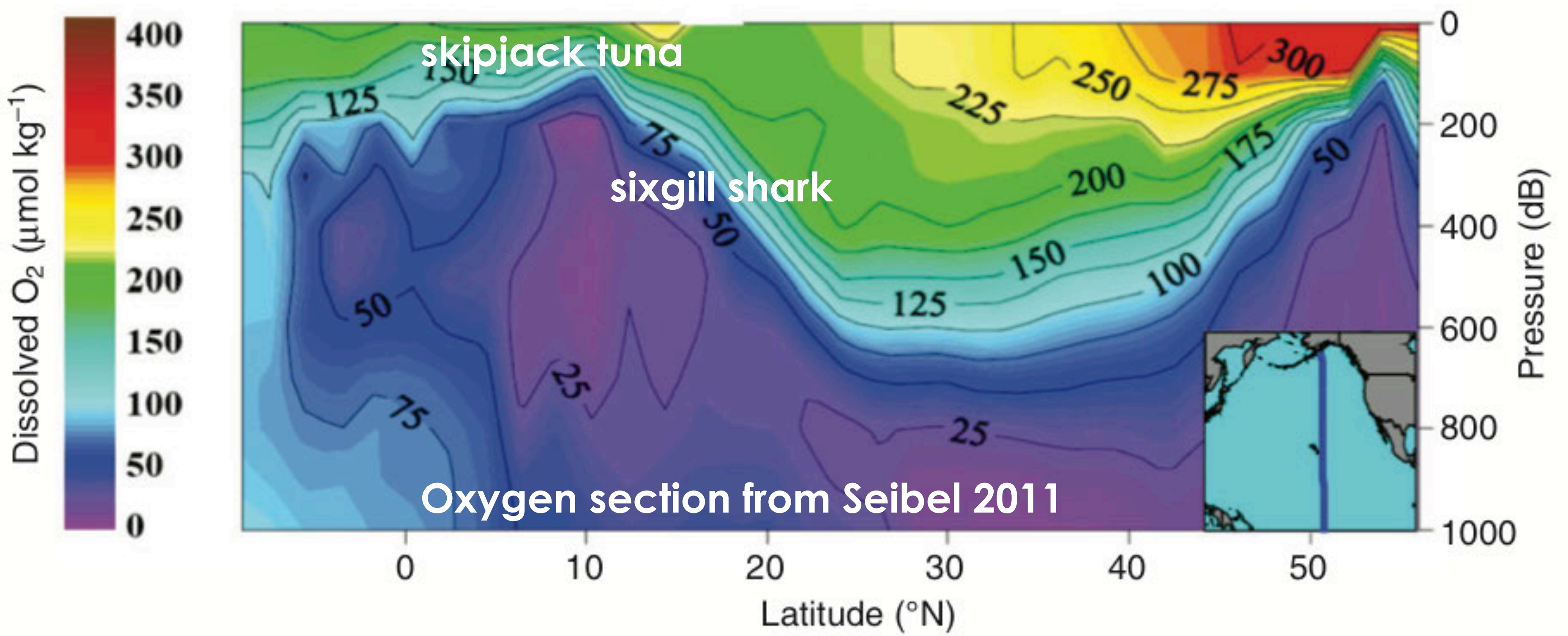


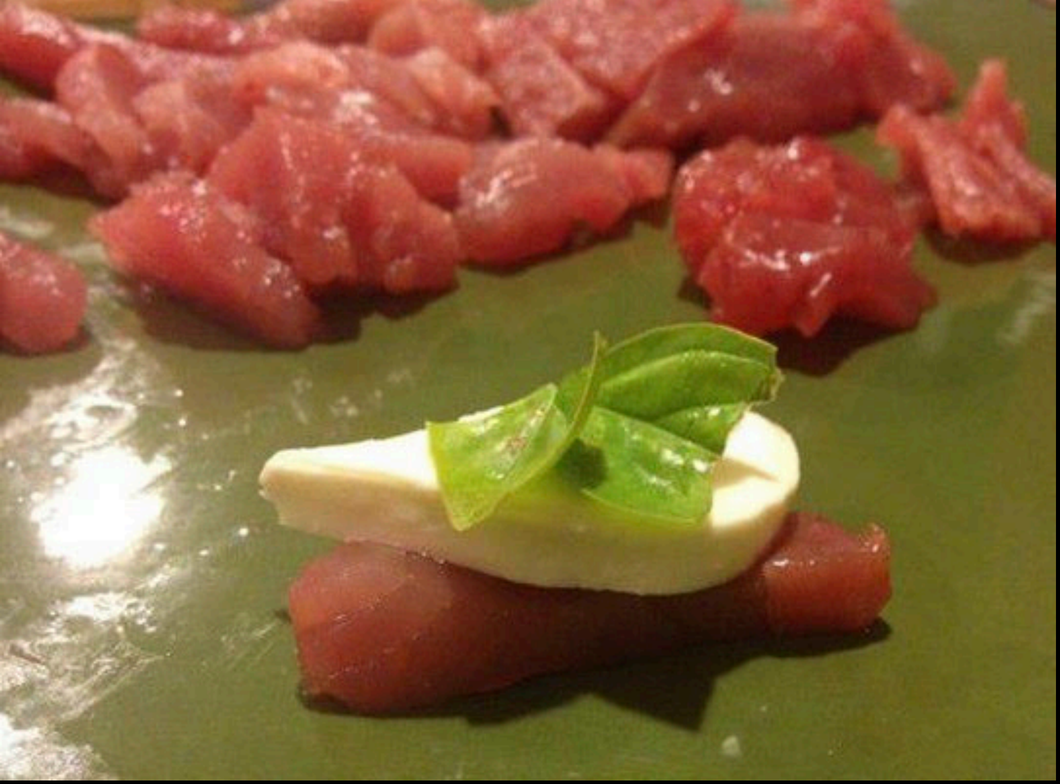
Comfort & Weng, accepted, DSRII

Adaptation to low oxygen: Metabolic rate



Garcia, Drazen and Weng, unpublished (undergraduate thesis)


skipjack tuna
sixgill shark
Oxygen section from Seibel 2011
Dissolved O_2 ($\mu mol\ kg^{-1}$)
400
350
300
250
200
150
100
50
0
150
125
75
50
50
75
25
25
225
250
275
300
200
175
150
125
100
50
Pressure (dB)
0
200
400
600
800
1000
0
10
20
30
40
50
Latitude (°N)

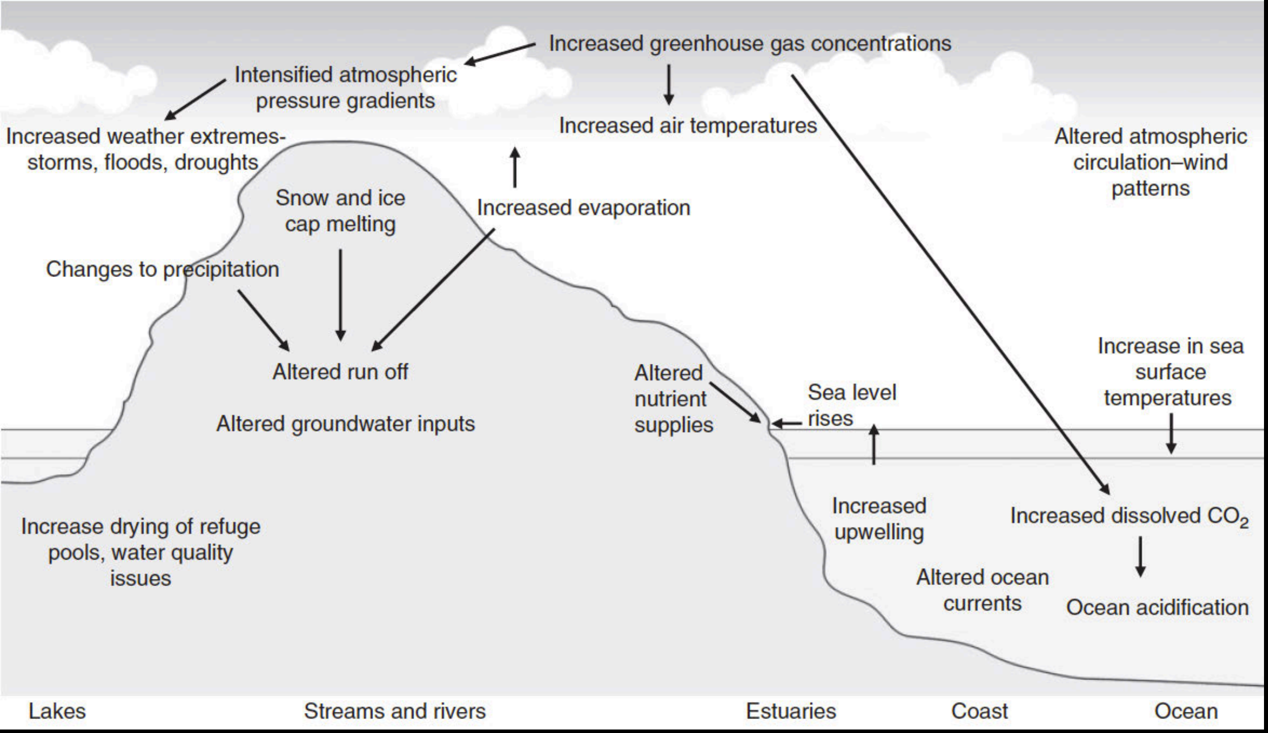


less habitat for
tasty things

more habitat
for yucky things

prediction, adaptation

What do we need to know to plan ahead?



Koehn, J. D., Hobday, A. J., Pratchett, M. S., and Gillanders, B. M., 2011, Climate change and Australian marine and freshwater environments, fishes and fisheries: synthesis and options for adaptation: Marine and Freshwater Research, v. 62, no. 9, p. 1148-1164.

adaptation

engagement with end-users

Rev Fish Biol Fisheries
DOI 10.1007/s11160-013-9311-0

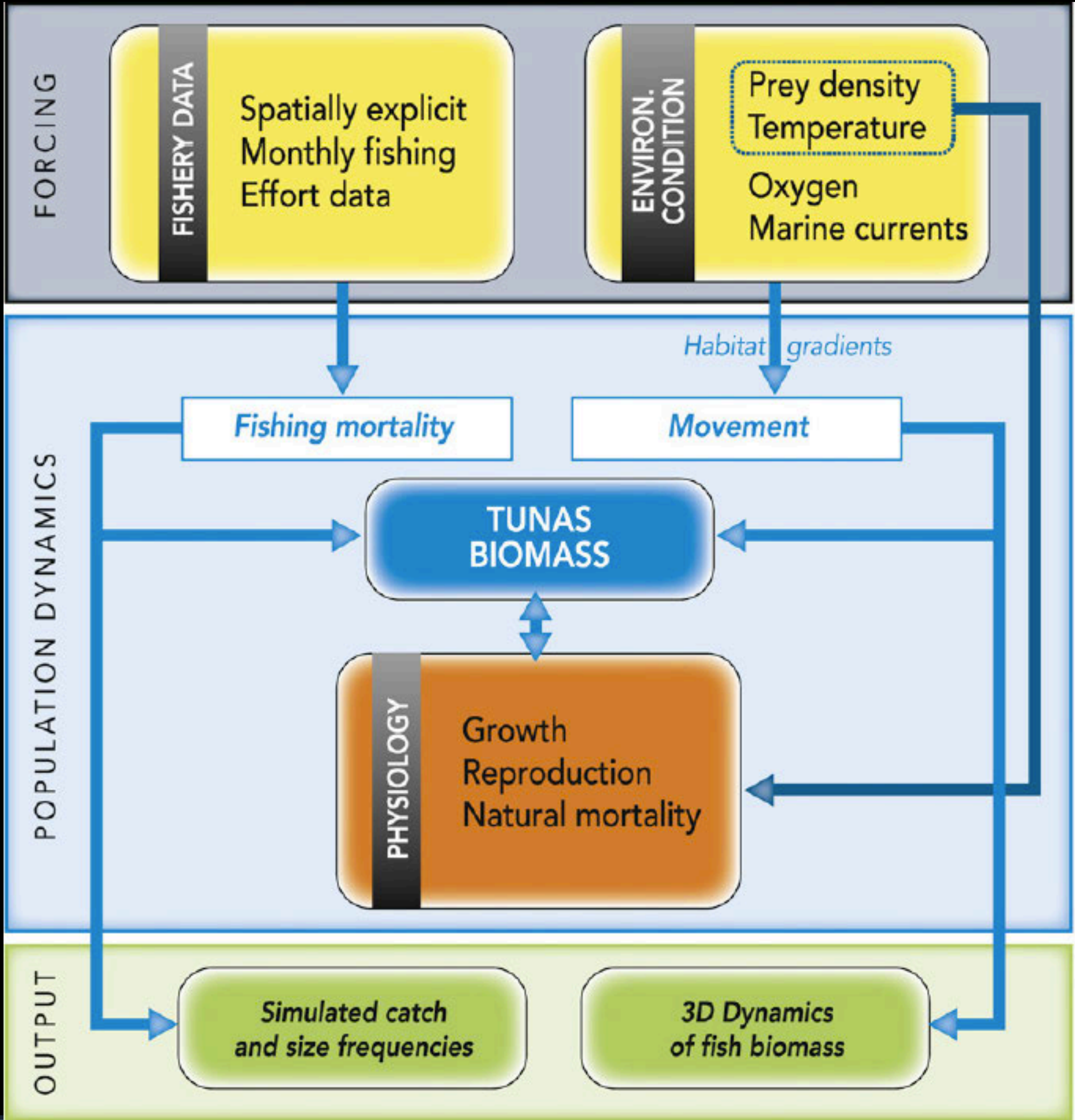
POINT-OF-VIEW

Climate impacts and oceanic top predators: moving from impacts to adaptation in oceanic systems

Alistair J. Hobday · Jock W. Young · Osamu Abe · Daniel P. Costa · Robert K. Cowen · Karen Evans · Maria A. Gasalla · Rudy Kloser · Olivier Maury · Kevin C. Weng

Maury, O., 2010, An overview of APECOSM, a spatialized mass balanced “Apex Predators ECOSystem Model” to study physiologically structured tuna population dynamics in their ecosystem: Progress in Oceanography, v. 84, no. 1, p. 113-117.

Dueri, S., Faugeras, B., and Maury, O., 2012, Modelling the skipjack tuna dynamics in the Indian Ocean with APECOSM-E: Part 1. Model formulation: Ecological Modelling, v. 245, p. 41-54.



Climatic Change (2013) 119:95–109
DOI 10.1007/s10584-012-0595-1

Modelling the impact of climate change on Pacific skipjack tuna population and fisheries

Patrick Lehodey · Inna Senina · Beatriz Calmettes · John Hampton · Simon Nicol

"The skipjack catch and biomass is predicted to slightly increase in the Western Central Pacific Ocean until 2050"

Western and Central Pacific Fisheries Commission

SCIENTIFIC COMMITTEE
NINTH REGULAR SESSION

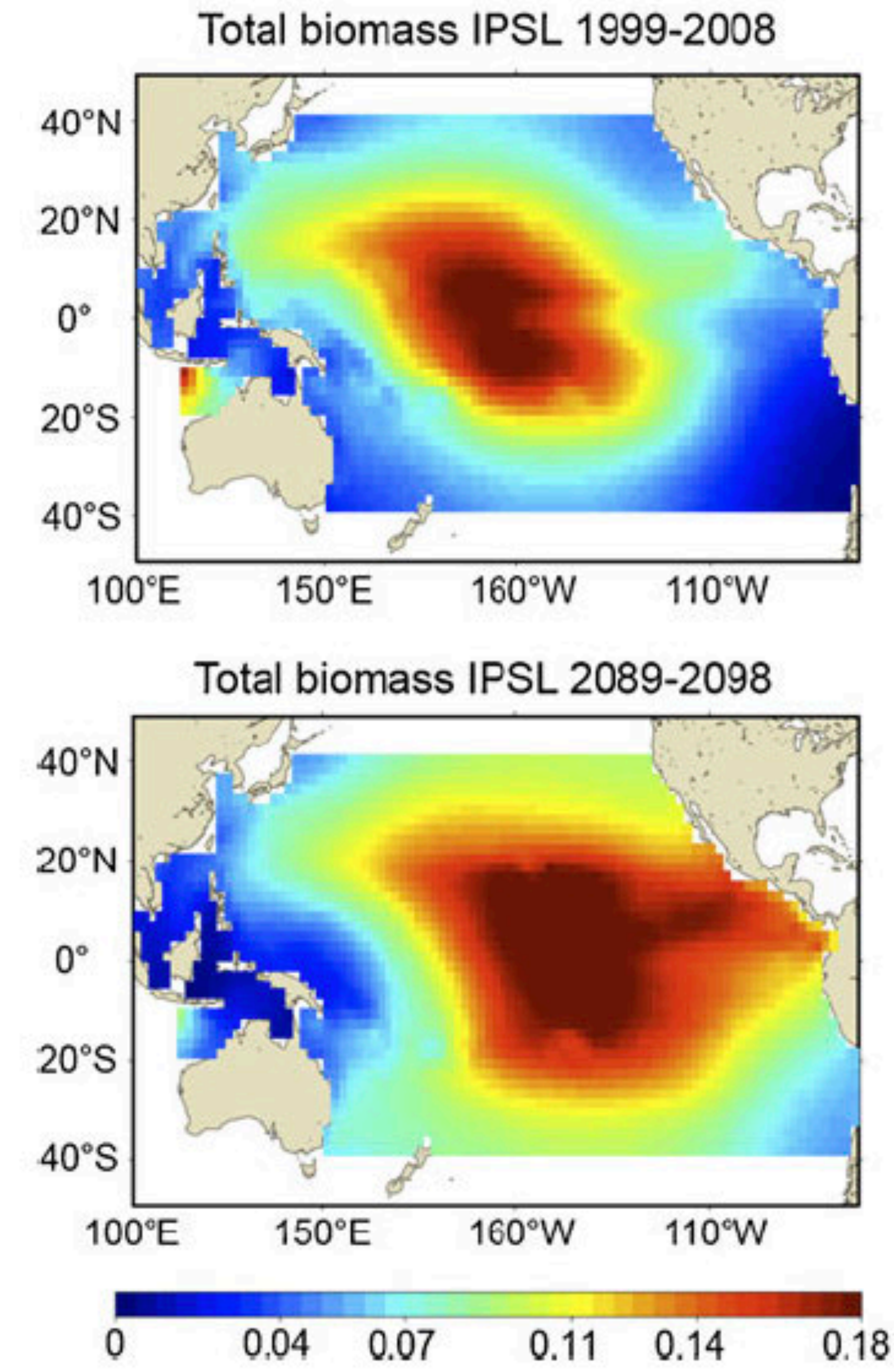
Pohnpei, Federated States of Micronesia
6-14 August 2013

Project 62: SEAPODYM applications in WCPO

WCPFC-SC9-2012/EB-WP-03 Rev 1

P.Lehodey[1], I.Senina[1], O.Titaud[1], B.Calmettes[1],

S.Nicol[2], J.Hampton[2], S.Caillot[2], P.Williams[2]



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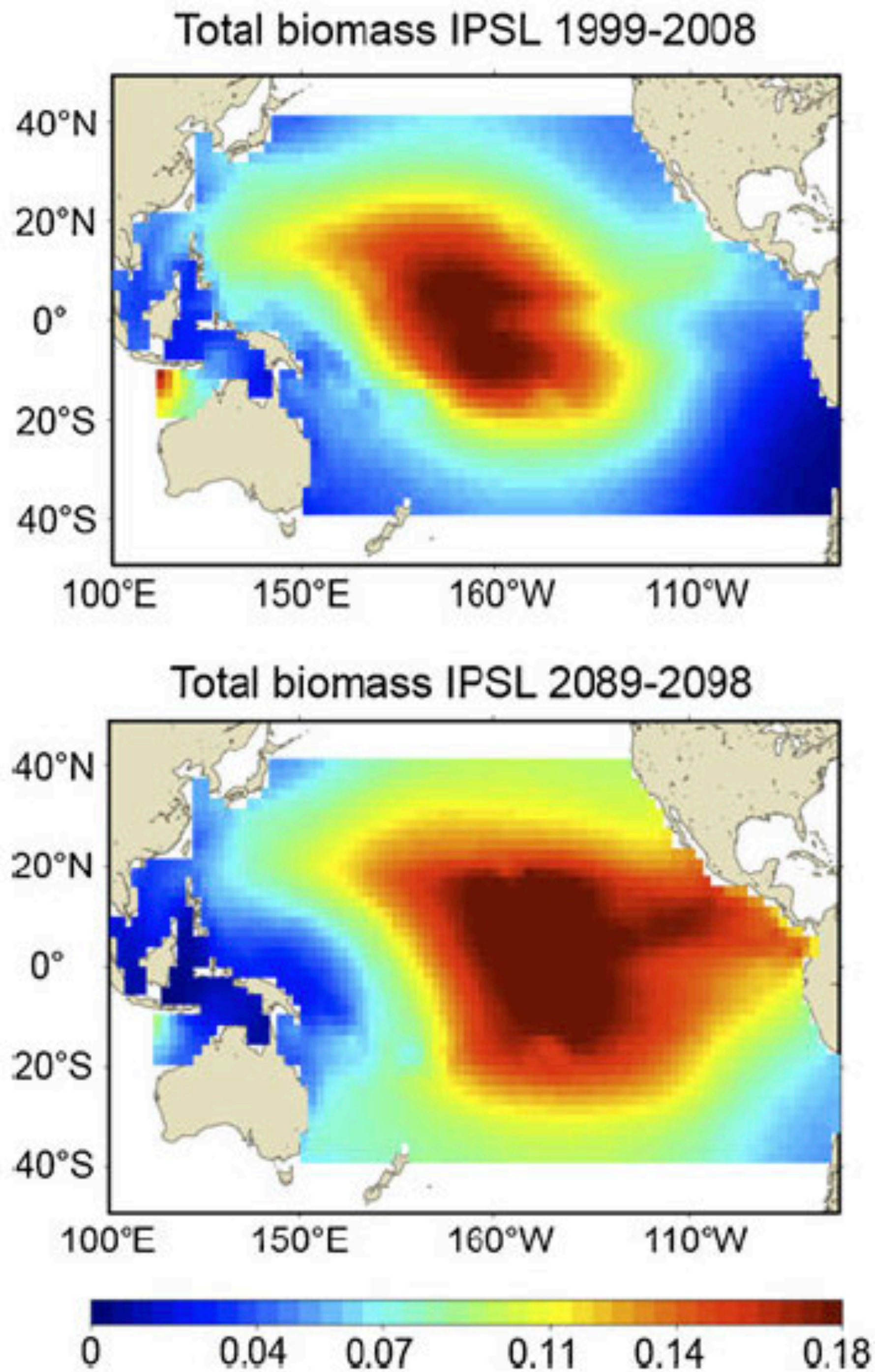
Modelling the impact of climate change on Pacific skipjack tuna population and fisheries

Patrick Lehodey • Inna Senina • Beatriz Calmettes •
John Hampton • Simon Nicol

State-of-the-art
model for pelagic fishes



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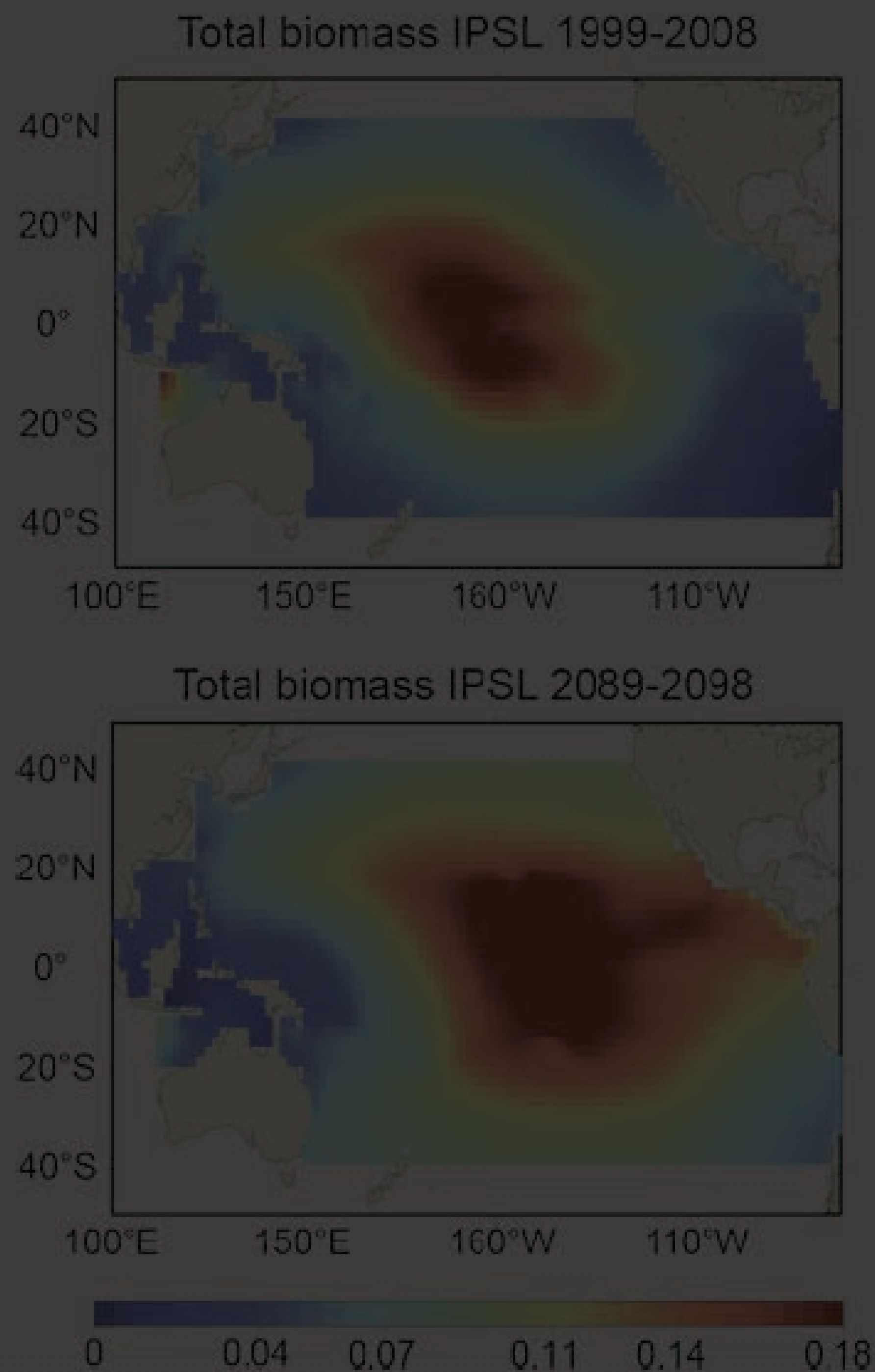
- **temperature**
- currents
- **dissolved oxygen**
- primary production



Climatic Change (2013) 119:95–109
DOI 10.1007/s10584-012-0595-1

Modelling the impact of climate change on Pacific skipjack tuna population and fisheries

Patrick Lehodey · Inna Senina · Beatriz Calmettes · John Hampton · Simon Nicol

CO_2 not considered

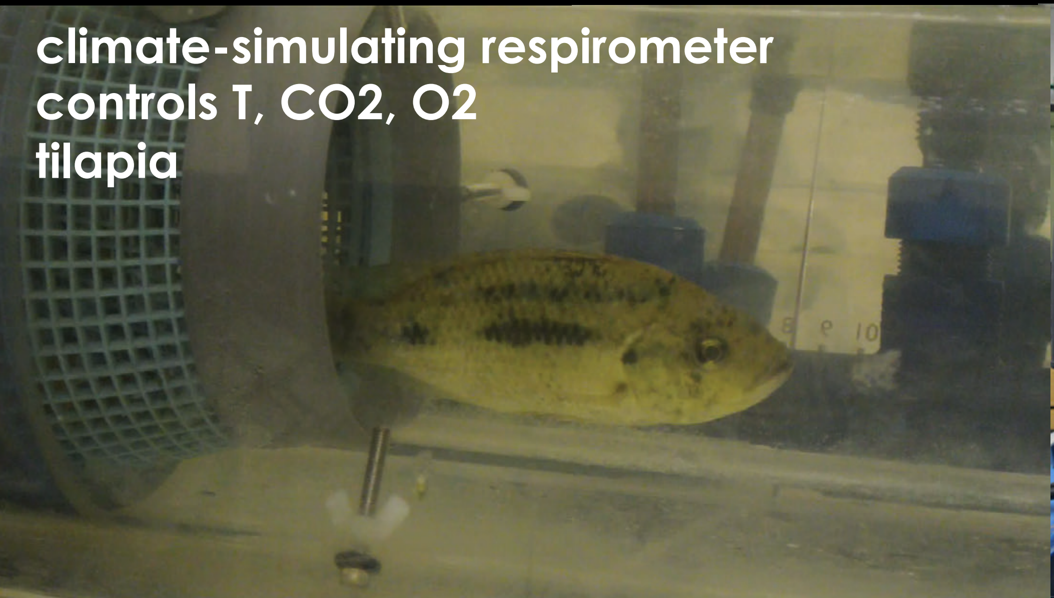
Create future climate in lab

Metabolic rate

Routine

Maximal

T, O_2, CO_2



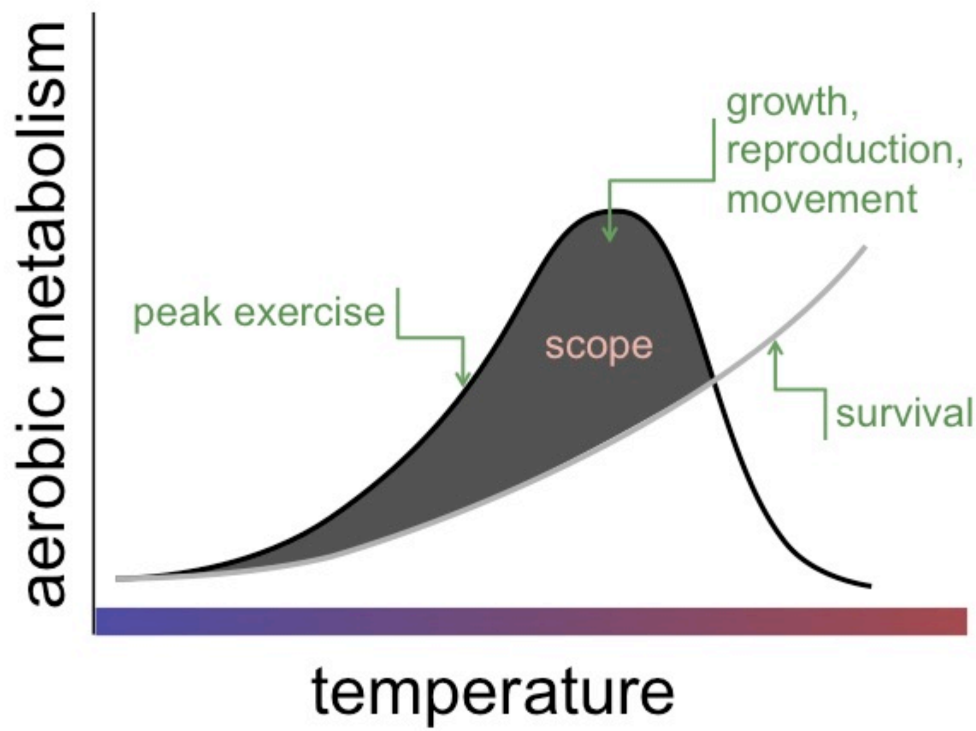
CHALLENGES FOR PEAK AEROBIC METABOLISM IN THE FUTURE OCEANS

The effect of multiple climate variables on exercise performance in a model teleost fish

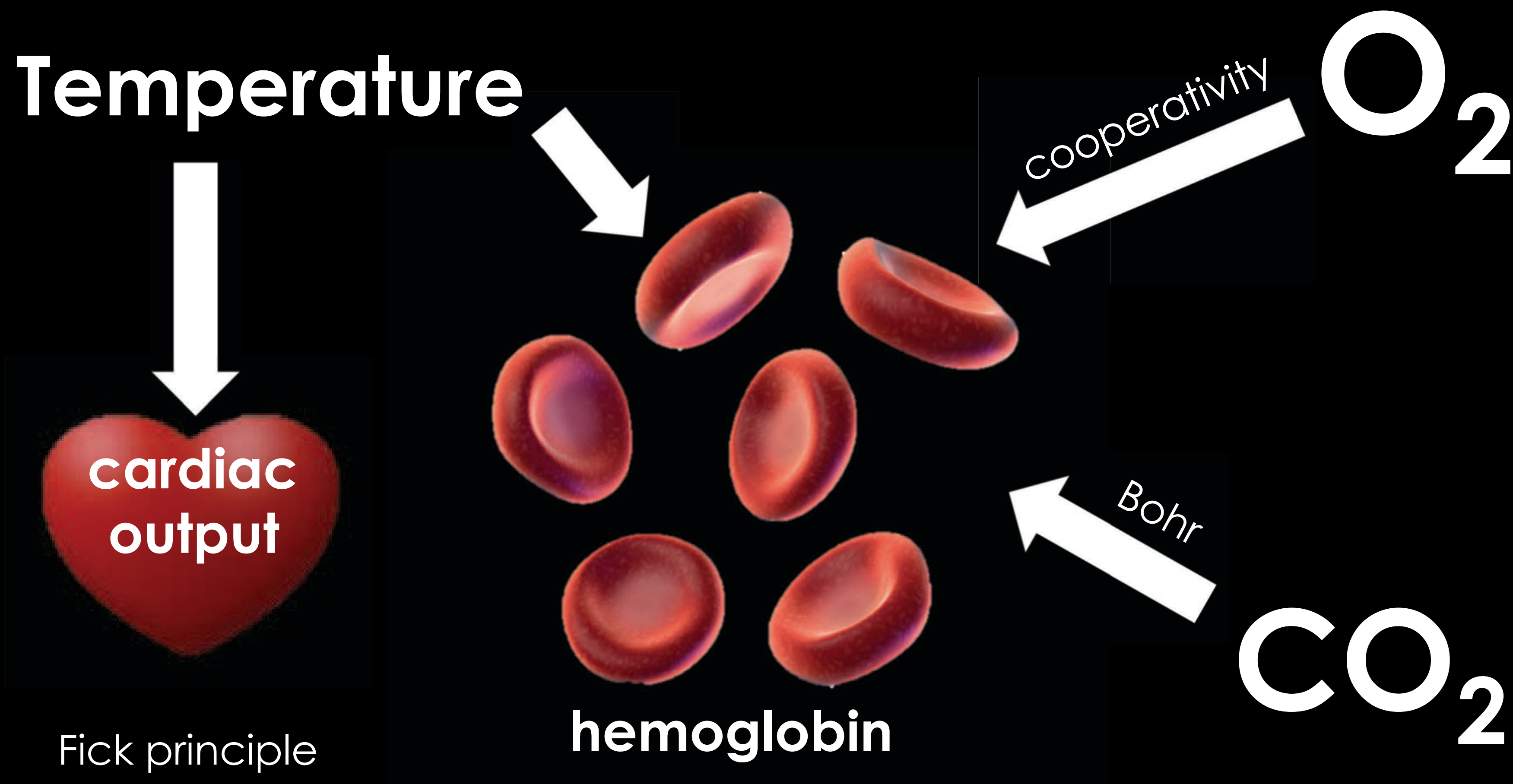
Gen Del Raye[1], Kevin C. Weng

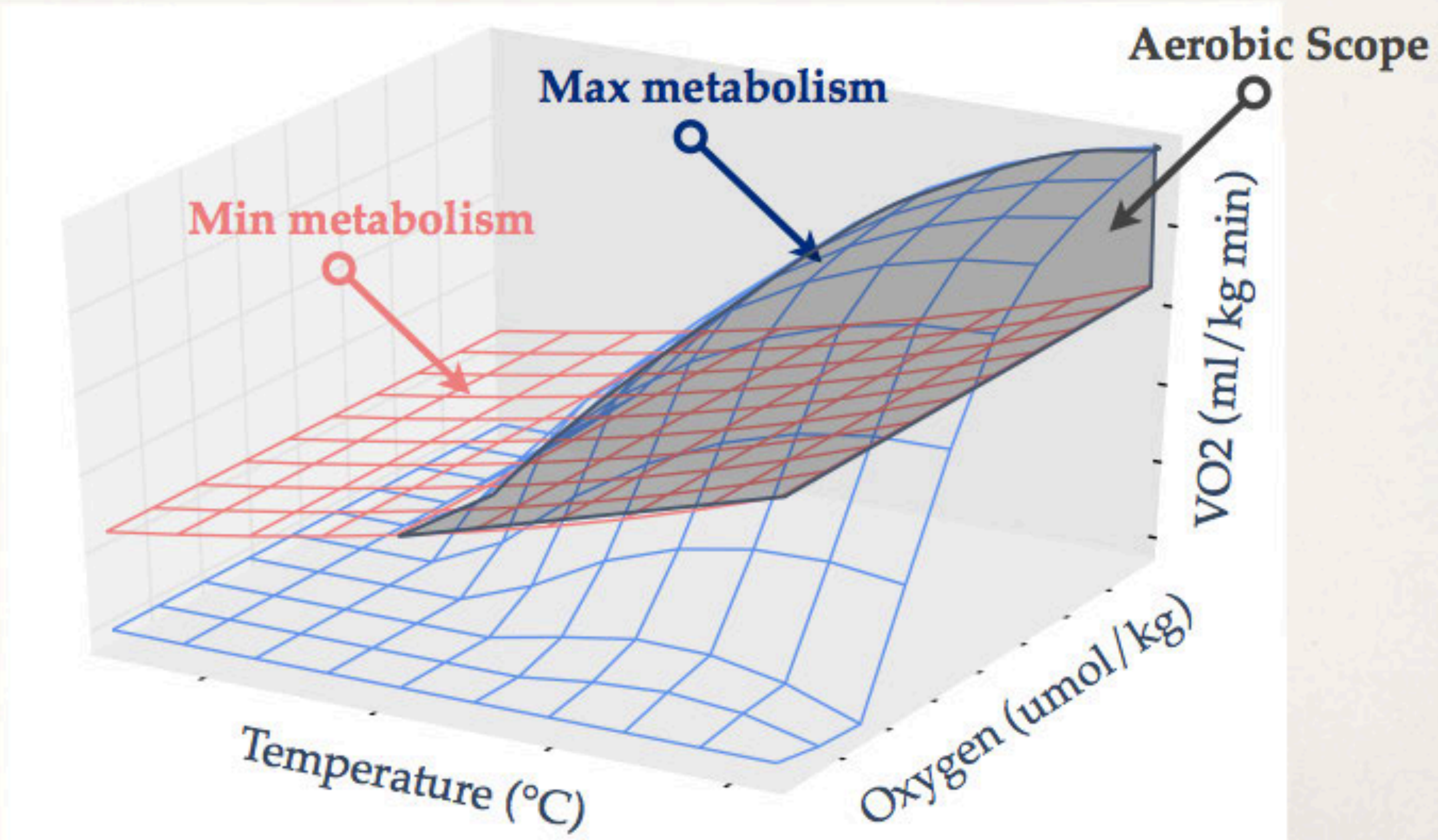
[1]gdelraye@hawaii.edu

Gen Del Raye
Wednesday, 2pm
Session 1 - 09



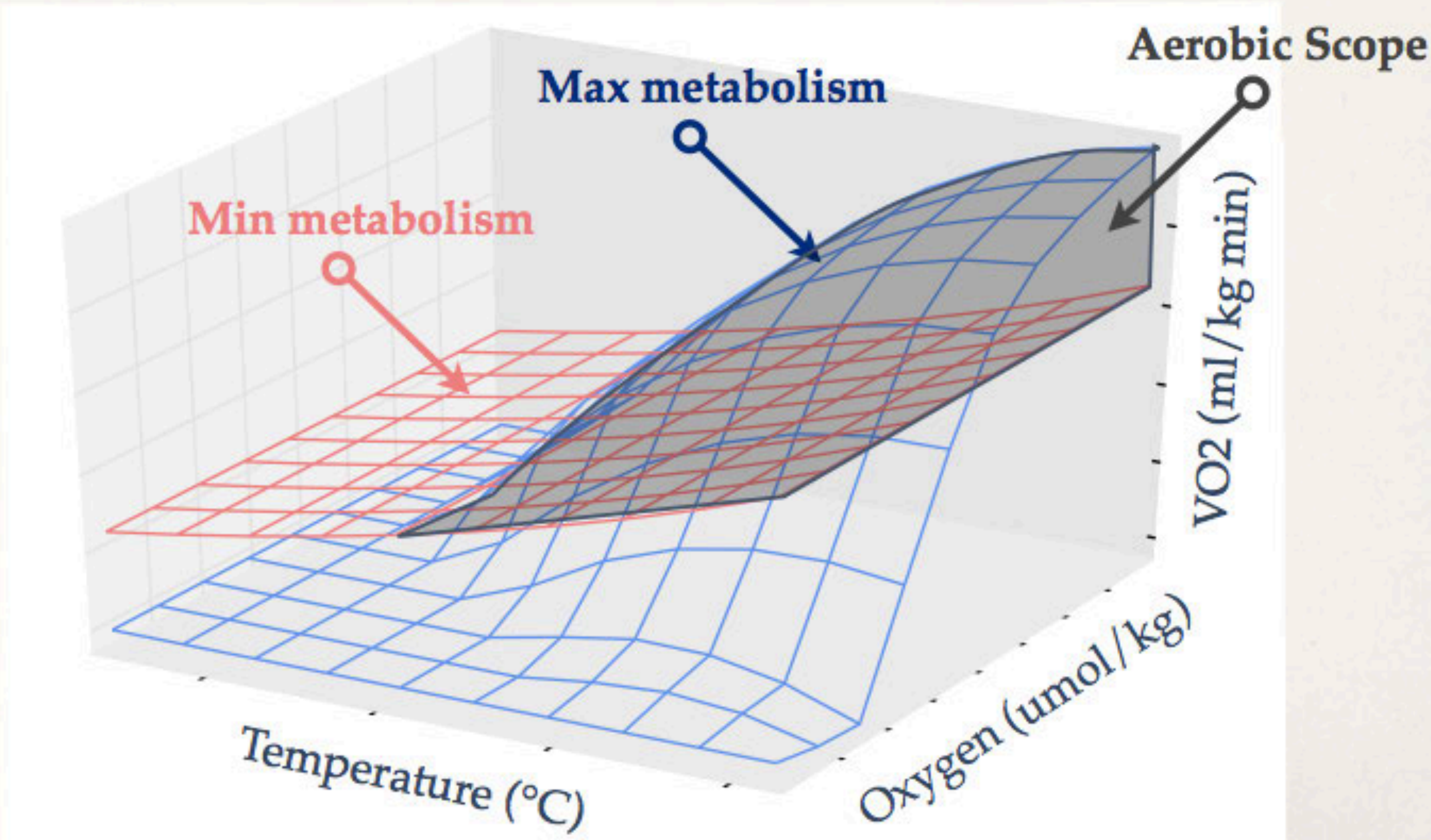
Nonlinear interactions of climate stressors





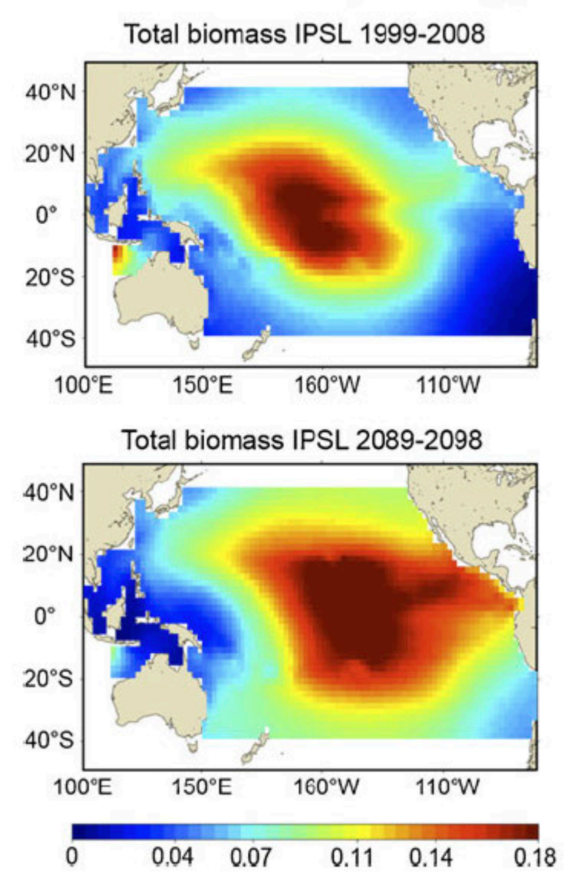
Incorporating CO_2, O_2 and T

Del Raye & Weng, in review DSRII



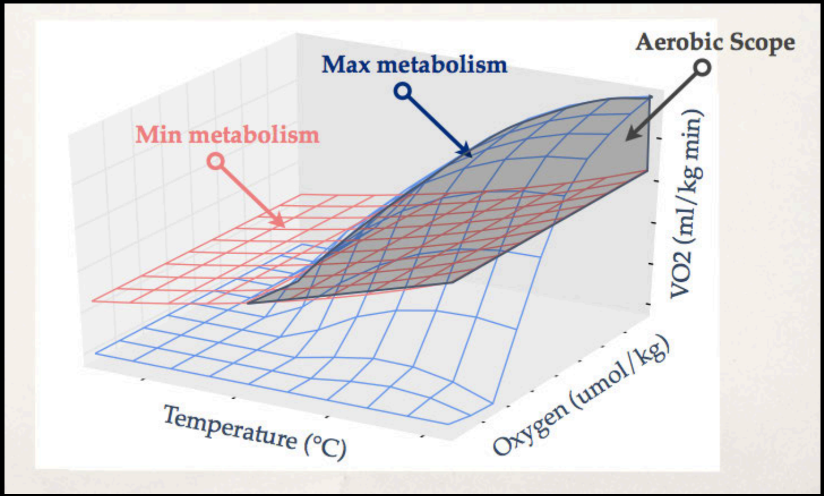
Growth, reproduction, behavior

- **temperature**
- currents
- **dissolved oxygen concentration**
- primary production



+

Interactions
T, O_2, CO_2

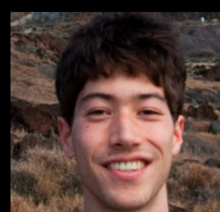


conclusions

- climate change may shrink the habitat of tunas and expand the habitat of OML-adapted species
- OML-adapted species might be less tasty
- Add CO_2, interactions to models

Funding

Team



Tom Swenarton, Gen Del Raye, Gadea Perez-Andujar, Christina Comfort, Danielle Garcia

Field assistance: Jeff Muir, Arik Pulsifer, David Slater, Chase Roberts, Steve Scherrer and others.

Thanks to Jeff Drazen, Jason Friedman, Mackenzie Gerringer, UH Marine Center, Suzanne Kruppa, JIMAR

PS: A brief note on CLIOTOP

CLIOTOP

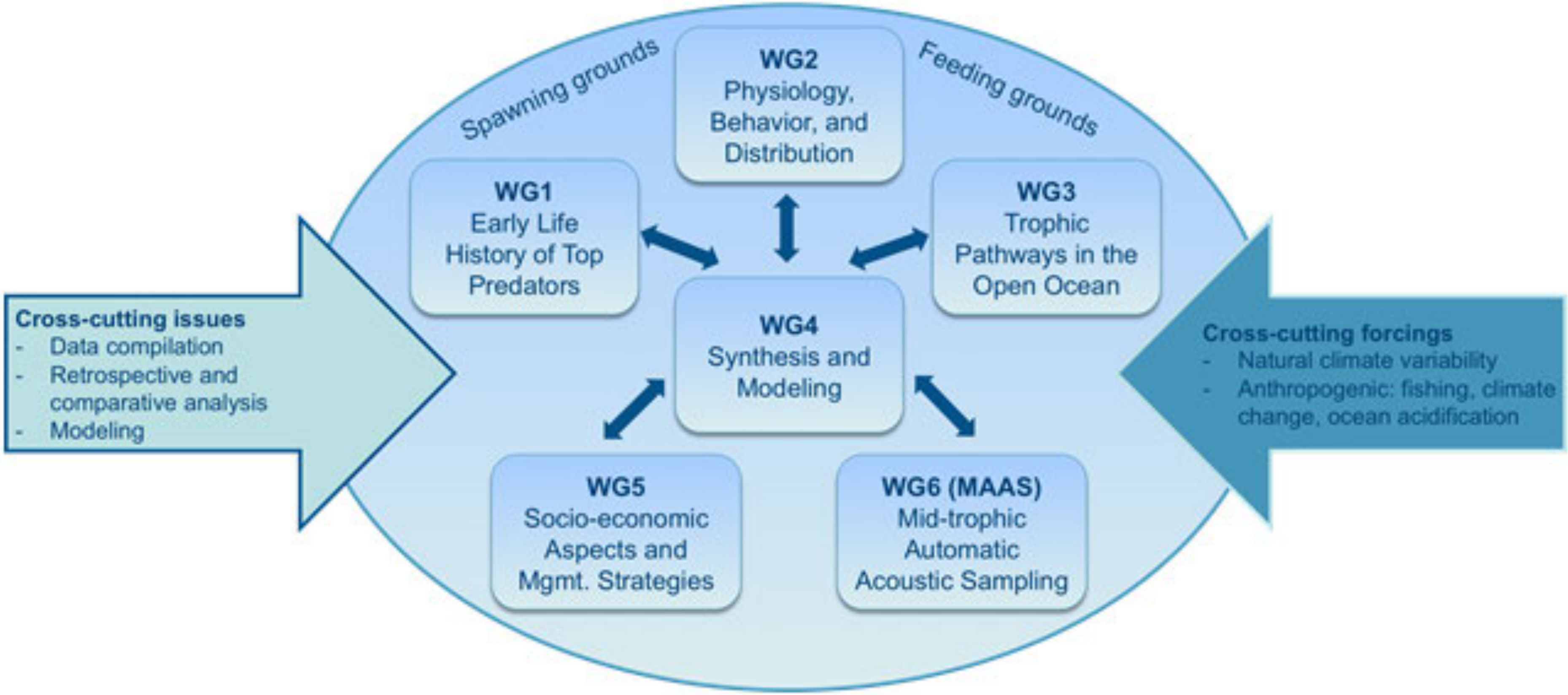
2005-2014

A 10 year international research effort

“A worldwide *comparative effort* to understand the *key processes* of *oceanic ecosystems* and their *top predator species** and determine the impact of *climate variability*”

** tunas, billfishes, sharks, marine mammals, turtles and seabirds*

GLOBEC | **IMBER**

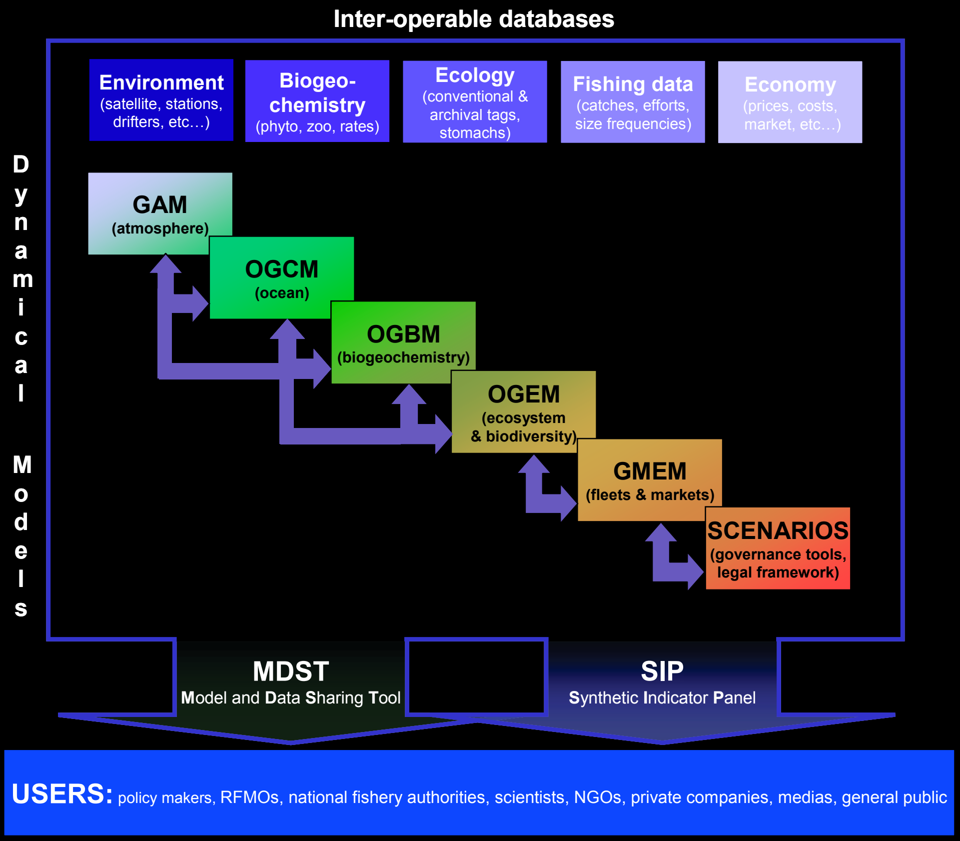


http://www.imber.info/index.php/Science/Regional-Programmes/CLIOTOP

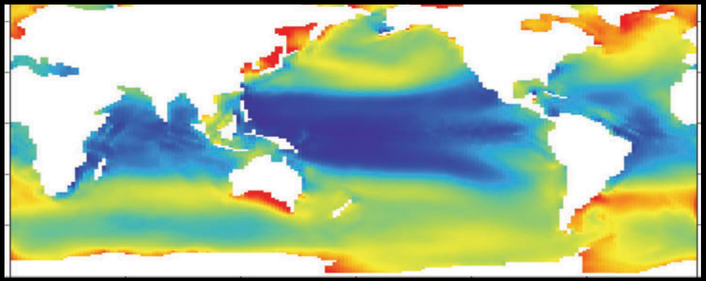
WG4: Synthesis and Modelling

Olivier Aumont, Patrick Lehodey, Olivier Maury

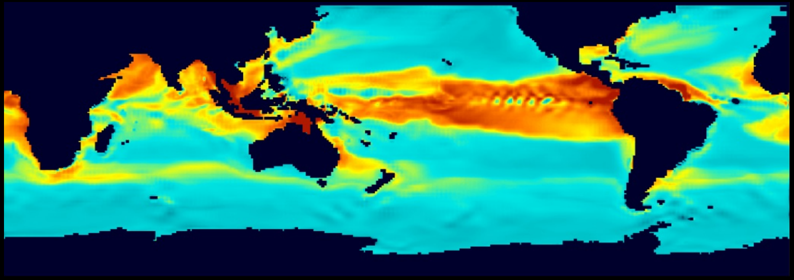
Two basin scale end-to-end ecosystem models linking physics, biogeochemistry, prey organisms to top predator dynamics:



SEAPODYM



APECOSM



The project **MACROES** (**MACR**oscope for **O**ceanic **E**arth **S**ystem) will help moving the WG toward **integrated Earth System modelling**:

- global interoperable databases
- 2 ways coupled global mechanistic numerical models (atmosphere, ocean, biogeochemistry, ecosystems & biodiversity, oceanic fisheries, fish markets)
- definition of governance scenarios