Colonization of the marine realm and the Great Oxidation Event: Experimentally assessing the plasticity and evolution of cyanobacterial salinity tolerance

Jennifer Reeve[1], Boswell Wing[2], Christopher Greidanus[3], Maxwell Pashayan[1], Anya Sukiennicki[1], and Paige Campbell[1]

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[3]University of Chicago

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Abstract

Earth's atmosphere underwent an irreversible, and geologically sudden, change approximately 2.5 billion years ago from oxygen free, to oxygenated, called the Great Oxidation Event (GOE). This change was driven by the evolution of a new form of photosynthesis which produced molecular oxygen as a byproduct. The group of bacteria in which this evolved, Cyanobacteria, are the only organisms to independently harness this form of photosynthesis. While we know that by the time of the GOE, Cyanobacteria were present, we do not know if they were present before the GOE. It has been proposed that Cyanobacteria were restricted to freshwater environments for hundreds of millions of years before the GOE, and only when they were able to inhabit the oceans did the GOE occur. We address this hypothesis by surveying the literature to understand how modern cyanobacteria respond to changes in salinity, as well as running a 1000 generation evolution experiment. We find evidence that just because a cyanobacterial species is found in freshwater does not mean it cannot live in marine salinities, and vice versa. Additionally, we find that prolonged exposure to a different salinity does not result in loss of ability to grow in the ancestral salinity.

Slides available as PDF or PPTX at: https://bit.ly/39Dk1Kc

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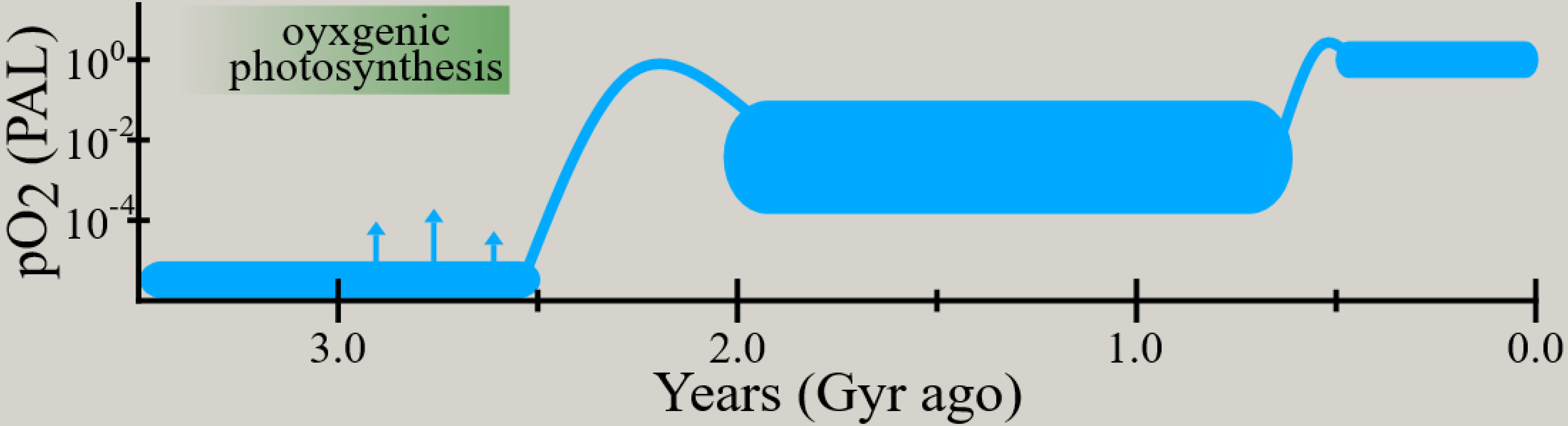
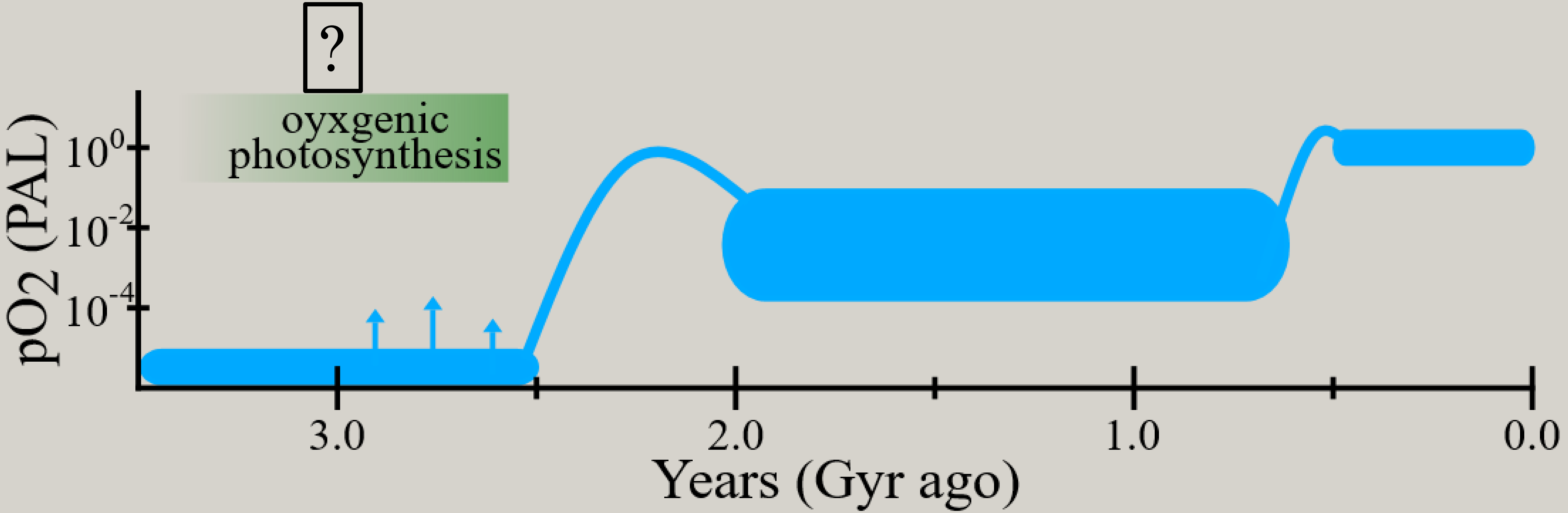
AbSciCon 2022 – Recent Advances, Development and New Challenges in Understanding Early Life

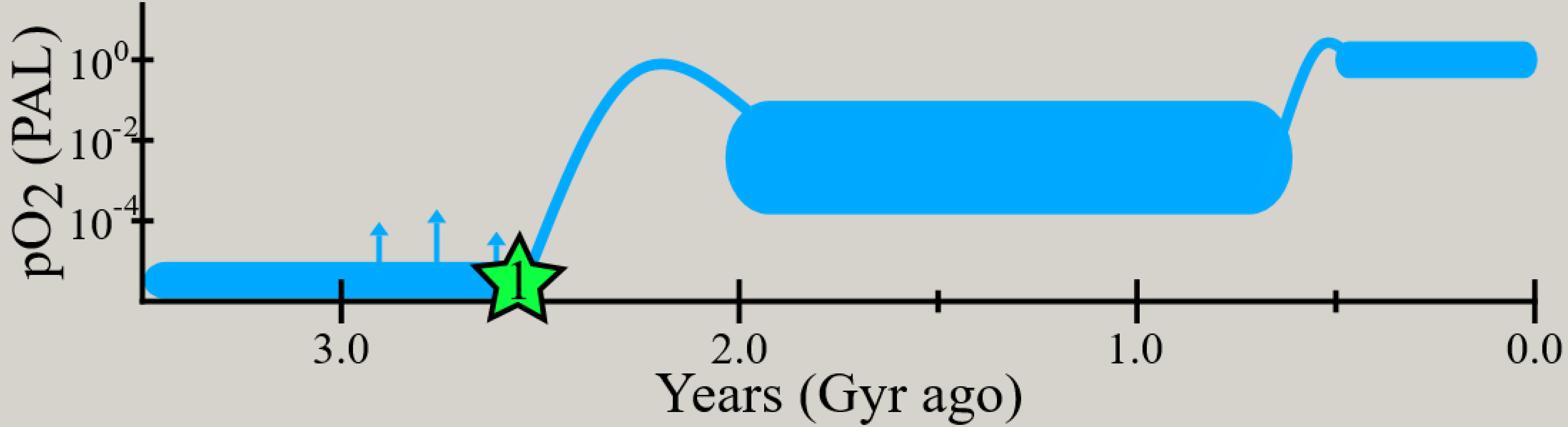
Cyanobacteria and the Great Oxidation Event (GOE)



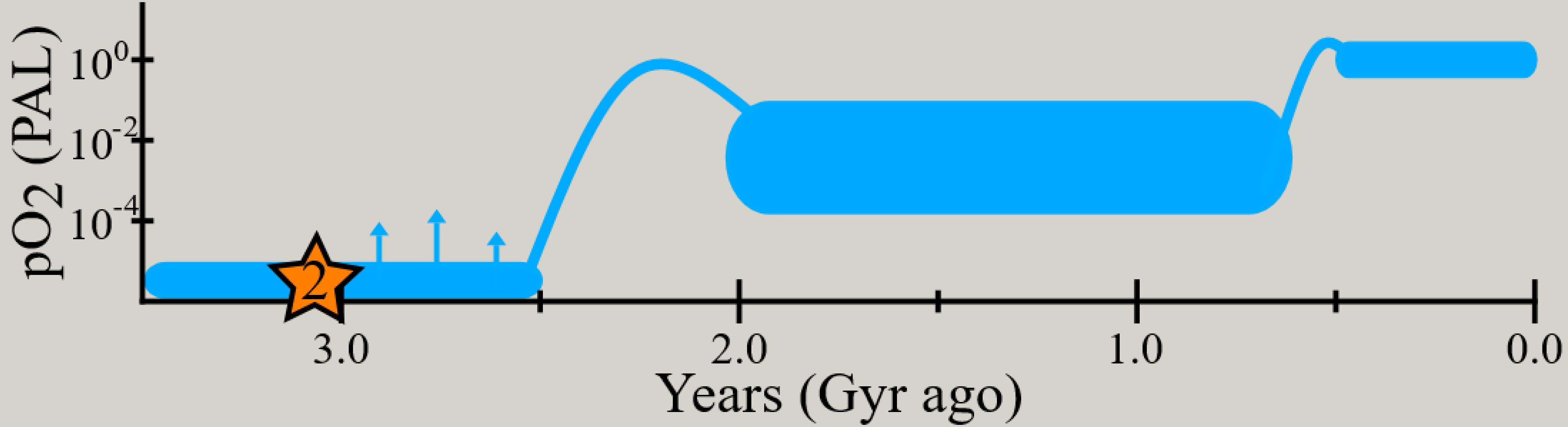
There are competing hypotheses about the timing of the origin of oxygenic photosynthesis and the GOE



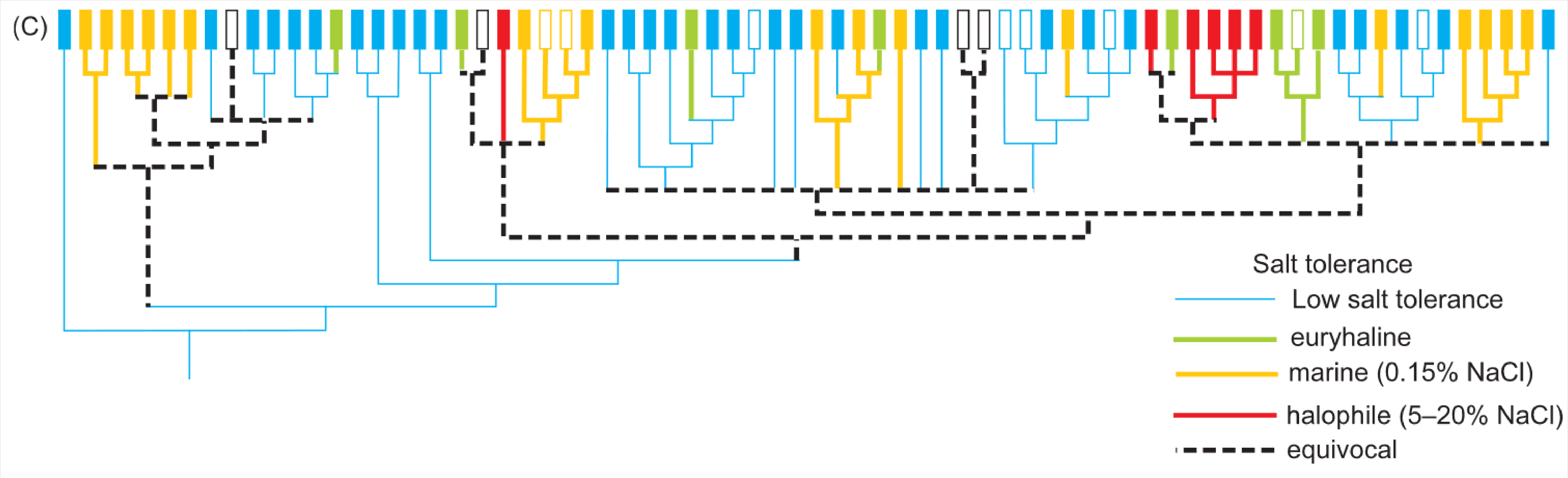
Hypothesis 1: Oxygenic photosynthesis evolved just prior the GOE



Hypothesis 2: Oxygenic photosynthesis evolved well before the GOE but was ecologically restricted



The transition from terrestrial to marine environments has been posited as a major constraint



Sánchez-Baracaldo et. al. 2005

Research questions

Does habitat predict salinity tolerance?

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Does habitat predict salinity tolerance?

Is salinity tolerance discrete?

We surveyed the literature to develop a database of cyanobacterial responses to changes in salinity

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Papers	Species	Growth rates	Salinity range
> 20	> 75	> 1000	0 – 230 ppt

Aquaculture Research, 2010, 41, 1348–1355 doi: 10.1111/j.1365-2109.2009.02423.x

Effects of salinity on the growth and proximate composition of selected tropical marine periphytic diatoms and cyanobacteria

Osmotic adjustment and organic solute accumulation in cyanobacteria from freshwater and marine habitats

R. H. Reed and W. D. P. Stewart

Salt-Tolerant *Synechococcus elongatus* UTEX 2973 Obtained Engineering of Heterologous Synthesis of Compatible Solute Glucosylglycerol

Jinyu Cui[1,2,3†], Tao Sun[1,2,4†], Lei Chen[1,2,3*] and Weiwen Zhang[1,2,3,4*]

Photosynthetic pigment production and metabolic and lipidomic

Responses of Cyanobacteria to Low Level Osmotic Stress: Implications for the Use of Buffers

By DEBORAH J. MOORE,[1*] ROBERT H. REED[1] AND WILLIAM D. P. STEWART[2]

Anabaena sp. to salt stress

M. N. Jha, G. S. Venkataraman* and B. D. Kaushik

logeny and salt-tolerance of freshwater Nostocales strains: contribution to their systematics and evolution

AZRA BANO AND PIRZADA J. A. SIDDIQUI*

Carbohydrate Accumulation and Osmotic Stress in Cyanobacteria

By ROBERT H. REED,* DOUGLAS L. RICHARDSON, STEPHEN R. C. WARR AND WILLIAM D. P. STEWART

Multiphasic osmotic adjustment in a euryhaline cyanobacterium

(Osmotic stress, *Synechocystis*; carbohydrate accumulation; ion transport)

Robert H. Reed, Stephen R.C. Warr, Douglas L. Richardson *, Deborah J. Moore and William D.P. Stewart

Influencia de la salinidad sobre crecimiento y composición bioquímica de la cianobacteria *Synechococcus* sp.

Influence of salinity on the growth and biochemical composition of the cyanobacterium *Synechococcus* sp.

Néstor Rosales
José Ortega
Roberta Mora
Ever Morales*

Growth and morphology of *Anabaena* strains (Cyanophyceae, Cyanobacteria) in cultures under different salinities

B.K. Stulp & W.T. Stam

Effect of salinity on some physiological and biochemical responses in the cyanobacterium *Synechococcus elongatus*

Maryam Rezayian[1,2], Vahid Niknam[2], and Mohammad Ali Faramarzi[1,*]

Effect of Carbon Content, Salinity and pH on *Spirulina platensis* for Phycocyanin, Allophycocyanin and Phycoerythrin Accumulation

Gaurav Sharma[1], Manoj Kumar[2], Mohammad Irfan Ali[1] and Nakuleshwar Dut Jasuja[1*]

Proteomic analyses of the cyanobacterium *Arthrospira* (*Spirulina*) *platensis* under iron and salinity stress

Mostafa M.S. Ismaiel[a,b,*], Michele D. Piercey-Normore[a], Christof Rampitsch[c]

Synthesis of glucosylglycerol in salt-stressed cells of the cyanobacterium *Microcystis firma**

M. Hagemann, N. Erdmann, and E. Wittenburg

Salt effects on 77K fluorescence and photosynthesis in the cyanobacterium *Synechocystis* sp. PCC 6803

Hendrik Schubert and Martin Hagemann

Antioxidative responses of *Nostoc ellipsosporum* and *Nostoc piscinale* to salt stress

Maryam Rezayian[1] · Vahid Niknam[1] · Mohammad Ali Faramarzi[2]

of salinity on growth, pigmentation, N_2 on and alkaline phosphatase activity of cultured *Trichodesmium* sp.

Fei-Xue Fu*, P. R. F. Bell

stis PCC6803: a euryhaline cyanobacterium

D.L. Richardson, R.H. Reed and W.D.P. Stewart

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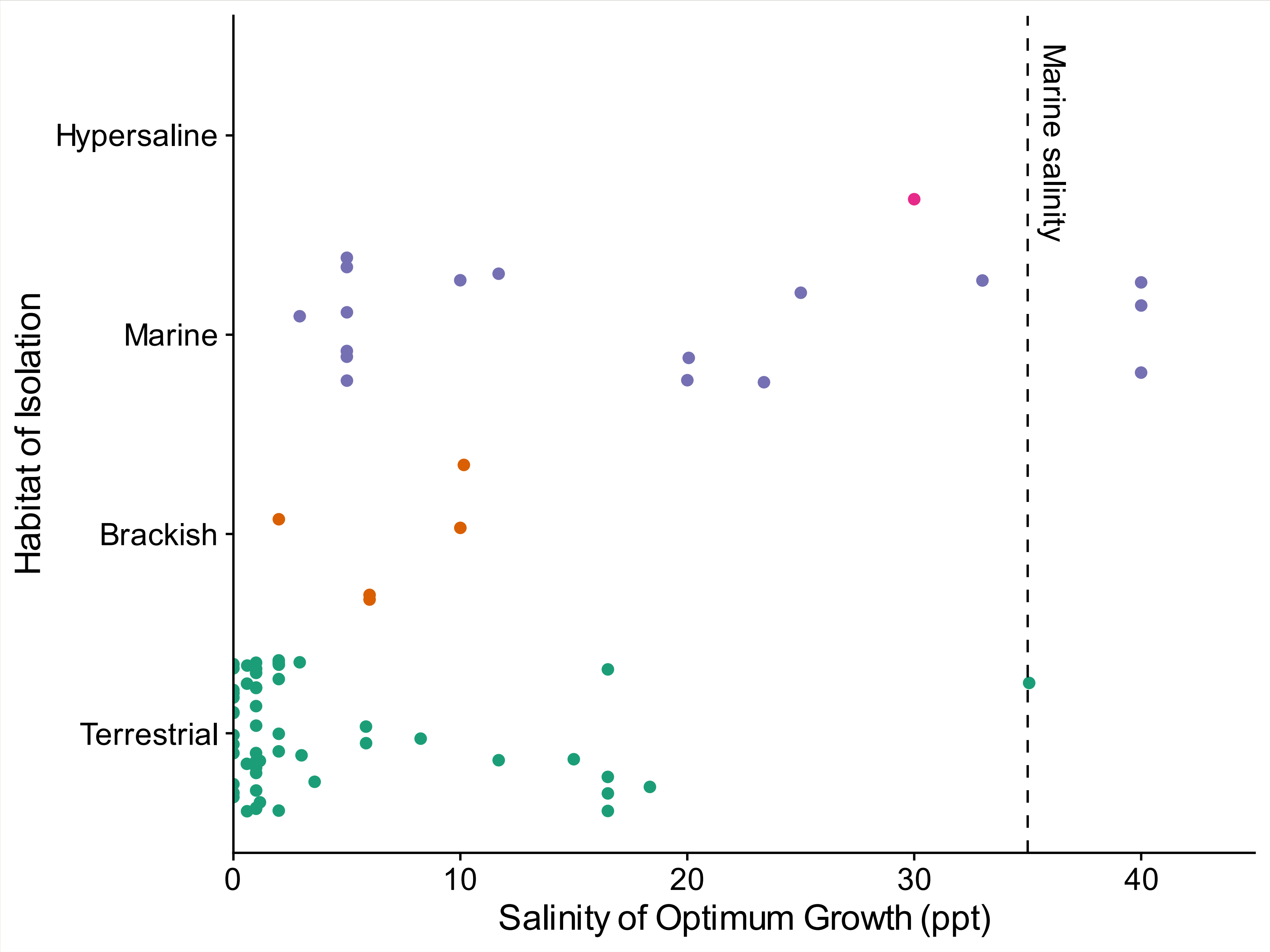

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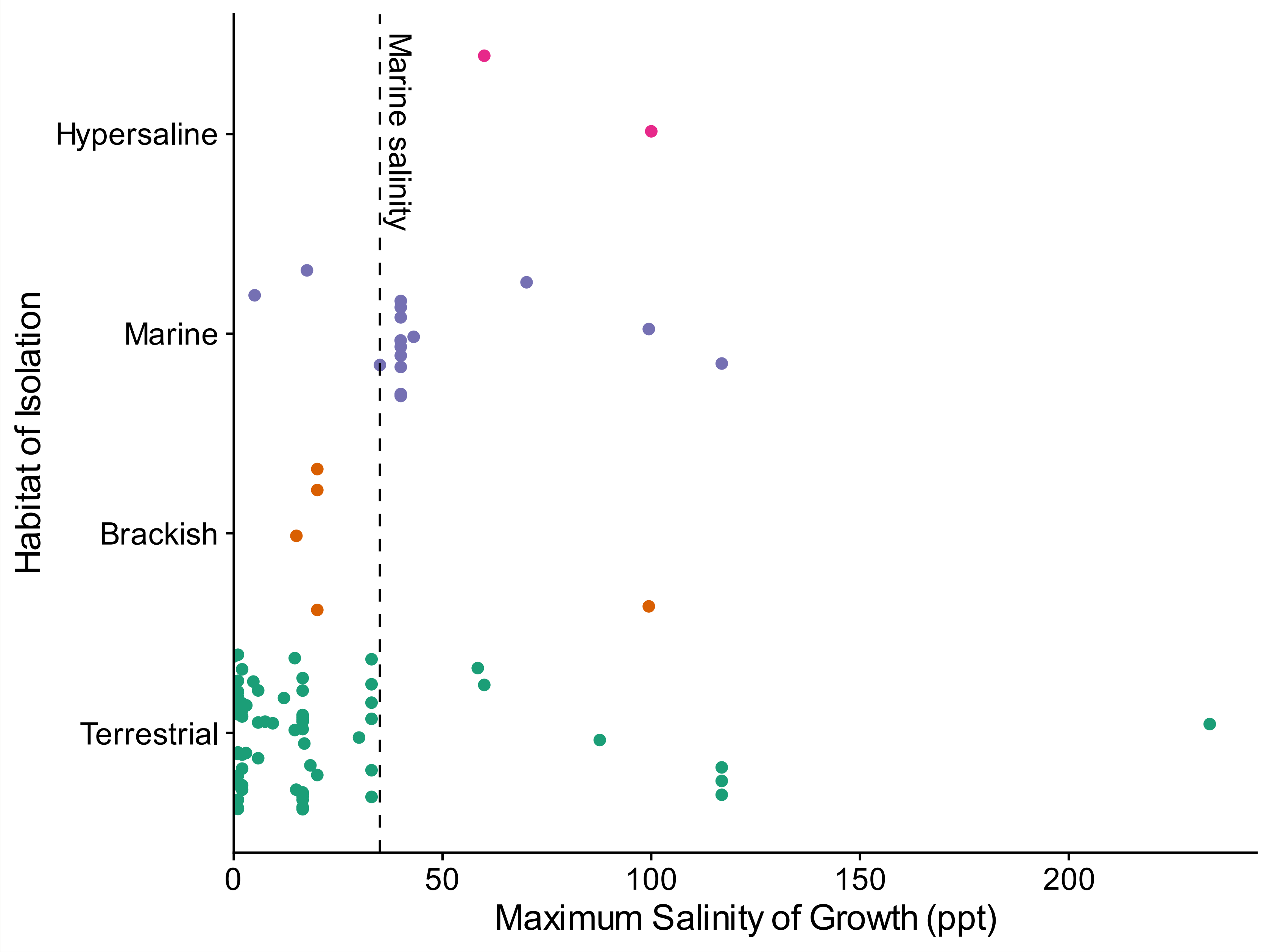

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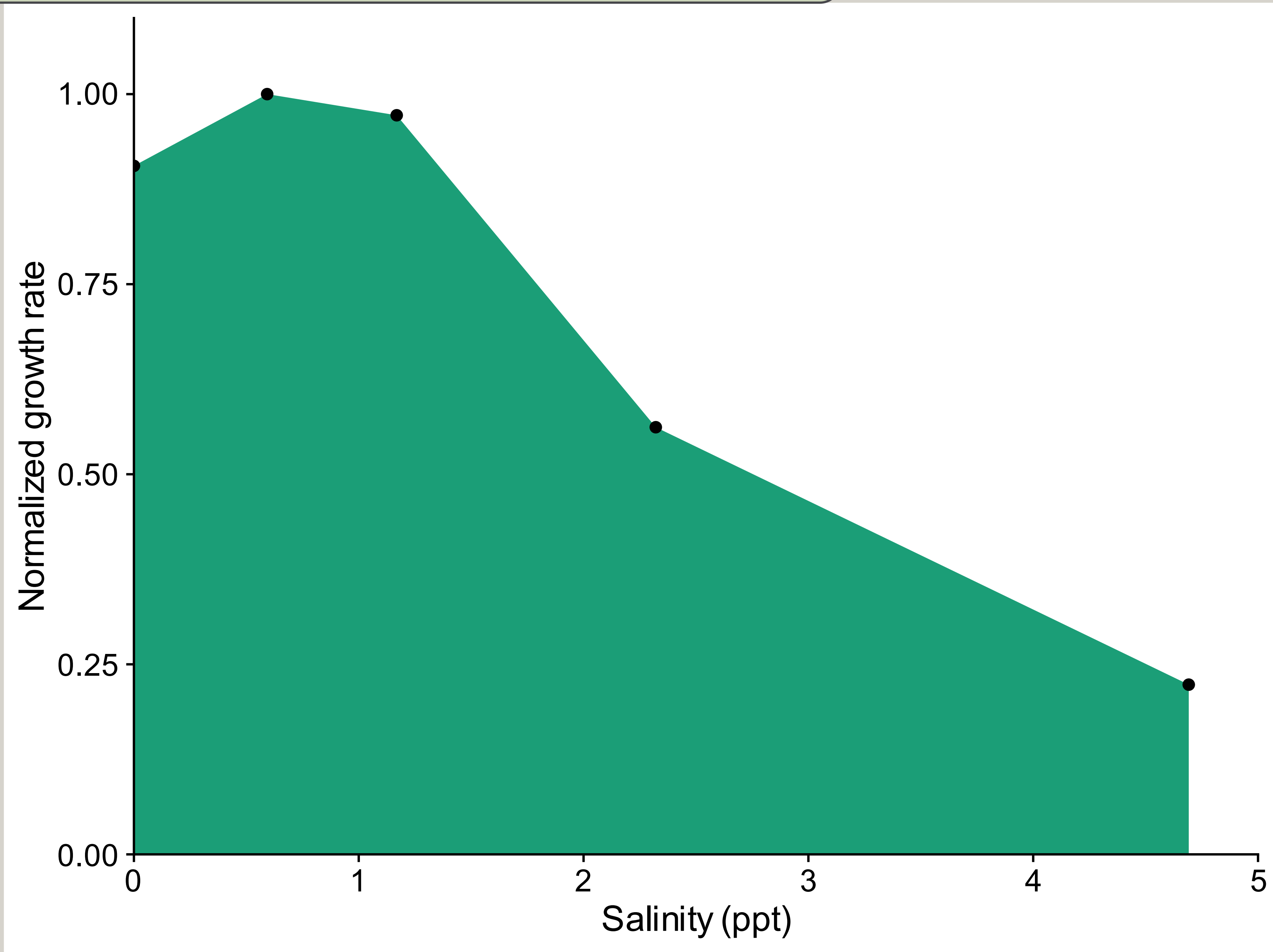

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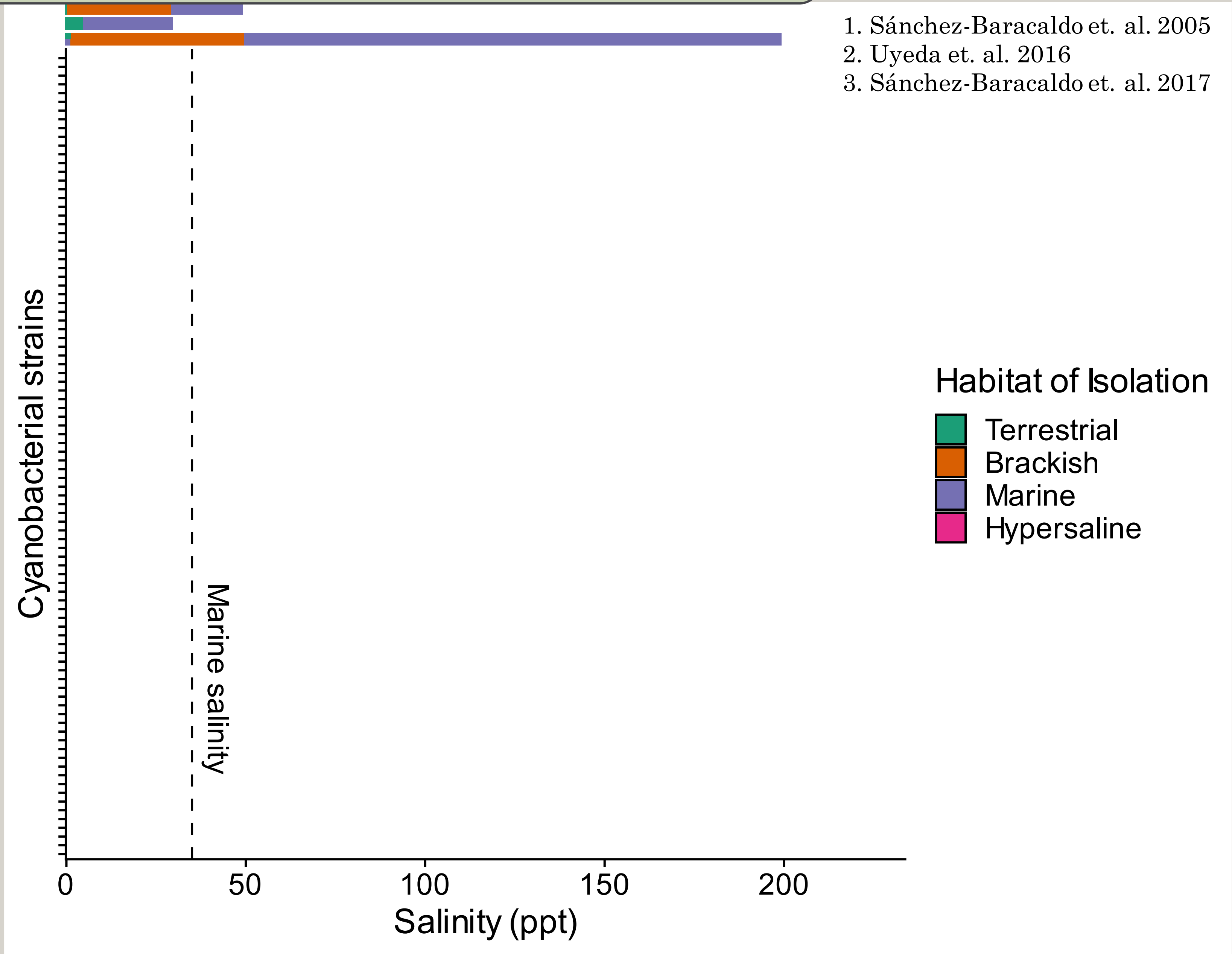

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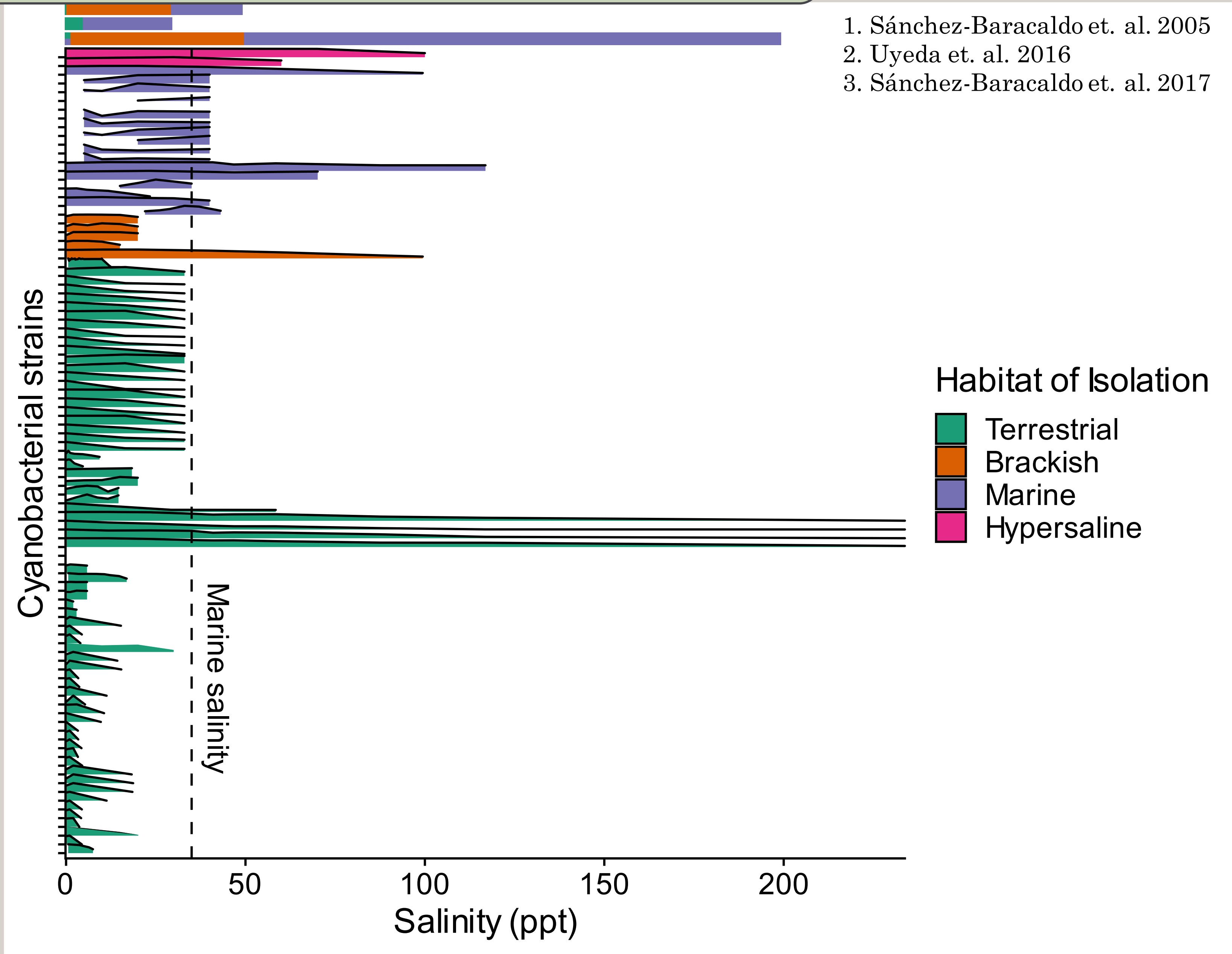

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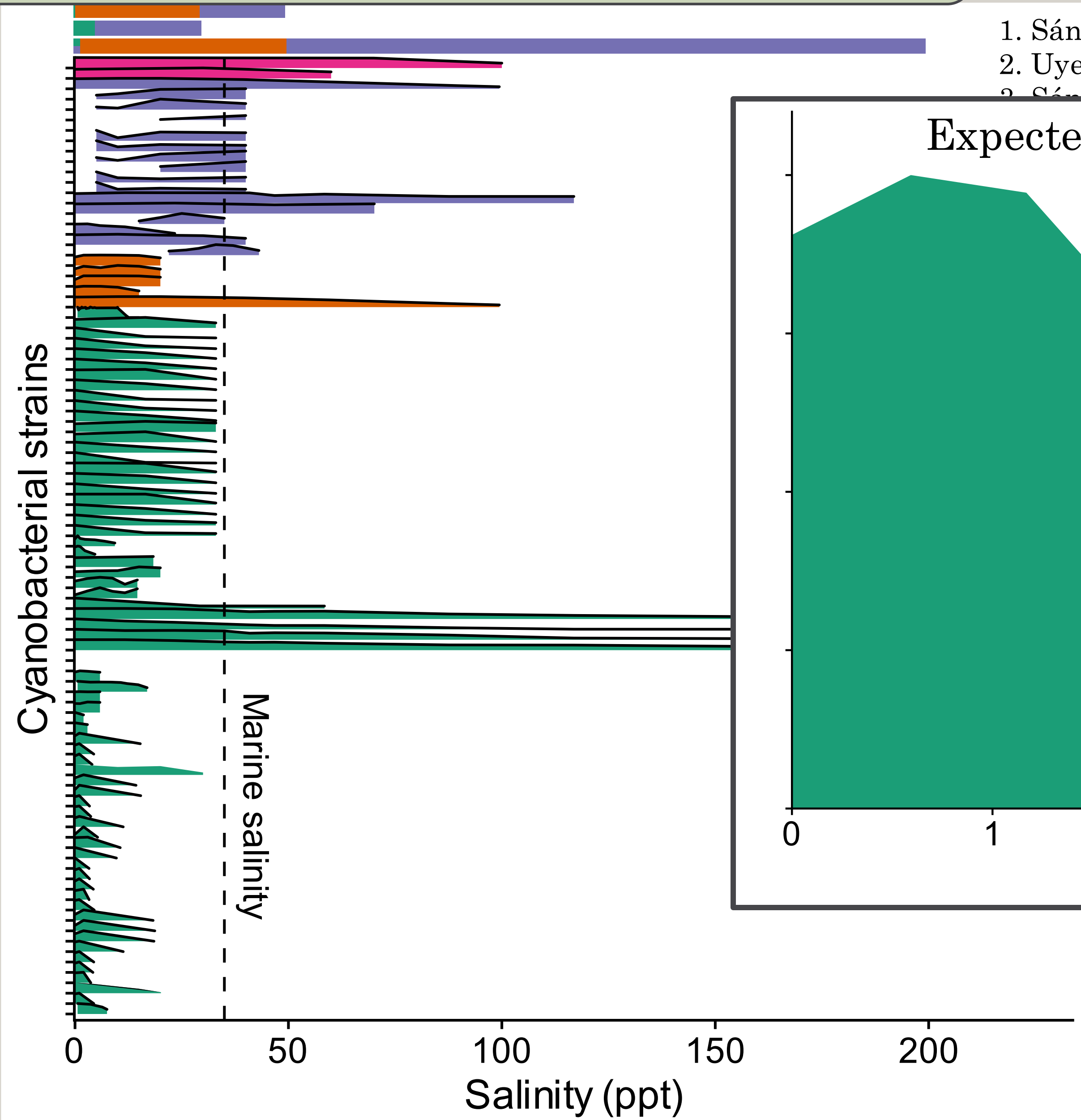
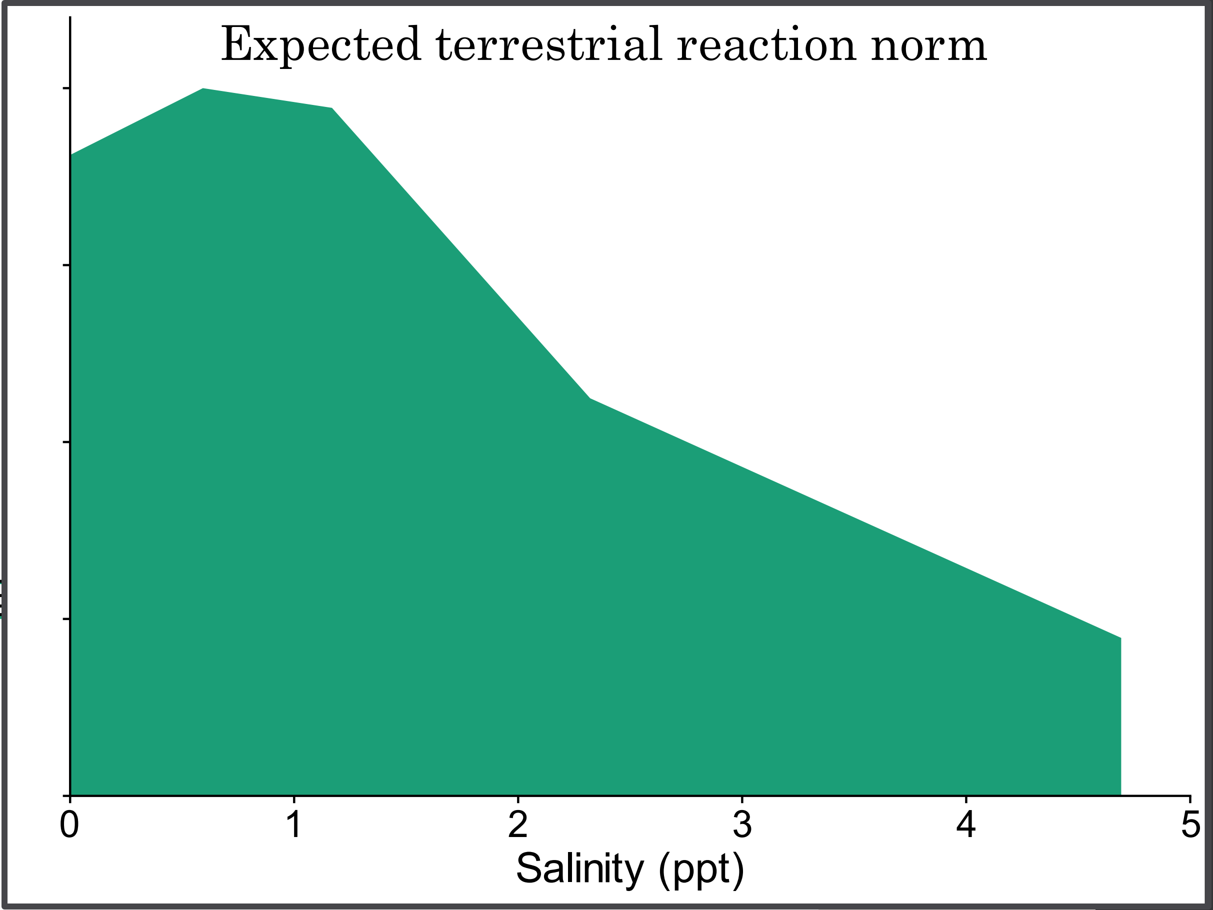


1. Sánchez-Baracaldo et. al. 2005
2. Uyeda et. al. 2016



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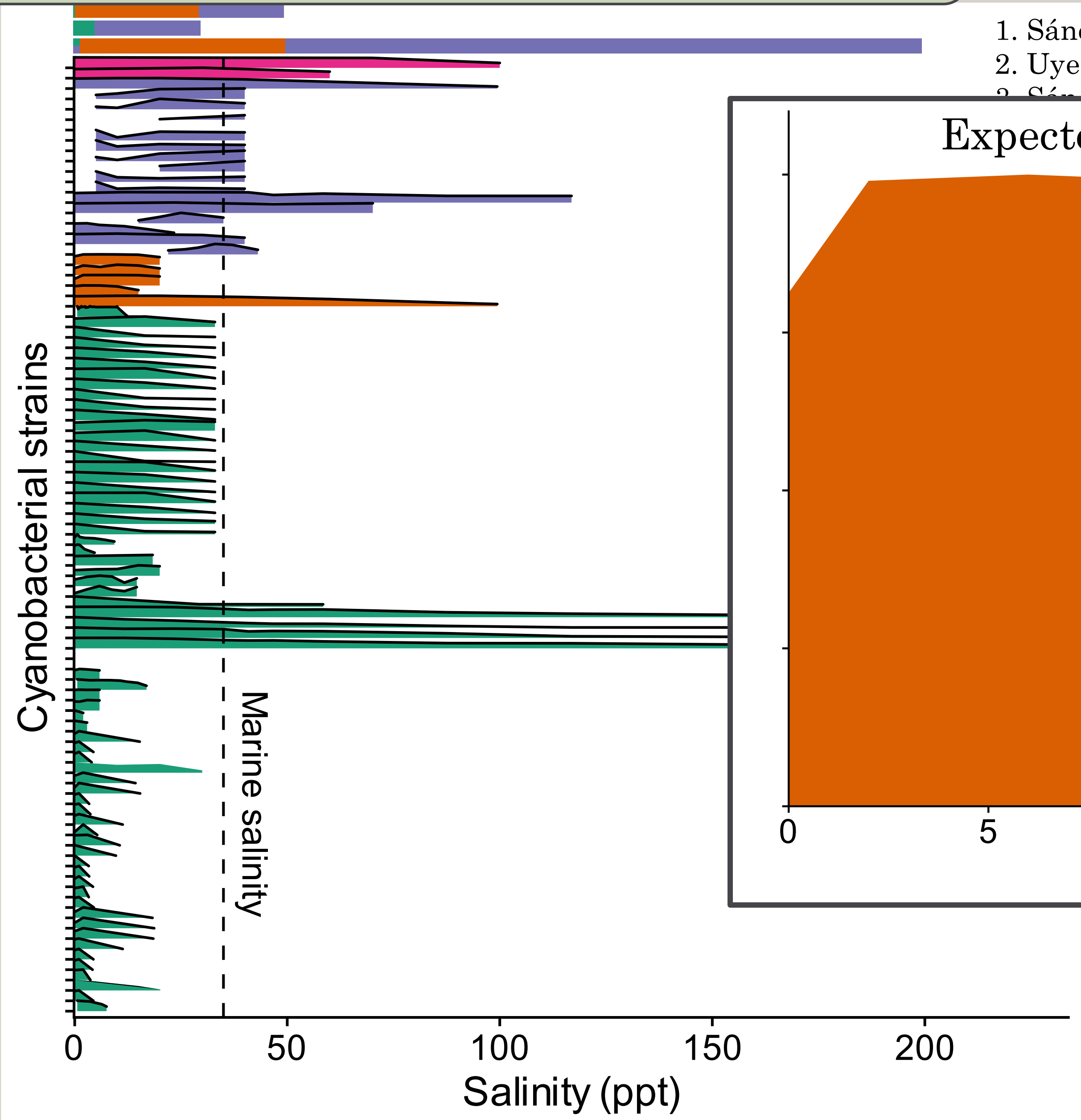

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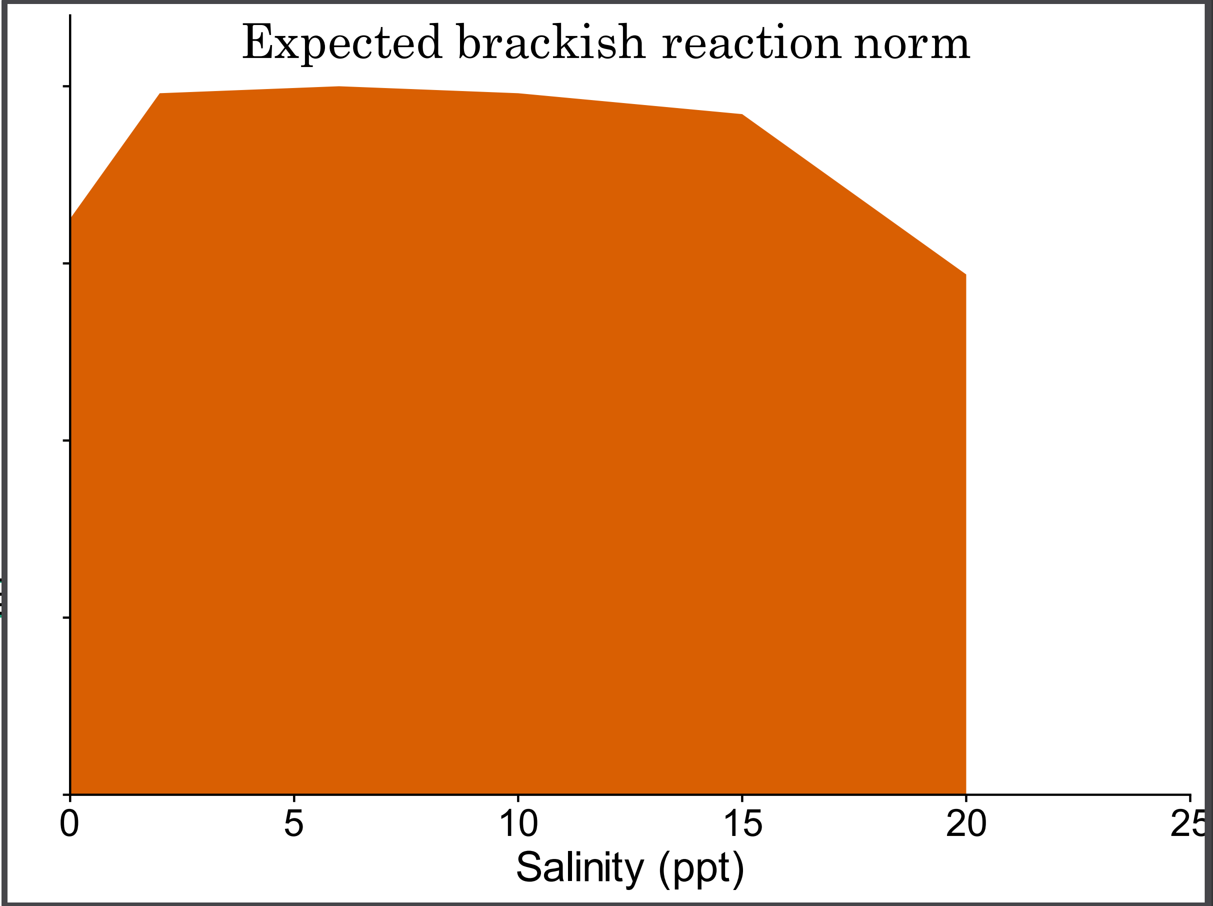

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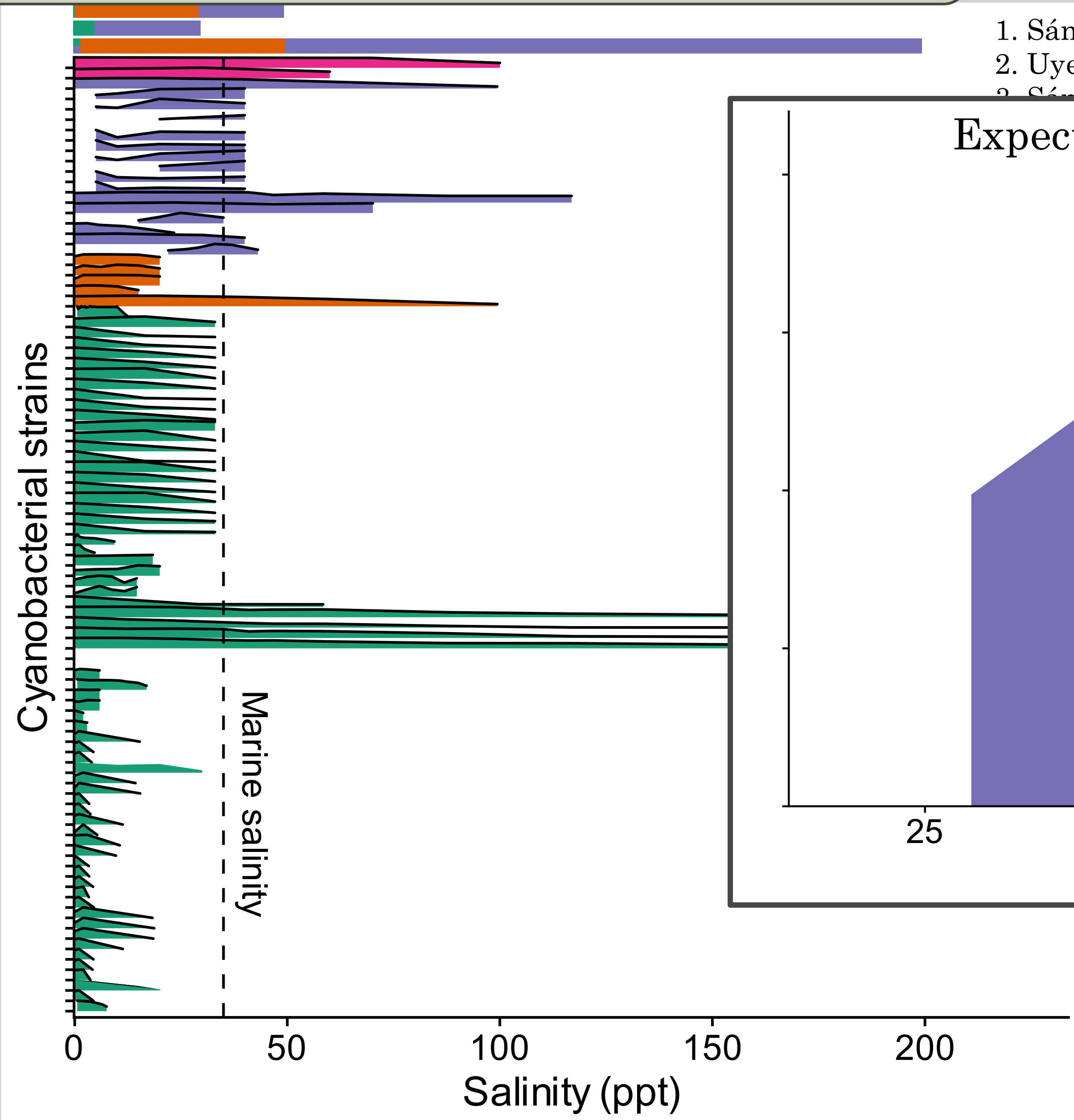

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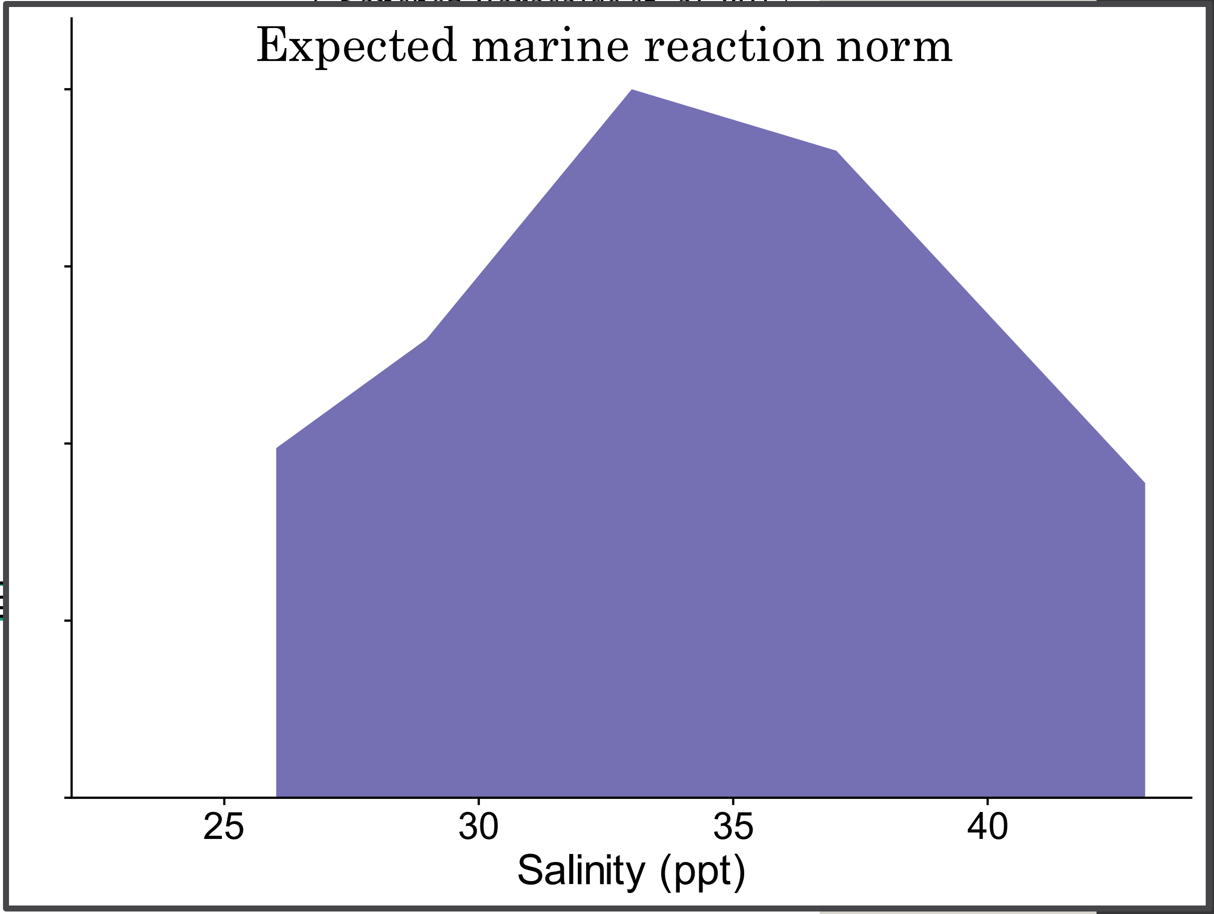

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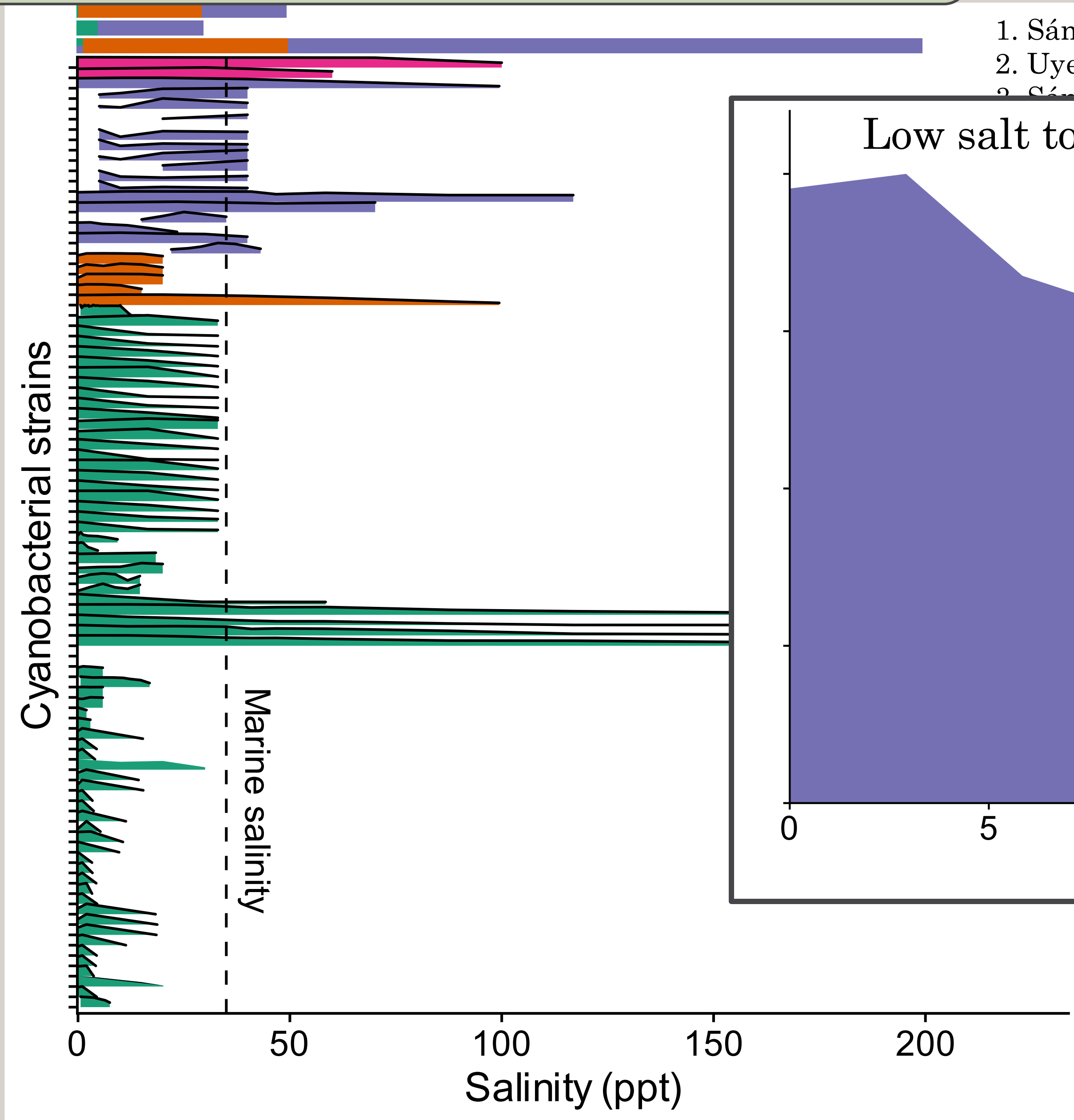

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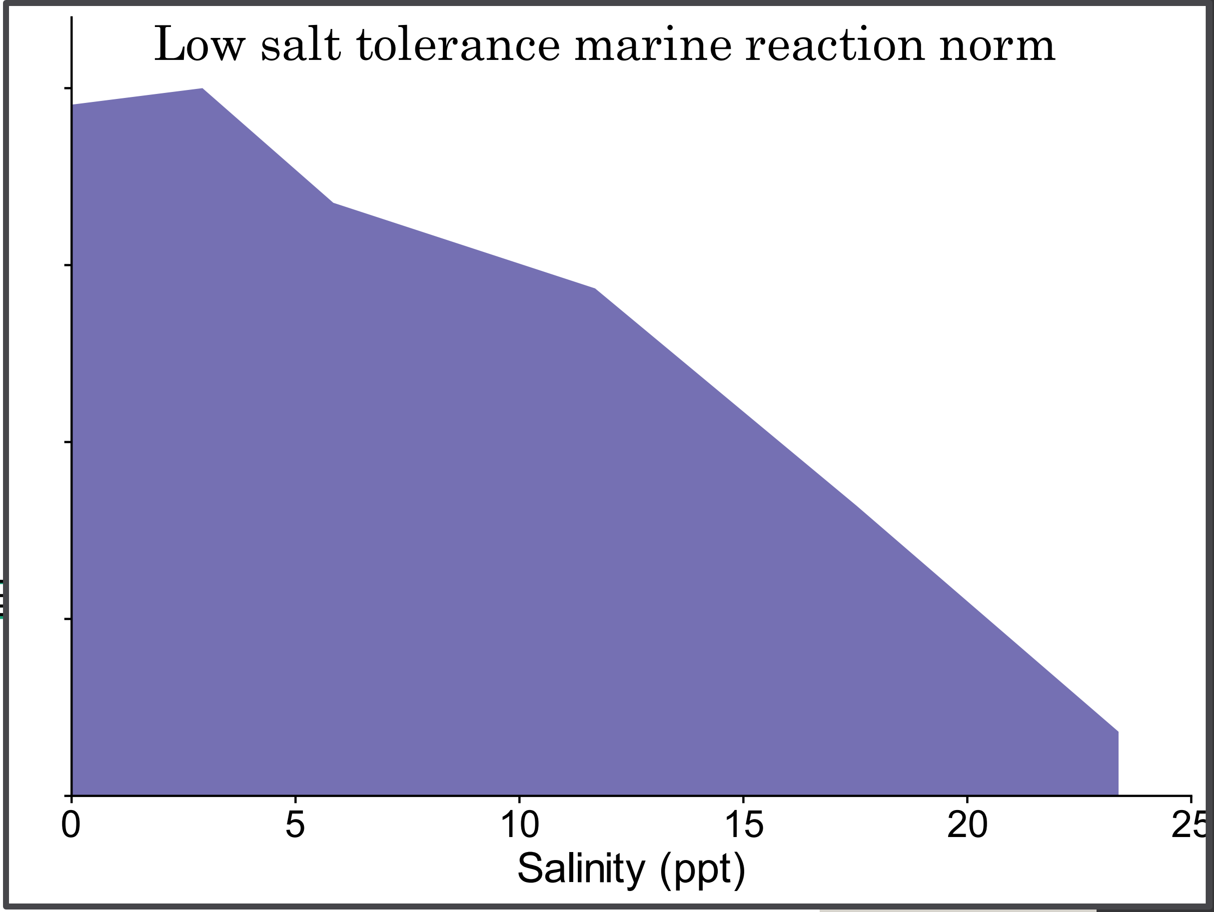

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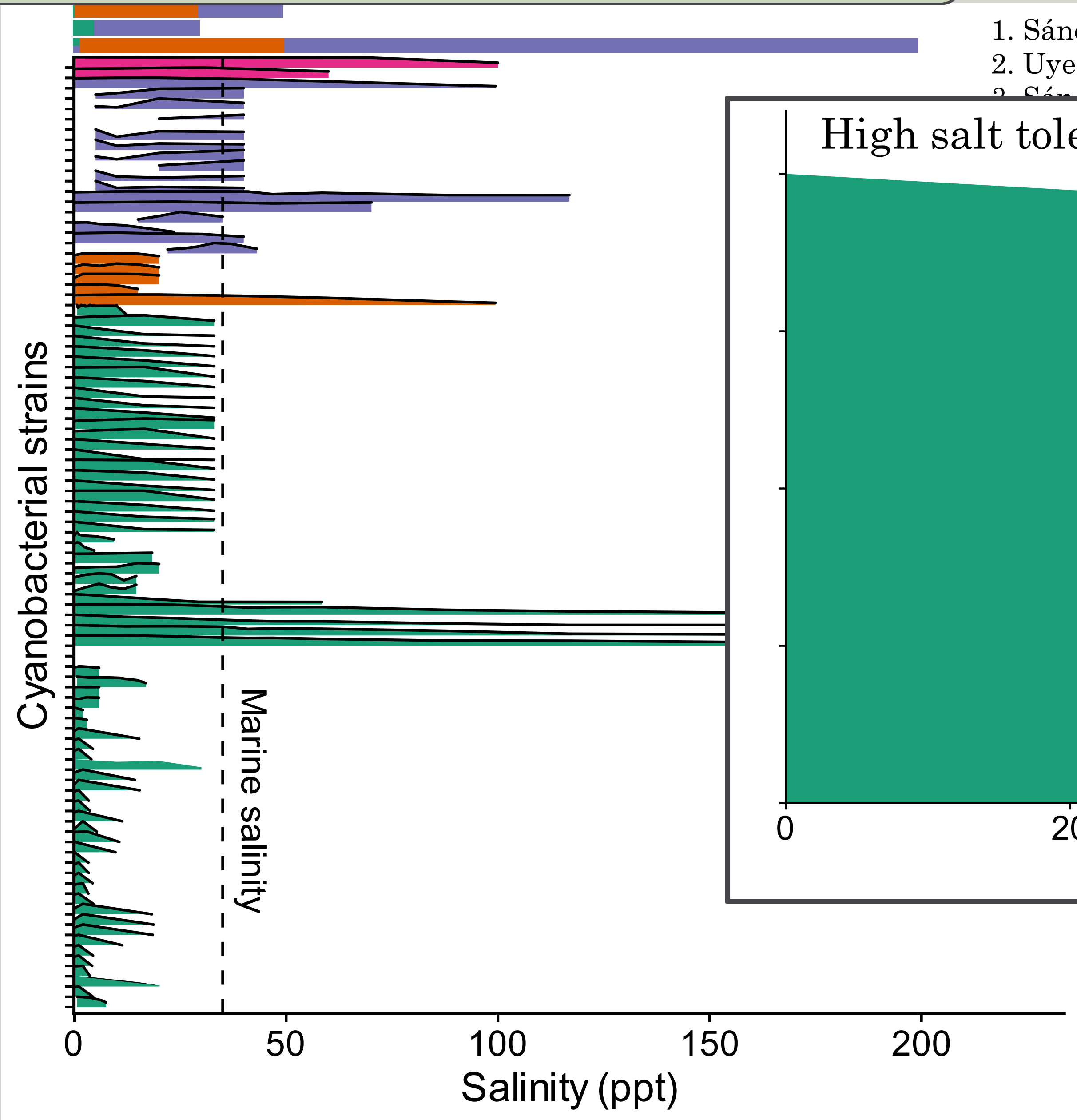

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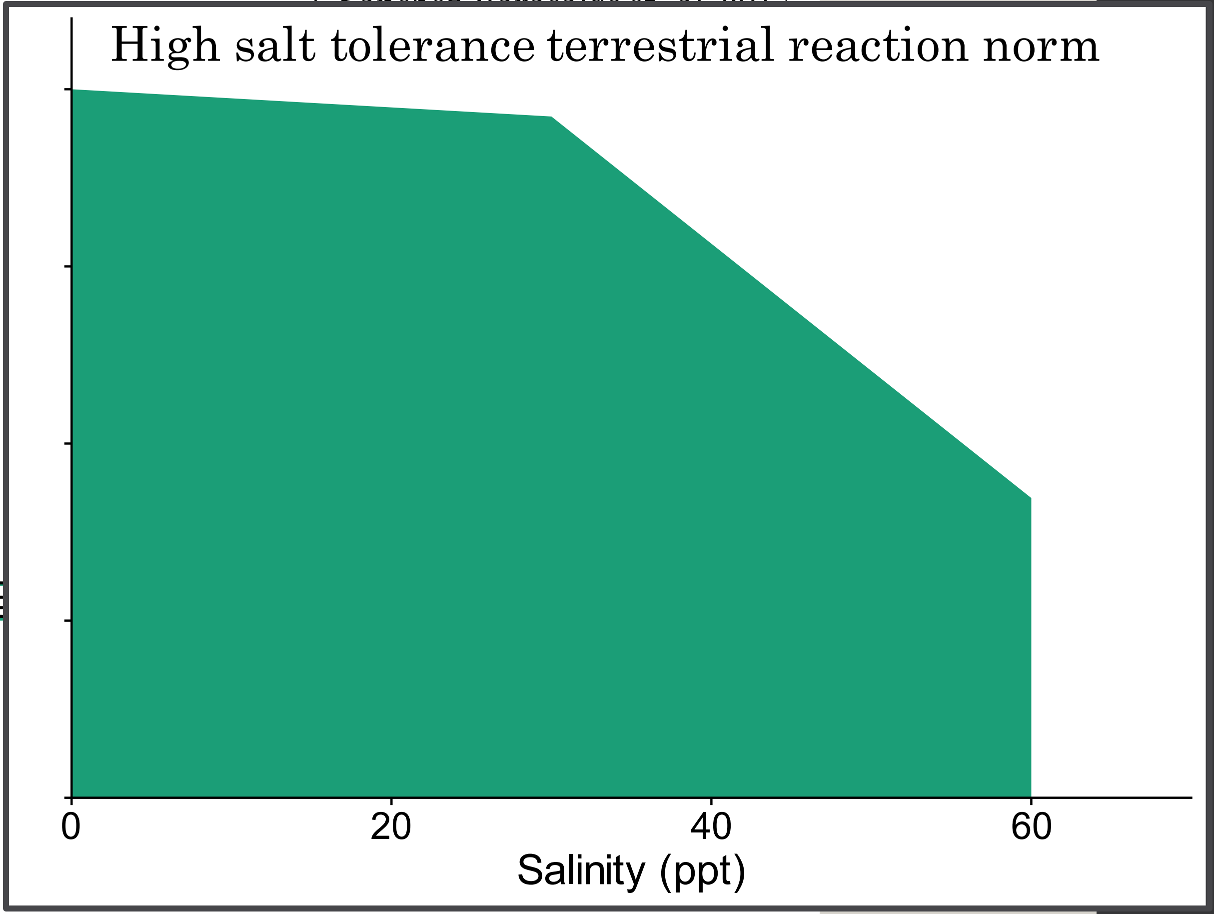

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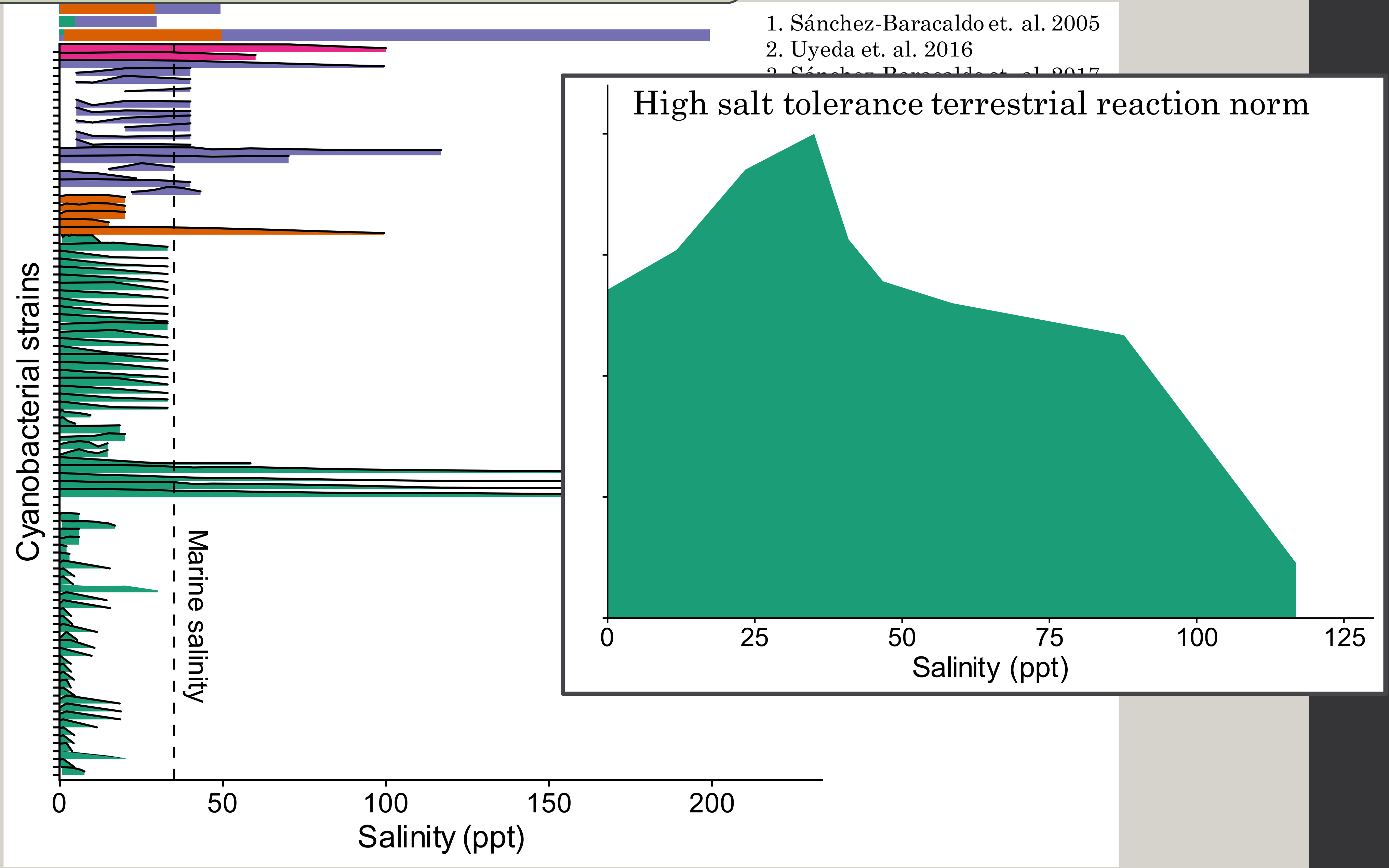

Research answers

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Sometimes but not always

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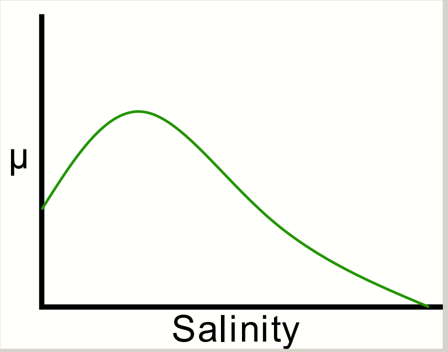
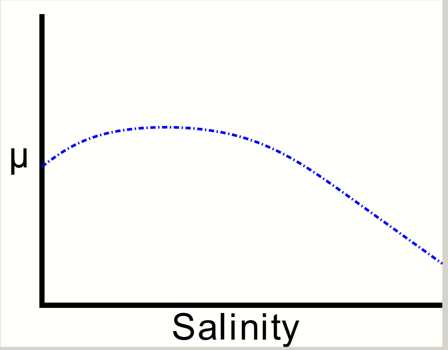
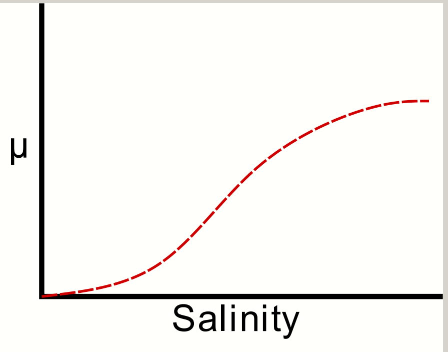
Sometimes but not always

No

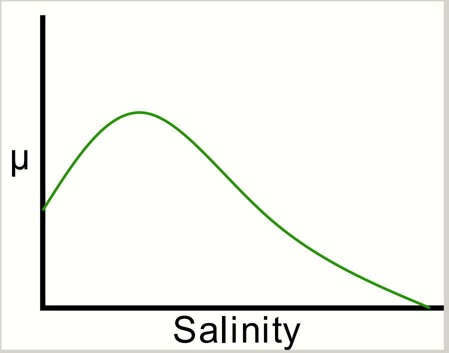
Future question: Can we identify molecular mechanisms behind the different response shapes?

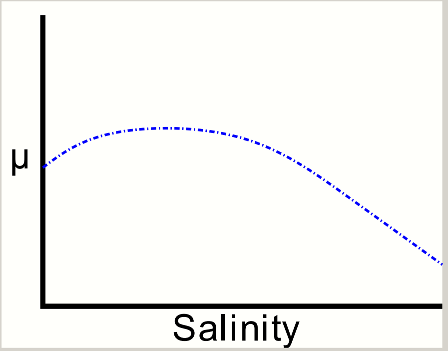


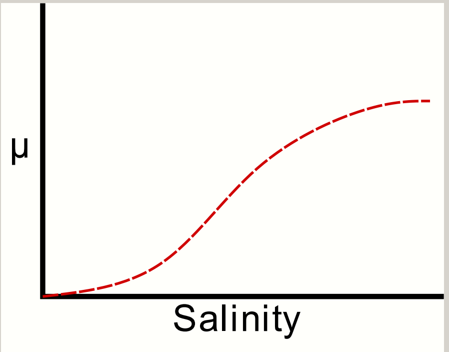


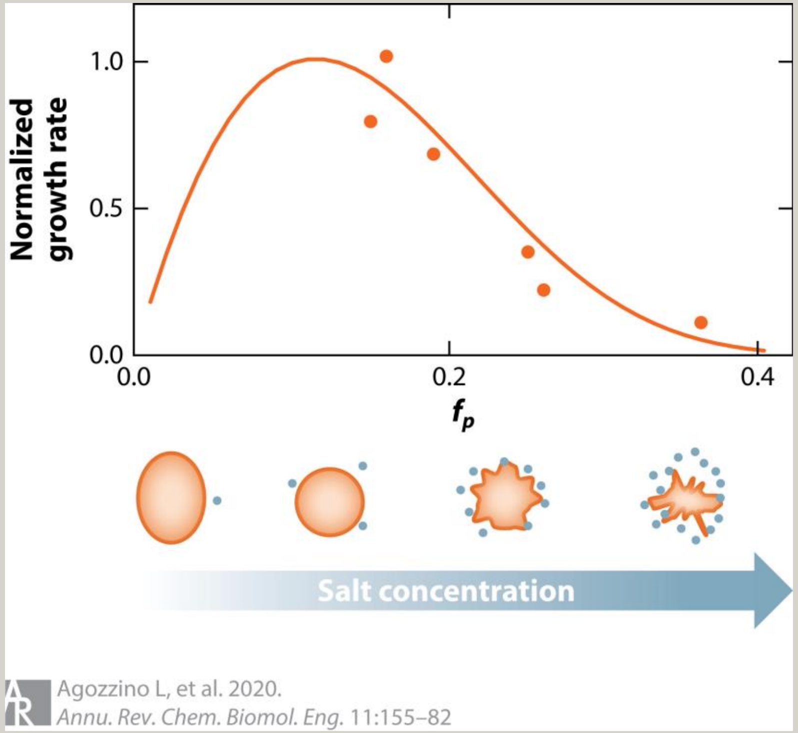


Future question: Can we identify molecular mechanisms behind the different response shapes?









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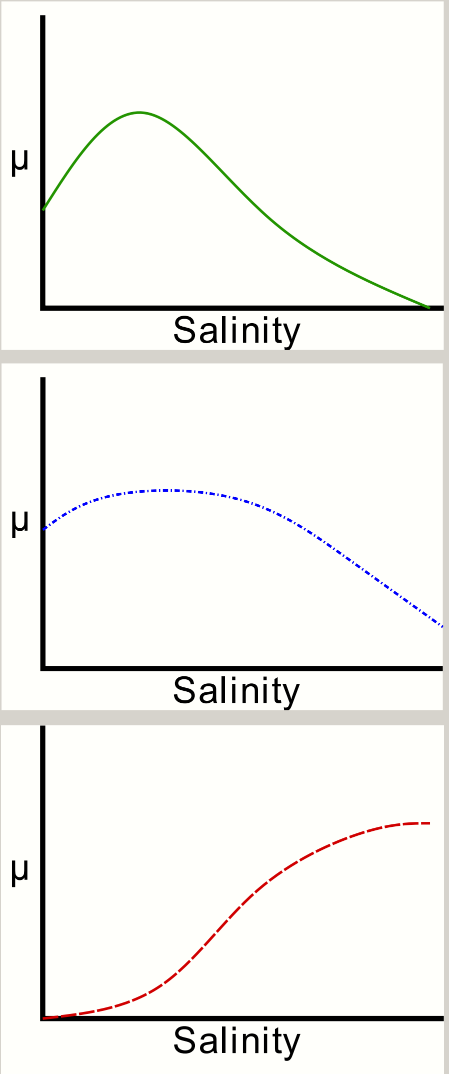
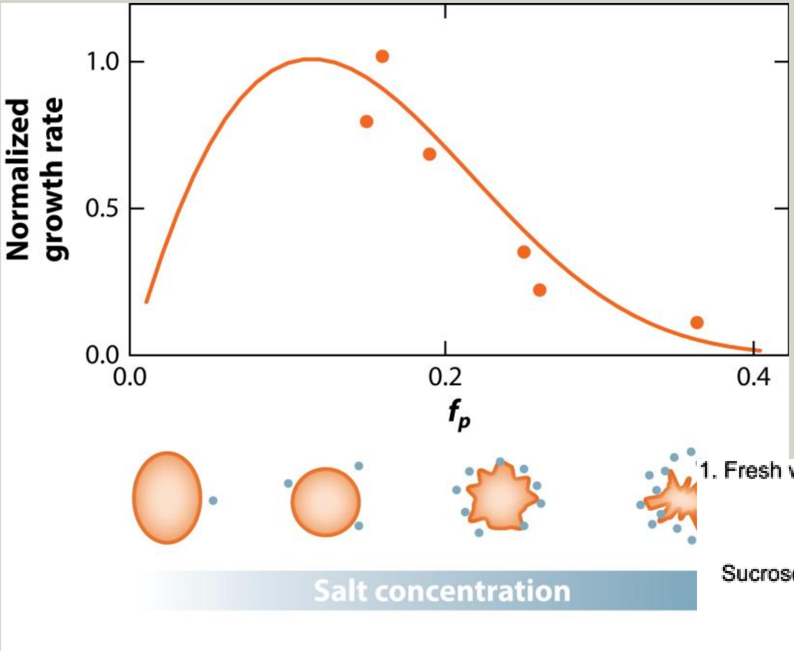
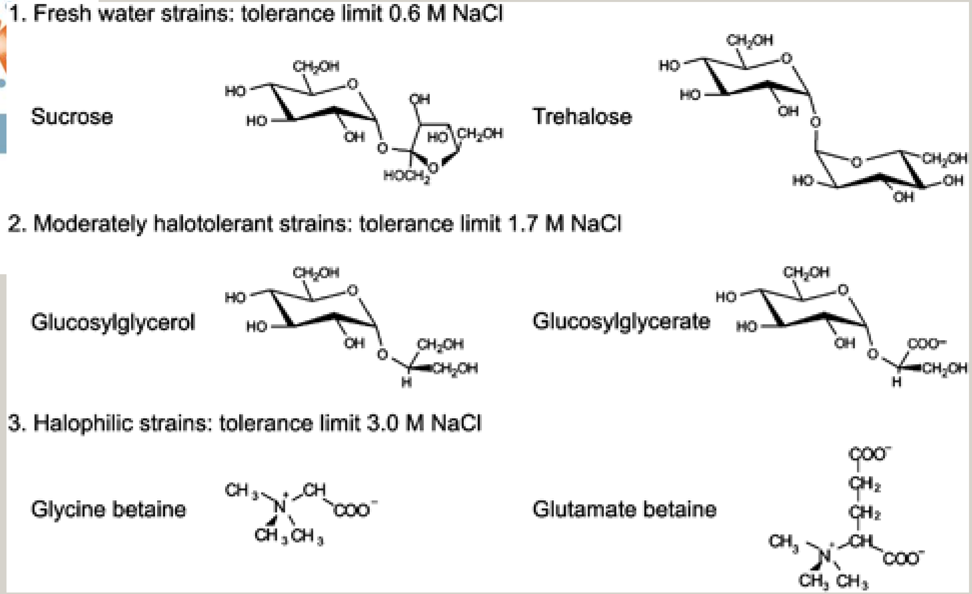
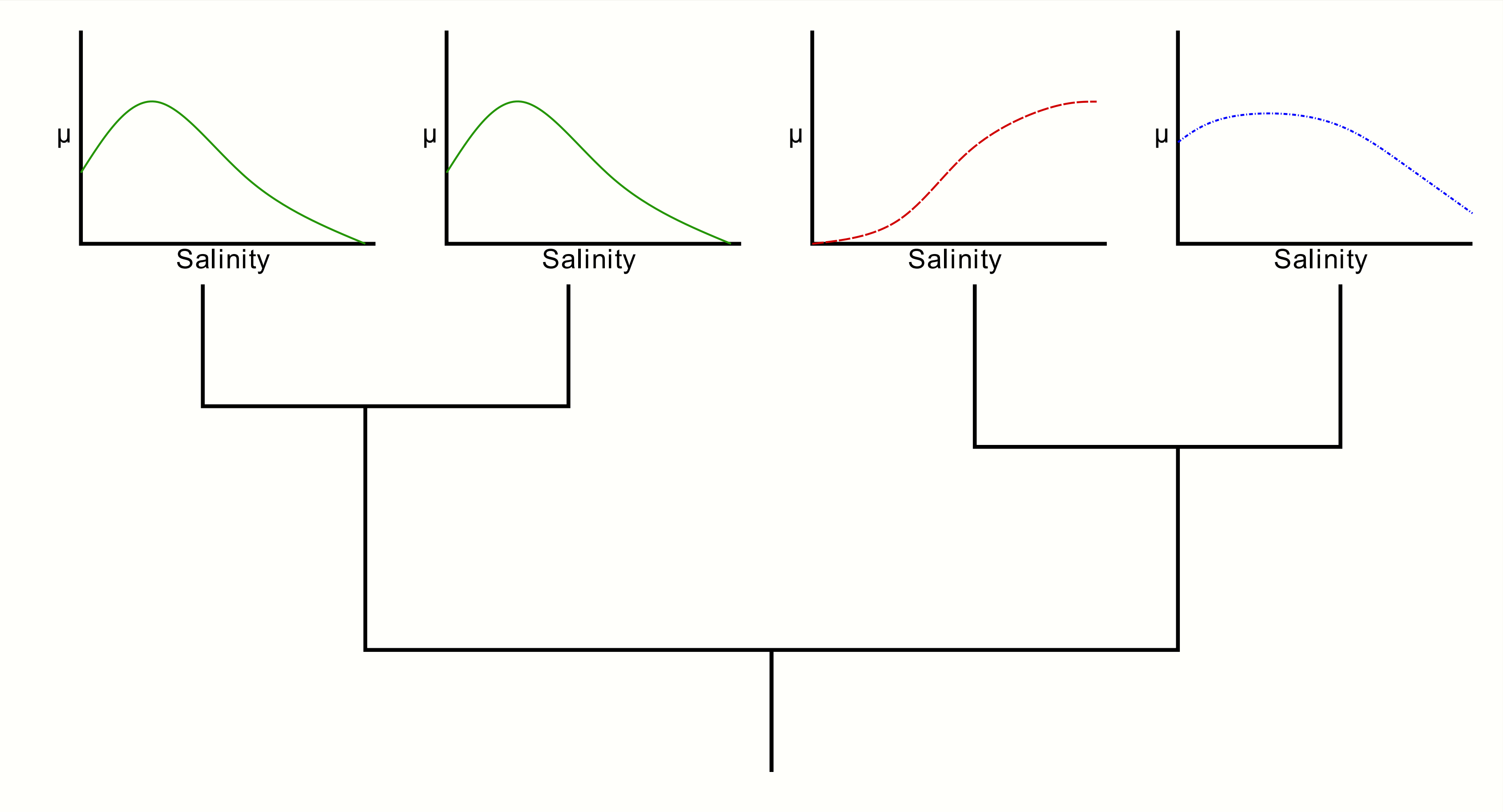




Agozzino L, et al. 2020.
Annu. Rev. Chem. Biomol. Eng. 11:155–82



Future question: How do these reaction norms evolve?



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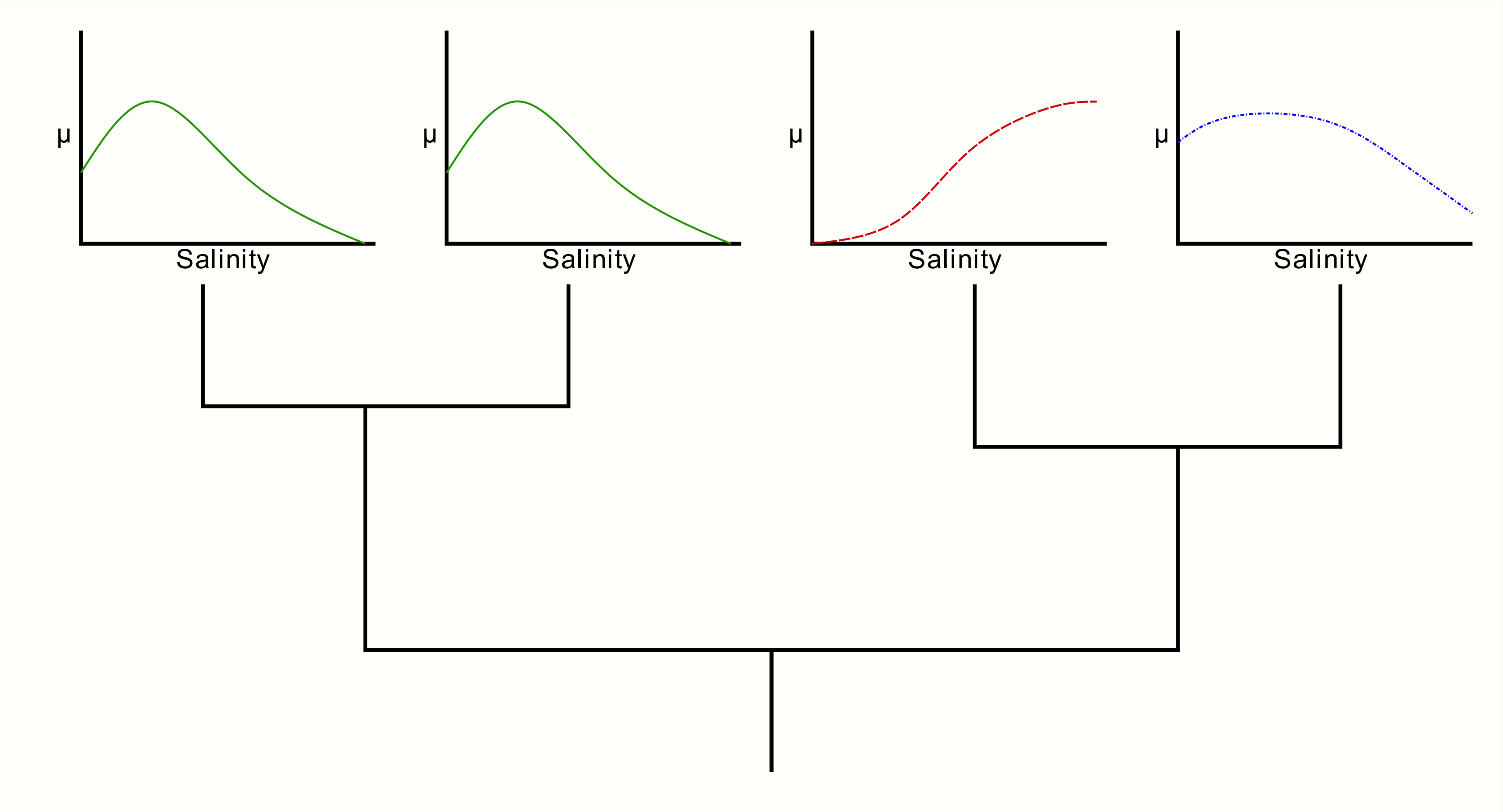
Ancestral state reconstruction



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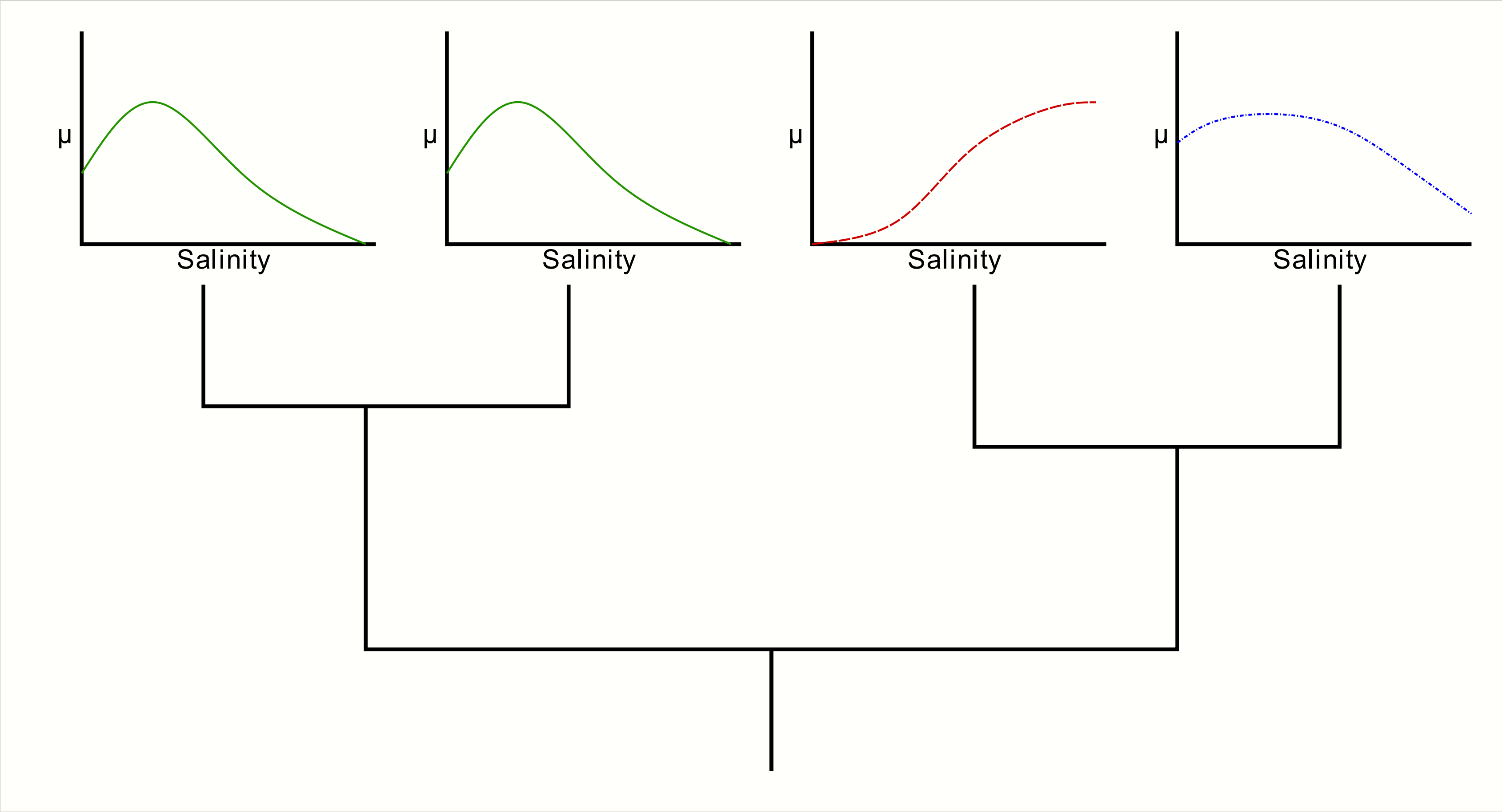
Experimental evolution



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- Adam Younkin
- Friends and family

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- Department of Geological Sciences, University of Colorado Boulder
- Biological Sciences Initiative, University of Colorado Boulder

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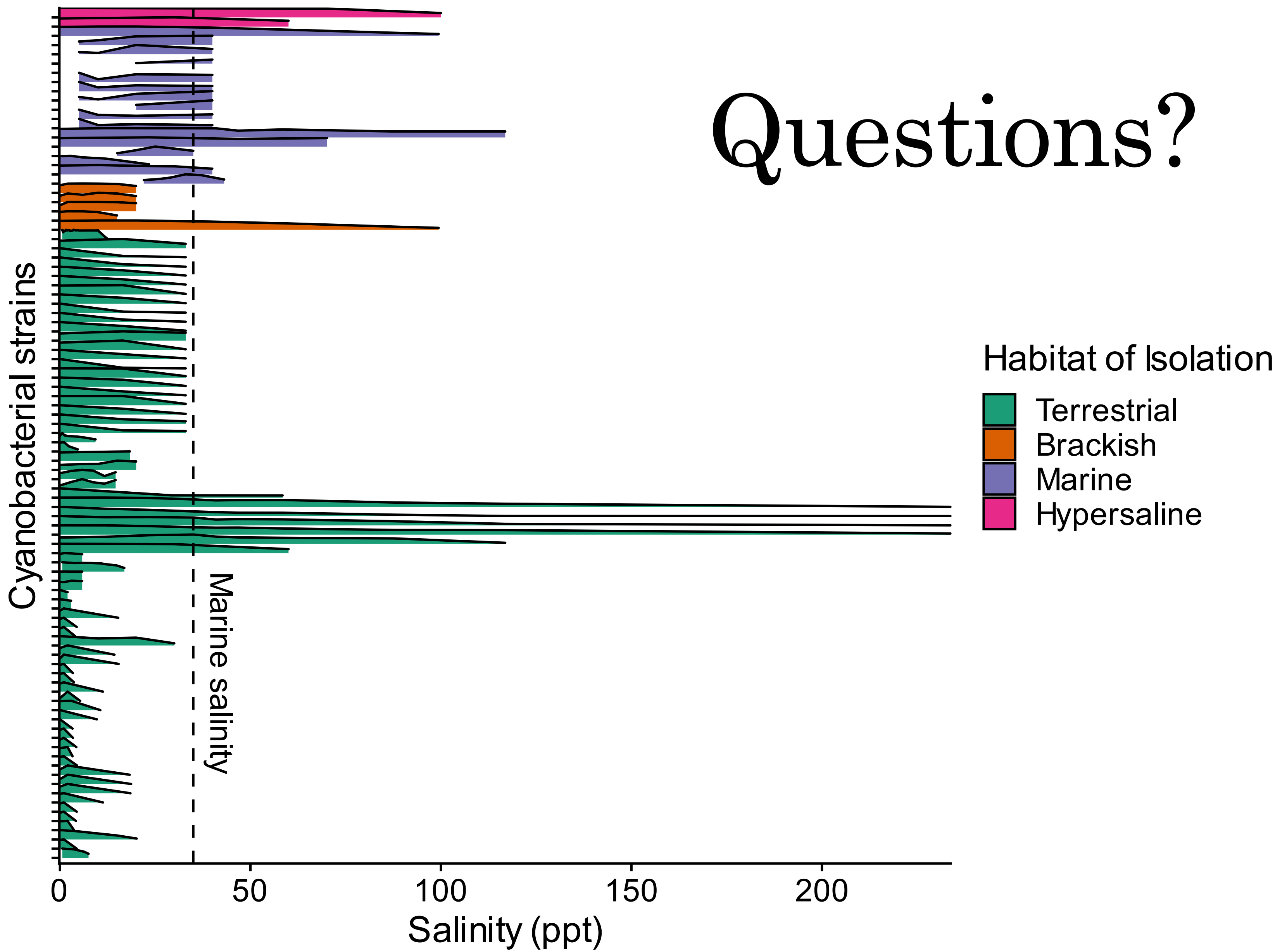
Questions?



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