Tara Oceans: Eco-Systems Biology at Planetary Scale

Chris Bowler CNRS



Fondation

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Co-directed by Etienne Bourgois and Eric Karsenti





agnès b.







The Plankton

THE INVISIBLE MULTITUDE

✓ BASIS OF THE OCEANIC FOOD WEB

SEQUESTER ATMOSPHERIC CO₂ IN THE OCEAN

GENERATE THE OXYGEN WE BREATHE

THE MOST IMPORTANT BIOLOGICAL CARBON PUMP ON THE PLANET

✓ AFFECT AND ARE AFFECTED BY CLIMATE CHANGE

>90% of the biomass in the ocean





0.1-100/litre



E.Reynaud, UCD, Dublin







E.Reynaud, UCD, [

Bacteria/Archaea:

0.1-1 billion/litre

TARA Ocean







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Adding Biological Parameters into Oceanographic Research







TARA OCEANS 2009 - 2013







Tara Oceans Global Sampling September 2009 – October 2013





The *Tara* Oceans Analysis Pipeline who is there, what do they do, with whom, and why ?

High Throughput Analysis Physico-chemistry **High Throughput Sequencing High Throughput Imaging** metazoa metazoa prokaryotes prokaryotes 1,000 µm 0.02 0.1 um 0.7 um Sum 10 um 20 am 100 µm 0.02 0.1 um 0.7 um 5um 10um 20um 300 µm 1,000 um 10.000 um 1.400 1.000 cell/body size cell/body size Total DN. PCR: 185, 285, 165, CO1 Metagenomics **Total gene diversity** Total organismal diversity Total RNA gh-Throughput Microscopy Flow Cytometry FlowCam ZooScan cDNA messenger cDNA total PCR: 185, 285, 165, CO1 Metatranscriptomics Metatranscriptomics Active organismal diversity Expressed gene diversity

OPEN access Freely available online

PLOS BIOLOGY

Community Page

A Holistic Approach to Marine Eco-Systems Biology

Eric Karsenti¹*, Silvia G. Acinas², Peer Bork¹, Chris Bowler^{3,4}, Colomban De Vargas^{3,5,6}, Jeroen Raes^{7,8}, Matthew Sullivan⁹, Detlev Arendt¹, Francesca Benzoni¹⁰, Jean-Michel Claverie^{3,11}, Mick Follows¹², Gaby Gorsky^{3,6,13}, Pascal Hingamp^{3,11}, Daniele Iudicone¹⁴, Olivier Jaillon¹⁵, Stefanie Kandels-Lewis¹, Uros Krzic¹, Fabrice Not^{3,5,6}, Hiroyuki Ogata^{3,11}, Stéphane Pesant^{16,17}, Emmanuel Georges Reynaud¹⁸, Christian Sardet^{3,6,19}, Michael E. Sieracki²⁰, Sabrina Speich²¹, Didier Velayoudon²², Jean Weissenbach¹⁵, Patrick Wincker¹⁵, the *Tara* Oceans Consortium⁵





SPECIAL ARCTORN

Tara Oceans studies plankton at PLANETARY SCALE

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Science May 22 2015

TARA OCLANS

Eukarvotic plankton diversity in the sunlit ocean

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Structure and function of the lobal ocean microbiome

Summers, "L. P. Coniba, S. Chatfree, J. R. Kultima, E. Labadia. Nalassar, B. Hjakanstöhl, G. Seiler, D. R. Blende, A. Alberti, M. Cerredo Carillo, P. L. Conna, C. Crazad, F. & Dolda, Experim 3 Terrory, J. W. Gassil, I. Galds, T. Hillichmant, Robaisha, C. Legelitte, G. Line Mendes, J. Postato, B. Peaker, M. Rays Linach, H. Sersensis, S. Visire-Silva, C. tuctor, 34, Picherali, 5, Searson, 8, Kasdels-Lewis, Sava Donata sordbaatam, C. Burriss, C. de Vargaa, G. Garrieg, N. Grinnieg, F. Augurery, D. Jasffermer, G. Jadfinst, F. Wol, H. Organs, B. Pesand, B. welch, 1. Storageness, M. H. Suffran, J. Welcomburg, F. Wiesher, Narsonit," J. Base," St G. Annae," P. Borle"

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one are made inter-shall reference game rational with +40 RECEIPT TO BE AND ADDRESS TO ANY ADDRESS AND ADDRESS AND ADDRESS. prokaryotot, and plasmakaryotos. Using 339 prokaryoteentriked samples, containing +35,000 species, we show vertical strately and a popularie community compaction and p arrive by integrations, rather than other incommunity farture or prography. We deputy amon microfilal tone functionality and reveal that v70% of its alwaydance is shared with the harash gat microbione despire the physicarthenical differences Between Bless then an systems.

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Patterns and ecological drivers of ocean viral communities

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Determinants of community structure in the global plankton Interactome

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Spoulae industrials networks are obtained by atomic and became factors. Here, as part of the Xiro Oceans present, we stabled the photo wear between one using environmental backets and ertext-lenal shand area profiles and found that evel competent factors are more predictors of experiently simplify, Wo tound associations across plantion familiantal types and phyloprovertic process to be manufactured y classificated on the network. and drives to both load and global patterns. We clean that Intersections among process, primary producers, viruses, and inside parasitic without and validate to their searched browtheses using information to confirm construction what is no think We have then previded a research to support further. respective result for webs and longesting follogical companerne best course madule.

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Environmental characteristics of Agulhas rings affect interocean plankton transport

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Addition rings provide the principal room for ocura maturata. structure from the lacks Facilie to the Atlantic Issis. Their influence on alphal serves circulation is well known, but their role in plankton transport is largely mentalored. We show that, although the course becomencie structure of standard communitine is continuous across the Agailtan choice point, South Atlantic plantice depends to almost compared with Indian Ocean search populations. Nucleiing and in sits excepting of a young Aprilian ring indicate that strang vertical realing drives complex vitragen civilian, oblights: concentrative restal where and improvement of through the start and the second planting starts of the starts of The ownedge load overtreement inside Antilkas characterized new the a tobative method is a contributing to the limited dispersal of bulies Generofunktors populations into the Albertic.

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Ocean Microbial Reference Gene Catalog



Assessment of global viral communities



5,476 Viral communities. Only 39 previously known

Viral populations are regionally dominant, but widespread

Data supports seed-bank hypothesis for viral ecology





Brum, Ignacio-Espinoza, Roux, et al. Science (2015)

A new world of marine protists

Saturation at around 130,000 OTUs

More than 10 times higher than the number of formally described marine eukaryotic plankton

Around one third cannot be assigned to any known taxonomic group







Scale bar 10µm



Sebastien COLIN, CNRS, Station Biologique de Roscoff, C.deVargas 's group

Determinants of community structure in the global ocean interactome



Lima-Mendez et al. Science (2015)

The global plankton interactome – an integrated "network of networks"



Biotic interactions more important than abiotic interactions



Lima-Mendez et al. Science (2015)

Most interactions are positive ...



Cooperation is more important than competition

Lima-Mendez et al. Science (2015)

... but diatoms are antisocial



Lima-Mendez et al. Science (2015)



The co-occurrence network can predict host-phage interactions that can be verified in metagenomes



Lima-Mendez et al. Science (2015)

From the global ocean to the single cell and back again A case study : Diatom interactions with other plankton



An unorthodox collaboration between a diatom (Fragillariopsis) and a ciliate (Salpingella)





An unorthodox collaboration between a diatom (Fragillariopsis) and a ciliate (Salpingella)









Identification of new morphotypes at other sampling sites



Colin, Vincent, Dolan; Unpublished

Adding Biological Parameters into Oceanographic Research







Real-Time Remote Sensing of Ocean Processes









Contextual Data from Sampling, Satellite, Argo Buoys, On-Board Instruments and Gliders



Temperature is the main driver of microbial community structure



Principal conclusions of the papers so far :

- The first end-to-end description of a continuous global ecosystem.
- Ocean microbiome consists of ~35,000 OTUs (mostly known) and 40 million genes (mostly unknown).
- Diversity of eukaryotic plankton is huge (~130,000 OTUs) but is finite. Around 90% are new and there is a considerable unknown component.
 - More than 5,000 viral communities described; >99% are new. Their distribution supports seed bank hypothesis.
 - Biotic interactions are more important than environmental drivers. Most interactions between plankton are positive.
 - Bacterial community composition driven largely by temperature.
 - All the data are public.

The analyses were performed on only 579 samples; the data deluge is coming !



All Tara Oceans data are public

40 million genes

Largest-ever DNA sequencing effort for ocean science.

Genetic sequences collected could represent tens of thousands of new species and ecosystem interactions.

Considering the size of the world's ocean, there is much, much more to discover.

11,535 gigabytes

Size of the *Tara* datasets in the European Nucleotide Archive as of May 2015. This represents 12,581 gigabases roughly equivalent to 135 fully sequenced human genomes.

Unlimited

Potential to discover new knowledge about life in the world's ocean.

Tara Oceans data: www.ebi.ac.uk/services/tara-oceans-data



TARA Oceans



A three year expedition

 To explore marine planktonic ecosystems and their sensitivity to climate change-induced modifications to the ocean

- To popularize science
- To educate

September 5th 2009: Departure from Lorient



March 31st 2012: Return to Lorient





Visit of UN Secretary General Ban-Ki Moon: Informing Policy makers about the Key Role of Ocean Life



School kids and TARA OCEANS





COP21 and the Paris Treaty have recognized the importance of the ocean !



United Nations

Framework Convention on

FCCC/CP/2015/L.9

Distr.: Limited

greenhouse gases referred to in the Convention,

Noting the importance of ensuring the integrity of all ecosystems, including oceans, and the protection of biodiversity, recognized by some cultures as Mother Earth, and noting the importance for some of the concept of "climate justice", when taking action to address climate change,

Affirming the importance of education, training, public awareness, public participation, public access to

Conference of the Parties Twenty-first session Paris, 30 November to 11 December 2015

Agenda item 4(b) Durban Platform for Enhanced Action (decision 1/CP.17) Adoption of a protocol, another legal instrument, or an agreed outcome with legal force under the Convention applicable to all Parties



ADOPTION OF THE PARIS AGREEMENT

















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Thank you !



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