

Invisible

The Tara Oceans Expedition

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The tiny, the imperceptible, the invisible: one might imagine that the indiscernible - due to their apparently insignificant qualities - could not have the importance of the large charismatic animals, that they could not have the effects of the organisms we can actually see. What this kind of mentality is unable to perceive is that it is precisely because of this concealment that these creatures are capable of multiplying exponentially; becoming the fundamental building blocks upon which the largest ecosystems are built.

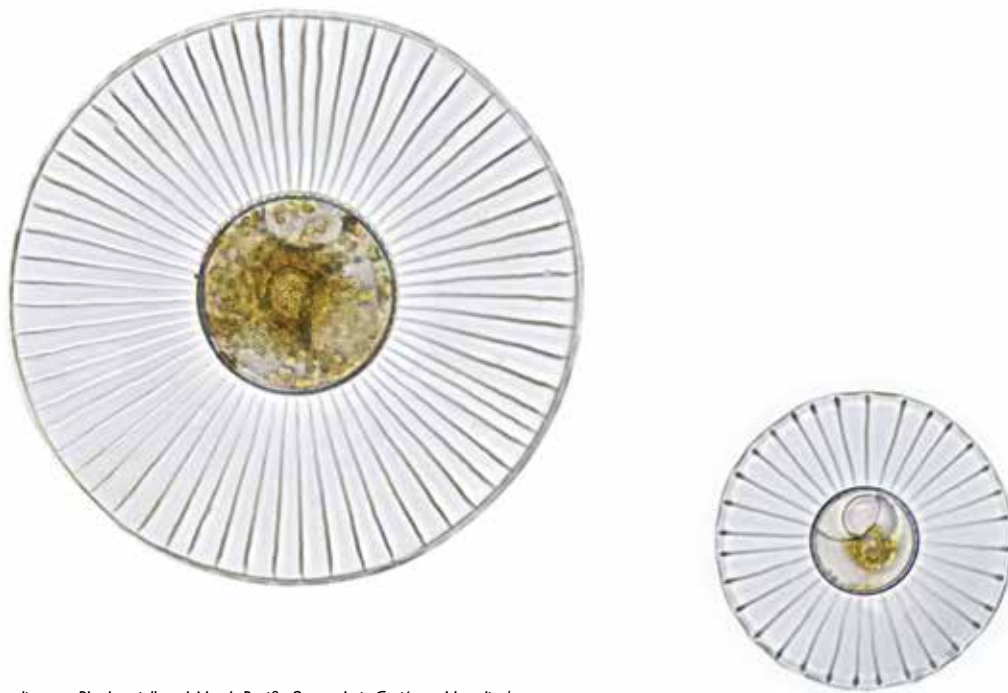


Phronima sp., Crustacea. North Pacific Ocean. Luis Gutiérrez-Heredia / UCD / Tara Oceans. 2009. Height: 2.4cm.

It is extraordinary to realise that 98% of the ocean cell mass is unicellular. One litre of water may contain hundreds of millions of unicellular organisms, hundreds of billions of viruses and bacteria are included. Each of these organisms has a definite form and although their life is brief, they are intrinsic elements in the composition of the seas. Their form is created and sustained by the flow of environmental factors in which they live. They are what they eat, what they breathe, where they multiply. Their presence and metabolism define the environment in which other beings live. They are the basis of the food chain; they sequester atmospheric CO₂ into the ocean, create deposits (rocks, oils...) and produce half of the oxygen we breathe. Therefore, while a planktonic organism is an individual and distinguishable entity, it is inseparable from the ocean that produced it. This is how the “tiny, the imperceptible, the invisible” are connected with the totality of the oceans and in turn, with the continents and the atmosphere. They

are our past, our present and studying them is like taking the pulse of our planet.

When these tiny beings are organised among themselves, they create highly adaptable and resilient relationships. The oceans are dominated by open chaotic systems formed by these relationships which allow constant responses to environmental changes. Oceanic areas organise themselves by changing their subtle regulatory capacity in response to each local change in the seas. These structures are stable to the extent that the conditions under which they were created are kept within certain limits, yet the large number of degrees of freedom inherent in these systems can also enable a new self-organisation to occur. However even though these systems may appear to be very stable, relatively small modifications can cause dramatic changes. Minute influences may act in such ways that the entire system is transformed. This is where human activities may have a major effect. We have caused significant disruptions in



Two diatoms, *Planktoniella sol*. North Pacific Ocean. Luis Gutiérrez-Heredia / UCD / Tara Oceans. 2011. Large: 25 µm diameter.



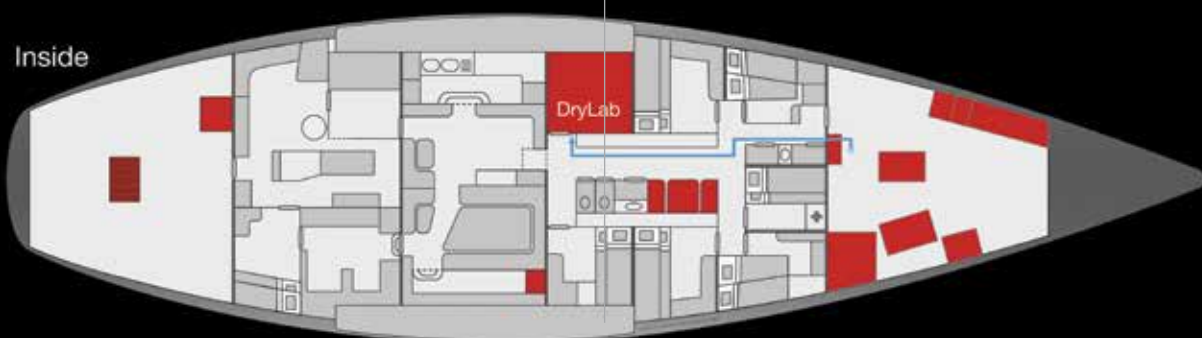
Squat lobster, Crustacea. North Pacific Ocean. Luis Gutiérrez-Heredia / UCD / Tara Oceans. 2009. Length: 6cm.



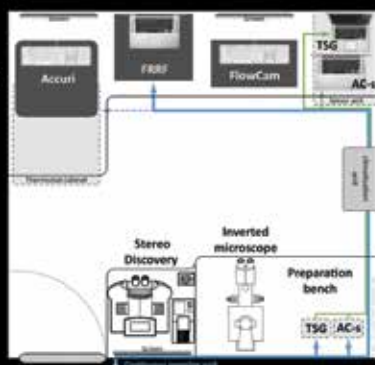
*Iridescent copepod. Crustacea. South Atlantic Ocean. Sebastien Colin / EPPO
/ CNRS / Tara Oceans. 2011. 300 μ m length.*



Inside



DryLab



Plan of the Tara vessel, including drylab setup.

the oceans with our comings and goings and as we know virtually nothing about the organisation, abundance and health of the most representative parts of the oceans we are unable to make accurate predictions of the effects of human activities. This is terrible, because we depend on the oceans; we are also part of that system. And if this system collapses, we will shortly follow.

Because of this manifest ignorance, prestigious expeditions have been organised in order to increase our inadequate knowledge of the oceans. The most famous were the four expeditions of Columbus (1492-1596), the three voyages around the globe of James Cook on the *HMS Endeavour* (1768-1780), the fateful excursion of Charles Darwin on the *HMS Beagle* (1831-1836) and one of the most featured one was achieved by Sir Charles Wyville Thomson on the *HMS Challenger* (1872-1877), lasting for nearly four years with the aim of studying the depths and the diversity of marine life, even though one of the reasons for this research in the English agenda was establishing dominance over an intercontinental telegraph system.

The scientific planning for the *HMS Challenger* expedition was a gargantuan work: transforming a military ship into a research centre at sea, recording with physics, chemistry, geology and natural history laboratories equipped with the most advanced instruments of the time. 6 scientists and 243 crew members sailed for 127,000 km (68,890 miles) sampling 362 stations, recording 492 depth soundings and dredging 133 times, discovering 4,700 new species. This trip went around the world touching every continent, including Antarctica, and scientists with great artistic skills - such as Ernst Haeckel - were involved and the publication of the results took far longer than the expedition itself (30 years) with the published results amounting to fifty heavy tomes. All kinds of research were conducted: such as studies of the water column and the animals contained therein, the collection and preservation of samples, scientific visits to several sites and above all a photographic record of the localities



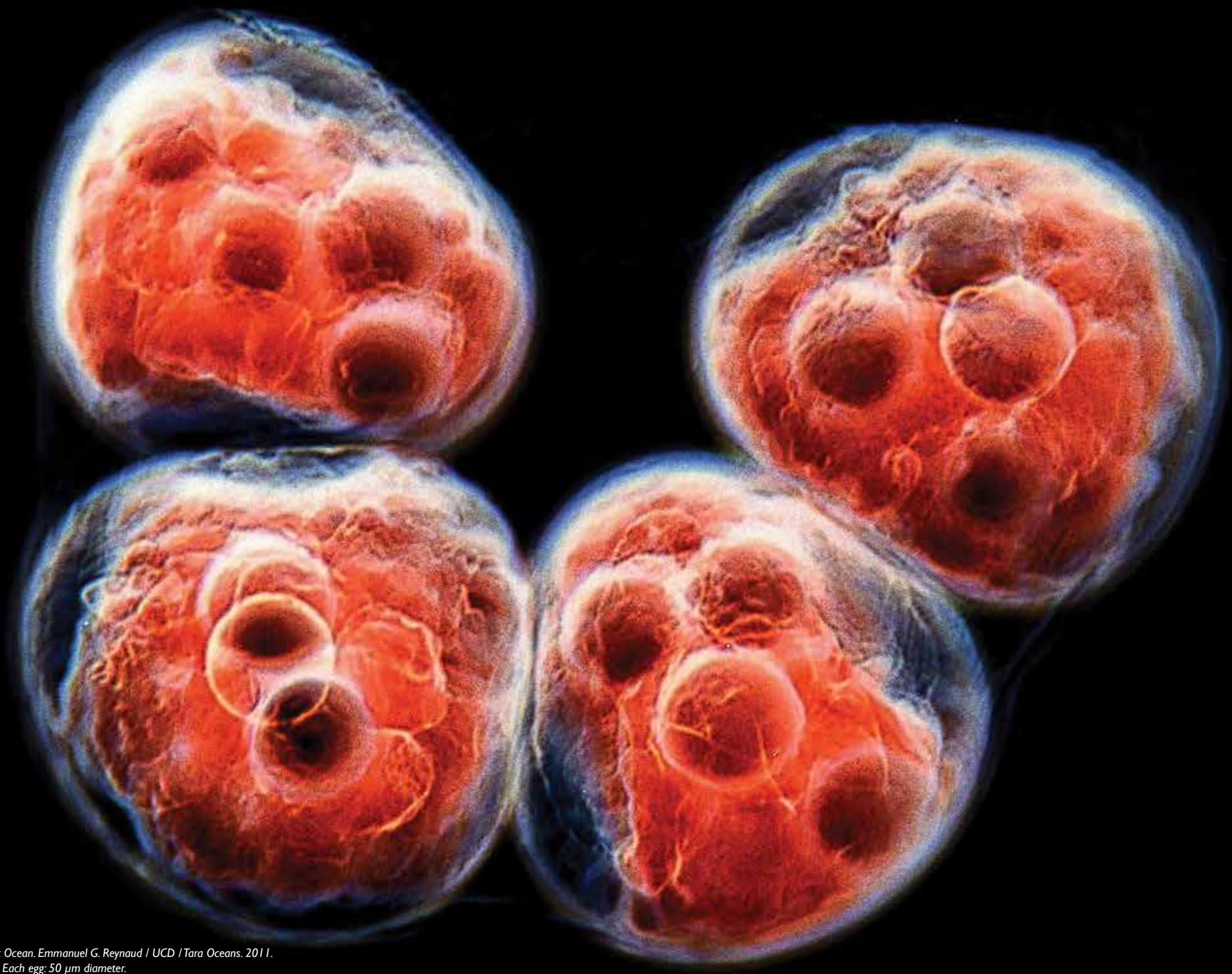
A dinoflagellate, *Protopteridinium*. North Pacific Ocean. Luis Gutiérrez-Heredia / UCD / Tara Oceans. 2011. 20 μ m height.

and specimens; a very young science at that time. One of a kind, this expedition resulted in major advances in what little was known about the world ocean biogeography. Even today, its publications and preserved specimens are studied.

As the last major world scientific exploration occurred 173 years ago, to Etienne Bourgois and Eric Karsenti it seemed a great idea to run a new global expedition along with the help and main financial support of the famous fashion designer Agnès B and here is where the concept of the Tara Oceans Expedition (2009-2012) was conceived. The Tara Oceans Expedition was a unique circumnavigation of the earth on a 36-meter schooner to analyse and



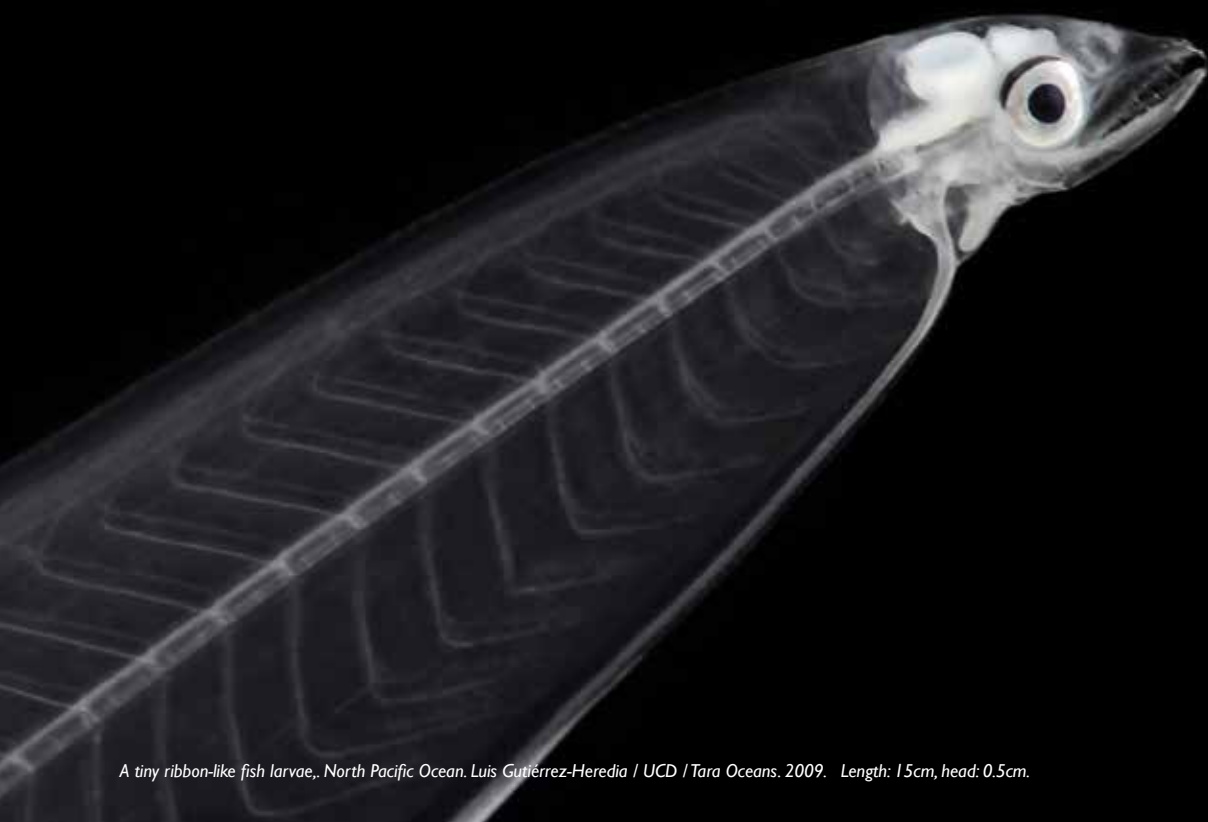
Squid, Mollusca. North Pacific Ocean. Luis Gutiérrez-Heredia / UCD / Tara Oceans. 2011. Length: 3.3cm.



*Calanoid copepod eggs, South Atlantic Ocean. Emmanuel G. Reynaud / UCD / Tara Oceans, 2011.
Artistic impression using false colours. Each egg: 50 μ m diameter.*



Comb jelly, Ctenophora. South Atlantic Ocean. Mattias Ormestad / Kahi Kai / Tara Oceans. 2010. 3cm diameter.

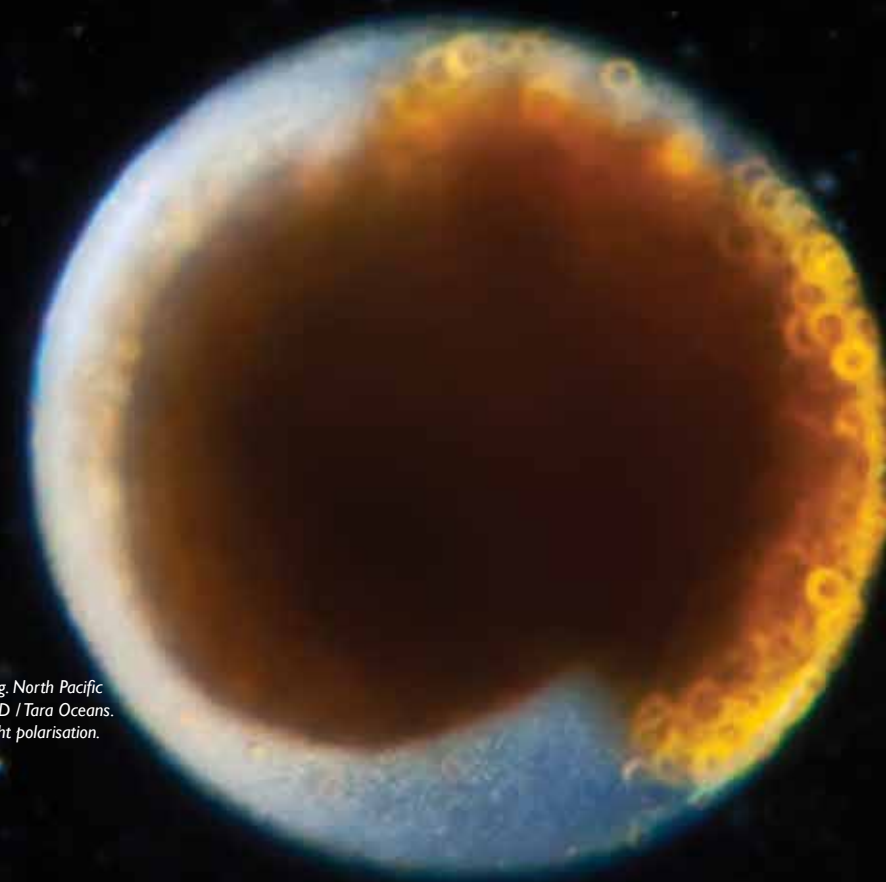
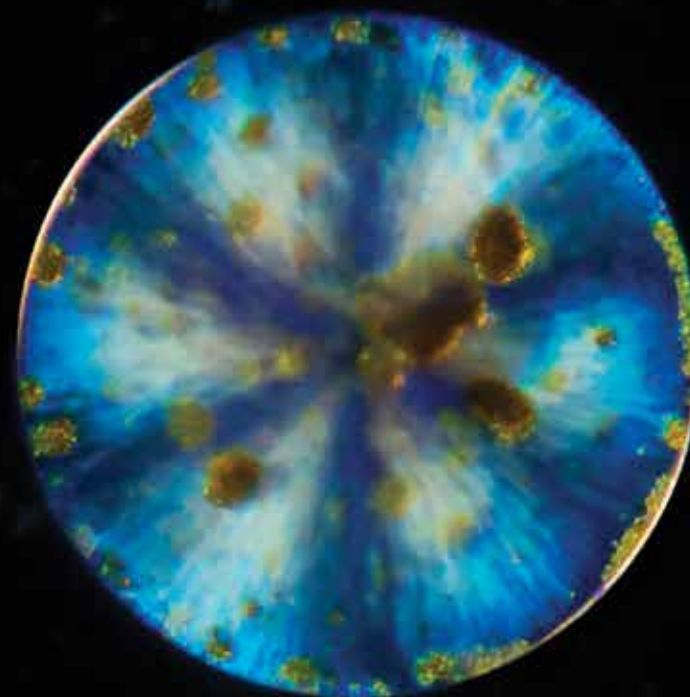


A tiny ribbon-like fish larvae, North Pacific Ocean. Luis Gutiérrez-Heredia / UCD / Tara Oceans. 2009. Length: 15cm, head: 0.5cm.

collect plankton communities and coral specimens to establish a freely-available database comprising satellite images, geochemical data, photographic images and genomic sequences to describe them as comprehensively as possible. The main idea was to have a more realistic picture of the oceans and marine life; very much like the purpose of the *HMS Challenger* expedition. With a cohort of nearly 200 scientists representing 12 disciplines and with the support of 65 laboratories and institutes around the world it was intended to generate a more holistic view of the sea utilising oceanographic, ecological, microbiological, genomic, molecular, cellular, systematic, taxonomic, bioinformatic and ecosystem modelling techniques. The range of studied organisms extended from viruses, giruses and bacteria through to archaea, protists and

planktonic metazoans to some nektonic metazoans. Included were trips to the Antarctic and 4 trips to coral reefs (Djibouti, Saint Brandon, Mayotte and the Gambier Archipelago). The planning of this trip envisaged an on-board crew performing data collection and processing, together with an onshore team conducting studies in laboratories focusing on specific areas with particular oceanographic qualities and maintaining contact through satellite techniques.

The Tara Oceans expedition has very similar features to the *HMS Challenger* expedition: distance, travel time, relative cost, compartmentalisation of the ship, use of classical sampling methods and state-of-the-art equipment, frequent land stops, focus on the relationships between physical, biogeochemical and biodiversity components, preservation of



A diatom, Bacillariophyta and an egg. North Pacific Ocean. Luis Gutiérrez-Heredia / UCD / Tara Oceans. 2011. The blue colour is due to light polarisation. Diatom: 50µm diameter.



Porpita sp., Cnidaria. North Pacific Ocean. Luis Gutiérrez-Heredia / UCD / Tara Oceans. 2011. 1 cm.



Silver hatchetfish, Osteichthyes. North Pacific Ocean. Luis Gutiérrez-Heredia. 2011. Length: 5cm.

samples, the long task of analysis and publication of results post-expedition not to mention the constant photographic record. This latter need gave rise to the creation of a unique imaging platform: the Tara Oceans Marine biology Imaging platform (**TAOMI**). A couple of the new features fulfilled by this expedition were the measurement of pollution and trash particles floating on the seas and raising public awareness of the critical role of microscopic marine life, by means of modern media and by giving tours to school children and to the public in general. Also a new angle, and a very special one, was the use of a schooner (the famed Tara) for the expedition. The use of a ship with lesser draught greatly reduced travel costs and the carbon footprint and most importantly this showed that expeditions of this dimension could be made with smaller vessels. TAOMI provided optimal imaging and cytometry equipment for the researchers on board during their three years journey. This was a challenge due to the boat size, its stability and the limited amount of energy available that posed problems for the optical instrument designers. 23 optical engineers trained online and acquired 9 million images over two and a half years. It is from this section that the most amazing and inspiring photos of this expedition were produced.

This expedition was and remains a great adventure, where brave 'Taranauts' sailed through sudden storms, awe-inspiring landscapes, hot tropical weather, pirate-infested waters and unhurried icebergs. It is an attempt to complete the neglected picture we have about the oceans, which continues to give us so much.

The TA.O.M.I. team : Dr Emmanuel G. Reynaud (Leader), Dr Eric Röttinger (Macrophotography/Kahikai) Jarred Swalwell, Uros Krzic, Mattias Ormestad, Michael Sieraki, Anne Doye, Sebastien Colin, Franck Preijger, Christian Rouviere, Fabrice Not, Jennifer Gillette, Cedric Guigand, Aldine Amiel, Sasha Tozzi, Patrick Chang, Noan LeBescot, Daniel Bailey, Edouard Leymarie, Gabriela Gilkes, Sophie

Marinesque, Jeremy Capoulade and Luis Gutierrez-Heredia.

Further readings and links

Articles

- Peat, FD and Briggs, J. 1999. Seven Life Lessons of Chaos. Harper Collins Publ. 207pp.
- Ernst Haeckel. Kunstformen der Natur (1904) — Art forms of Nature, with plates representing detailed marine animal forms
- Helen M. Rozwadowski, Fathoming the Ocean (2005), Harvard University Press. ISBN 0-674-02756-6
- R. M. Corfield, The Silent Landscape: the Scientific Voyage of HMS Challenger (2003), Joseph Henry Press. ISBN 0-309-08904-2
- Eric Karsenti and Dino di Meo Tara Oceans, Chronicles of a Scientific Expedition published by Tara expeditions and Actes sud (in French only)
- Karsenti E. et al. A holistic approach to marine eco-systems biology PLoS Biology (2011) Volume 9 (10)
- E.G.Reynaud (Ed.). Imaging Marine Life: Macrophotography and Microscopy Approaches for Marine Biology Print ISBN: 9783527327447; Online ISBN: 9783527675418; DOI: 10.1002/9783527675418

Web links

- <http://oceans.taraexpeditions.org/>
- <http://www.kahikaiimages.com/-/galleries/exhibitions/alive-adrift>
- <http://www.kahikaiimages.com/-/galleries/exhibitions/inhale-a-journey-into-the-coral-reef>
- http://en.wikipedia.org/wiki/Challenger_expedition
- <http://www.nhm.ac.uk/nature-online/science-of-natural-history/expeditions-collecting/hms-challenger-expedition/>

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Emmanuel G. Reynaud received his PhD in 1999 at the University Paris-XI Orsay, France, where he studied cell cycle regulation in rhabdomyosarcoma derived cell lines. He went on an EMBO long term fellowship in Dr Rainer's Pepperkok laboratory in EMBL, Heidelberg, Germany, where he developed new approaches in cell biology such as the combination of microcontact printing and laser nanosurgery for in toto golgi apparatus removal. In order to further explore the possibility of light microscopy, he moved to Prof. Ernst H.K. Stelzer lab to help with the development of light sheet microscopy in collaboration with Carl Zeiss Microscopy GmbH leading to the release of the Light Sheet Z.I microscope and several patents. He was appointed Stokes Lecturer in Cell Biology at University College Dublin in Ireland in 2009 while running the imaging platform onboard the schooner Tara during the Tara Oceans Expedition (2009-2012). Currently, he leads the "R" Lab, a multidisciplinary environment working on 3D cell biology from 3D cell culture to 3D microscopy and 3D printing.



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Luis Gutiérrez Heredia is a third year PhD student in University College Dublin in use of 3D imaging systems for marine biology research. He got his MSc in Biological Photography and Imaging from the University of Nottingham, England in 2010. He also participated in the Tara Oceans Expedition in 2009 and is the image curator of the image database of the expedition from 2009 to 2010. He is deeply interested in the use of 3D imaging in census of marine biology, from microscopic organisms to macroscopic colonies.

