



CNRS UPMC
Station Biologique
Roscoff



THÈSE DE DOCTORAT DE L'UNIVERSITÉ PIERRE ET MARIE CURIE

Spécialité : Biologie marine – École Doctorale Diversité du Vivant

Pour obtenir le grade de

DOCTEUR de l'UNIVERSITÉ PIERRE ET MARIE CURIE

PATRONS DE BIODIVERSITÉ À L'ÉCHELLE GLOBALE CHEZ LES DINOFLAGELLÉS PLANCTONIQUES MARINS

BIODIVERSITY PATTERNS OF MARINE PLANKTONIC DINOFLAGELLATES AT A GLOBAL SCALE

SUPERVISORS:

DR. RAFFAELE SIANO

DYNECO/Pelagos, IFREMER Brest

DR. COLOMBAN DE VARGAS

UPMC/CNRS Station Biologique de Roscoff

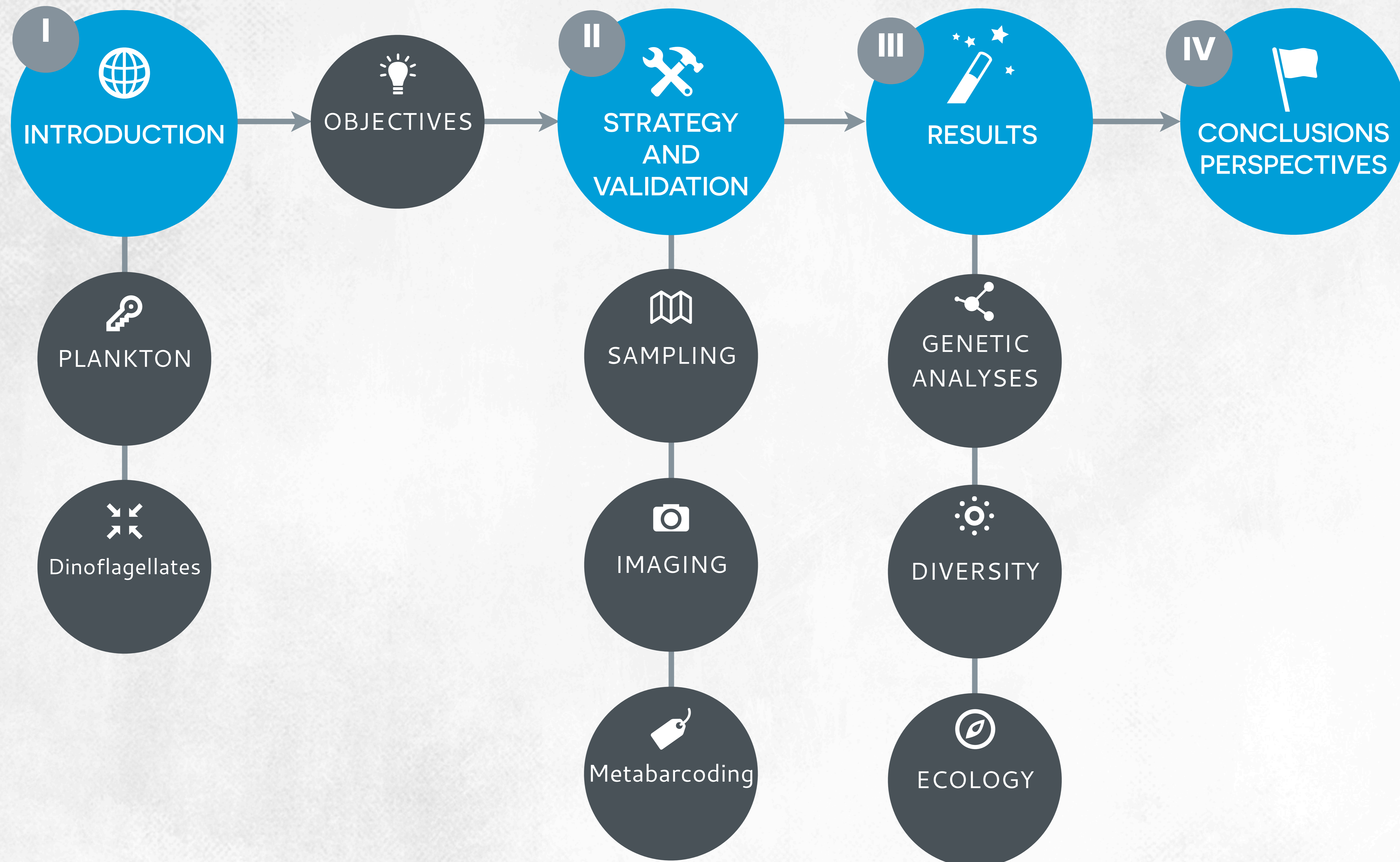


PRESENTED BY **NOAN LE BESCOT**

10th of March 2014

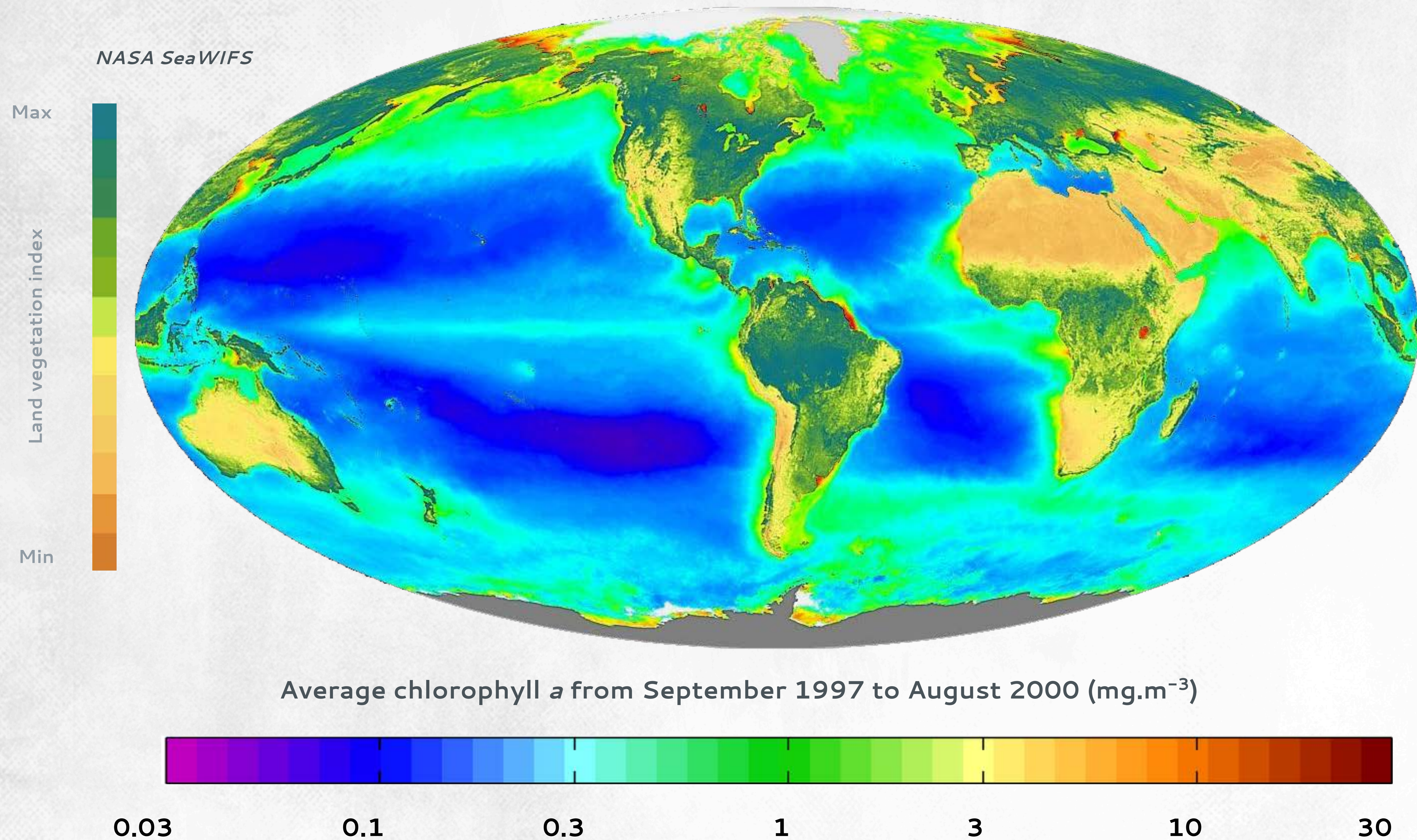
UMR7144, Team EPEP, Station Biologique de Roscoff (CNRS / UPMC) – Roscoff (France)

PRESENTATION SUMMARY



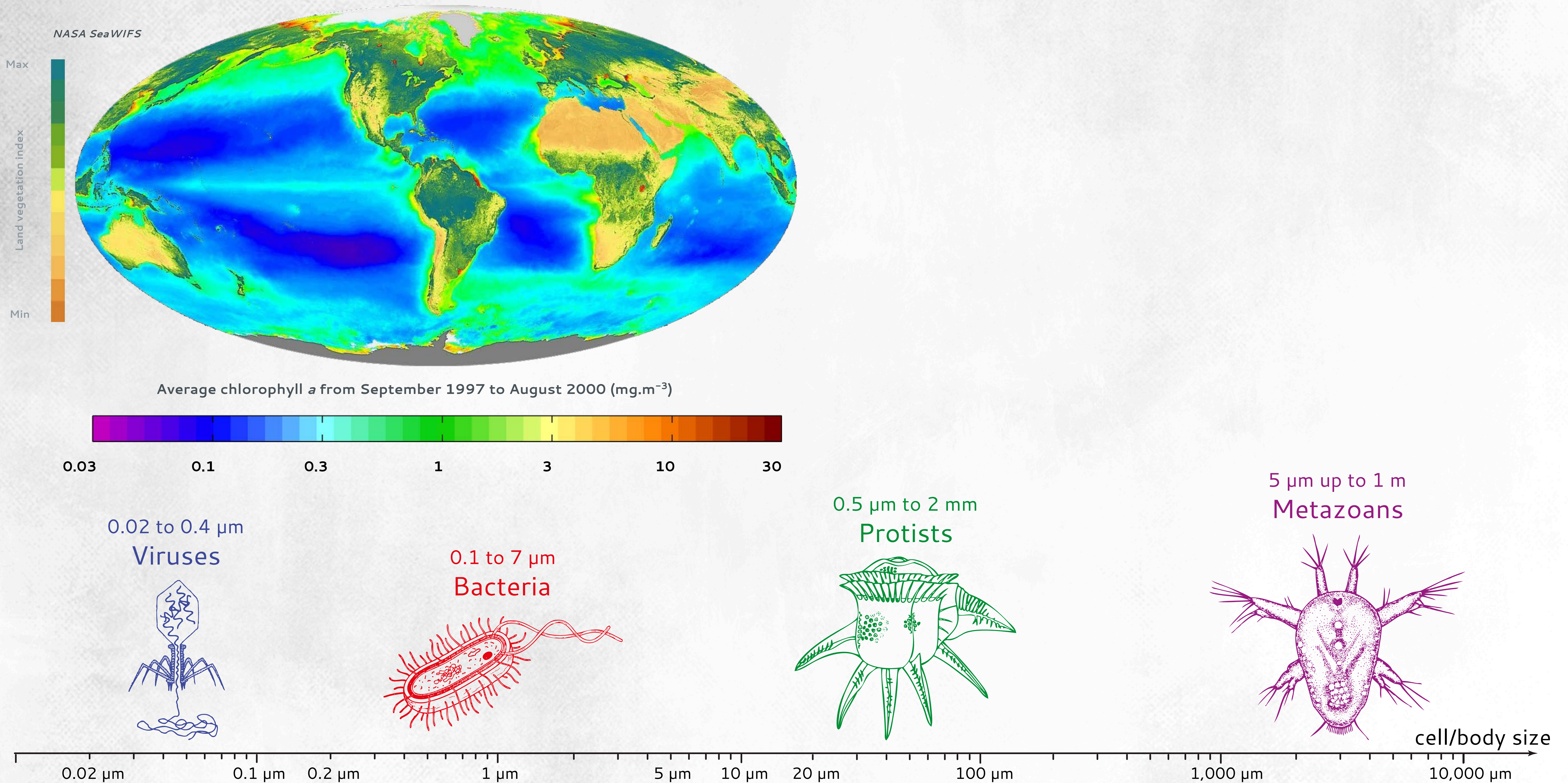
PLANKTON

Plankton includes diverse groups of organisms that live in the water column and cannot swim against currents.



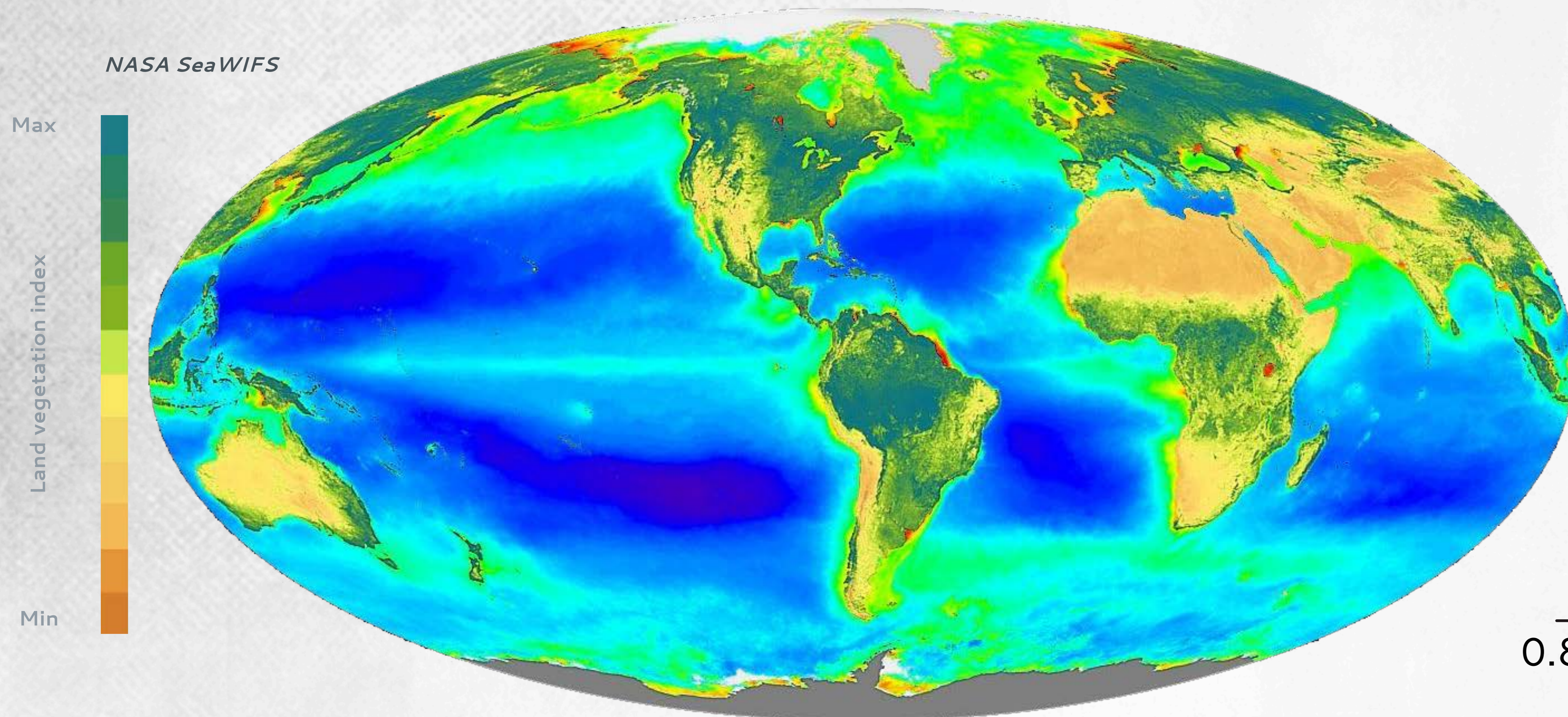
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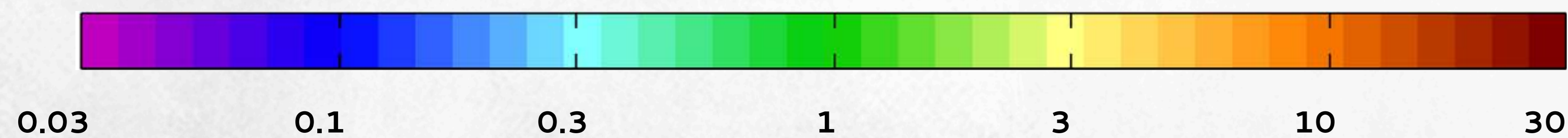


PLANKTON

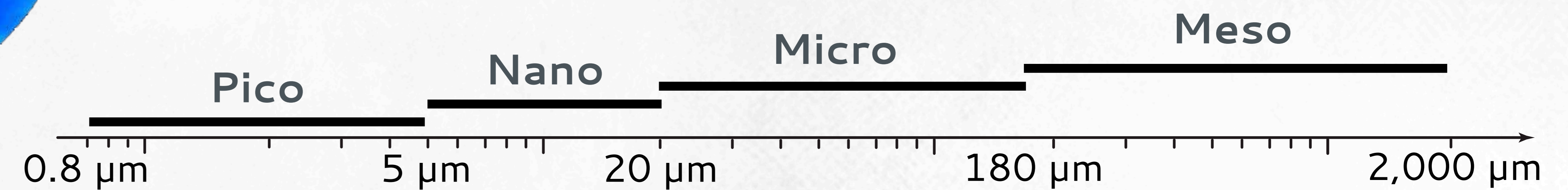
Plankton includes diverse groups of organisms that live in the water column and cannot swim against currents.



Average chlorophyll a from September 1997 to August 2000 ($\text{mg}\cdot\text{m}^{-3}$)

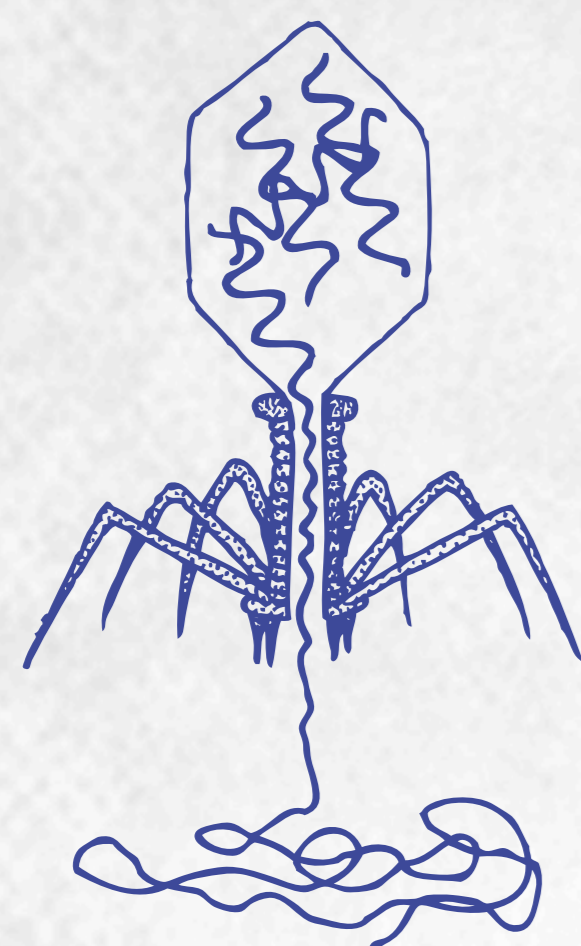


Pico-plankton	0.8 ↔ 5 μm
Nano-plankton	5 ↔ 20 μm
Micro-plankton	20 ↔ 180 μm
Meso-plankton	180 ↔ 2,000 μm

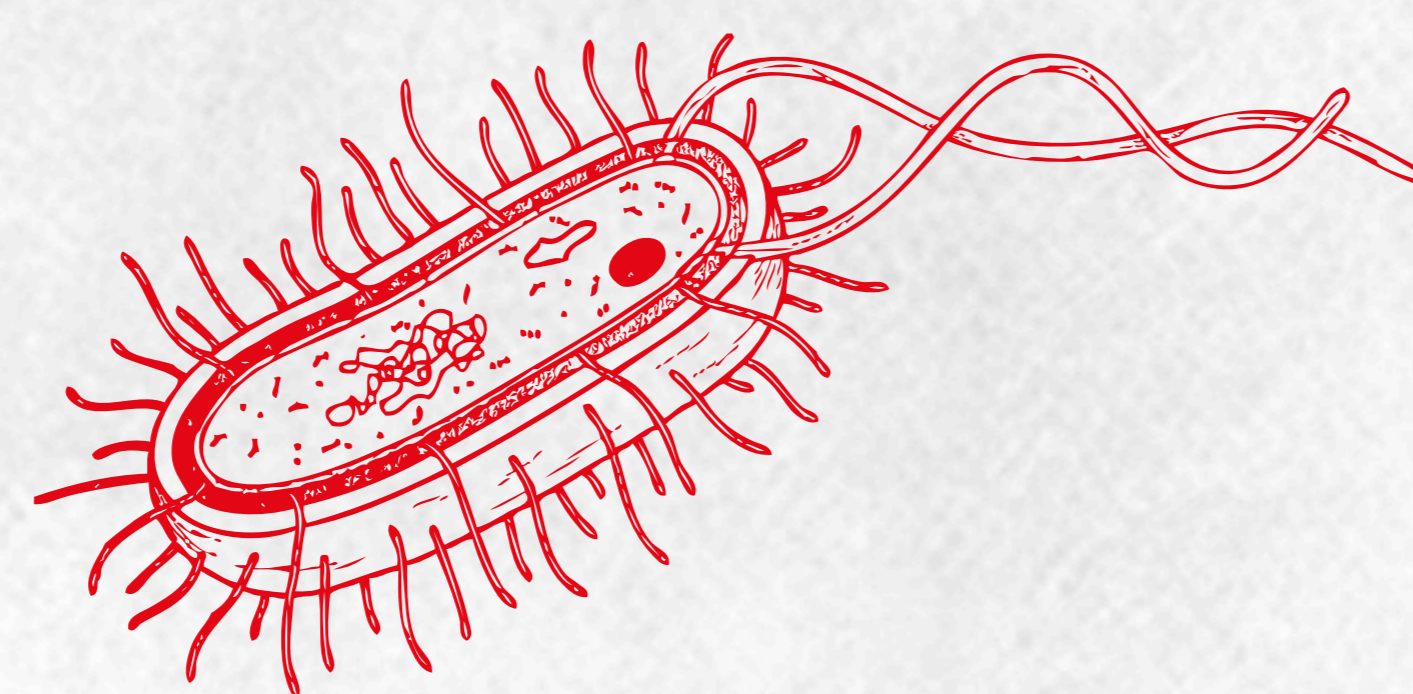


This fractionation is not traditional

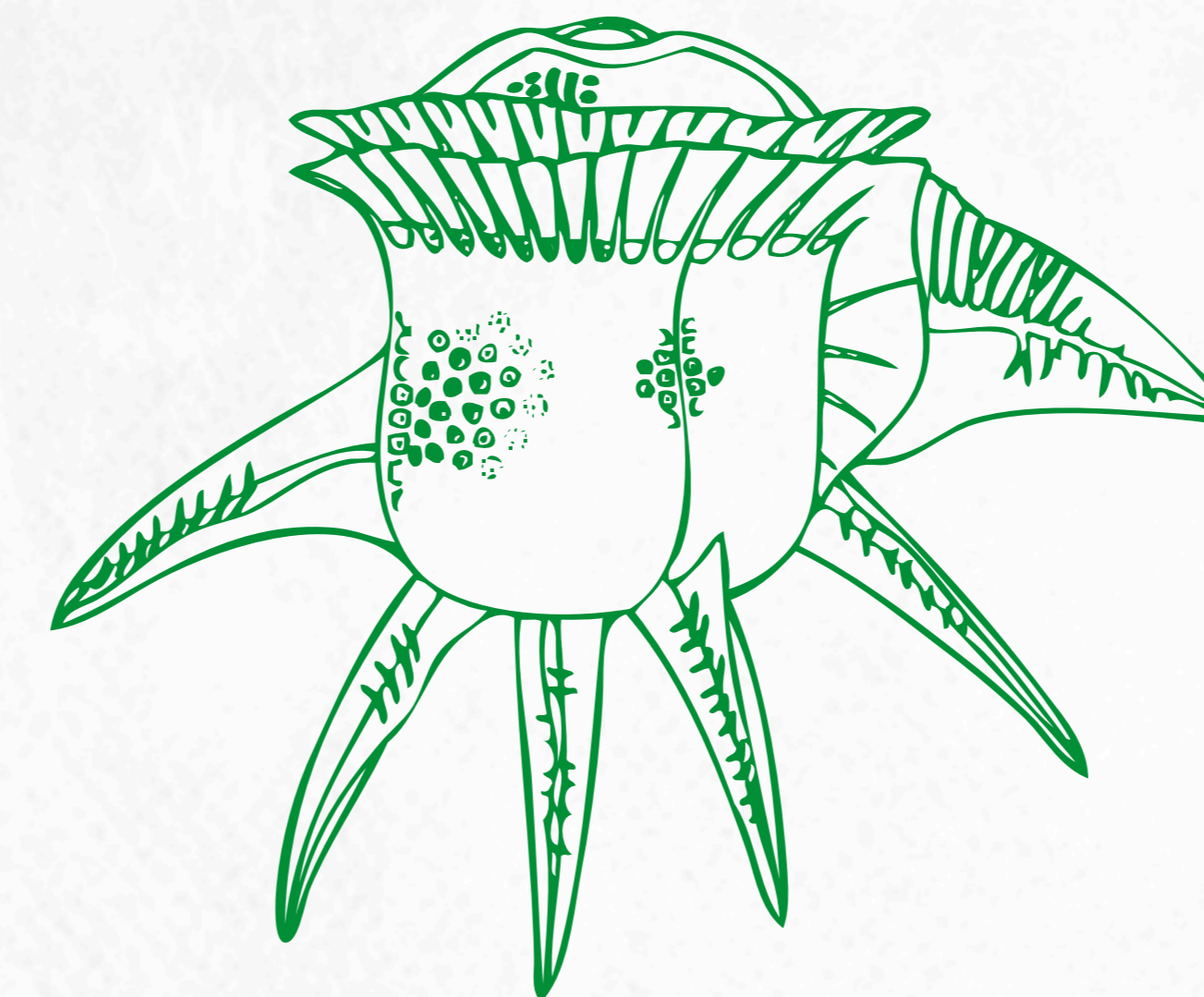
0.02 to 0.4 μm
Viruses



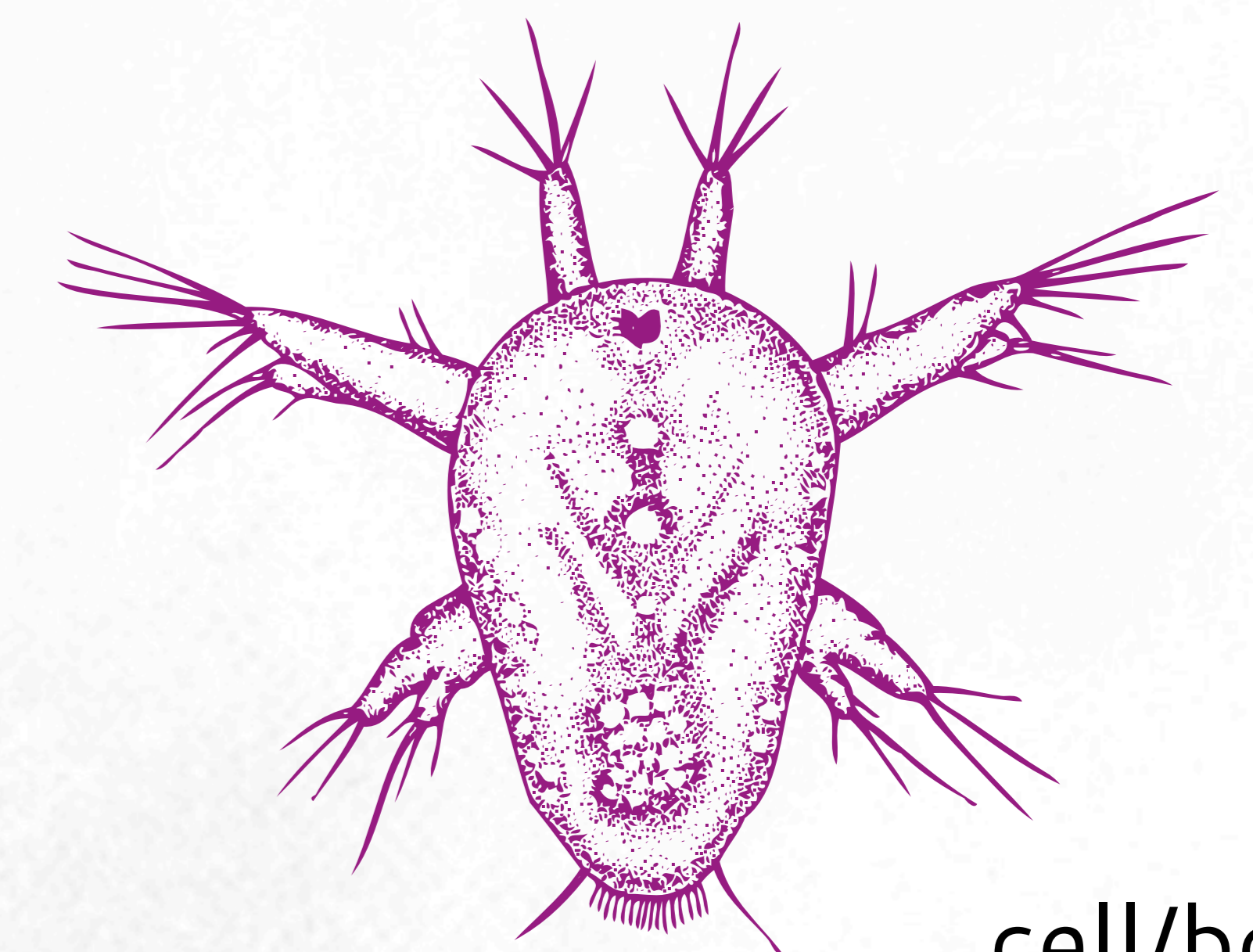
0.1 to 7 μm
Bacteria



0.5 μm to 2 mm
Protists



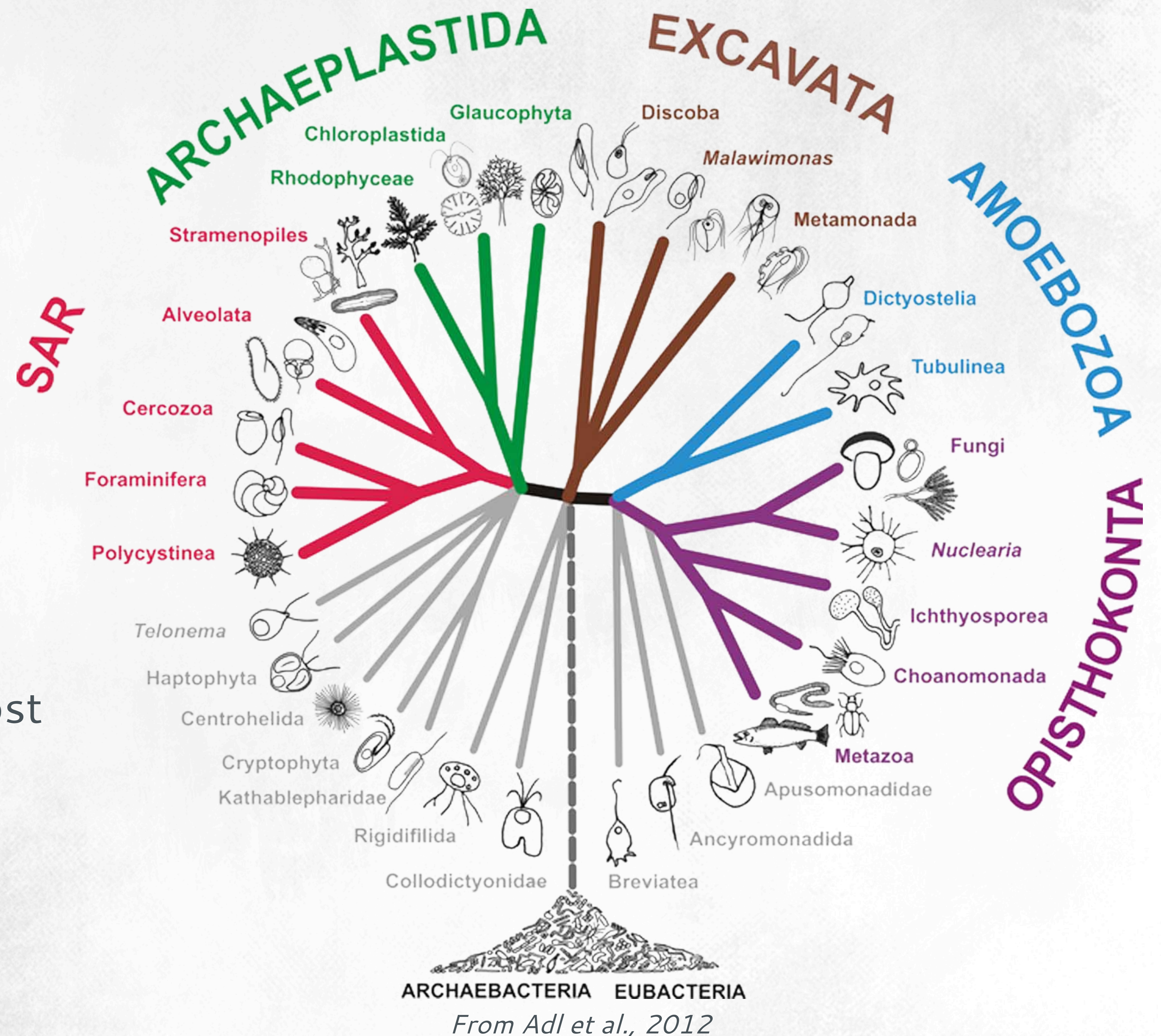
5 μm up to 1 m
Metazoans



cell/body size

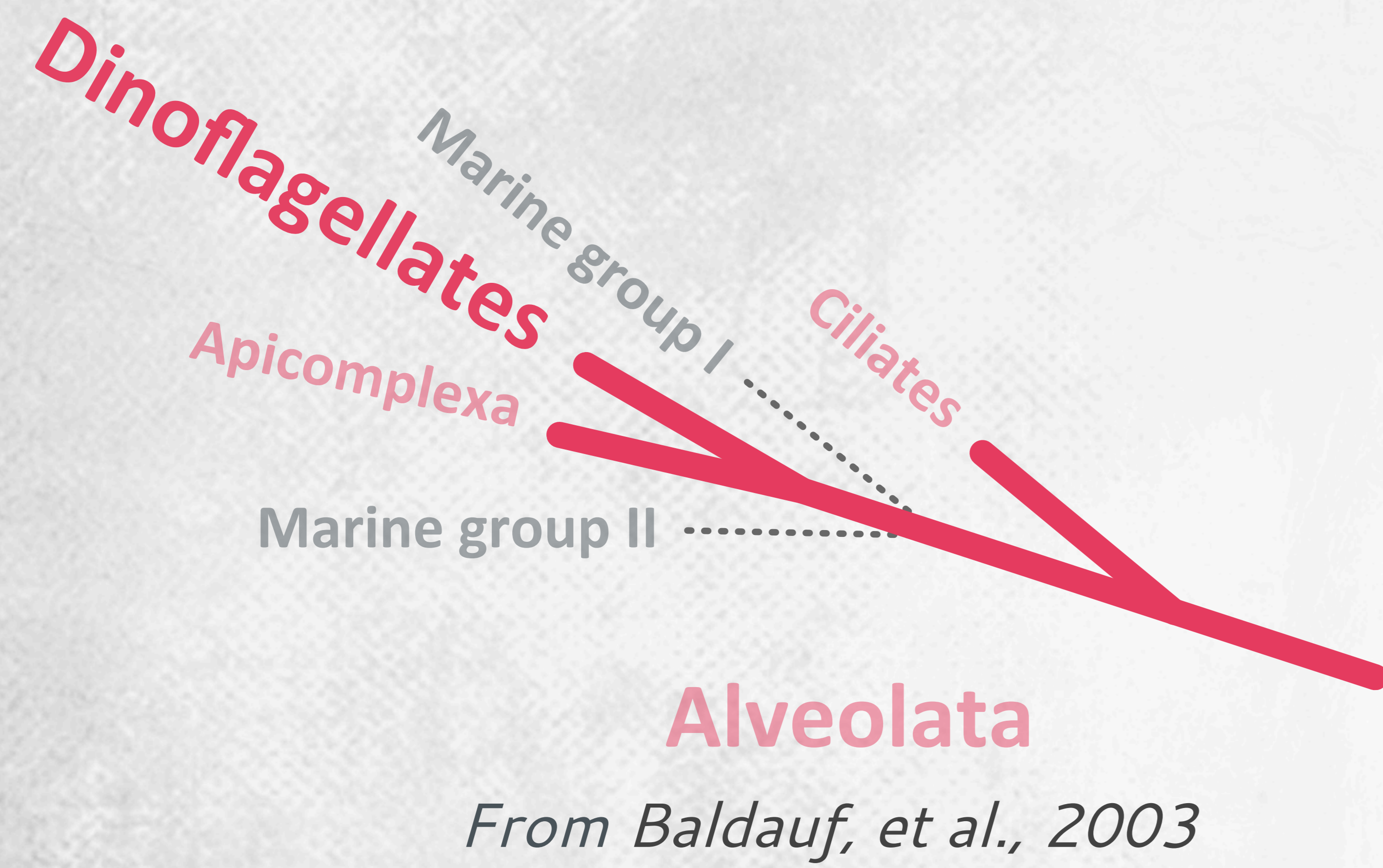


PLANKTON DIVERSITY

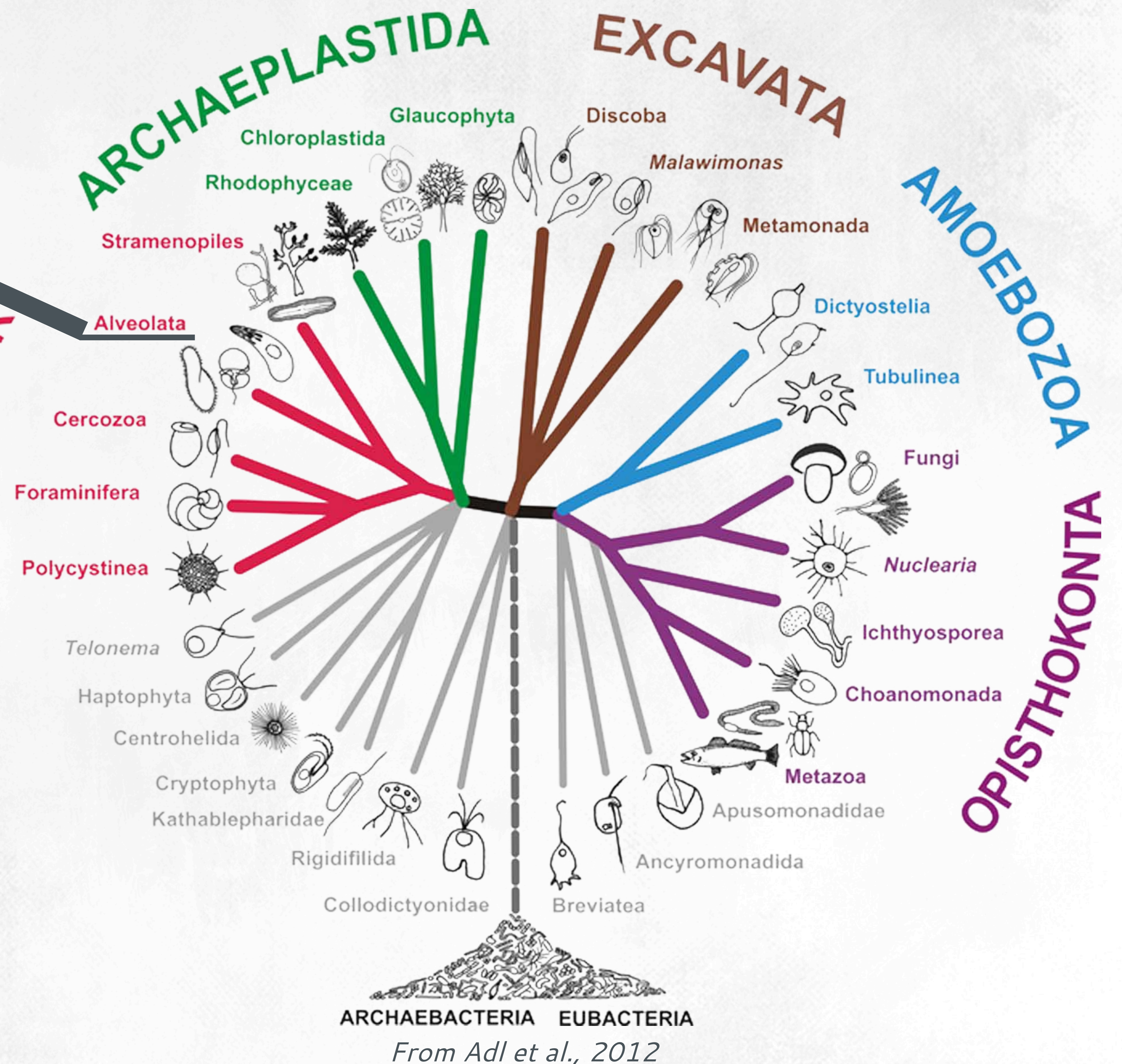


Plankton is represented in almost all groups of the tree of life

PLANKTON DIVERSITY



Plankton is represented in almost all groups of the tree of life

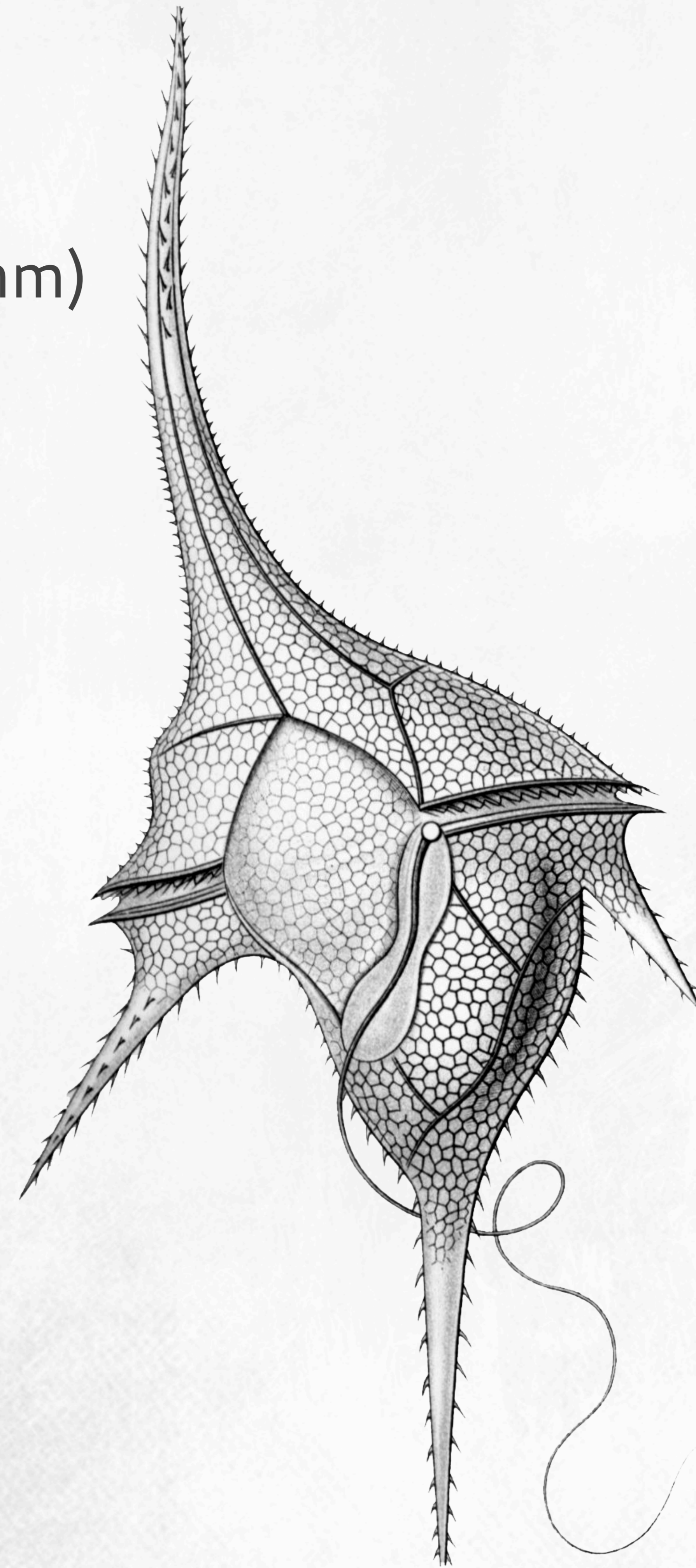


DINOFLAGELLATES

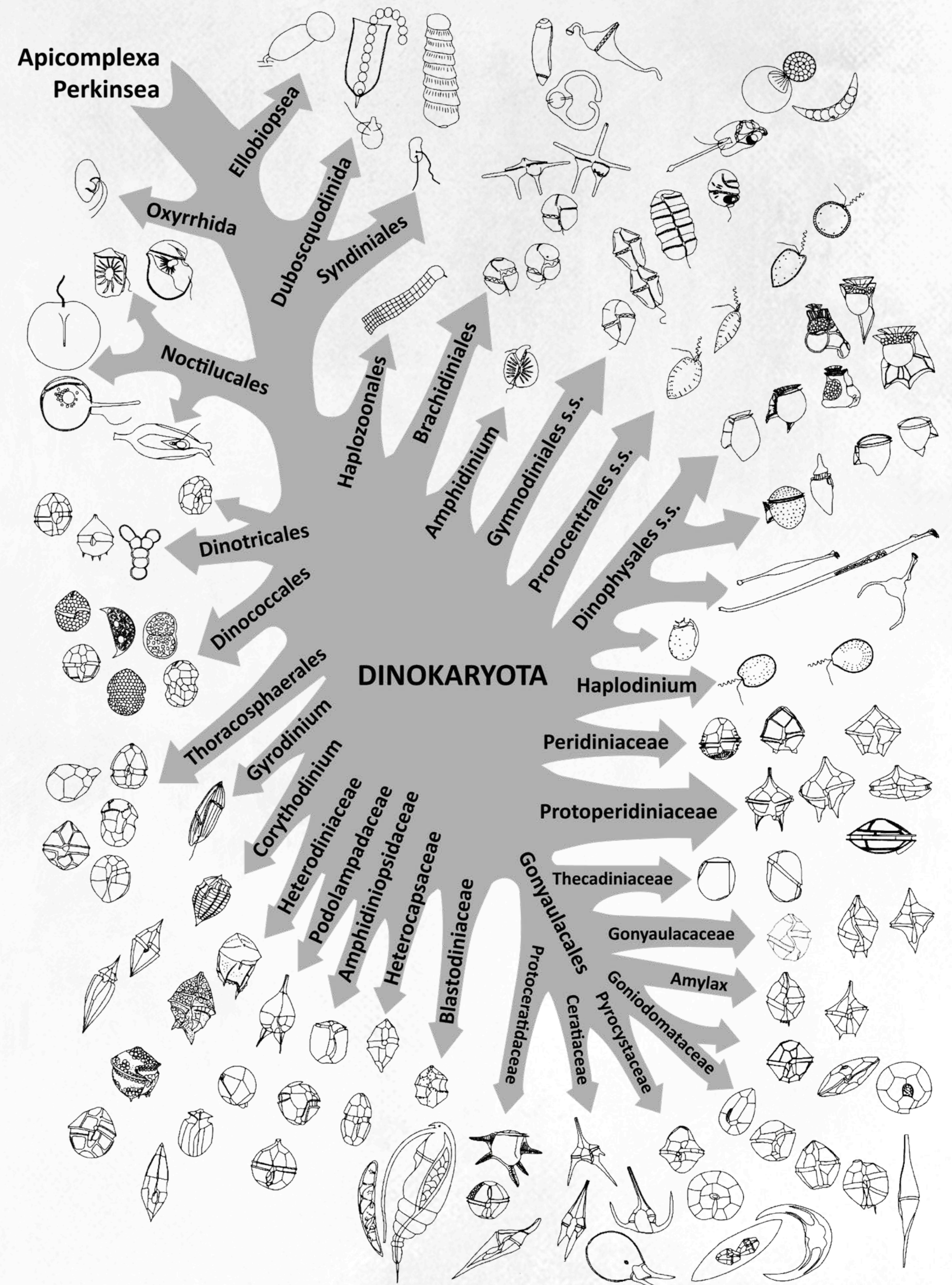
Dinoflagellates are eukaryotic and unicellular

Morphology

- ▶ two dimorphic flagella
- ▶ variable classes of size (<10 μm to <2mm)
- ▶ wide variety of shapes



Drawing of Ernst Haeckel



From Gómez, 2012

DINOFLAGELLATES

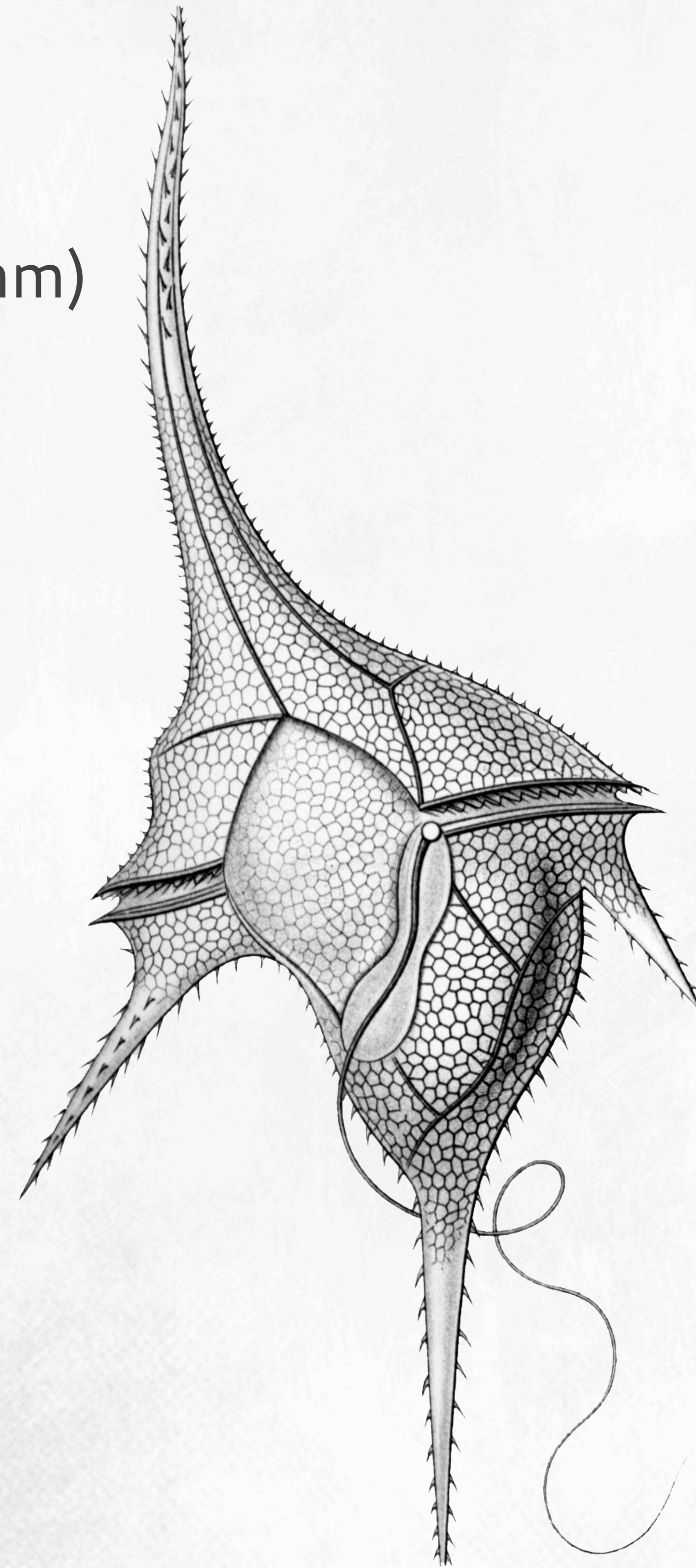
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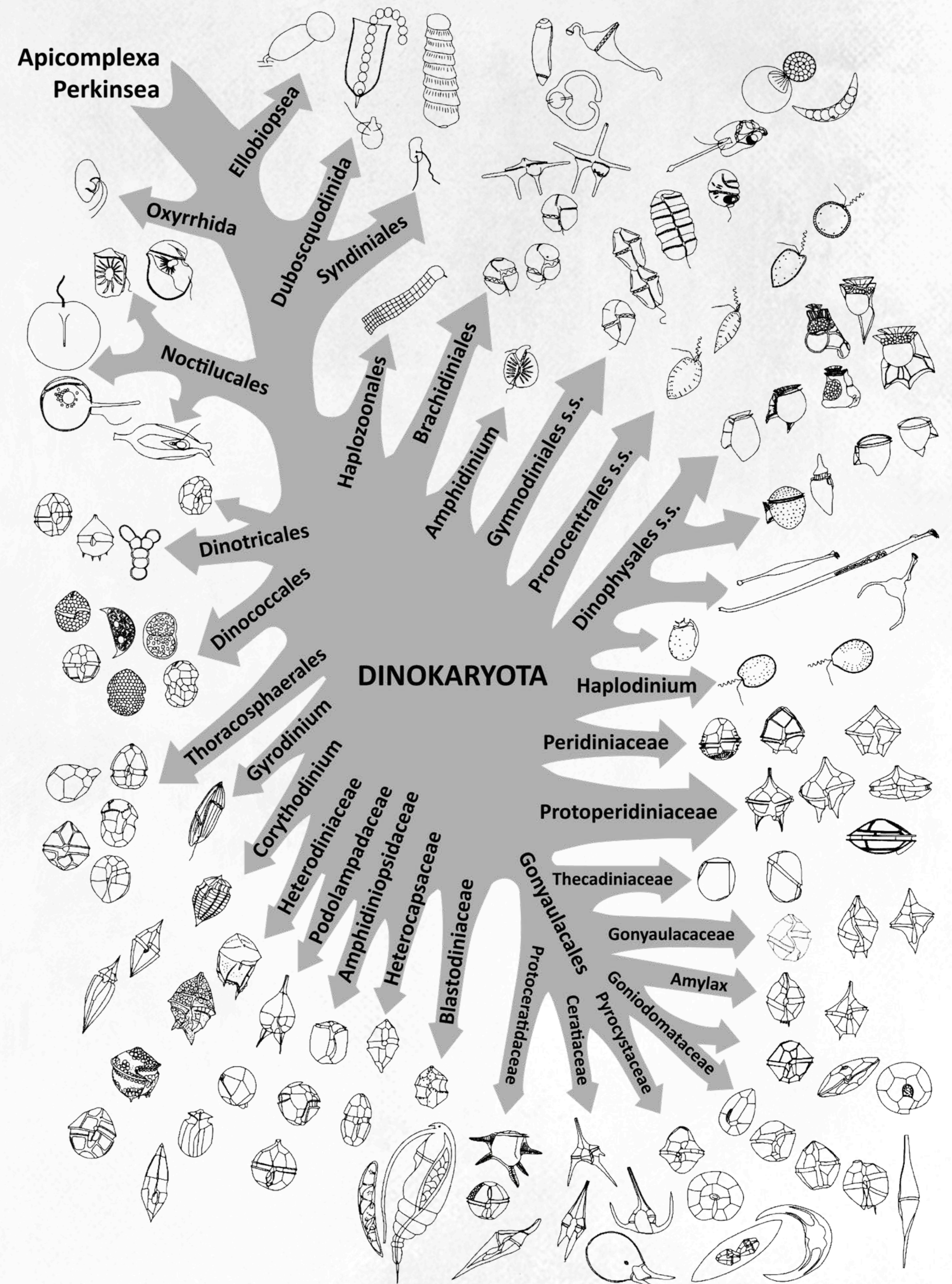
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Ultrastructure

- ▶ with or without polysaccharidic plates (thecate / athecate dinoflagellates)
- ▶ with or without chloroplastes



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DINOFLAGELLATES

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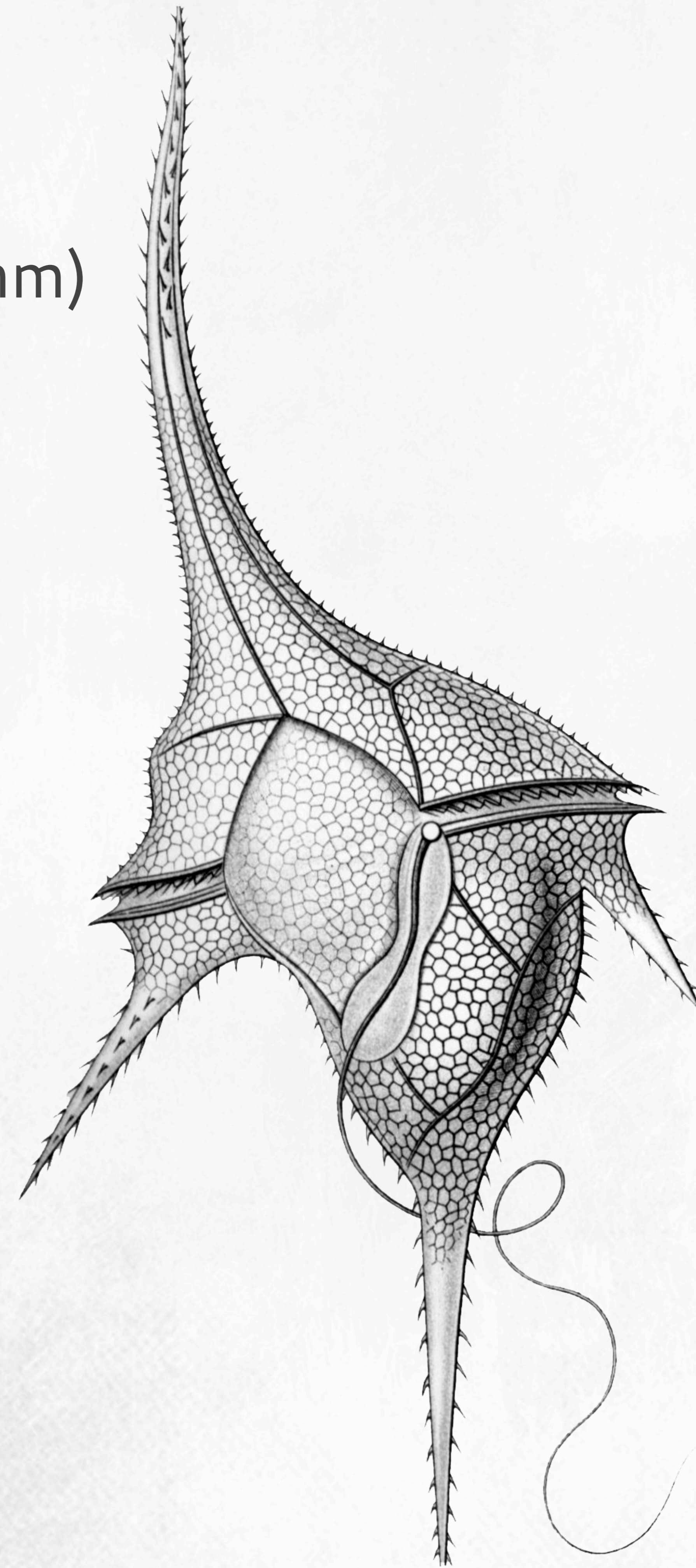
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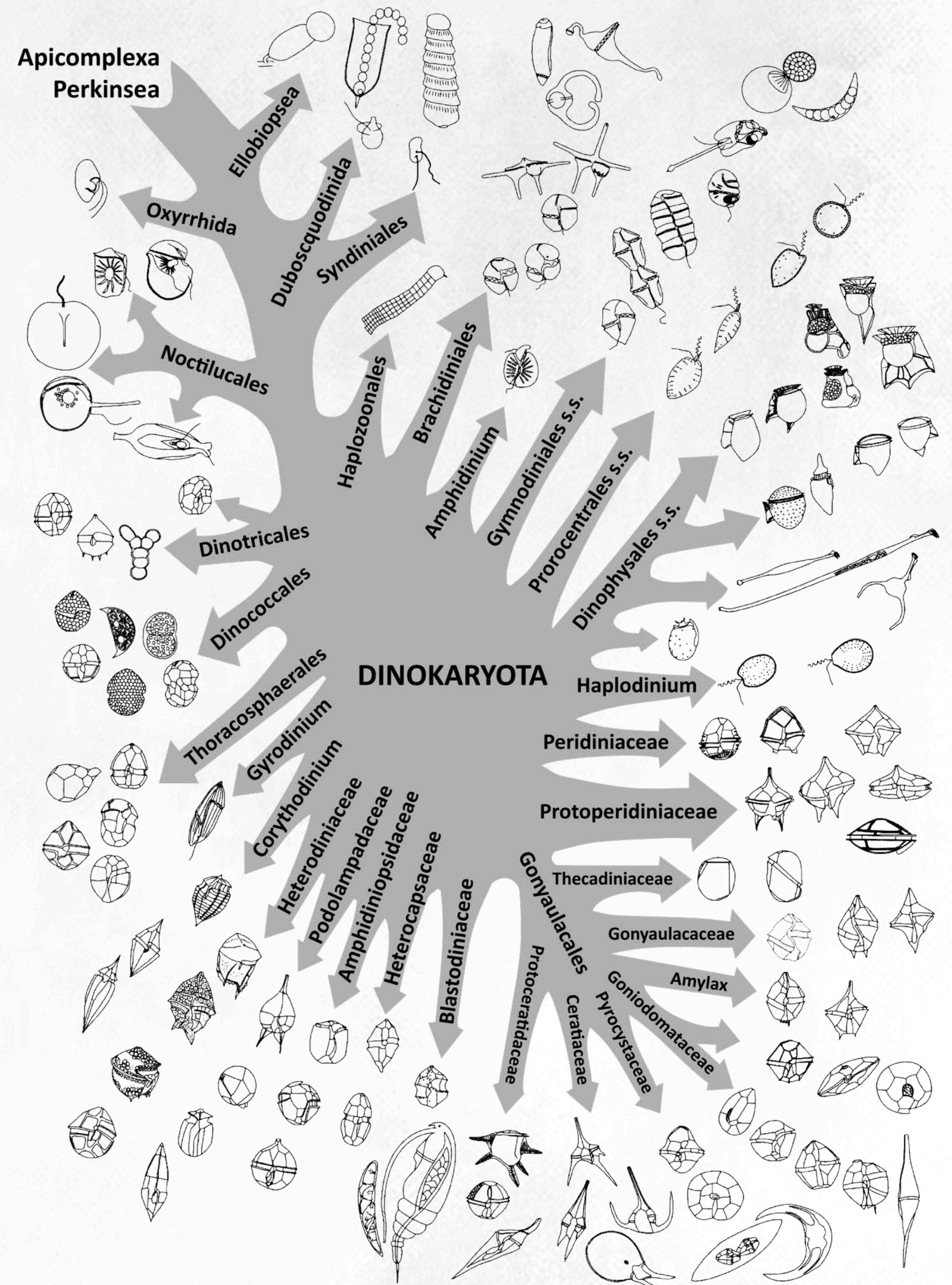
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- ▶ with or without chloroplasts

Physiology

- ▶ pigment variety (Chl a, b, c peridinin, fucoxanthin and derivatives)

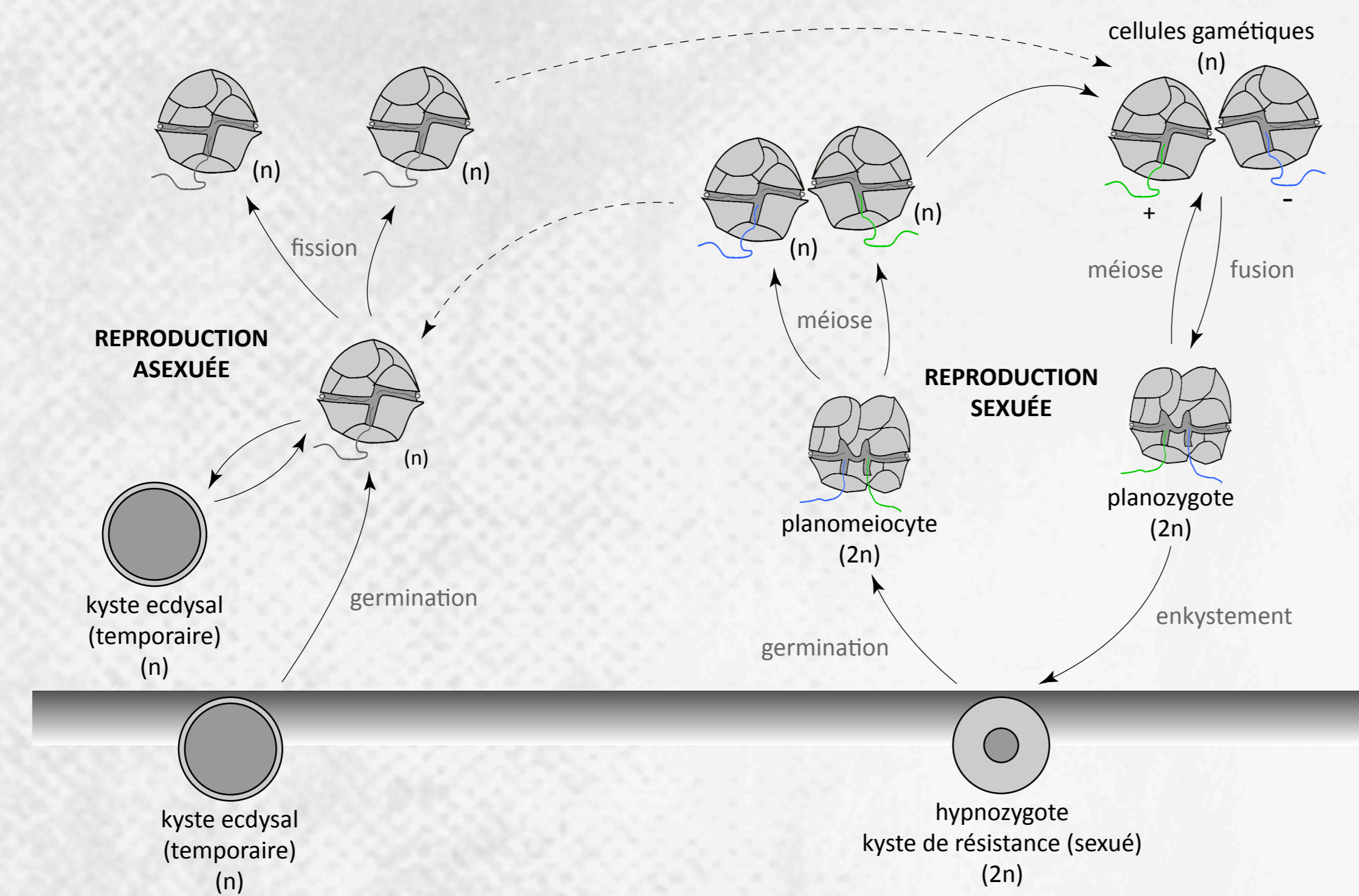


Drawing of Ernst Haeckel



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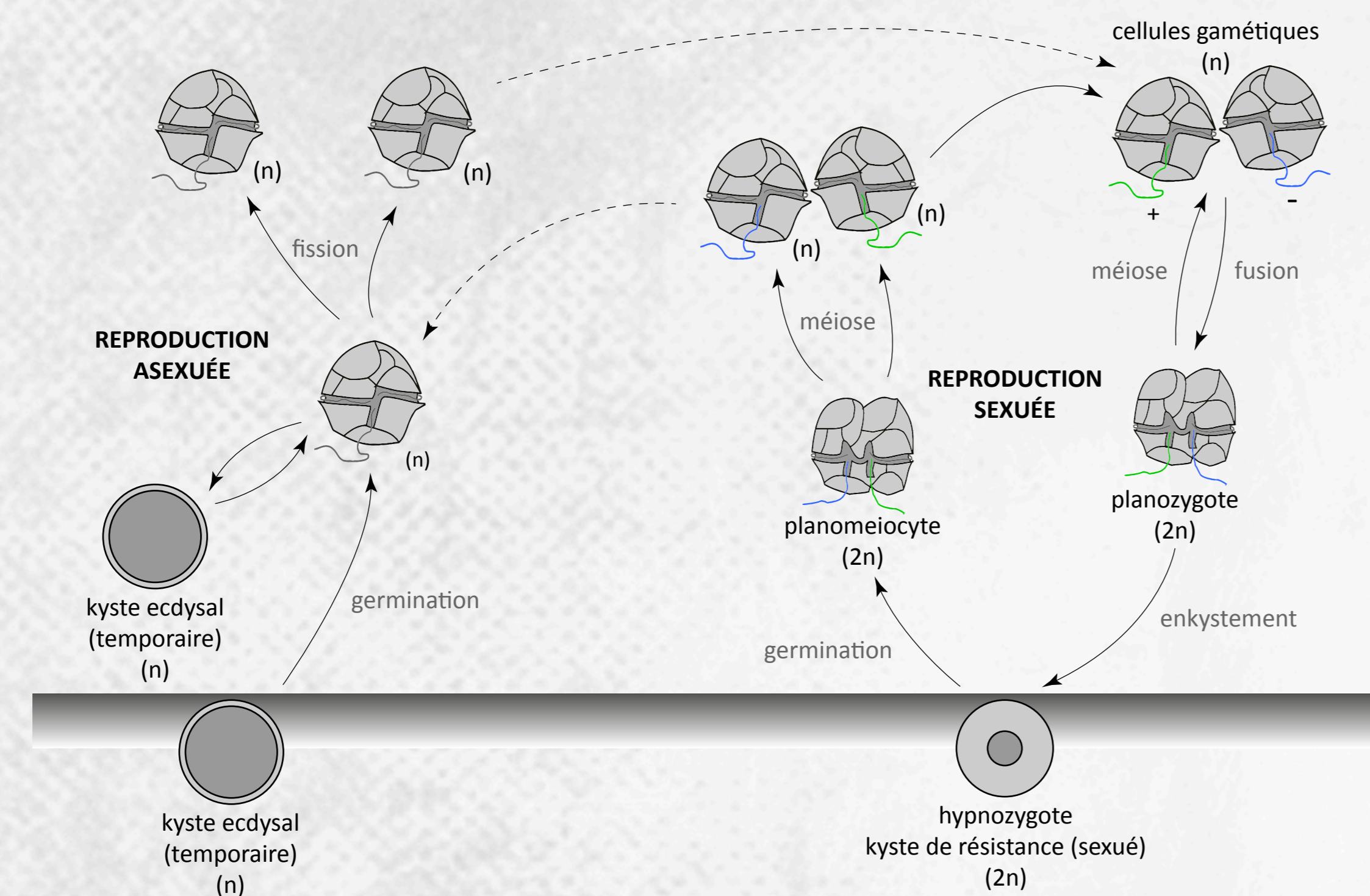
DINOFLAGELLATES



Biology

- ▶ life cycle with alternating sexual and asexual stages
- ▶ existence of resistant stages (cysts)
- ▶ different life strategies (symbiotic, single / colony, parasitic, kleptoplastidic)

DINOFLAGELLATES



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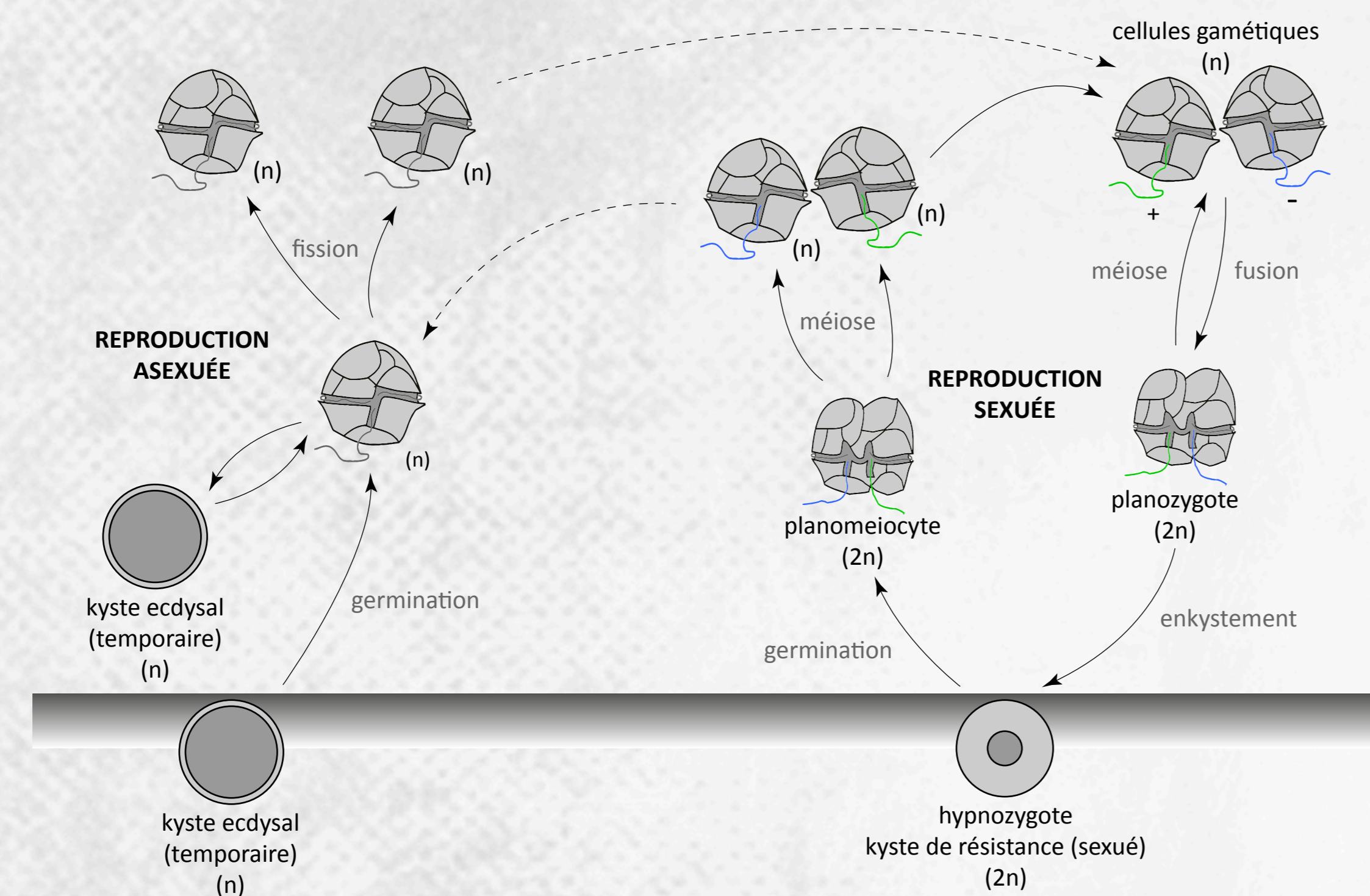
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- ▶ present in diverse habitats (plankton and benthos)
- ▶ cosmopolitan and abundant in all the seas

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Importance for humans

- ▶ some species produce toxins harmful to humans and marine life

PSP: Paralytic Shellfish Poisoning

DSP: Diarrhetic Shellfish Poisoning

ichthyotoxic species



DINOFLAGELLATES

how have they been studied so far?

Culture and morphological analyses



© Willfried Thomas

DINOFLAGELLATES

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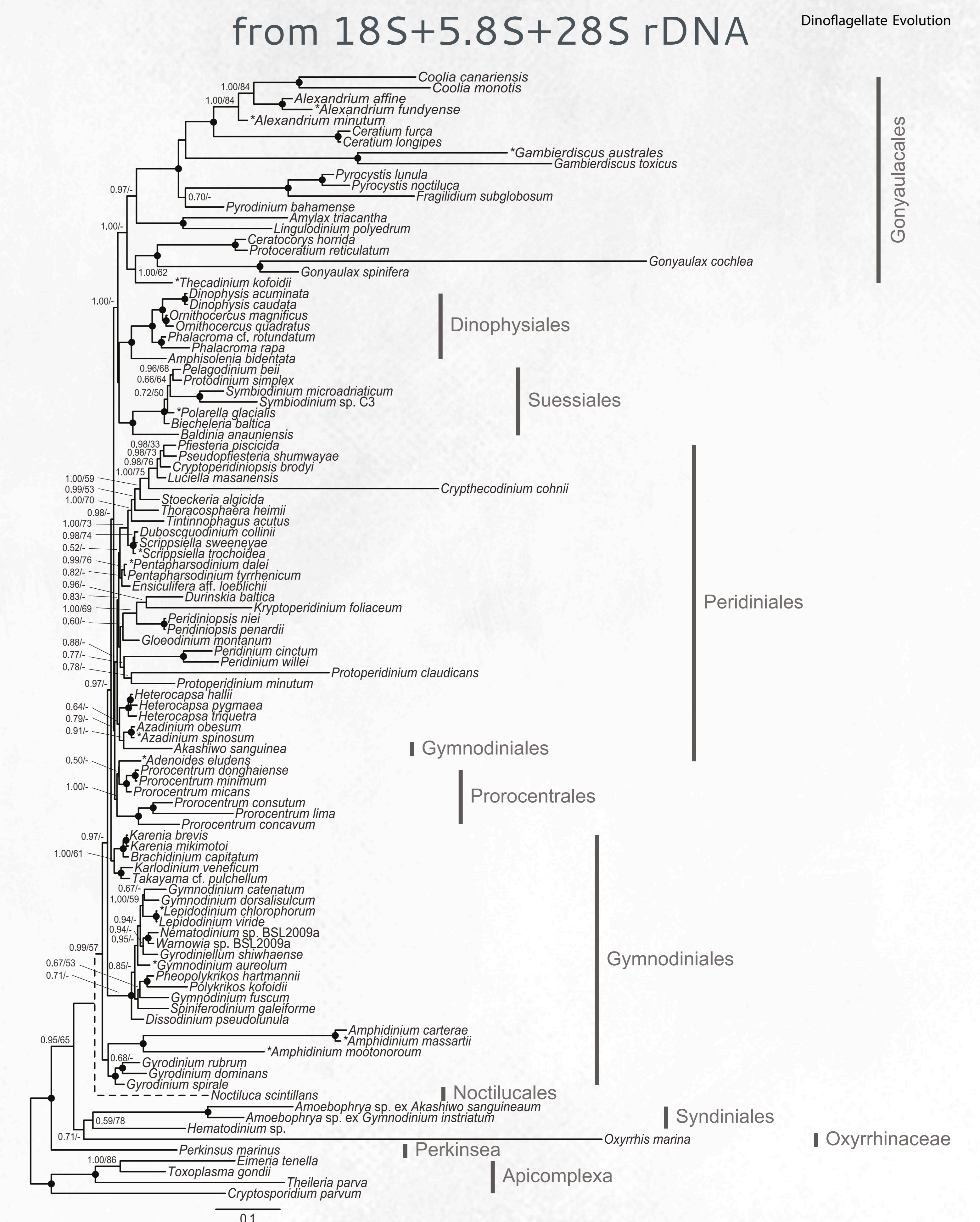
Culture and morphological analyses



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Phylogeny and evolution
LSU, COI, cob, 18S, ITS



Orr et al., 2012

DINOFLAGELLATES

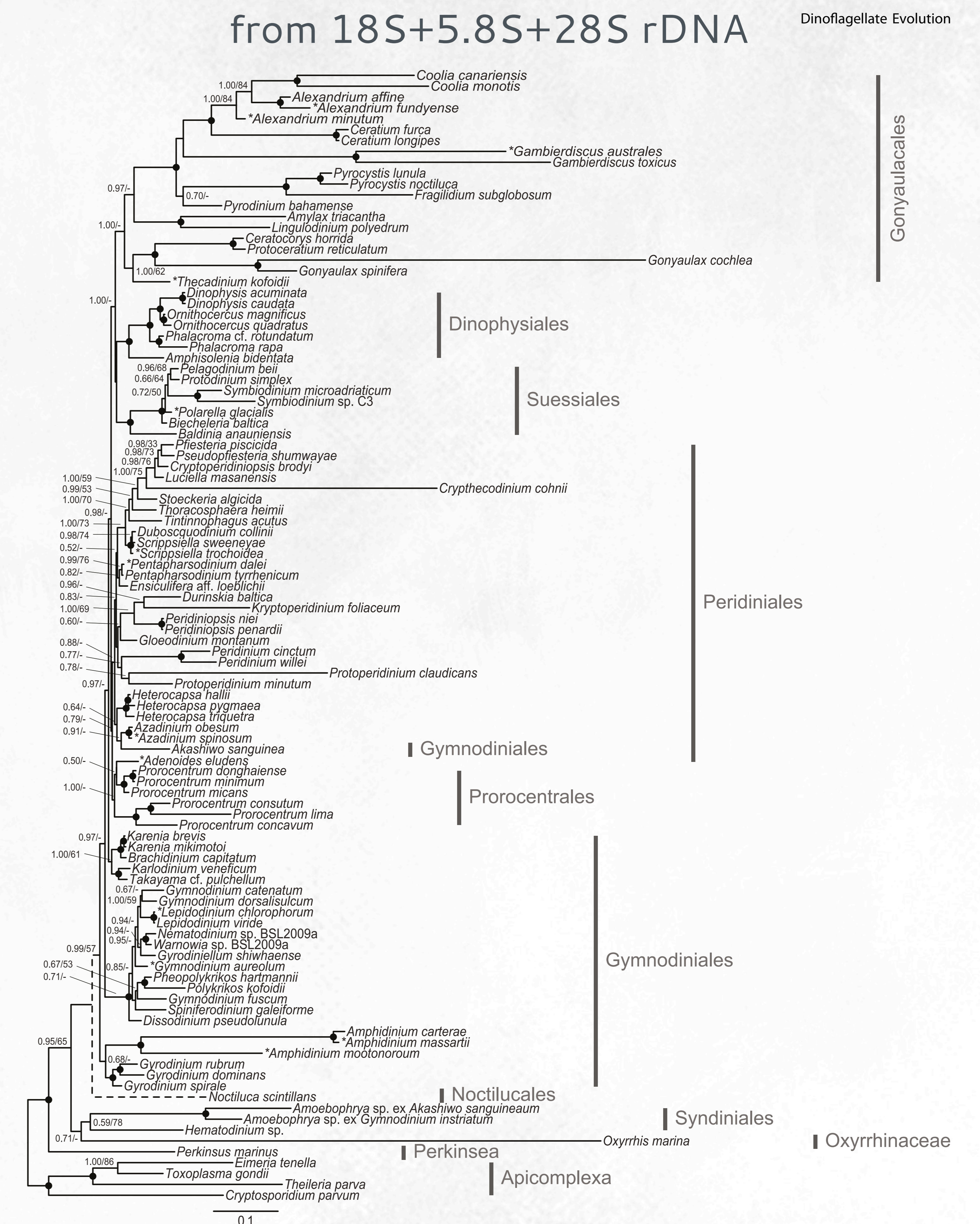
how have they been studied so far?

Culture and morphological analyses

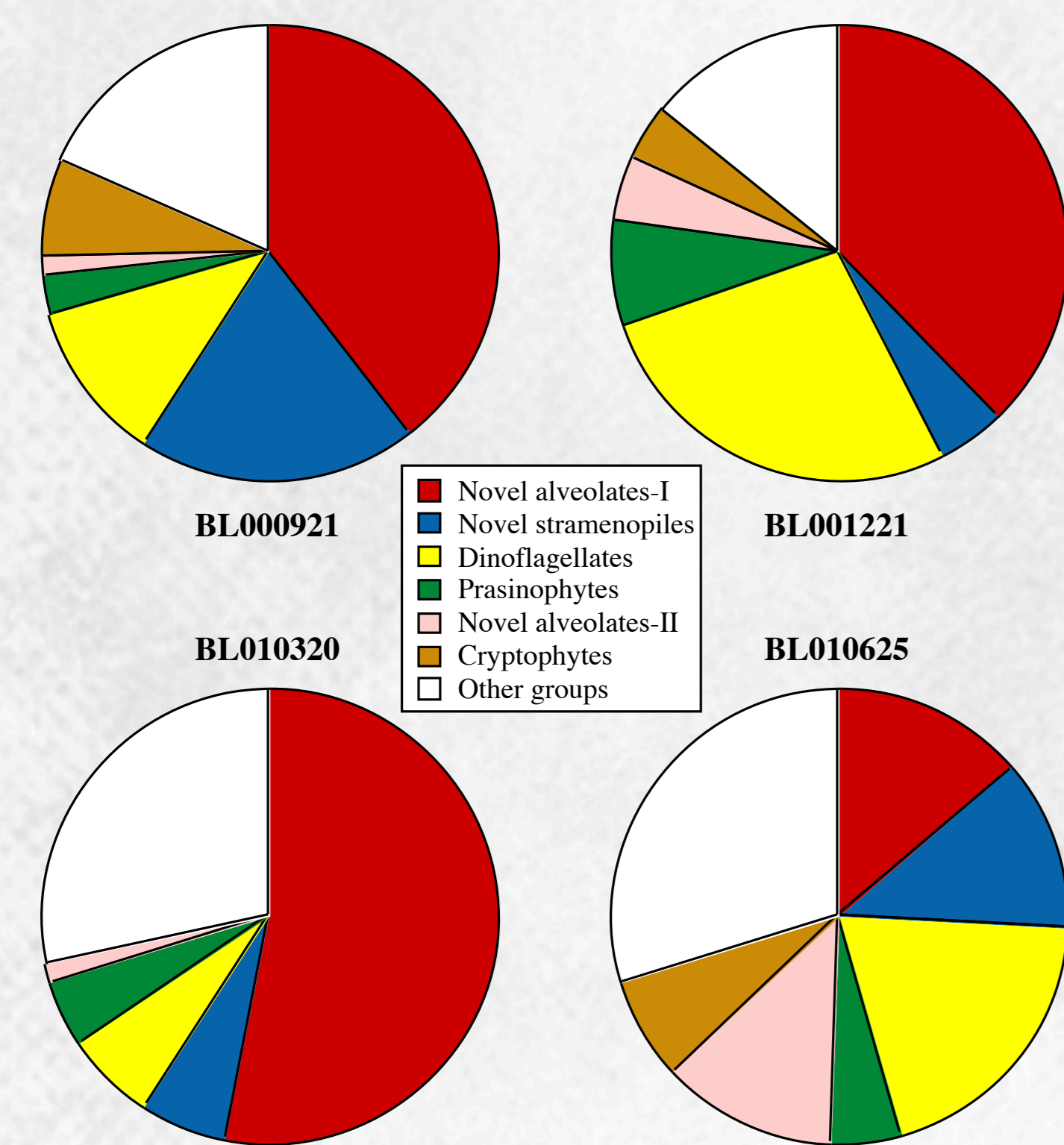


Phylogeny and evolution
LSU, COI, cob, 18S, ITS

from 18S+5.8S+28S rDNA



Clone libraries



Massana, et al., 2004

Orr et al., 2012

DINOFLAGELLATES

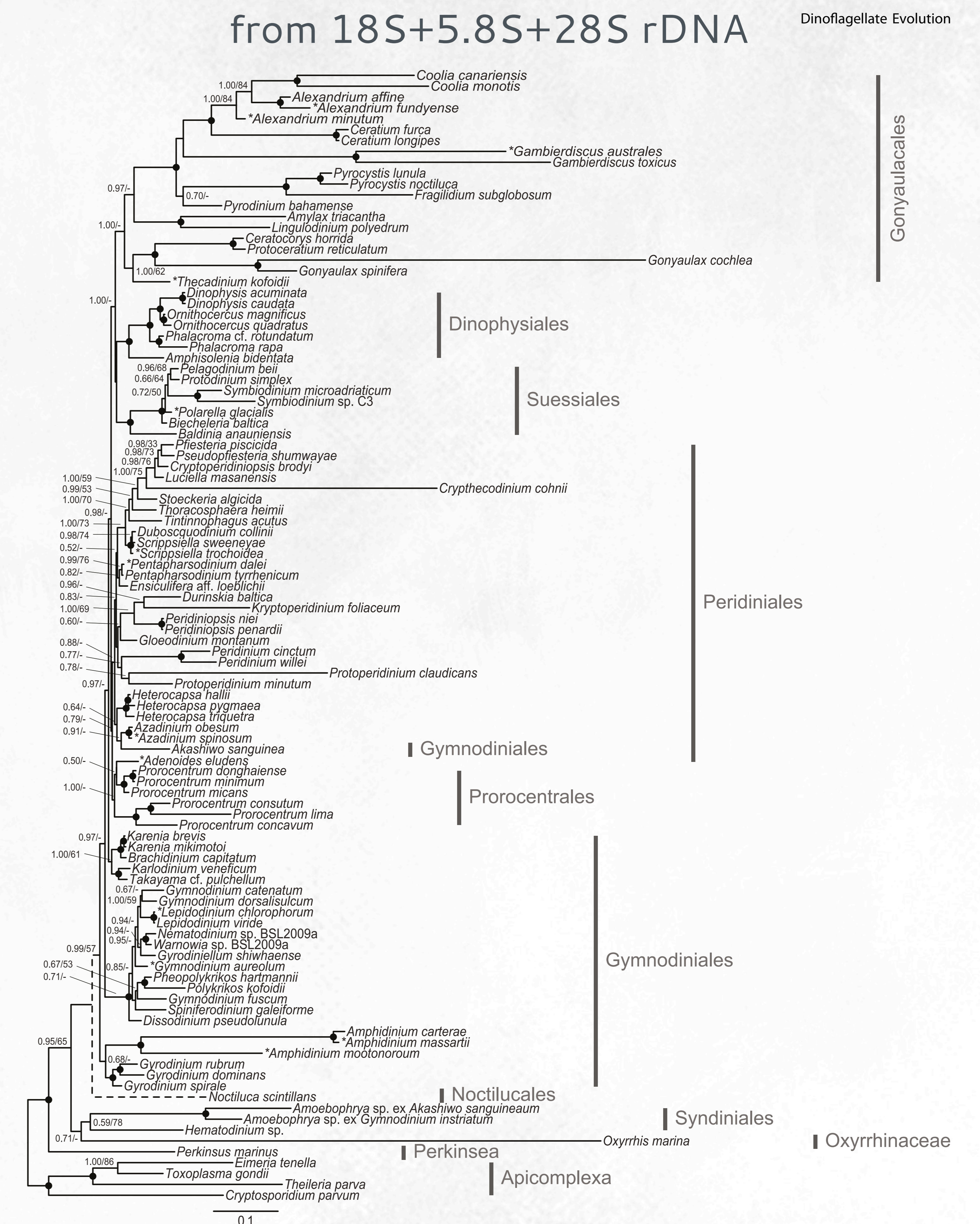
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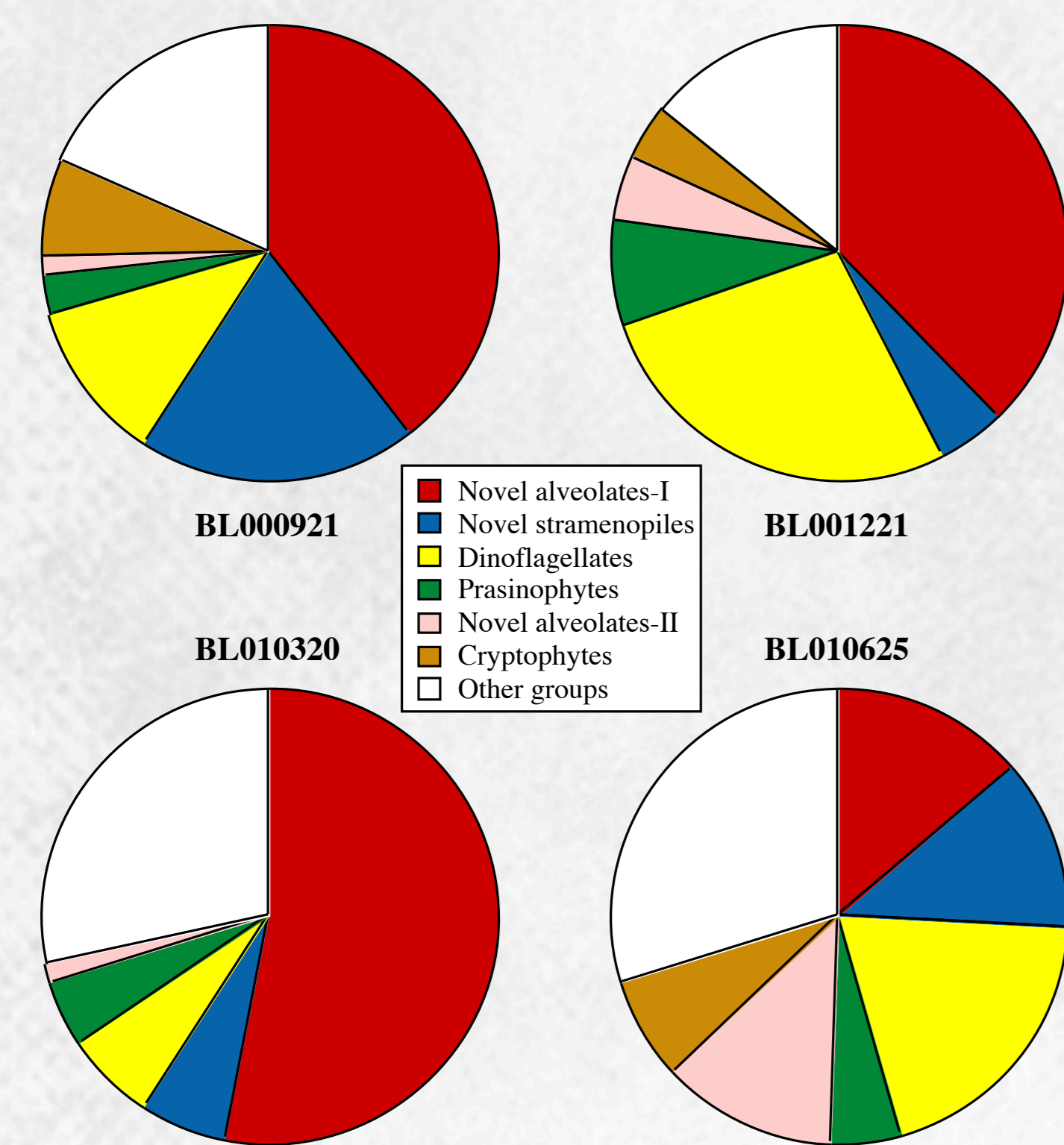


Phylogeny and evolution
LSU, COI, cob, 18S, ITS

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Clone libraries



Massana, et al., 2004

Lack of a complete view
of the communities

OBJECTIVE

Search for **global patterns of biodiversity** and **community structure** of marine pelagic dinoflagellates across the World's Ocean.

OBJECTIVE

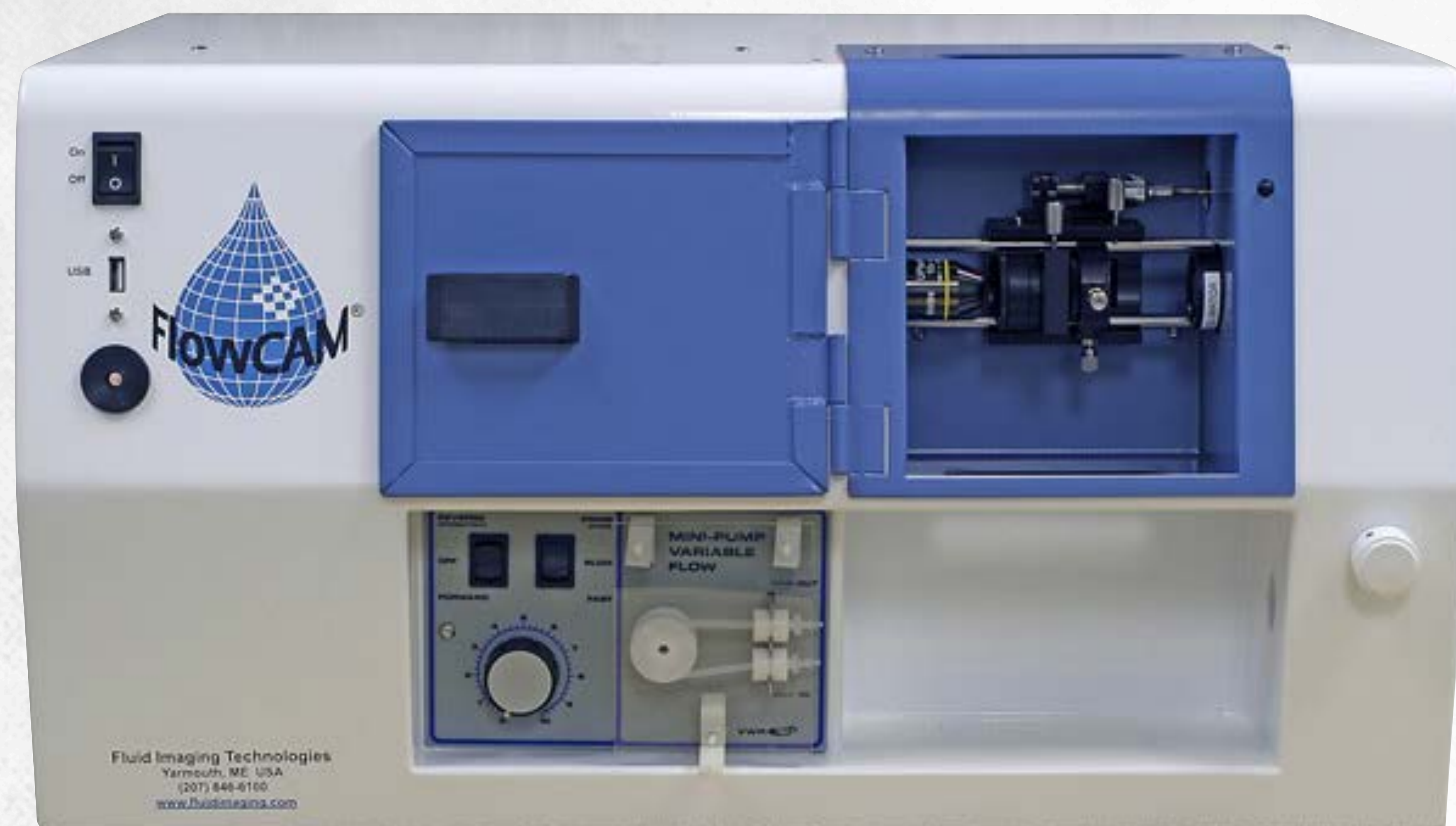
Search for **global patterns of biodiversity** and **community structure** of marine pelagic dinoflagellates across the World's Ocean.

use of high-throughput technologies

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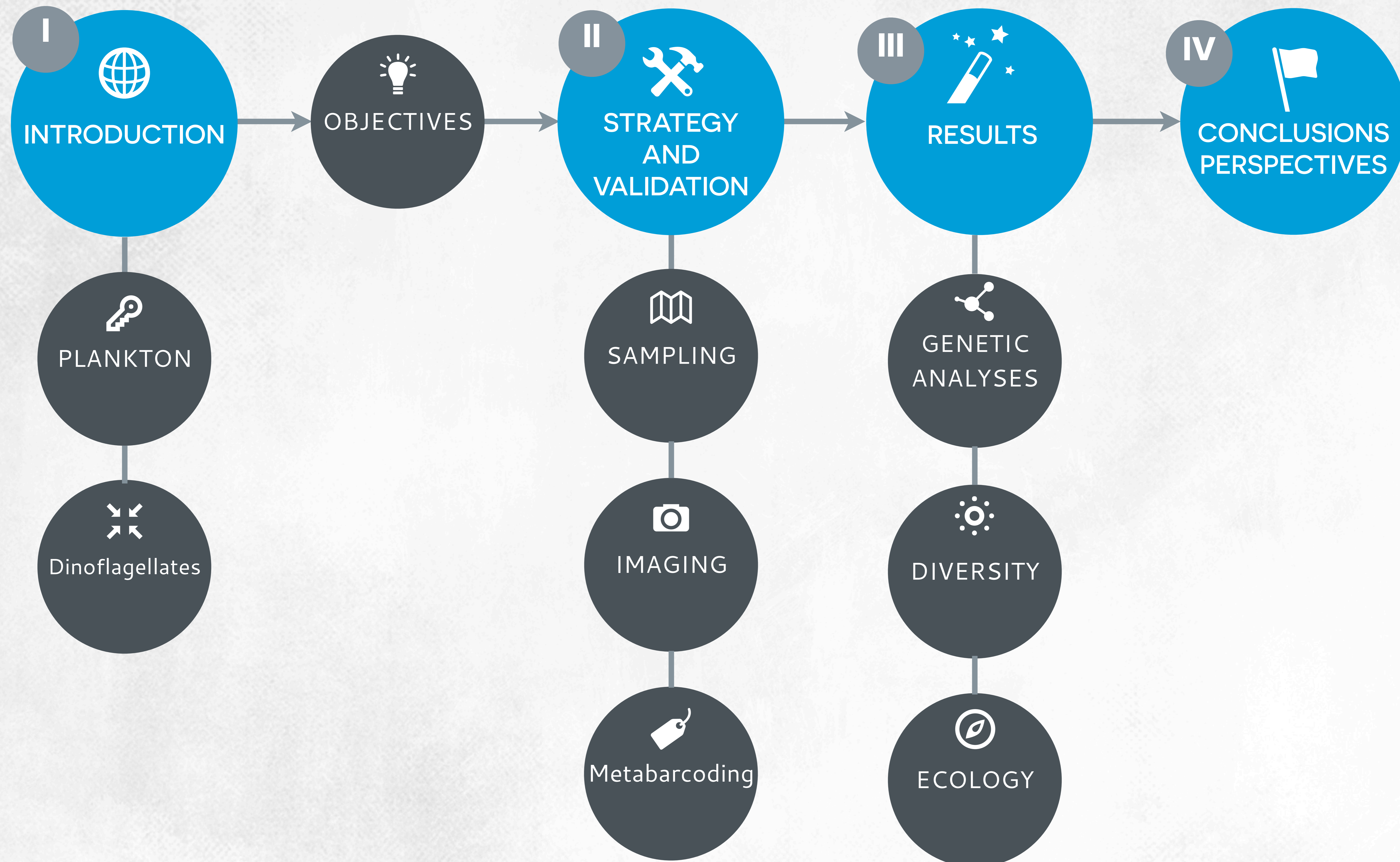


imaging

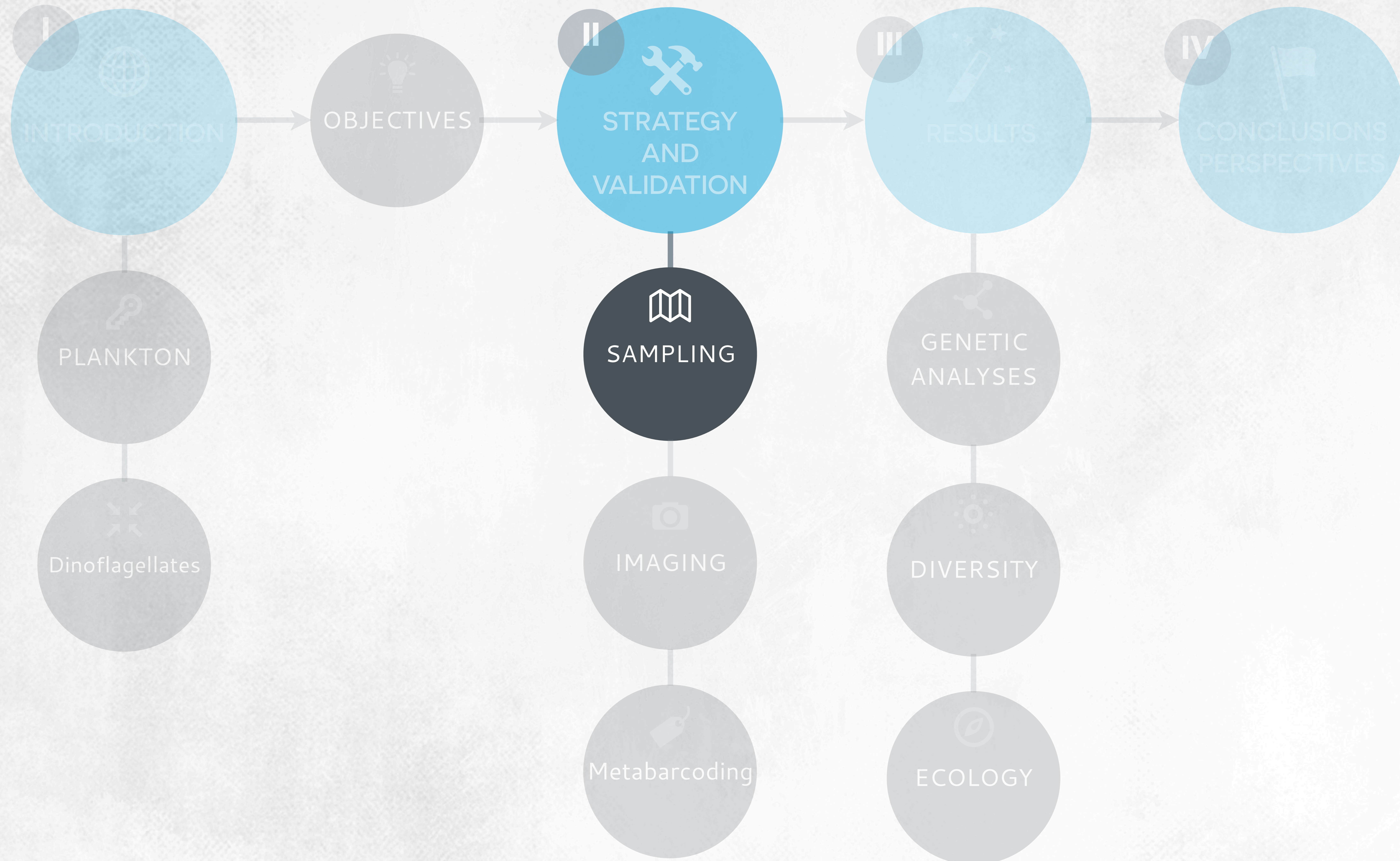


sequencing

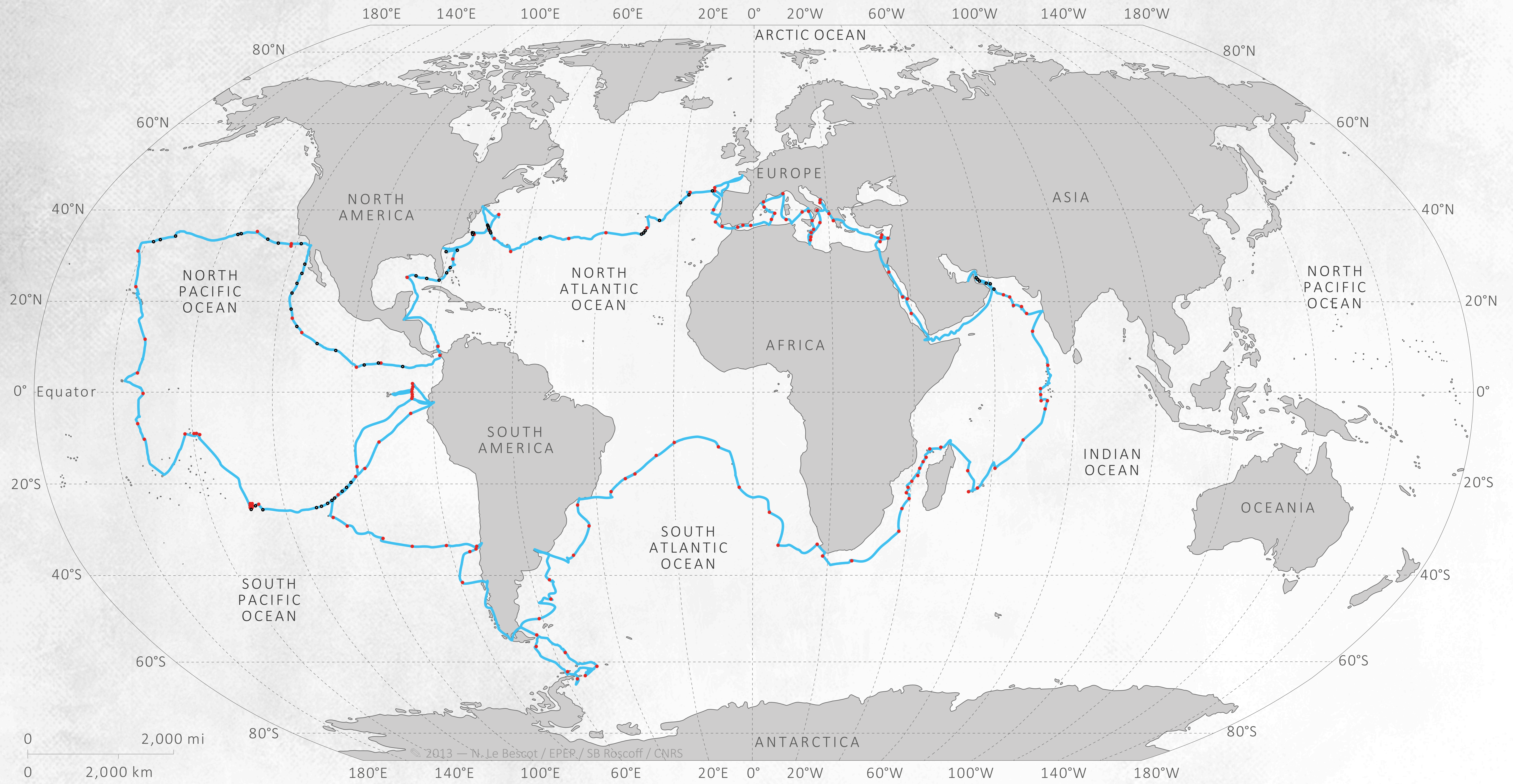
PRESENTATION SUMMARY



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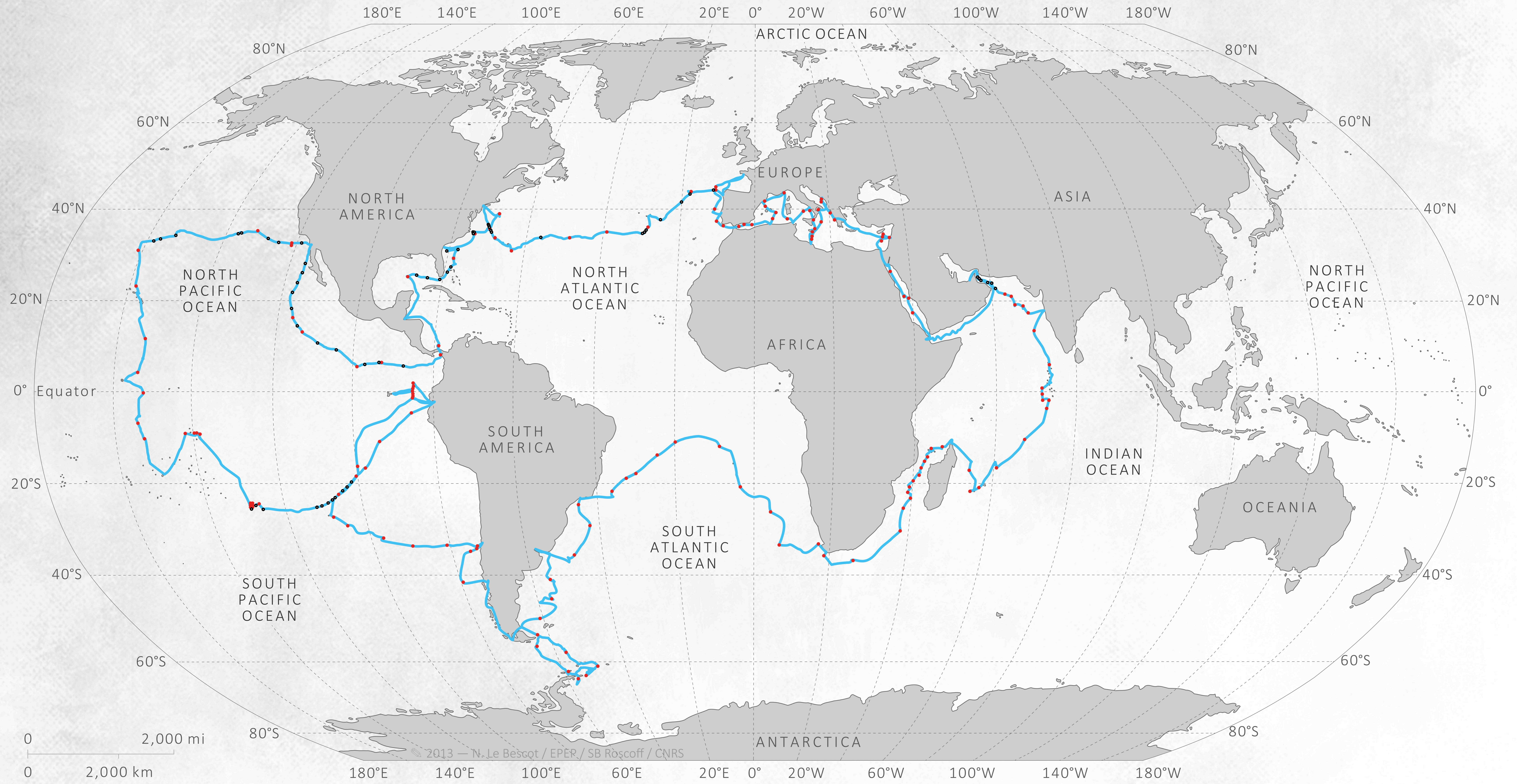


SAMPLING



TARA OCEANS

SAMPLING

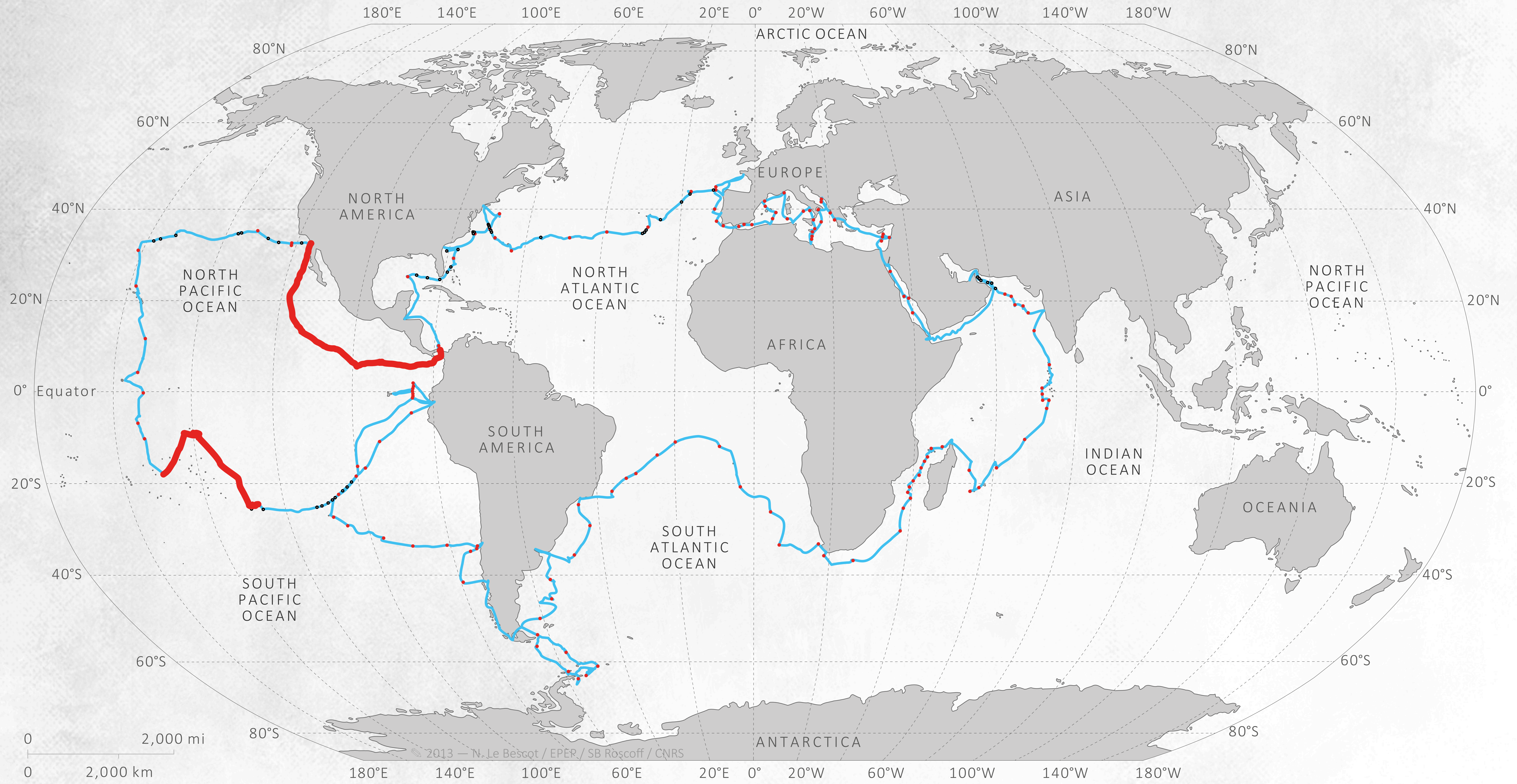




© Francis Latreille

TARA OCEANS

SAMPLING

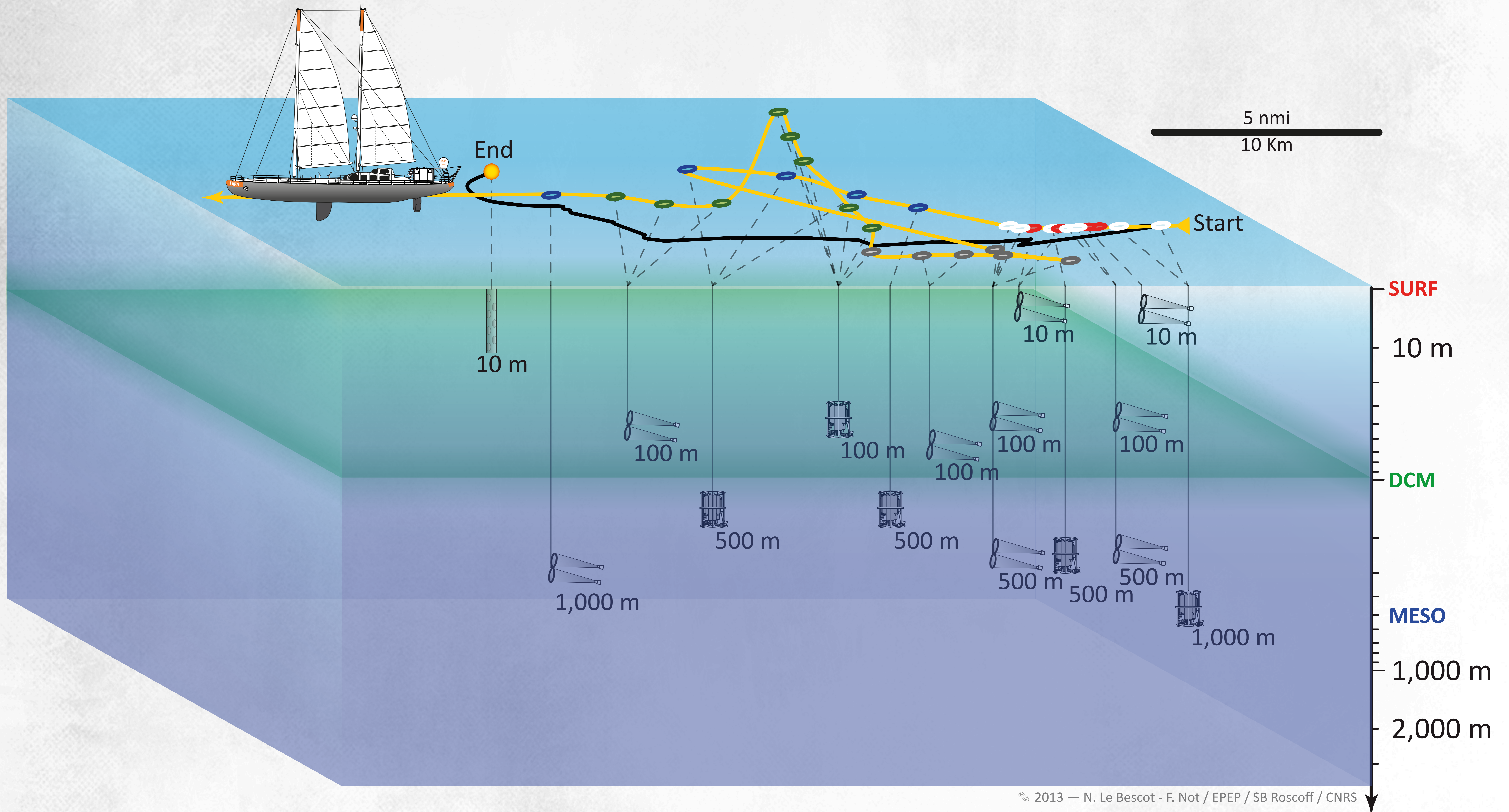


► Involved since the beginning of the project

► About 5 months on board for sampling

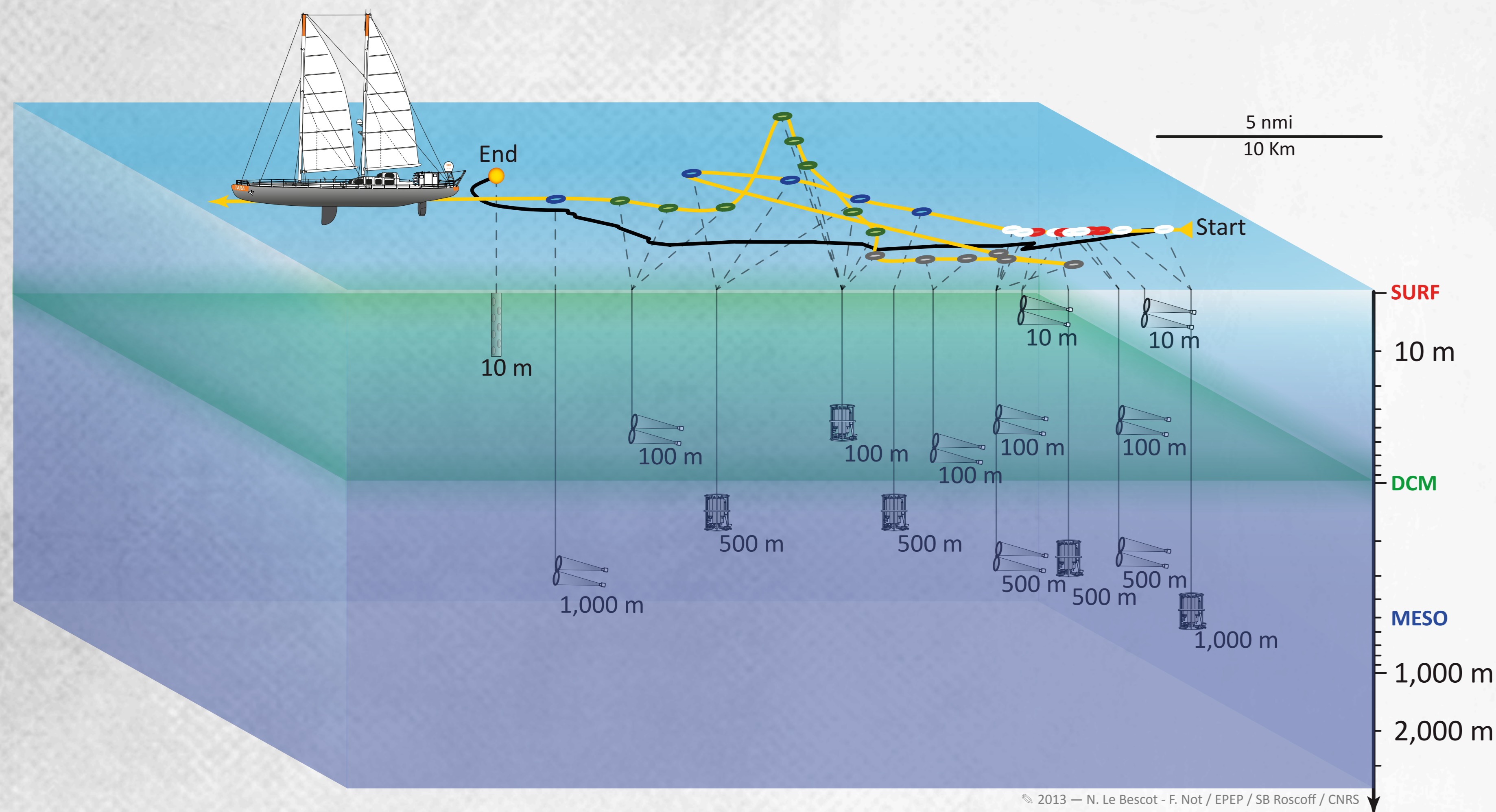
SAMPLING

Chronology and spatial distribution of devices at a station



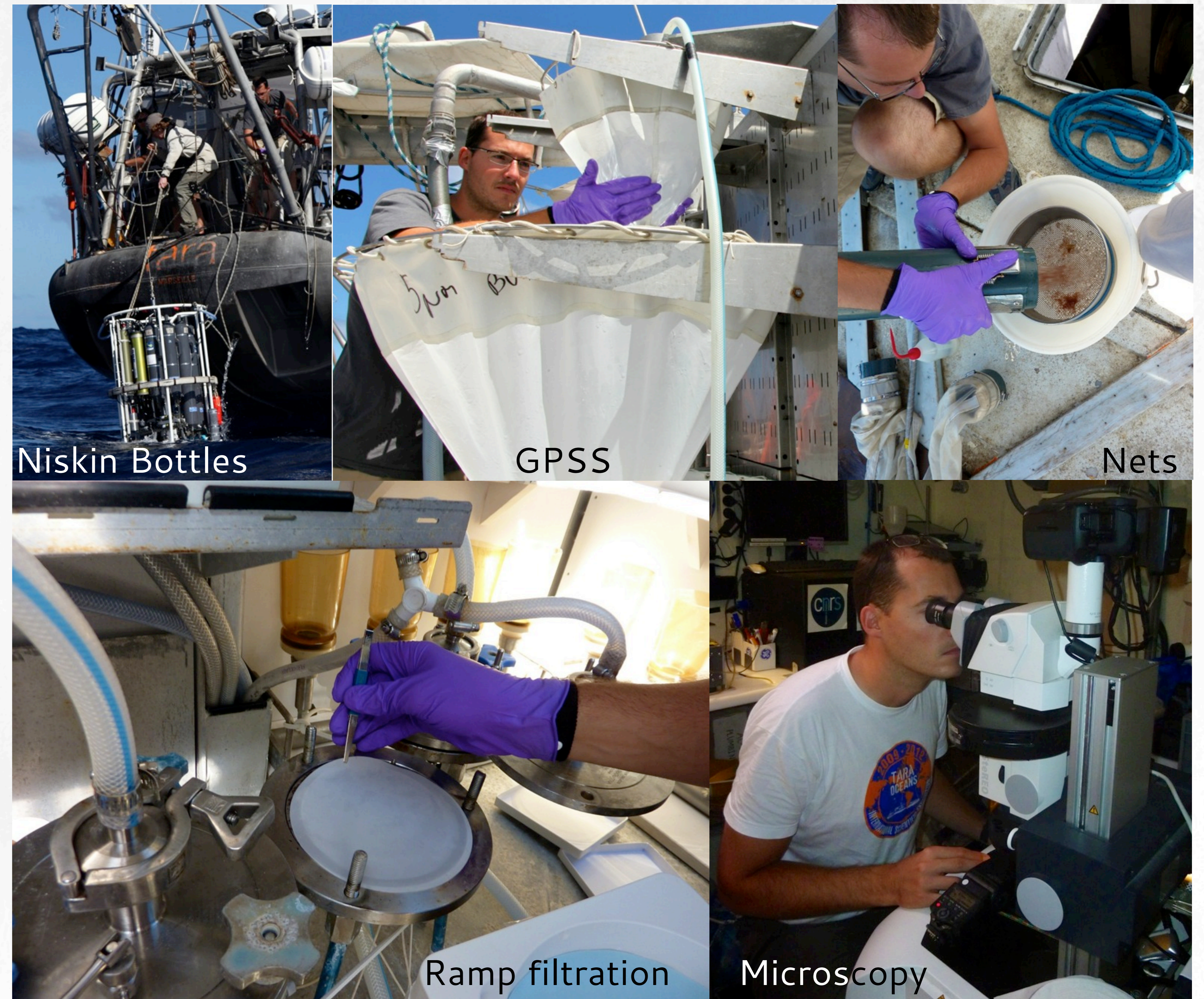
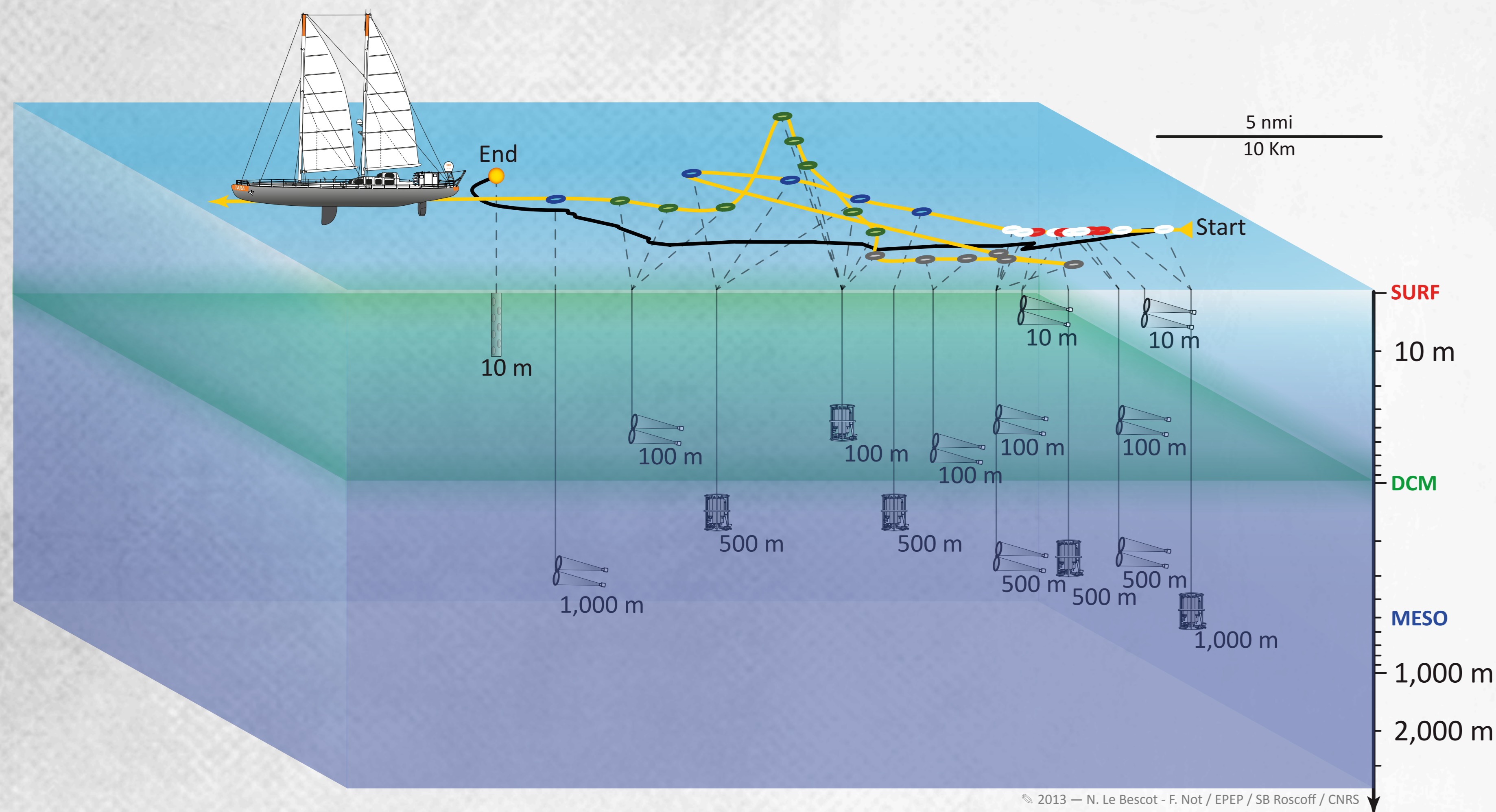
SAMPLING

Chronology and spatial distribution of devices at a station



SAMPLING

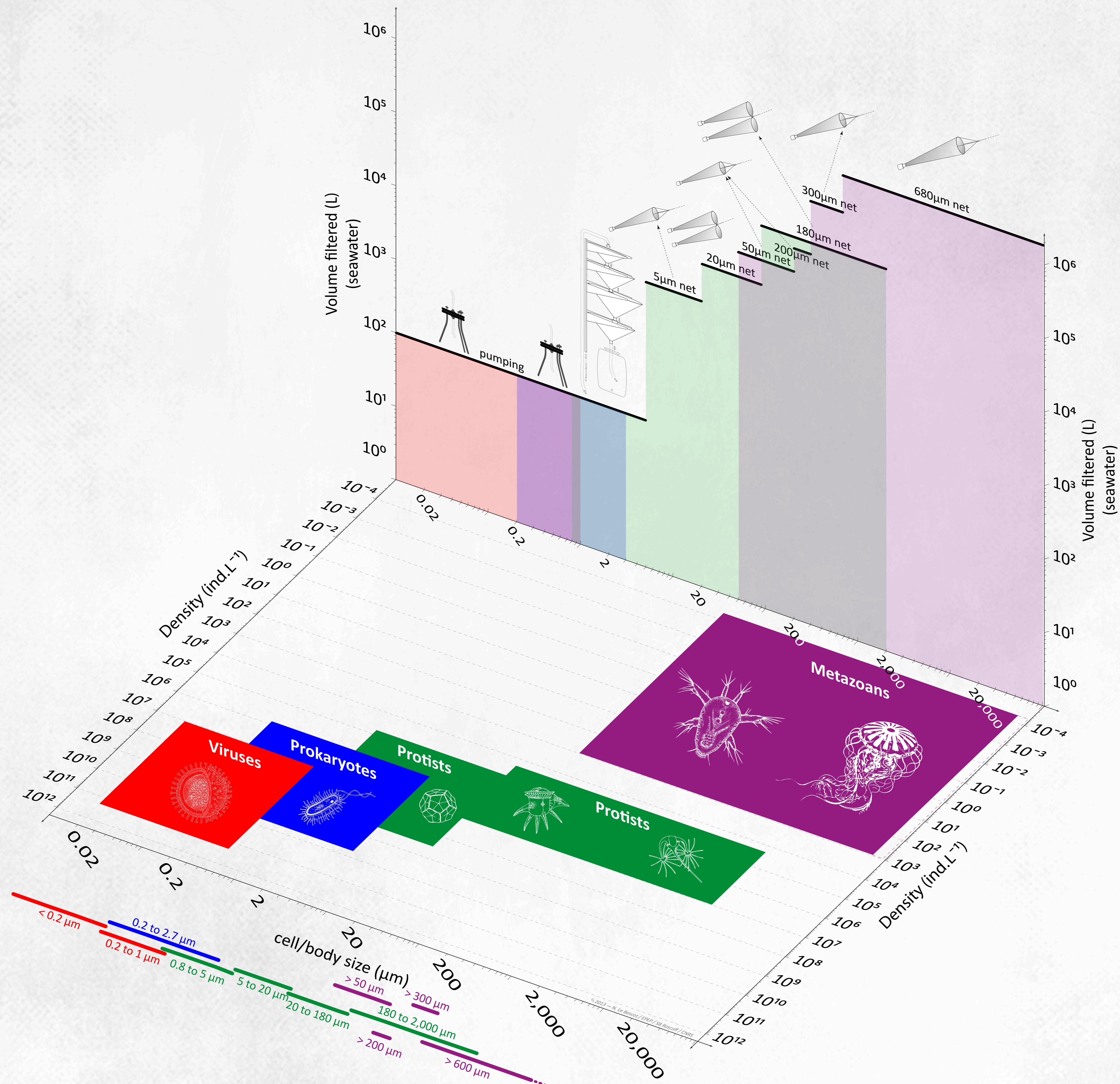
Chronology and spatial distribution of devices at a station



► One sample split in different sub-samples for genetic and morphological analyses

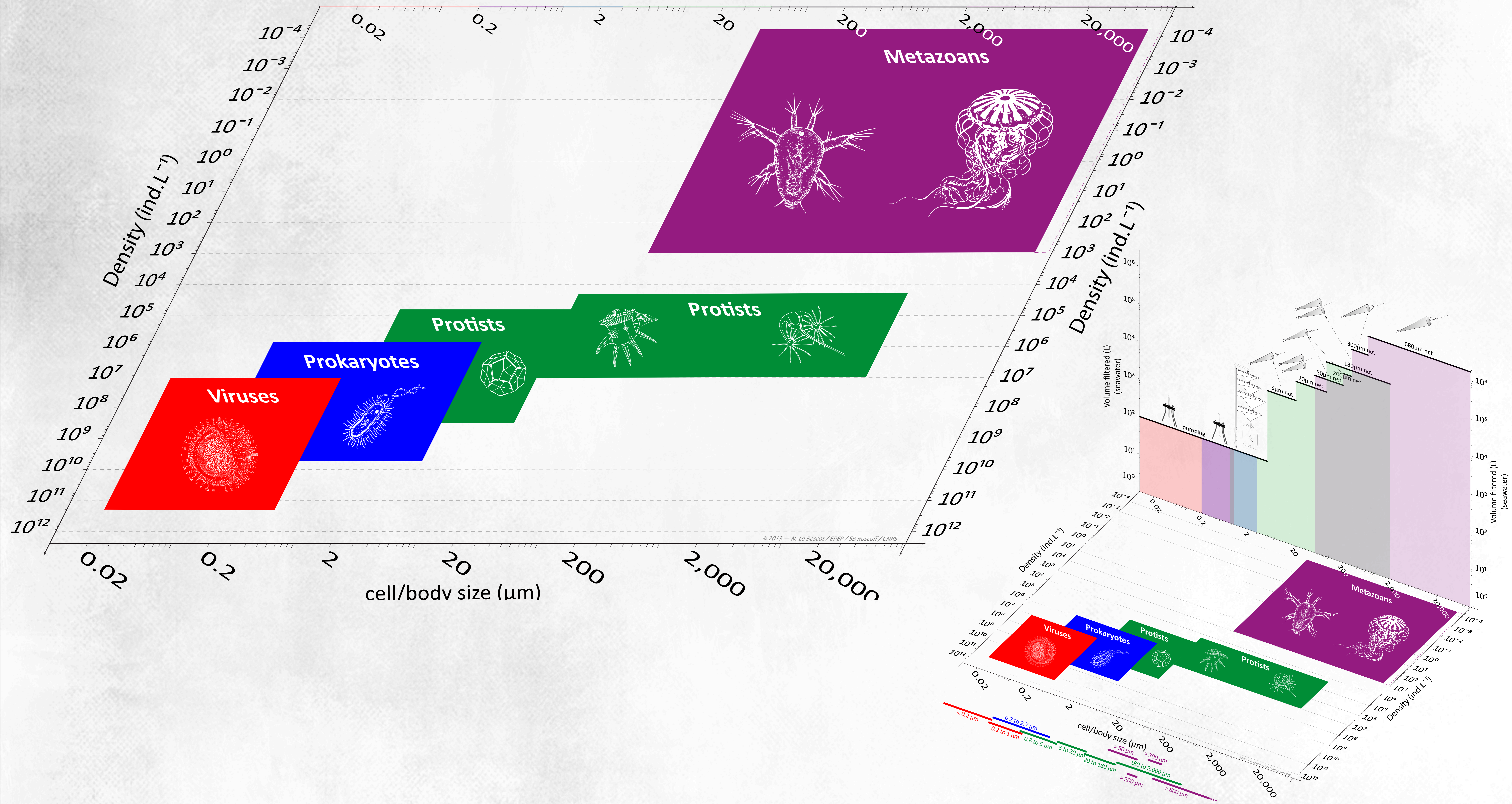
SAMPLING

Size fractionation and seawater volumes used



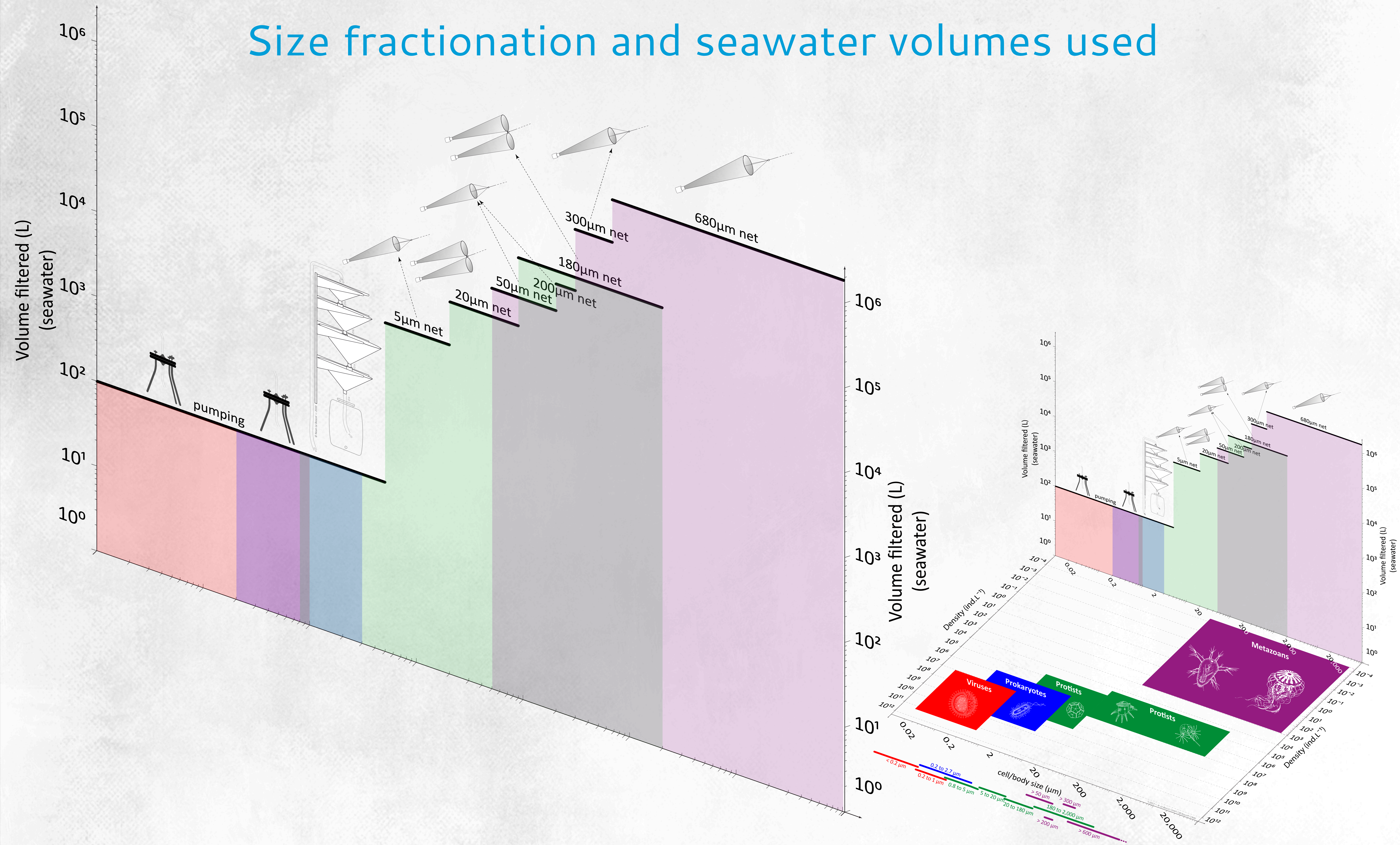
SAMPLING

Size fractionation and seawater volumes used



SAMPLING

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Size fractionation and seawater volumes used

Submitted to PLoSOne

The Tara Oceans Expedition: A comprehensive sampling of marine plankton biota in their environmental context

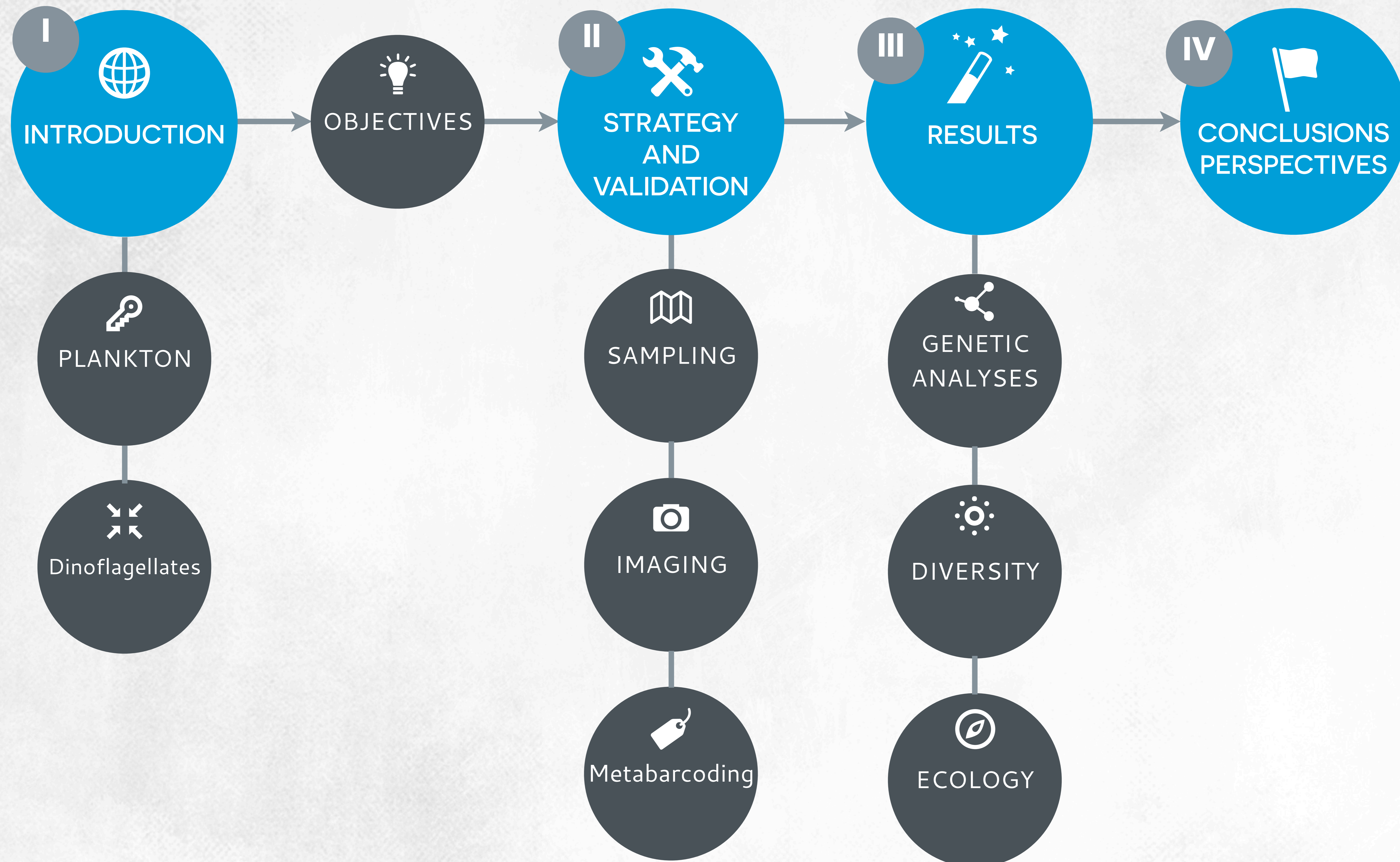
Fabrice Not^{1*}, Stéphane Pesant^{2*}, Marc Picheral^{3*}, Stephanie Kandels-Lewis^{4*}, **Noan Le Bescot**^{1*}, Sarah Searson^{3,5}, Céline Dimier¹, Julie Poulain⁶, Sarah Romac¹, Hervé Le Goff⁷, Margaux Carmichael¹, Johan Decelle¹, Jean-Baptiste Romagnan³, Isabel Ferrera⁸, Hugo Sarmento⁹, Camille Clerissi¹⁰, Lucie Subirana¹⁰, Jennifer R. Brum¹¹, Lionel Guidi³, Francois Roullier³, Léo Berline³, Joséphine Ras³, Lucie Bittner¹, Ian Probert¹, Sébastien Colin¹, Sasha Tozzi¹², Nicole Poulton¹³, Jean-Pierre Gattuso³, Uros Krzic⁴, Lee Karp-Boss¹⁴, Christian Sardet³, Shinichi Sunagawa⁴, Jeroen Raes¹⁵, Olivier Jaillon⁶, Patrick Wincker⁶, Michael Sieracki¹³, Emmanuel Boss¹⁶, Sabrina Speich¹⁷, Pierre Testor⁷, Fabrizio D'ortenzio³, Lars Stemmann³, Nigel H. Grimsley¹⁰, Pascal Hingamp¹⁸, Daniele Iudicone¹⁹, Emmanuel G. Reynaud²⁰, Matthew B. Sullivan¹¹, Silvia G. Acinas⁸, Hiroyuki Ogata²¹, Christopher Bowler²², Colomán de Vargas¹, Gabriel Gorsky³, Eric Karsenti⁴, Etienne Bourgois²³, and the Tara Oceans Consortium

* These authors contributed equally to this work.
Corresponding author: not@sb-roscoff.fr

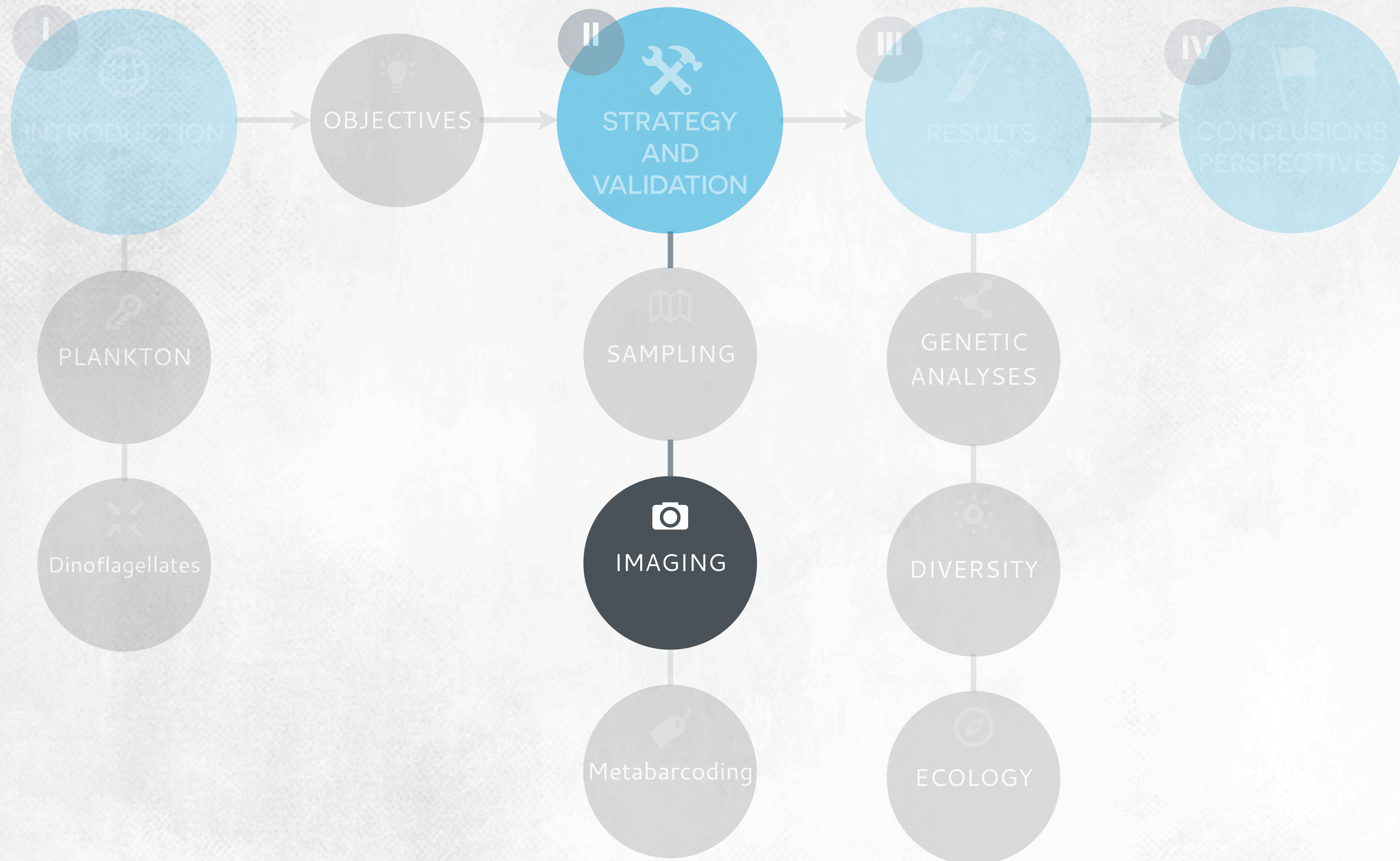
¹ CNRS (UMR7144), Université & Pierre et Marie Curie (Paris 06), Station Biologique de Roscoff, Roscoff, France, ² MARUM—Center for Marine Environmental Sciences, Universität Bremen, Bremen, Germany, ³ CNRS-UPMC, Laboratoire d'Océanographie de Villefranche (LOV), Villefranche-sur-Mer, France, ⁴ European Molecular Biology Laboratory (EMBL), Heidelberg, Germany, ⁵ Department of Oceanography, University of Hawai'i at Manoa, Honolulu, HI, USA, ⁶ CEA, Institut de Génétique, Genoscope, Evry, France, ⁷ Laboratoire d'Océanographie et de Climatologie: Expérimentations et Approches Numériques (LOCEAN), CNRS/UPMC/IRD/MNHN, Paris, France, ⁸ Department of Marine Biology and Oceanography, Institute of Marine Science (ICM), CSIC, Passeig Marítim de la Barceloneta, Barcelona, Spain, ⁹ Federal University of Rio Grande do Norte, Department of Oceanography and Limnology, 'PPG Ecologia', Natal, Brazil, ¹⁰ CNRS (UMR7232), Université Pierre et Marie (Paris 06), Observatoire Océanologique, Banyuls-sur-Mer, France
¹¹ University of Arizona, Tucson, Arizona, United States of America, ¹² University of California Santa Cruz (UCSC), Ocean Sciences, Santa Cruz, United States of America, ¹³ Bigelow Laboratory for Ocean Sciences, Bigelow Drive, East Boothbay, United States of America, ¹⁴ School of Marine Sciences, University of Maine, Orono, ME, United States of America, ¹⁵ Vrije Universiteit Brussel (VIB), Department of Structural Biology, Brussel, Belgium, ¹⁶ Bigelow Laboratory for Ocean Sciences, Bigelow Drive, East Boothbay, United States of America
¹⁷ Université de Bretagne Occidentale (UBO), Institut Universitaire Européen de la Mer (IUEM), Brest, France, ¹⁸ CNRS, Aix-Marseille Université, Laboratoire Information Génomique et Structurale (UMR 7256), Mediterranean Institute of Microbiology (FR 3479), Marseille, France, ¹⁹ Stazione Zoologica Anton Dohrn di Napoli, Napoli, Italy, ²⁰ Earth Institute, UCD, Belfield, Dublin 4, Ireland, ²¹ Education Academy of Computational Life Sciences, Tokyo Institute of Technology, Tokyo, Japan, ²² Environmental and Evolutionary Genomics, Institut de Biologie de l'Ecole Normale Supérieure (IBENS), CNRS (UMR 8197) INSERM (U1024), Paris, France, ²³ Tara Expeditions, 12 rue Dieu, 75001 Paris, France

- ▶ Small organisms: 100L
- ▶ Biggest ones: hundreds of thousands of liters

PRESENTATION SUMMARY

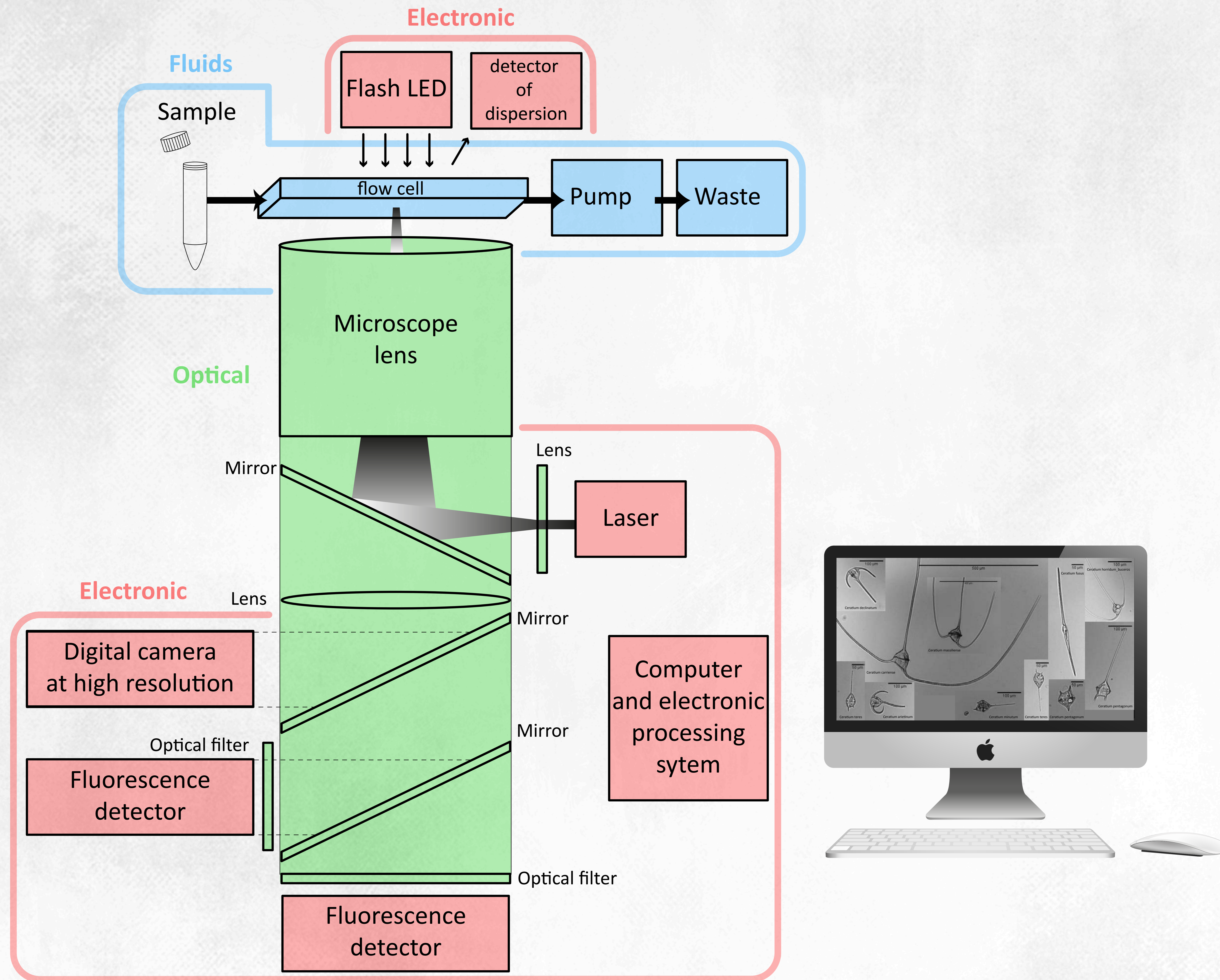


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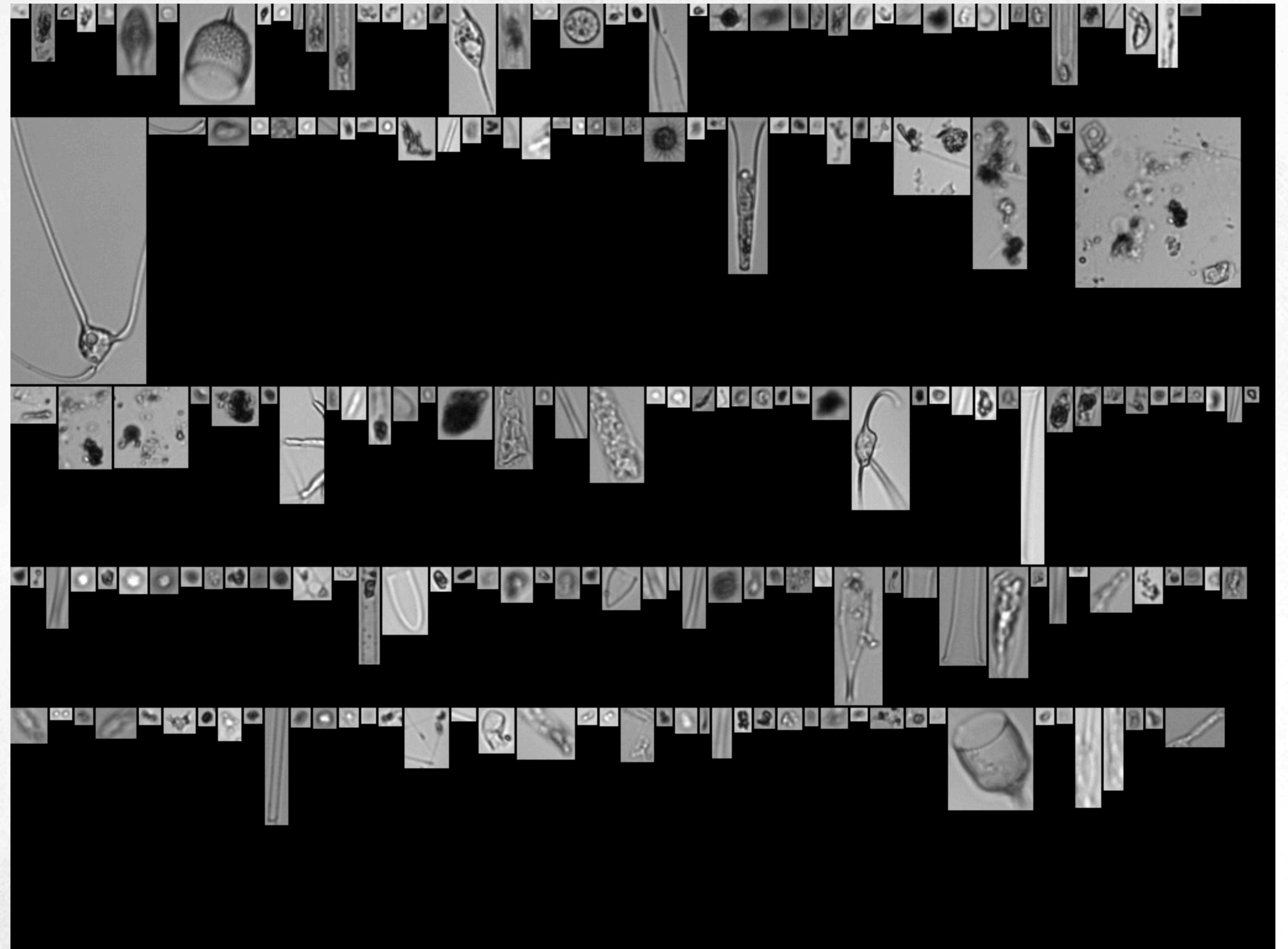
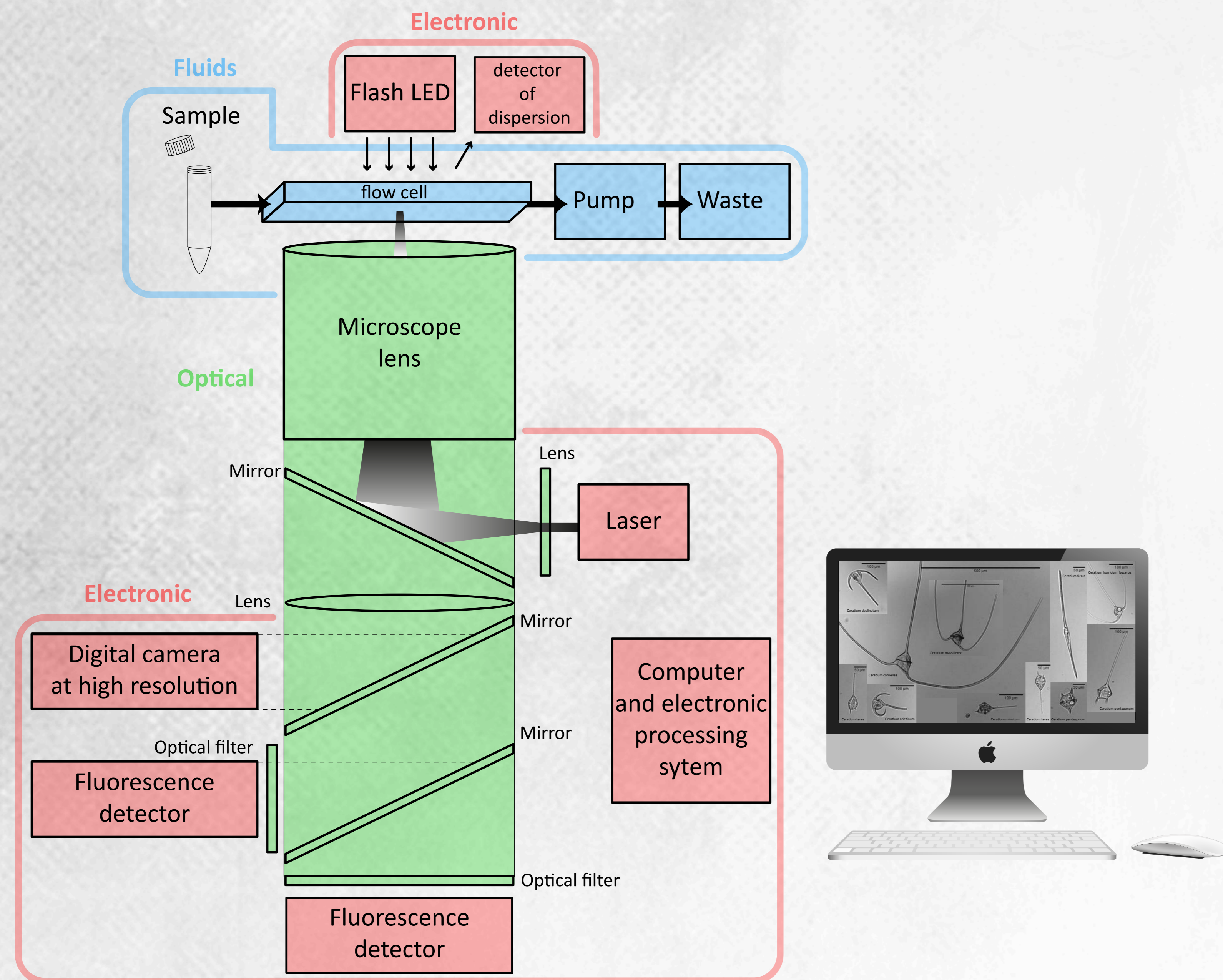
THE FLOWCAM

a technique for high-throughput imaging



THE FLOWCAM

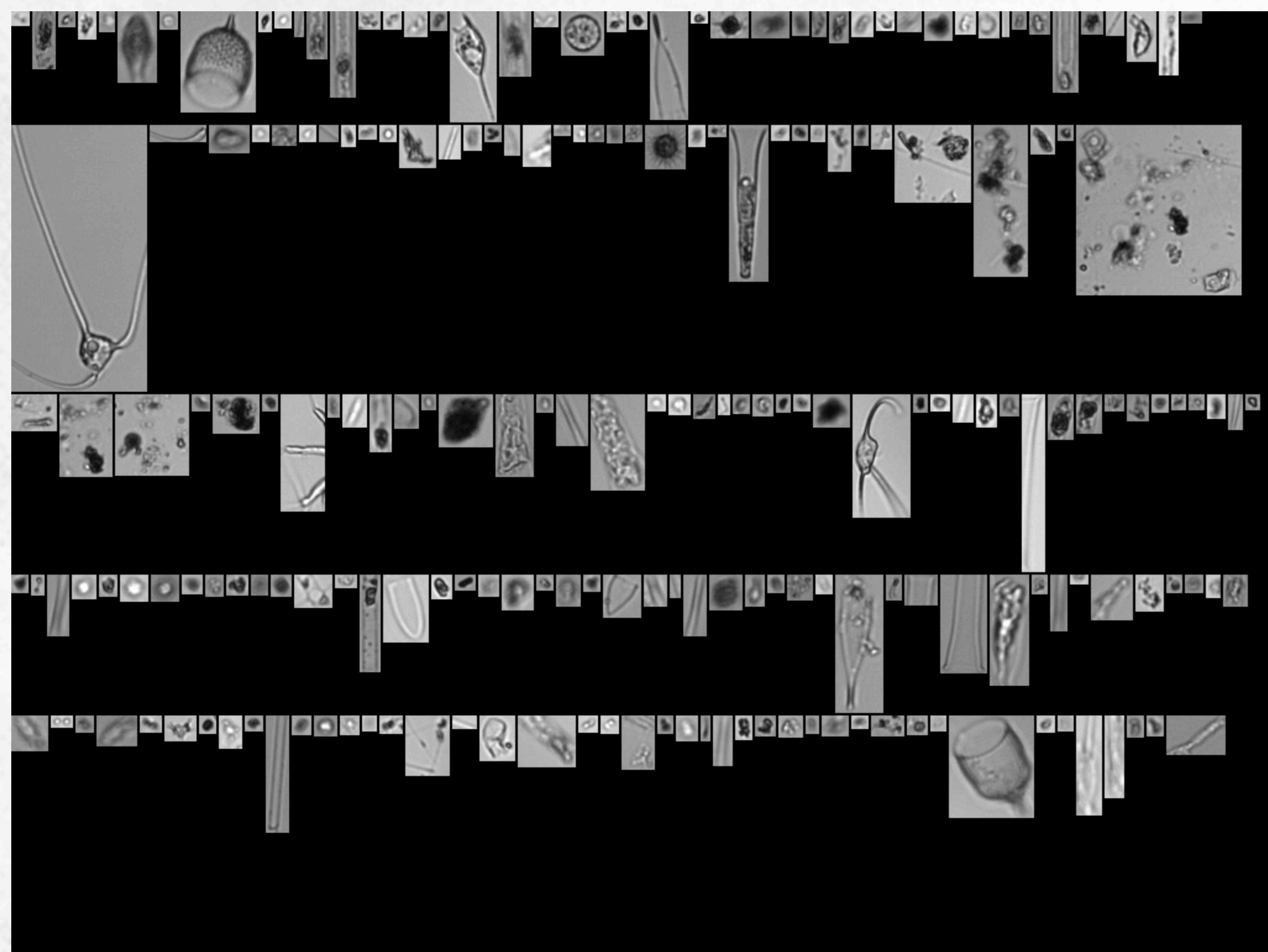
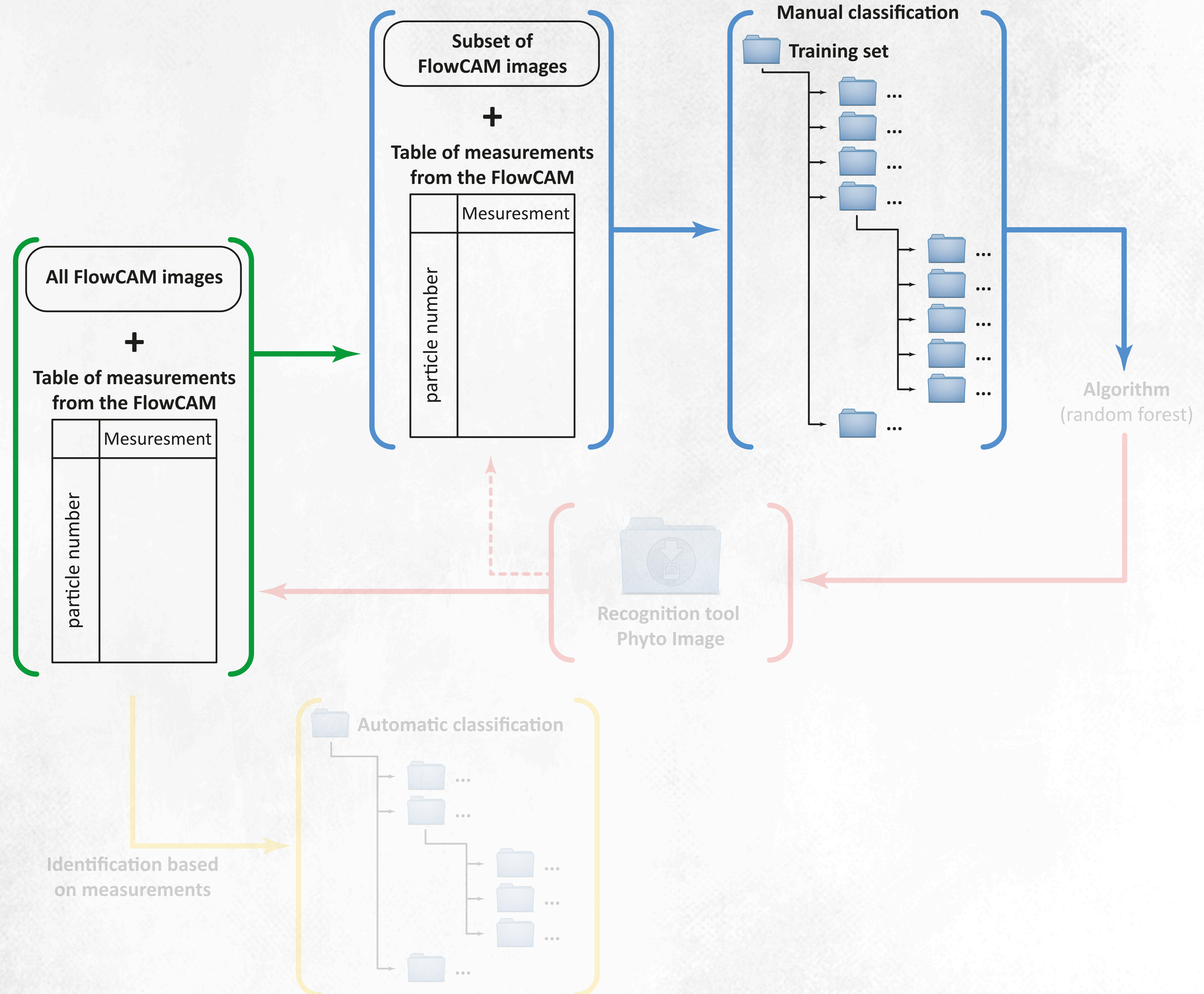
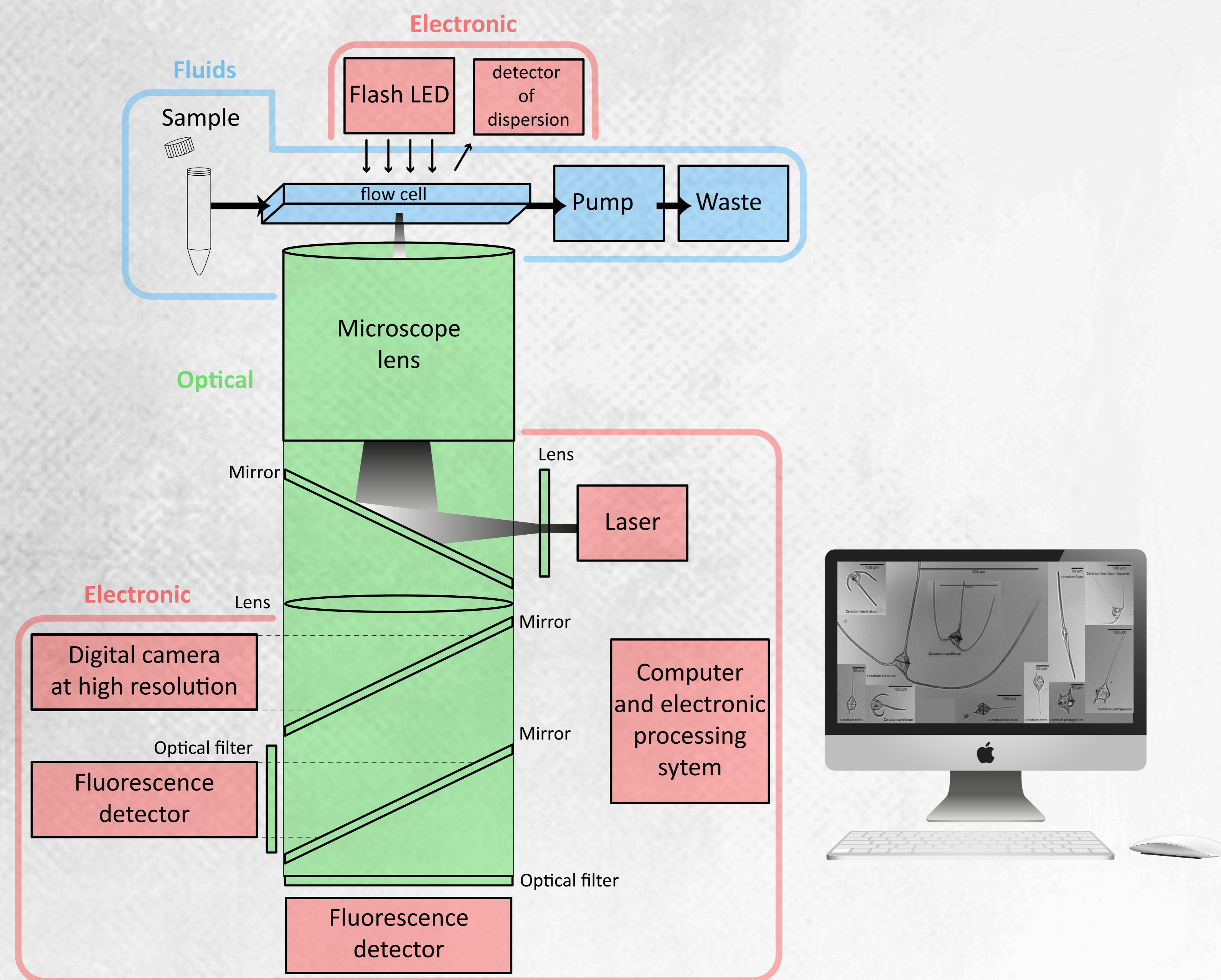
a technique for high-throughput imaging



Example of station 30 at surface

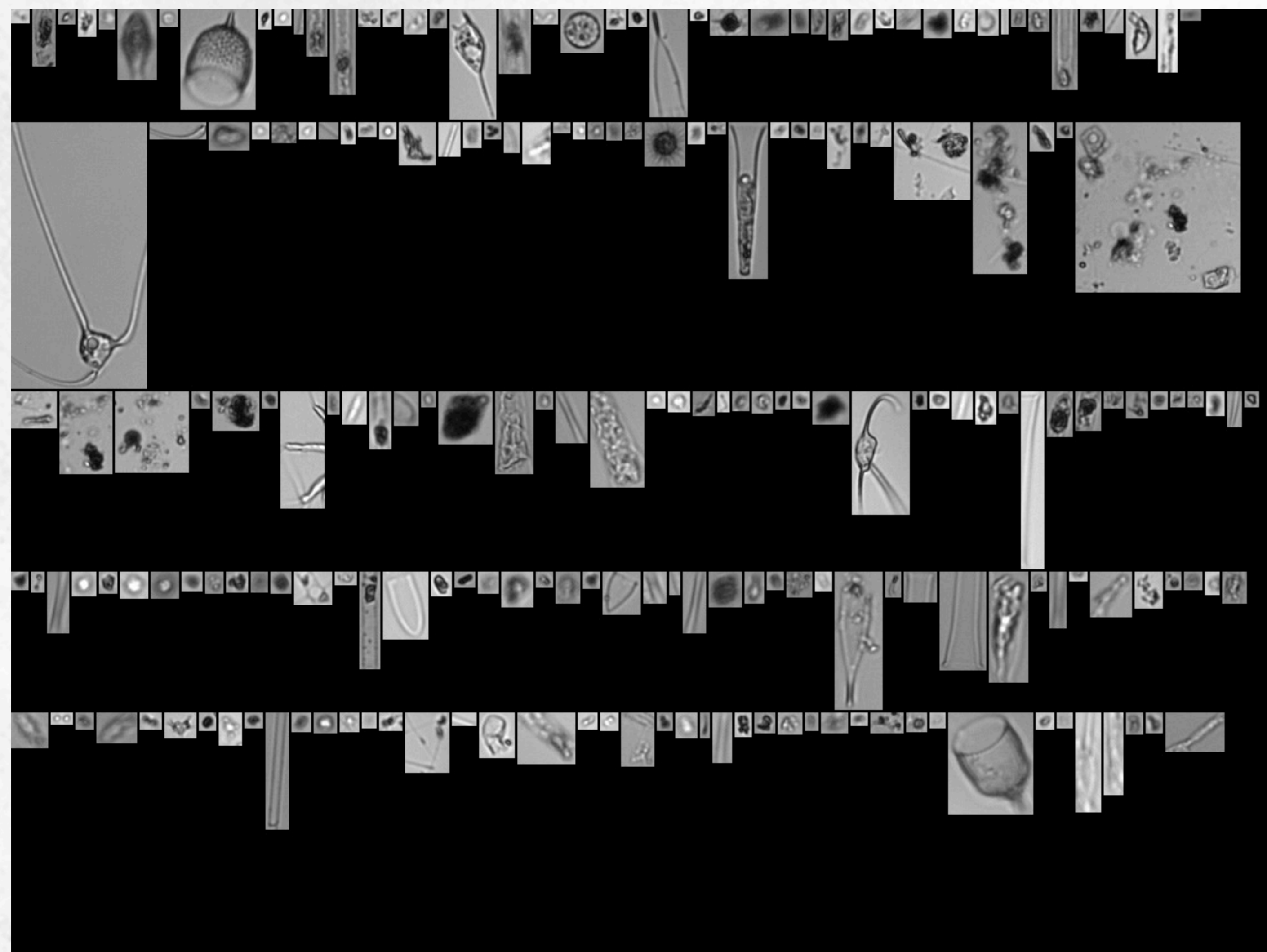
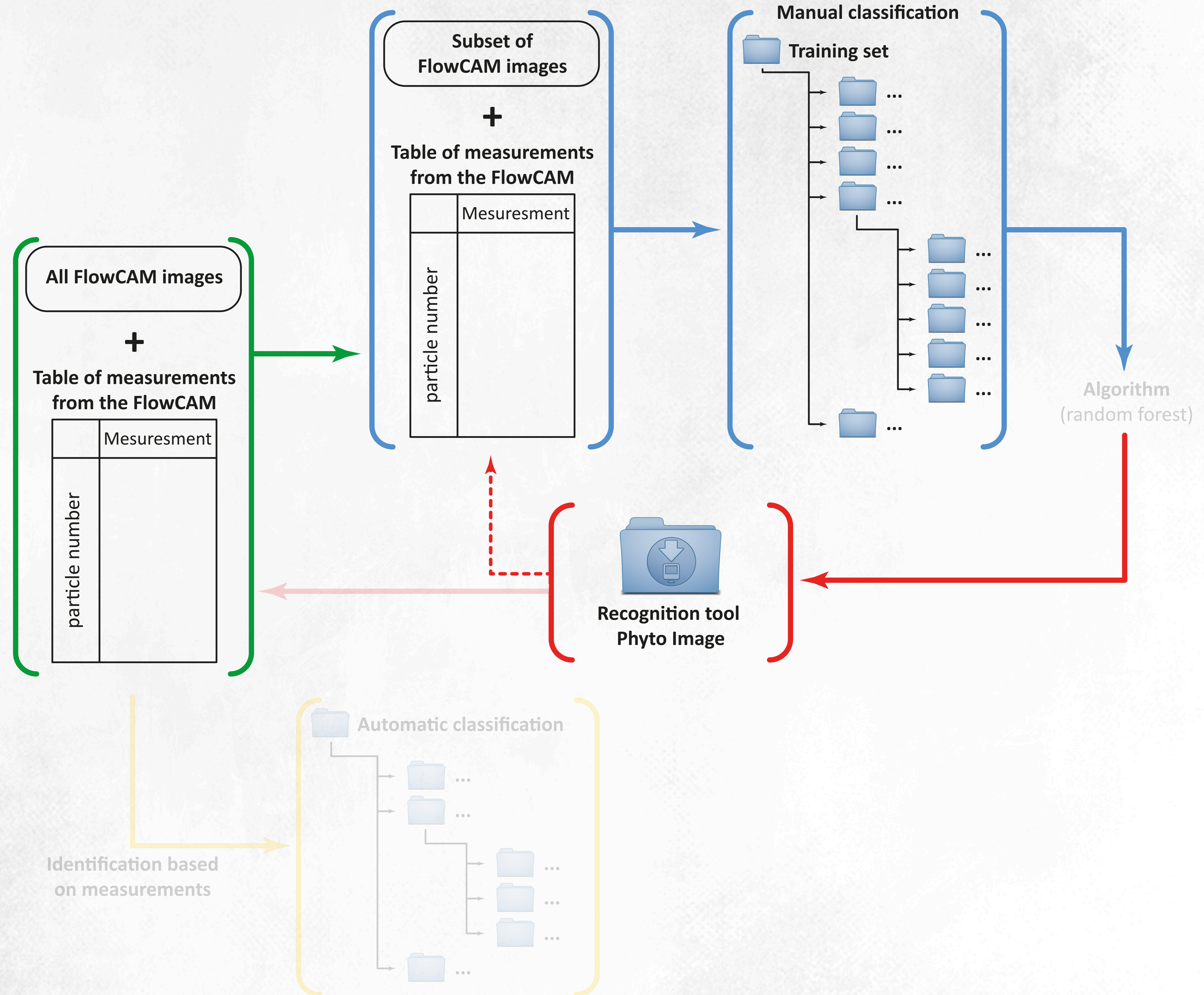
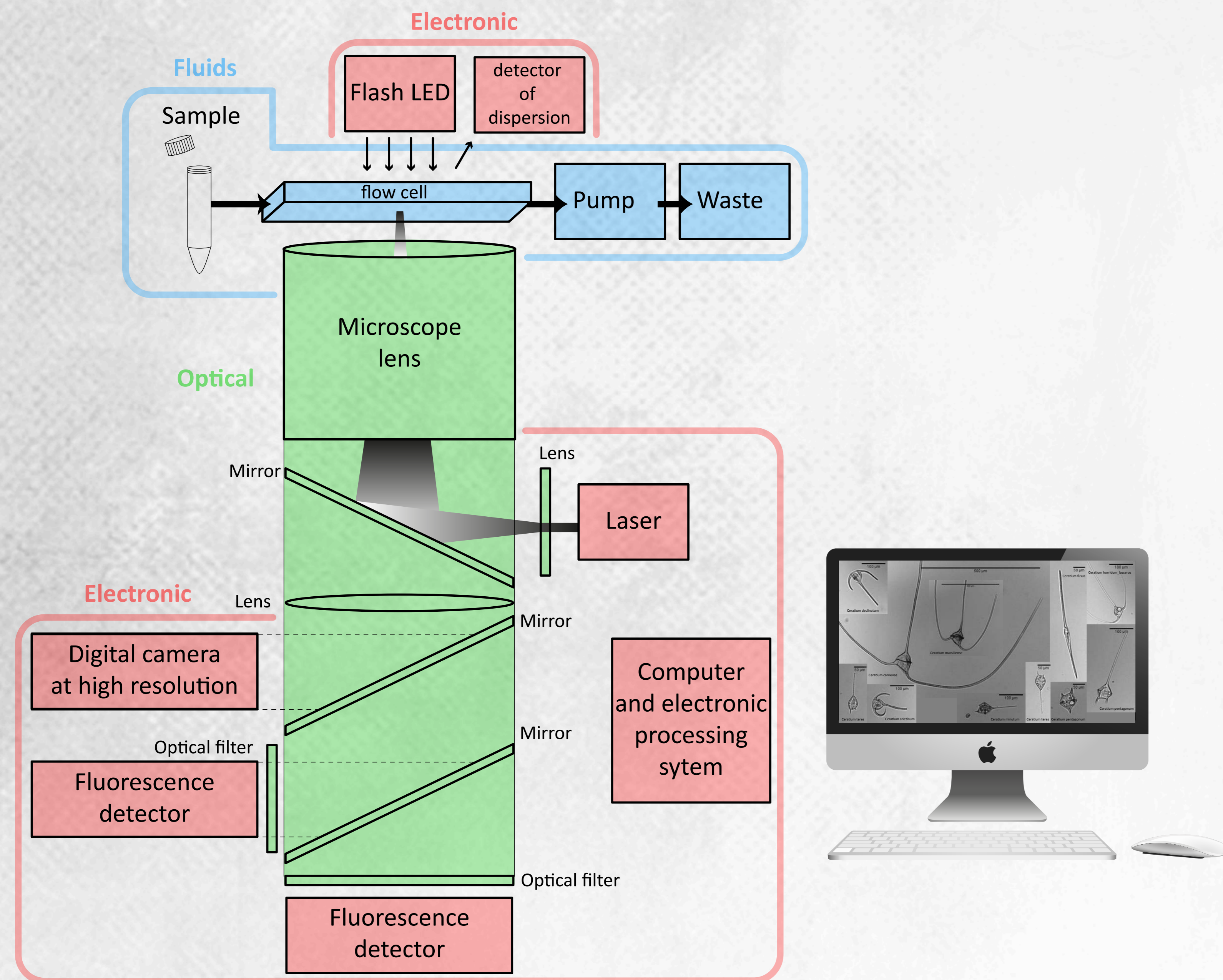
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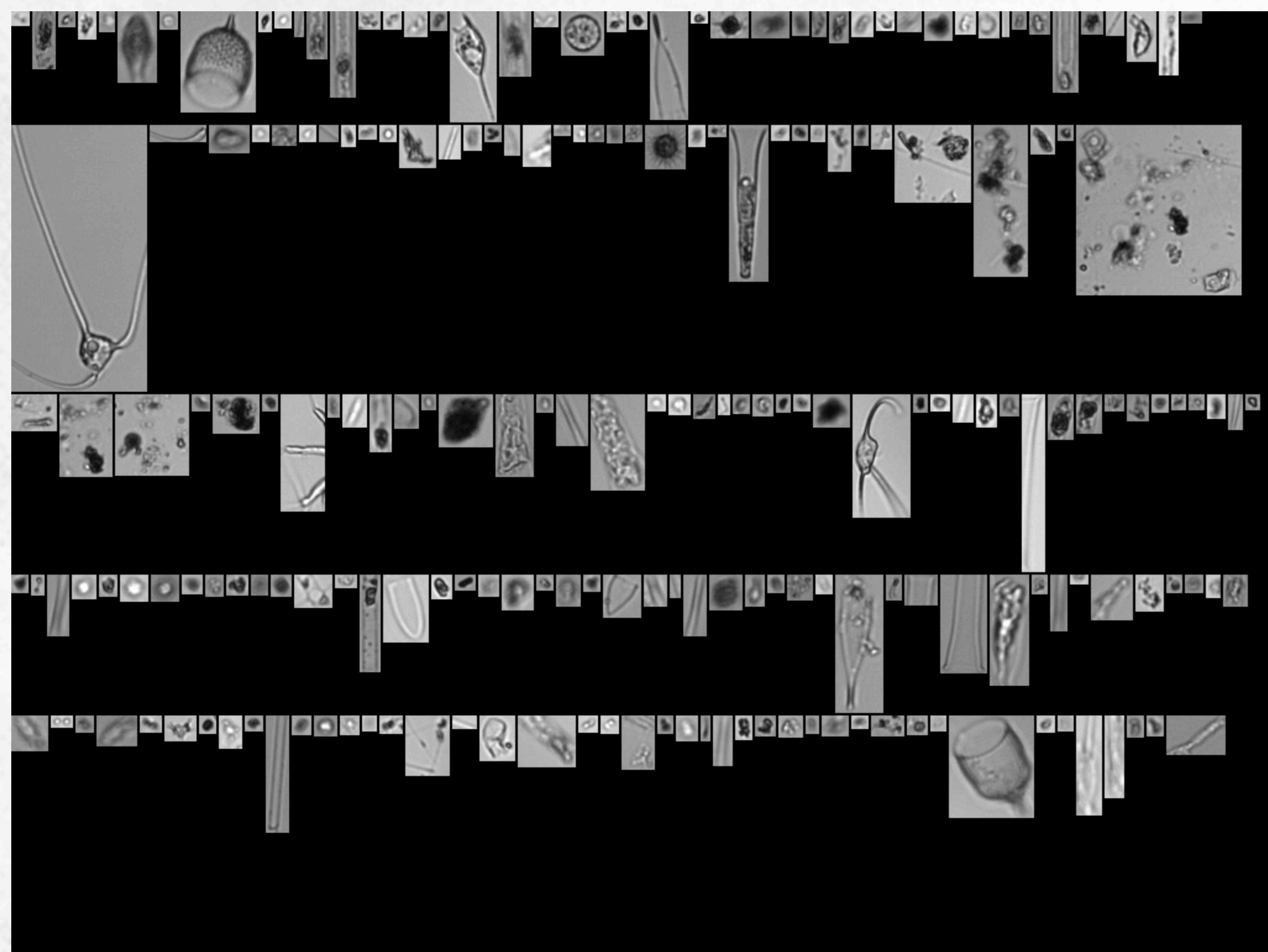
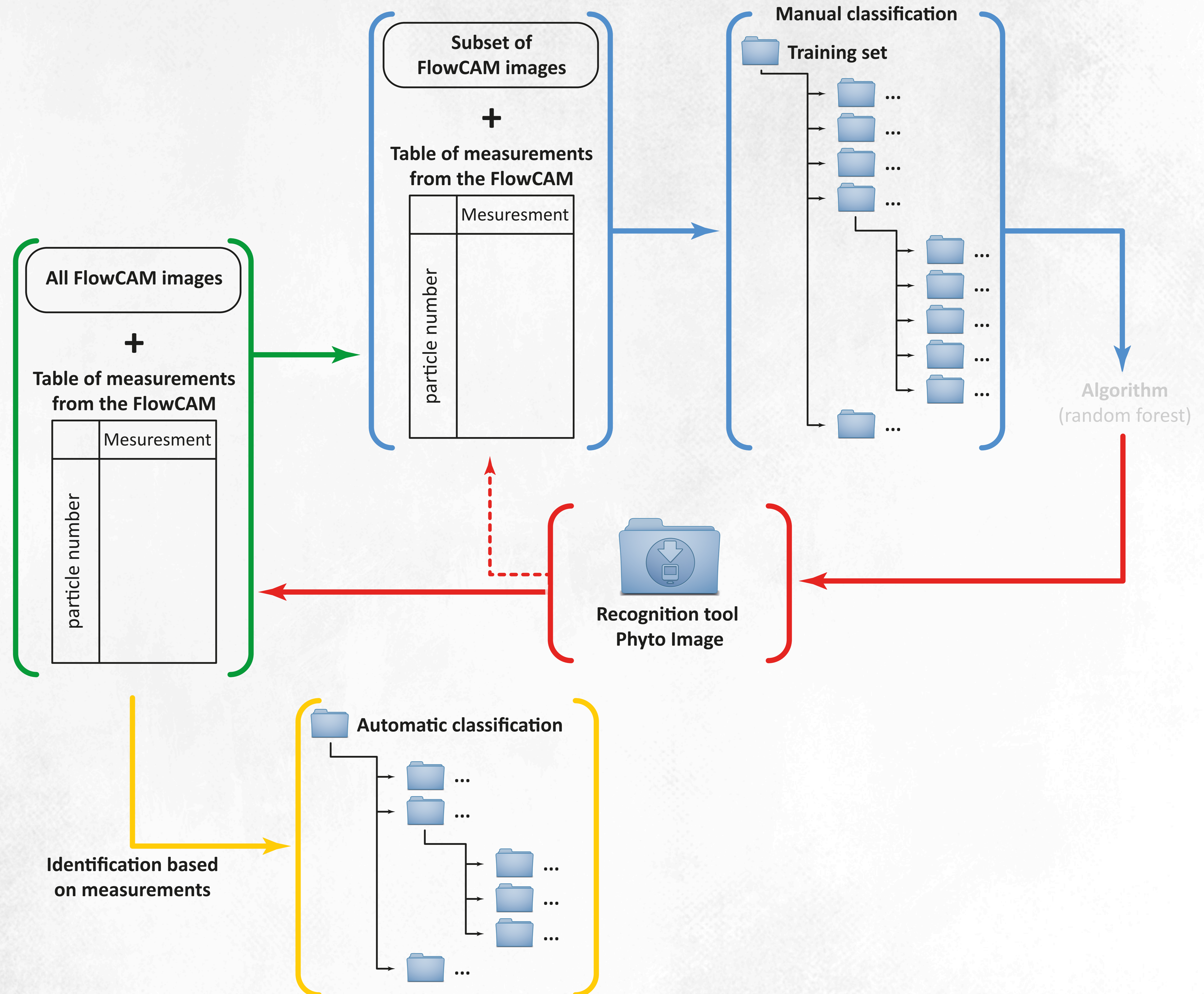
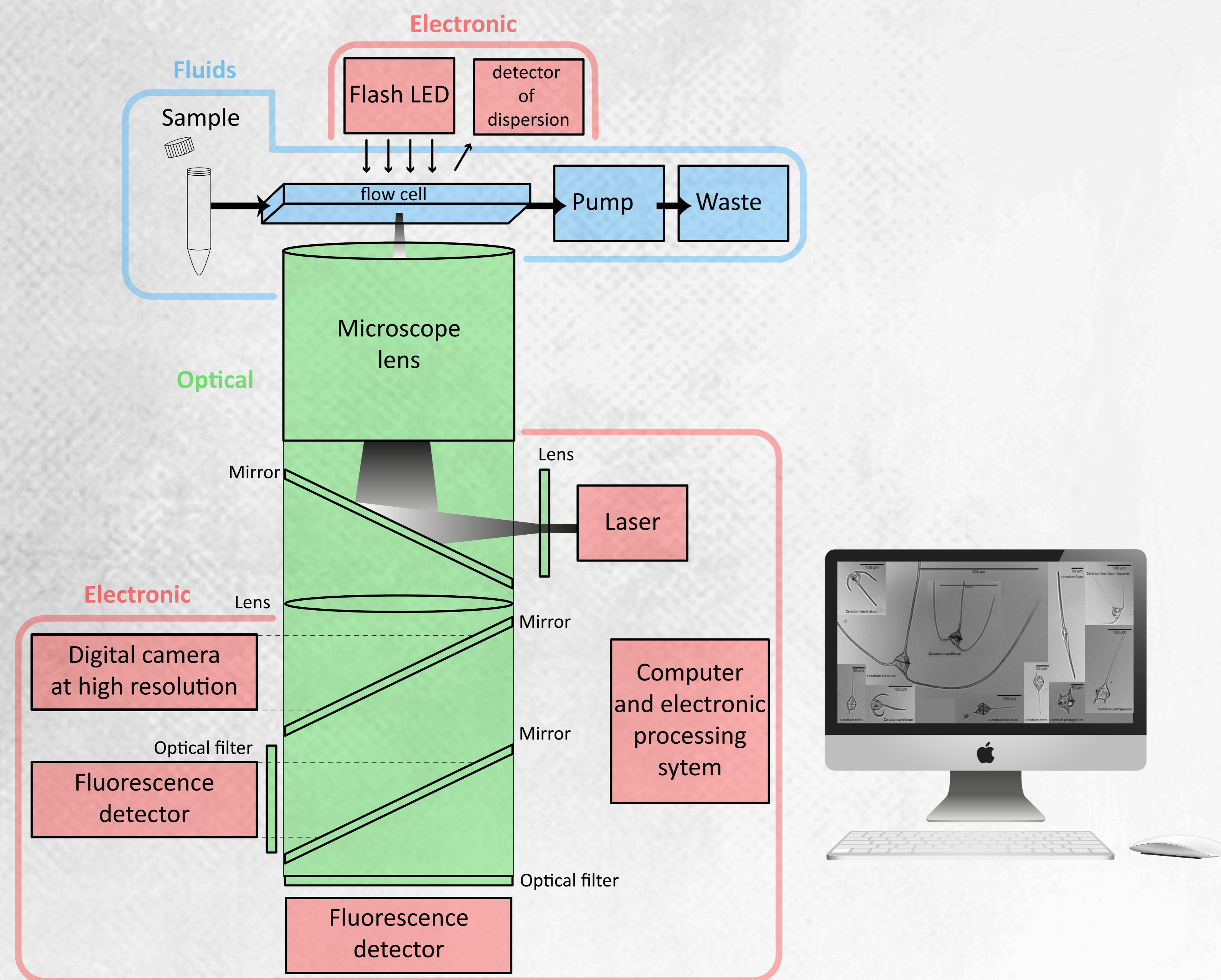
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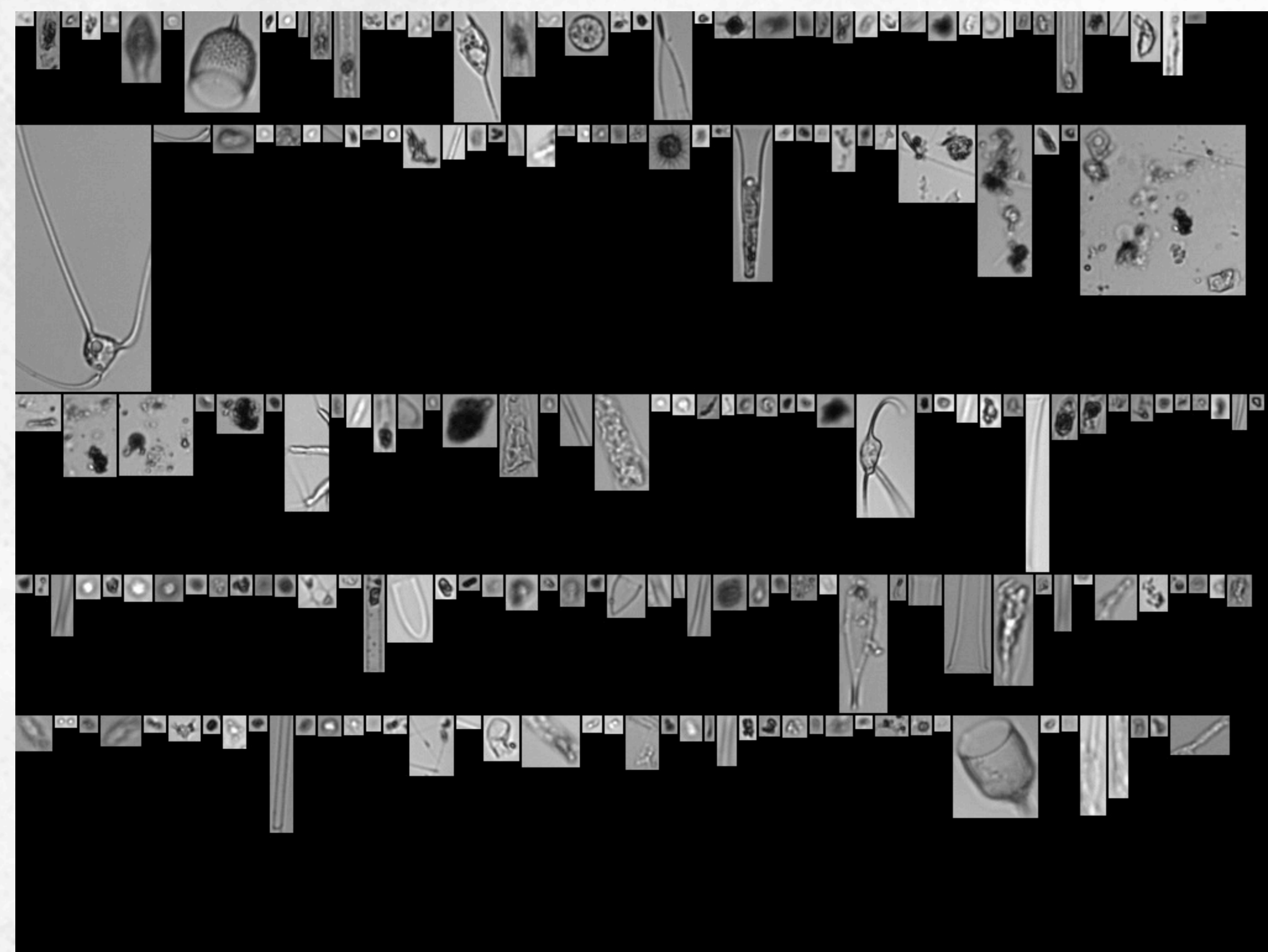
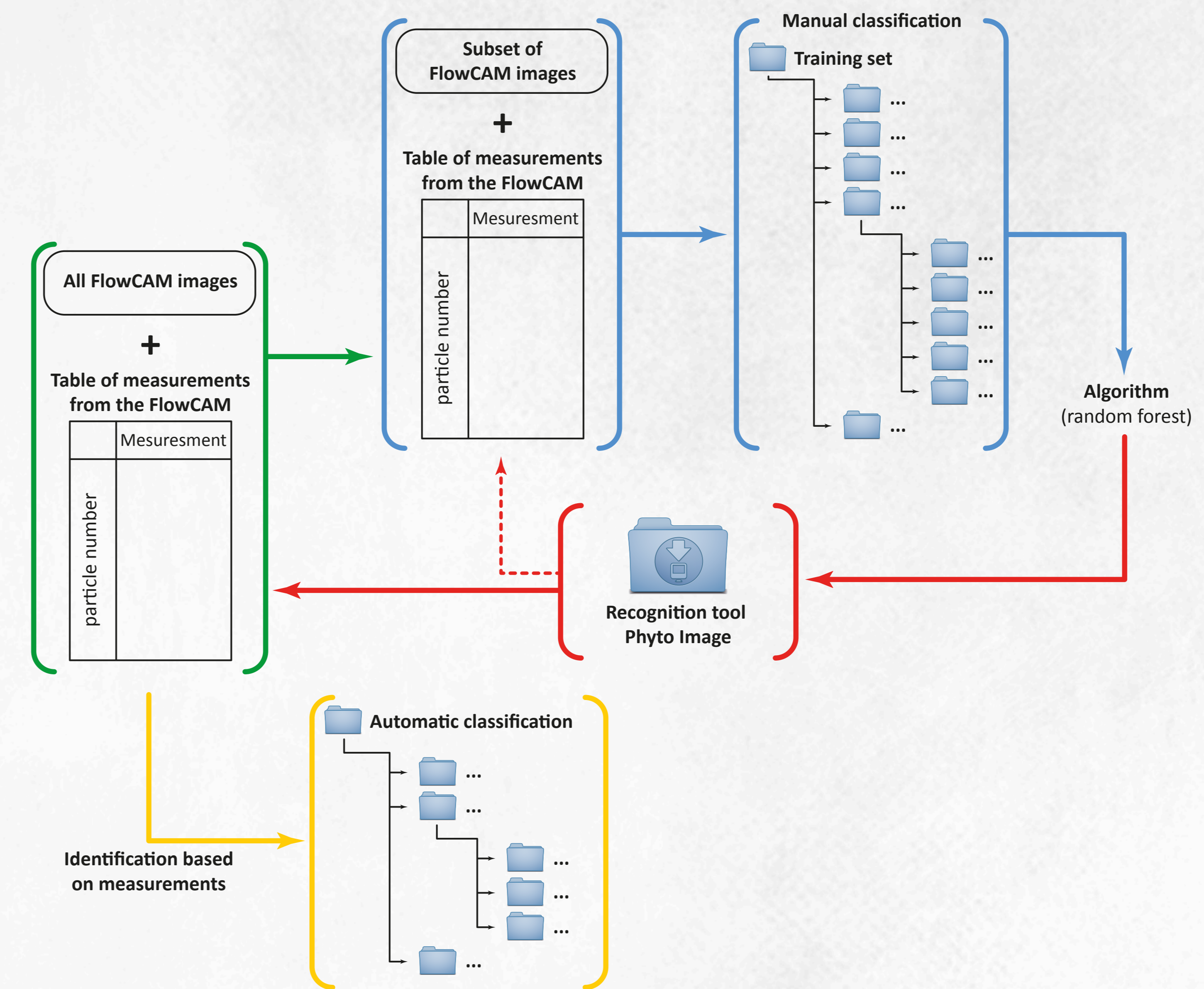
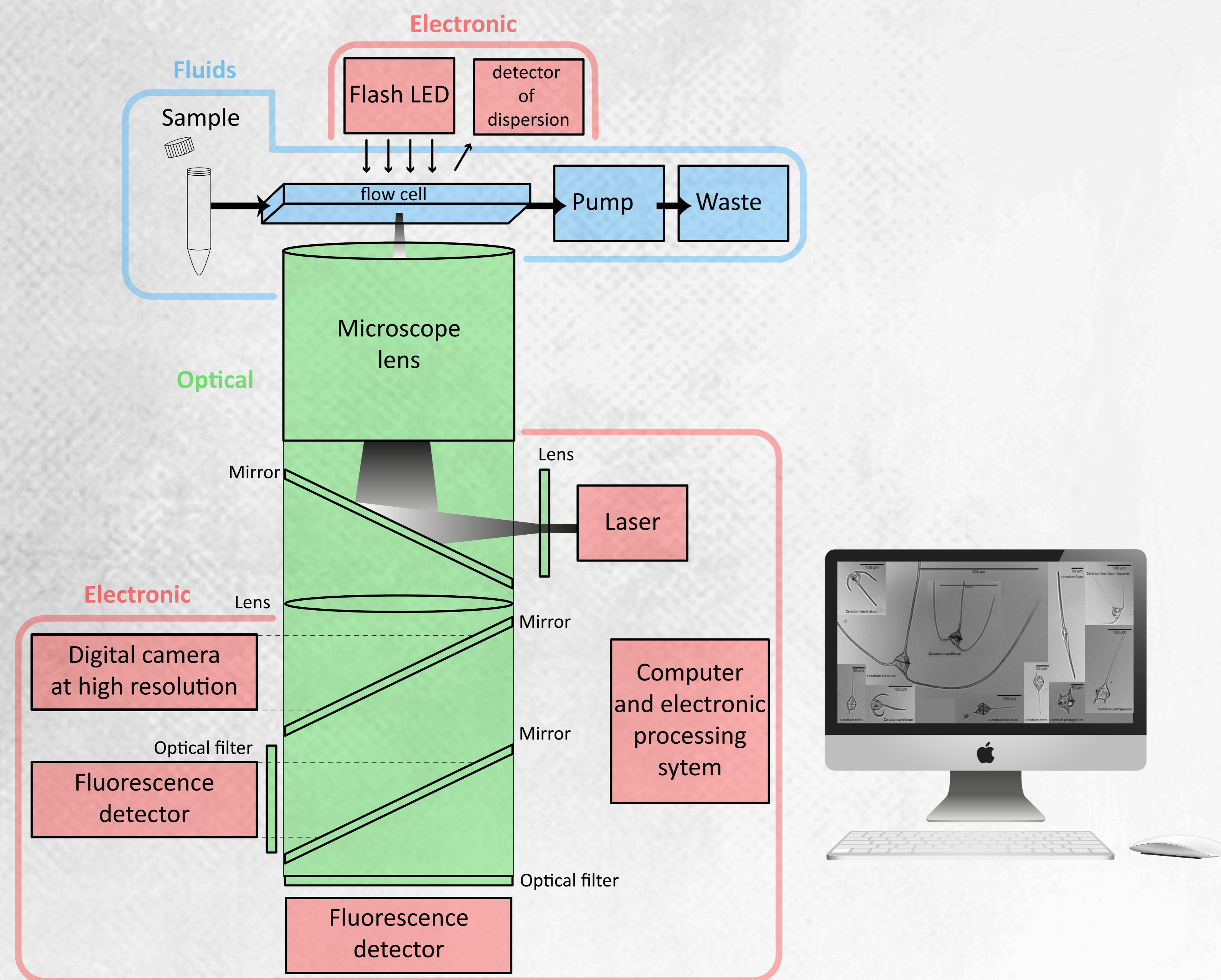
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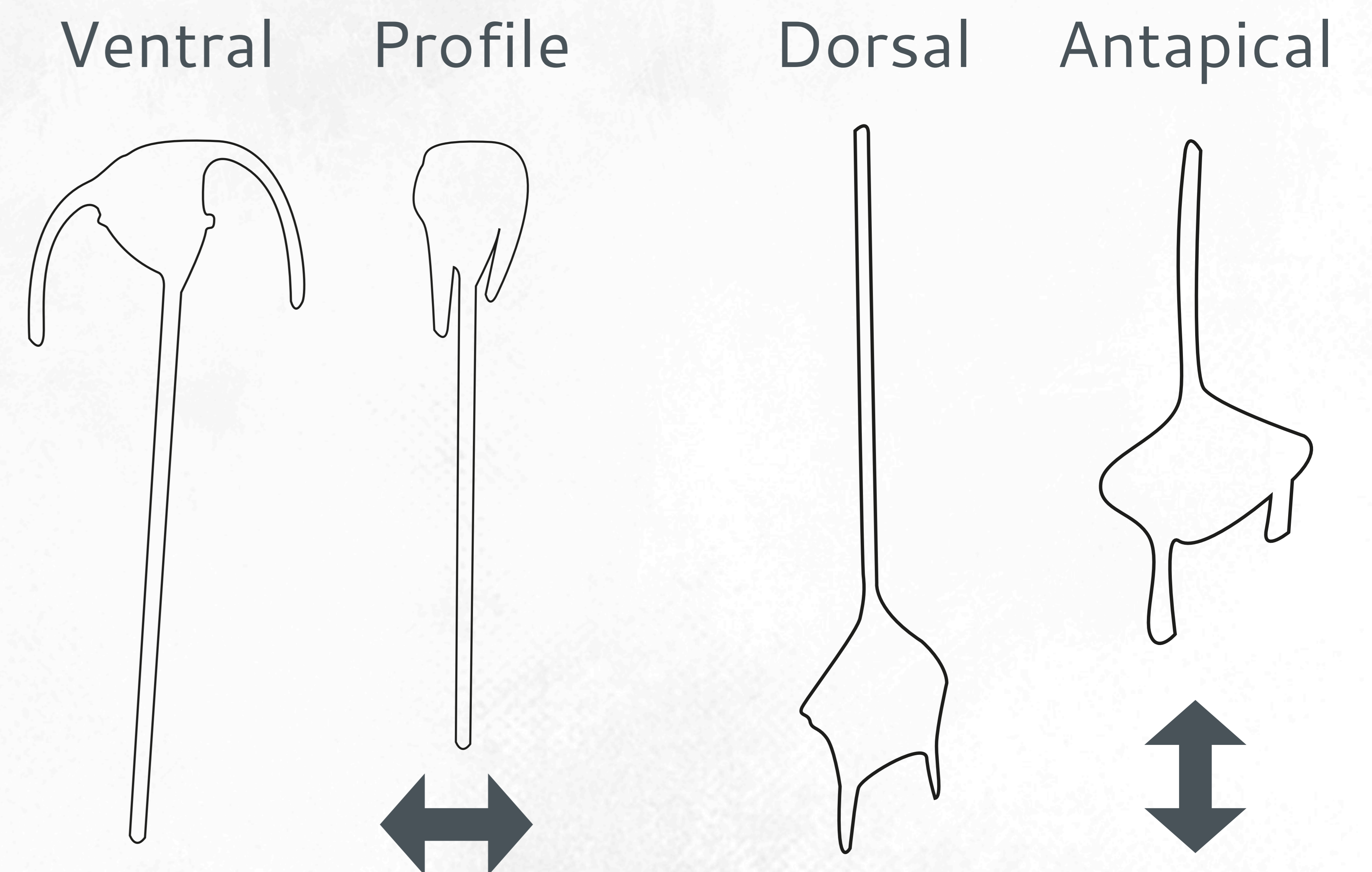


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a technique for high-throughput imaging

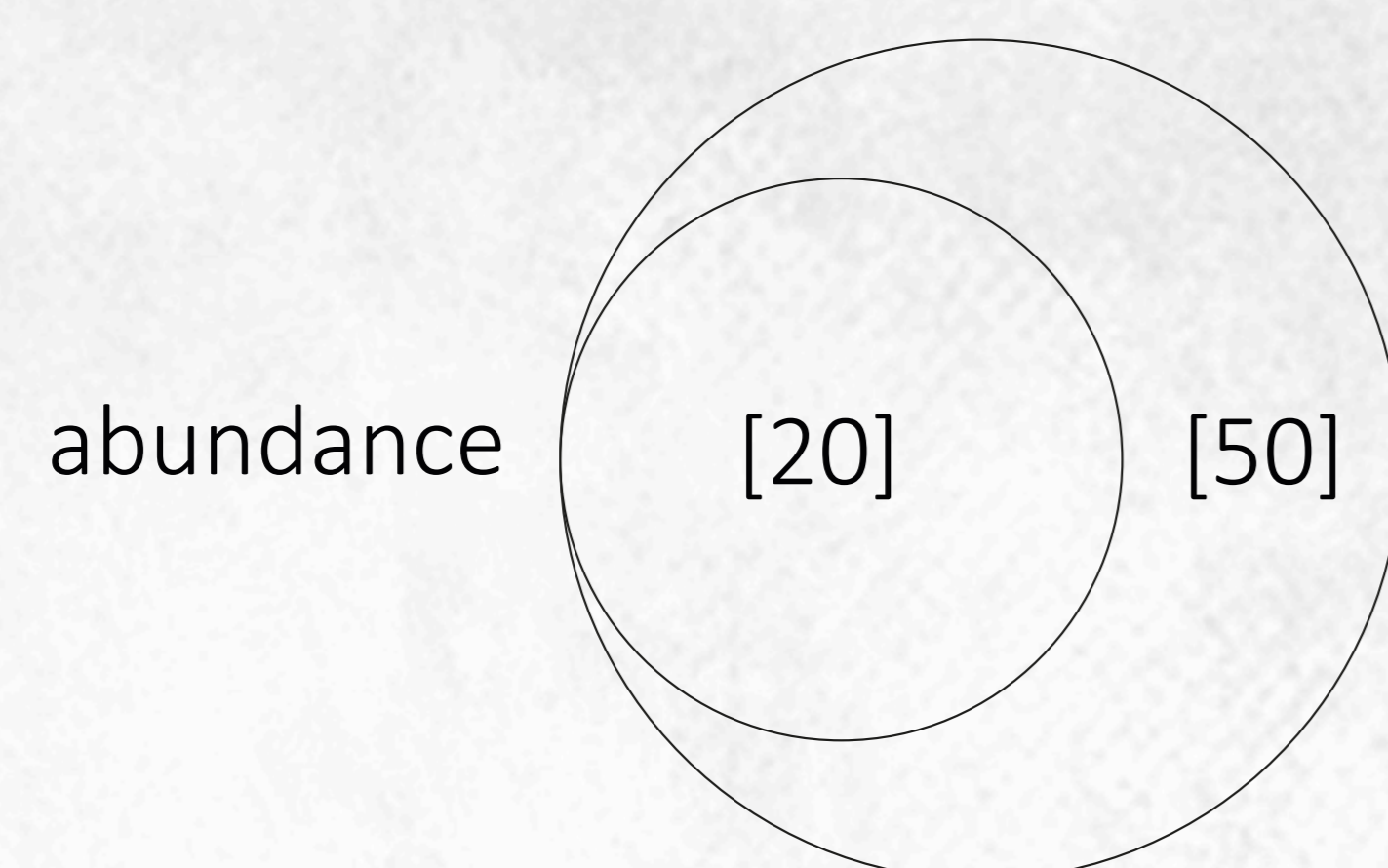
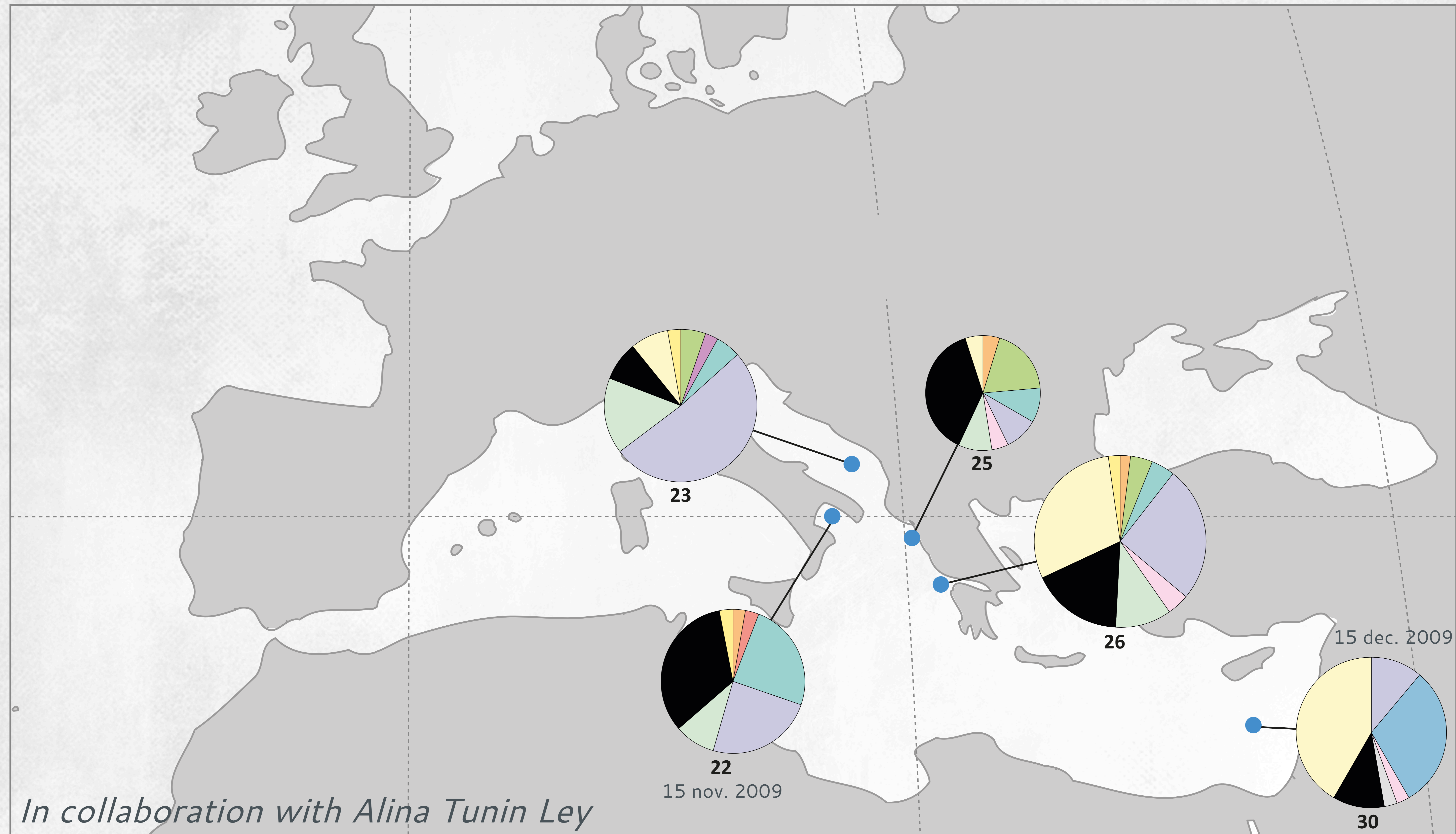


the challenge of the 3D



THE FLOWCAM

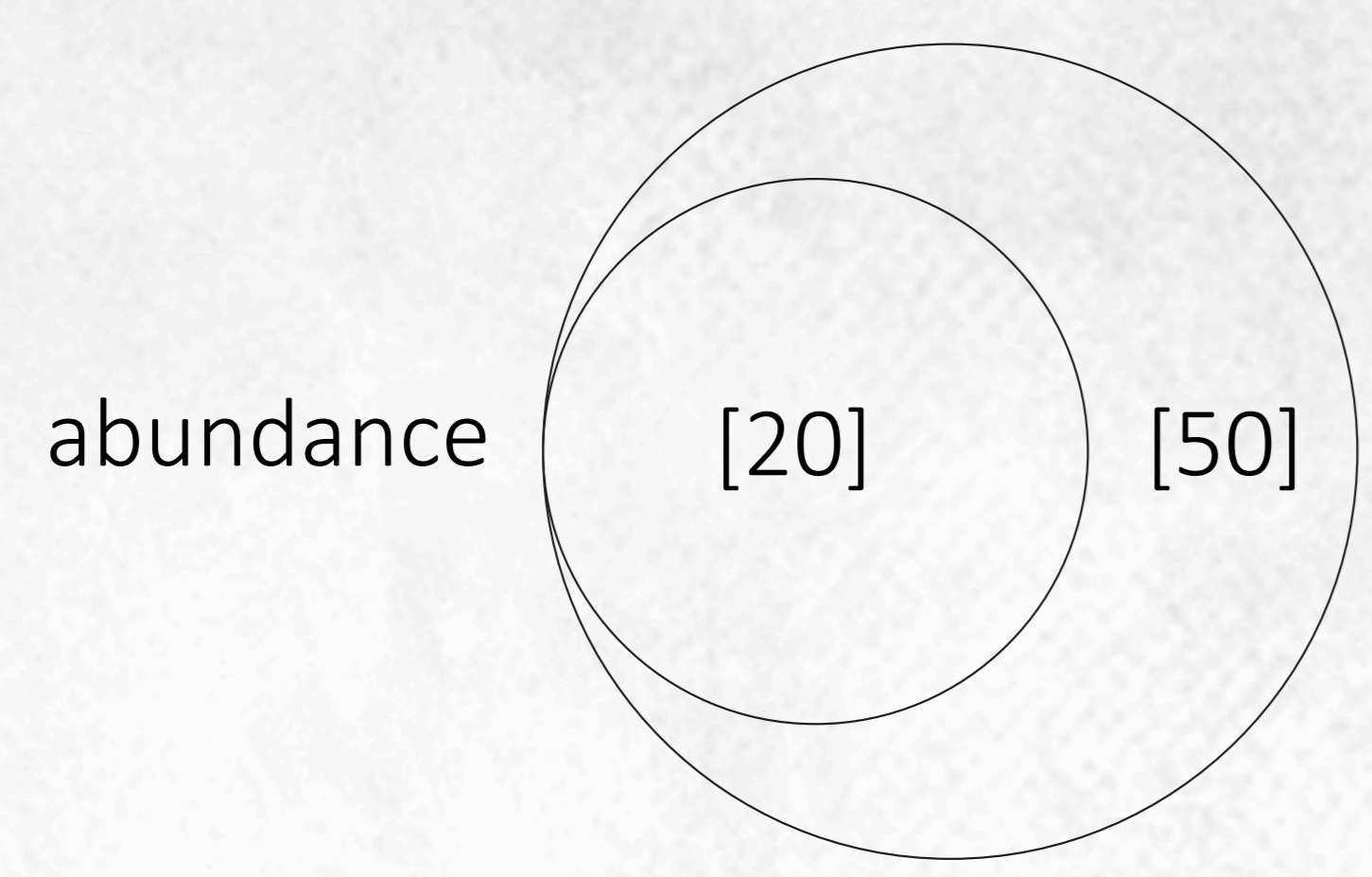
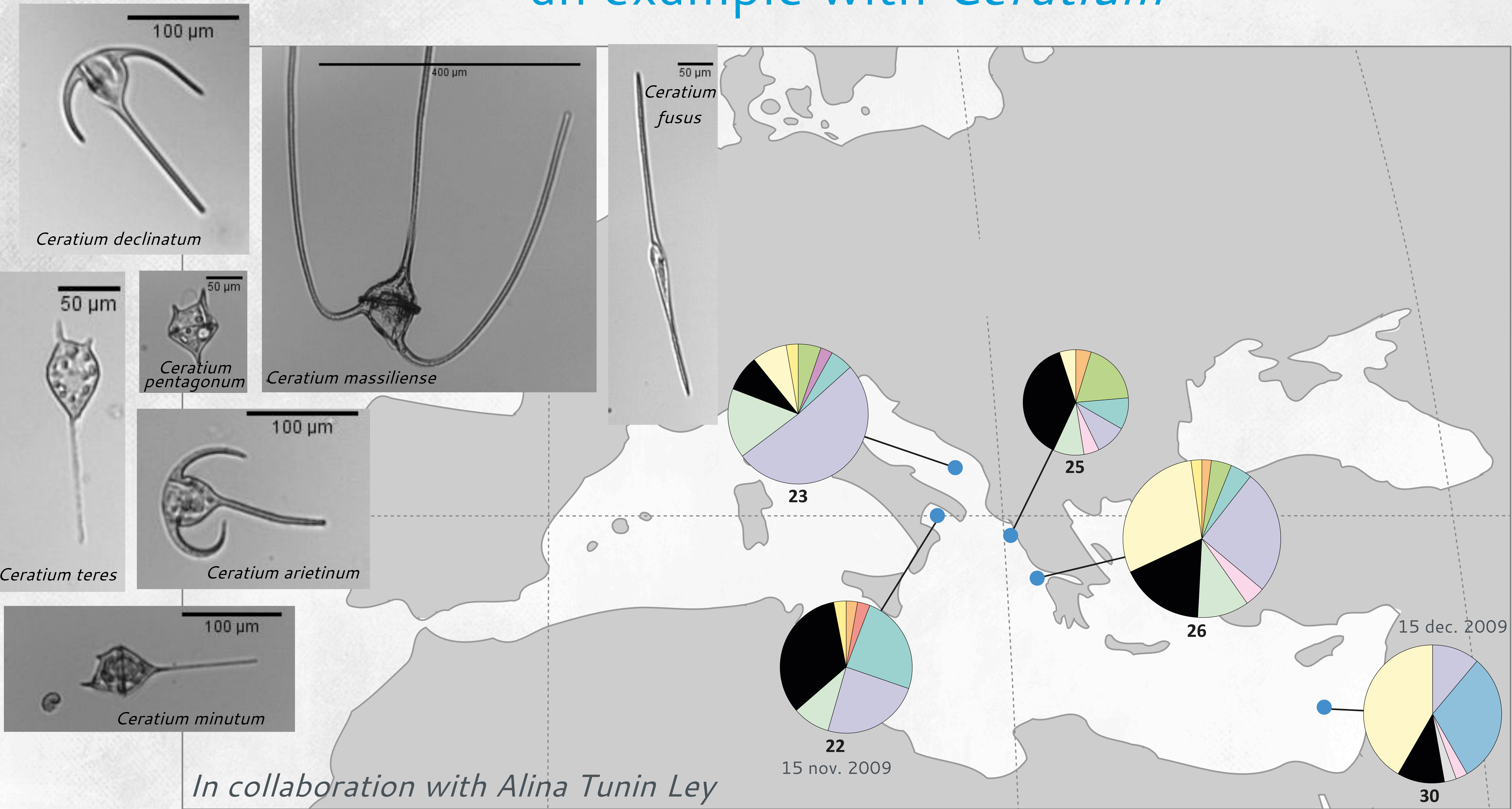
an example with *Ceratium*



- | | | | |
|----------------------------|----------------------------|-----------------------------|------------------------------|
| <i>Ceratium tripos</i> | <i>Ceratium macroceros</i> | <i>Ceratium extensum</i> | <i>Ceratium</i> undetermined |
| <i>Ceratium teres</i> | <i>Ceratium horridum</i> | <i>Ceratium declinatum</i> | |
| <i>Ceratium pentagonum</i> | <i>Ceratium fusus</i> | <i>Ceratium contortum</i> | |
| <i>Ceratium minutum</i> | <i>Ceratium furca</i> | <i>Ceratium candelabrum</i> | |

THE FLOWCAM

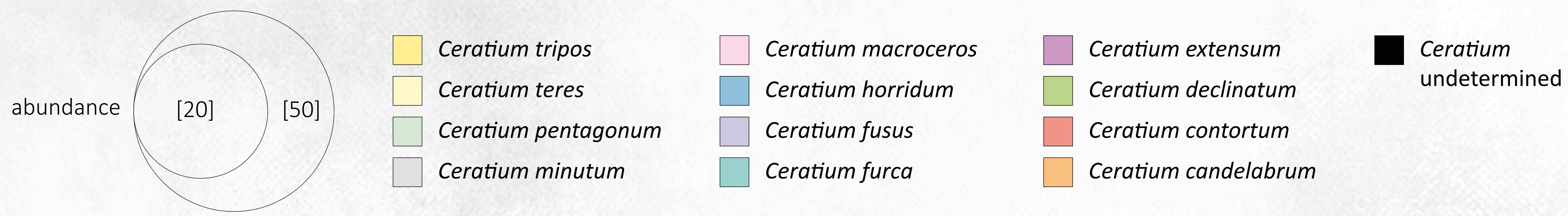
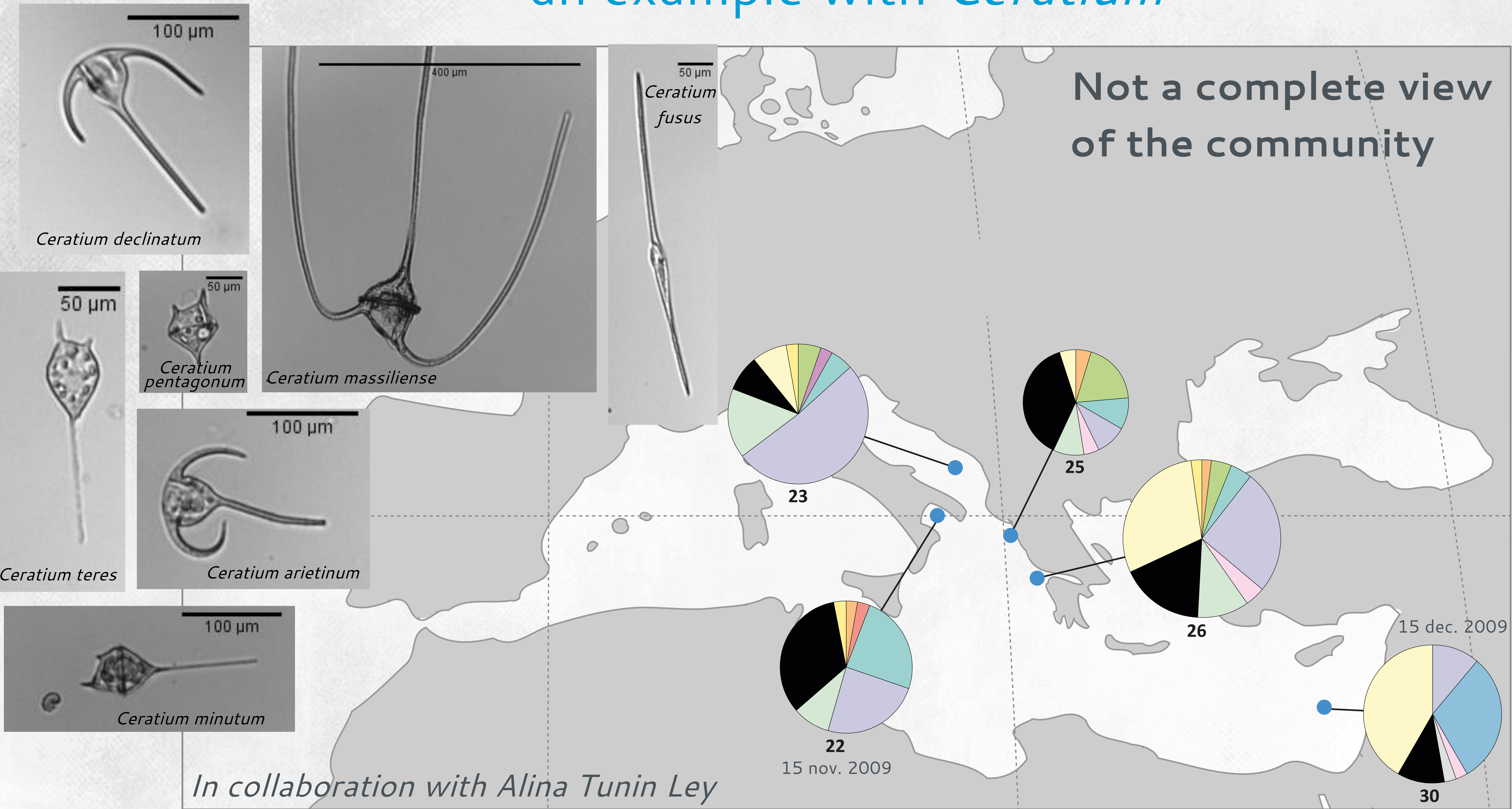
an example with *Ceratium*



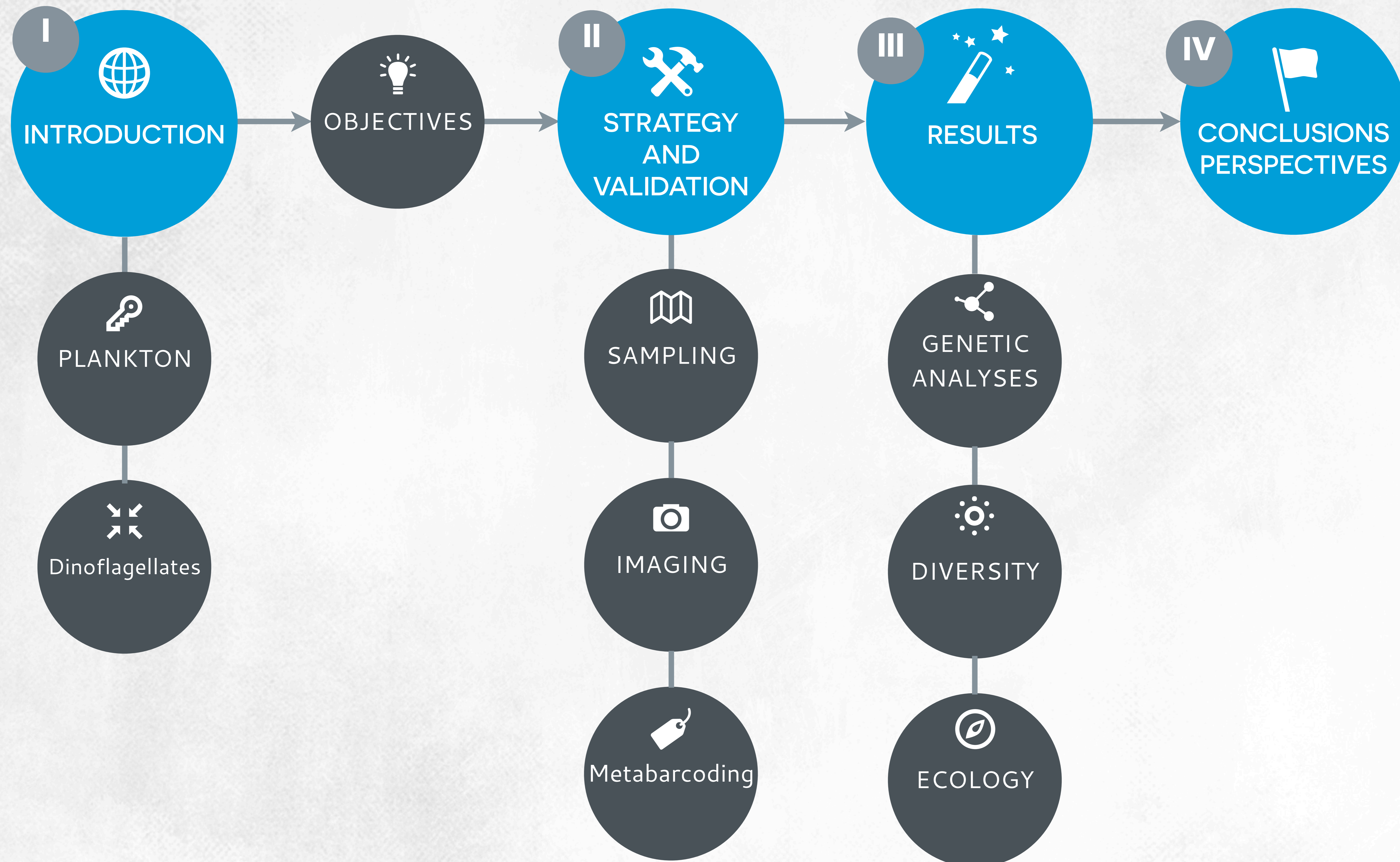
- | | | | |
|--|---|--|---|
| <i>Ceratium triplos</i> | <i>Ceratium macroceros</i> | <i>Ceratium extensum</i> | <i>Ceratium</i> undetermined |
| <i>Ceratium teres</i> | <i>Ceratium horridum</i> | <i>Ceratium declinatum</i> | |
| <i>Ceratium pentagonum</i> | <i>Ceratium fusus</i> | <i>Ceratium contortum</i> | |
| <i>Ceratium minutum</i> | <i>Ceratium furca</i> | <i>Ceratium candelabrum</i> | |

THE FLOWCAM

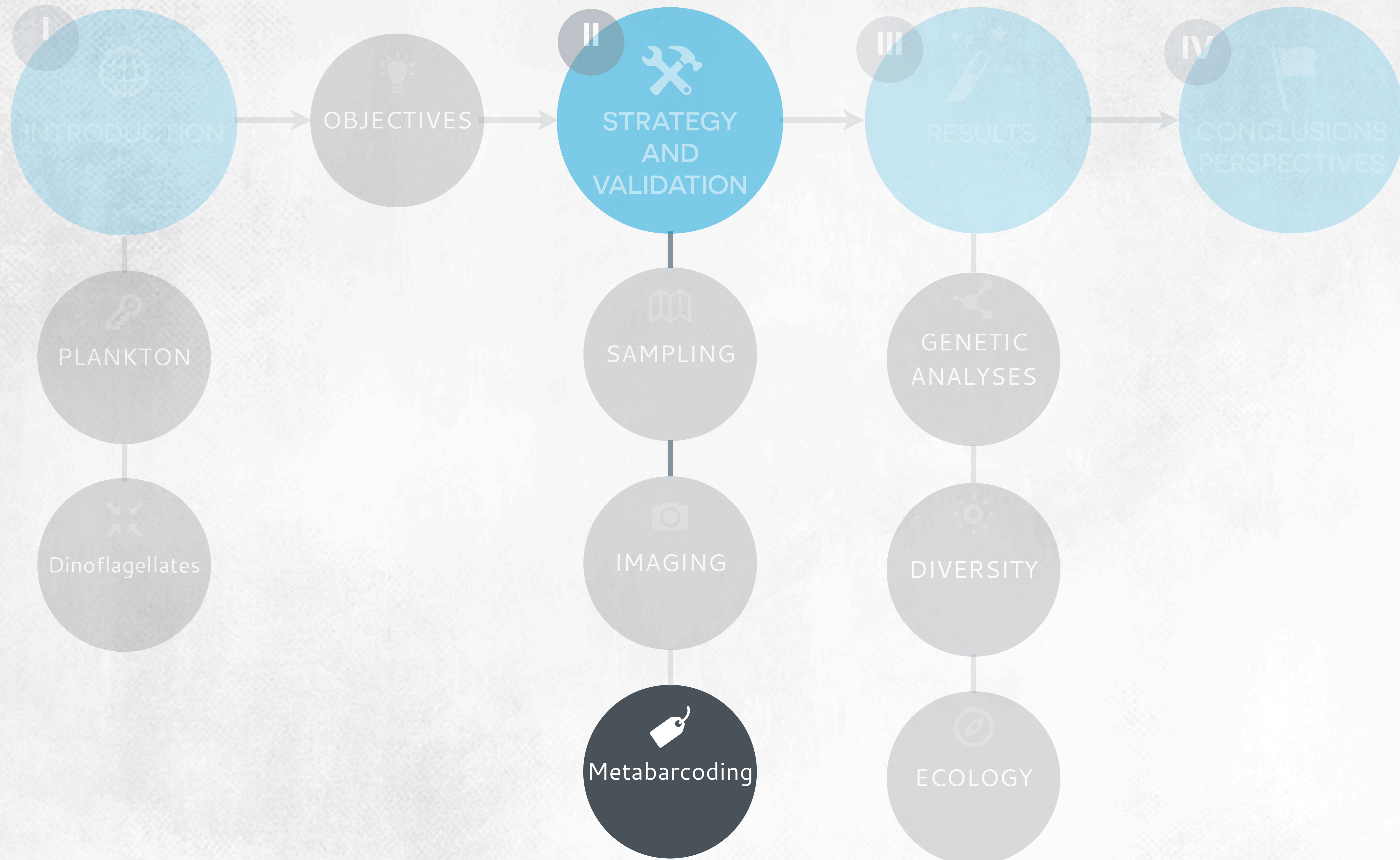
an example with *Ceratium*



PRESENTATION SUMMARY



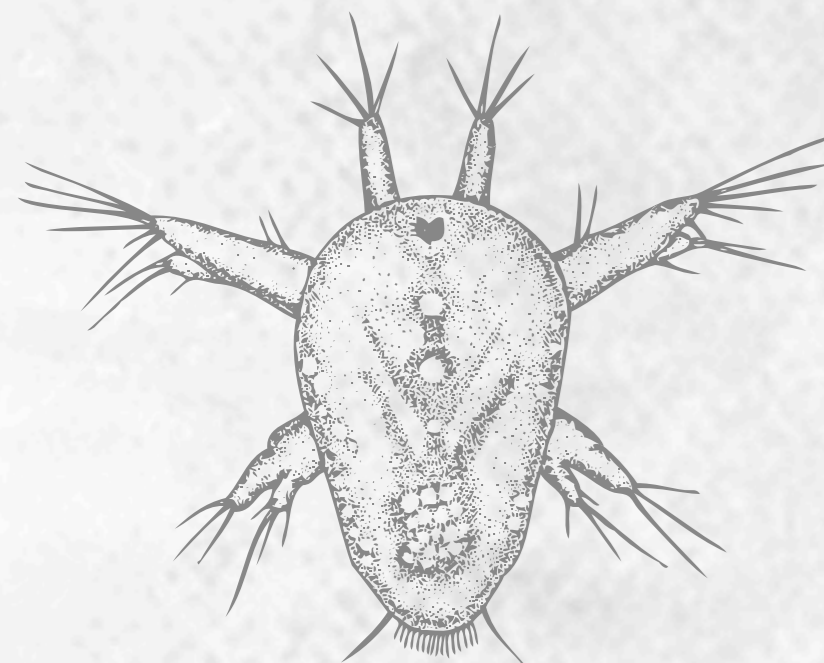
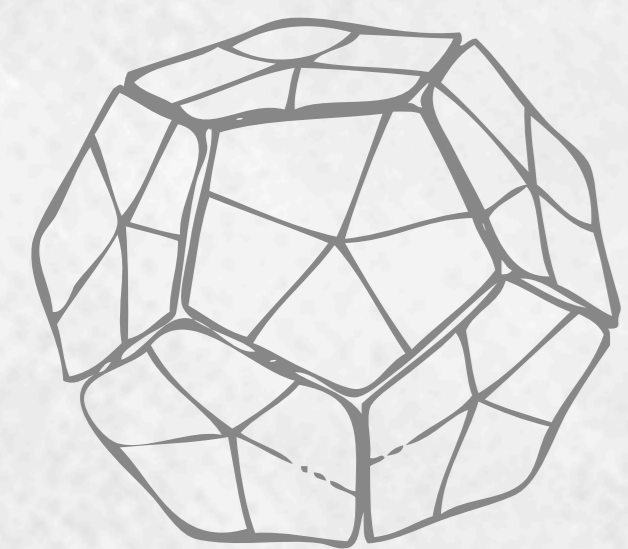
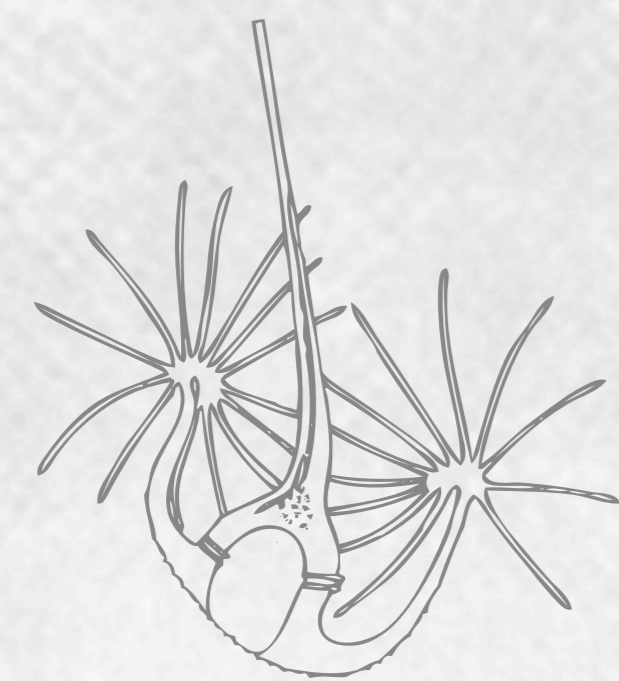
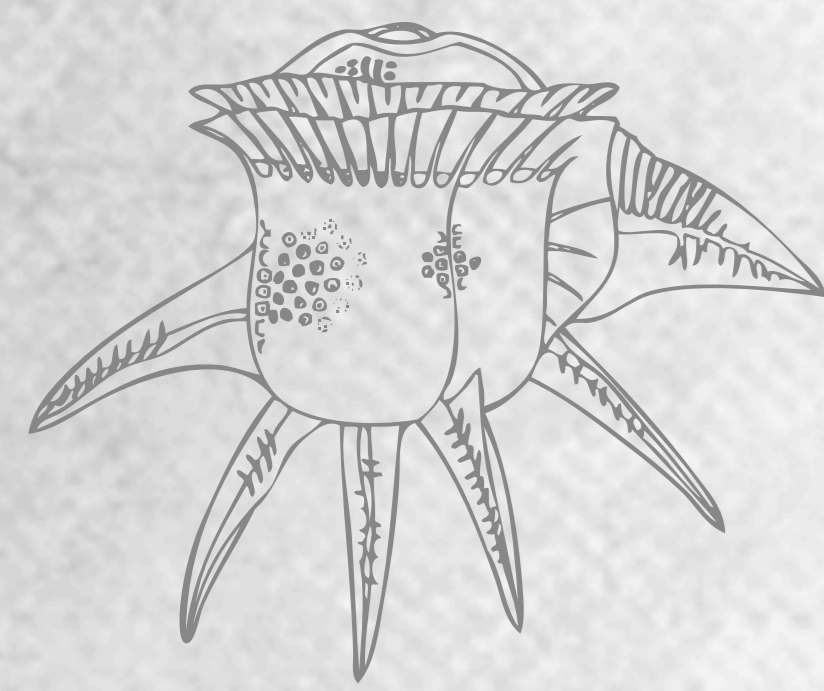
PRESENTATION SUMMARY



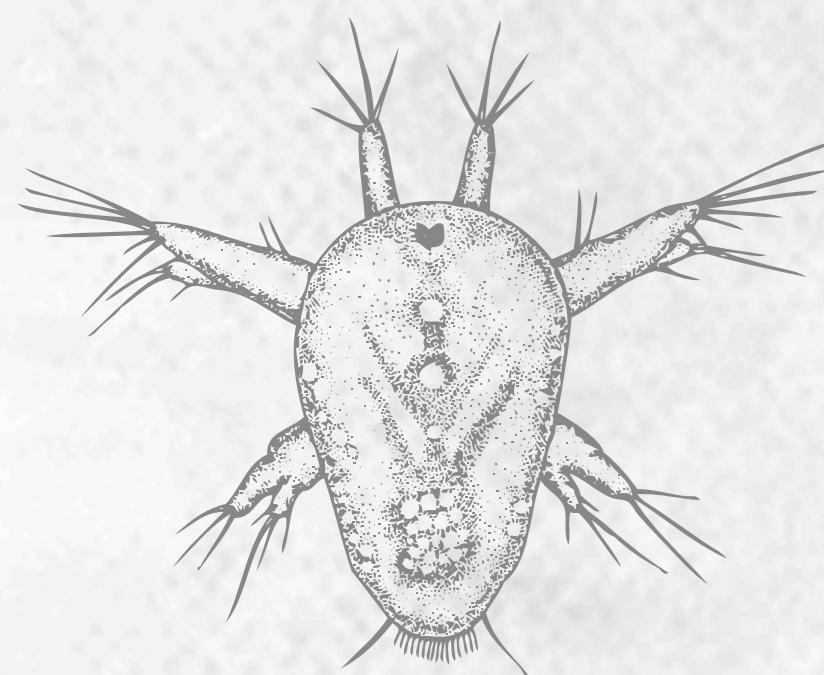
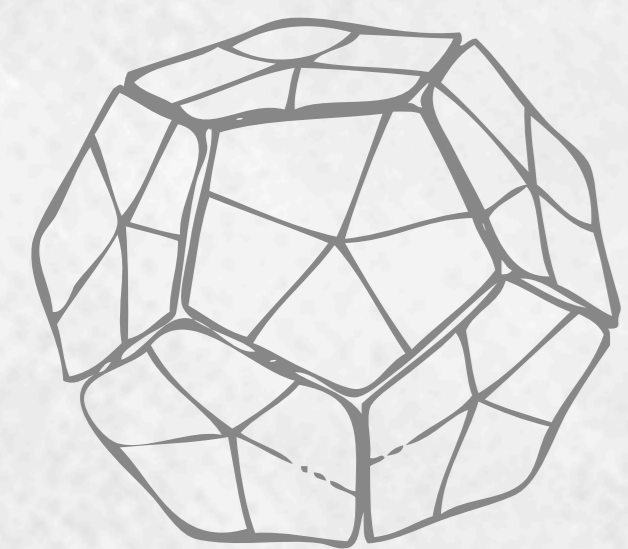
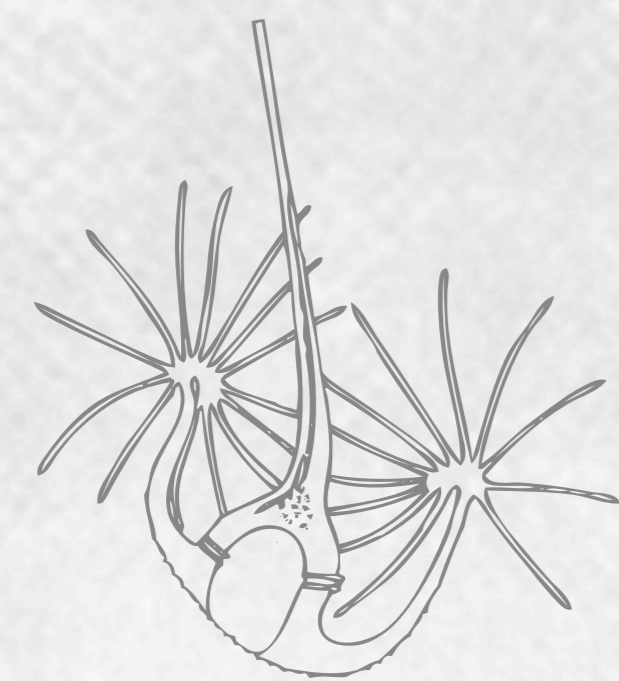
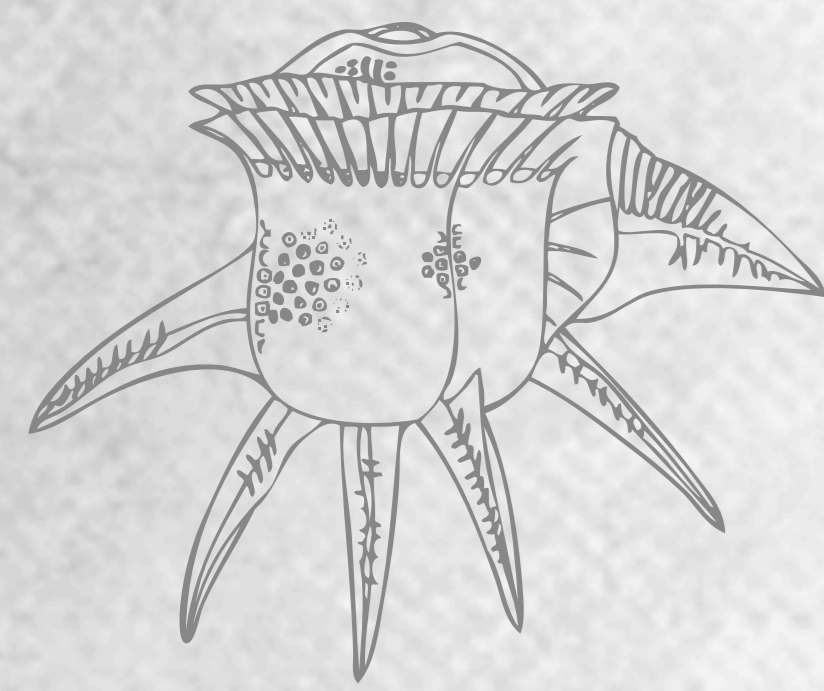
METABARCODING



METABARCODING



METABARCODING



Use of pre-barcode for protists

Pawlowski et al., 2012

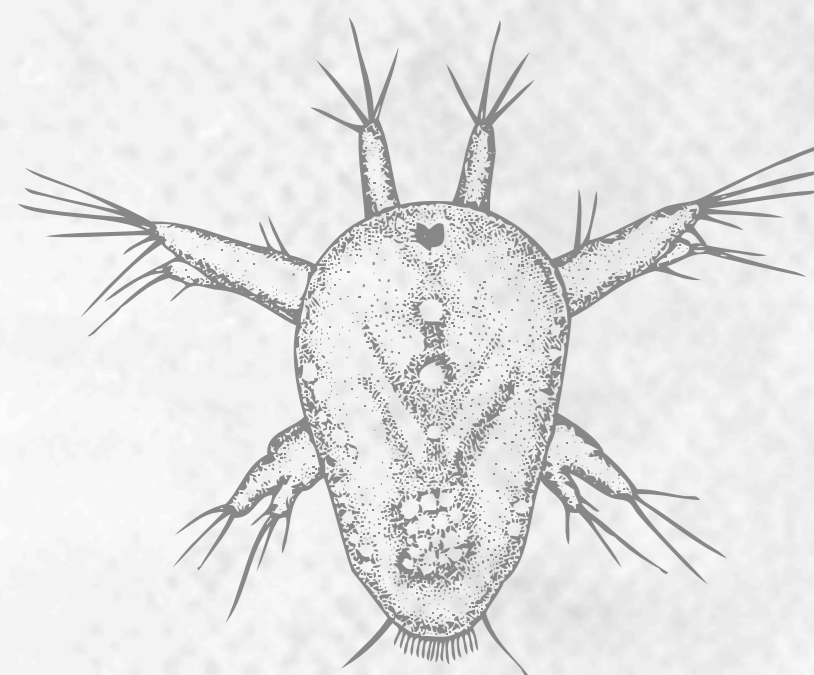
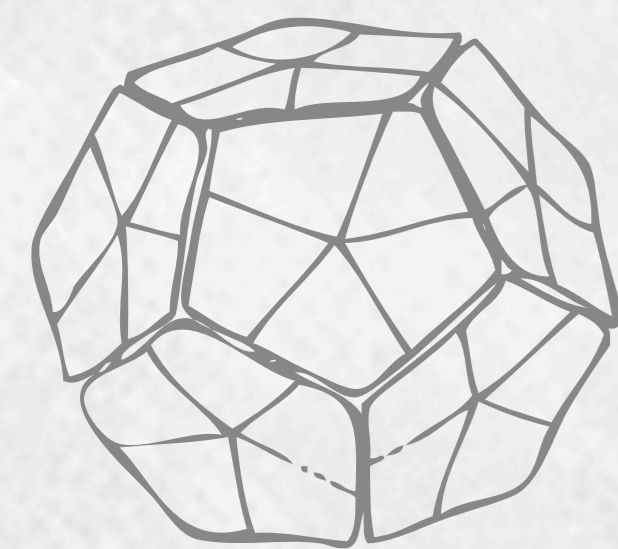
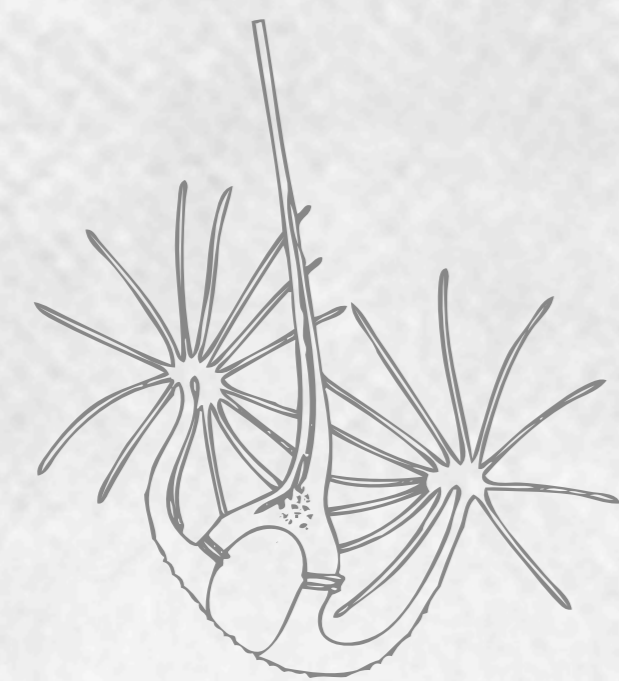
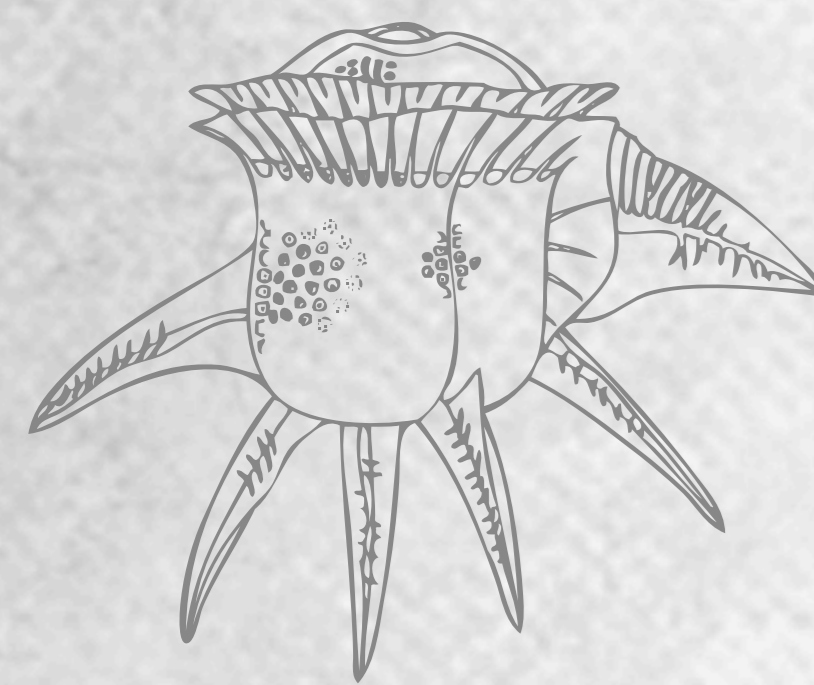
METABARCODING

Different markers have been tested for dinoflagellates:

Mitochondrial: COI, cob → problems of amplification, difficulties with environmental samples, few references

Zhang et al., 2007; Lin et al., 2009; Stern et al., 2010

Ribosomal (nuclear): ITS, LSU → variable rank of evolution (low resolution) *Stern et al., 2012; Saldarriaga et al., 2004*



Use of pre-barcode for protists

Pawlowski et al., 2012

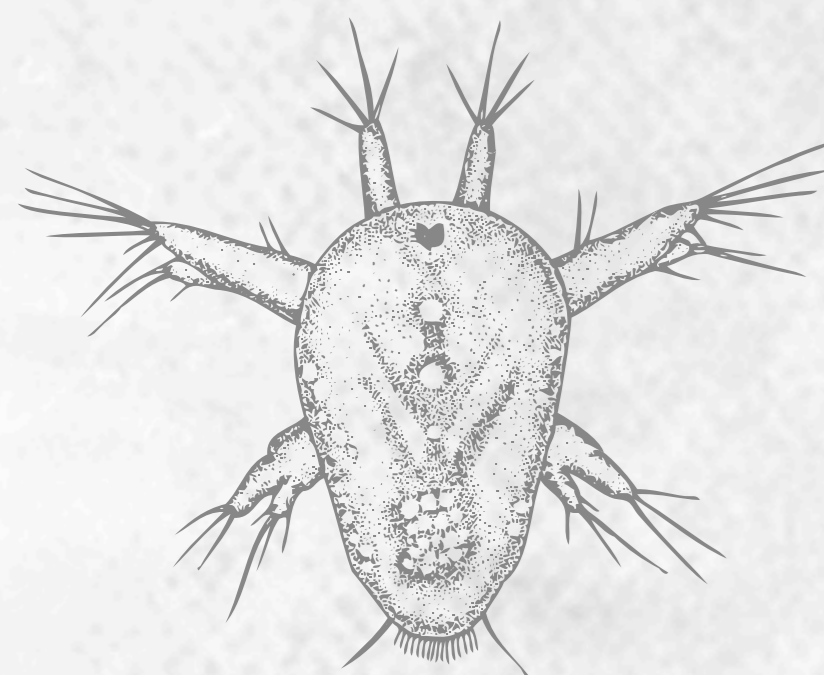
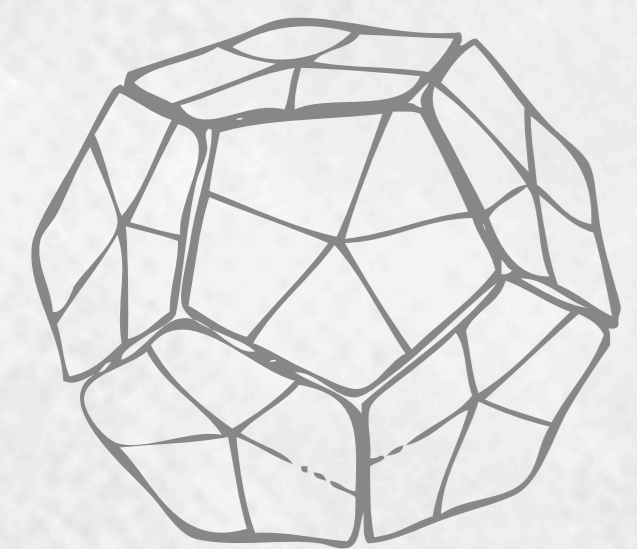
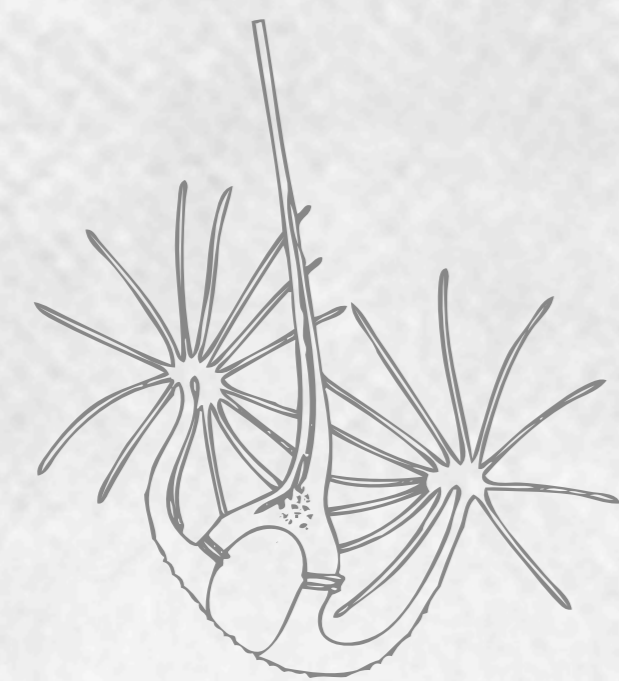
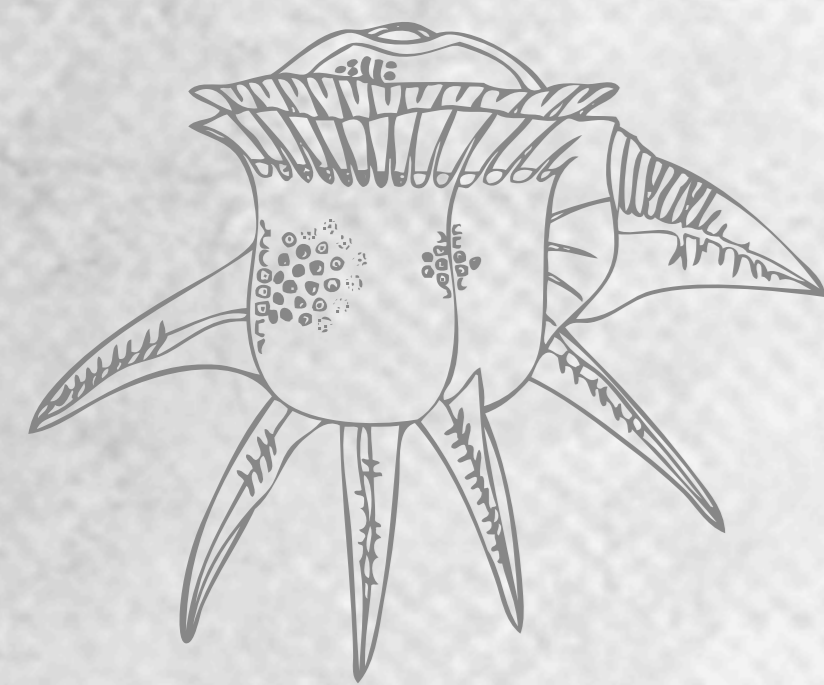
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Use of pre-barcode for protists

Pawlowski et al., 2012

- ▶ High number of references in 18S rDNA

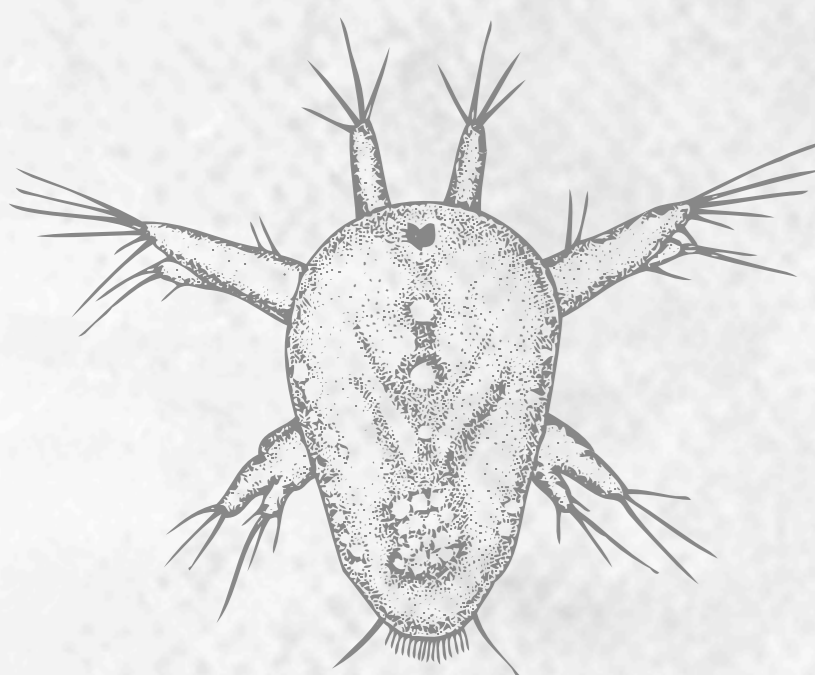
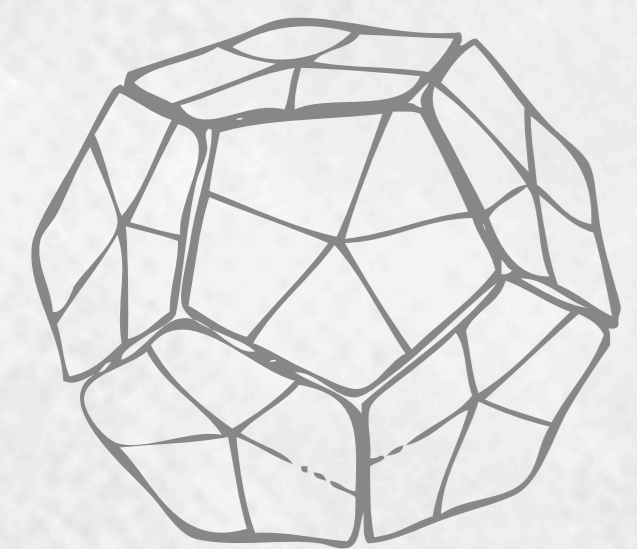
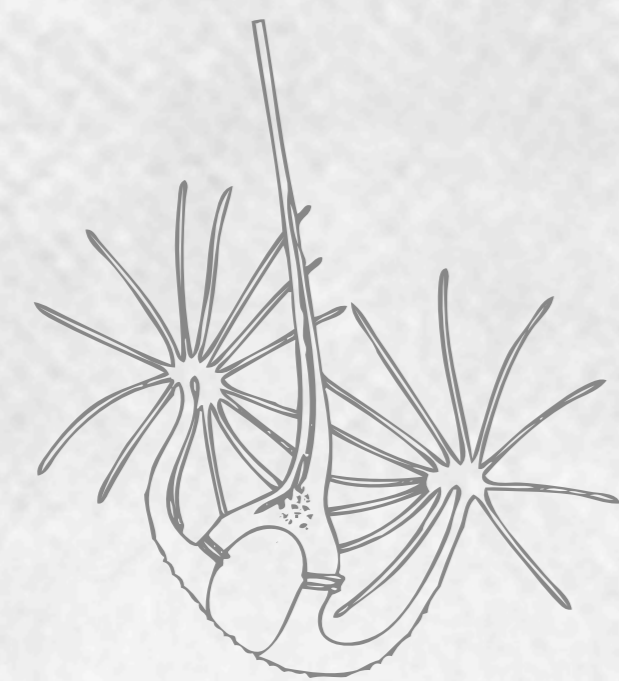
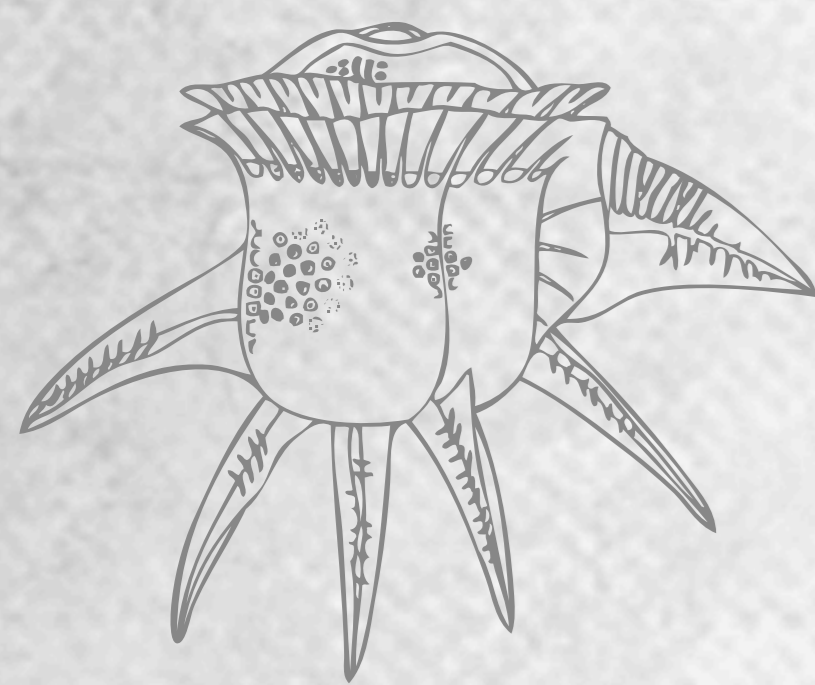
METABARCODING

Different markers have been tested for dinoflagellates:

Mitochondrial: COI, cob → problems of amplification, difficulties with environmental samples, few references

Zhang et al., 2007; Lin et al., 2009; Stern et al., 2010

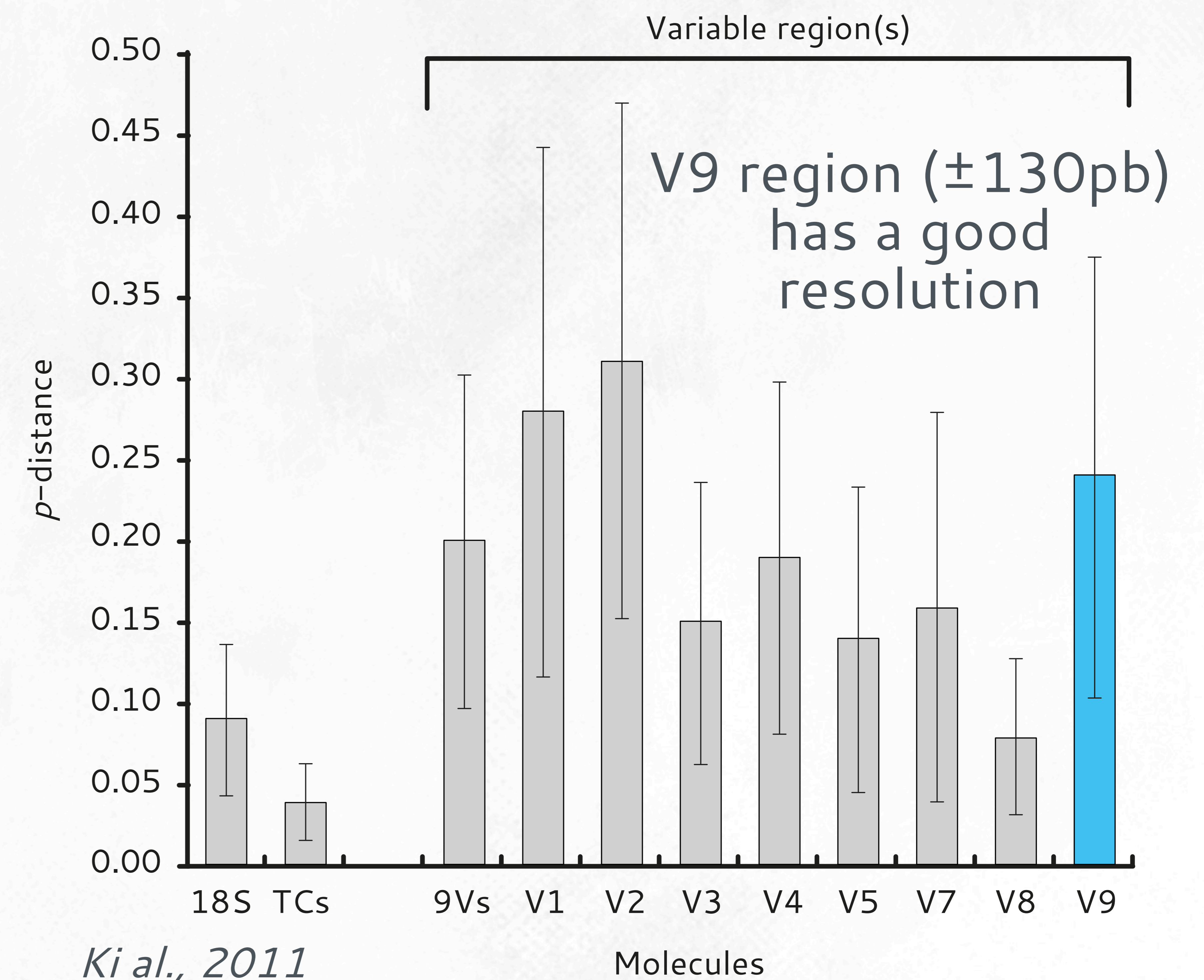
Ribosomal (nuclear): ITS, LSU → variable rank of evolution (low resolution) *Stern et al., 2012; Saldarriaga et al., 2004*



Use of pre-barcode for protists

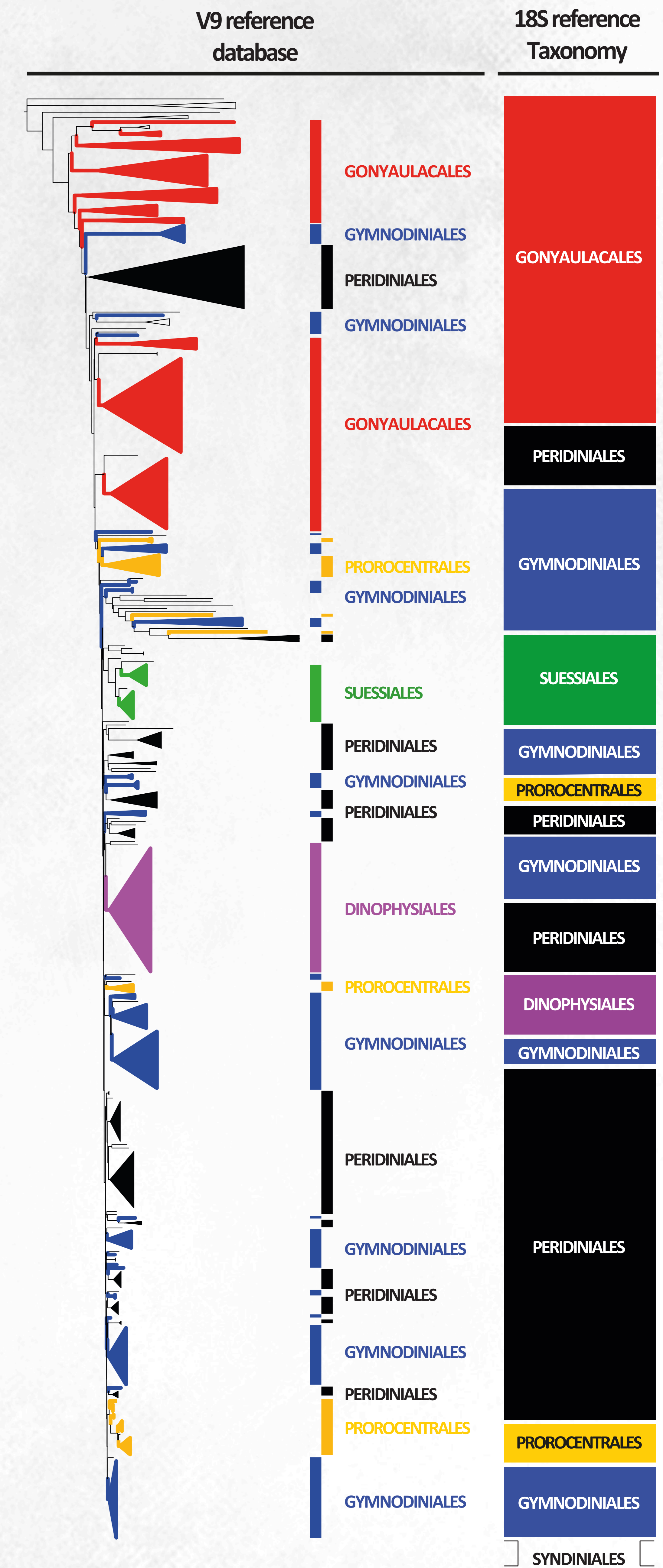
Pawlowski et al., 2012

- ▶ High number of references in 18S rDNA



REFERENCE DATABASE

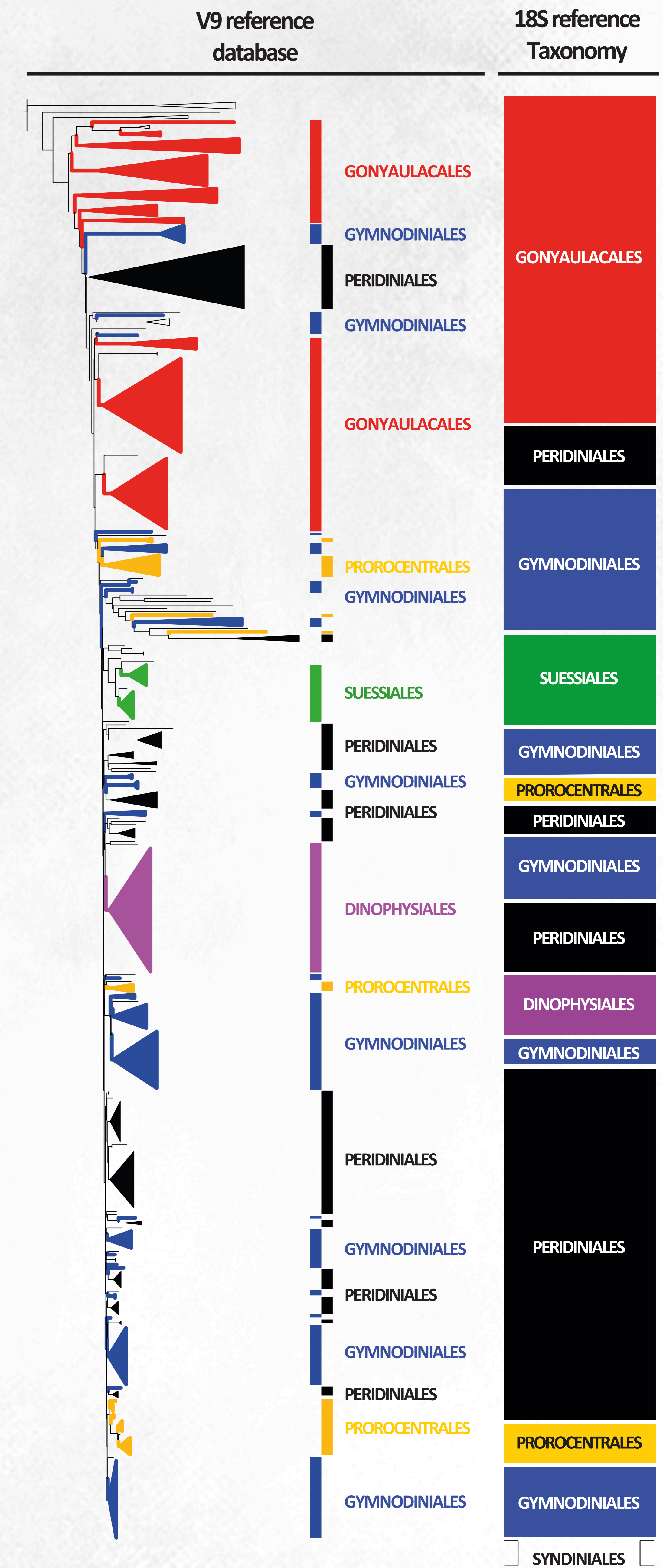
Database composed of dinoflagellate 18s rDNA sequences (including V4 and V9) available on NCBI before June, 30 2012



REFERENCE DATABASE

Database composed of dinoflagellate 18s rDNA sequences
(including V4 and V9) available on NCBI before June, 30 2012

▶ **1,191 ref sequences**
DinR2
Guillou et al., 2013



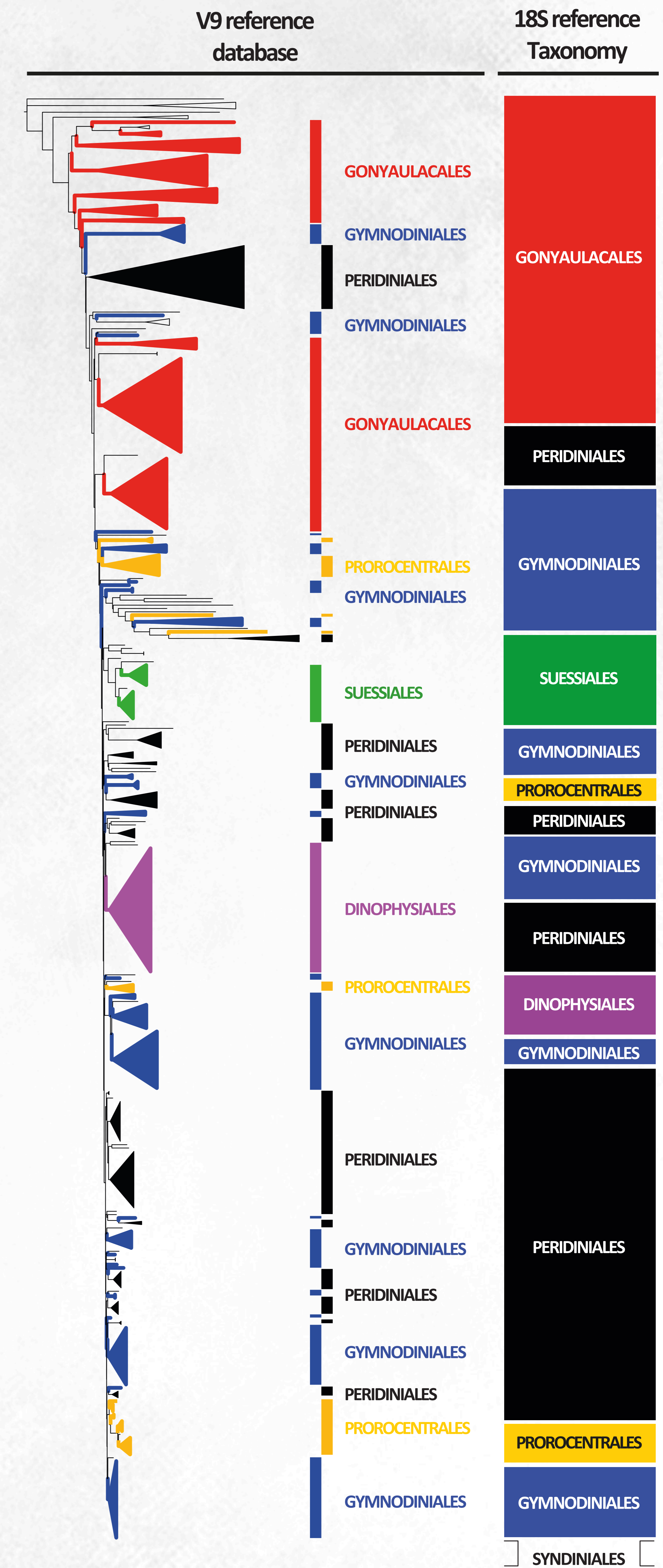
REFERENCE DATABASE

Database composed of dinoflagellate 18s rDNA sequences (including V4 and V9) available on NCBI before June, 30 2012

Dinoflagellates have been assigned to 11 orders:

- Dinophysiales
- Gonyaulacales
- Gymnodiniales
- Lophodinales
- Noctilucales
- Peridinales
- Phytodinales
- Prorocentrales
- Pyrocystales
- Suessiales
- Thoracosphaerales

and one group:
- Uncultured



REFERENCE DATABASE

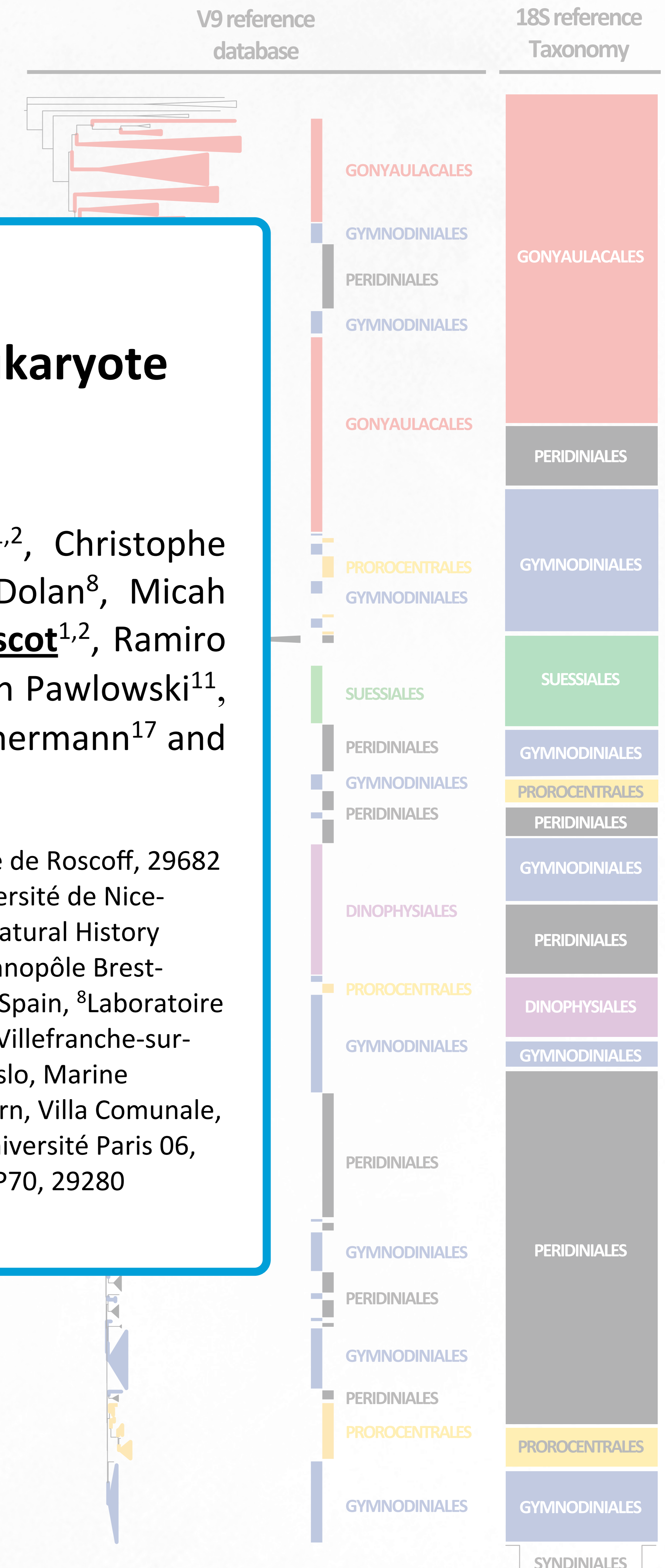
Database composed of dinoflagellate 18s rDNA sequences (including V4 and V9) available on NCBI before June, 30 2012

Published in *Nucleic Acids Research*, 2013, Vol. 41

The Protist Ribosomal Reference database (PR²): a catalog of unicellular eukaryote Small Sub-Unit rRNA sequences with curated taxonomy

Laure Guillou^{1,2}, Dipankar Bachar^{3,4}, Stéphane Audic^{1,2}, David Bass⁵, Cédric Berney⁵, Lucie Bittner^{1,2}, Christophe Boute^{1,2}, Gaétan Burgaud⁶, Colombar de Vargas^{1,2}, Johan Decelle^{1,2}, Javier del Campo⁷, John R. Dolan⁸, Micah Dunthorn⁹, Bente Edvardsen¹⁰, Maria Holzmann¹¹, Wiebe H.C.F. Kooistra¹², Enrique Lara¹³, **Noan Le Bescot**^{1,2}, Ramiro Logares⁷, Frédéric Mahé^{1,2}, Ramon Massana⁷, Marina Montresor¹², Raphael Morard^{1,2}, Fabrice Not^{1,2}, Jan Pawlowski¹¹, Ian Probert^{14,15}, Anne-Laure Sauvadet^{1,2}, Raffaele Siano¹⁶, Thorsten Stoeck⁹, Daniel Vaultot^{1,2}, Pascal Zimmermann¹⁷ and Richard Christen^{3,4}

¹CNRS, UMR 7144, Adaptation et Diversité en Milieu Marin, 29682 Roscoff, France, ²UPMC Université Paris 06, UMR 7144, Station Biologique de Roscoff, 29682 Roscoff, France, ³CNRS, UMR 7138, Systématique Adaptation Evolution, Parc Valrose, BP71. F06108 Nice cedex 02, France, ⁴UMR 7138, Université de Nice-Sophia Antipolis, Systématique Adaptation Evolution, Parc Valrose, BP71. F06108 Nice cedex 02, France, ⁵Department of Life Sciences, The Natural History Museum, Cromwell Road, London SW7 5BD, UK, ⁶Laboratoire Universitaire de Biodiversité et Ecologie Microbienne (EA3882), ESMISAB, Technopôle Brest-Iroise, 29280 Plouzané, France, ⁷Department of Marine Biology and Oceanography, Institut de Ciències del Mar (CSIC), Barcelona, Catalonia, Spain, ⁸Laboratoire d'Océanographie de Villefranche, Marine Microbial Ecology, UPMC Université Paris 06 et CNRS, UMR7093, Station Zoologique, BP28, 06230 Villefranche-sur-Mer, France, ⁹Department of Ecology, University of Kaiserslautern, 67663 Kaiserslautern, Germany, ¹⁰Department of Biology, University of Oslo, Marine Biology, NO-0316 Oslo, Norway, ¹¹Department of Genetics and Evolution, University of Geneva, Switzerland, ¹²Stazione Zoologica Anton Dohrn, Villa Comunale, 80121 Naples, Italy, ¹³Laboratory of Soil Biology, University of Neuchâtel, Rue Emile Argand 11, CH-2000, Neuchâtel, Switzerland, ¹⁴UPMC Université Paris 06, 29682 Roscoff, France, ¹⁵CNRS, FR2424, Station Biologique de Roscoff, 29682 Roscoff, France, ¹⁶Ifremer, Centre de Brest, DYNECO/Pelagos BP70, 29280 Plouzané, France and ¹⁷Point Compétence Informatique, Rue Jean-Baptiste Say, 56850 Caudan, France



Dinoflagellat

- Dinophys
- Gonyaula
- Gymnodin
- Lophodini
- Noctiluca
- Peridiniai
- Phytodini
- Prorocent
- Pyrocysta
- Suessiale
- Thoracos

and one group:
- Uncultured

REFERENCE DATABASE: VALIDATION

Taxonomy		Size fractions 20to180																					
		Presence/Absence																					
		stn052		stn064		stn065		stn066		stn067		stn068		stn070		stn072		stn076		stn078		stn082	
Order	Genus	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9
Dinophysiales	Dinophysis																						
	Histioneis																						
	Ornithocercus																						
	Phalacroma																						
Gonyaulacales	Alexandrium																						
	Amphidoma	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	
	Ceratocorys																						
	Cladopyxis	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	
	Goniodoma	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	
	Gonyaulax																						
	Lingulodinium																						
	Neoceratium																						
	Paleopalacroma	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	
	Protoceratium																						
Gymnodiniales	Amphidinium																						
	Gymnodinium																						
	Gyrodinium																						
Peridinales	Blepharocysta	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	
	Corythodinium	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	
	Diplopsalis																						
	Oxytoxum	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	
	Podolampas	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	
Prorocentrales	Protoperidinium																						
	Mesoporos	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	
	Prorocentrum																						
Pyrocystales	Pyrocystis																						
Other dinoflagellates																							

Microscopy observations were performed on fixed samples by Eleonora Scalco in Naples.

REFERENCE DATABASE: VALIDATION

Taxonomy		Size fractions 20to180																						
		Presence/Absence																						
		stn052		stn064		stn065		stn066		stn067		stn068		stn070		stn072		stn076		stn078		stn082		stn084
Order	Genus	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	
Dinophysiales	Dinophysis																							
	Histioneis																							
	Ornithocercus																							
	Phalacroma																							
Gonyaulacales	Alexandrium																							
	Amphidoma	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Ceratocorys																							
	Cladopyxis	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Goniodoma	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Gonyaulax																							
	Lingulodinium																							
	Neoceratium																							
	Paleopalacroma	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Protoceratium																							
Gymnodiniales	Amphidinium																							
	Gymnodinium																							
	Gyrodinium																							
Peridinales	Blepharocysta	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Corythodinium	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Diplopsalis																							
	Oxytoxum	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Podolampas	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
Prorocentrales	Protoperidinium																							
	Mesoporos	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Prorocentrum																							
Pyrocystales	Pyrocystis																							
Other dinoflagellates																								

► Only 2 genera present in DinR2 are not detected

- *Diplopsalis*
- *Phalacroma*

Microscopy observations were performed on fixed samples by Eleonora Scalco in Naples.

REFERENCE DATABASE: VALIDATION

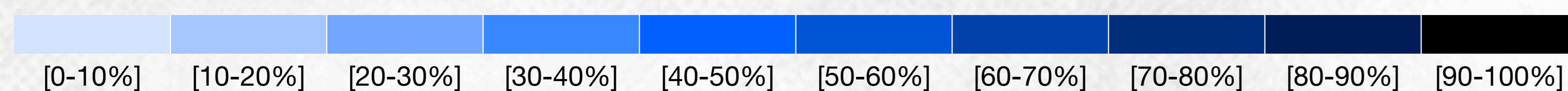
Taxonomy		Size fractions 20to180																						
		Presence/Absence																						
		stn052		stn064		stn065		stn066		stn067		stn068		stn070		stn072		stn076		stn078		stn082		stn084
Order	Genus	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	
Dinophysiales	Dinophysis																							
	Histioneis																							
	Ornithocercus																							
	Phalacroma																							
Gonyaulacales	Alexandrium																							
	Amphidoma	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Ceratocorys																							
	Cladopyxis	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Goniodoma	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Gonyaulax																							
	Lingulodinium																							
	Neoceratium																							
	Paleopalacroma	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Protoceratium																							
Gymnodiniales	Amphidinium																							
	Gymnodinium																							
	Gyrodinium																							
Peridinales	Blepharocysta	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Corythodinium	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Diplopsalis																							
	Oxytoxum	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Podolampas	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
Prorocentrales	Protoperidinium																							
	Mesoporos	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
Pyrocystales	Prorocentrum																							
	Pyrocystis																							
Other dinoflagellates																								

► Only 2 genera present in DinR2 are not detected

- *Diplopsalis*
- *Phalacroma*

Taxonomy		Size fractions 20to180																							
		Abundance (in %)																							
		stn052		stn064		stn065		stn066		stn067		stn068		stn070		stn072		stn076		stn078		stn082		stn084	
Order	Genus	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9		
Dinophysiales	Dinophysis		0,03	1,47	0,02	13,64	0,01					2,05	0,01	0,76	0,04			2,90	0,01	5,31	0,06		0,11	2,02	3,01
	Histioneis		0,18		0,09		0,09					0,68			0,01			0,83	0,10	0,88	0,02				
	Ornithocercus	7,14	9,19		3,20		0,73						0,11		0,84			2,30	0,41	2,95		0,96			
	Phalacroma						6,25						6,11		2,17		1,24		0,88						
Gonyaulacales	Alexandrium		7,77		2,93		1,76		8,66	2,63	0,71	4,79	2,23	2,29	2,60		3,79	0,83	7,04		12,22		0,05		
	Amphidoma		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	0,83	N/A		N/A		N/A		N/A
	Ceratocorys		0,17		0,09		0,15							0,06		0,02	0,41	0,17	1,77	2,29					
	Cladopyxis		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	0,83	N/A	N/A		N/A		N/A	N/A
	Goniodoma		N/A		N/A		N/A	4,69	N/A		N/A	2,05	N/A		N/A		N/A	2,49	N/A	7,08	N/A		N/A		N/A
	Gonyaulax	3,57	7,61	13,24	7,11		2,45	28,13	52,50	1,32	0,28	5,48	2,77	8,40	5,68	13,04	7,13	8,71	8,94	34,51	20,14	1,77	0,79		
	Lingulodinium		0,02		0,01		9,09		6,25	0,06			1,53				0,02				0,05				
	Neoceratium	21,43	23,03	7,35	21,53	18,18	12,62	1,56	7,58		1,05	33,56	21,01	12,21	26,09	13,04	29,98	32,78	57,16	4,42	17,15	16,81	56,54		0,21
	Paleopalacroma		N/A		2,94		N/A		N/A		N/A		N/A	1,53	N/A		N/A	1,66	N/A		N/A		N/A		N/A
	Protoceratium	3,57	0,02		0,01						1,07			0,76	0,01			4,56		0,88	0,33				
Gymnodiniales	Amphidinium		0,06		0,04		0,11					0,01		0,07		0,05		0,03		0,02	0,88	0,01		0,01	
	Gymnodinium		1,56		0,20		0,20	1,56	0,10		0,01		11,45	0,58	13,04	0,27		0,08		0,04	5,31				
	Gyrodinium		0,03		0,02		0,12	1,56	0,01		0,12		0,01	0,76	0,03		0,25		0,02		0,01				
Peridinales	Blepharocysta		N/A	4,41	N/A	18,18	N/A	N/A		N/A	13,01	N/A	0,76	N/A	2,17	N/A	5,39	N/A	4,42	N/A		N/A		N/A	
	Corythodinium		N/A		N/A		N/A		N/A		0,68	N/A		N/A		N/A		N/A		N/A		N/A		N/A	
	Diplopsalis			5,88			0,01	1,56		1,32		2,05					0,41		2,65						
	Oxytoxum		N/A	2,94	N/A		N/A	1,56	N/A		N/A	2,05	N/A	0,76	N/A	8,70	N/A	0,83	N/A		N/A		N/A		N/A
	Podolampas	3,57	N/A		N/A		N/A	1,56	N/A		N/A	1,37	N/A		N/A		N/A	1,24	N/A		N/A		N/A		N/A
Prorocentrales	Protoperidinium	17,86	18,65	23,53	26,00	36,36	55,01	9,38	13,55	35,53	76,03	24,66	59,06	22,14	27,50	15,22	23,80	17,01	4,89	12,39	18,89	59,29	11,63	64,65	14,29
	Mesoporos		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	0,88	N/A		N/A		N/A
Pyrocystales	Prorocentrum		0,10		0,08		0,11	6,25	0,31	38,16	2,35	2,74	0,09	4,58	0,45	2,17	0,14		0,06	2,65	0,05	1,77	0,07	2,02	0,23
	Pyrocystis		1,57		0,28		0,61	1,56	0,17				0,04	2,29	3,16		0,47		0,48		0,24				
Other dinoflagellates		42,86	19,00	36,76	34,52	4,55	21,10	28,13	15,58	21,05	18,18	4,11	14,05	22,90	30,99	30,43	30,51	10,37	15,97	21,24	24,25	14,16	30,75	31,31	81,62

► Most abundant genera and orders are found with the two methods



Microscopy observations were performed on fixed samples by Eleonora Scalco in Naples.

REFERENCE DATABASE: VALIDATION

Taxonomy		Size fractions 20to180																						
		Presence/Absence																						
		stn052		stn064		stn065		stn066		stn067		stn068		stn070		stn072		stn076		stn078		stn082		stn084
Order	Genus	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	
Dinophysiales	Dinophysis																							
	Histioneis																							
	Ornithocercus																							
	Phalacroma																							
Gonyaulacales	Alexandrium																							
	Amphidoma	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Ceratocorys																							
	Cladopyxis	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Goniodoma	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Gonyaulax																							
	Lingulodinium																							
	Neoceratium																							
	Paleopalacroma	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Protoceratium																							
Gymnodiniales	Amphidinium																							
	Gymnodinium																							
	Gyrodinium																							
Peridinales	Blepharocysta	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Corythodinium	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Diplopsalis																							
	Oxytoxum	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
	Podolampas	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A
Prorocentrales	Prorocentrum																							
	Pyrocystis																							
Other dinoflagellates																								

► Only 2 genera present in DinR2 are not detected

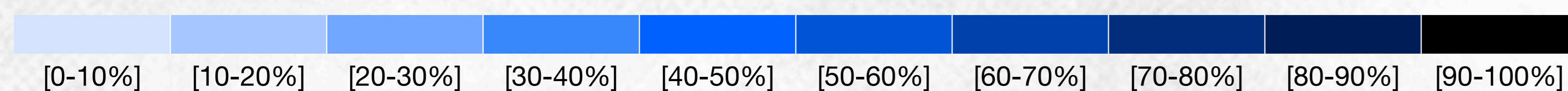
→ *Diplopsalis*

→ *Phalacroma*

► DinR2 seems to be adapted to identify orders and genera

Taxonomy		Size fractions 20to180																								
		Abundance (in %)																								
		stn052		stn064		stn065		stn066		stn067		stn068		stn070		stn072		stn076		stn078		stn082		stn084		
Order	Genus	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9	Micro	V9			
Dinophysiales	Dinophysis		0,03	1,47	0,02	13,64	0,01					2,05	0,01	0,76	0,04			2,90	0,01	5,31	0,06		0,11	2,02	3,01	
	Histioneis		0,18		0,09							0,68				0,15		0,83	0,10	0,88	0,02					
	Ornithocercus	7,14	9,19		3,20		0,73						0,11		0,84		2,30	0,41	2,95		0,96					
	Phalacroma						6,25						6,11		2,17		1,24		0,88							
Gonyaulacales	Alexandrium		7,77		2,93		1,76		8,66	2,63	0,71	4,79	2,23	2,29	2,60		3,79	0,83	7,04		12,22		0,05			
	Amphidoma		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	0,83	N/A		N/A		N/A		N/A	
	Ceratocorys		0,17		0,09		0,15							0,06		0,02	0,41	0,17	1,77	2,29						
	Cladopyxis		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	0,83	N/A	N/A		N/A		N/A		
	Goniodoma		N/A		N/A		N/A	4,69	N/A		N/A	2,05	N/A		N/A		N/A	2,49	N/A	7,08	N/A		N/A		N/A	
	Gonyaulax	3,57	7,61	13,24	7,11		2,45	28,13	52,50	1,32	0,28	5,48	2,77	8,40	5,68	13,04	7,13	8,71	8,94	34,51	20,14	1,77	0,79			
	Lingulodinium		0,02		0,01		9,09		6,25	0,06				1,53			0,02				0,05					
	Neoceratium	21,43	23,03	7,35	21,53	18,18	12,62	1,56	7,58		1,05	33,56	21,01	12,21	26,09	13,04	29,98	32,78	57,16	4,42	17,15	16,81	56,54		0,21	
	Paleopalacroma		N/A		2,94		N/A		N/A		N/A		N/A	1,53	N/A		N/A	1,66	N/A		N/A		N/A		N/A	
	Protoceratium	3,57	0,02		0,01						1,07				0,76	0,01				0,88	0,33					
Gymnodiniales	Amphidinium		0,06		0,04		0,11						0,01		0,07		0,05		0,03		0,02	0,88	0,01		0,01	
	Gymnodinium		1,56		0,20		0,20	1,56	0,10		0,01			11,45	0,58	13,04	0,27		0,08		0,04	5,31				
	Gyrodinium		0,03		0,02		0,12	1,56	0,01		0,12		0,01	0,76	0,03		0,25		0,02		0,01					
Peridinales	Blepharocysta		N/A	4,41	N/A	18,18	N/A	N/A		N/A	13,01	N/A	0,76	N/A	2,17	N/A	5,39	N/A	4,42	N/A		N/A		N/A		
	Corythodinium		N/A		N/A		N/A		N/A		0,68	N/A		N/A		N/A		N/A		N/A		N/A		N/A		
	Diplopsalis			5,88			0,01	1,56		1,32			2,05				0,41		2,65							
	Oxytoxum		N/A	2,94	N/A		N/A	1,56	N/A		N/A	2,05	N/A	0,76	N/A	8,70	N/A	0,83	N/A		N/A		N/A		N/A	
	Podolampas	3,57	N/A		N/A		N/A	1,56	N/A		N/A	1,37	N/A		N/A		N/A	1,24	N/A		N/A		N/A		N/A	
Prorocentrales	Prorocentrum	17,86	18,65	23,53	26,00	36,36	55,01	9,38	13,55	35,53	76,03	24,66	59,06	22,14	27,50	15,22	23,80	17,01	4,89	12,39	18,89	59,29	11,63	64,65	14,29	
	Mesoporos		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	0,88	N/A		N/A		N/A	
Pyrocystales	Pyrocystis		1,57		0,28		0,61	1,56	0,17		38,16	2,35	2,74	0,09	4,58	0,45	2,17	0,14		0,06	2,65	0,05	1,77	0,07	2,02	0,23
	Other dinoflagellates	42,86	19,00	36,76	34,52	4,55	21,10	28,13	15,58	21,05	18,18	4,11	14,05	22,90	30,99	30,43	30,51	10,37	15,97	21,24	24,25	14,16	30,75	31,31	81,62	

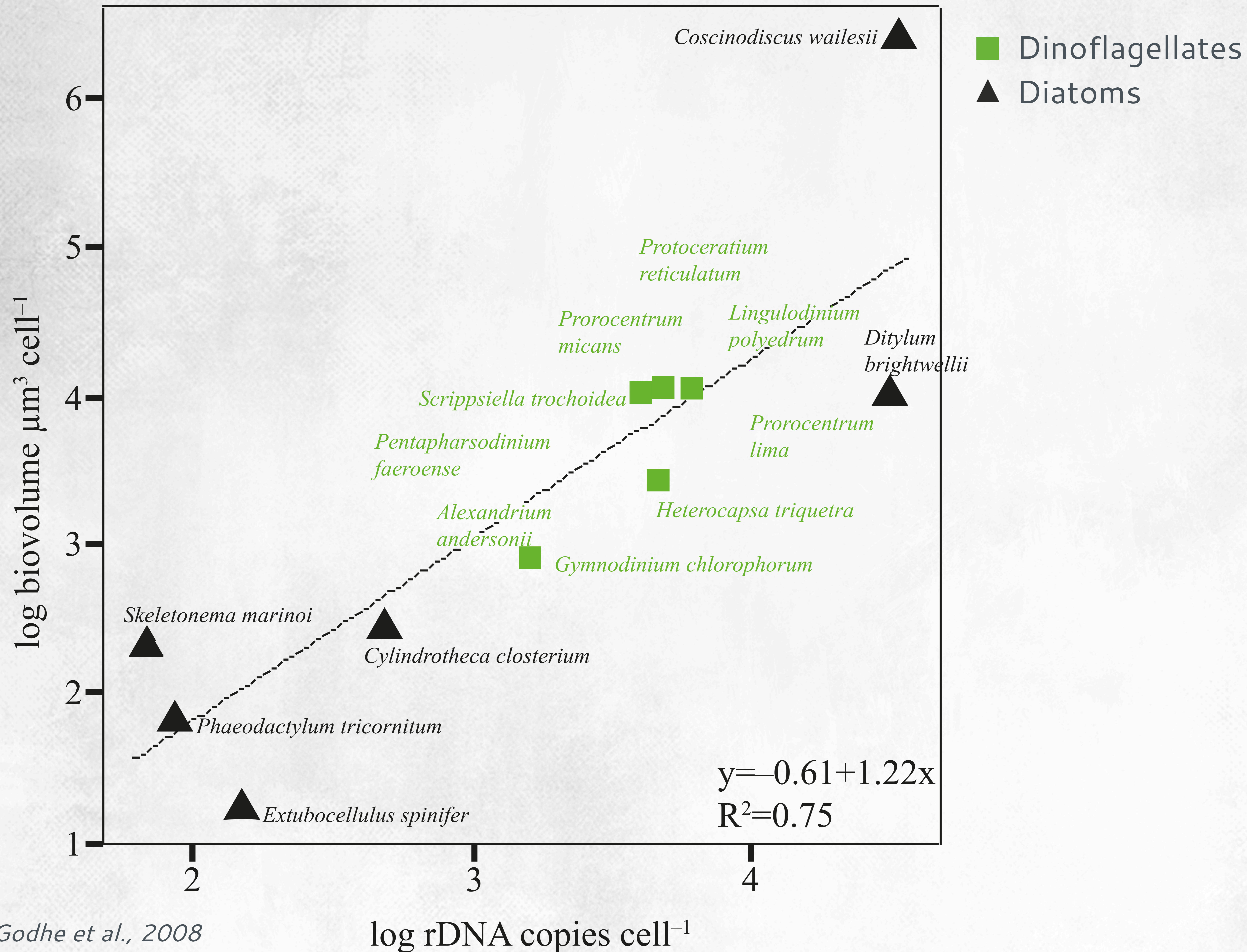
► Most abundant genera and orders are found with the two methods



Microscopy observations were performed on fixed samples by Eleonora Scalco in Naples.

RICHNESS / ABUNDANCE

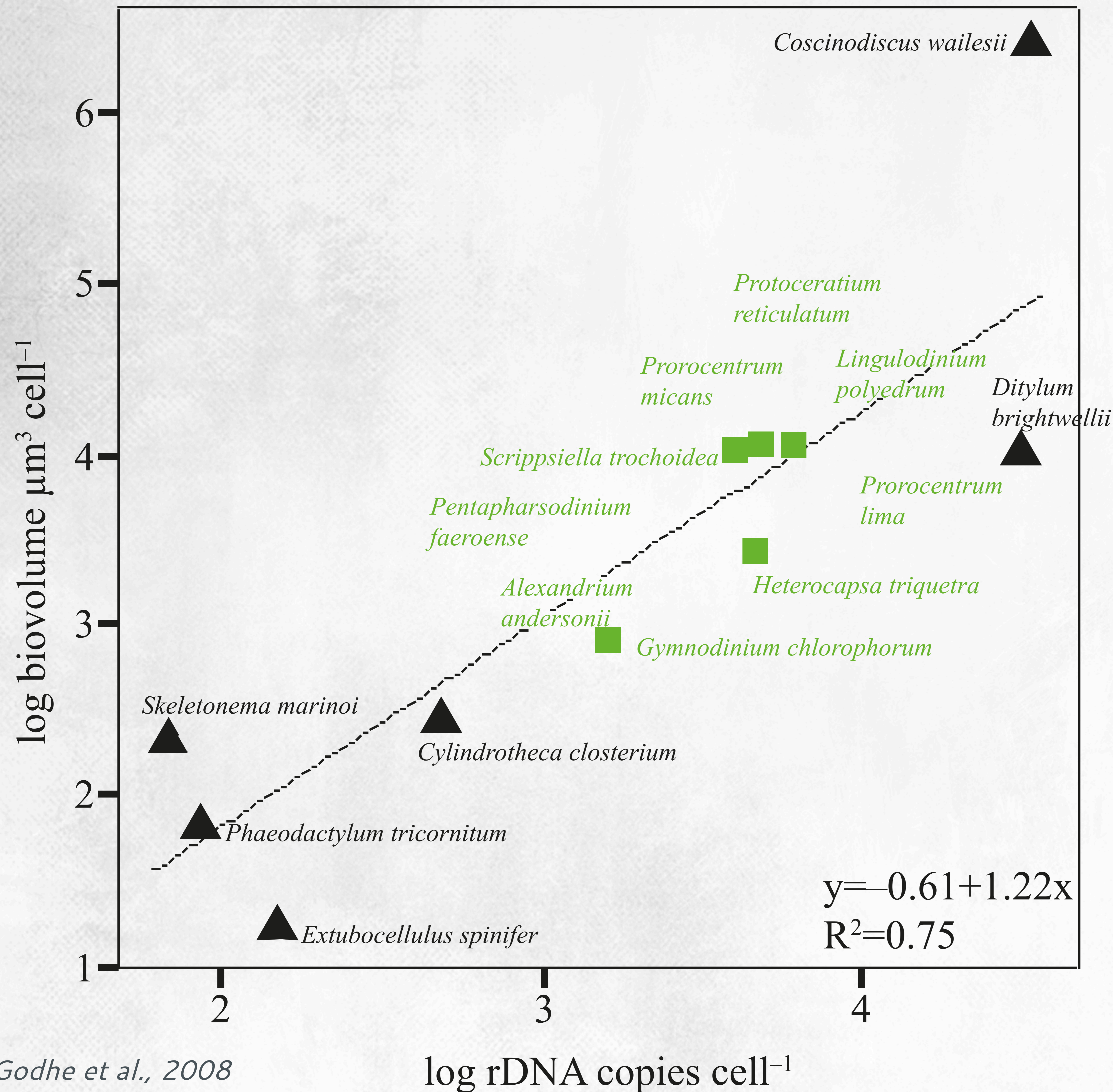
between copy number and cell biovolume



Godhe et al., 2008

RICHNESS / ABUNDANCE

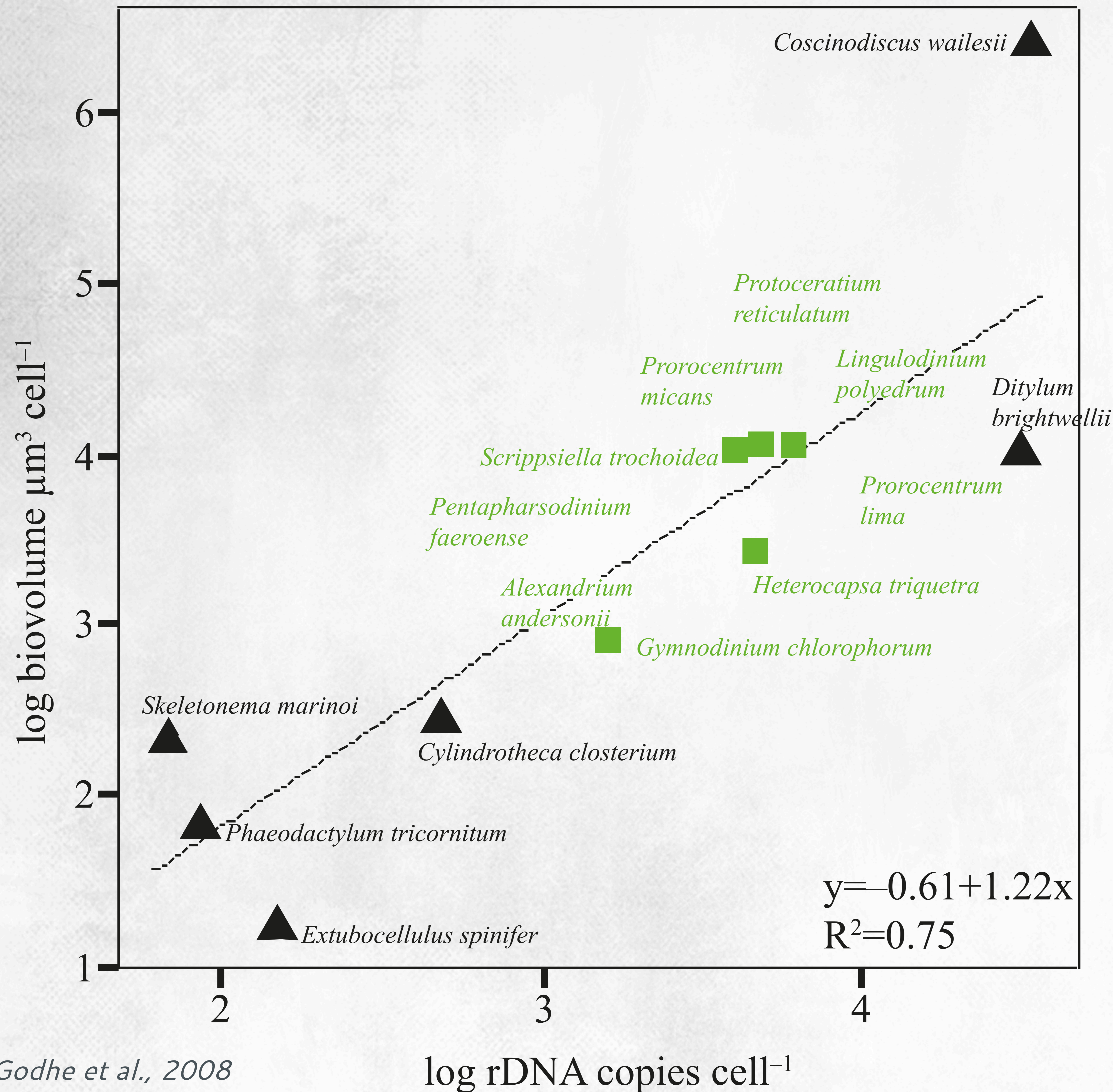
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Copy number can be linked to cell biovolume

RICHNESS / ABUNDANCE

between copy number and cell biovolume

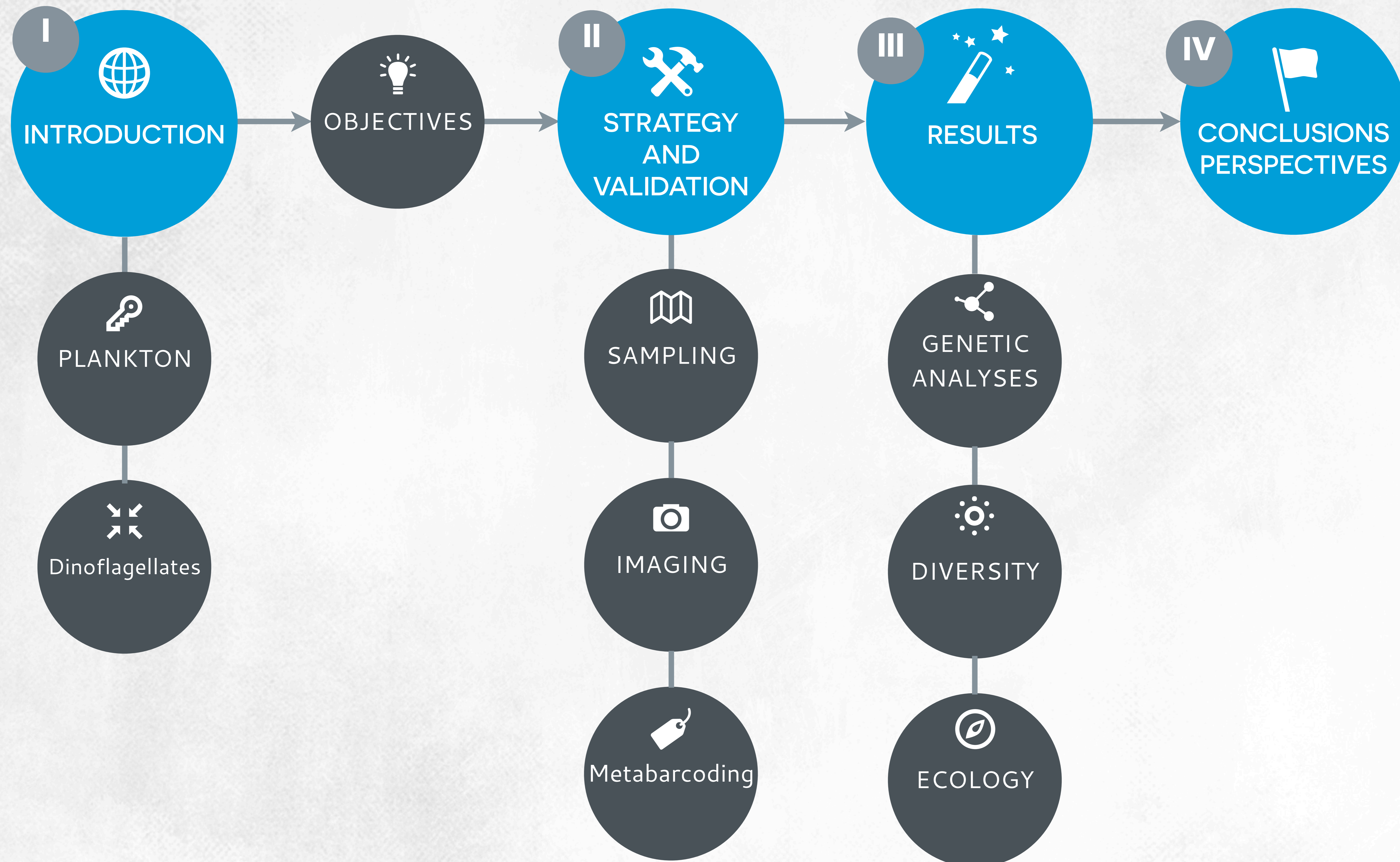


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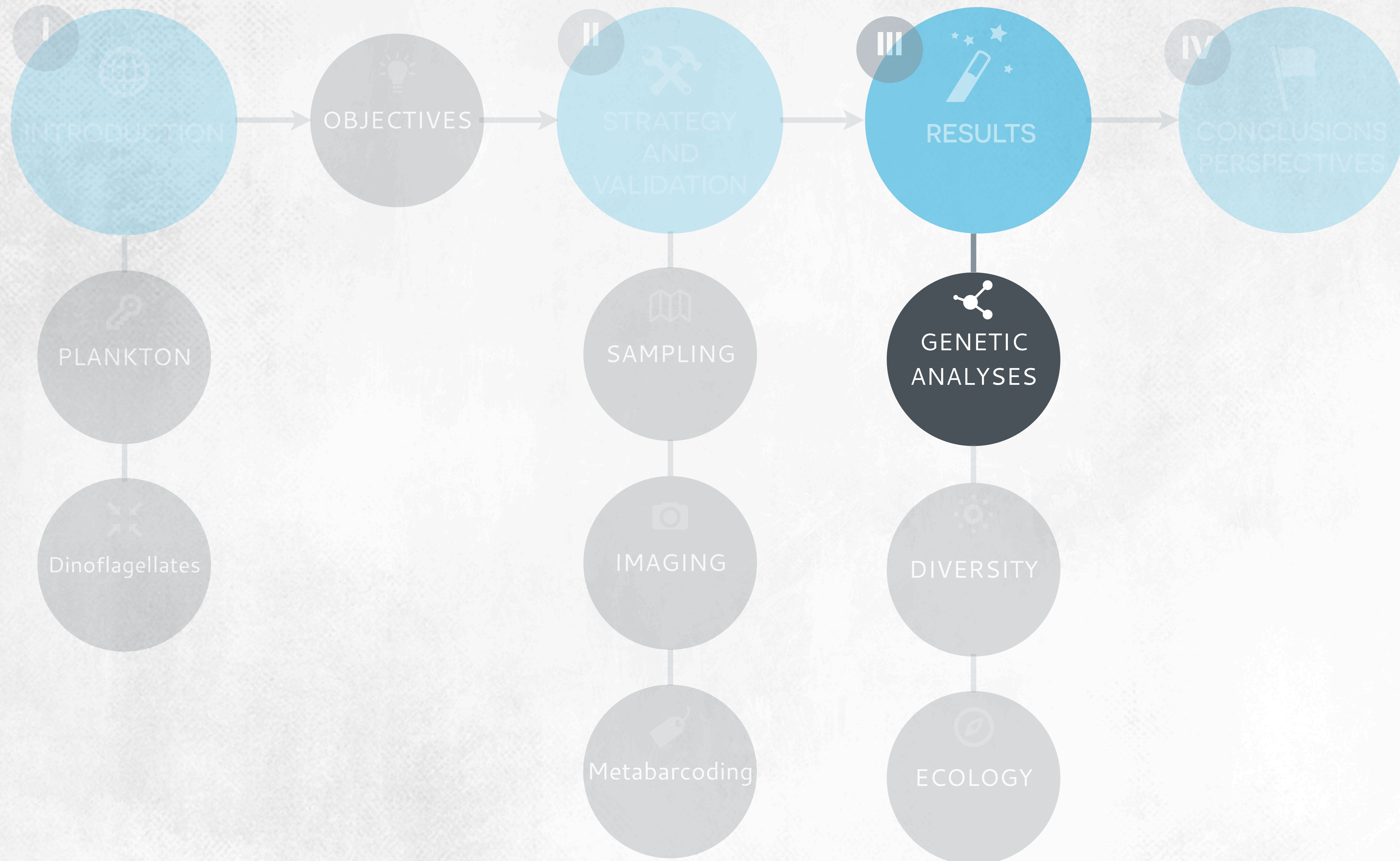
► Metabarcoding can be used to quantify the biodiversity

► Counting data should be transformed into biovolume data

PRESENTATION SUMMARY

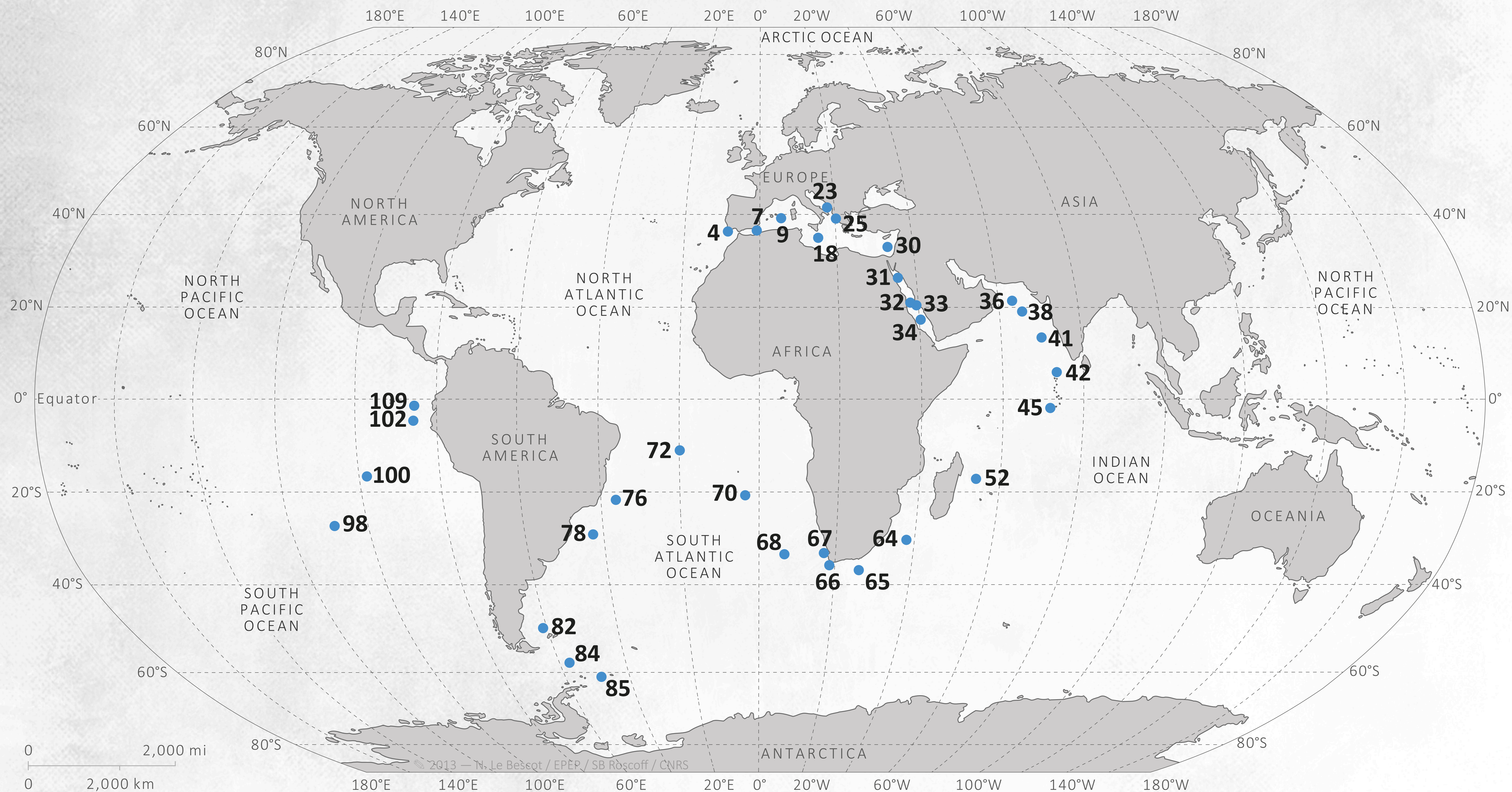


PRESENTATION SUMMARY



DATA TREATMENT

our workflow



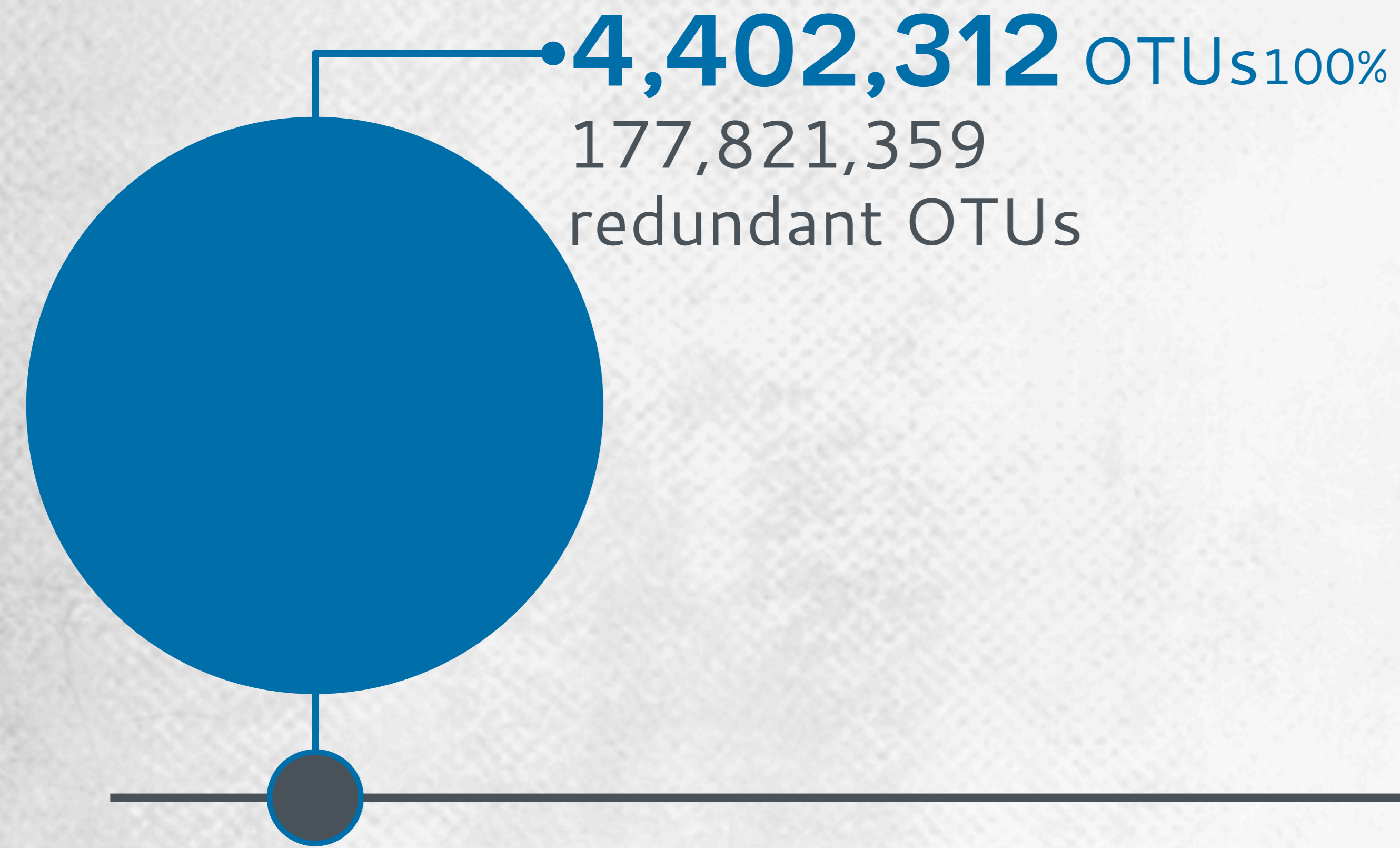
▶ **33 stations (over 154) – surface data**

only 14 stations present pico, nano, micro and meso fraction

DATA TREATMENT

our workflow

full dataset



Primers:

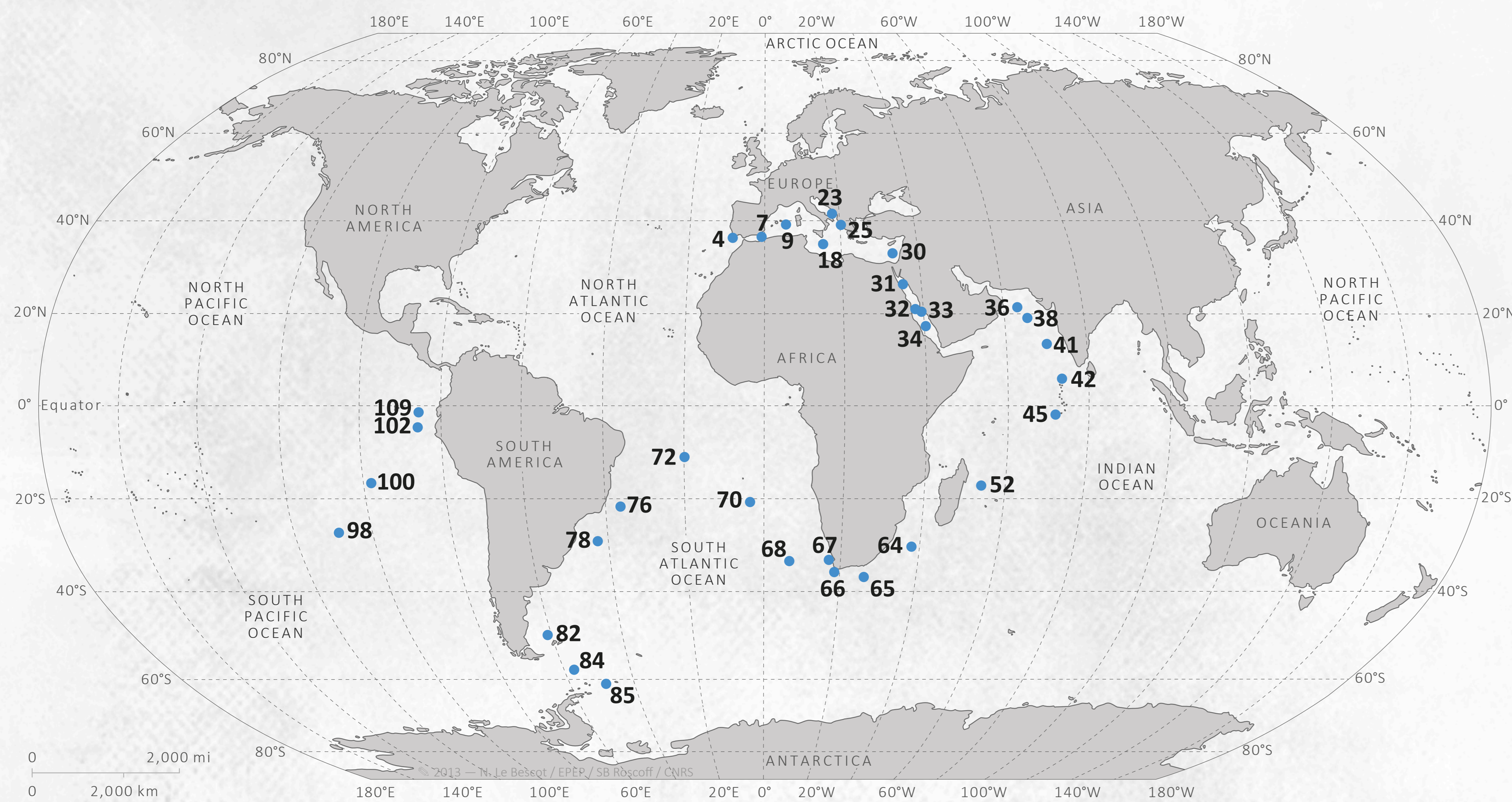
f 5'-TTGTACACACCGCCC-3'

r 5'-CCTTCYGCAGGTTACCTAC-3'

(Amaral-Zettler et al., 2009)

▶ **33 stations (over 154)** – surface data

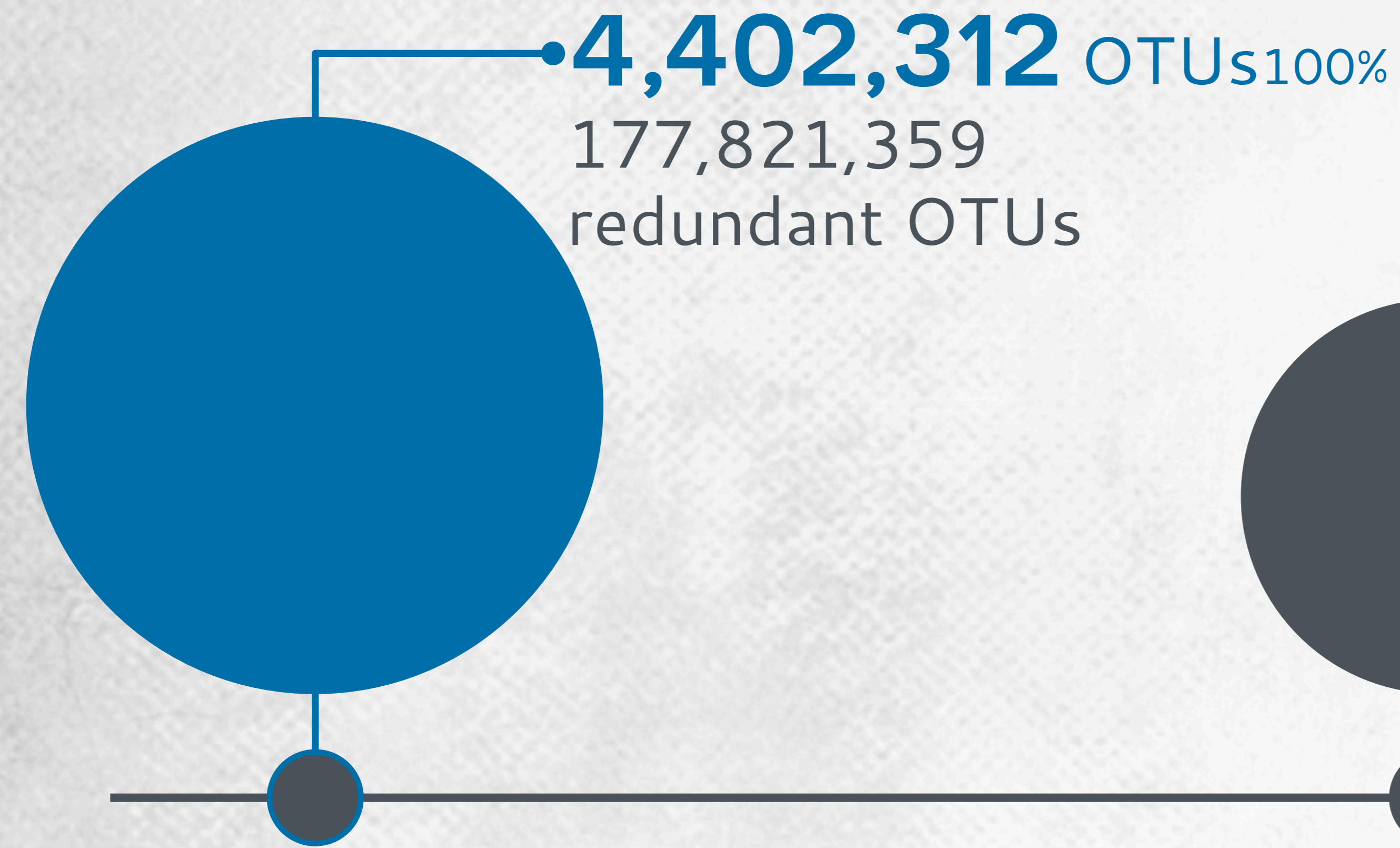
only 14 stations present pico, nano, micro and meso fraction



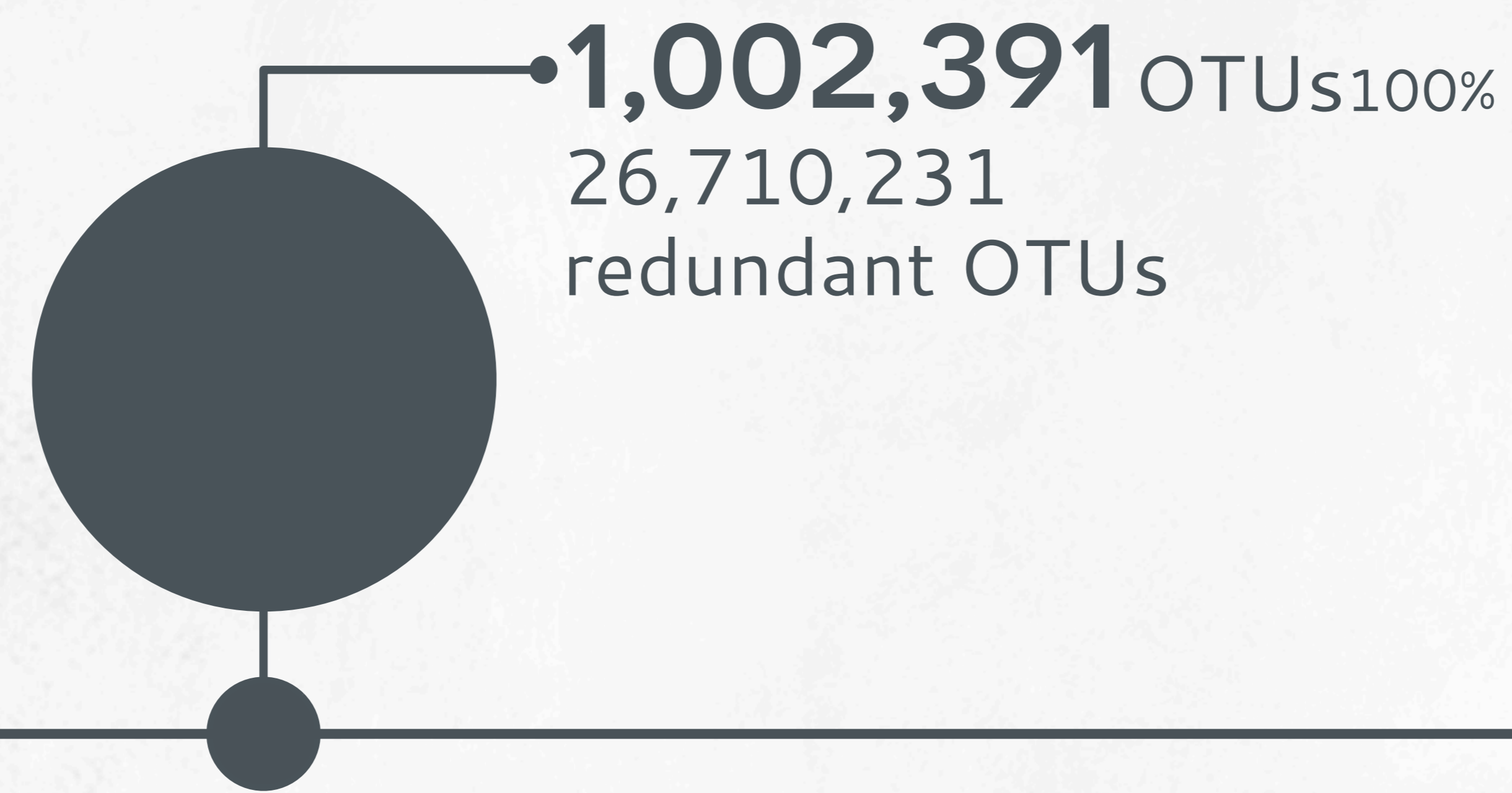
DATA TREATMENT

our workflow

full dataset



dinoflagellate dataset



Primers:

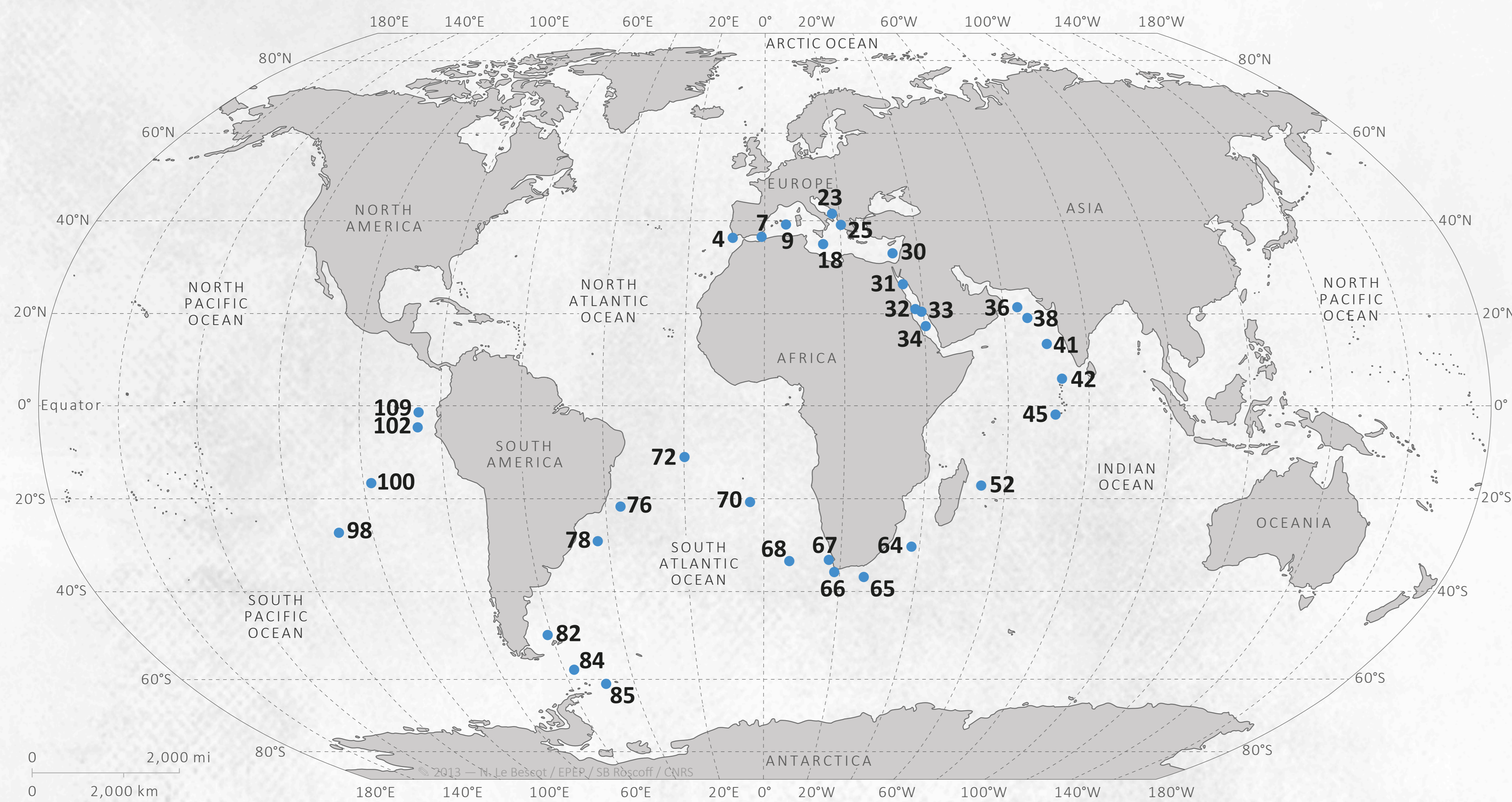
f 5'-TTGTACACACCGCCC-3'

r 5'-CCTTCYGCAGGTTACCTAC-3'

(Amaral-Zettler et al., 2009)

▶ 33 stations (over 154) – surface data

only 14 stations present pico, nano, micro and meso fraction



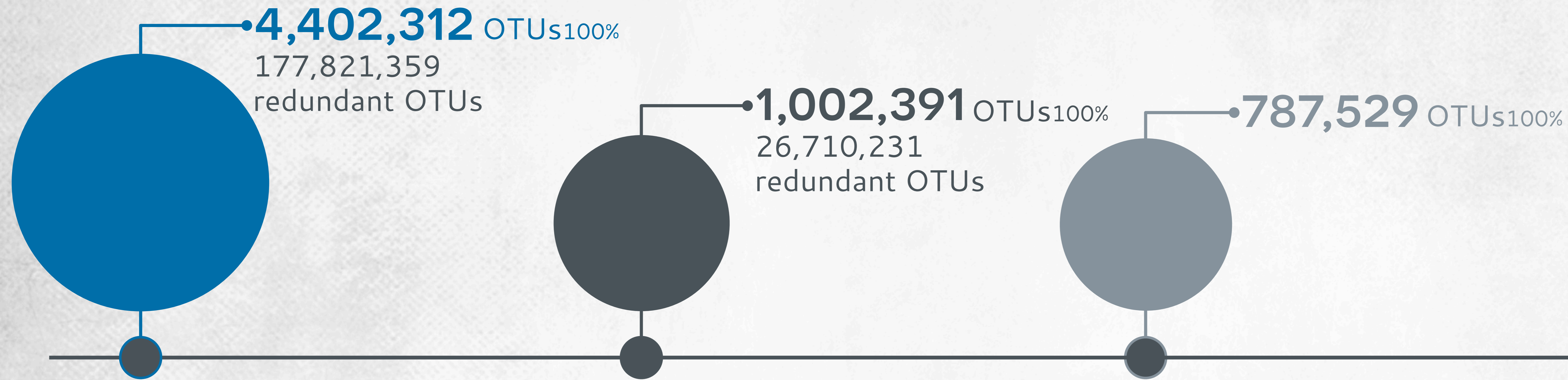
DATA TREATMENT

our workflow

full dataset

dinoflagellate dataset

cut-off at 10 or more copies



Primers:

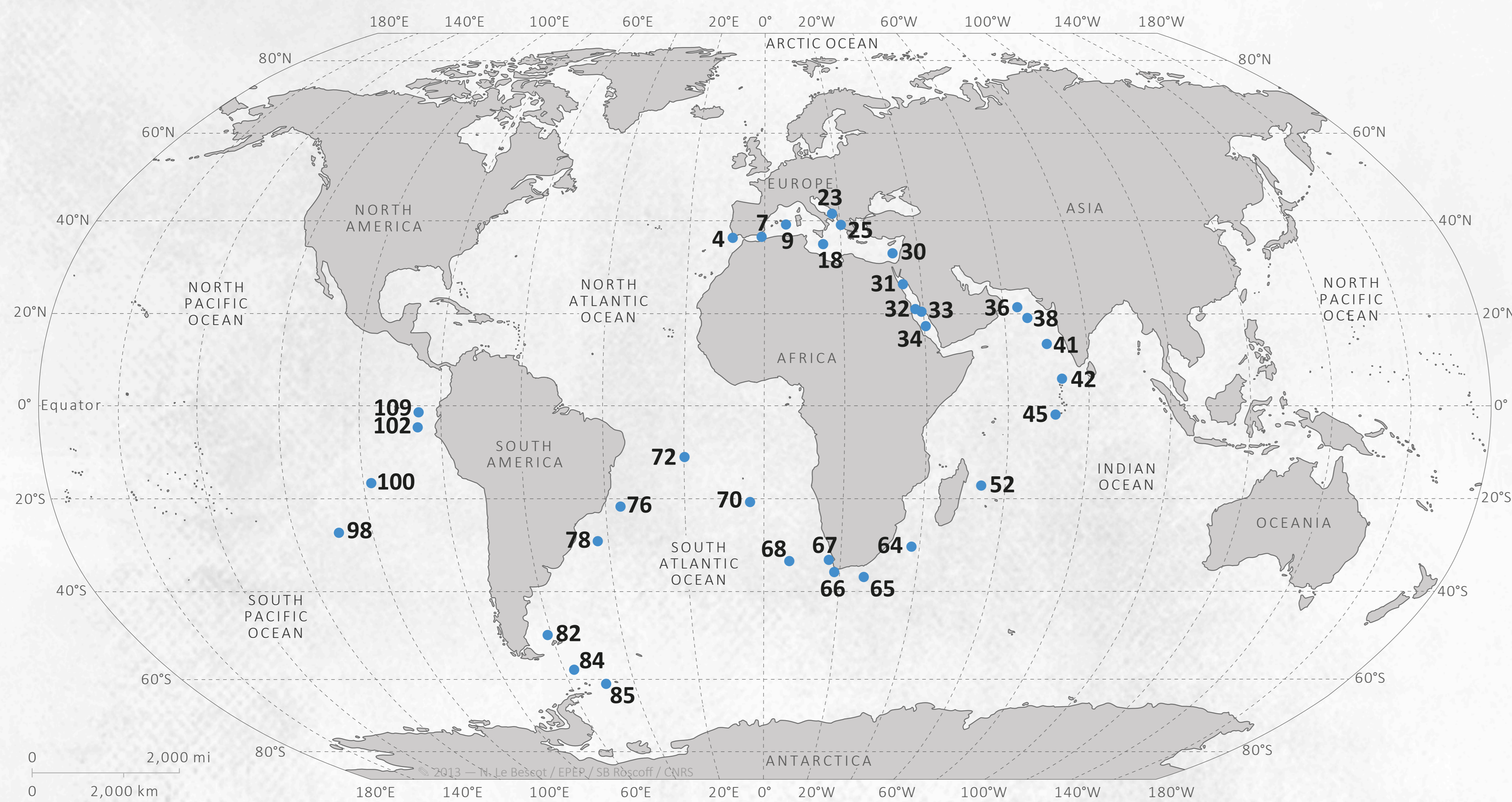
f 5'-TTGTACACACCGCCC-3'

r 5'-CCTTCYGCAGGTTACCTAC-3'

(Amaral-Zettler et al., 2009)

▶ 33 stations (over 154) – surface data

only 14 stations present pico, nano, micro and meso fraction



DATA TREATMENT

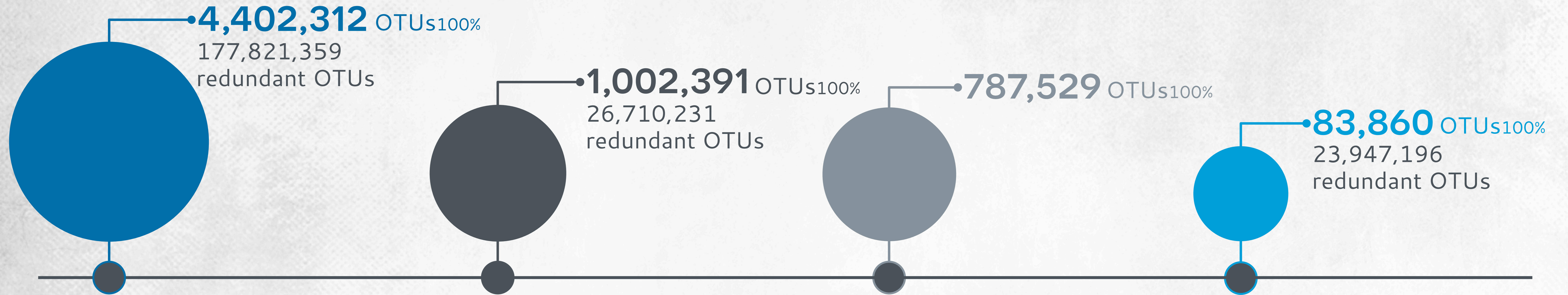
our workflow

full dataset

dinoflagellate dataset

cut-off at 10 or more copies

cut-off at 90% or more identity



Primers:

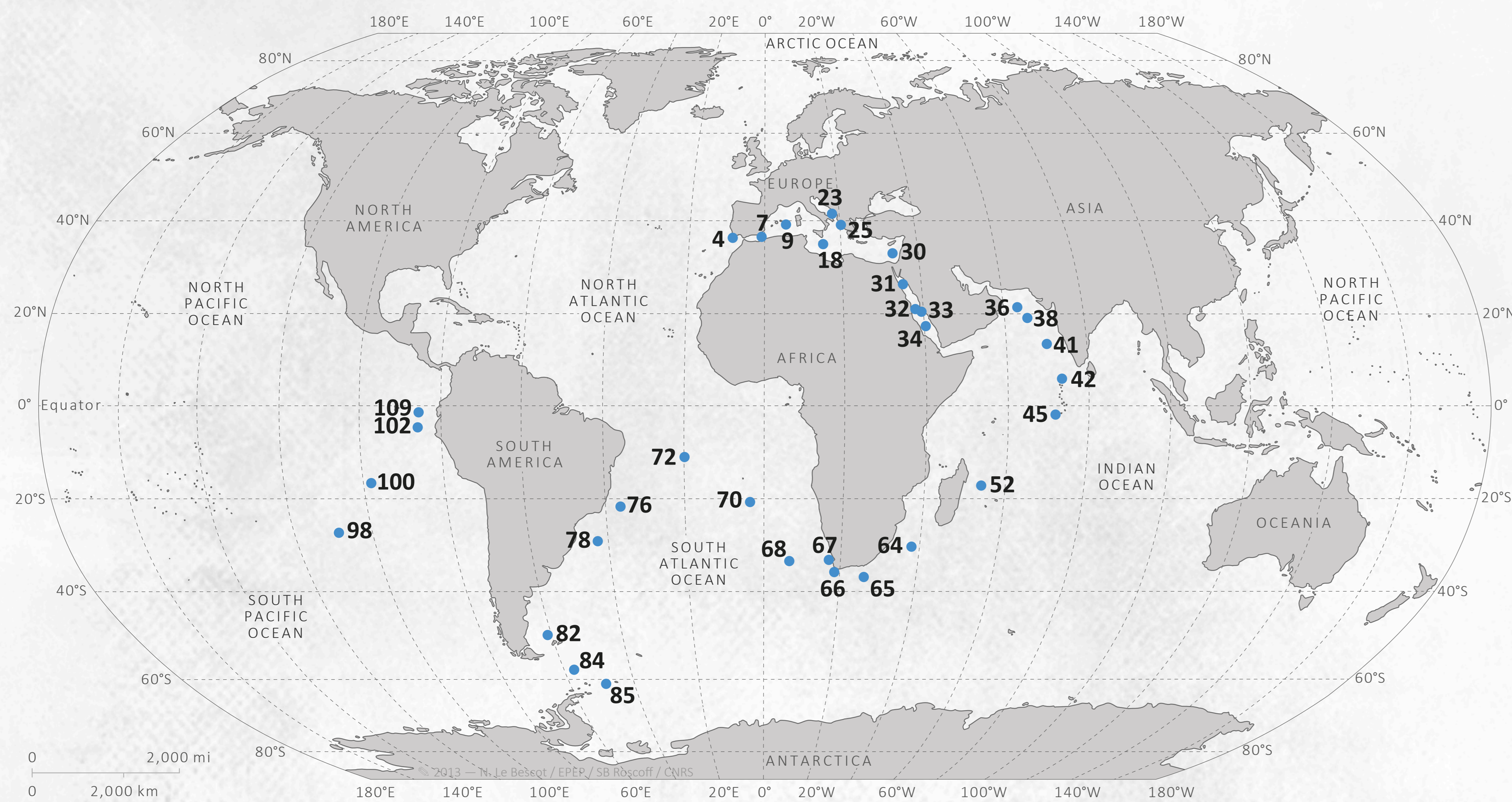
f 5'-TTGTACACACCGCCC-3'

r 5'-CCTTCYGCAGGTTACCTAC-3'

(Amaral-Zettler et al., 2009)

▶ 33 stations (over 154) – surface data

only 14 stations present pico, nano, micro and meso fraction



DATA TREATMENT

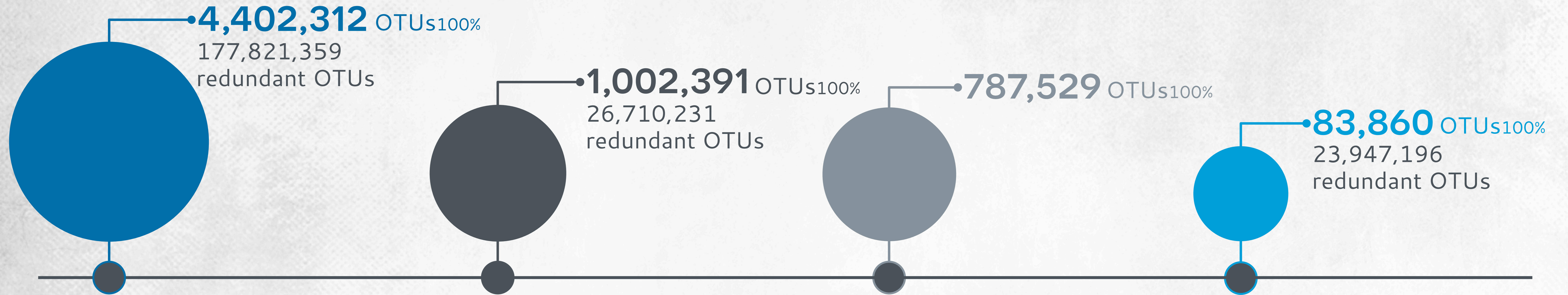
our workflow

full dataset

dinoflagellate dataset

cut-off at 10 or more copies

cut-off at 90% or more identity



Primers:

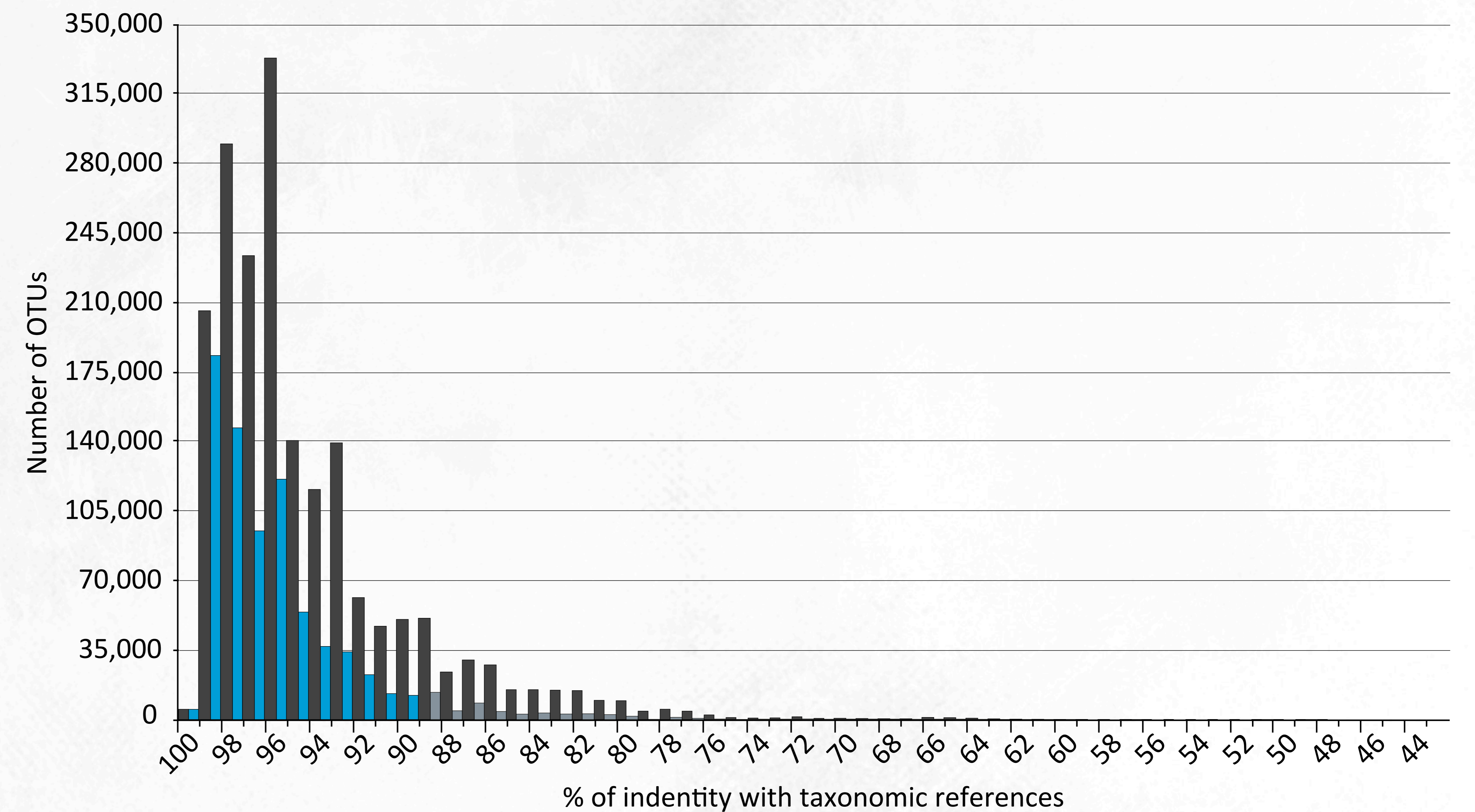
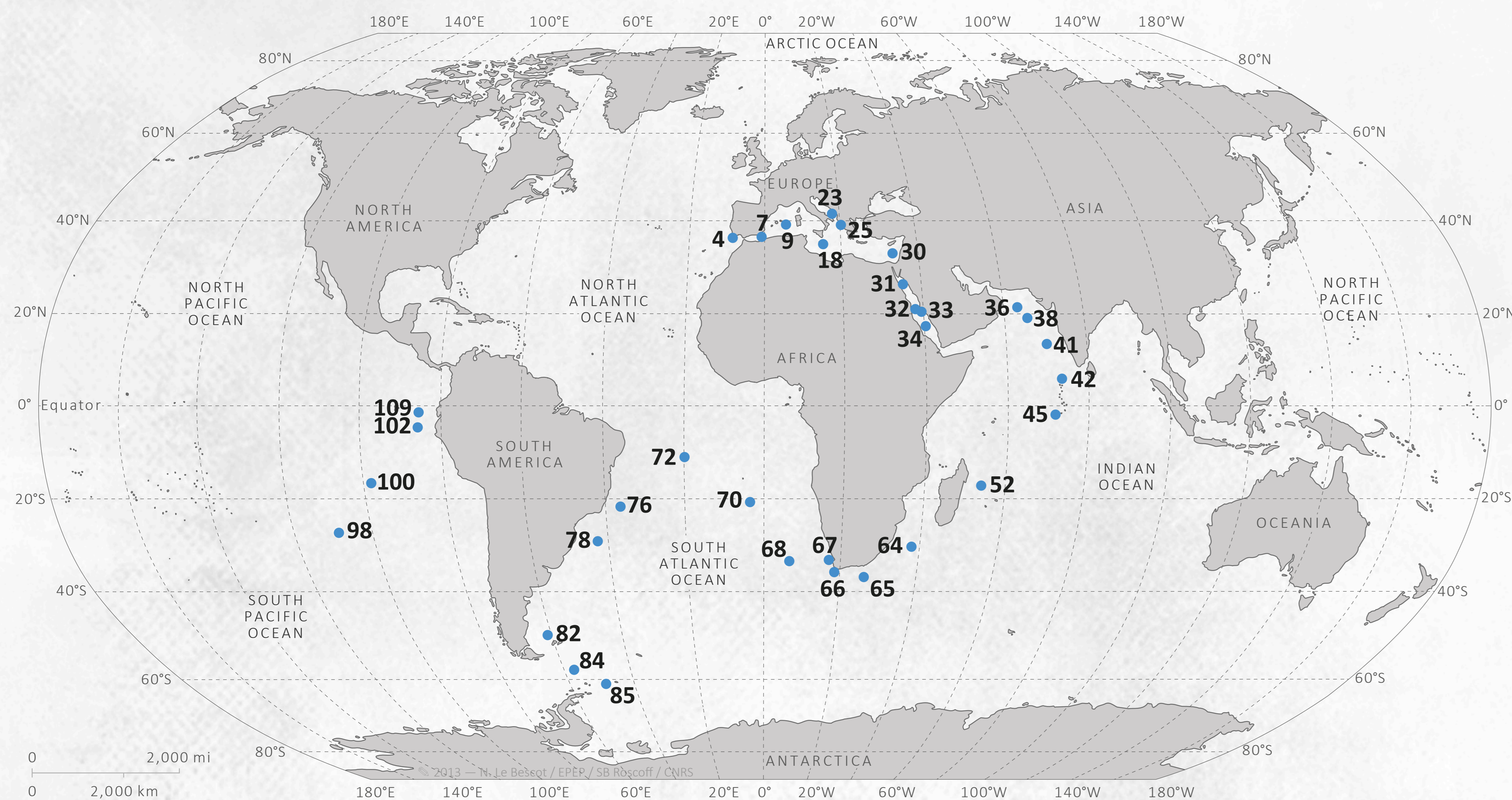
f 5'-TTGTACACACCGCCC-3'

r 5'-CCTTCYGCAGGTTACCTAC-3'

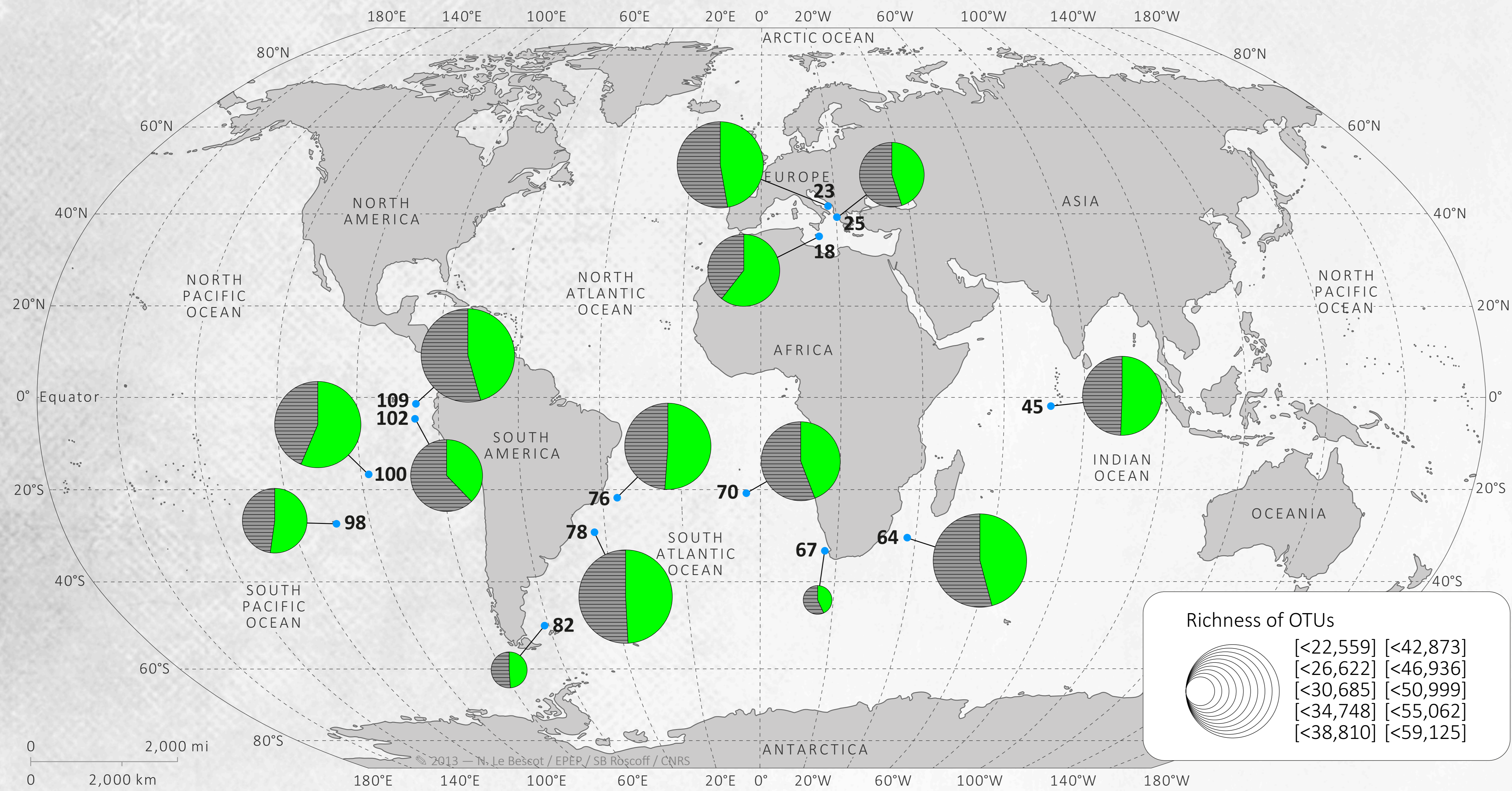
(Amaral-Zettler et al., 2009)

▶ 33 stations (over 154) – surface data

only 14 stations present pico, nano, micro and meso fraction



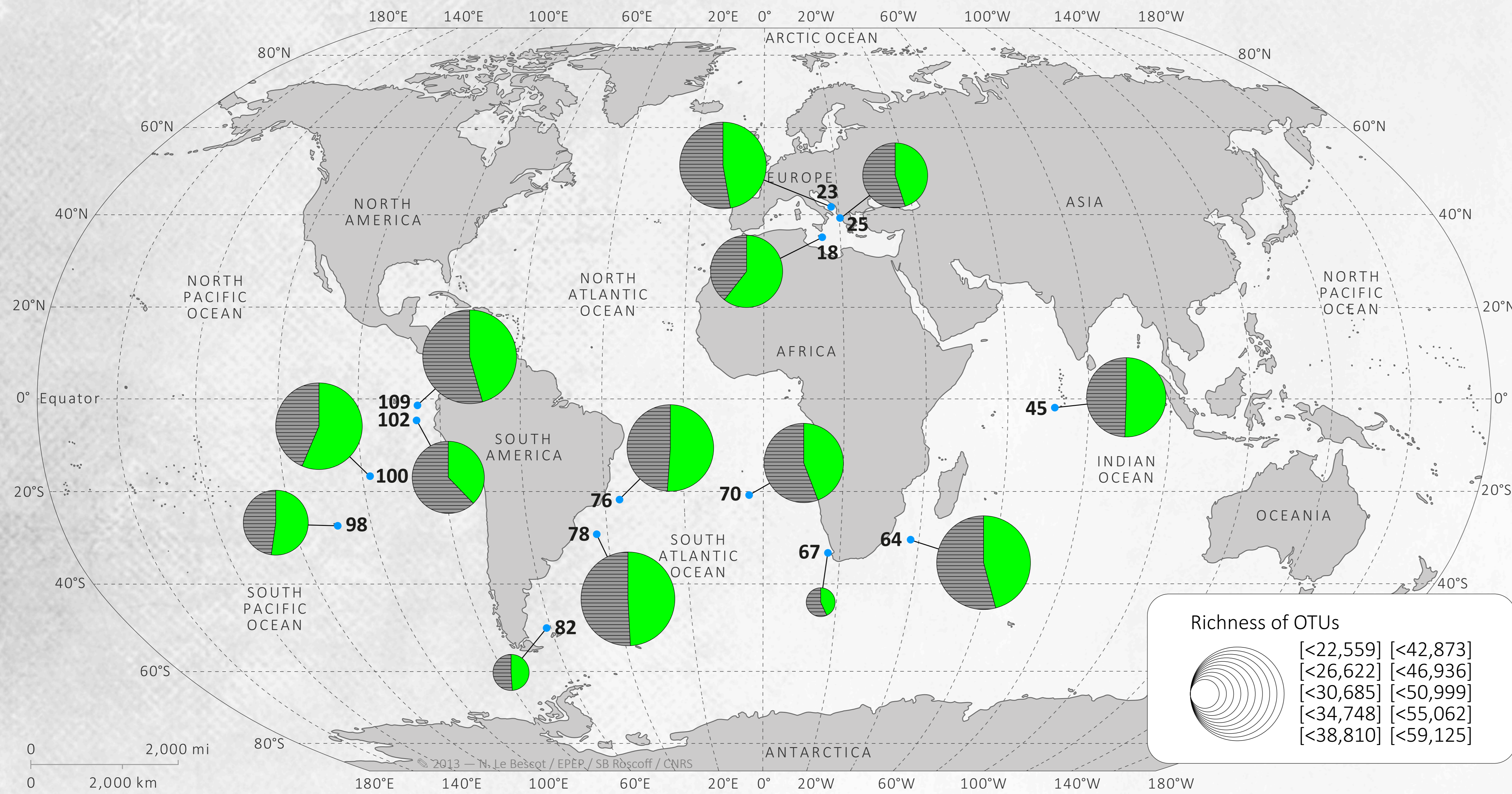
DINOFLAGELLATES / PROTISTS



OTU richness

- Sampling point
- Dinophyceae
- ▨ Other protists

DINOFLAGELLATES / PROTISTS

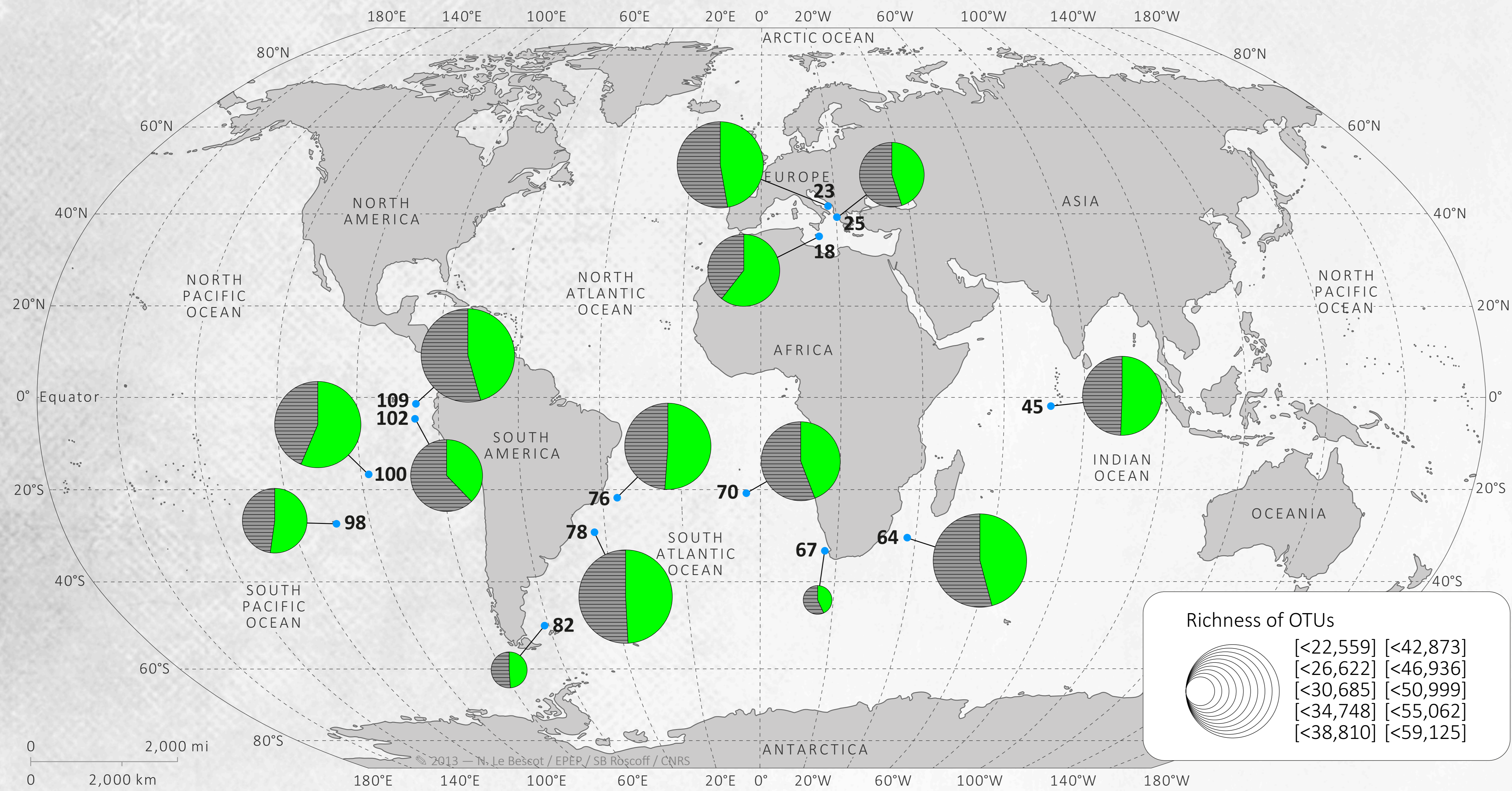


OTU richness

▶ 49% of known protists [38%–61%]

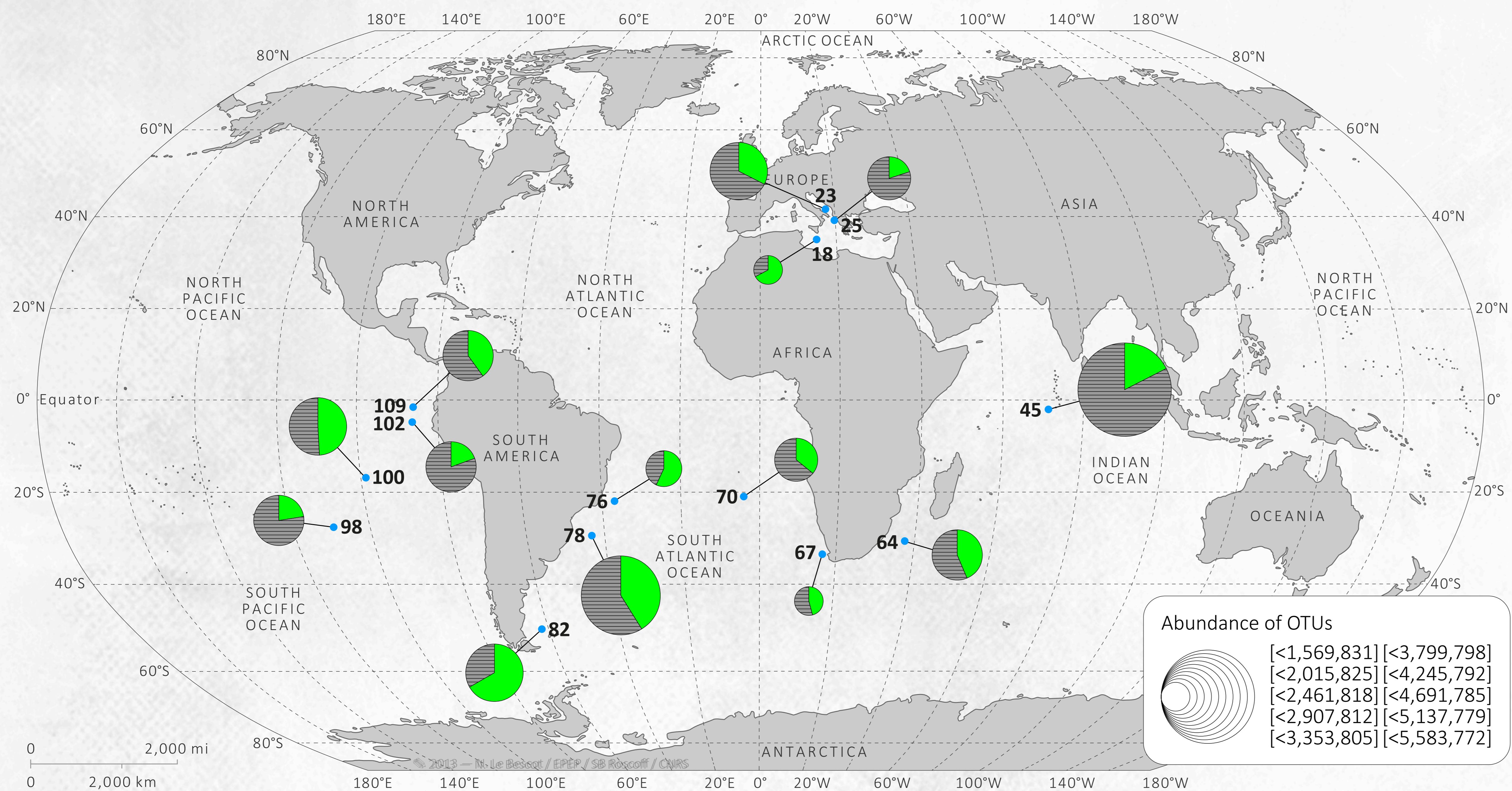
• Sampling point ■ Dinophyceae ▨ Other protists

DINOFLAGELLATES / PROTISTS



OTU richness

▶ 49% of known protists [38%–61%]



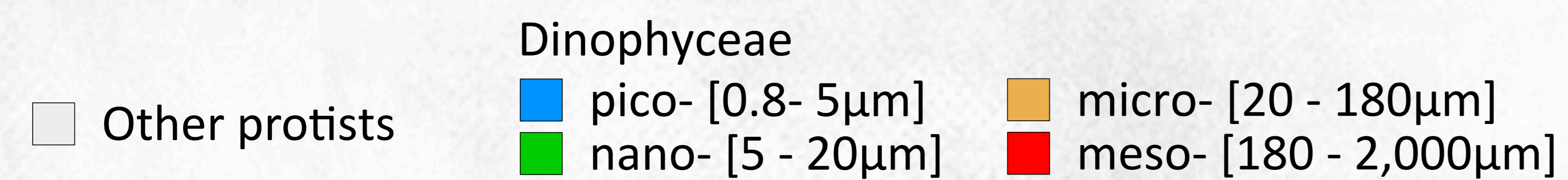
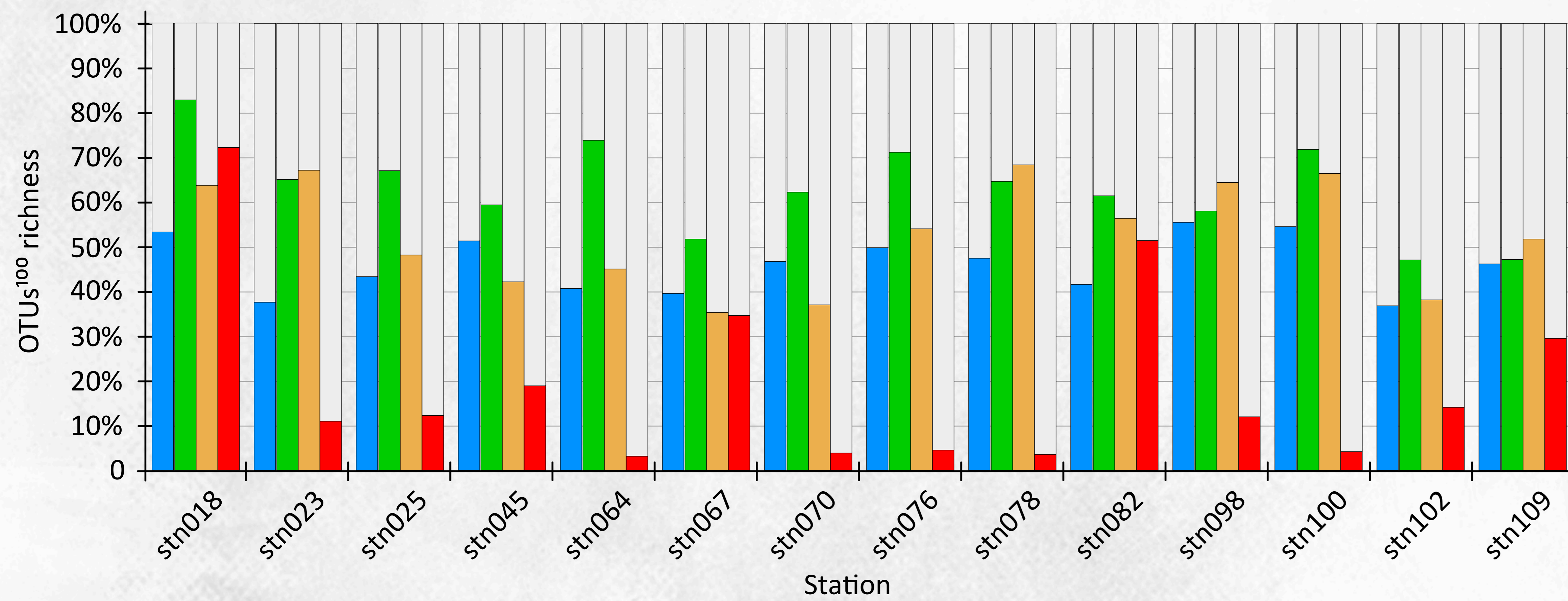
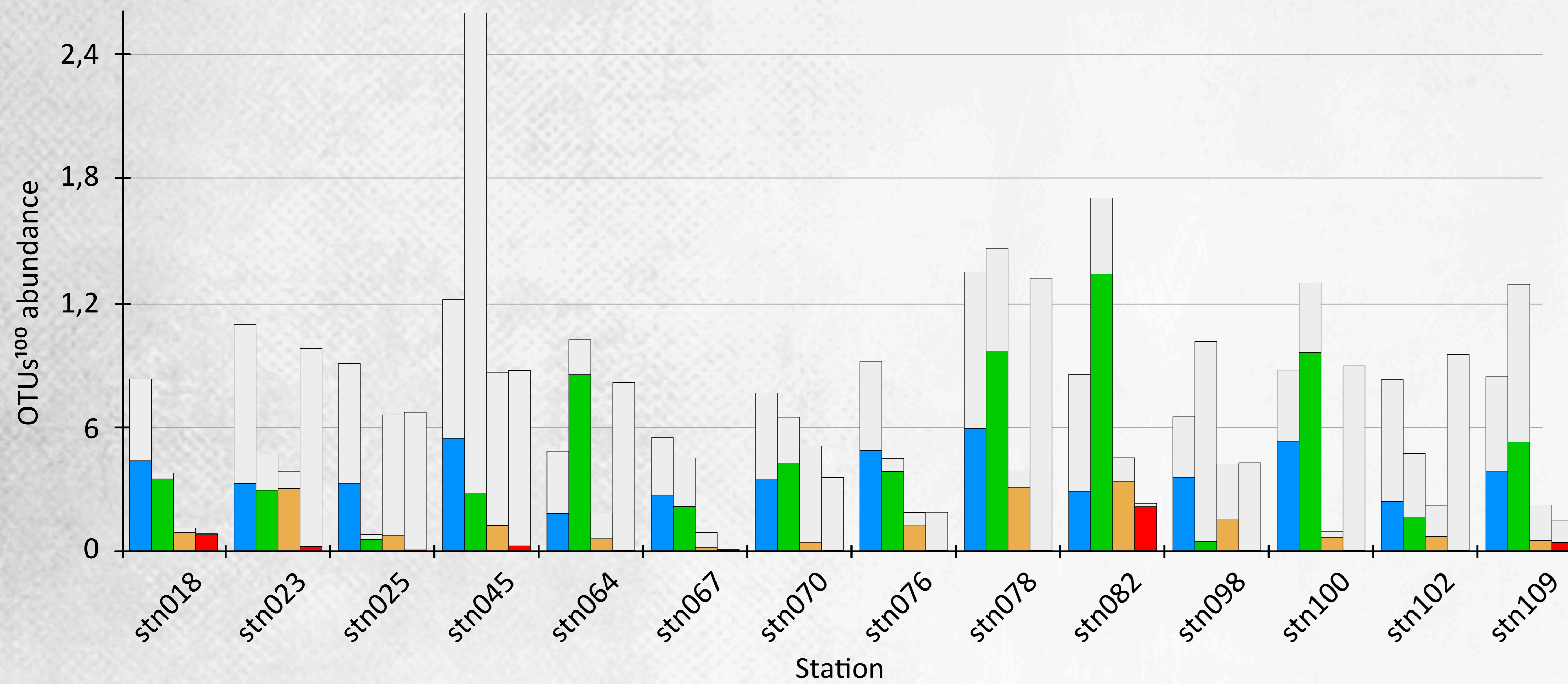
OTU abundance

▶ 40% of known protists [18–67%]

● Sampling point ■ Dinophyceae ▨ Other protists

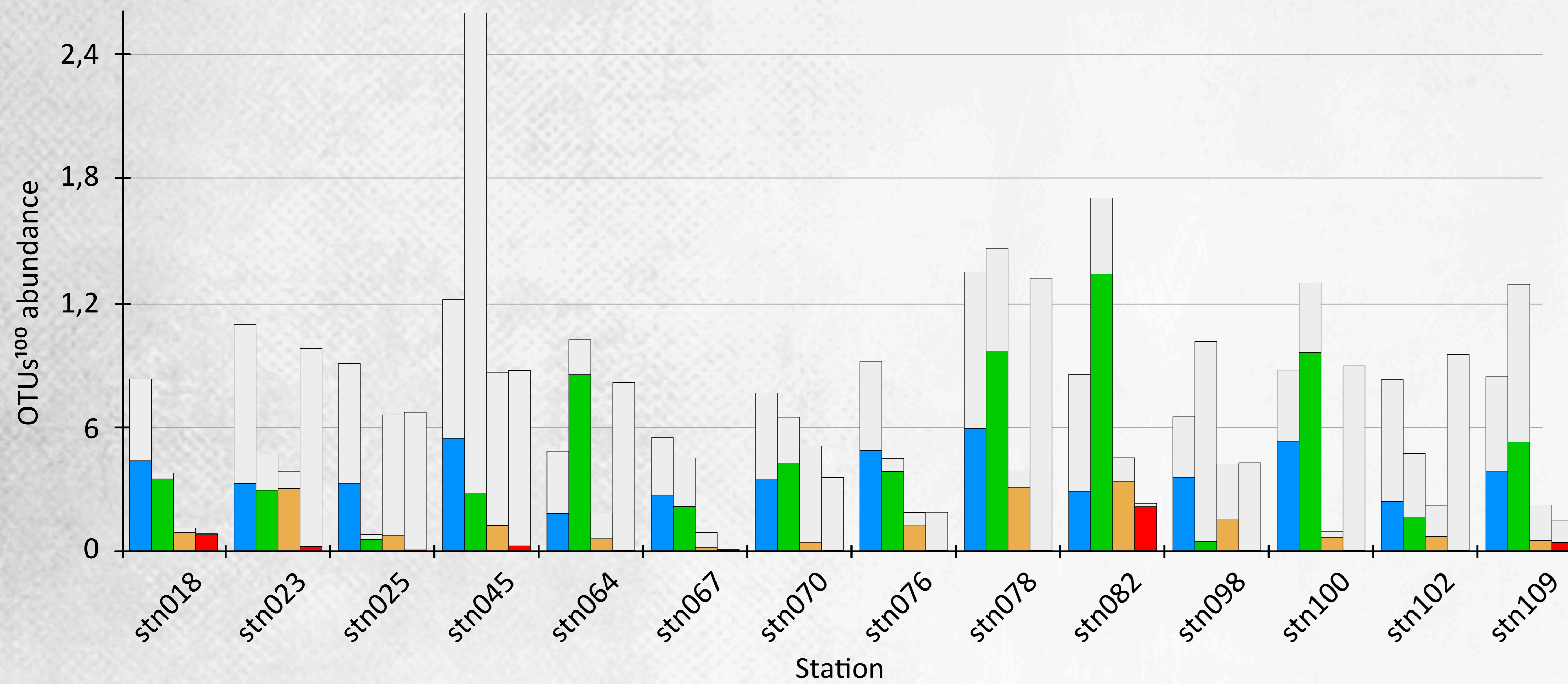
DINOFLAGELLATES / PROTISTS

Dinoflagellate OTU abundance and richness varied over the whole protistan community and across size fractions

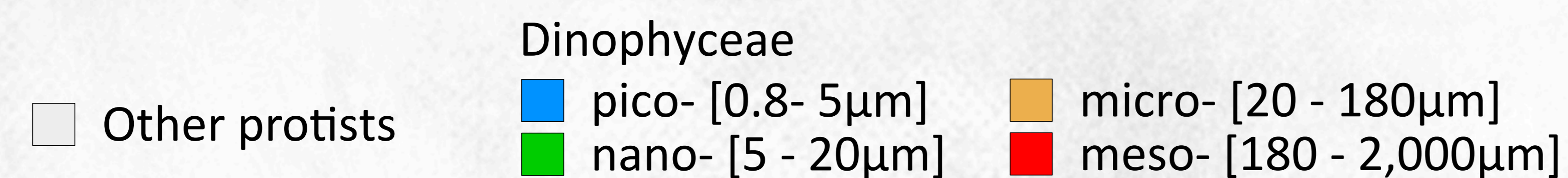
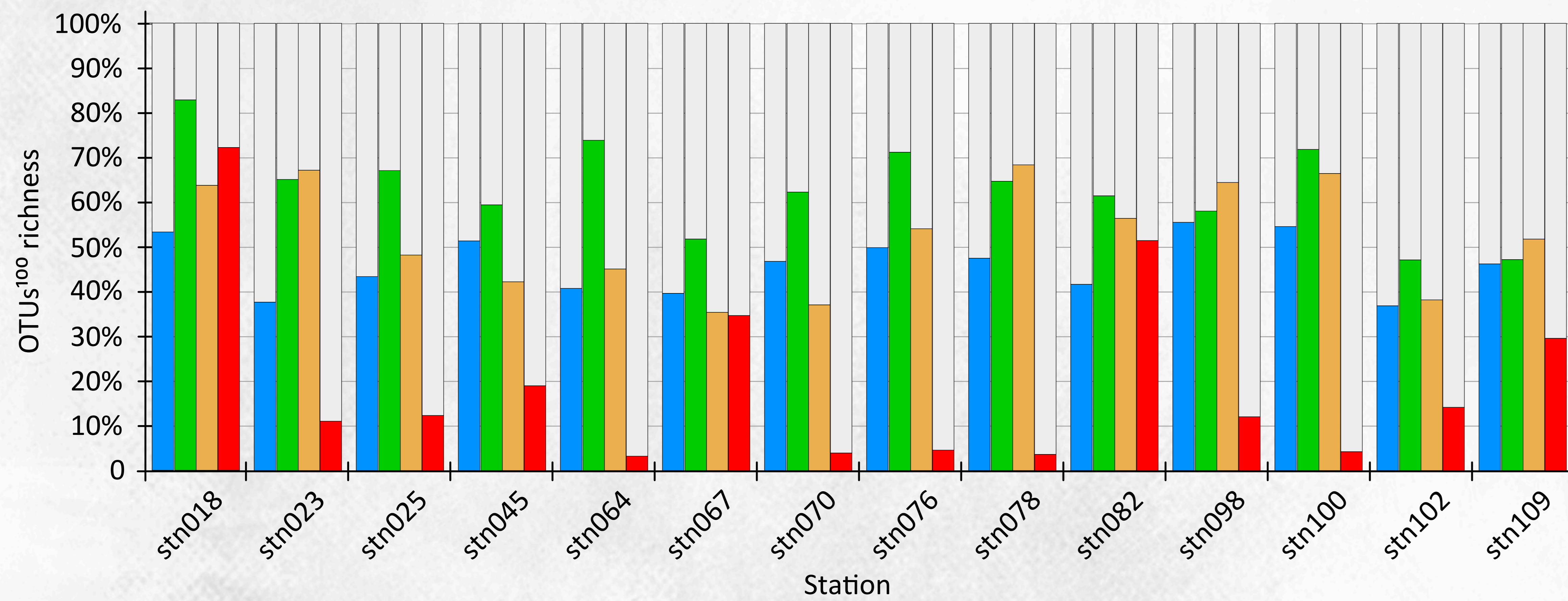


DINOFLAGELLATES / PROTISTS

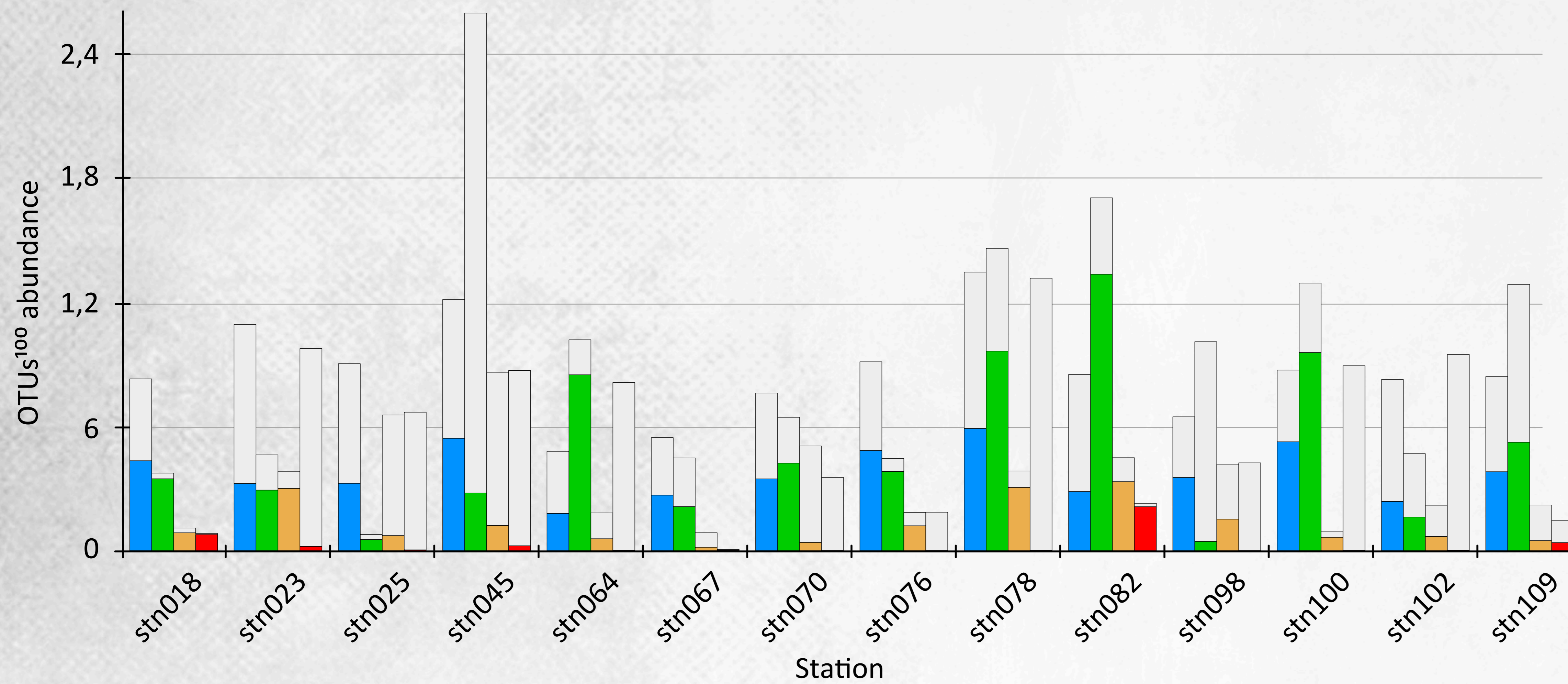
Dinoflagellate OTU abundance and richness varied over the whole protistan community and across size fractions



► The highest abundances are observed in the **pico** (0.8–5µm) and **nano** (5–20µm) plankton

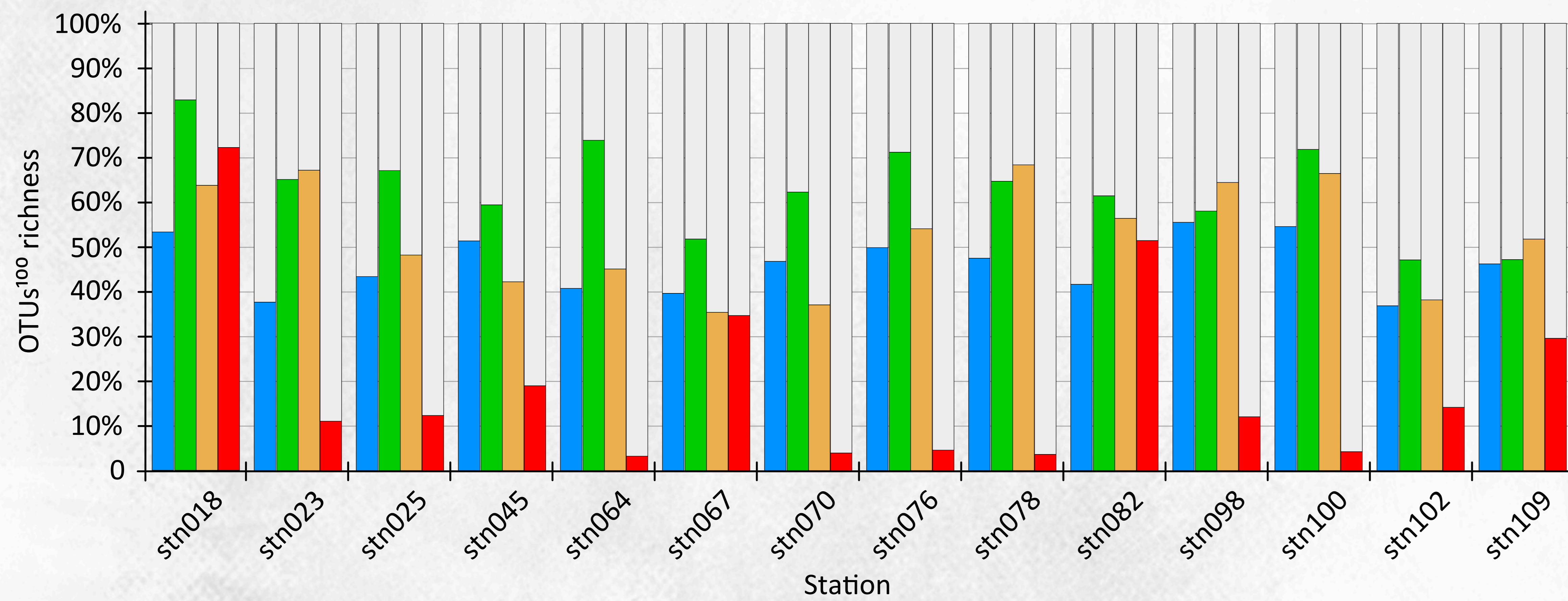


DINOFLAGELLATES / PROTISTS

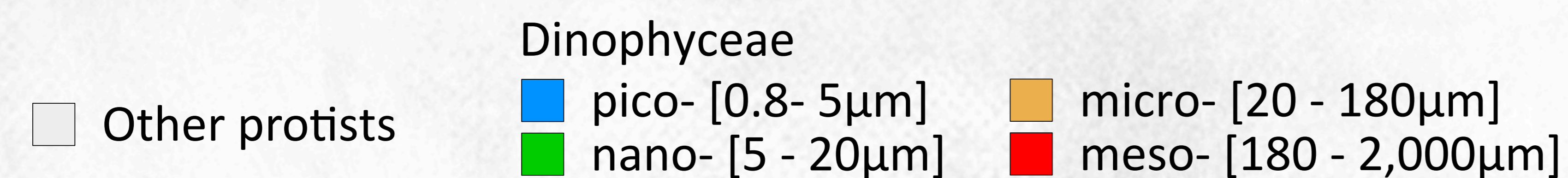


Dinoflagellate OTU abundance and richness varied over the whole protistan community and across size fractions

- ▶ The highest abundances are observed in the **pico** (0.8–5µm) and **nano** (5–20µm) plankton



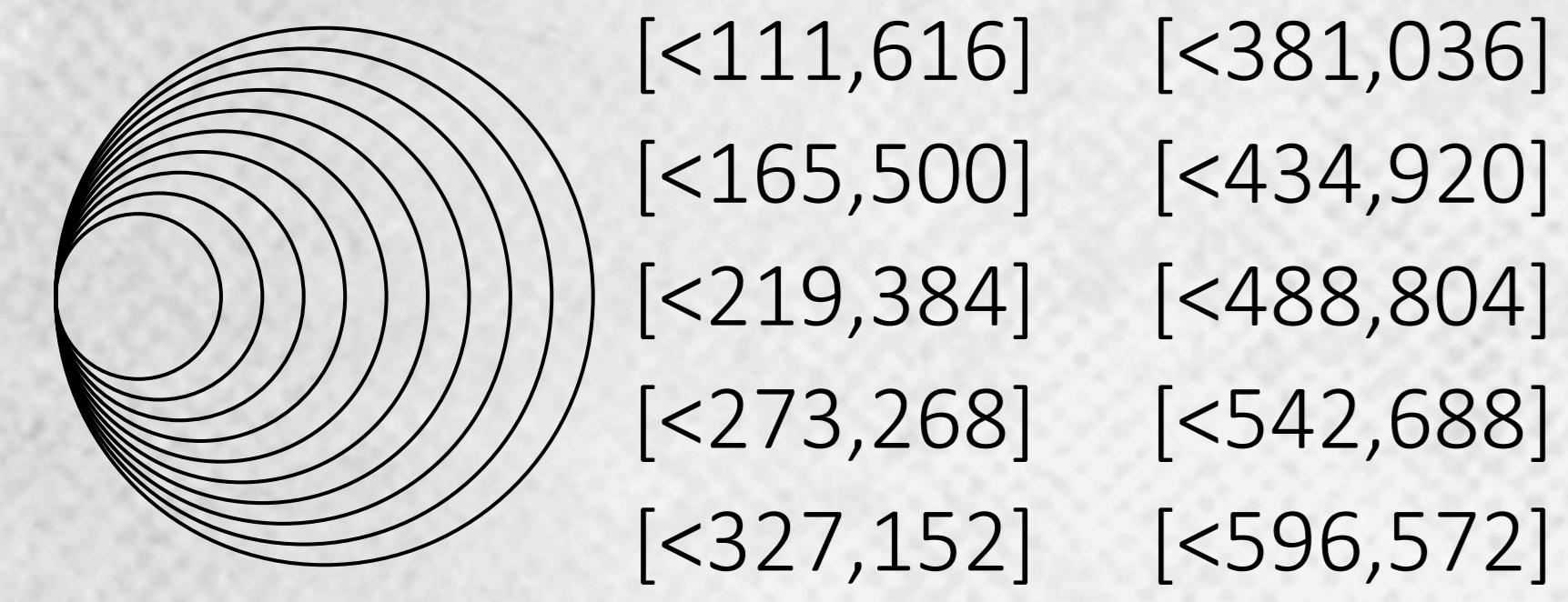
- ▶ The highest relative richness values are observed in the **nano** (5–20µm) and **micro** (20–180µm) plankton



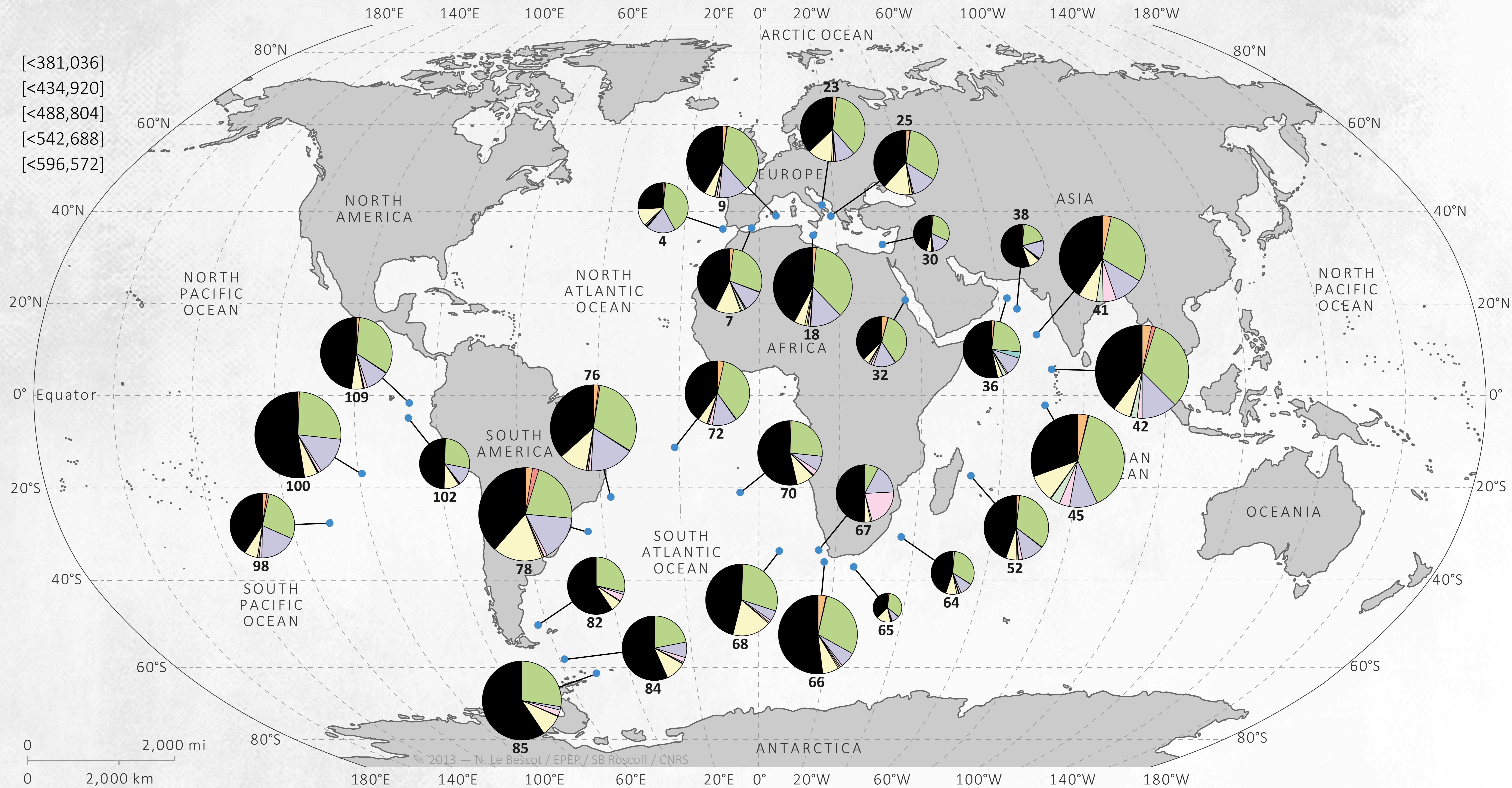
PICO-DINOFLAGELLATES [0.8–5µm]

abundance by orders

● Sampling point

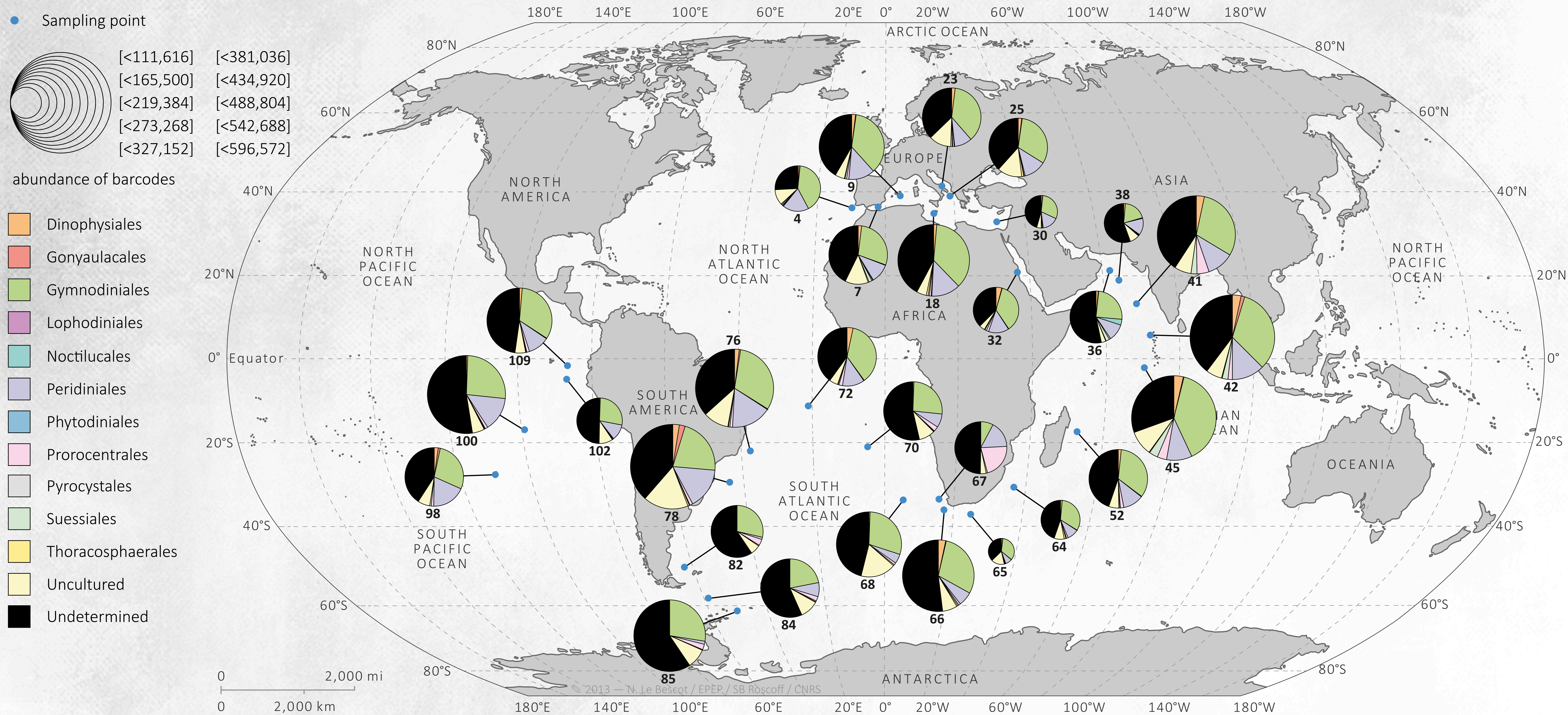


abundance of barcodes



PICO-DINOFLAGELLATES [0.8–5µm]

abundance by orders



► This is the first observation of the pico-dinoflagellate community

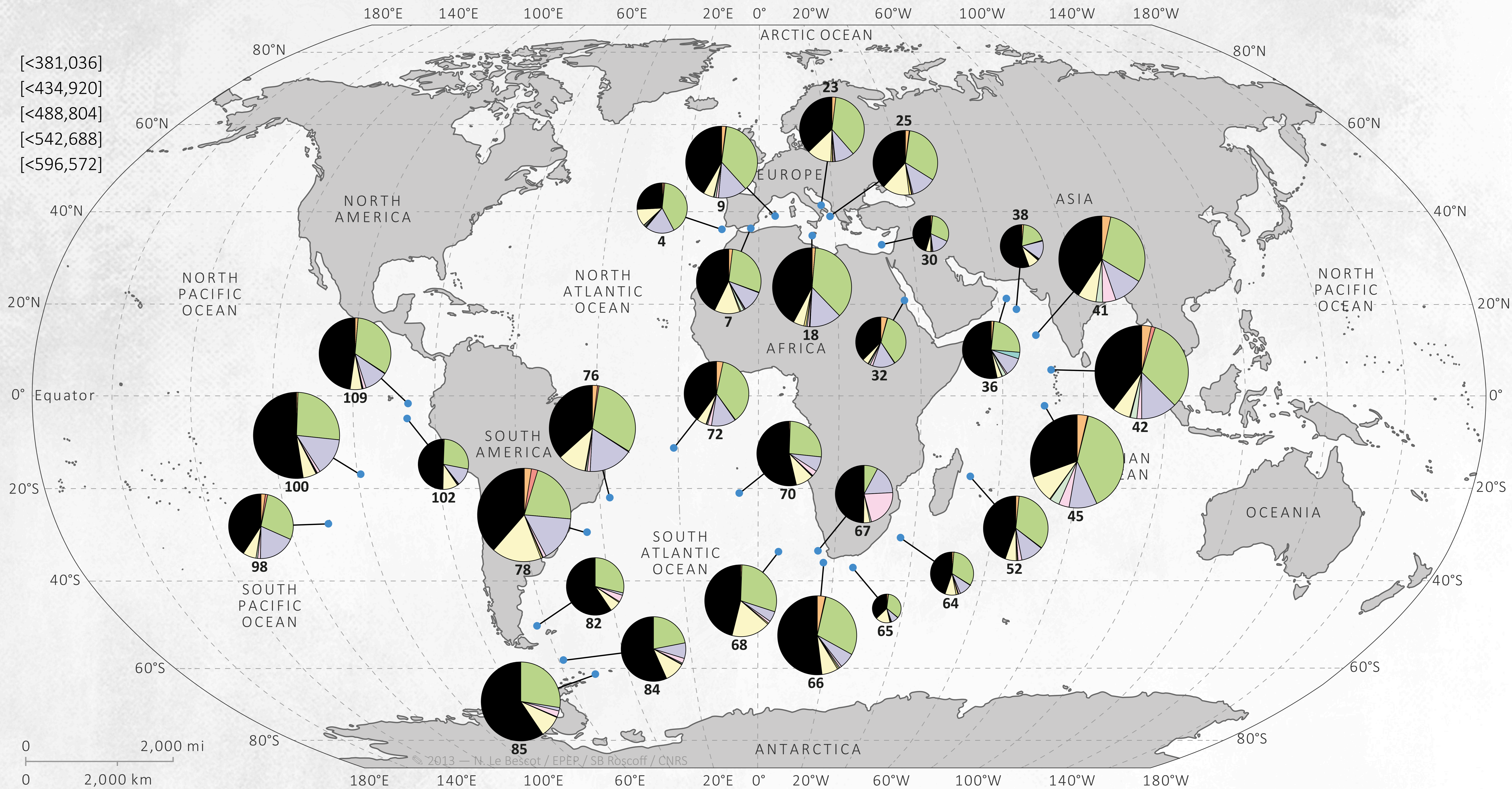
PICO-DINOFLAGELLATES [0.8–5µm]

abundance by orders

● Sampling point



abundance of barcodes



Gymnodiniales 30%
(8–41%)

► This is the first observation of the pico-dinoflagellate community

PICO-DINOFLAGELLATES [0.8–5µm]

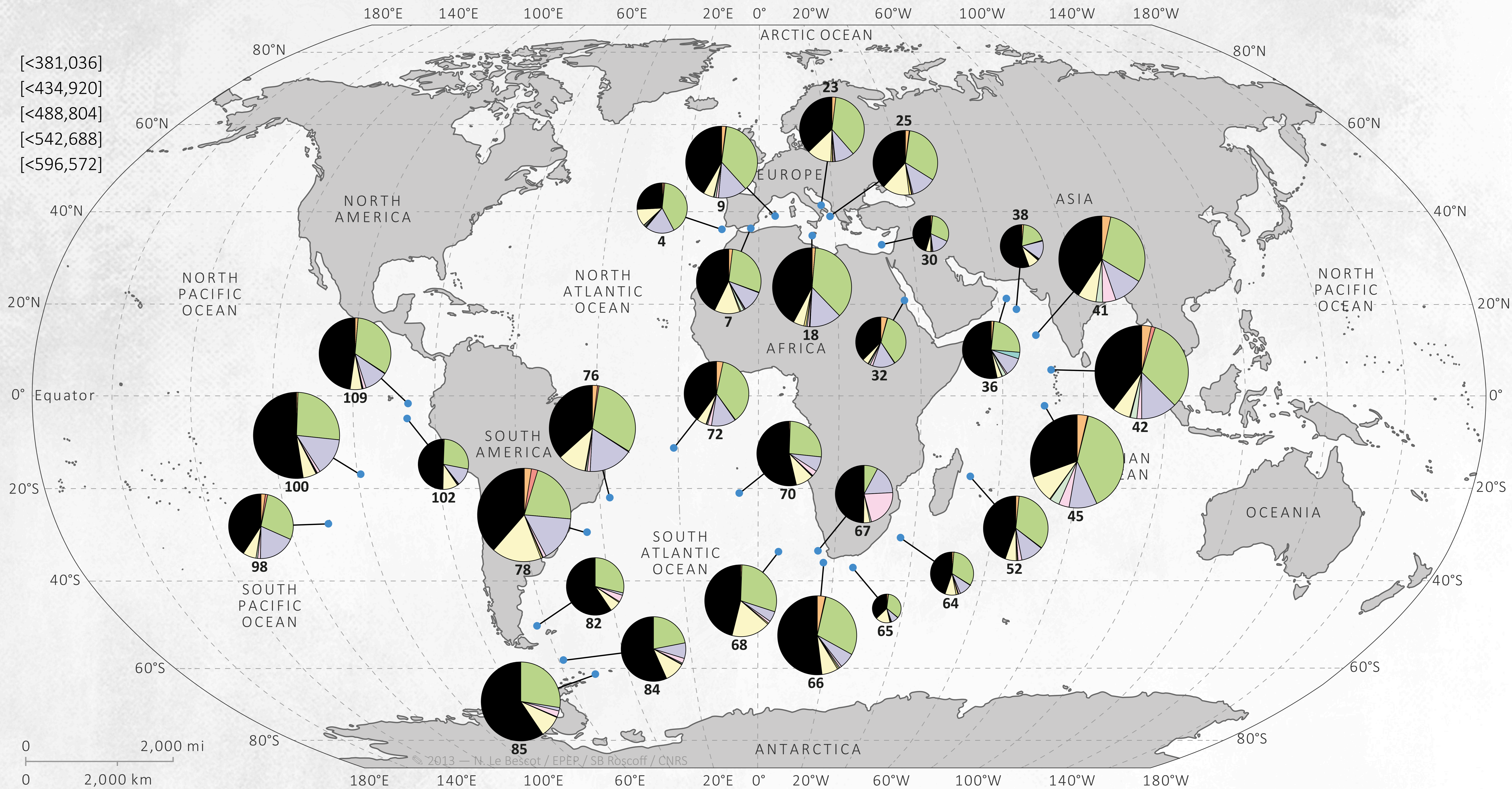
abundance by orders

● Sampling point

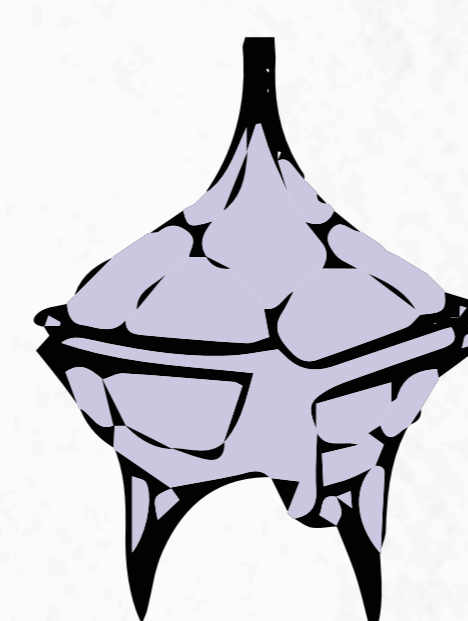


abundance of barcodes

- Dinophysiales
- Gonyaulacales
- Gymnodiniales
- Lophodiniales
- Noctilucales
- Peridinales
- Phytodiniales
- Prorocentrales
- Pyrocystales
- Suessiales
- Thoracosphaerales
- Uncultured
- Undetermined



Gymnodiniales 30%
(8–41%)



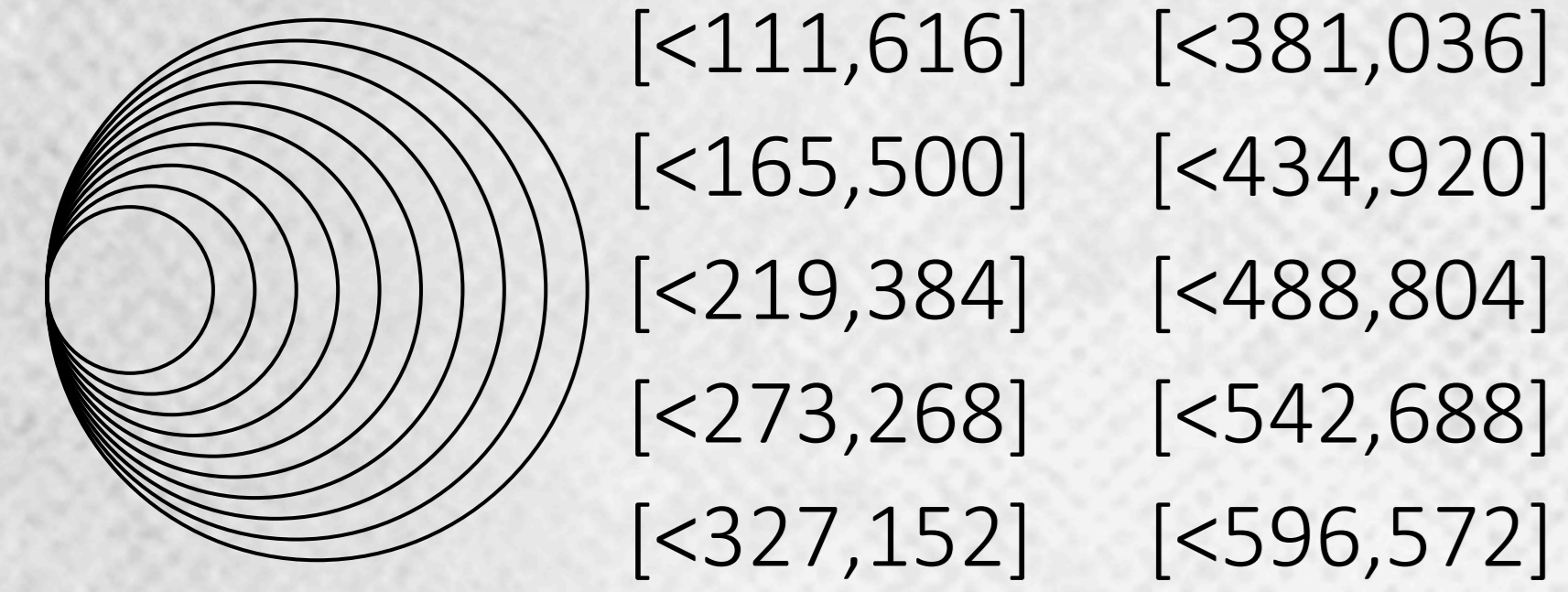
Peridinales 11%
(8–19%)

► This is the first observation of the pico-dinoflagellate community

PICO-DINOFLAGELLATES [0.8–5µm]

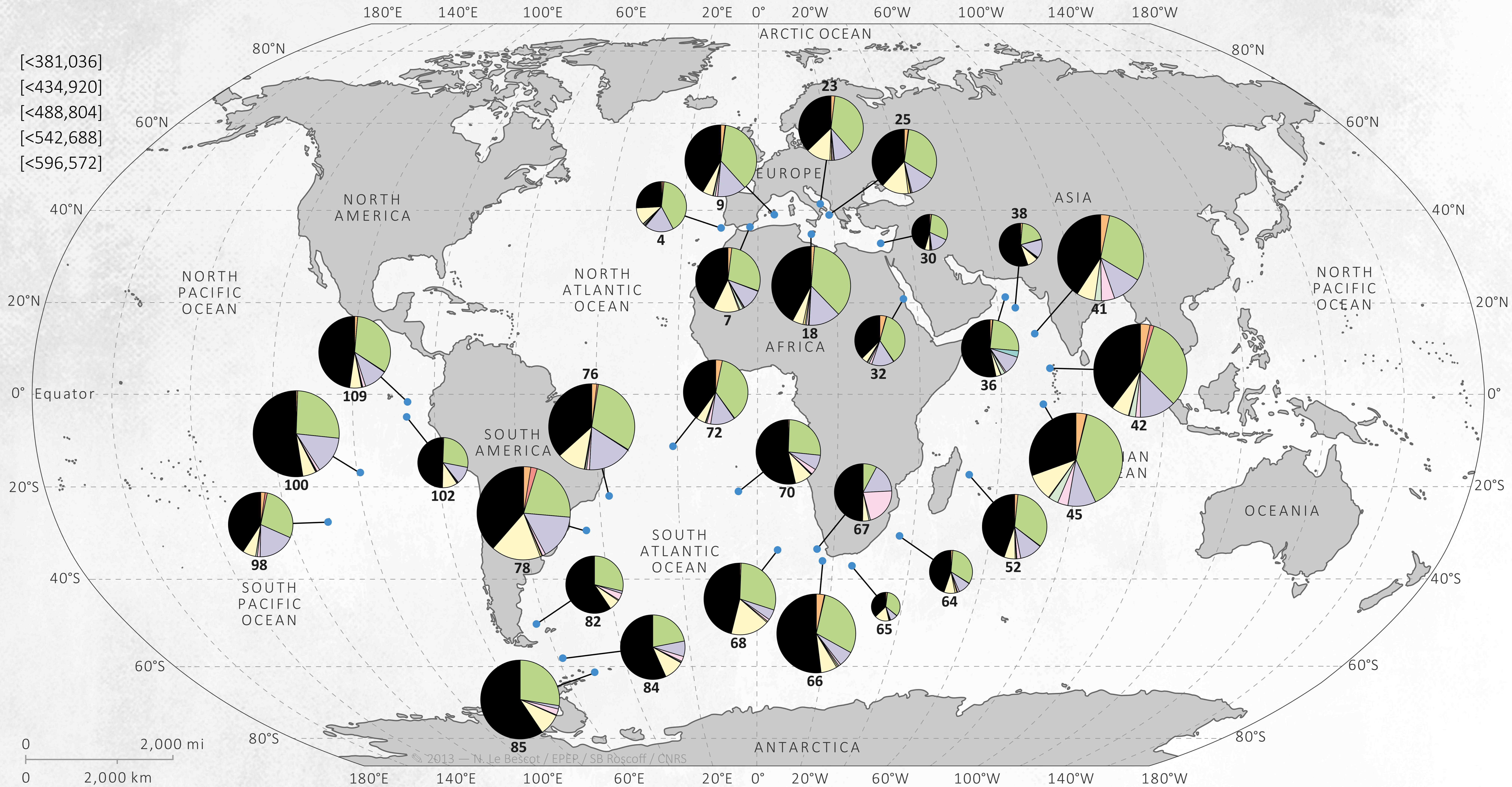
abundance by orders

● Sampling point

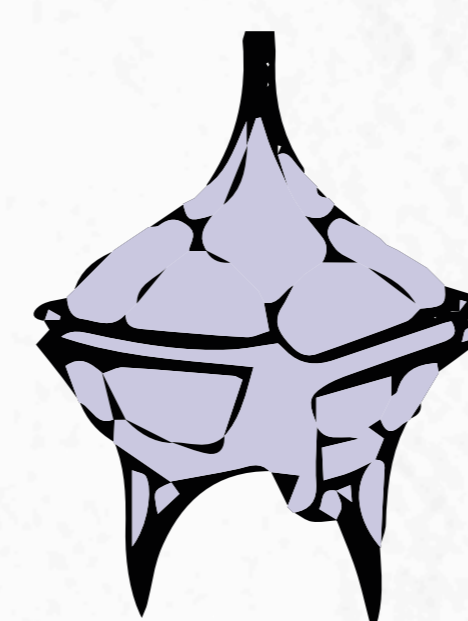


abundance of barcodes

- Dinophysiales
- Gonyaulacales
- Gymnodiniales
- Lophodiniales
- Noctilucales
- Peridiniales
- Phytodiniales
- Prorocentrales
- Pyrocystales
- Suessiales
- Thoracosphaerales
- Uncultured
- Undetermined



Gymnodiniales 30%
(8–41%)



Peridiniales 11%
(8–19%)

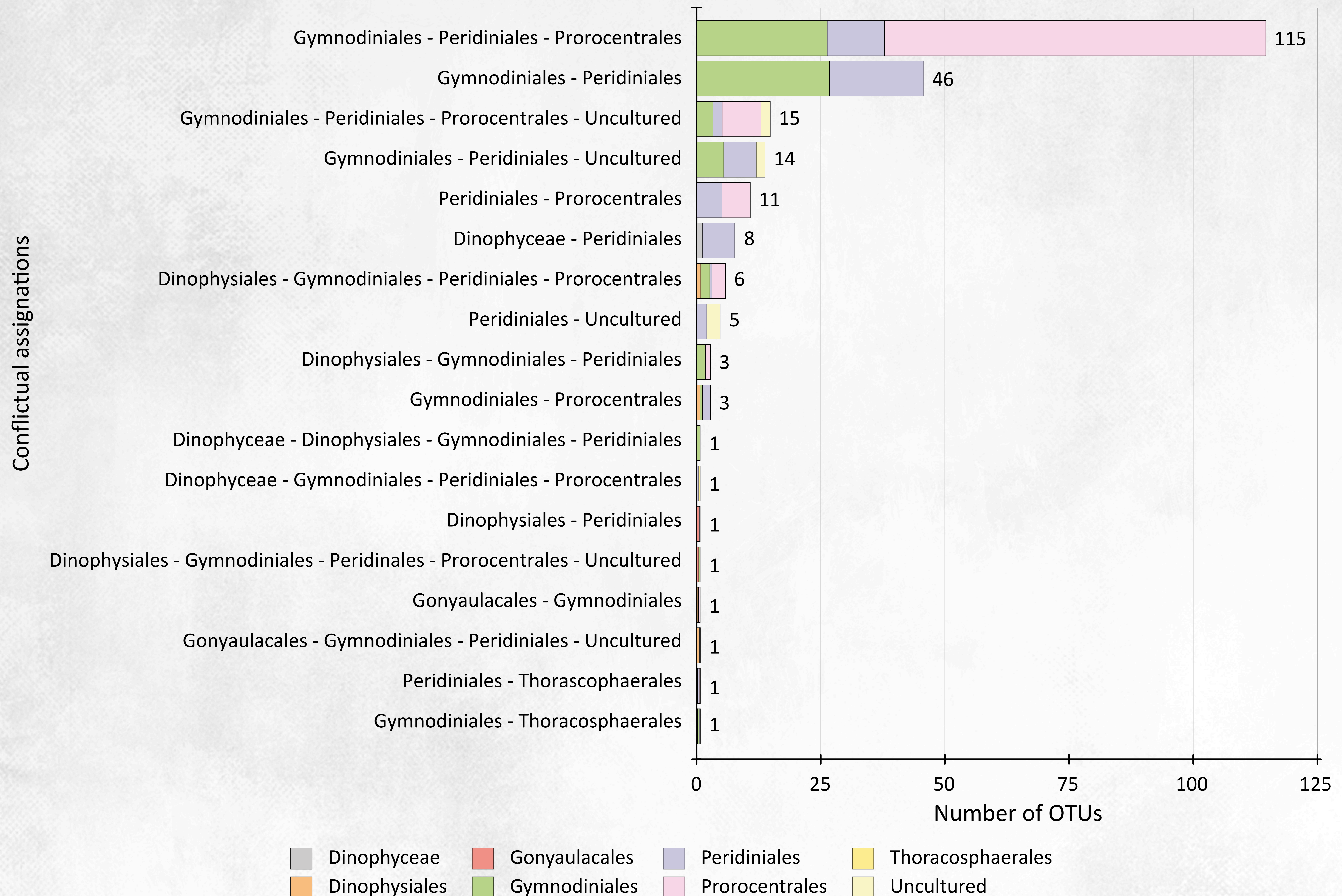


Undetermined 45%
(26–59%)

► This is the first observation of the pico-dinoflagellate community

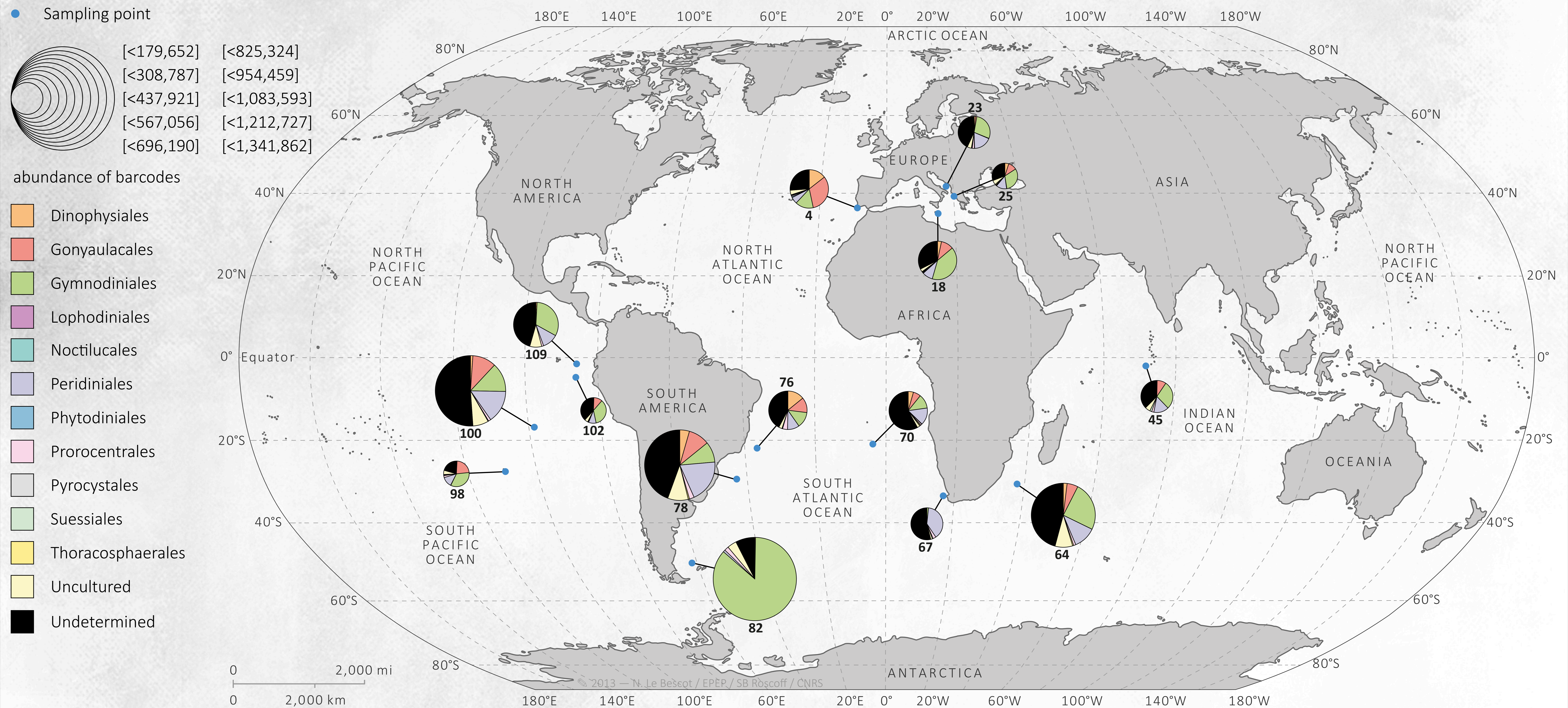
UNDETERMINED

why?



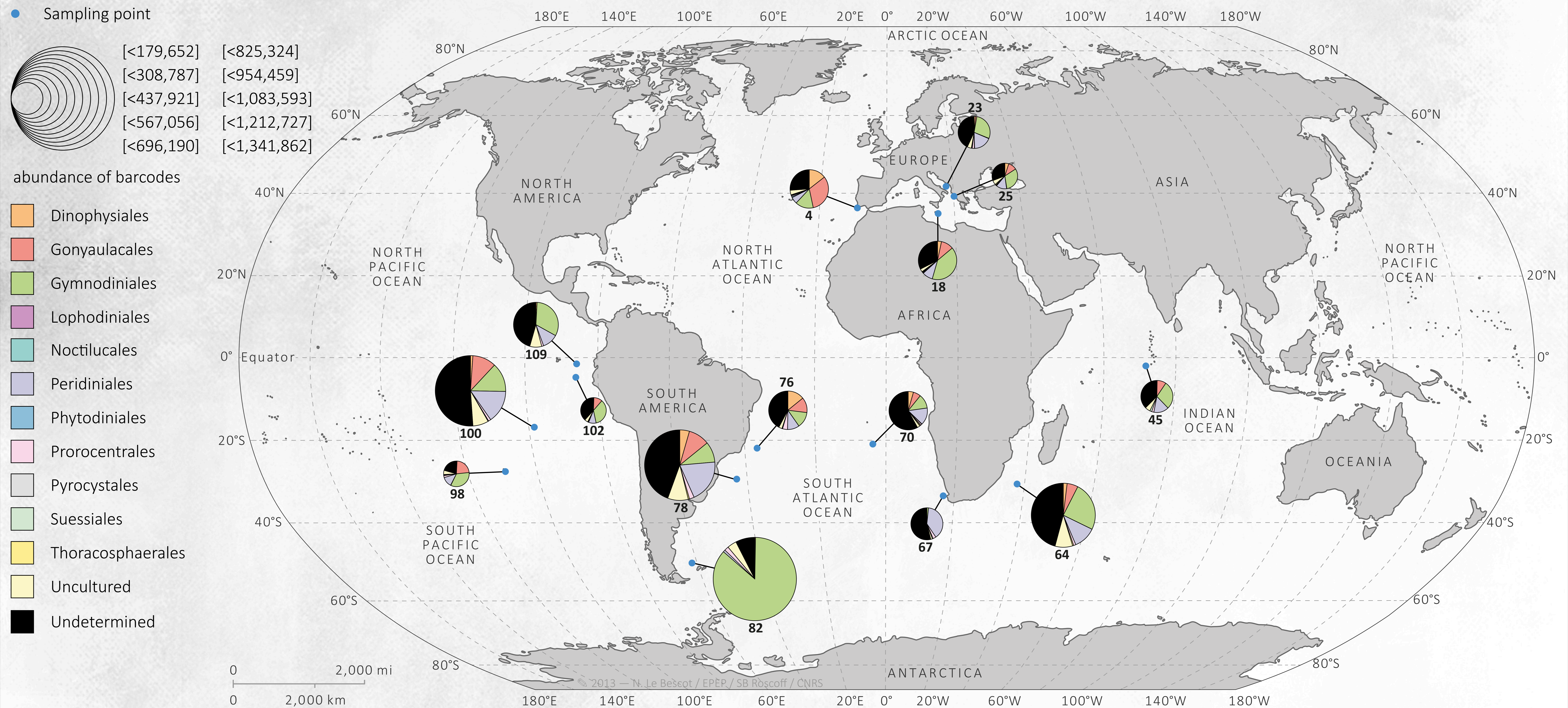
NANO-DINOFLAGELLATES [5-20µm]

abundance by orders



NANO-DINOFLAGELLATES [5-20µm]

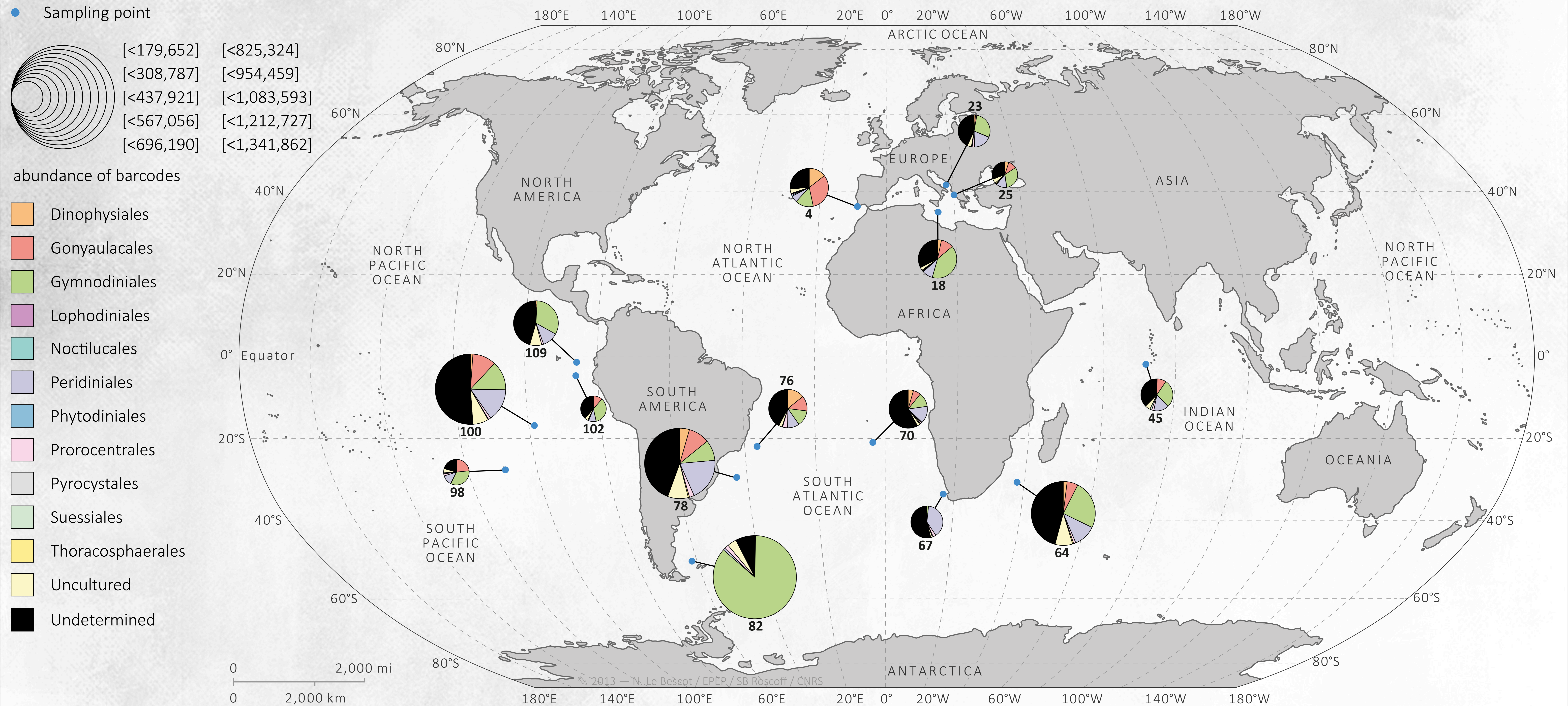
abundance by orders



? Undetermined 35%

NANO-DINOFLAGELLATES [5-20µm]

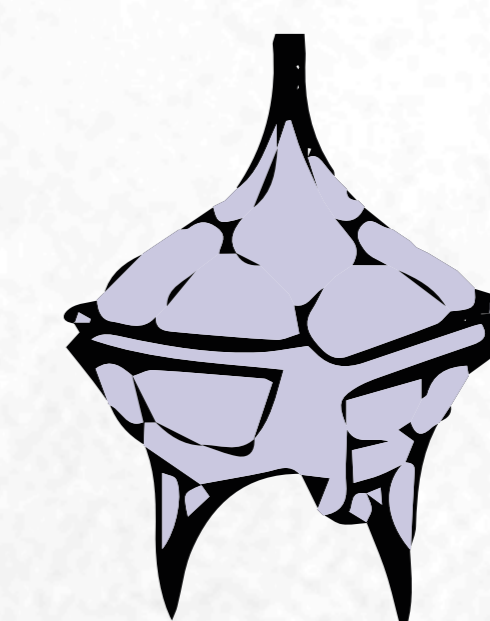
abundance by orders



? Undetermined 35%



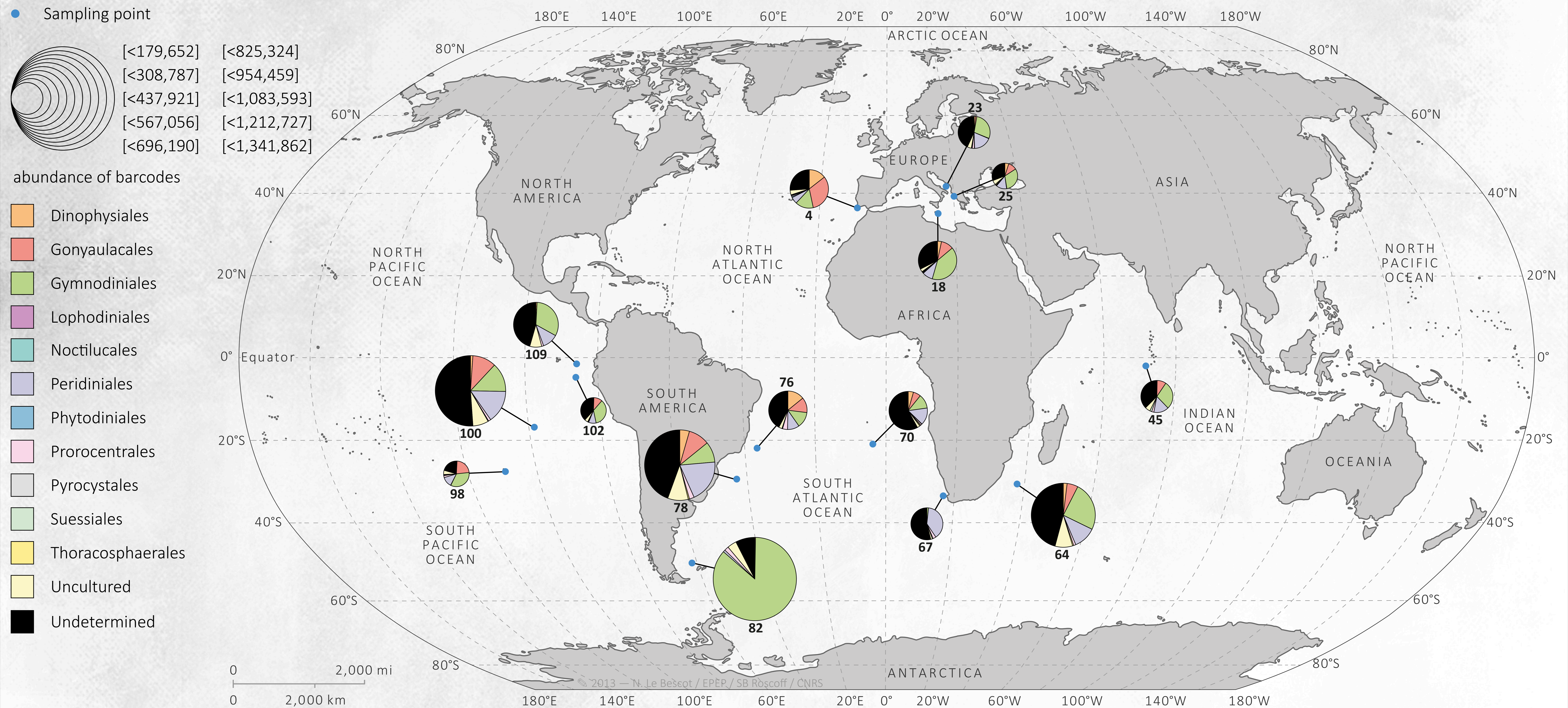
Gymnodiniales



Peridinales

NANO-DINOFLAGELLATES [5-20µm]

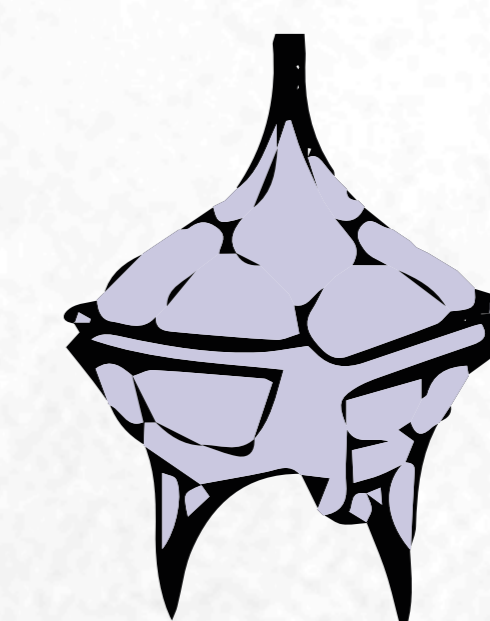
abundance by orders



? Undetermined 35%



Gymnodiniales



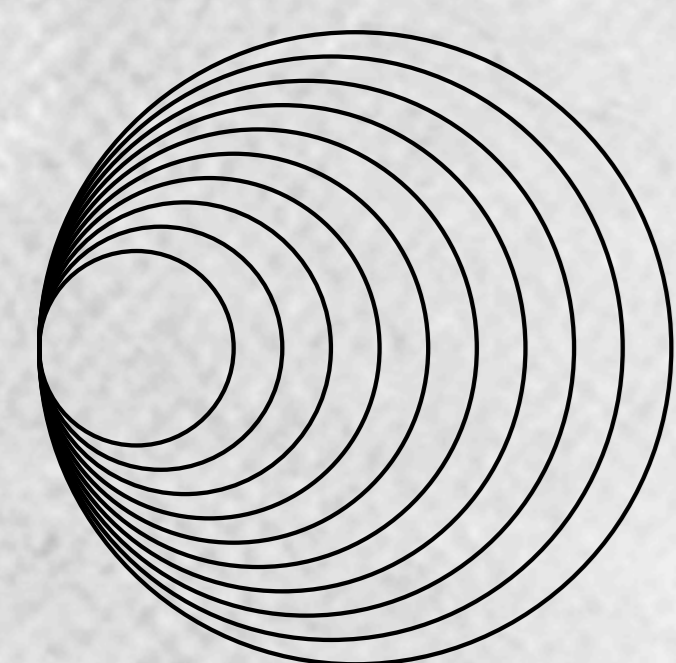
Peridinales

► No dominant pattern

MICRO-DINOFLAGELLATES [20-180µm]

abundance by orders

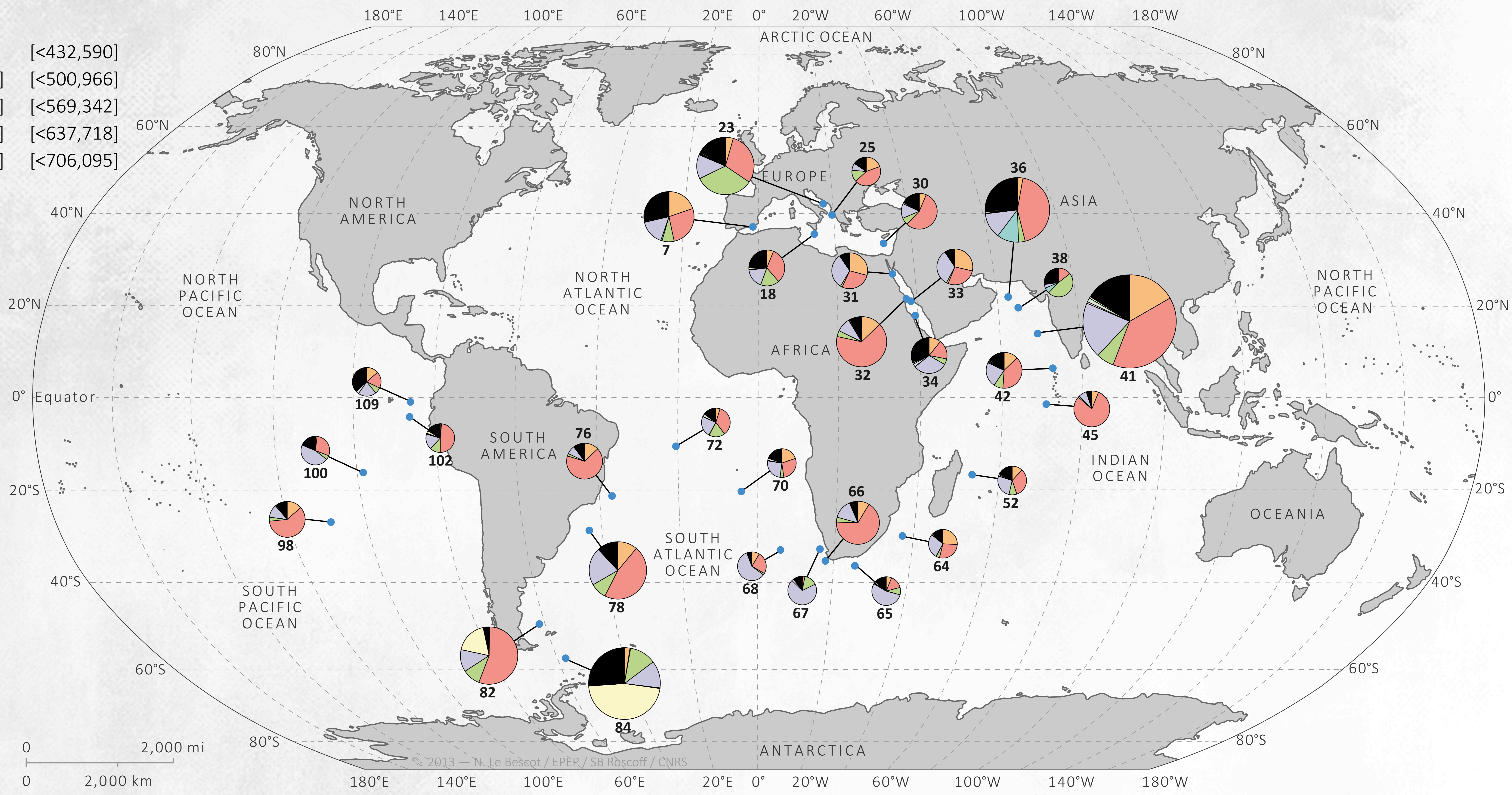
● Sampling point



[<90,709]	[<432,590]
[<159,085]	[<500,966]
[<227,461]	[<569,342]
[<295,837]	[<637,718]
[<364,214]	[<706,095]

abundance of barcodes

- Dinophysiales
- Gonyaulacales
- Gymnodiniales
- Lophodinales
- Noctilucales
- Peridinales
- Phytodinales
- Prorocentrales
- Pyrocystales
- Suessiales
- Thoracosphaerales
- Uncultured
- Undetermined



© 2013 — N. Le Bescot / EPEP / SB Roscoff / CNRS

MICRO-DINOFLAGELLATES [20-180µm]

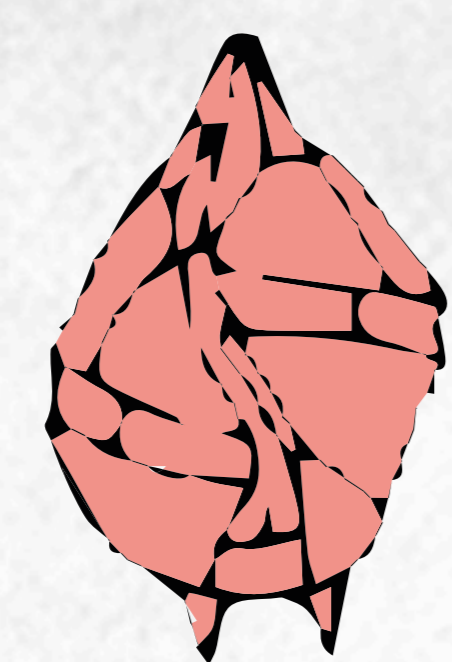
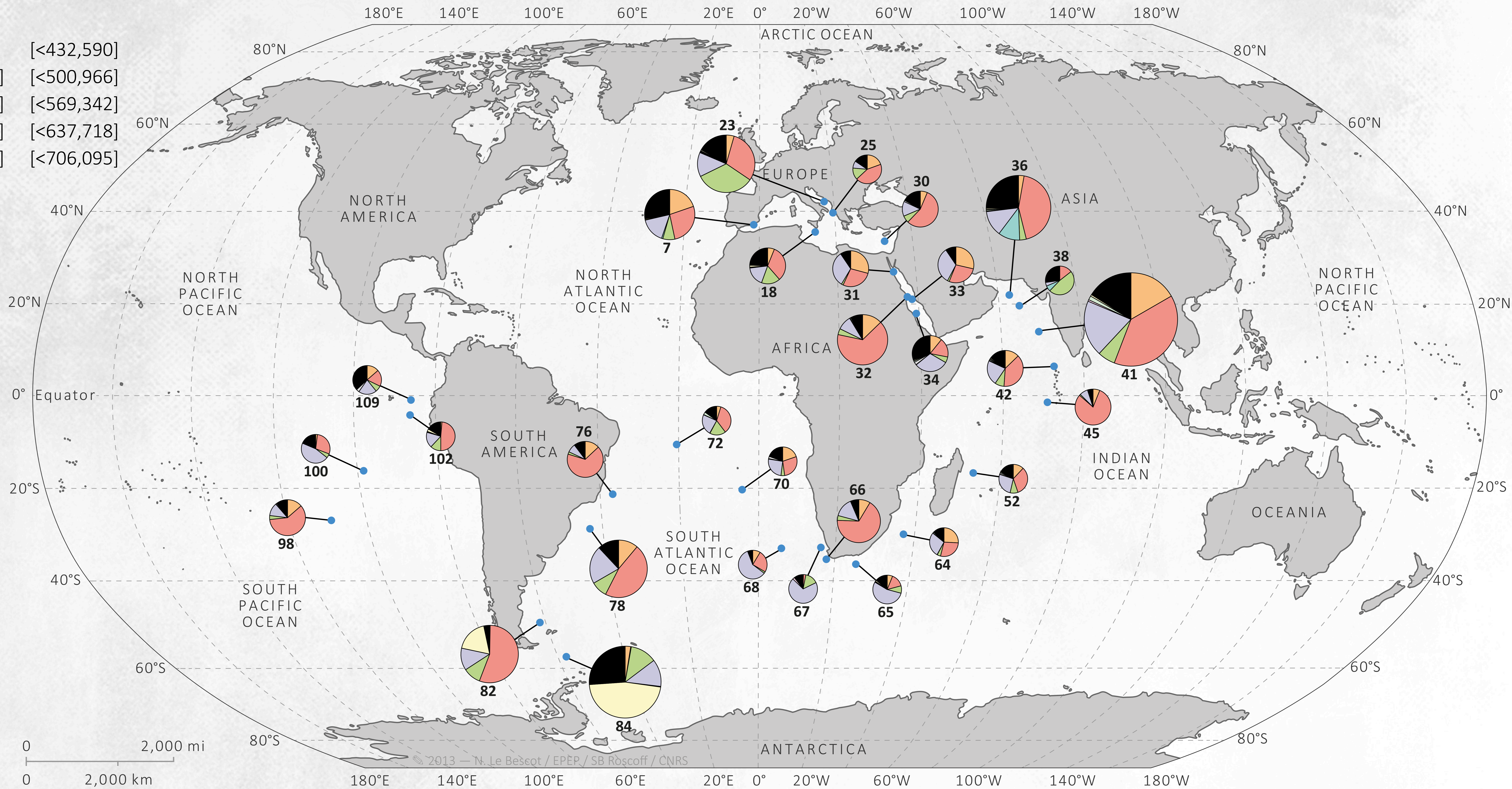
abundance by orders

● Sampling point



abundance of barcodes

- Dinophysiales
- Gonyaulacales
- Gymnodiniales
- Lophodiniales
- Noctilucales
- Peridiniales
- Phytodiniales
- Prorocentrales
- Pyrocystales
- Suessiales
- Thoracosphaerales
- Uncultured
- Undetermined



Gonyaulacales 37%
(18-80%)

MICRO-DINOFLAGELLATES [20-180µm]

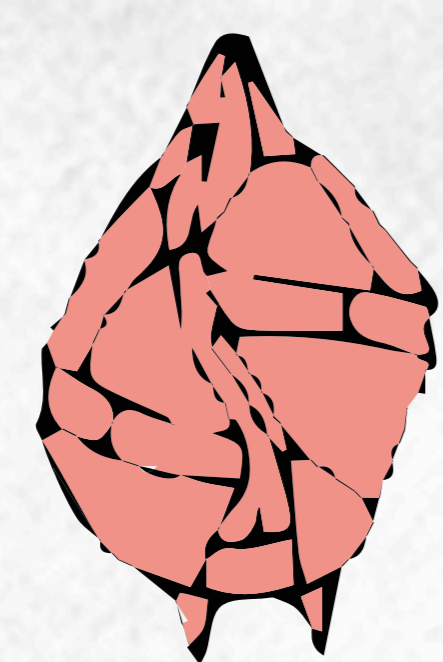
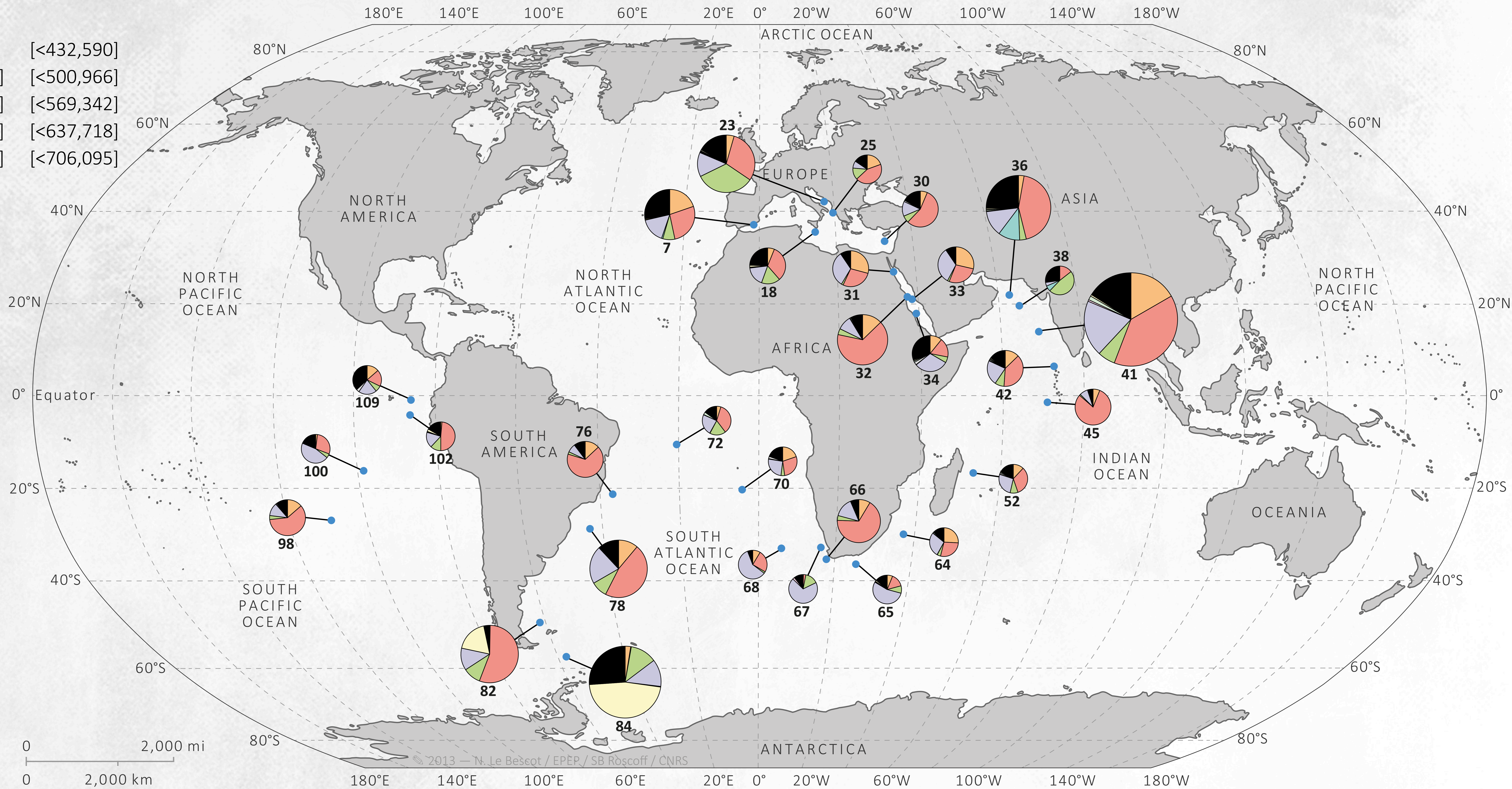
abundance by orders

● Sampling point

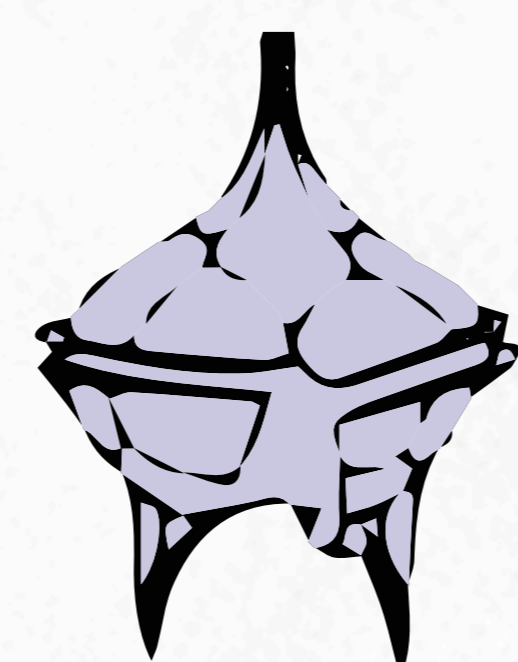


abundance of barcodes

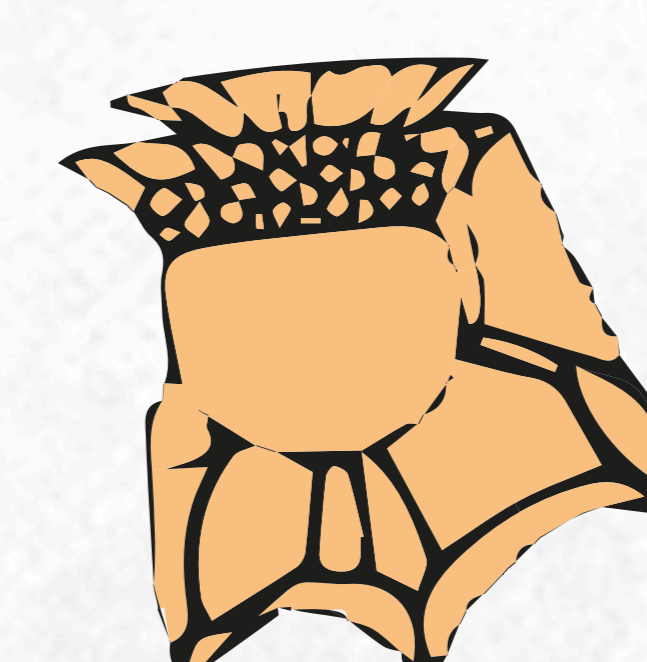
- Dinophysiales
- Gonyaulacales
- Gymnodiniales
- Lophodiniales
- Noctilucales
- Peridinales
- Phytodiniales
- Prorocentrales
- Pyrocystales
- Suessiales
- Thoracosphaerales
- Uncultured
- Undetermined



Gonyaulacales 37%
(18-80%)



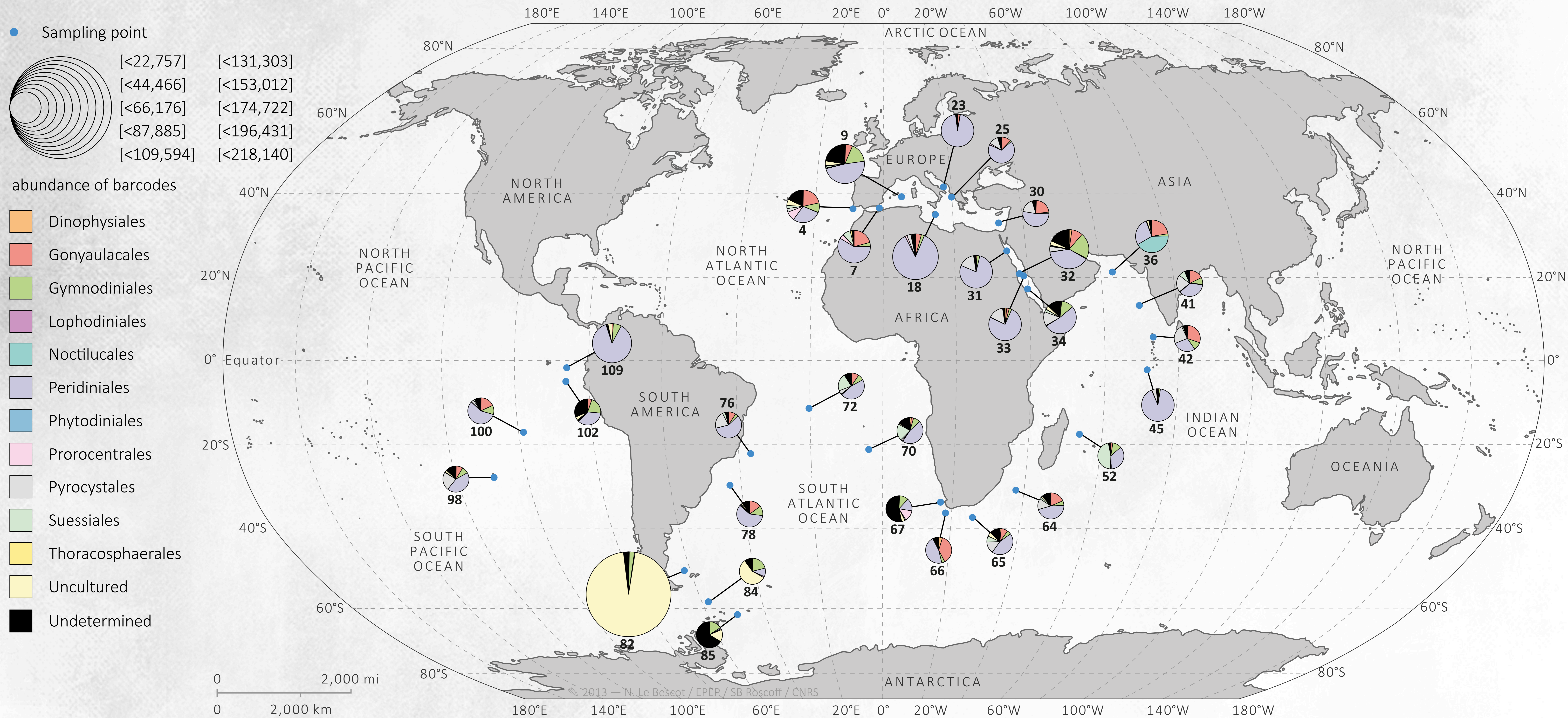
Peridinales 23%
(21-69%)



Dinophysiales

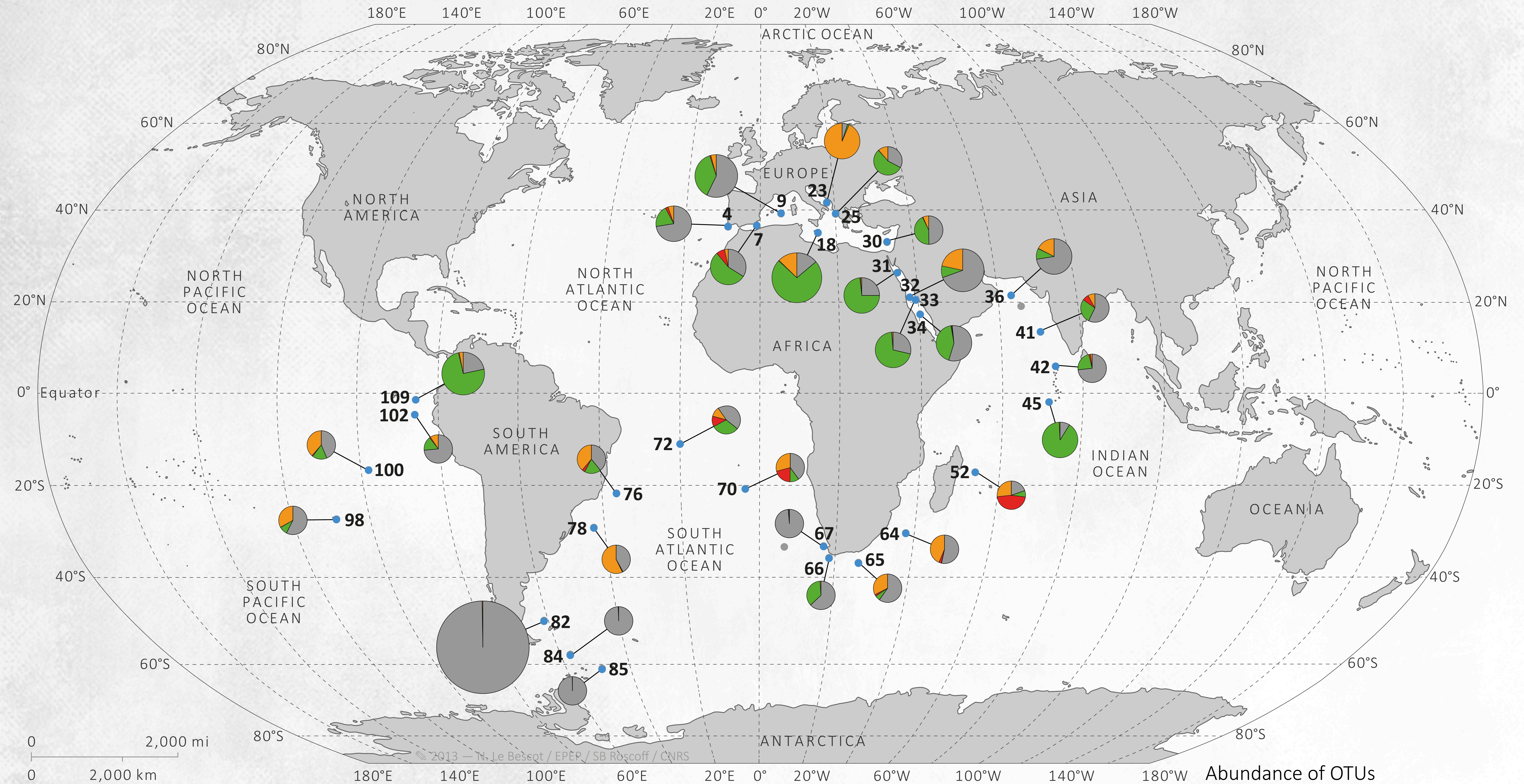
DINOFLAGELLATES IN MESO-PLANKTON [180–2,000µM]

abundance by orders

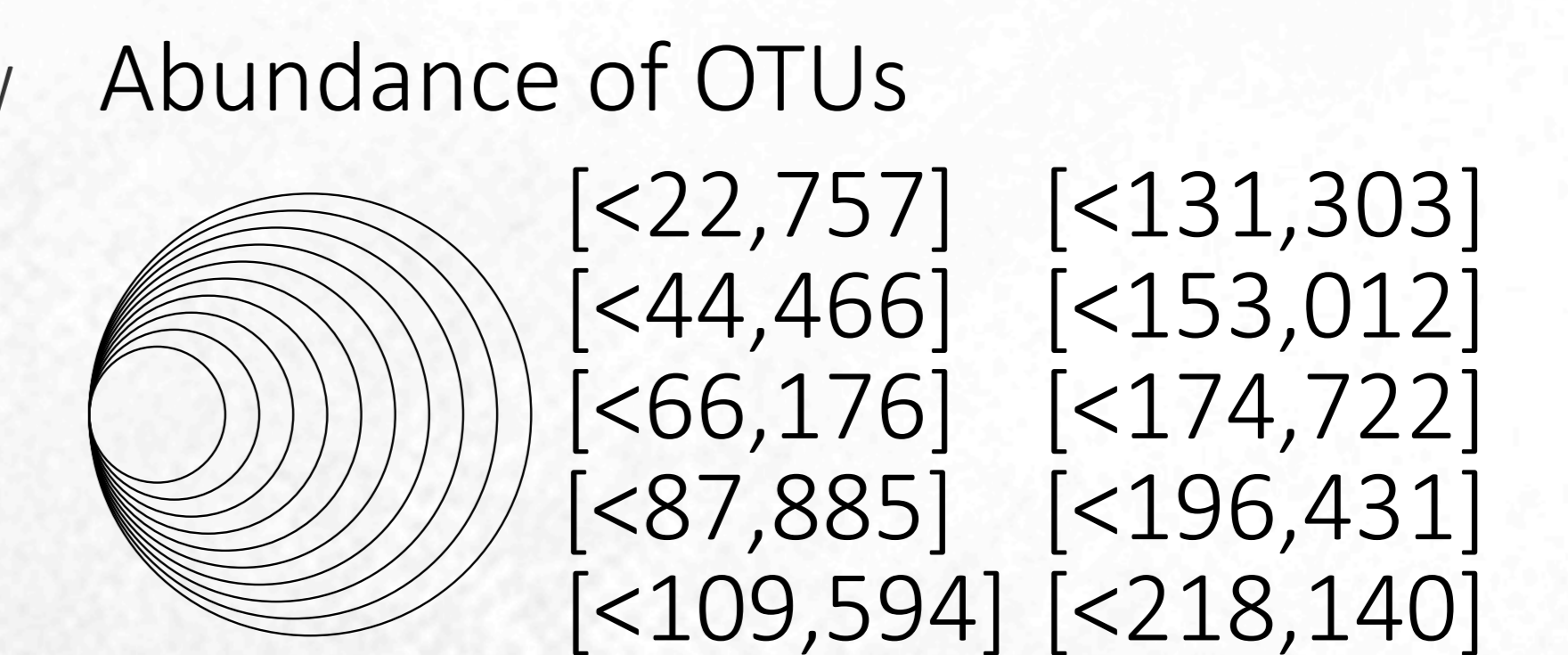


DINOFLAGELLATES IN MESO-PLANKTON [180–2,000µM]

symbiotic (mutualistic or parasitic) genera



• Sampling point • Sampling point with none-available data
■ *Brandtodinium* ■ *Blastodinium* ■ *Pelagodinium* ■ Other Dinoflagellates



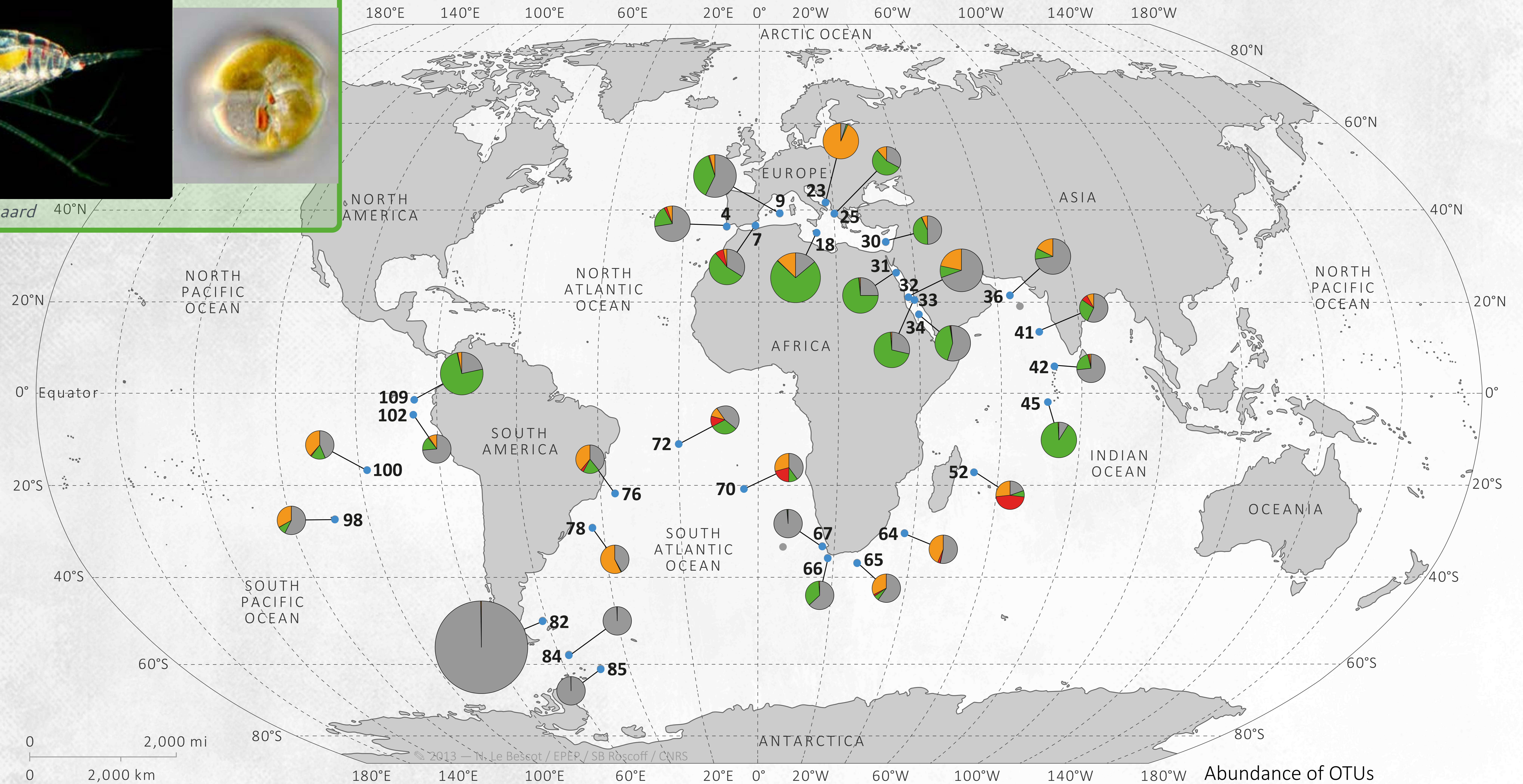
DINOFLAGELLATES IN MESO-PLANKTON [180–2,000µM]

symbiotic (mutualistic or parasitic) genera

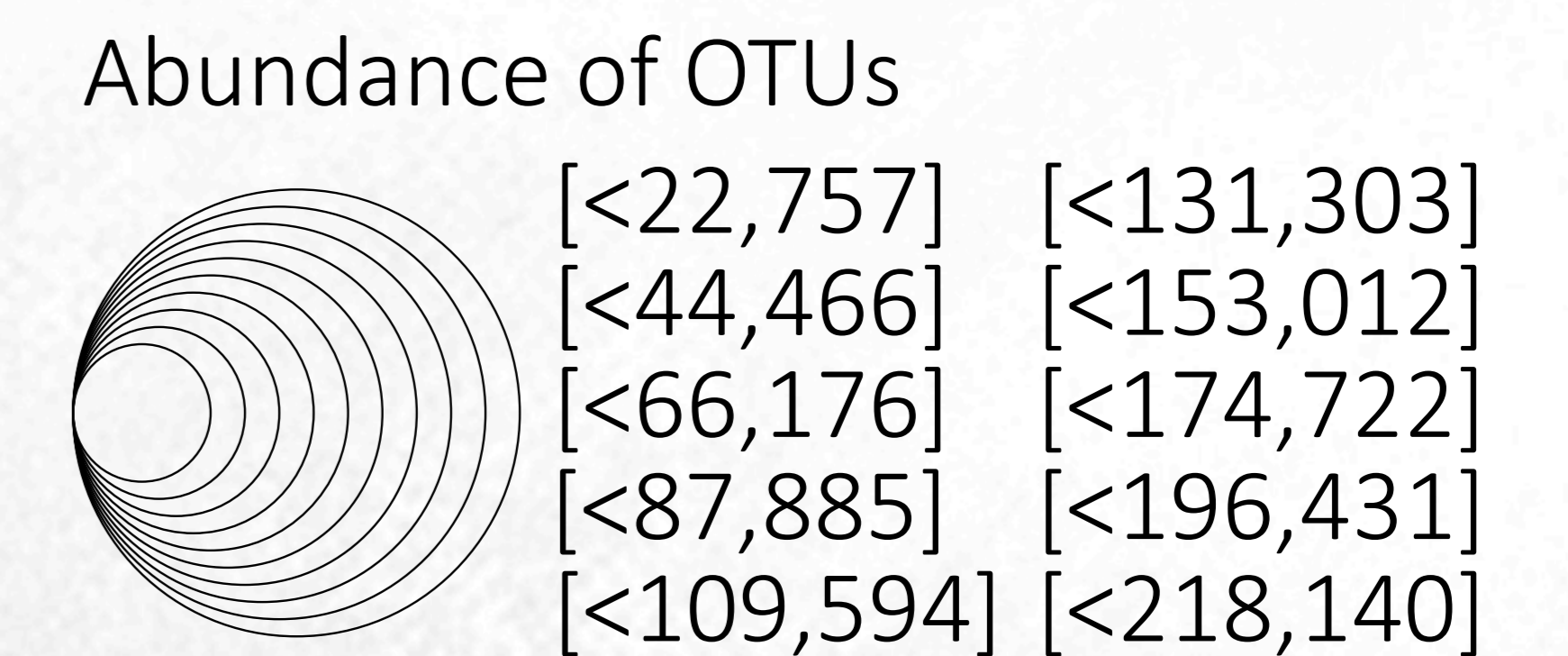
Blastodinium



© Alf Skovgaard



• Sampling point • Sampling point with none-available data
■ *Brandtodinium* ■ *Blastodinium* ■ *Pelagodinium* ■ Other Dinoflagellates



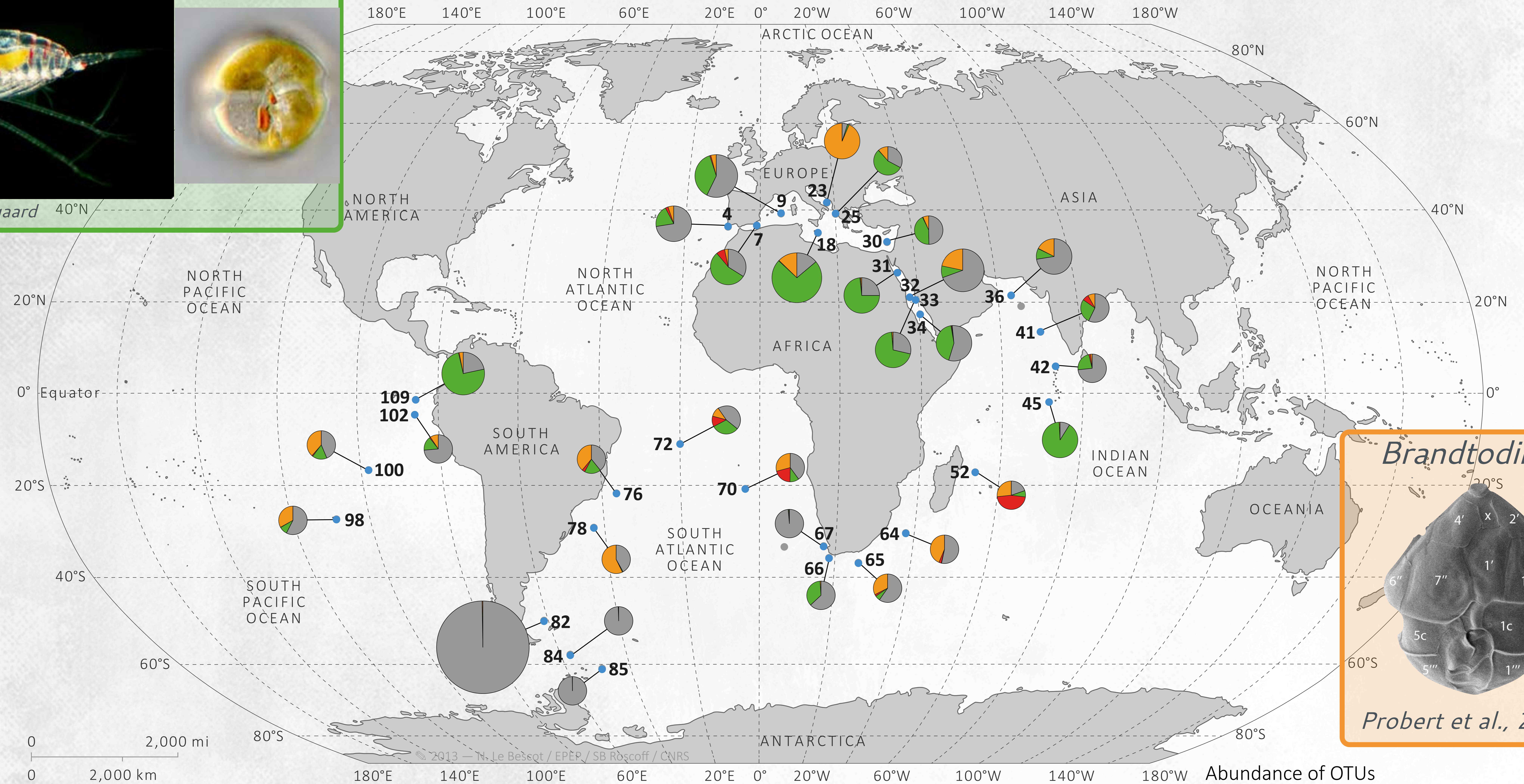
DINOFLAGELLATES IN MESO-PLANKTON [180–2,000µM]

symbiotic (mutualistic or parasitic) genera

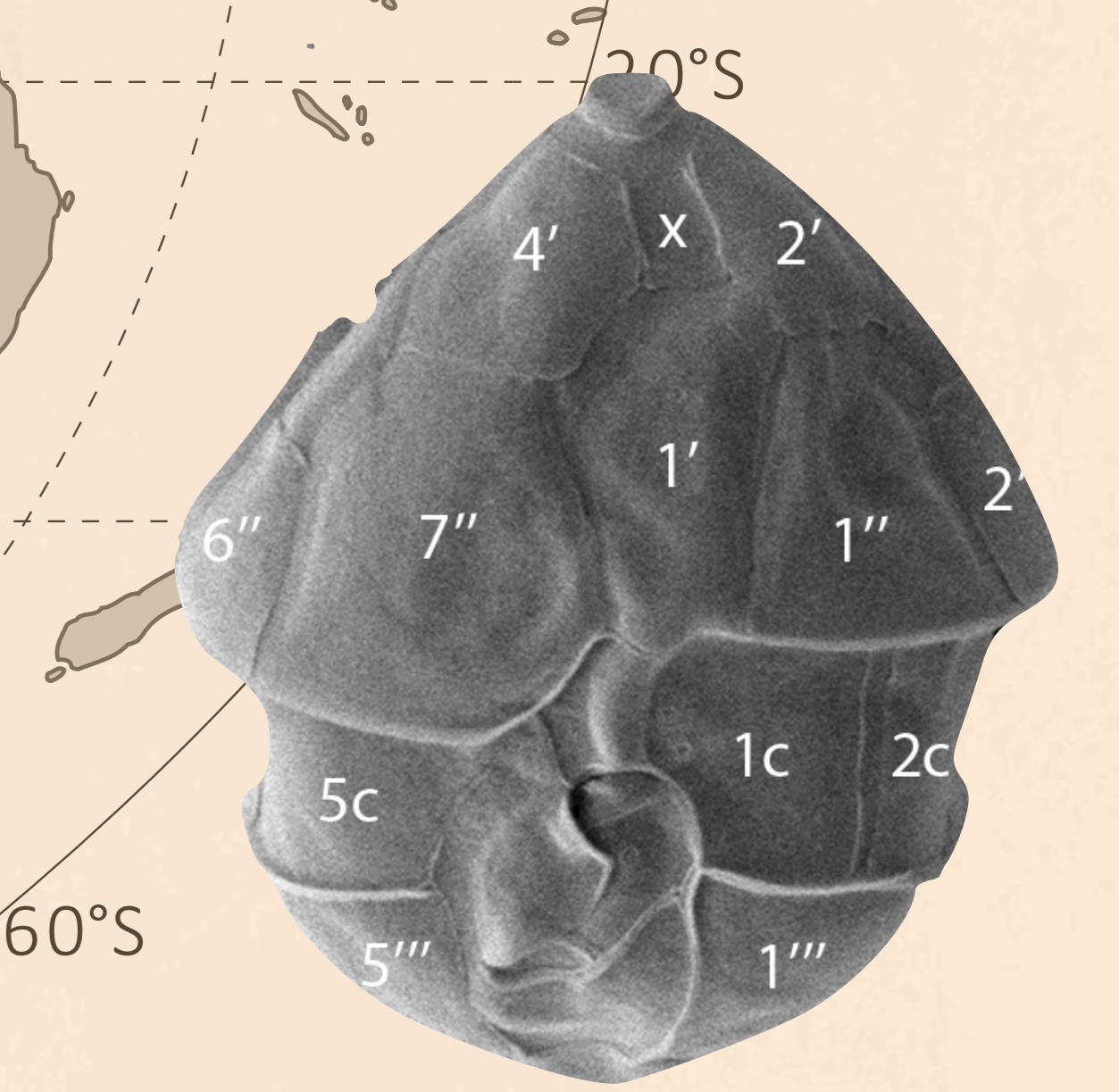
Blastodinium



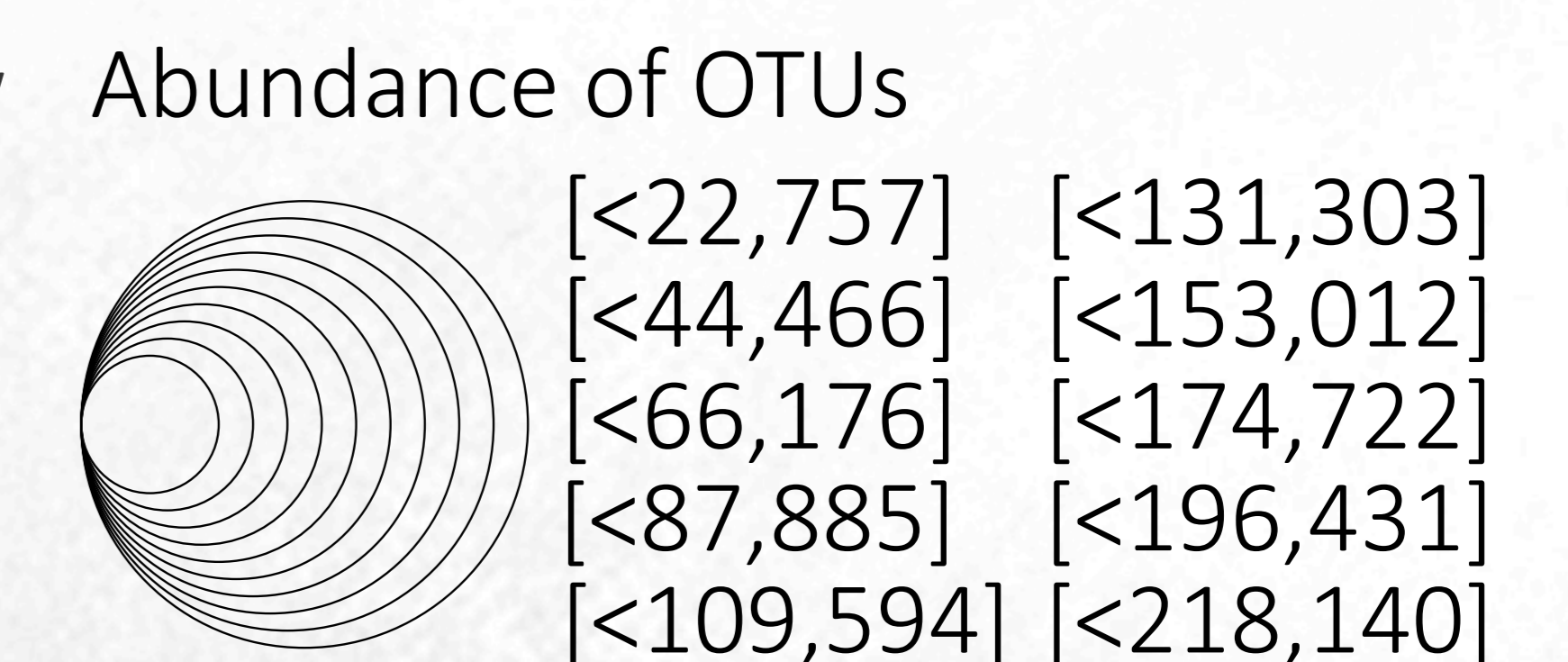
© Alf Skovgaard



Brandtodinium



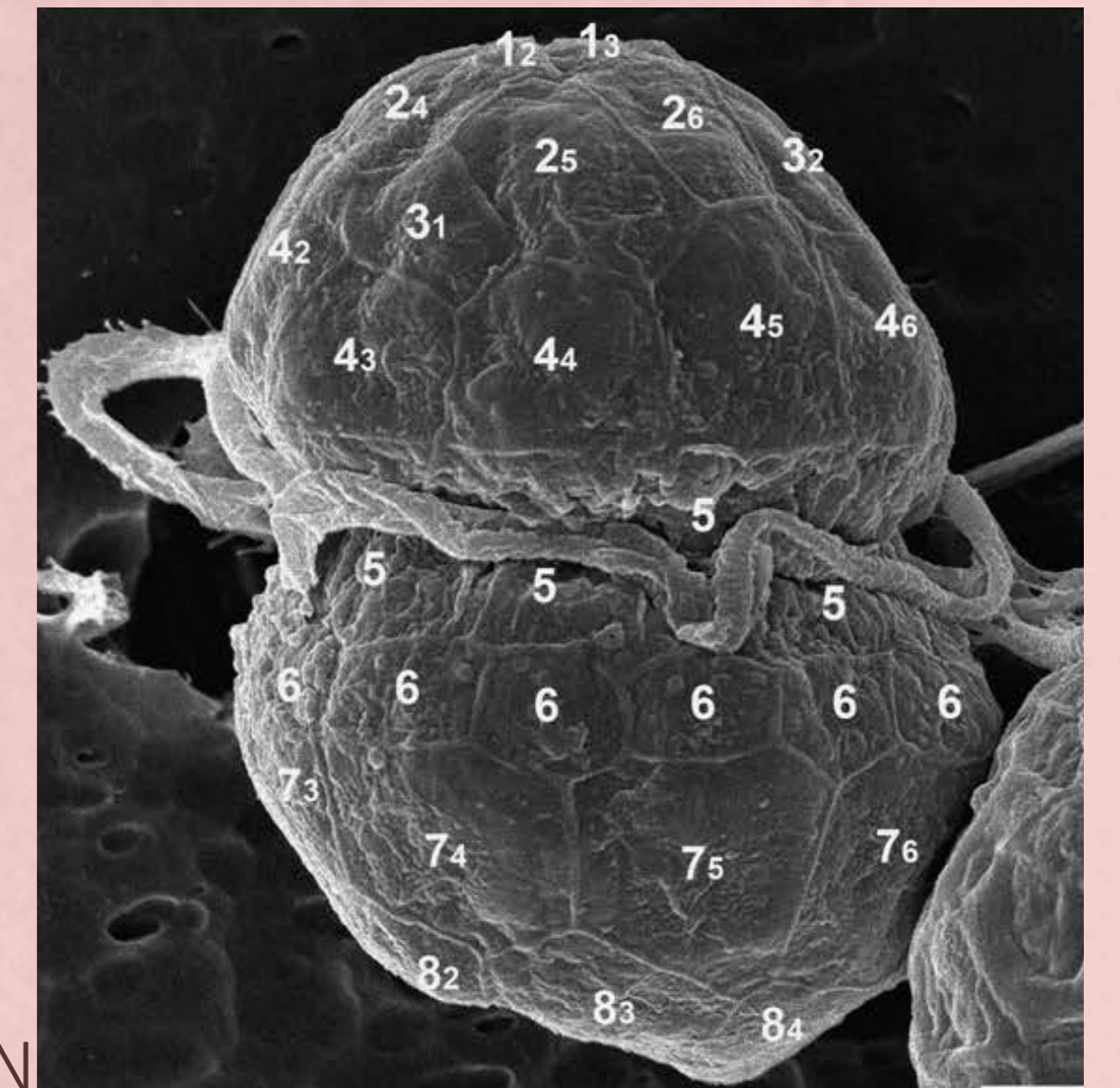
Probert et al., 2014



DINOFLAGELLATES IN MESO-PLANKTON [180–2,000µM]

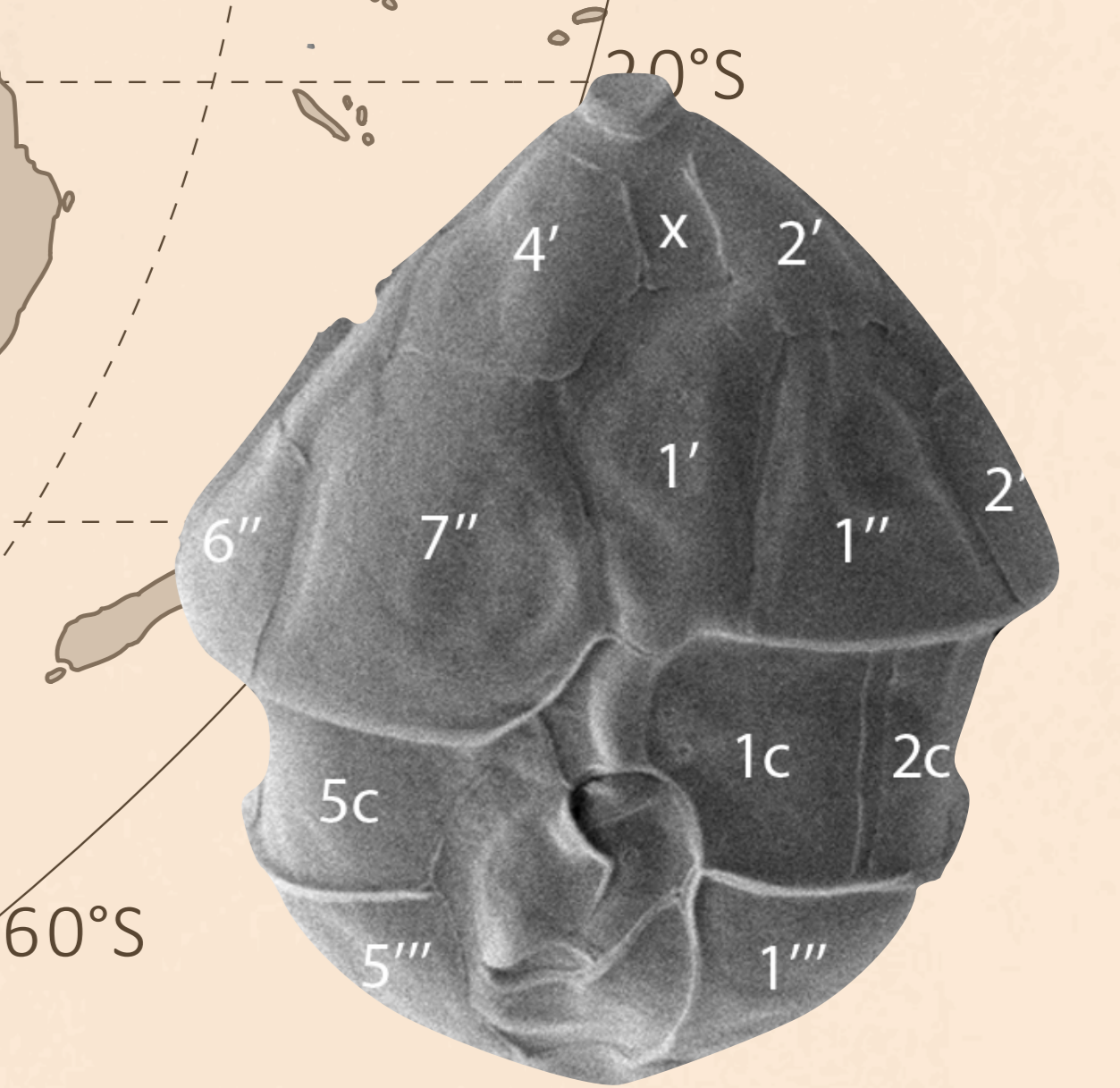
symbiotic (mutualistic or parasitic) genera

Blastodinium

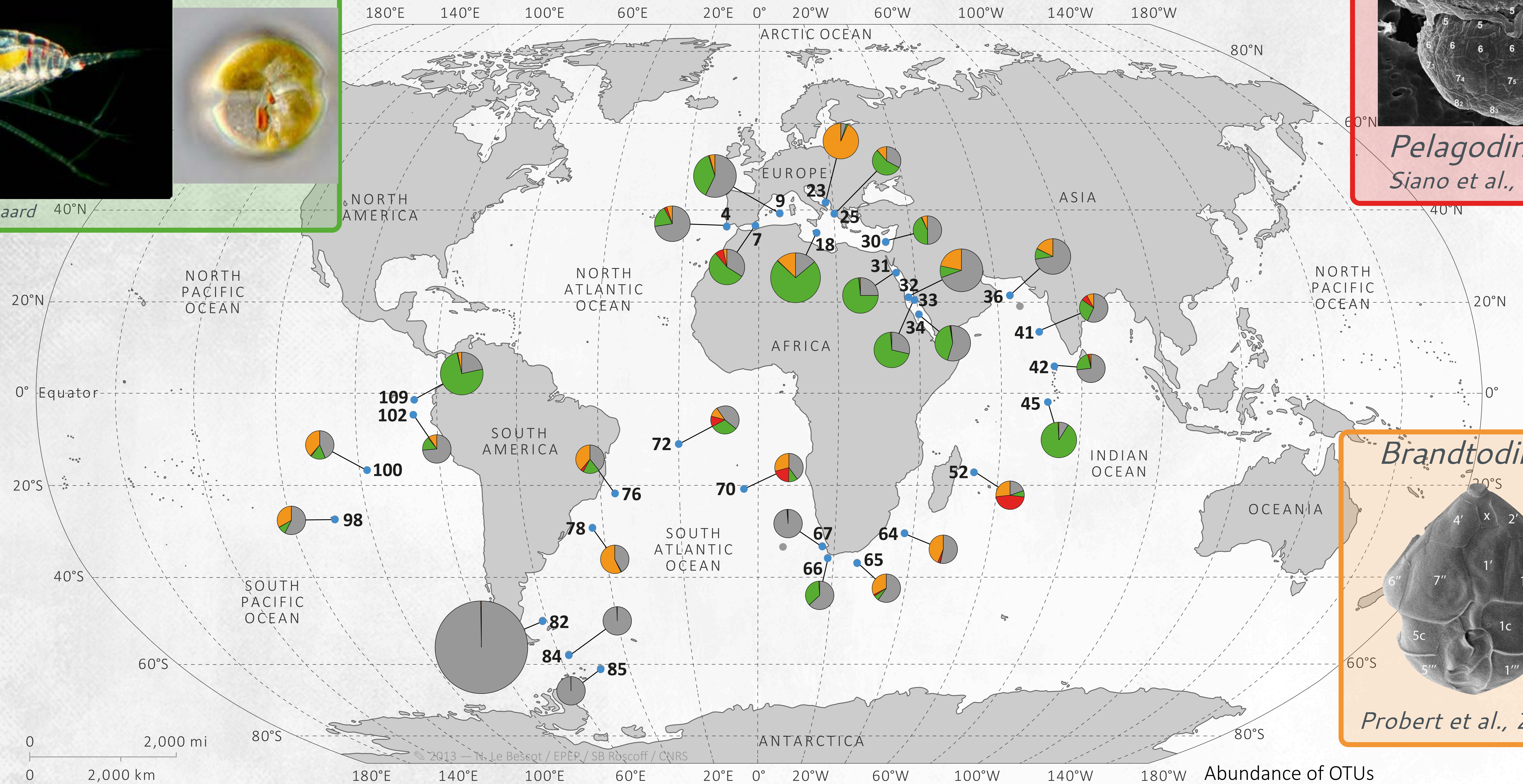


Pelagodinium
Siano et al., 2010

Brandtodinium

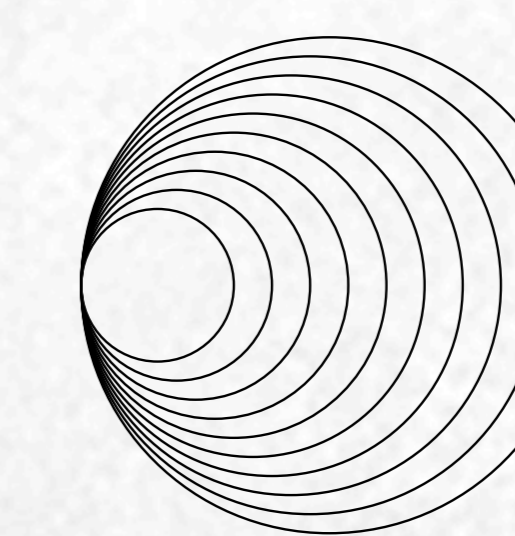


Probert et al., 2014



● Sampling point ● Sampling point with none-available data

■ *Brandtodinium* ■ *Blastodinium* ■ *Pelagodinium* ■ Other Dinoflagellates

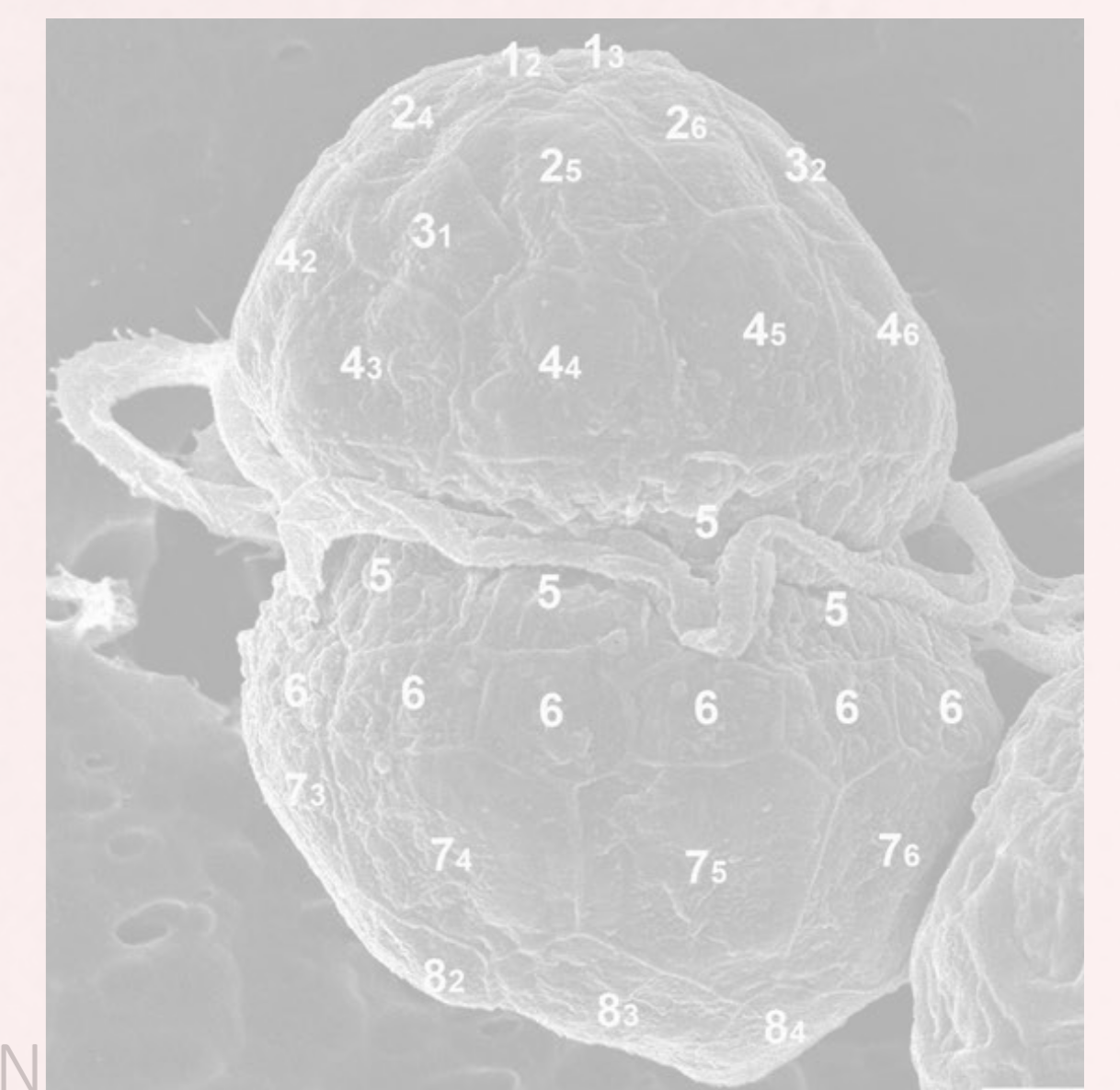
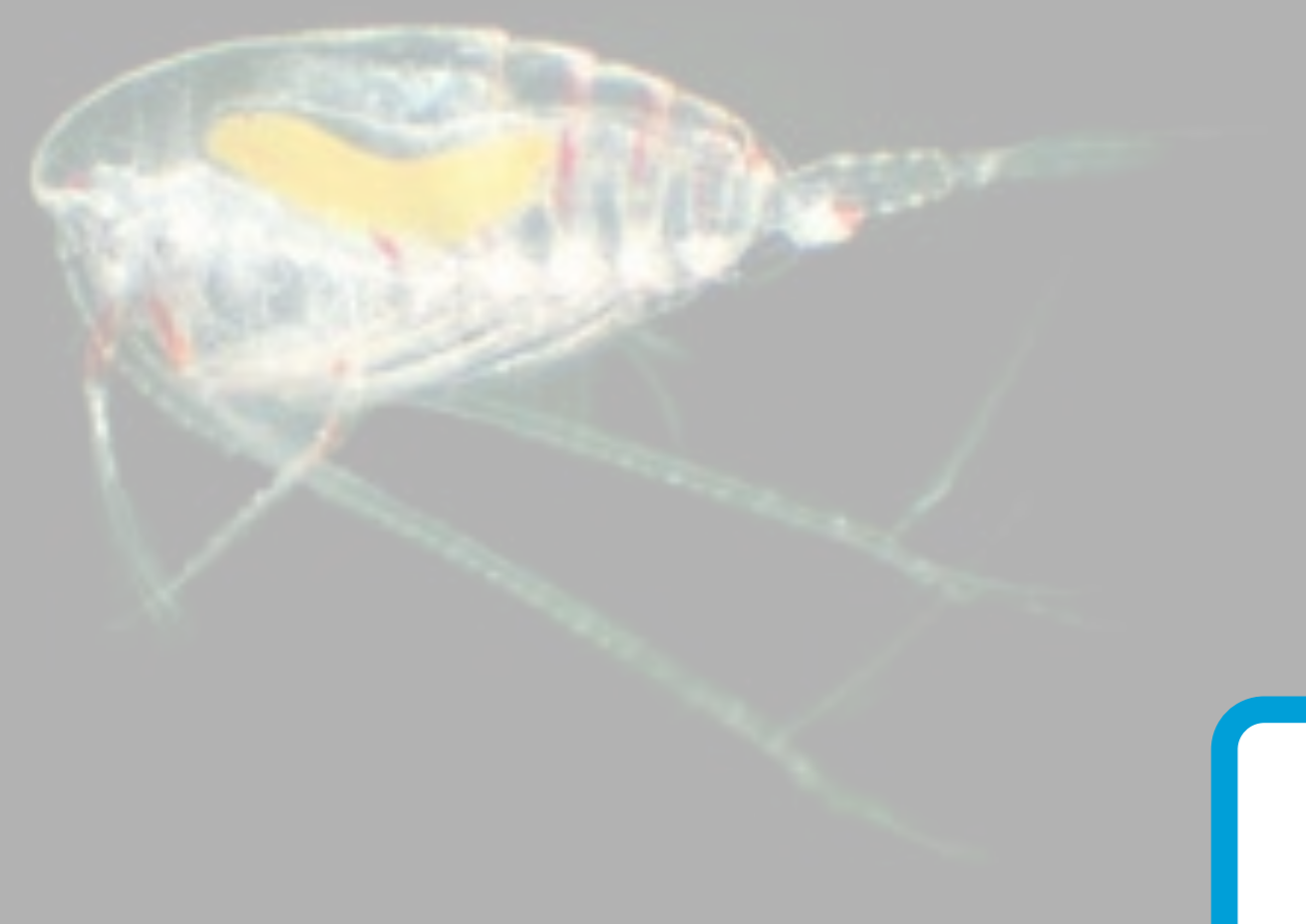


[<22,757]	[<131,303]
[<44,466]	[<153,012]
[<66,176]	[<174,722]
[<87,885]	[<196,431]
[<109,594]	[<218,140]

DINOFLAGELLATES IN MESO-PLANKTON [180–2,000µM]

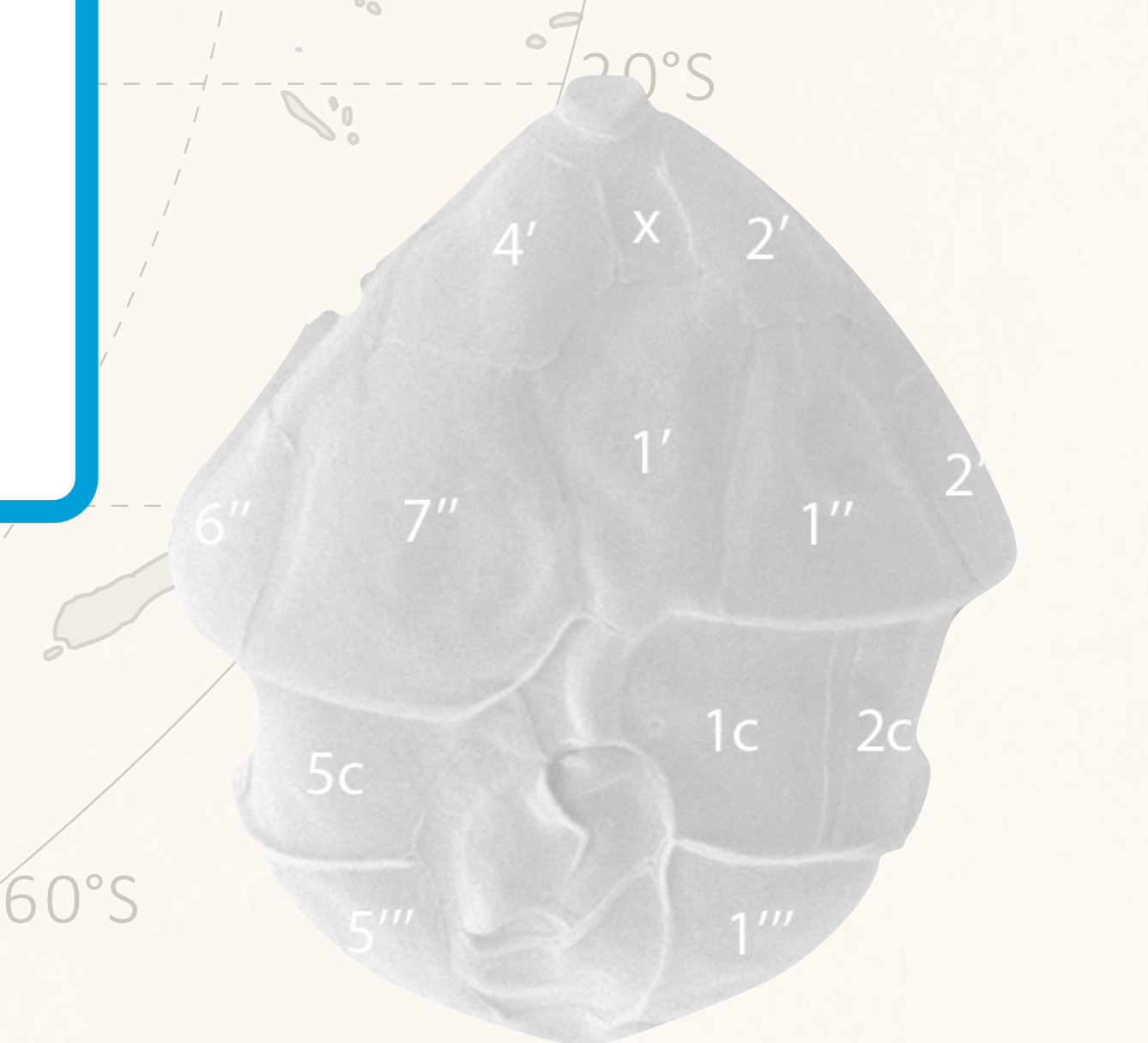
symbiotic (mutualistic or parasitic) genera

Blastodinium



Pelagodinium
Siano et al., 2010

Brandtodinium



Probert et al., 2014

Global patterns of pelagic dinoflagellate diversity across protist size classes unveiled by metabarcoding

Noan Le Bescot^{1,2}, Frédéric Mahé^{1,2,3}, Stéphane Audic^{1,2}, Dimier Céline^{1,2}, Marie-José Garet^{1,2}, Julie Poulain⁴, Patrick Wincker⁴, Colombar de Vargas^{1,2}, Raffaele Siano⁵

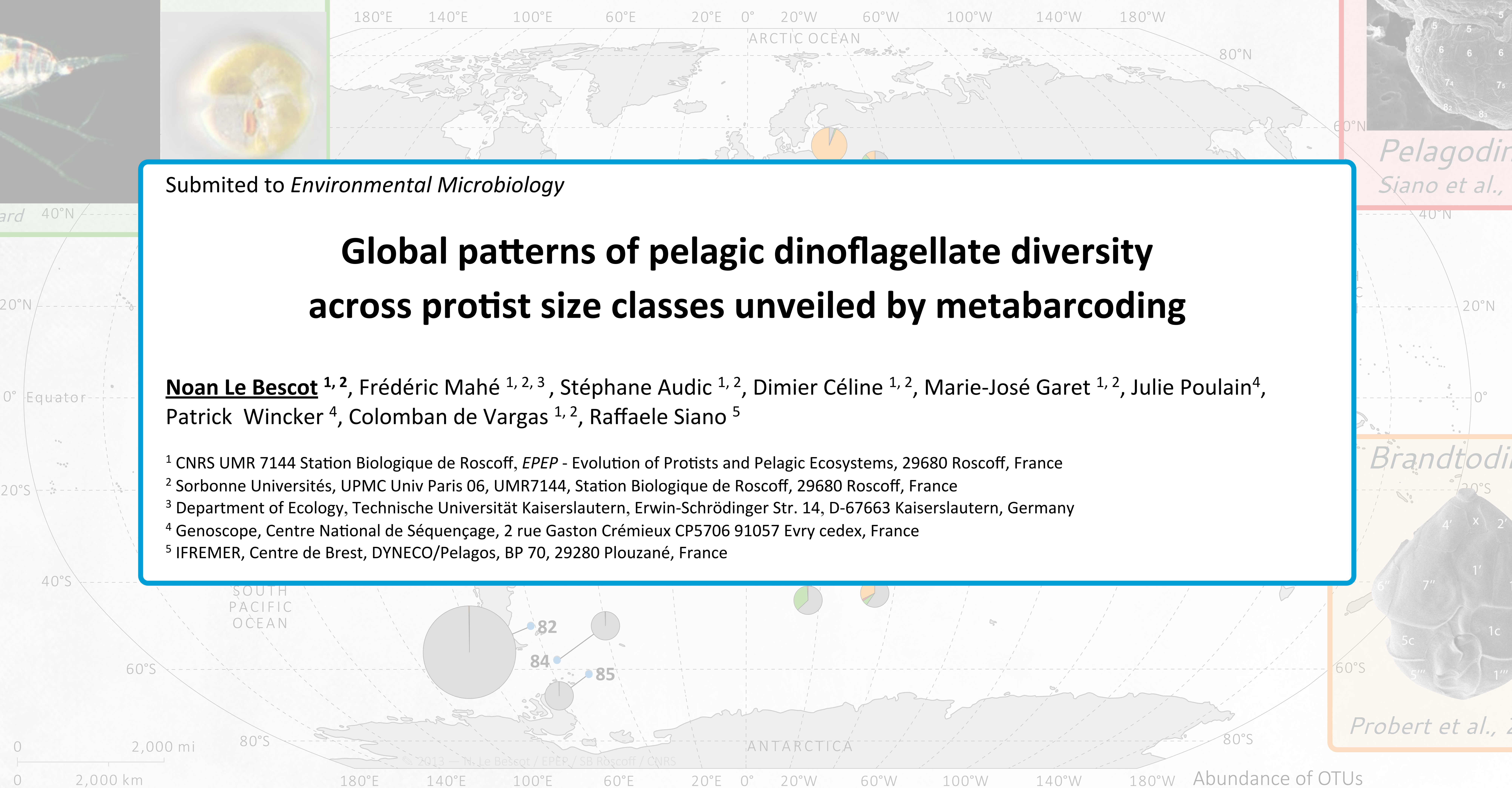
¹ CNRS UMR 7144 Station Biologique de Roscoff, *EPEP* - Evolution of Protists and Pelagic Ecosystems, 29680 Roscoff, France

² Sorbonne Universités, UPMC Univ Paris 06, UMR7144, Station Biologique de Roscoff, 29680 Roscoff, France

³ Department of Ecology, Technische Universität Kaiserslautern, Erwin-Schrödinger Str. 14, D-67663 Kaiserslautern, Germany

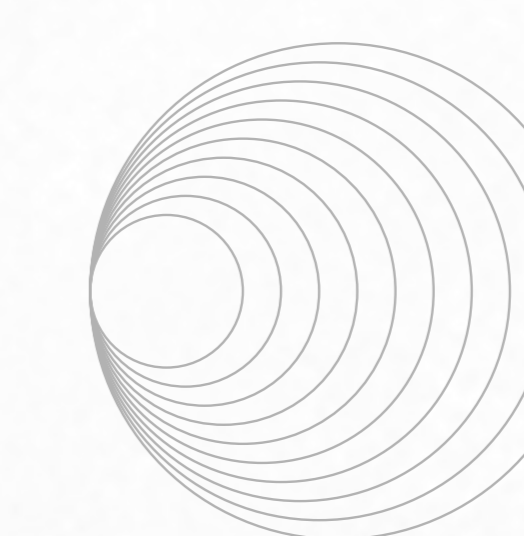
⁴ Genoscope, Centre National de Séquençage, 2 rue Gaston Crémieux CP5706 91057 Evry cedex, France

⁵ IFREMER, Centre de Brest, DYNECO/Pelagos, BP 70, 29280 Plouzané, France



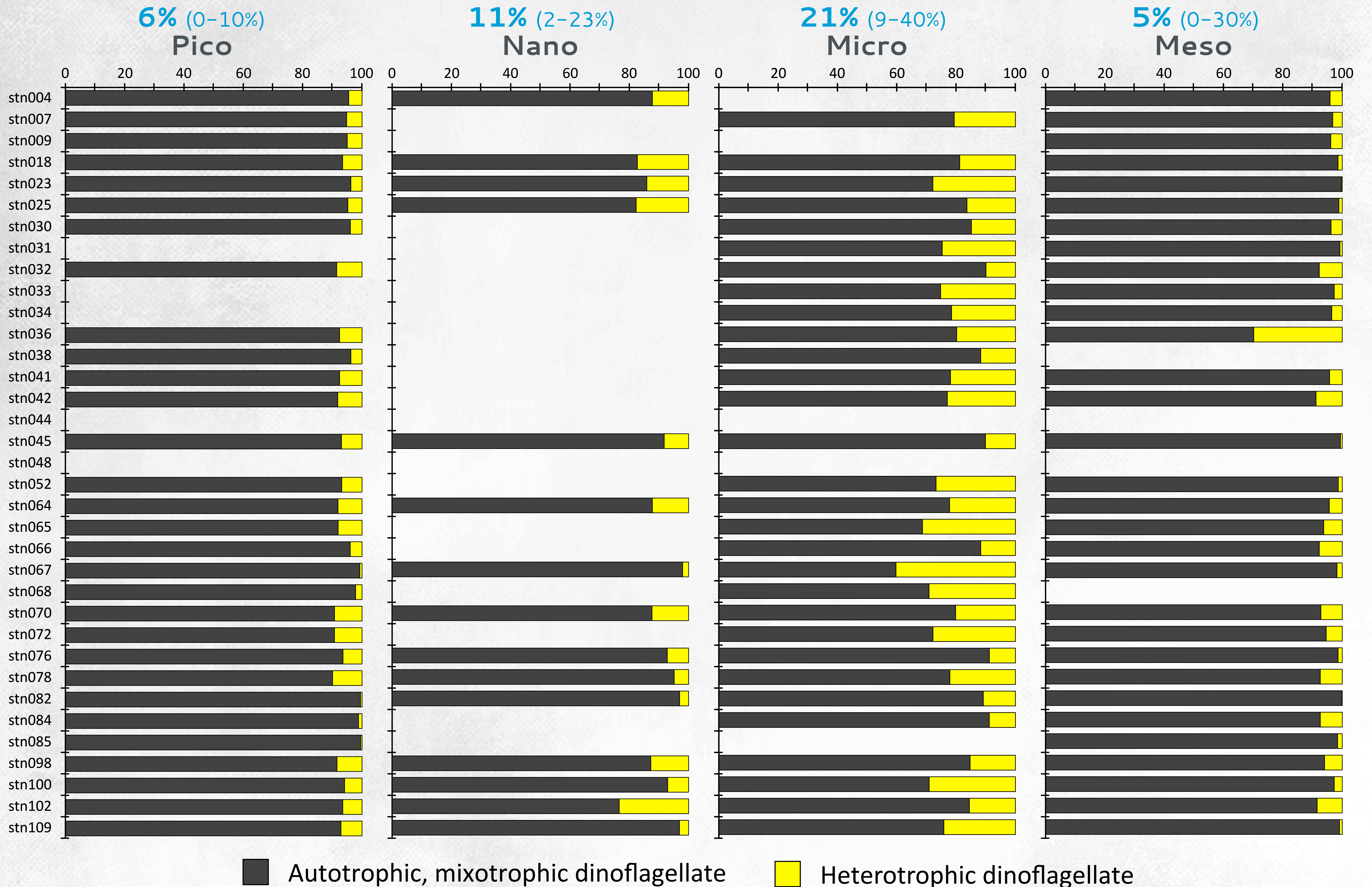
● Sampling point ● Sampling point with none-available data

■ *Brandtodinium* ■ *Blastodinium* ■ *Pelagodinium* ■ Other Dinoflagellates

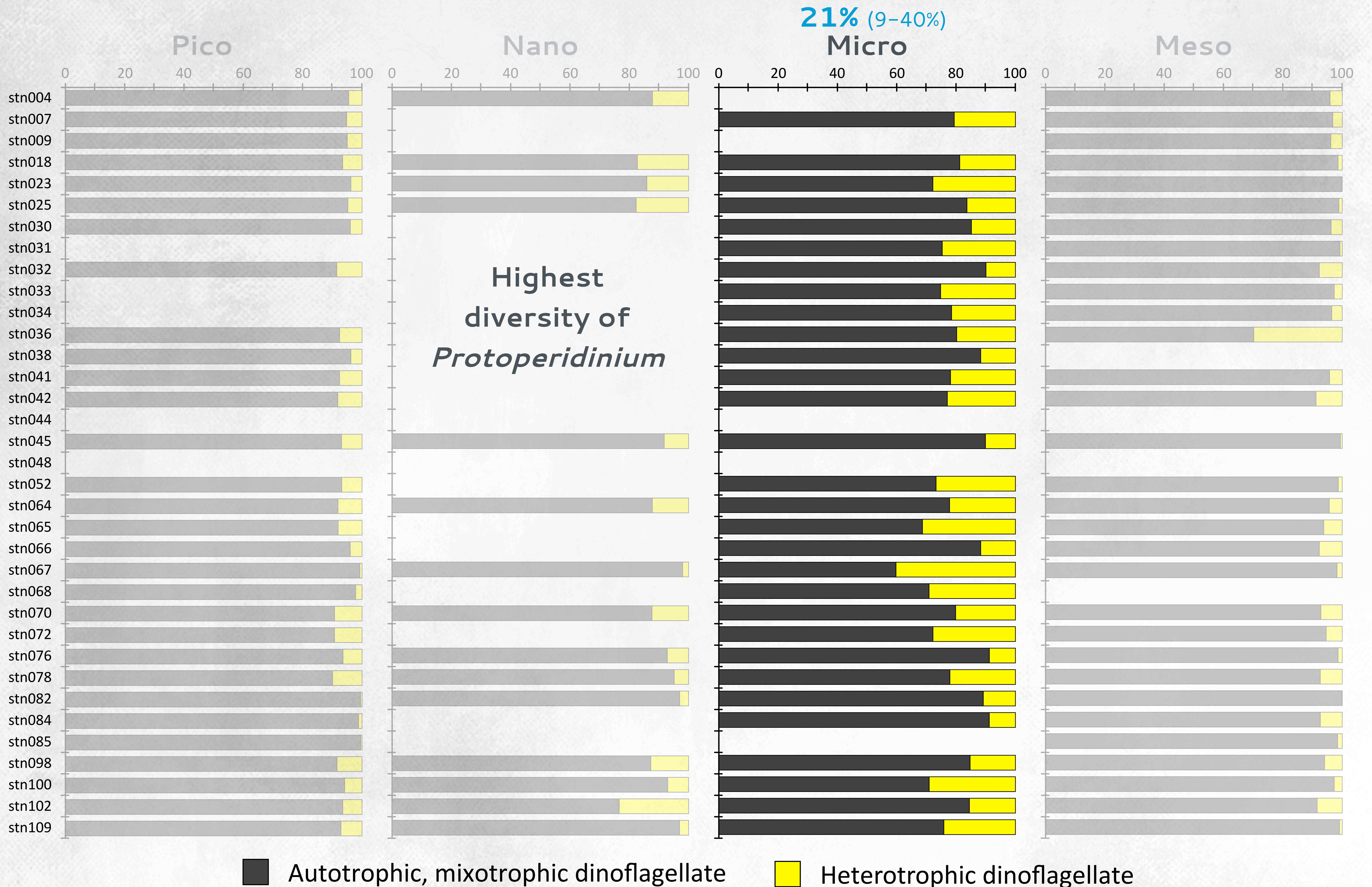


[<22,757]	[<131,303]
[<44,466]	[<153,012]
[<66,176]	[<174,722]
[<87,885]	[<196,431]
[<109,594]	[<218,140]

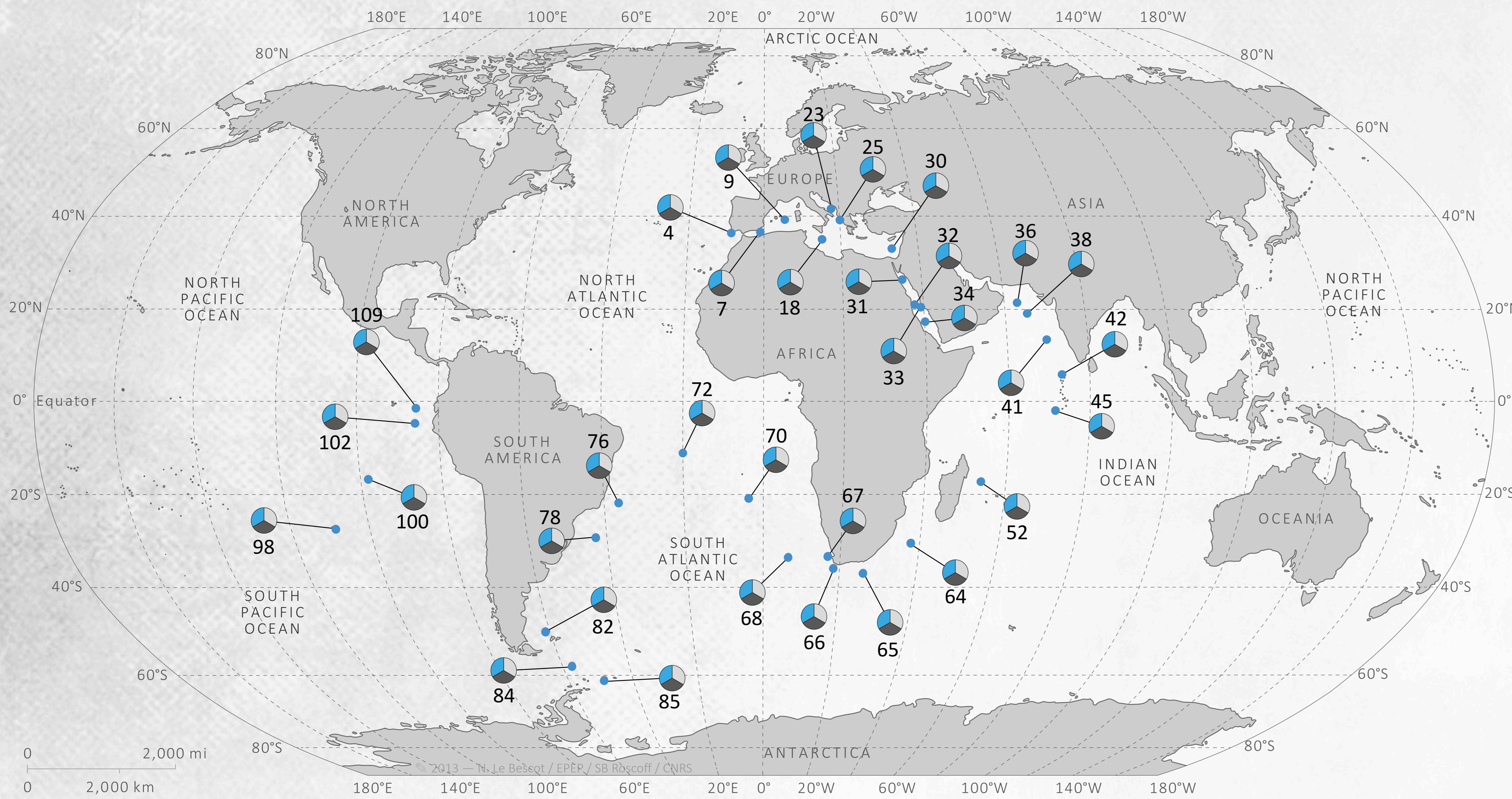
DINOFLAGELLATES TROPHIC MODES



DINOFLAGELLATES TROPHIC MODES



TOXIC DINOFLAGELLATES



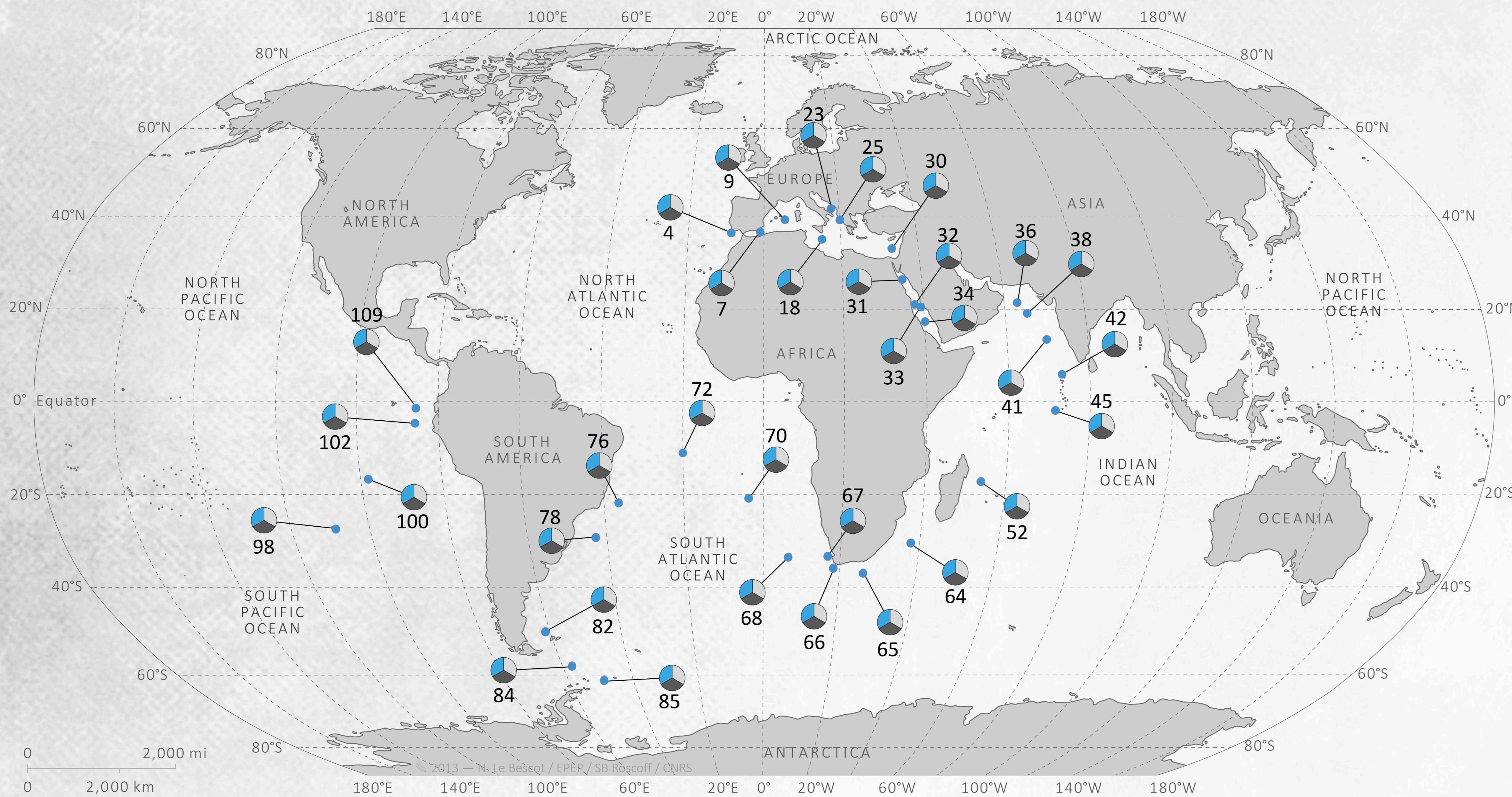
Ichthyotoxic

Present everywhere

Source: <http://www.marinespecies.org/hab/dinoflag.php>

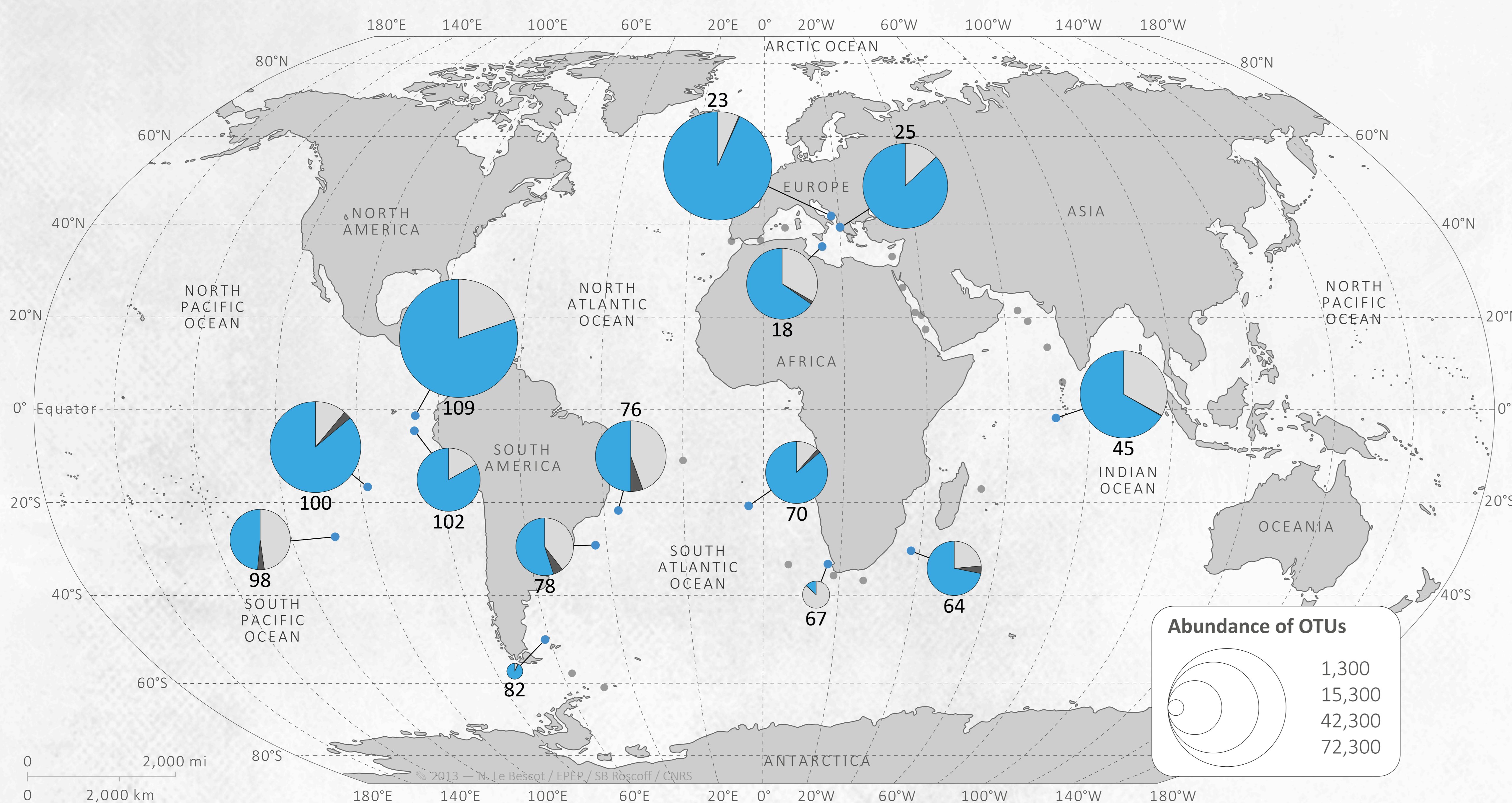
- Sampling point
- Sampling point with none-available data
- Toxic *Karlodinium*
- Toxic *Karenia*
- No Toxic *Karenia*

TOXIC DINOFLAGELLATES



Ichthyotoxic

Present everywhere



relatively abundant everywhere

Source: <http://www.marinespecies.org/hab/dinoflag.php>

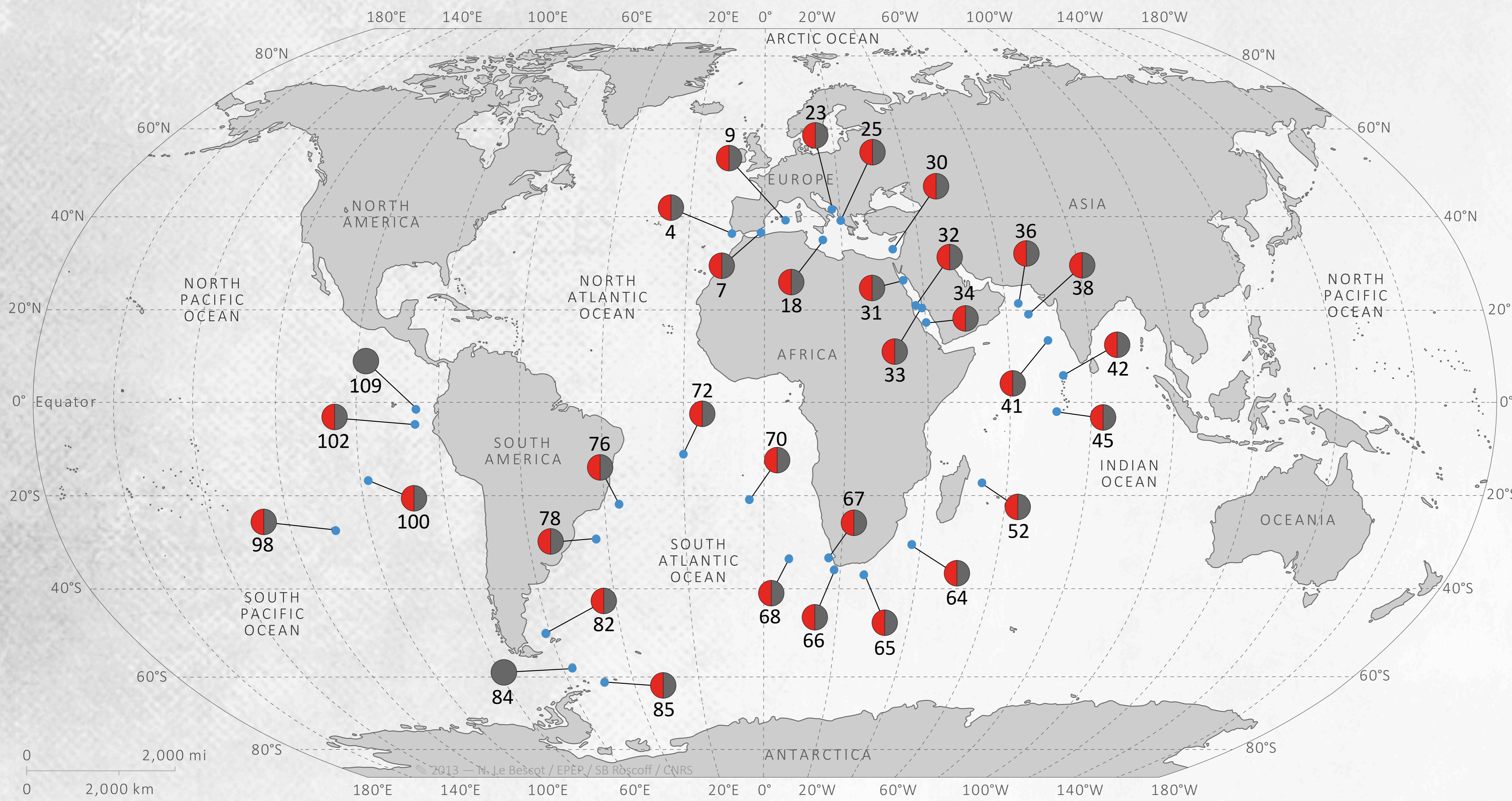
- Sampling point
- Sampling point with none-available data
- Toxic *Karlodinium*
- Toxic *Karenia*
- No Toxic *Karenia*

Abundance of OTUs



TOXIC DINOFLAGELLATES

PSP: Paralytic Shellfish Poisoning



Source: <http://www.marinespecies.org/hab/dinoflag.php>

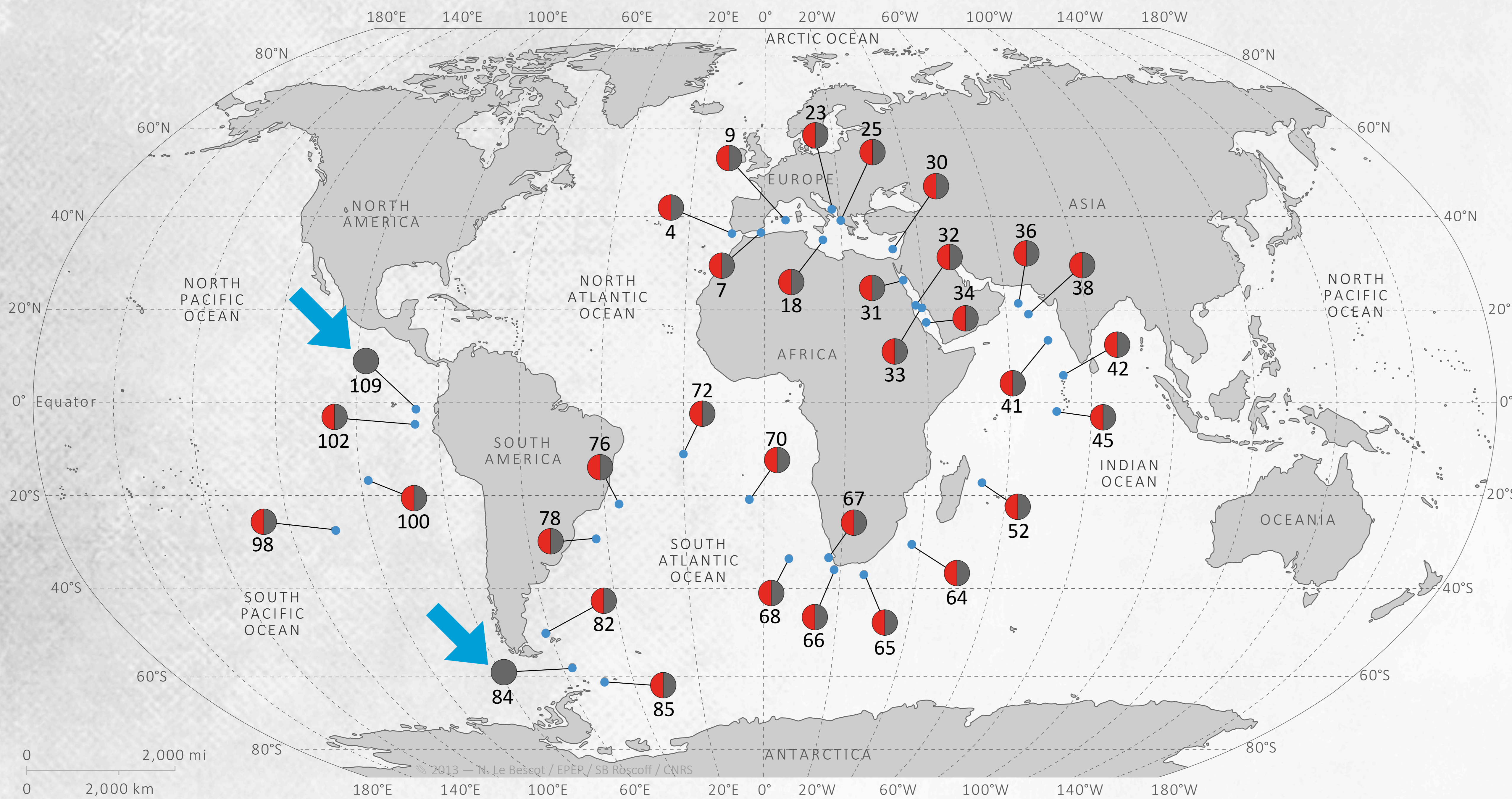
● Sampling point ● Sampling point with none-available data

■ Toxic *Alexandrium* ■ No Toxic *Alexandrium*

TOXIC DINOFLAGELLATES

PSP: Paralytic Shellfish Poisoning

Present in 31 stations



Source: <http://www.marinespecies.org/hab/dinoflag.php>

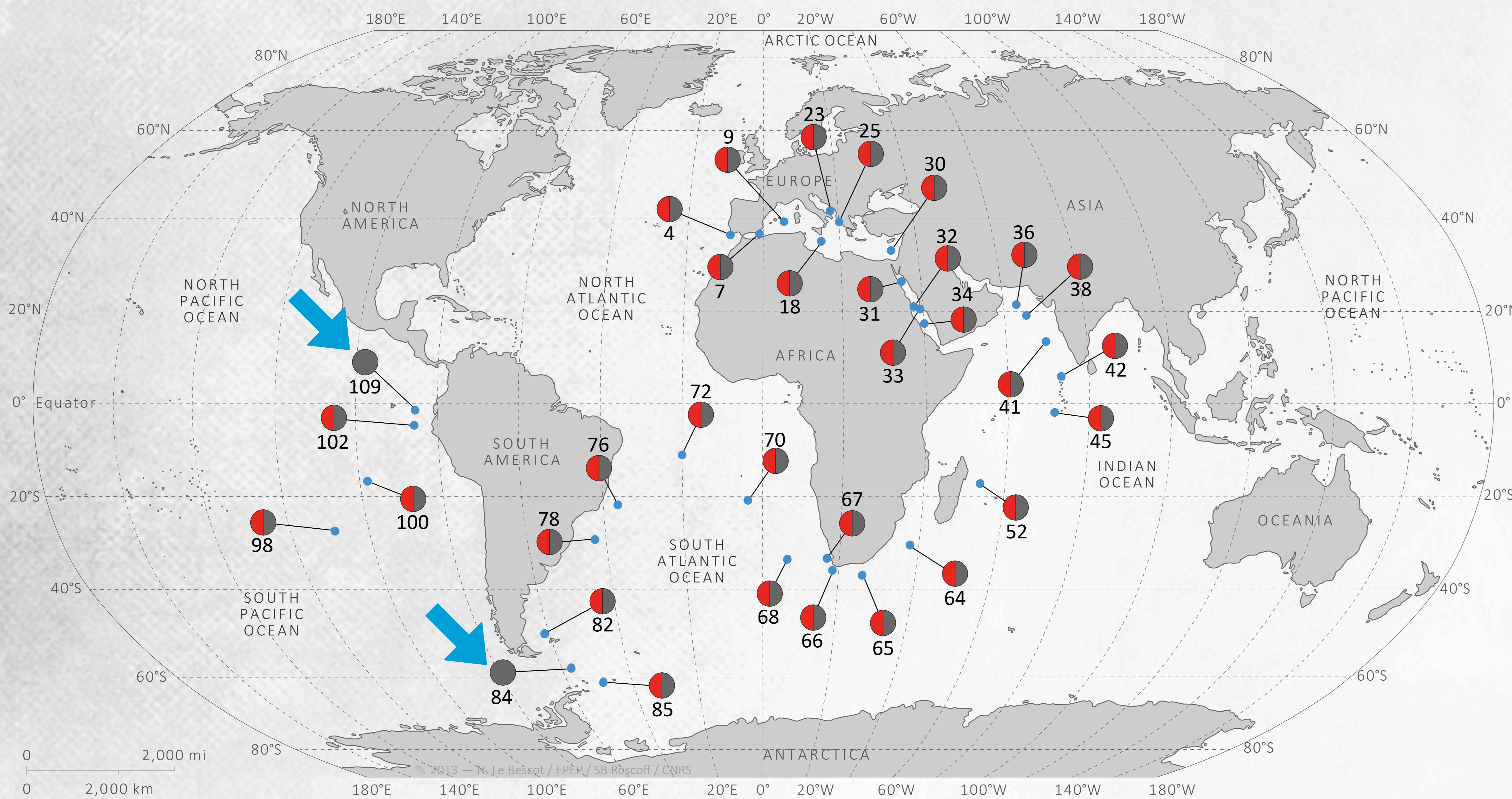
● Sampling point ● Sampling point with none-available data

■ Toxic *Alexandrium* ■ No Toxic *Alexandrium*

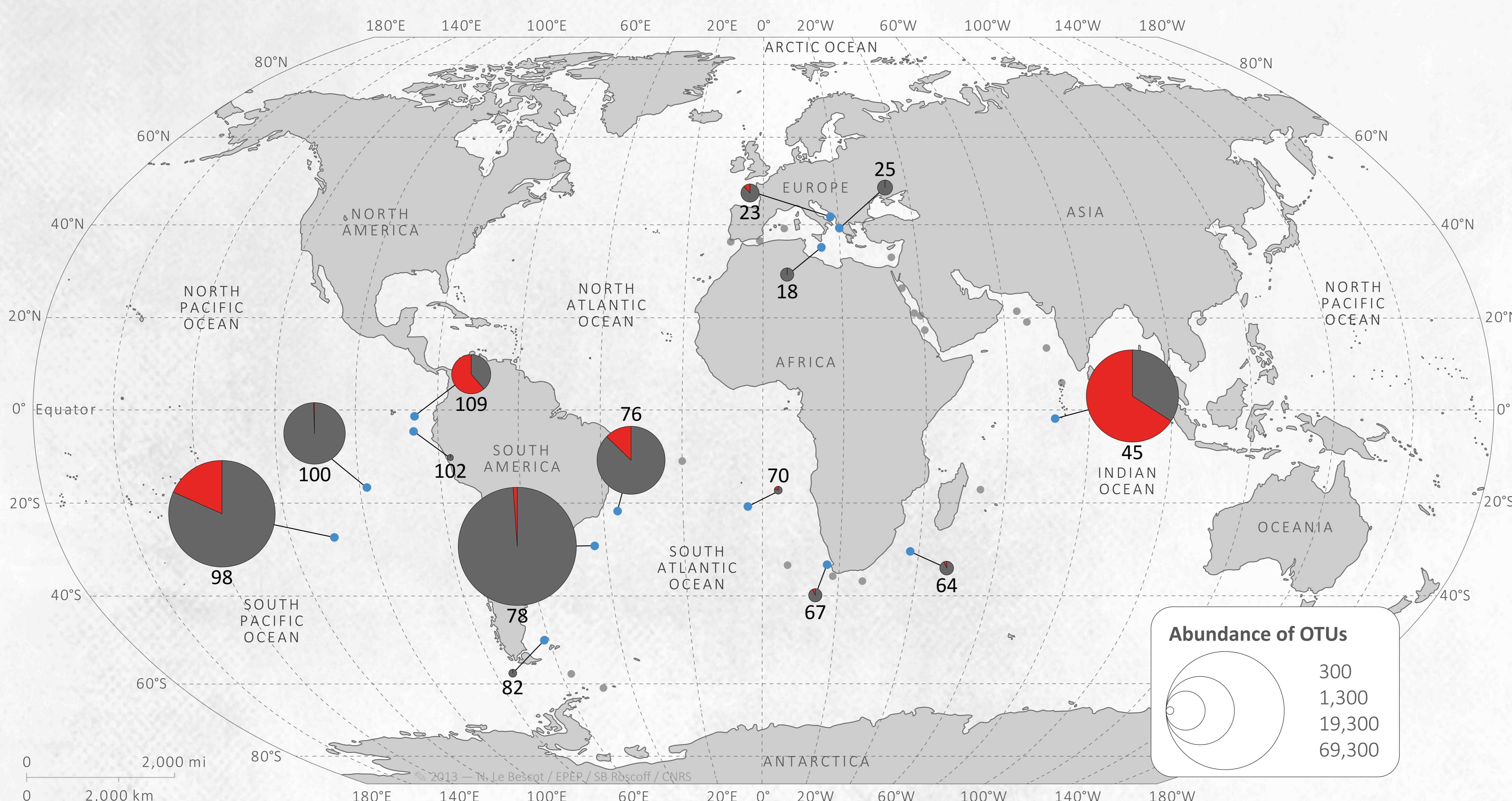
TOXIC DINOFLAGELLATES

PSP: Paralytic Shellfish Poisoning

Present in 31 stations



higher abundance of genus *Alexandrium* in open oceans

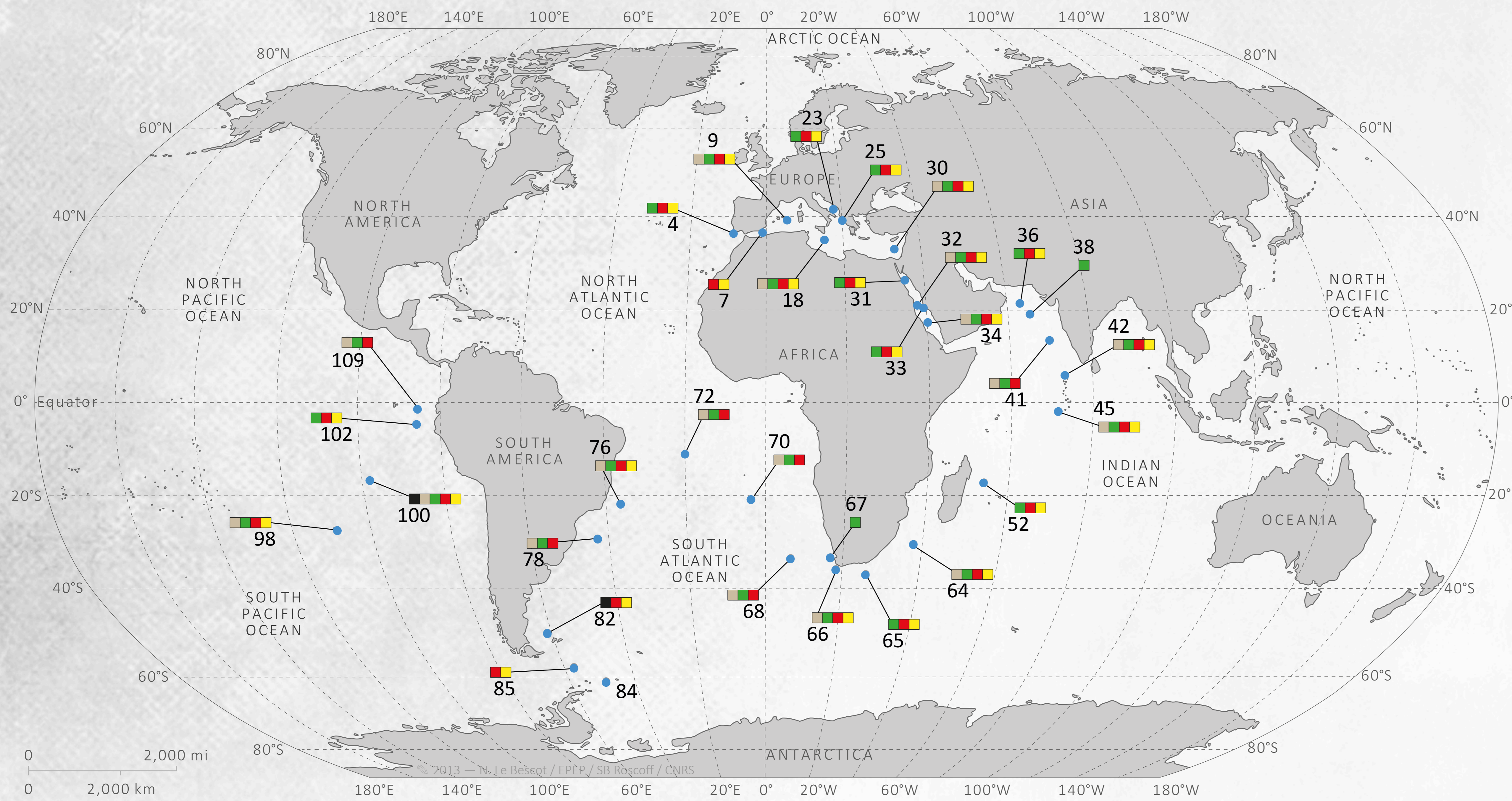


Source: <http://www.marinespecies.org/hab/dinoflag.php>

- Sampling point ● Sampling point with none-available data
- Toxic *Alexandrium* ■ No Toxic *Alexandrium*

TOXIC DINOFLAGELLATES

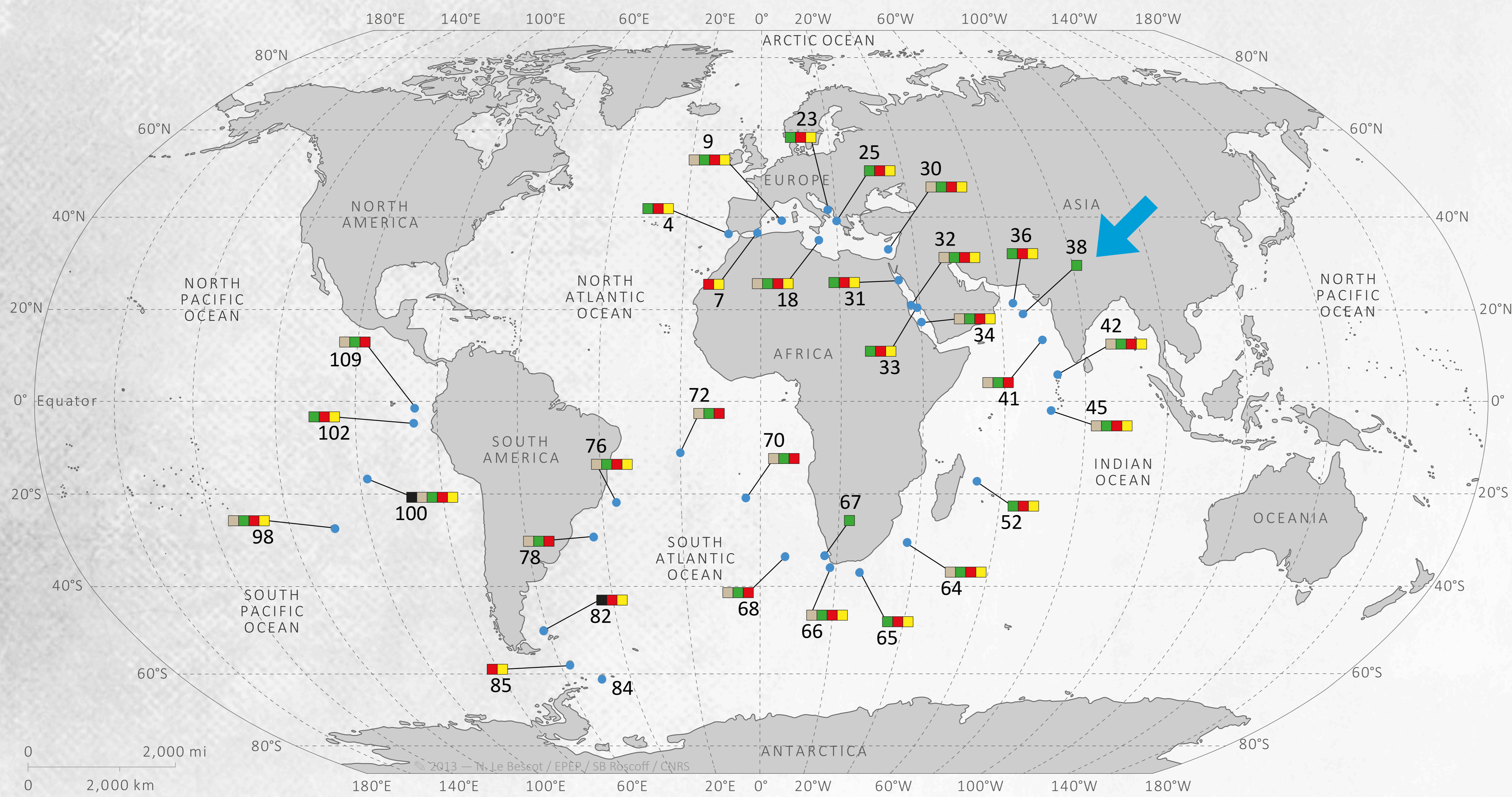
DSP: Diarrhetic Shellfish Poisoning



Source: <http://www.marinespecies.org/hab/dinoflag.php>

- Sampling point ● Sampling point with none-available data
- Toxic *Phalacroma* ■ No Toxic *Phalacroma* ■ Toxic *Lingulodinium*
- Toxic *Dinophysis* ■ No Toxic *Dinophysis*

TOXIC DINOFLAGELLATES



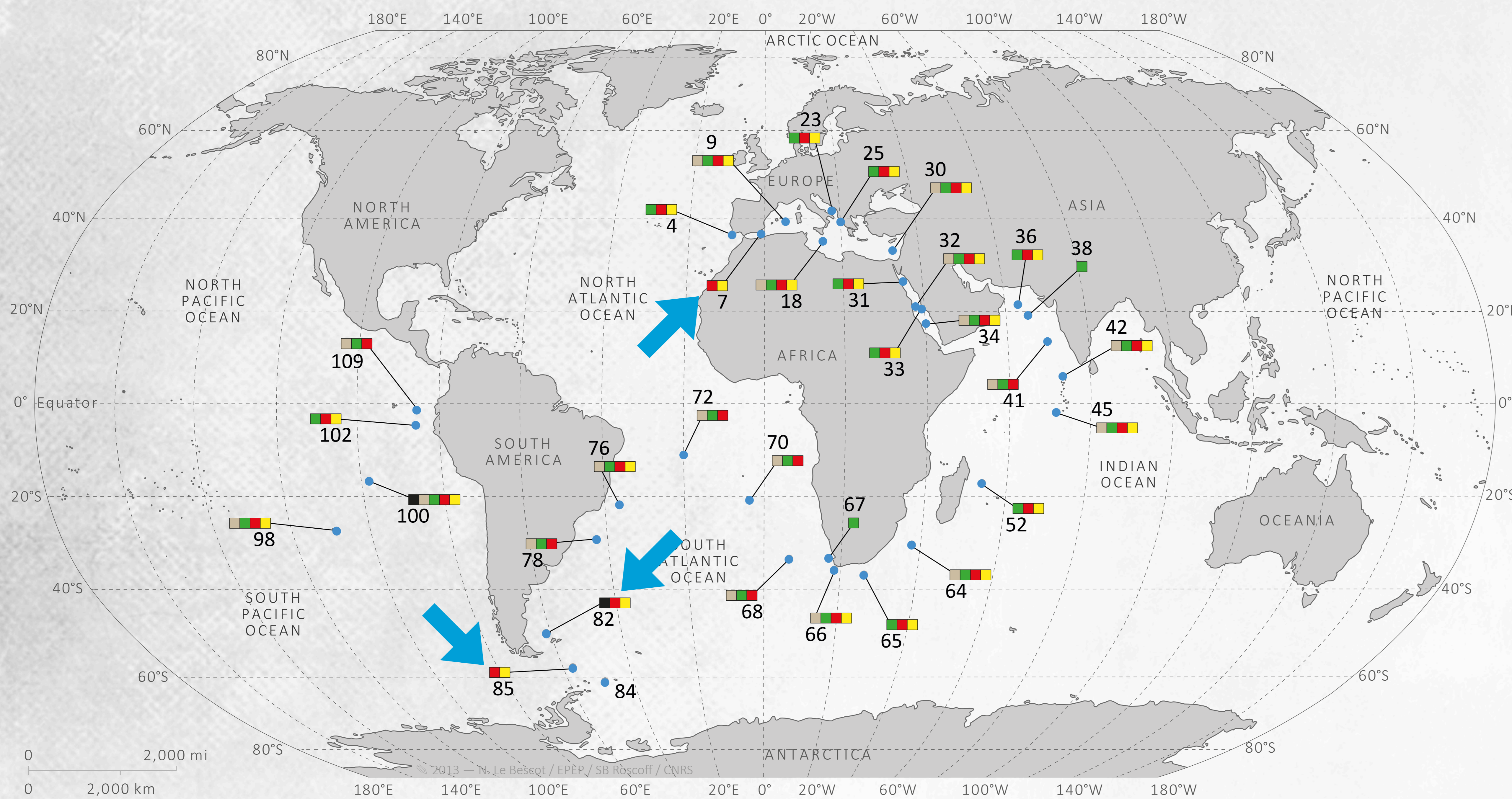
DSP: Diarrhetic Shellfish Poisoning

Toxic *Dinophysis* detected in 32 stations

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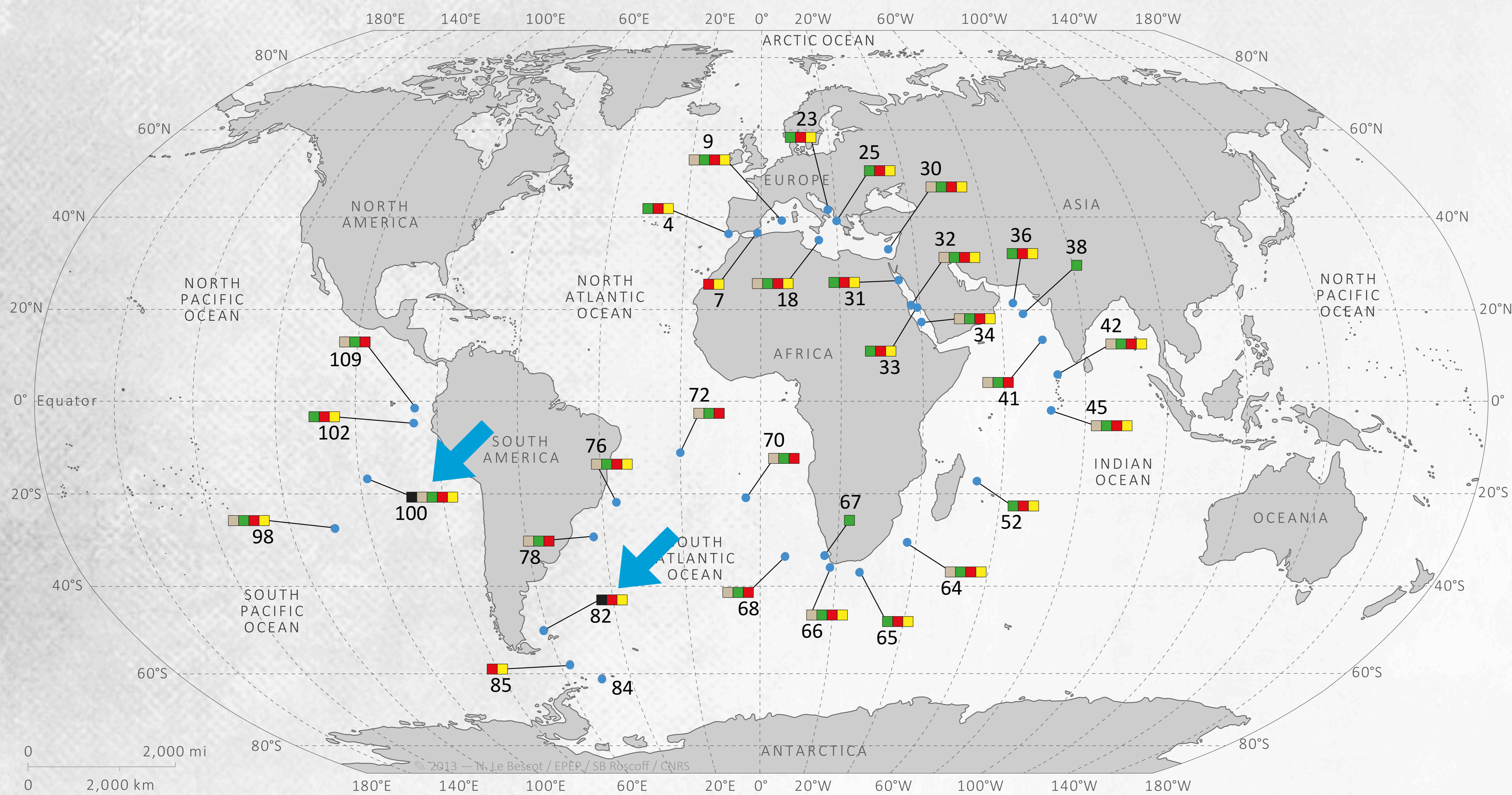
Toxic *Dinophysis* detected in 32 stations

Toxic *Lingulodinium* detected in 30 stations

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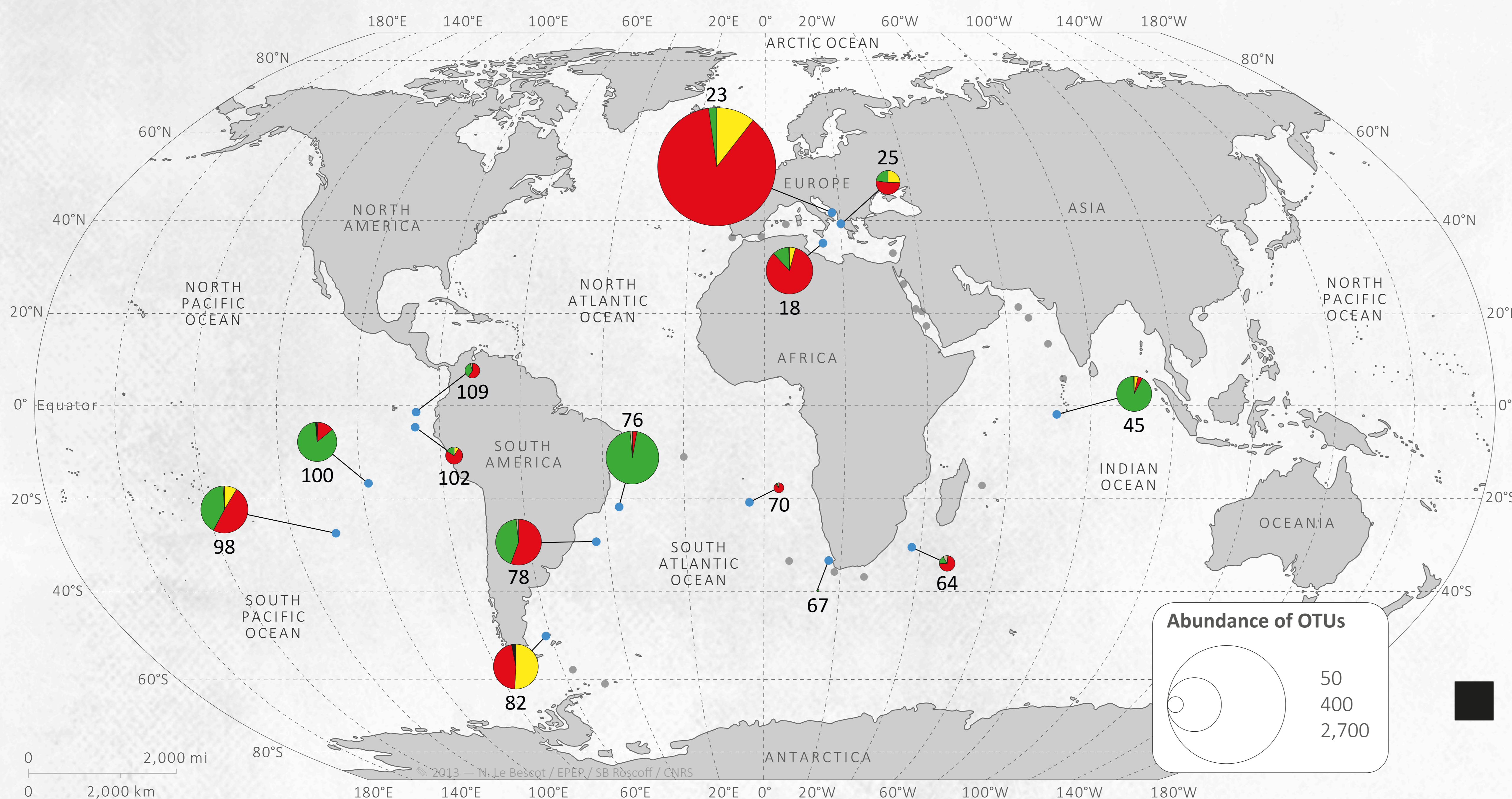
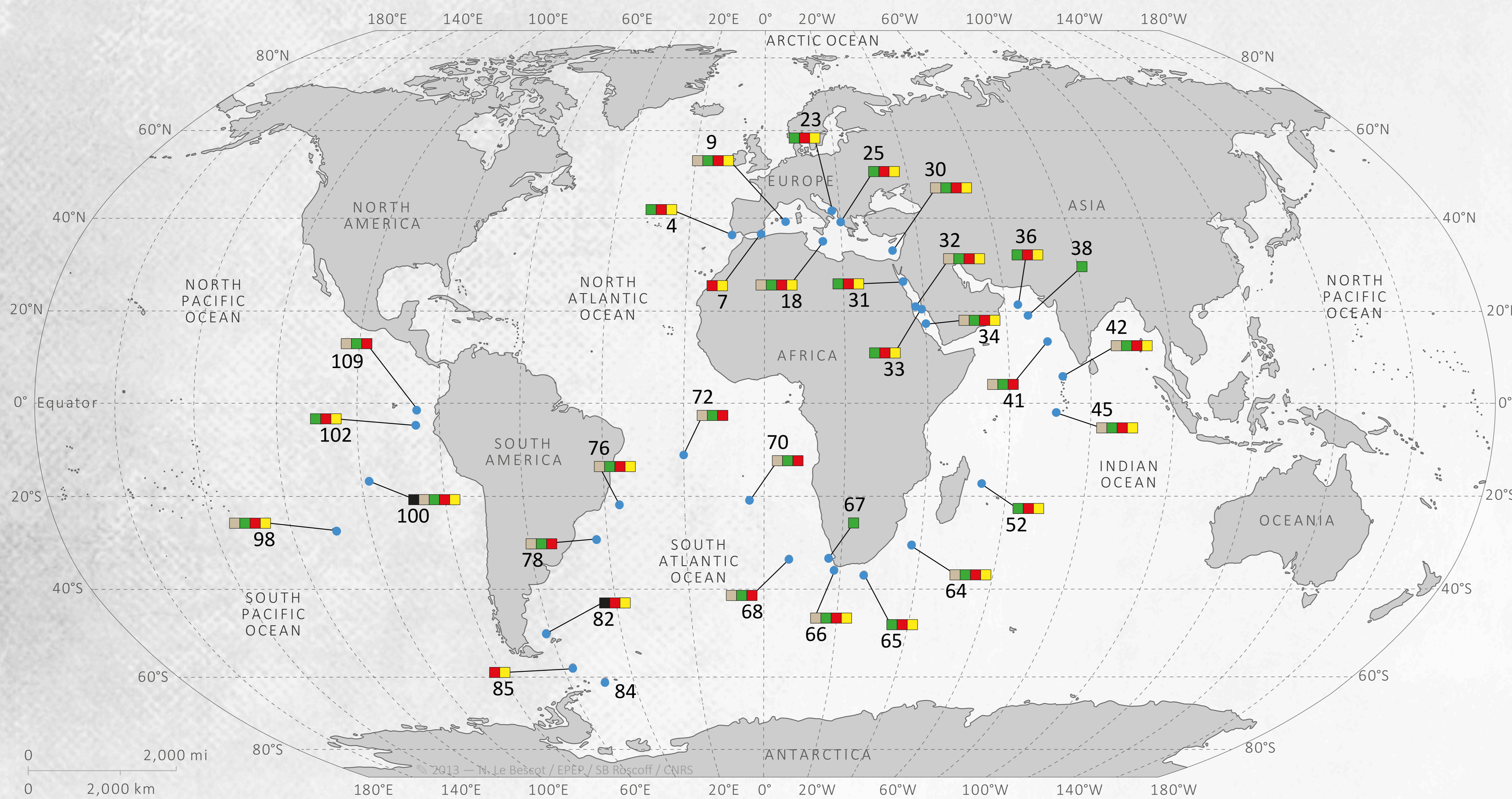
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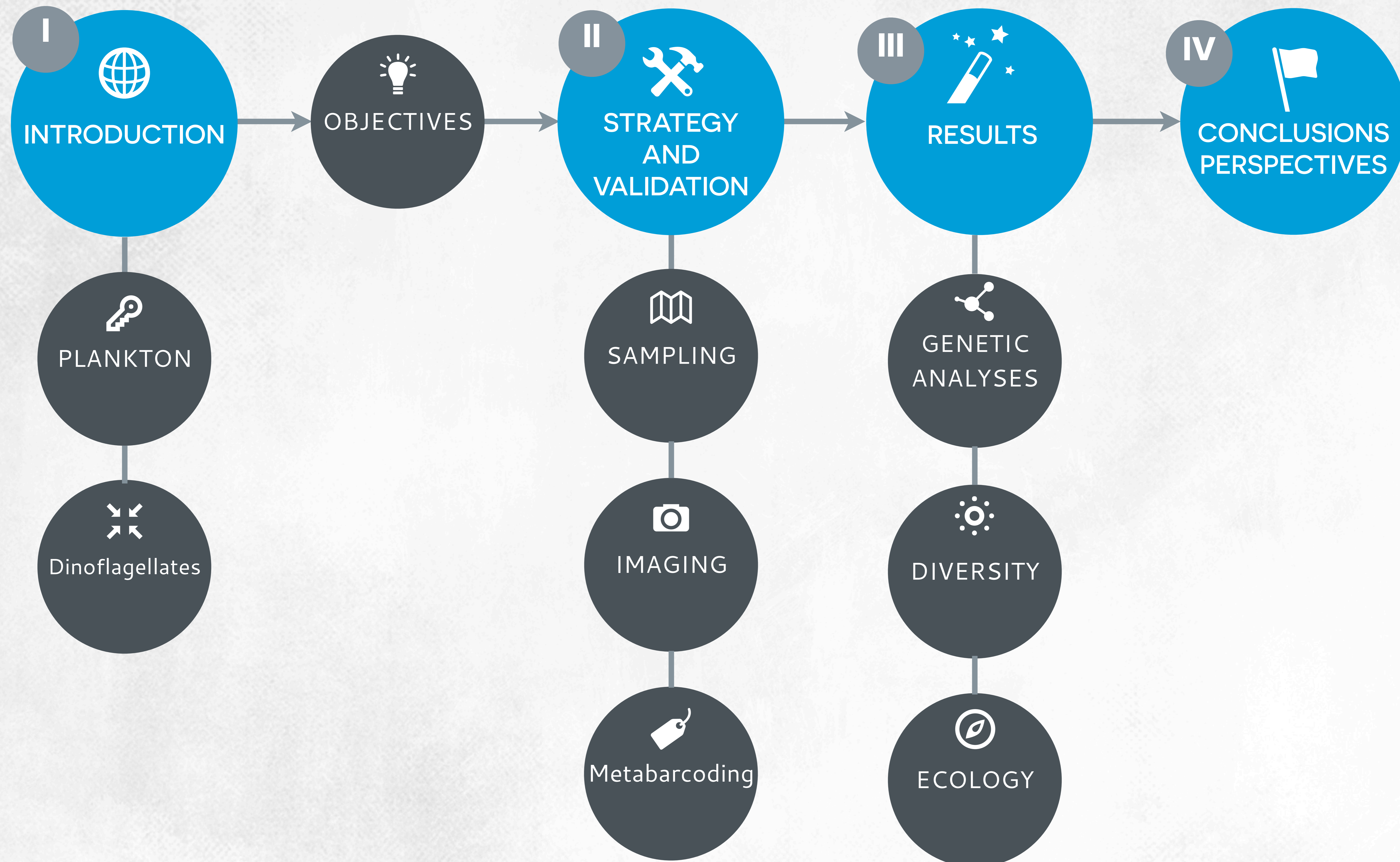


relatively higher abundance in open oceans

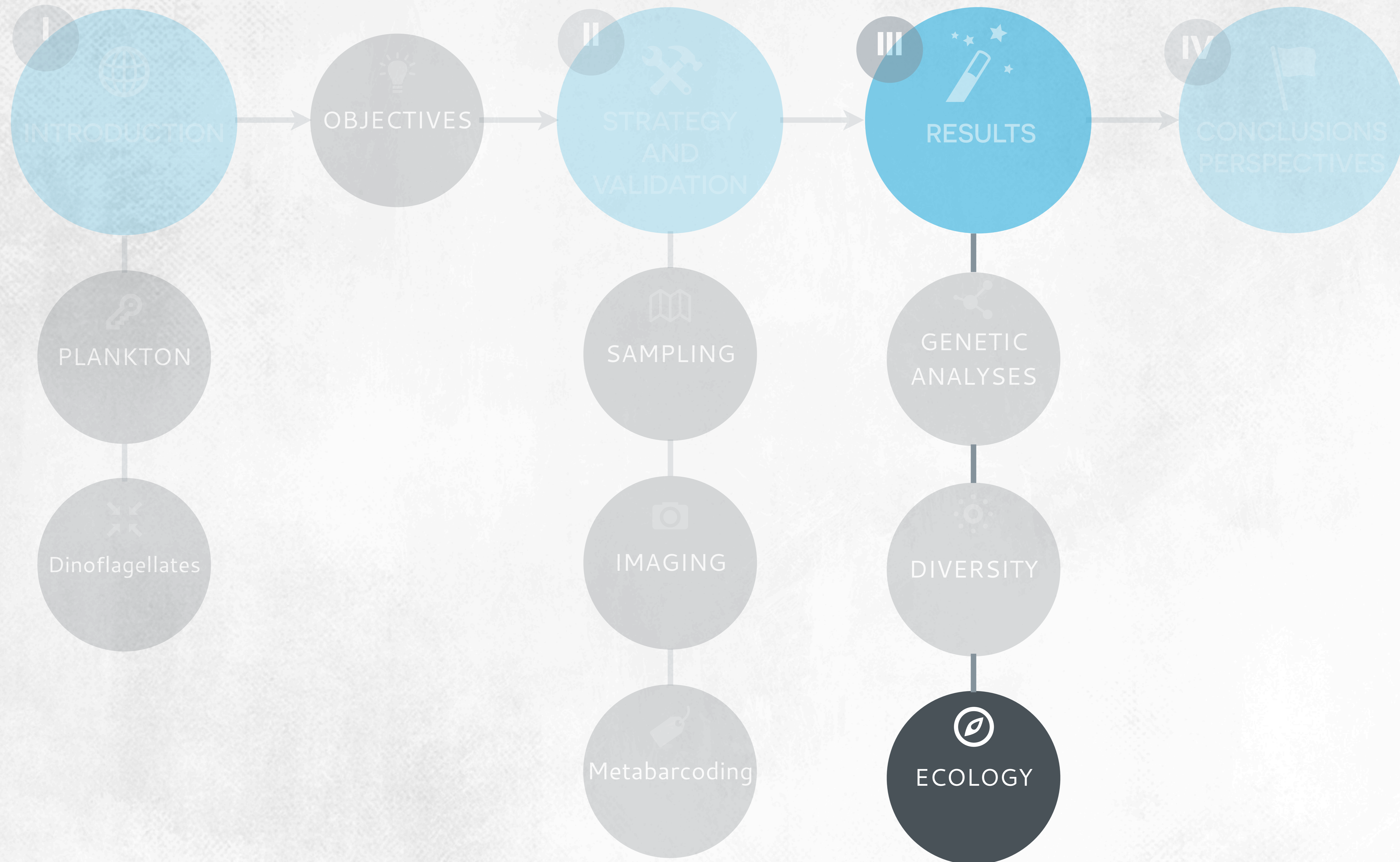
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PRESENTATION SUMMARY

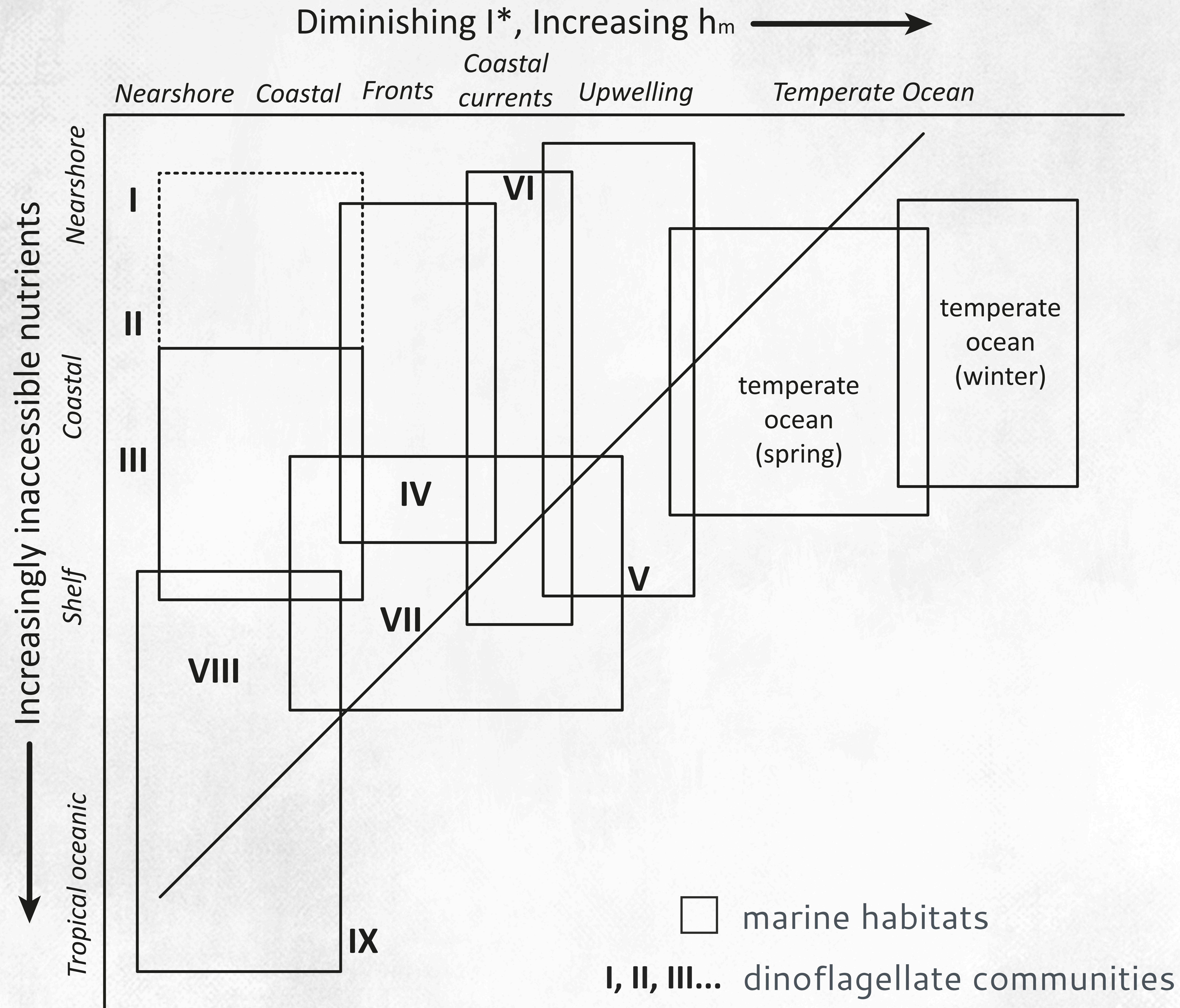


PRESENTATION SUMMARY



COMMUNITY ASSEMBLY

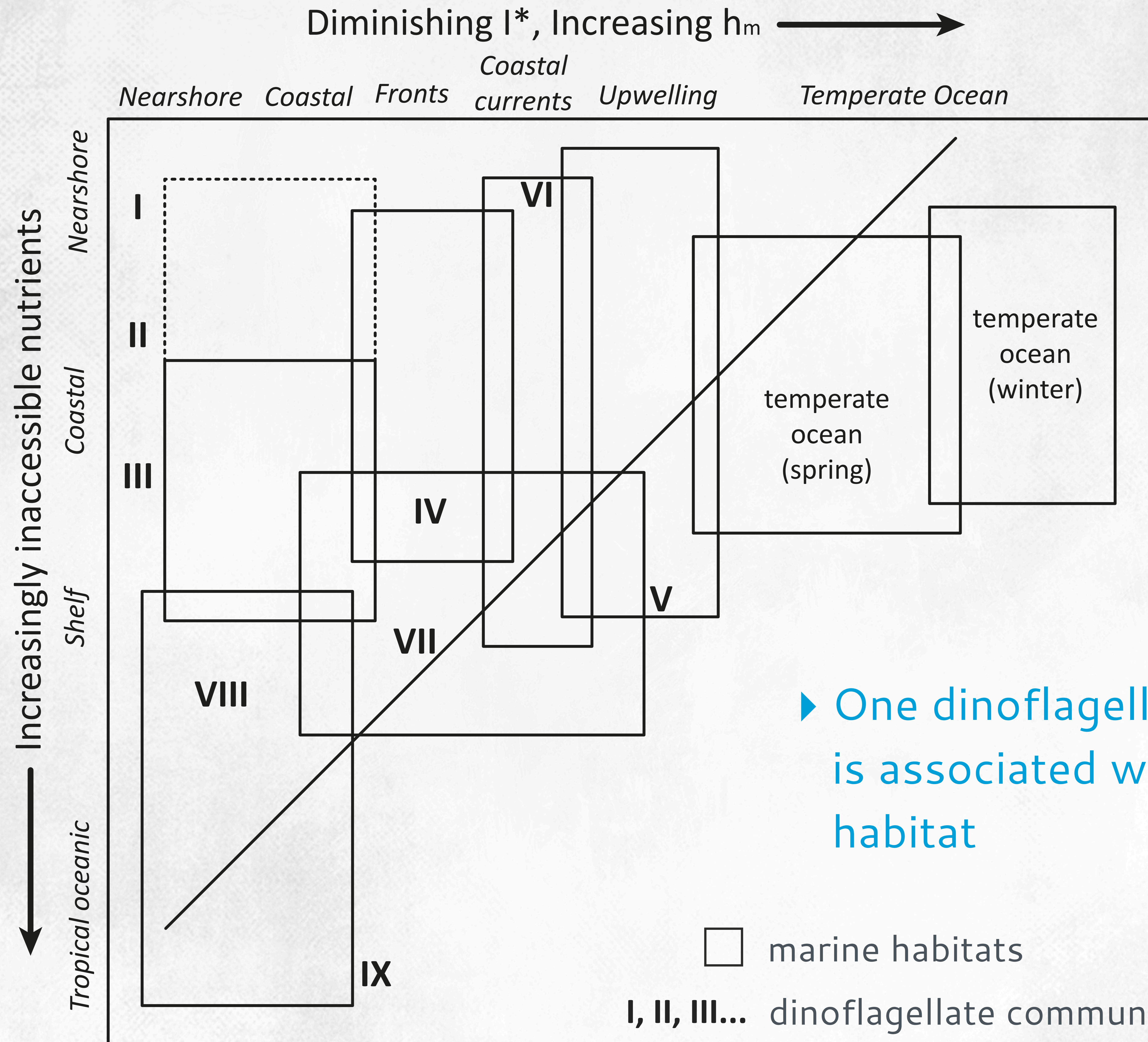
can we predict the community?



Smayda and Reynolds, 2001

COMMUNITY ASSEMBLY

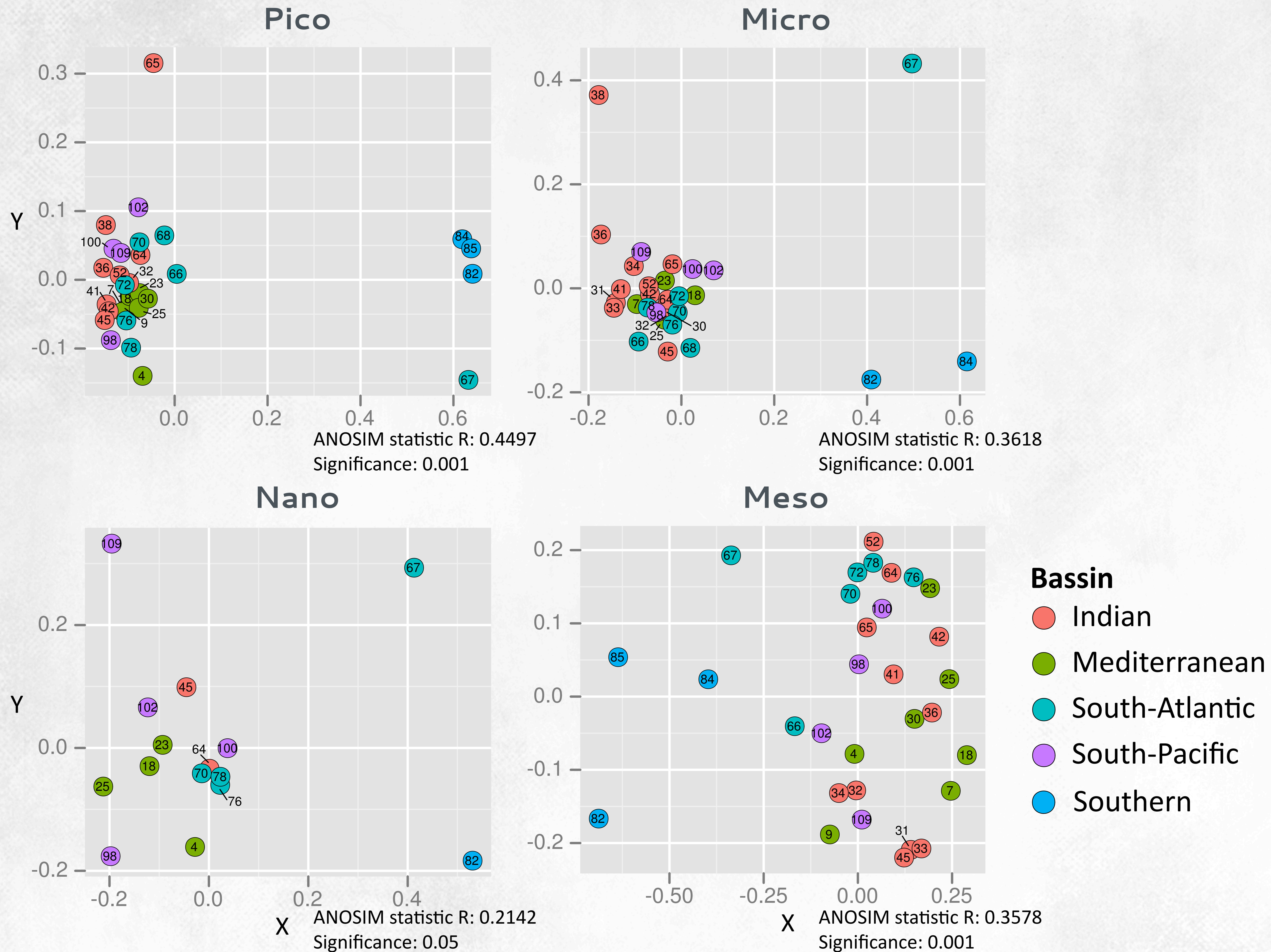
can we predict the community?



► One dinoflagellate community is associated with a marine habitat

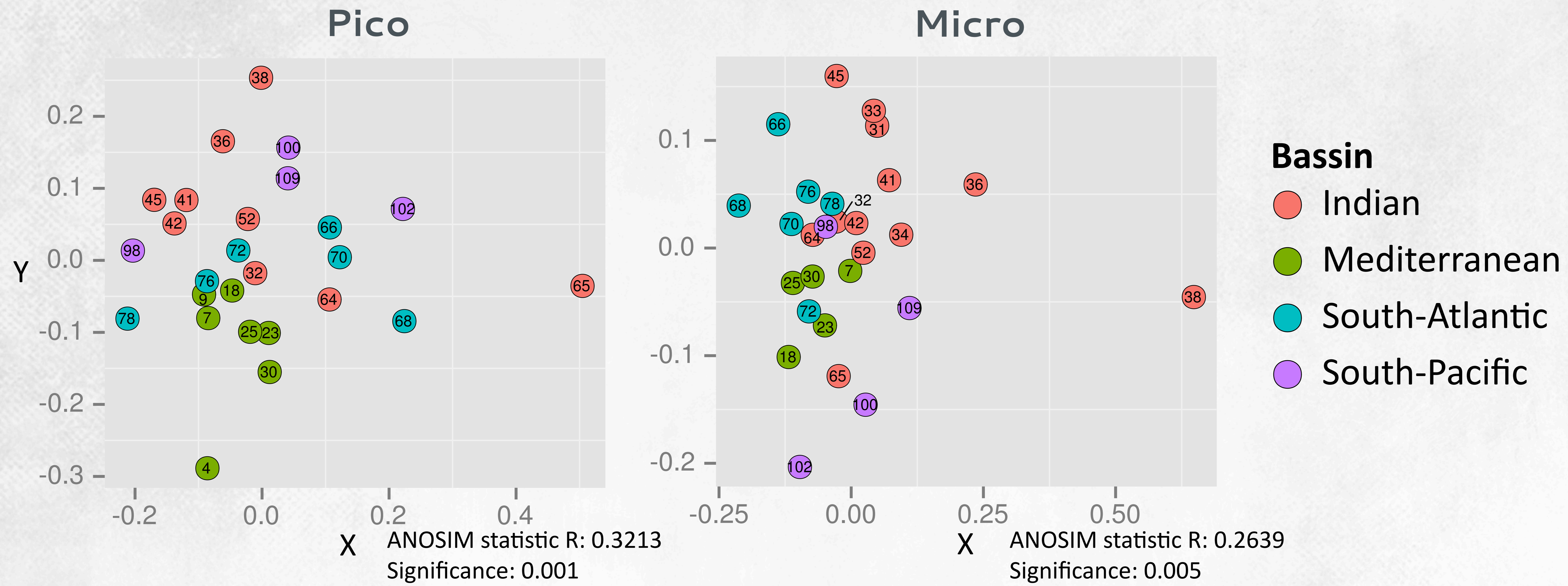
COMMUNITY COMPARISON

Bray Curtis dissimilarity (OTU)



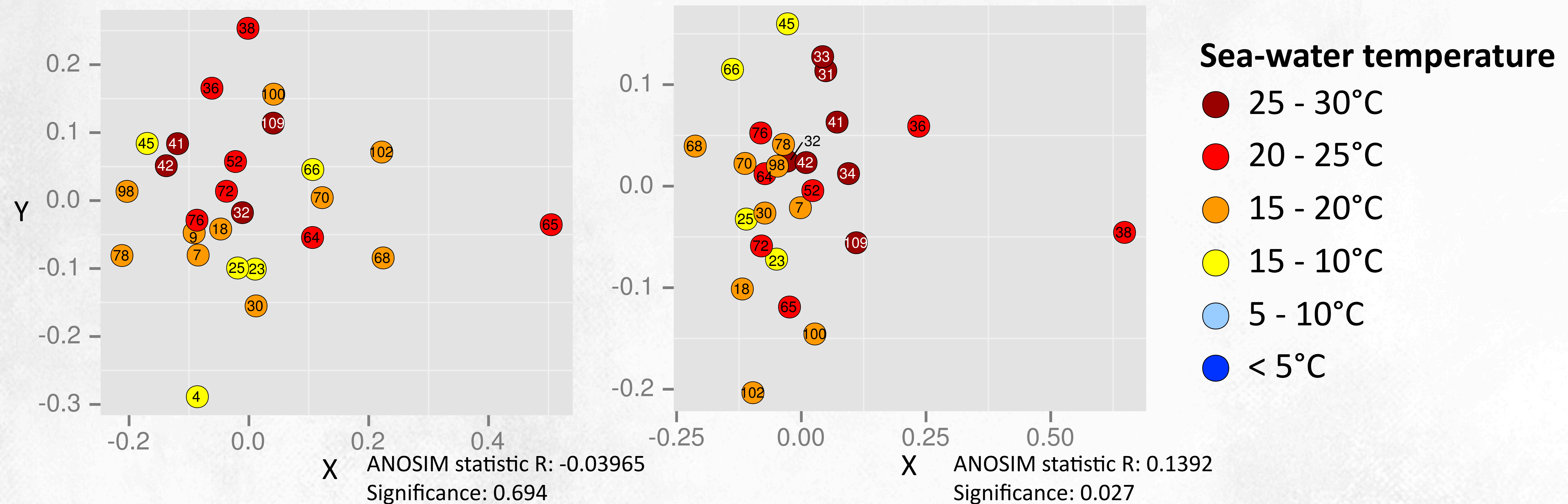
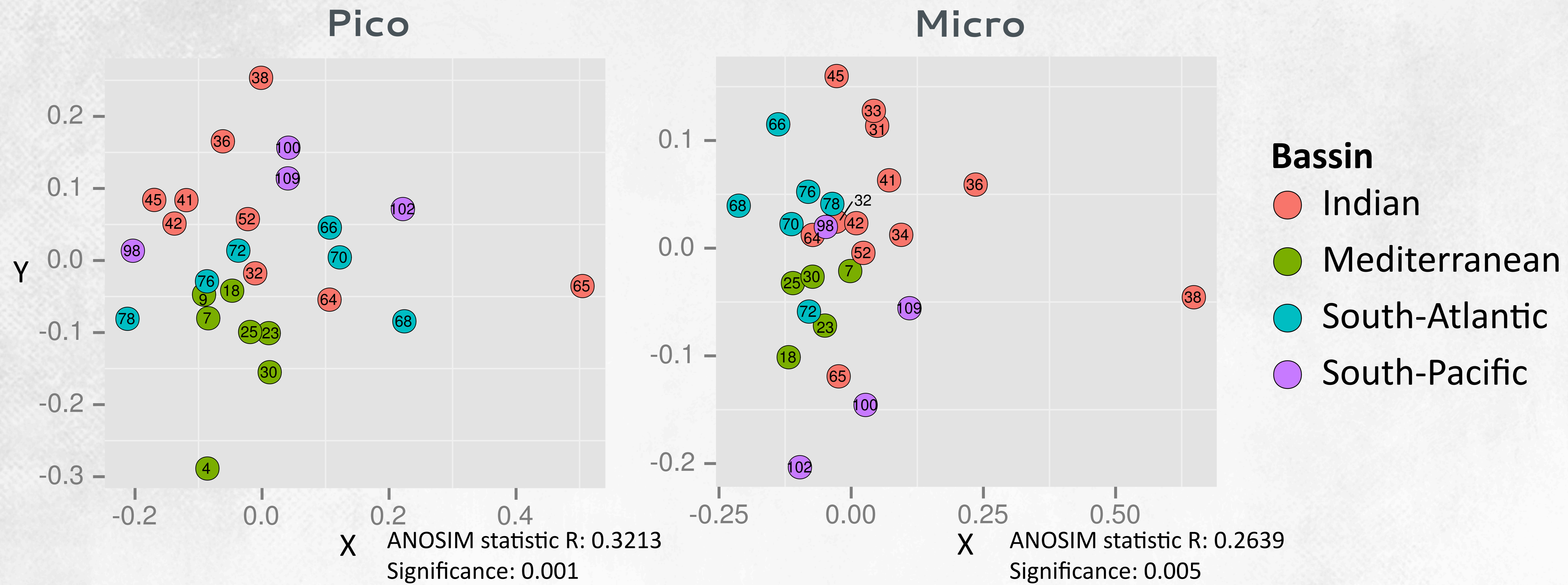
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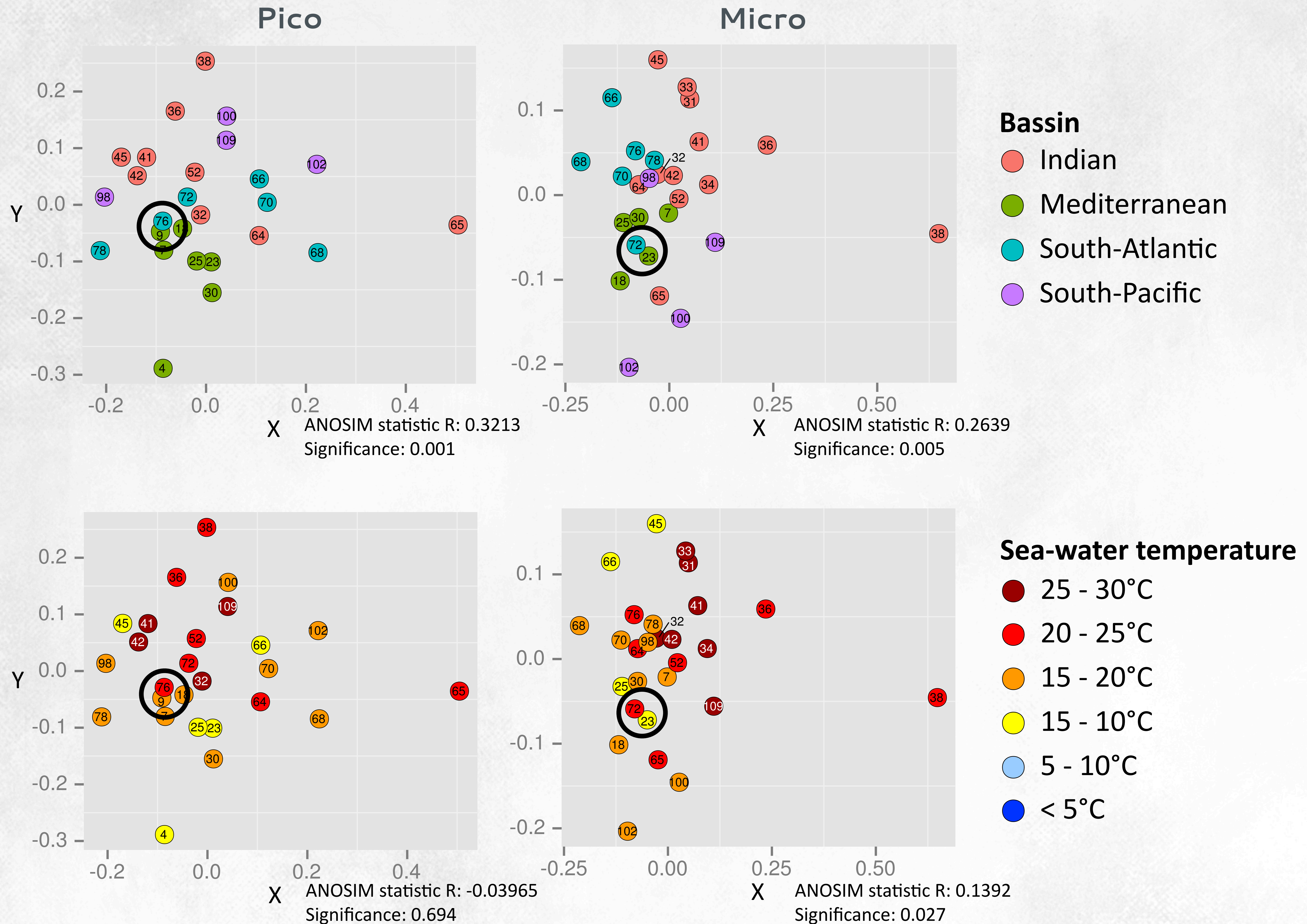
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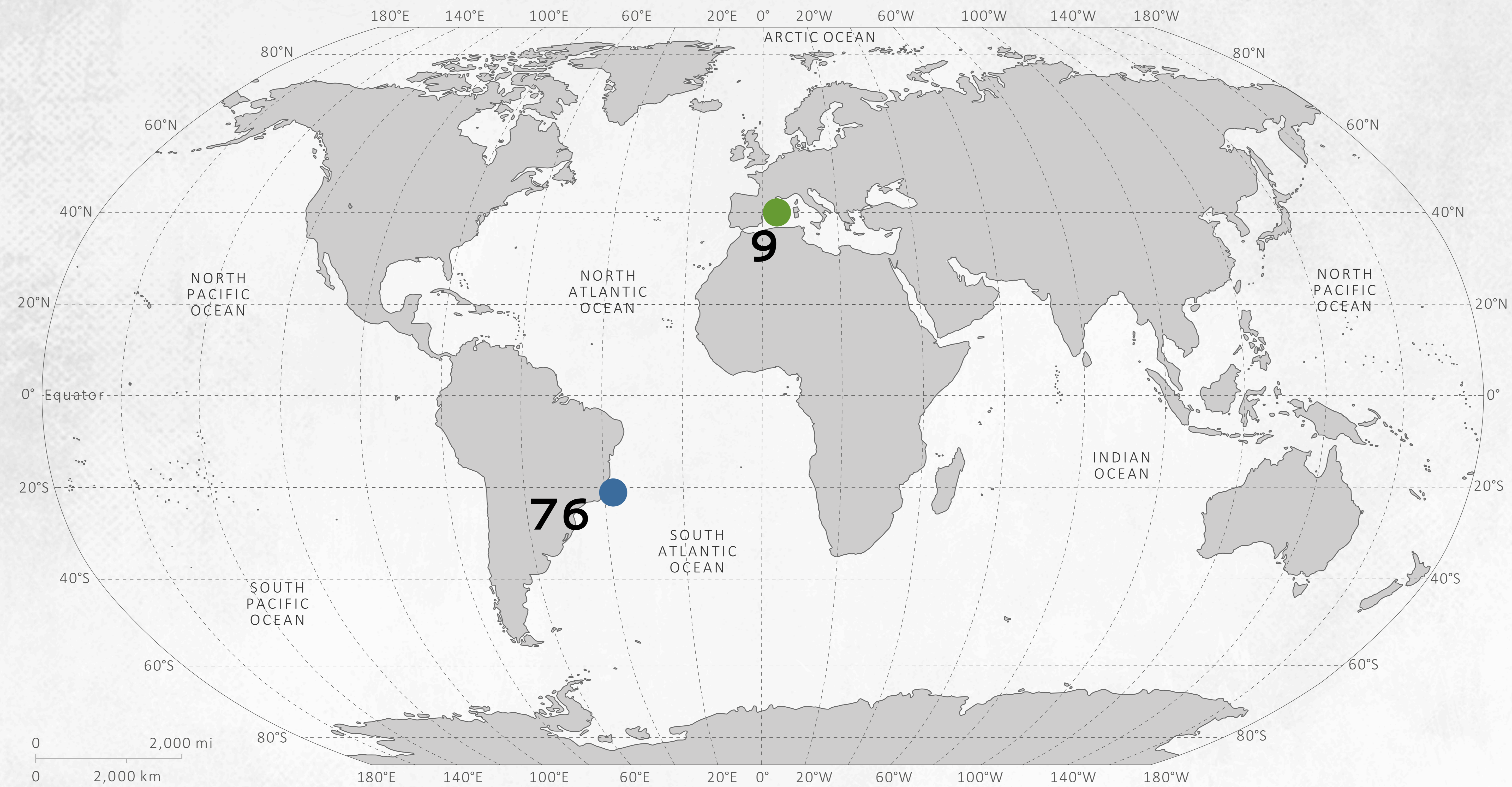
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COMMUNITY COMPARISON

taxonomic assignation / OTU

PICO DINOFLAGELLATES



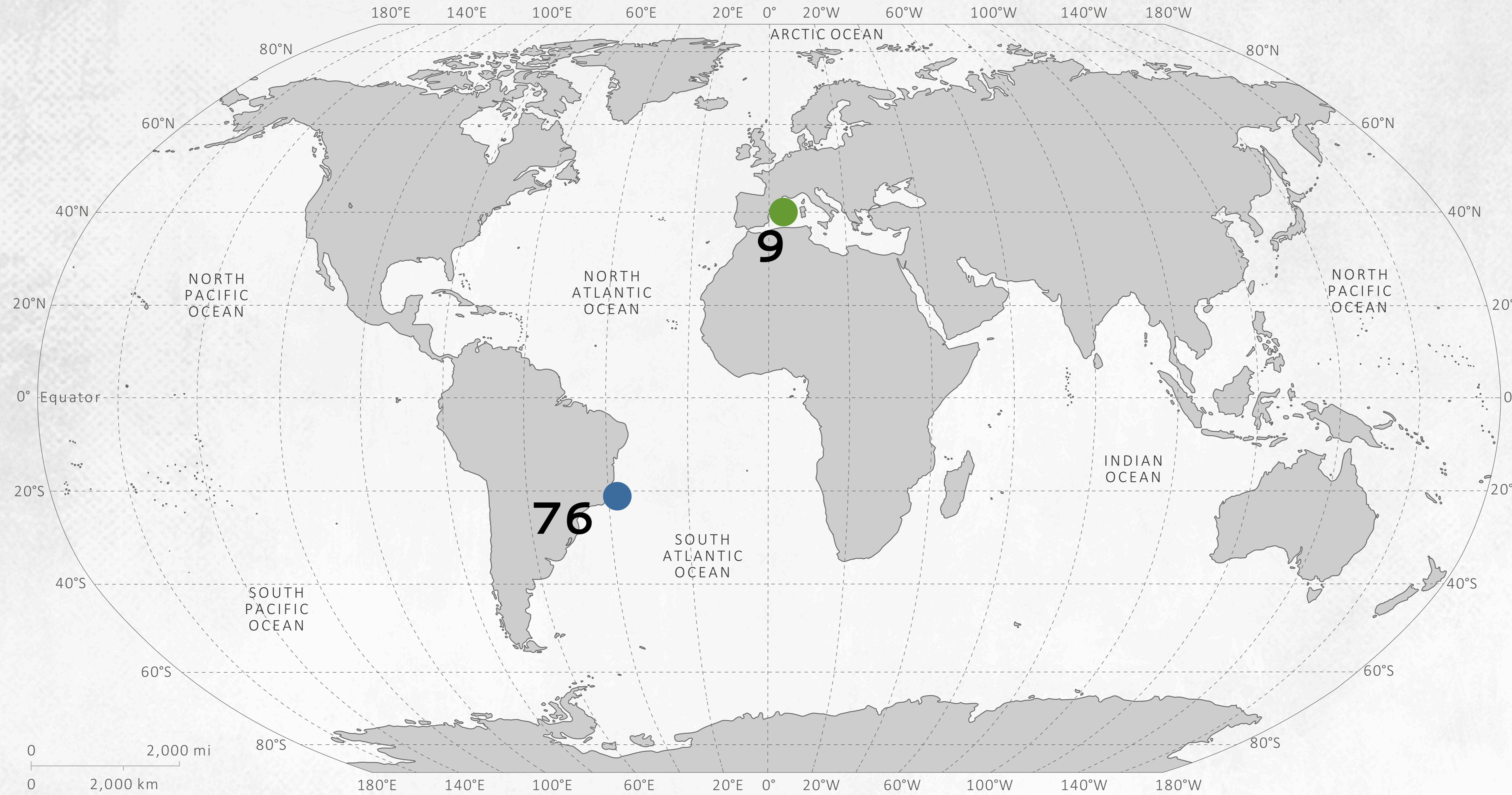
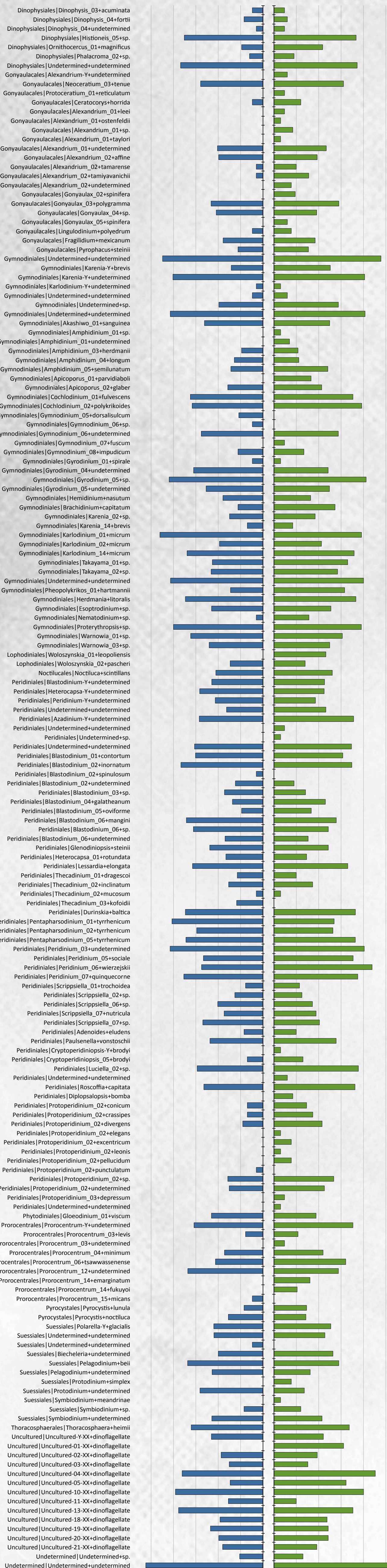
COMMUNITY COMPARISON

taxonomic assignment / OTU

PICO DINOFLAGELLATES

STATION

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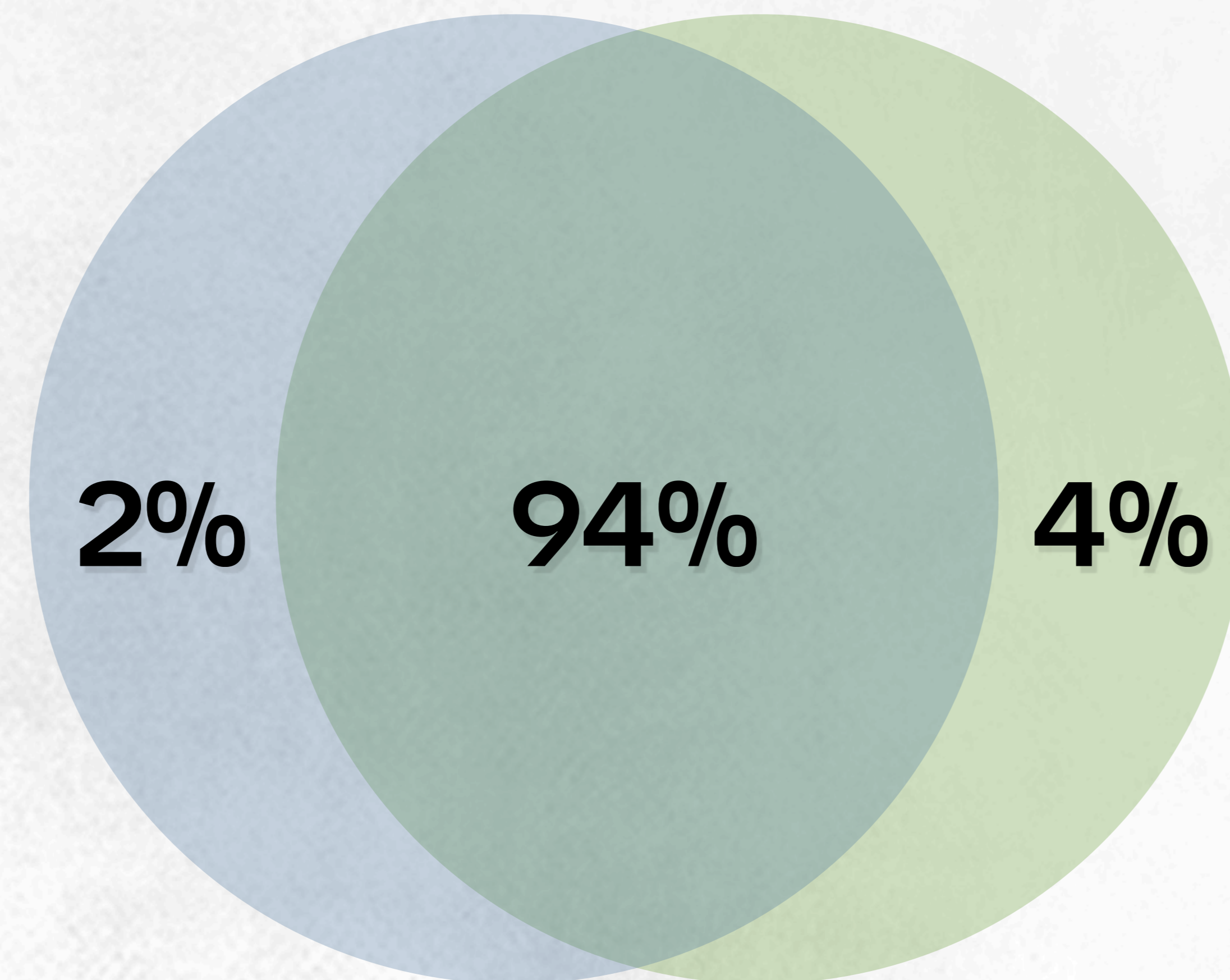
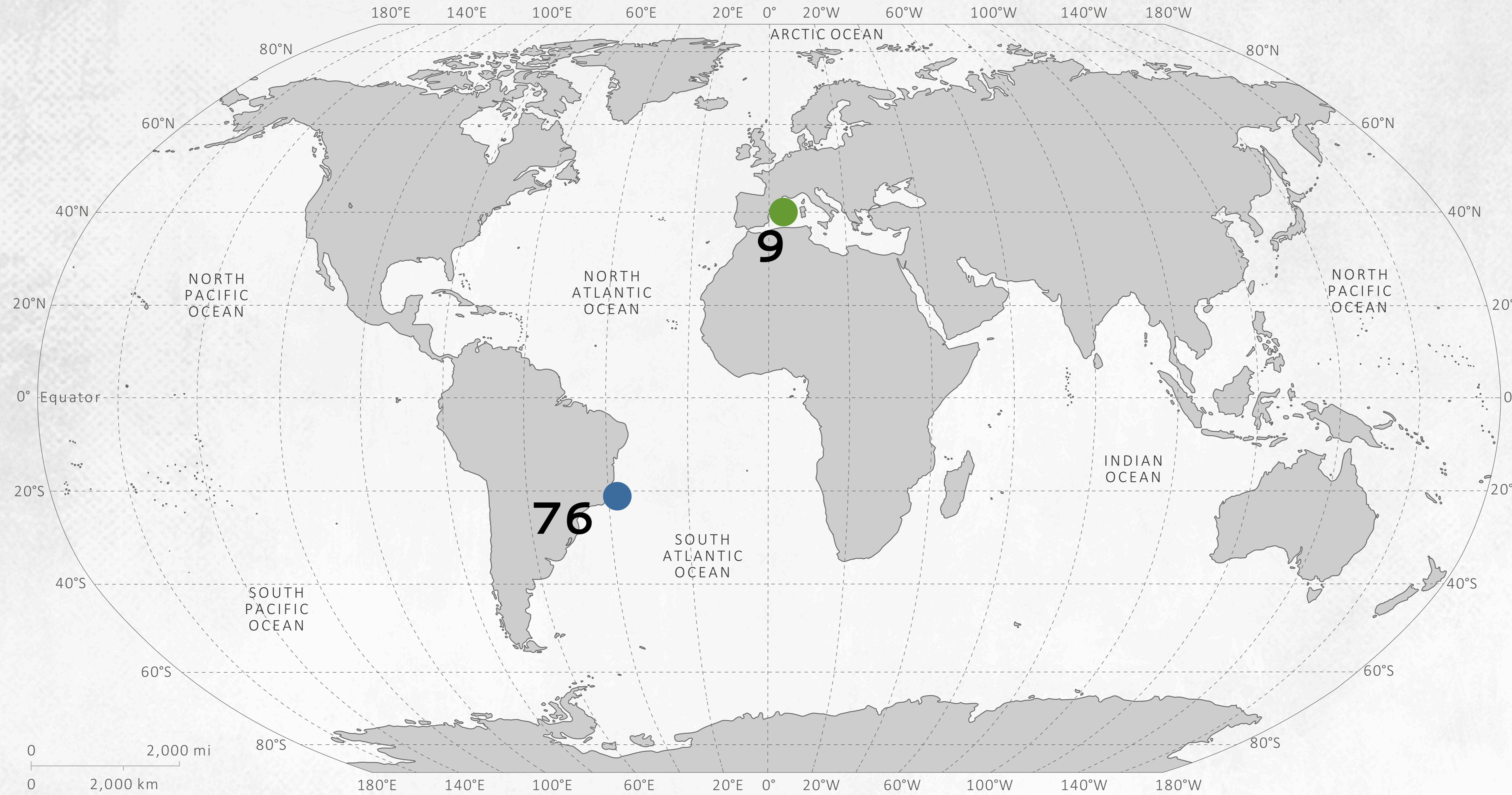
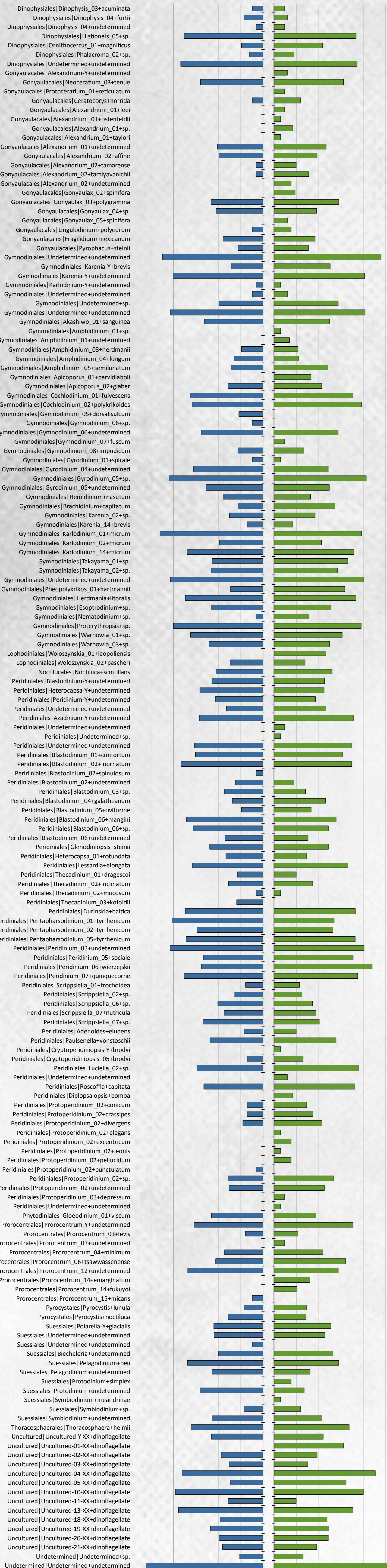
COMMUNITY COMPARISON

taxonomic assignment / OTU

PICO DINOFLAGELLATES

STATION

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ABUNDANCE

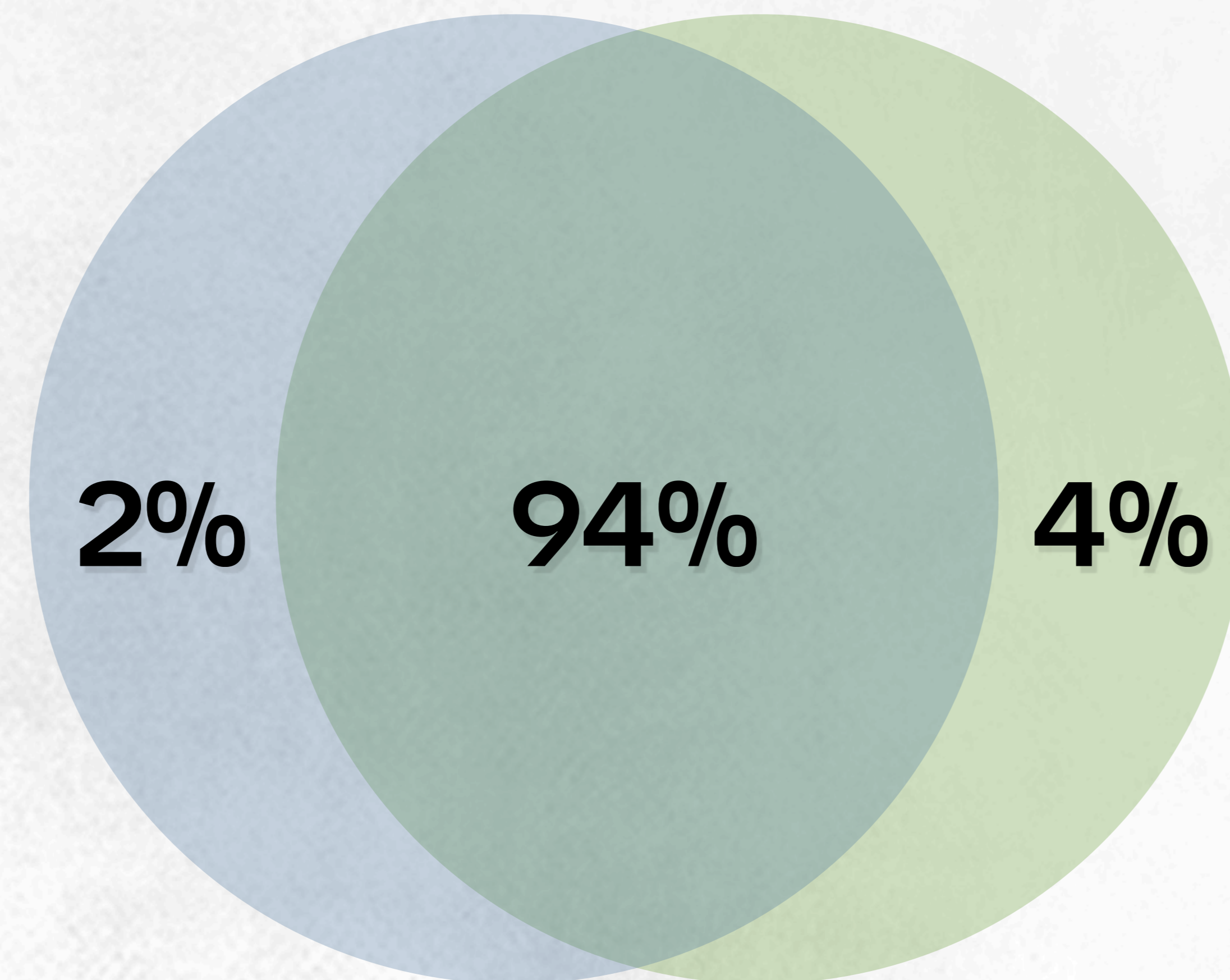
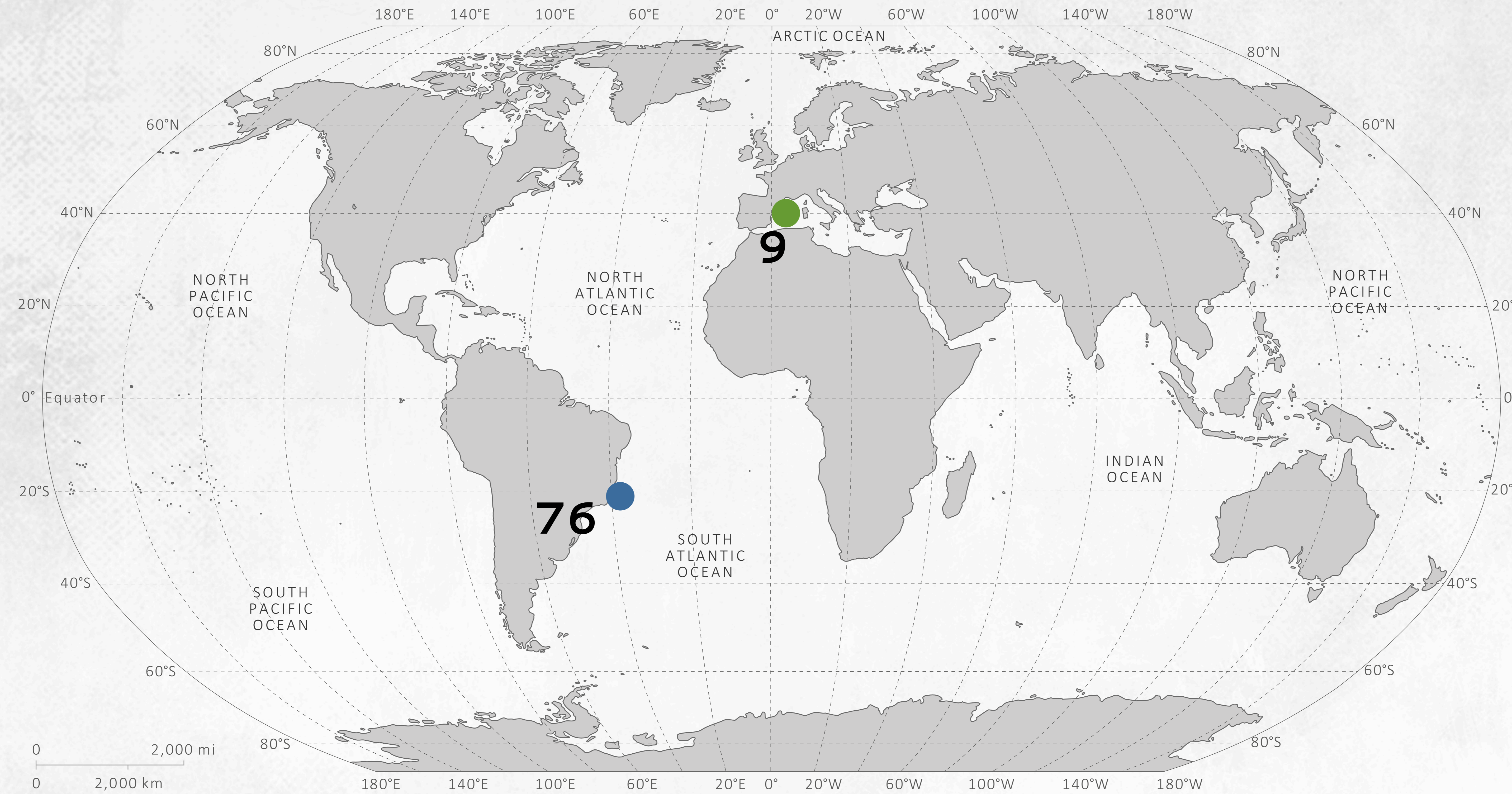
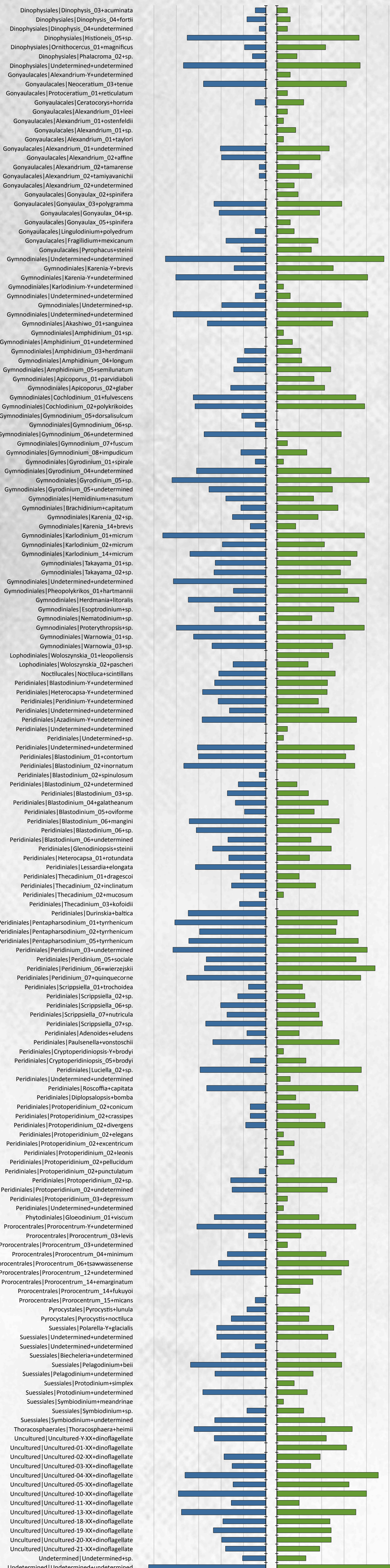
COMMUNITY COMPARISON

taxonomic assignment / OTU

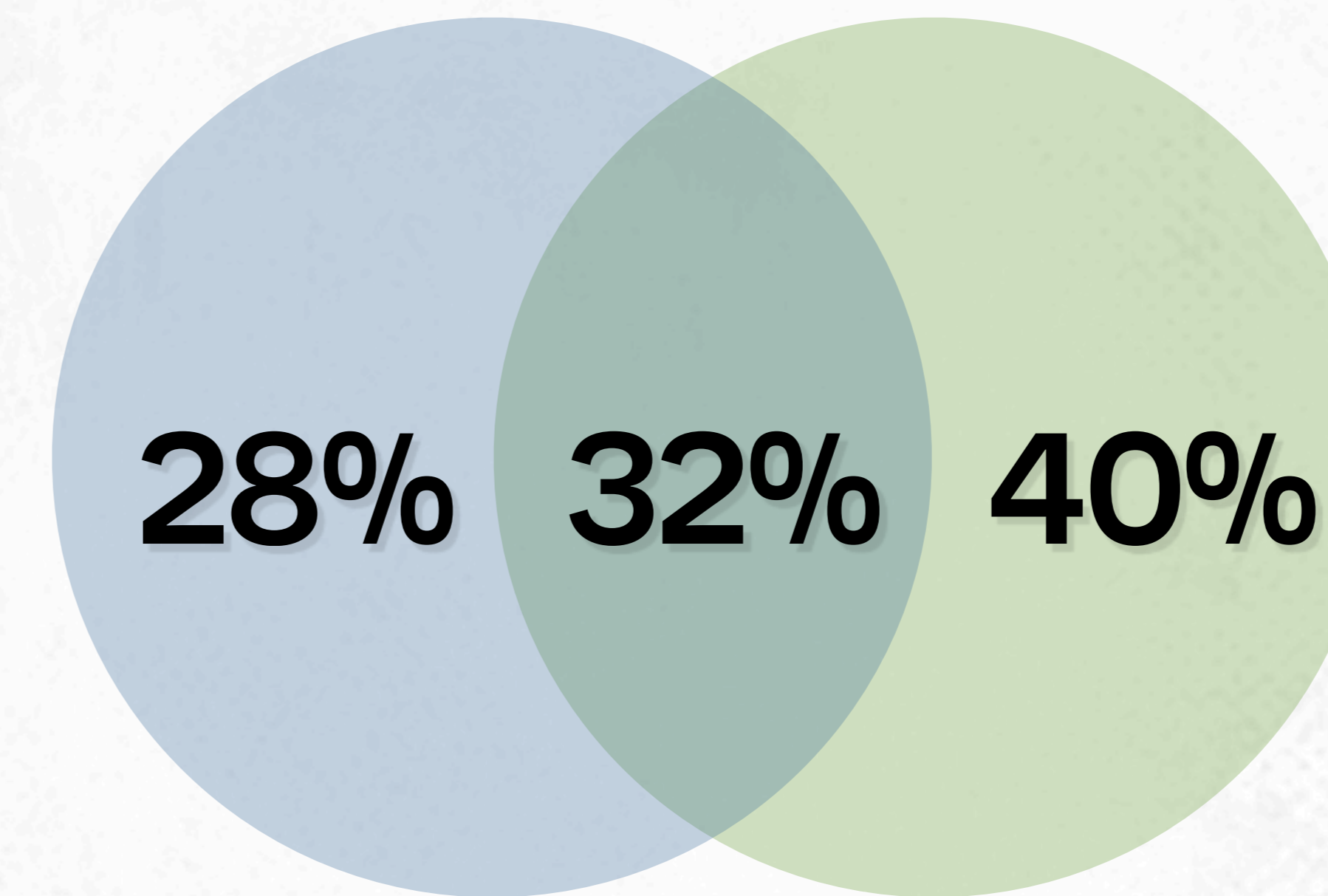
PICO DINOFLAGELLATES

STATION

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ABUNDANCE



RICHNESS

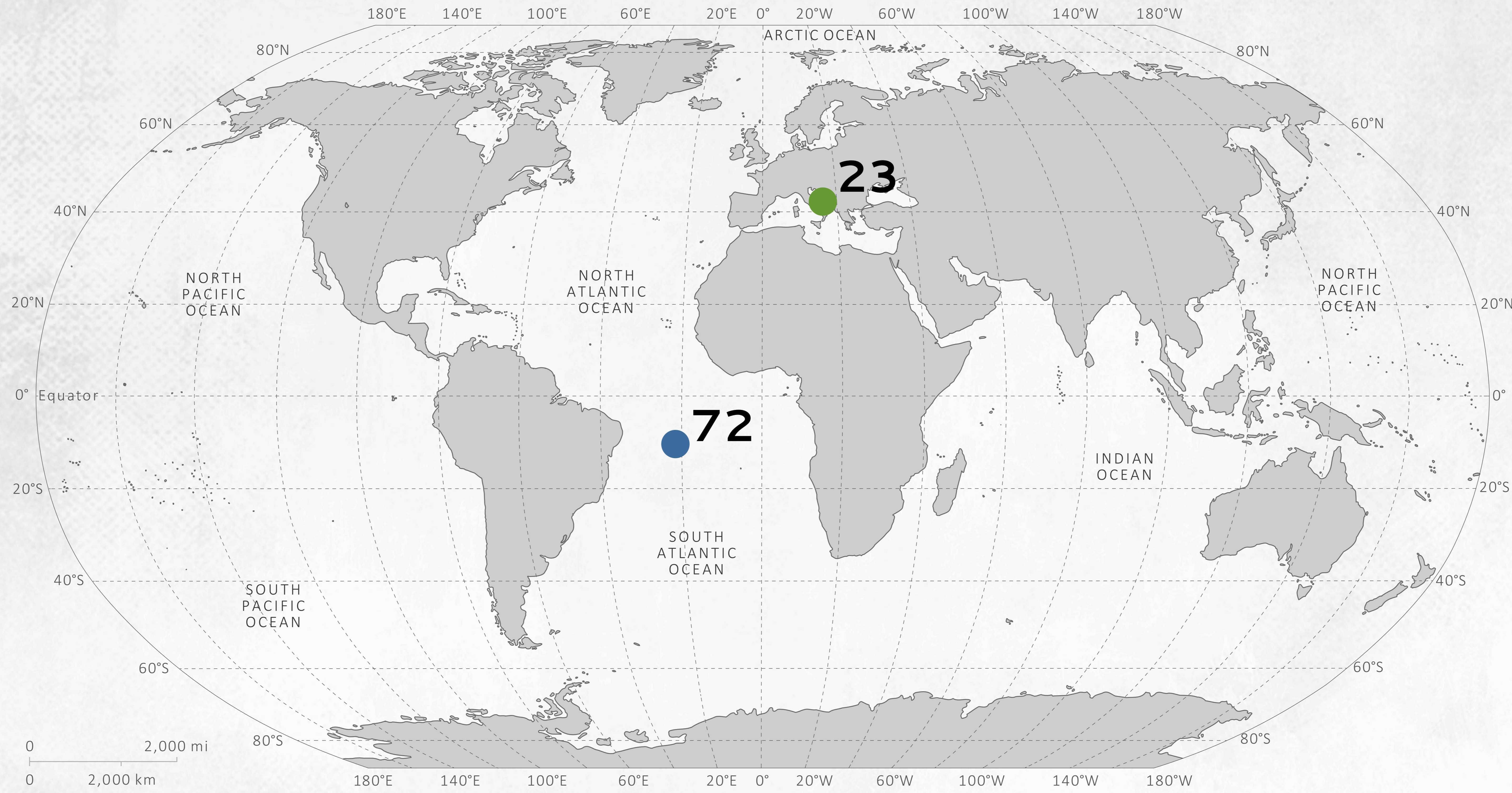
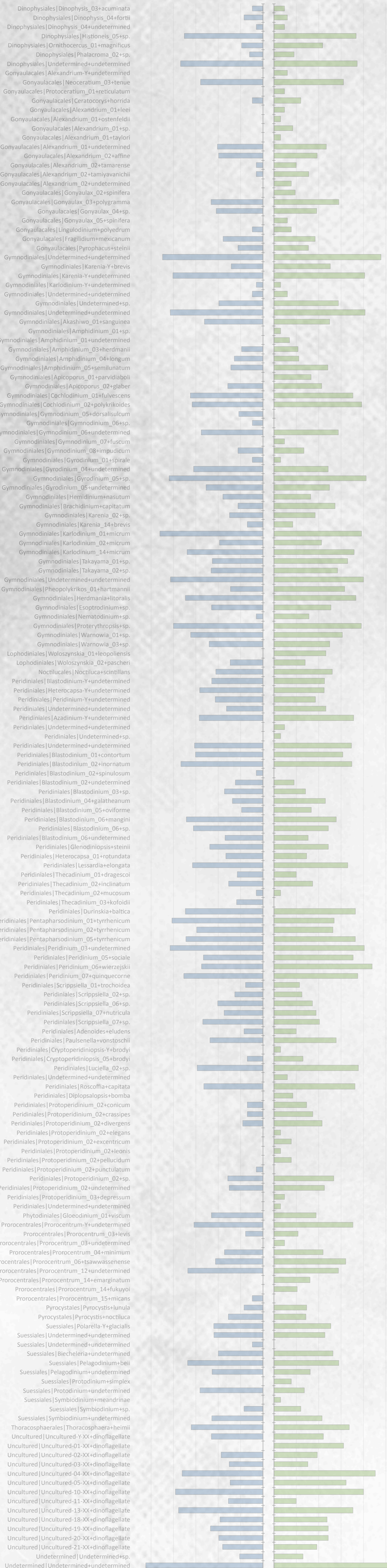
COMMUNITY COMPARISON

taxonomic assignment / OTU

MICRO DINOFLAGELLATES

STATION

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COMMUNITY COMPARISON

taxonomic assignment / OTU

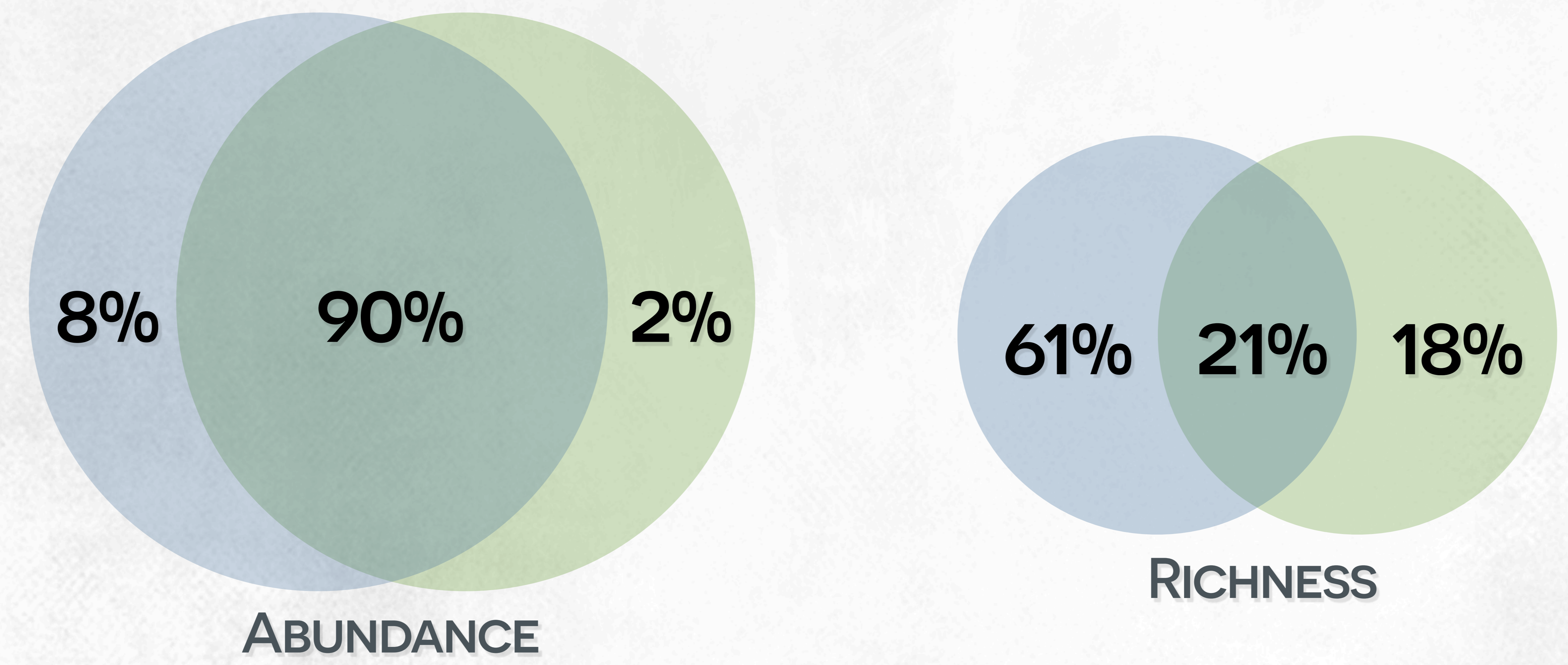
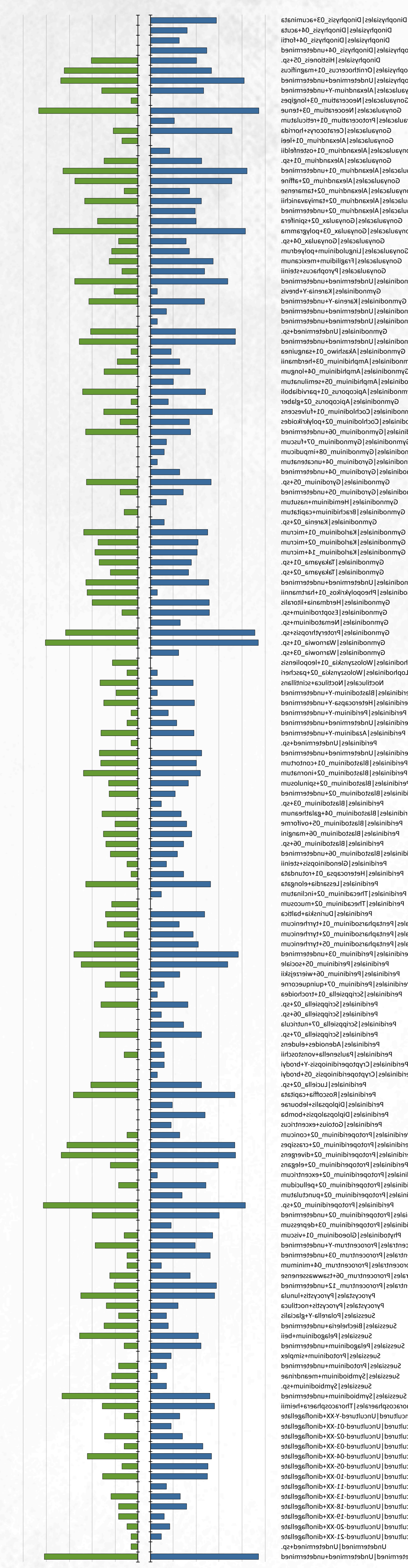
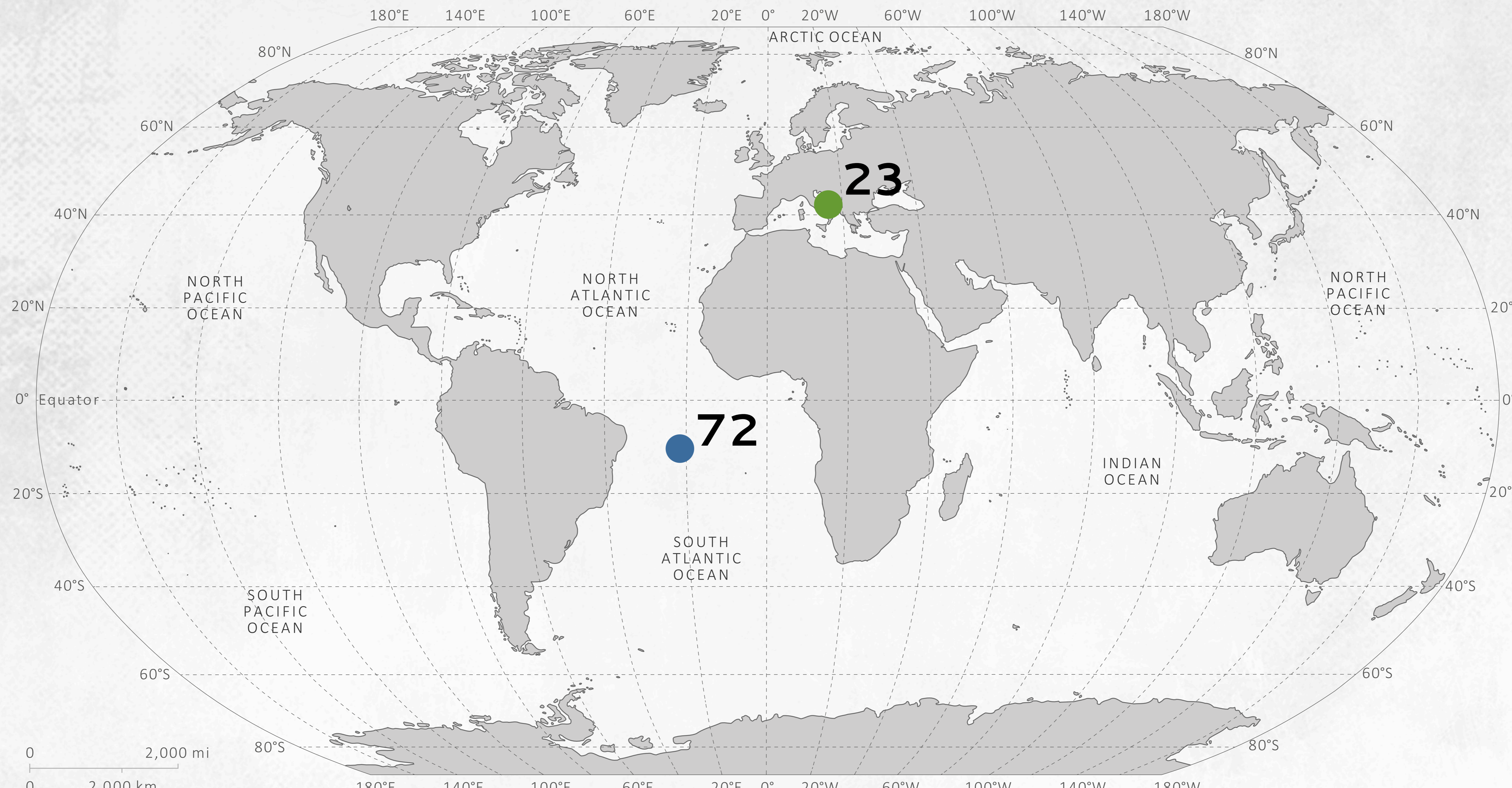
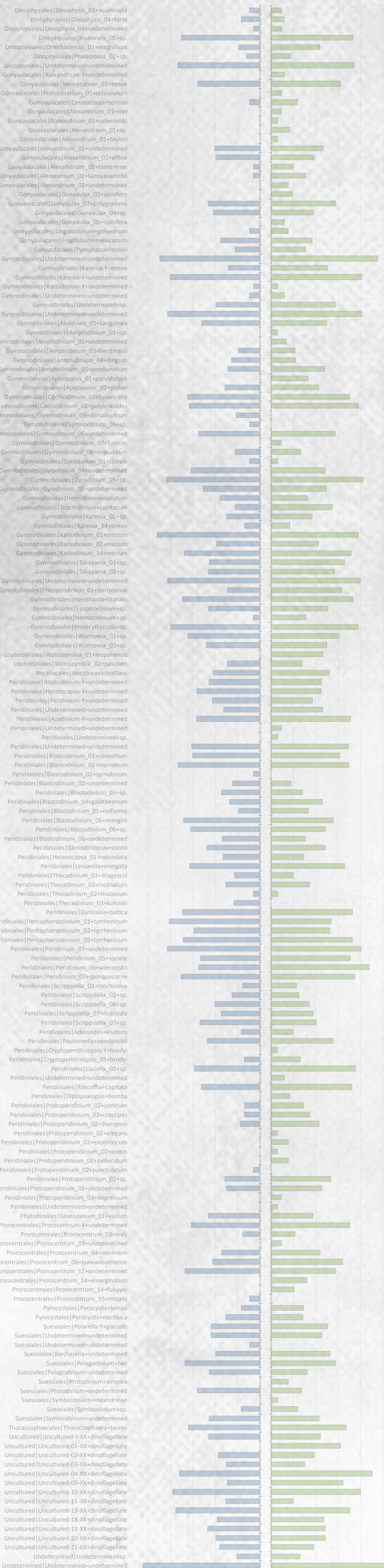
STATION

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STATION

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MICRO DINOFLAGELLATES



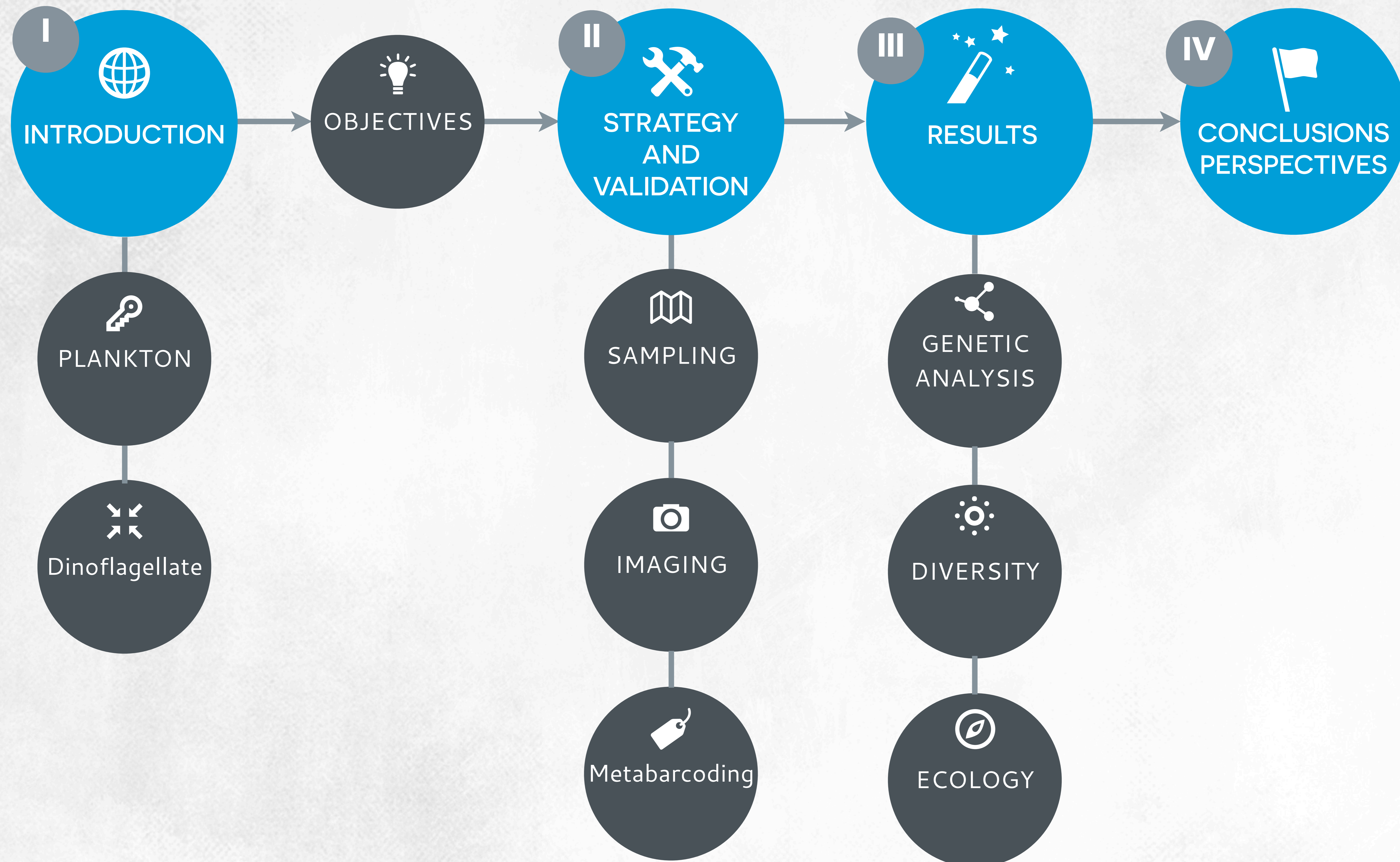
COMMUNITY COMPARISON

These results are preliminary

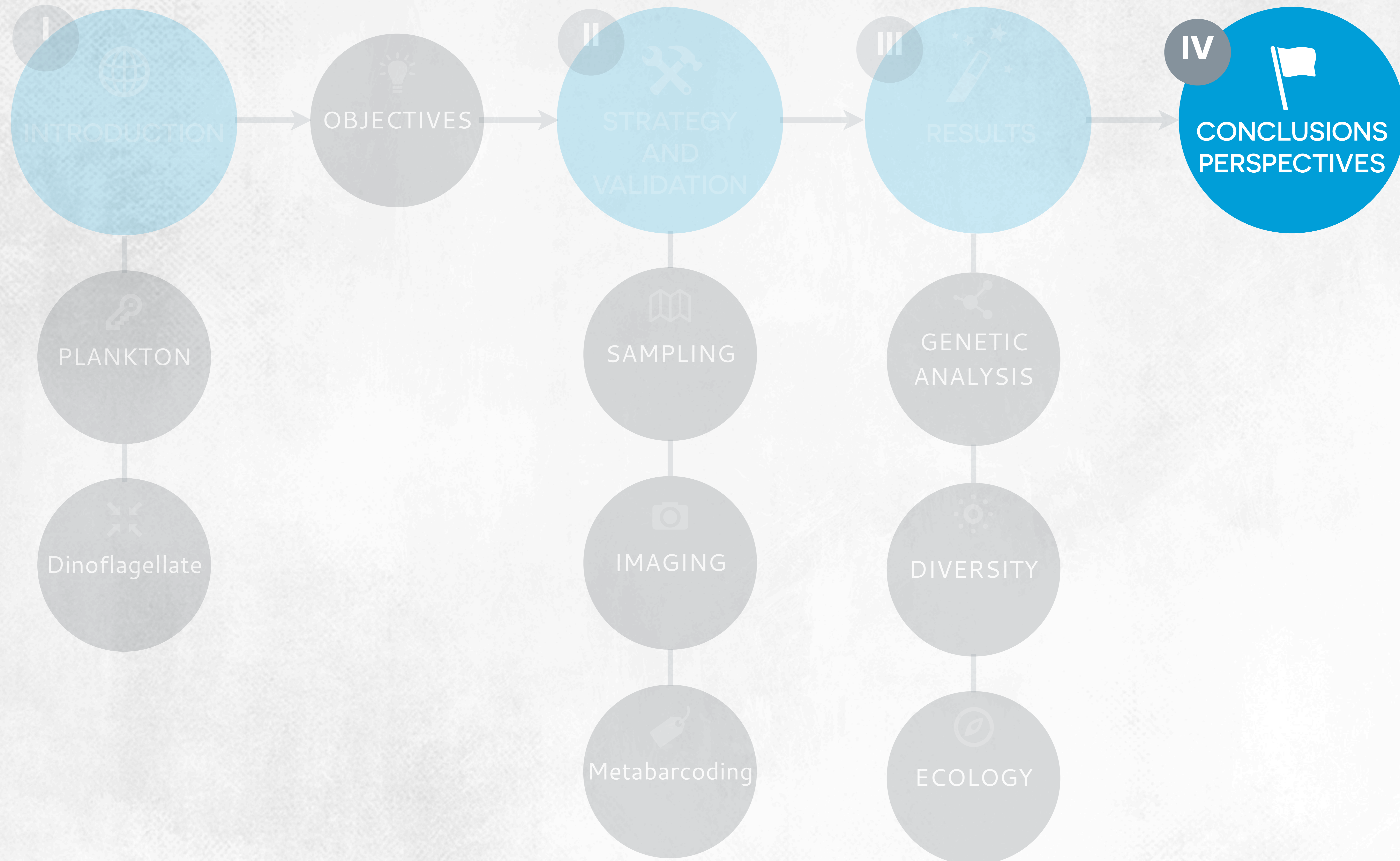
More physico-chemical parameters should be taken into account to discriminate among stations

These observations may contradict the commonly accepted paradigm that associates a marine habitat to a dinoflagellate community, but more data should be analyzed across time scales

PRESENTATION SUMMARY



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CONCLUSION

A morphogenetic sampling strategy allows a complete picture of global dinoflagellate biodiversity.

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Global metabarcoding analysis of dinoflagellates showed the existence of coherent and recurrent biodiversity patterns independent of spatial and temporal scales.

Dinoflagellate communities in the world's oceans are organized at the taxonomic level of order across the different plankton size fractions.

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Preliminary ecological analyses showed that similar dinoflagellate communities are found in contrasting environmental conditions.

PERSPECTIVES

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- ➔ Use more environmental parameters to discriminate stations and make a more accurate assessment of dinoflagellate community structuring across the world's oceans.



Philippe Grosjean
Kevin Denis



Emmanuel Reynaud
Maureen Williams

Tara team
Hervé Bourmaud
Julien Girardot

Christophe Boutte
Frédéric Mahé
Raphaele Morard

Aliou Dia
Frédéric Lepelletier
Doriane Stagnol



Adriana Zingone
Eleonora Scalco
Raffaele Siano
Marina Montresor
Francesca Benzoni
Fabrizio d'Ortenzo
Gabriele Procaccini
Bianca Silva
Daniele Ludicone
Martina Ferraris
Alice Soccodato
Sabrina Speich



Francisco Cornejo Castillo
Silvia Acinas Gonzalez

Mathieu Oriot
Vincent Le Pennec
François Noël
Sibylle d'Orgeval
Éric Beiro

Elmahdi Bendif
Lucie Bittner
Marie-José Garet
Angélique Gobet
Margaux Carmichael

Dominique Boeuf
Florian Humily
Grégory Farrant
Justine Pittera
Pauline Gosselin



Sarah Searson

Pierre Testor
Fabrice Not

Nicolas Henry
Amandine Pillonel

Patricia Bonin



Luis Gutierrez
Iliana Espinoza

Hervé Le Goff
Céline Dimier

Camille Poirier
Damien Guiffant

Jean-Baptiste Fournier
Jean-Charles Leclerc



Shruti Malviya
Alok Arun

Sophie Nicaud
Loïc Valette

Solenn Mordret
Julien Laurent

Nathalie Kowalczyk
Laure Noël



Mattias Ormestad

Daniel Cron
Céline Blanchard

Nathalie Simon
Gaby Gorsky

Florentine Riquet
Kevin Cascella



Hiroyuki Ogata
Atsuko Tanaka

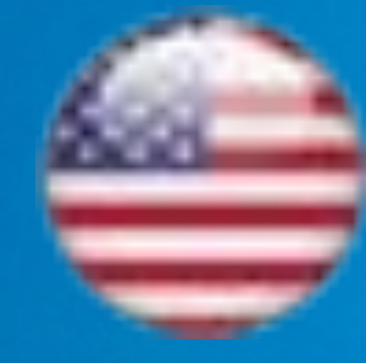
François Aurat
Alain Giese

Marc Picheral
Lars Stemmann

Vlad Costache
Alexia Guillouzo



Cornelia Maier
Éric Roettinger
Steffi Kandels-Lewis
Mona Otto
Hanna Dehmer



Nicole Poulton
Mike Sieraki
Matthew B Sullivan
Daniel Richter

Baptiste Bernard
Yann Chavance
Martin Hertau
Dorothee Désobry
Denis De la Broise

Jean Baptiste Romagnan
Rodolphe Lemée
Lionel Guidi

Marie Rescan
And many many more...



Rowena Stern
Nigel Grimsley
Chris Bowler
John R Dolan



Uros Krzic

Éric Karsenti
Alban Ramette

Samuel Chaffron
Josephine Ras

My family
My Parents
Delphine Rioual

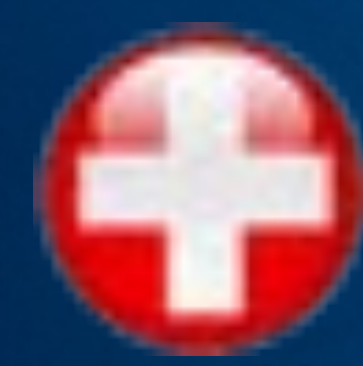


Stéphane Pesant

Laure Guillou
Sébastien Colin

Alina Tunin Ley
Émilie Villar

Scoubidou
Gribouillou



Colomban de Vargas
Jan Pawlowski
Claudio Stalder



Étienne Bourgois
Agnès Bourgois
Romain Troublé
Philippe Clais

Johan Decelle
Sarah Romac
Stéphane Audic
Nathalie Babic

Bernard Kloireg
François H Lallier

All PhytoPk
Christophe Caron
Nathalie Quimerch

All my friends
everywhere around
the world !

Béatrice Noblot
Hélène Huelvan
Brigitte Riou

A big kiss to those
who have not find
their names ;)



**THANK
YOU**