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What Lives in the Sea?

Census of Marine Life Publishes Historic Roll Call of Species in 25 Key Ocean Areas

Representing the most comprehensive and authoritative answer yet to one of humanity's most ancient questions -- "what lives in the sea?" -- [Census of Marine Life](#) scientists today released an inventory of species distribution and diversity in key global ocean areas.

Scientists combined information collected over centuries with data obtained during the decade-long Census to create a roll call of species in 25 biologically representative regions -- from the Antarctic through temperate and tropical seas to the Arctic.

Their papers help set a baseline for measuring changes that humanity and nature will cause.

Published by the open access journal PLoS ONE, the landmark [collection of papers](#) and overview synthesis will help guide future decisions on exploration of still poorly-explored waters, especially the abyssal depths, and provides a baseline for still thinly-studied forms, especially small animals.

Australian and Japanese waters, which each feature almost 33,000 forms of life that have earned the status of "species" (and thus a scientific name such as [Carcharodon carcharias](#), a.k.a. the great white shark), are by far the most biodiverse. The oceans off China, the Mediterranean Sea and the Gulf of Mexico round out the top five areas most diverse in known species.

In a prelude to the ultimate summary of the landmark, decade-long marine census, to be released Oct. 4 in London, national and regional committees of the Census compiled the inventory of known and new species in the 25 key marine regions.

The 13 committees include over 360 scientists whose collective knowledge, including published and unpublished data, was assembled to create the initial profile of known marine biodiversity in Antarctica, Atlantic Europe, Australia, Baltic Sea, Brazil, Canada (East, West and Arctic), Caribbean Sea, China, Indian Ocean, Japan, Mediterranean Sea, New Zealand, South Africa, South America (Tropical East Pacific and Tropical West Atlantic), South

Korea, the Humboldt Current, the Patagonian Shelf, and the USA (Northeast, Southeast, Hawaii, Gulf of Mexico, and California).

Major inventories continue in highly diverse areas such as Indonesia, Madagascar and the Arabian Sea, which have yet to report.

Scientists find that the number of known, named species contained in the 25 areas ranged from 2,600 to 33,000 and averaged about 10,750, which fall into a dozen groups. On average, about one-fifth of all species were crustaceans which, with mollusks and fish, make up half of all known species on average across the regions. The full breakdown follows:

- * 19% Crustaceans (including crabs, lobsters, crayfish, shrimp, krill and barnacles)
- * 17% Mollusca (including squid, octopus, clams, snails and slugs)
- * 12% Pisces (fish, including sharks)
- * 10% Protozoa (unicellular micro-organisms)
- * 10% algae and other plant-like organisms
- * 7% Annelida (segmented worms)
- * 5% Cnidaria (including sea anemones, corals and jellyfish)
- * 3% Platyhelminthes (including flatworms)
- * 3% Echinodermata (including starfish, brittle stars, sea urchins, sand dollars and sea cucumbers)
- * 3% Porifera (including sponges)
- * 2% Bryozoa (mat or ‘moss animals’)
- * 1% Tunicata (including sea squirts)

The rest are other invertebrates (5%) and other vertebrates (2%). The scarce 2% of species in the “other vertebrates” category includes whales, sea lions, seals, sea birds, turtles and walrus. Thus some of the best-known marine animals comprise a tiny part of marine biodiversity.

The authors note that their work constitutes a roll call of marine plant and animal species – either present or absent in 25 regions. It does not represent the abundance or biomass they represent.

The most cosmopolitan species

Many species appear in more than one region. Current holders of the title “most cosmopolitan” marine species are two opposite kinds: microscopic plants (algae) and single-celled animals called protozoa and copepod in the plankton, and the seabirds and marine mammals that traverse the oceans throughout their lives.

Among fish, the manylight viperfish ([*Chauliodus sloani*](#)) can be considered the Everyman of the deep ocean. Census data shows the fish has been recorded in more than one-quarter of the world’s marine waters.

How the microscopic species can be cosmopolitan is still a subject of research, and may be due to their ability to survive unsuitable environmental conditions and then reach enormous

abundance in a suitable environment.

Says Patricia Miloslavich of Universidad Simón Bolívar, Venezuela, co-senior scientist of the Census and leader of the regional studies: “To create this baseline, the Census of Marine Life explored new areas and new ecosystems, discovering new species and records of species in new places.

“We reviewed what had been documented through the huge efforts of scientists in years past. However, most of this information was scattered or unavailable except at a very local level. The Census has made a tremendous contribution by bringing order to chaos. This previously scattered information is now all reviewed, analyzed and presented in a collection of papers at an open access journal.”

Says lead author of the summary, Mark Costello of the Leigh Marine Laboratory, University of Auckland, New Zealand: “Sparse, uneven marine sampling in much of the world underlies this initial inventory, and future research will undoubtedly alter the profile presented today.”

He adds that finding such great difference in the proportions of species across regions challenges assumptions that scientists can extrapolate knowledge of biodiversity from one location to another.

“This inventory was urgently needed for two reasons,” says Dr. Costello. “First, dwindling expertise in taxonomy impairs society’s ability to discover and describe new species. And secondly, marine species have suffered major declines -- in some cases 90% losses -- due to human activities and may be heading for extinction, as happened to many species on land.”

Regional results *(please see full details in the table appended below)* :

- Even less diverse regions such as the Baltic or Northeast USA still have about 4,000 known species.
- Relative to its volume of water, the Baltic, followed by China, has some of the highest known diversity.
- Relative to their seabed area, South Korea, China, South Africa and the Baltic, had most species.
- The relative contribution of different kinds of life to the species in each region varied greatly and enigmatically. While variation in research effort may be part of the explanation, it also seems that species have not flourished equally around the world.
- Crustaceans (including crabs, lobsters, crayfish, shrimp, krill and barnacles) contributed 22% to 35% of species for Alaska, Antarctica, Arctic, Brazil, California, Caribbean, and Humboldt regions, but only 10% for the Baltic.
- Mollusks (clams, snails, squid and slugs) contributed 26% of the species in Australia and Japan, but only 5% to 7% of the species in the Baltic, California, Arctic, and Eastern and Western Canada.

- Fish comprised 28% of species in the Tropical West Atlantic and Southeast USA, but only 3% to 6% for the Arctic, Antarctica, Baltic, and Mediterranean.
- Of the less species-rich groups, Annelida (worms) contributed 28% of the species for the Tropical Eastern Pacific, but only 3% for Japan.
- Plants and algae (mostly algae) contributed about one third of species in the Baltic, Arctic, Atlantic Europe, and Western Canada, but few in Antarctica, Caribbean, China, Humboldt, Tropical Eastern Pacific, and Tropical Western Atlantic.

Where to find unique, “endemic” or alien invasive species

- The number of unique “endemic” species seen nowhere else on Earth provides another measure of biodiversity. The relatively isolated regions Australia, New Zealand, Antarctica or South Africa have the most endemic species. They may have suffered fewer extinctions from climate cooling thousands of years ago during glaciation. Or, species from regions that escaped glaciers may have reached them more easily when the glaciers melted.

Endemics comprise about half of New Zealand and Antarctic marine species and a quarter of those in Australian and South Africa. The Caribbean, China, Japan, and Mediterranean each have less than 2,000 endemic species, and the Baltic only 1 – a seaweed ([*Fucus radicans*](#)).

- To encounter invasive species, visit the Mediterranean. It had the most alien species among the 25 regions with over 600 (4% of the all species inventoried), most of which arrived from the Red Sea via the Suez Canal.
- Many aliens have also invaded the European Atlantic, New Zealand, Australian Pacific, and Baltic waters. Mollusks, crustaceans, and fish were the most common invading aliens.

How much is unknown?

Says Dr. Ian Poiner, CEO of the Australian Institute for Marine Science and Chair of the Census Scientific Steering Committee: “Consider that a well-informed person walking along a familiar seashore might identify 20 species or so; a fish monger perhaps 100. Even in the world’s least diverse marine regions, there are 50 to 100 times as many named species than an expert would know without resorting to field guides.”

Many of the species records used for the report are part of the 10-year-old [Ocean Biogeographic Information System](#) (OBIS), a massive global database of what/where records and a major Census legacy. An interested person can find precise places on a world map where a marine organism has been reliably observed.

OBIS has consolidated almost 30 million records from the Census projects and more than

800 databases contributed by institutions around the world.

Says Edward Vanden Berghe, who leads development and management of the database: “A map of records in OBIS today underlines the uneven sampling of oceanic regions,” he adds. “So even as records accumulate, the importance of orderly sampling grows.”

Almost all the species in the key regional areas are included in the unprecedented list of 185,000 marine species created by the [World Register of Marine Species](#) (WoRMS), an affiliate of the [International Oceanographic Commission](#) (IOC).

draws on discoveries of Census scientists and their colleagues, past and present. It chronicles “the variety, beauty, weirdness and wonder that characterizes life in the sea.”

“The sea today is in trouble,” says Dr. Knowlton. “Its citizens have no vote in any national or international body, but they are suffering and need to be heard. Much has changed just in the few decades that I have spent on and under the sea, but it remains a wondrous and enriching place, and with care it can become even more so.”

Greatest threats

According to the Census studies published in PLoS ONE, the main threats to marine life to date have been overfishing, lost habitat, invasive species and pollution, although the relative importance of the threats varied among regions. Emerging threats include rising water temperature and acidification, and the enlargement of areas characterized by low oxygen content (called *hypoxia*) of seawater. These too will vary regionally (surface temperature, for example) whereas others are more global (such as acidification).

Overfishing not only depletes the exploited fish themselves but also depletes other species like turtles, albatrosses, sharks and mammals, caught unintentionally. It alters food webs within ecosystems.

Coastal urbanization, sediment runoff and nutrients in sewage and fertilizer washed from the land and causing eutrophication and hypoxia are destroying marine habitats.

The more enclosed seas -- Mediterranean, Gulf of Mexico, China’s shelves, Baltic, and Caribbean -- were reported to have the most threatened biodiversity.

State-of-knowledge index

Census scientists created a relative “state-of-knowledge index,” grading each region according to how well it was known, including the availability of guides to the identification of species and their number of taxonomic experts.

In a nutshell, the studies found that while the depth of knowledge varies across regions, knowledge in all regions is inadequate.

Australia, China and all three European regions scored the highest index results while the Tropical West Atlantic, Tropical East Pacific and Canadian Arctic were well below average. But, even in regions with the highest index scores, knowledge of marine biodiversity is poor. In Australia it is estimated that only about 10% of marine life in its Exclusive Economic Zone is known.

Scientists say the availability of comprehensive species identification guides strongly boost the discovery and management of marine biodiversity resources.

“We must increase our knowledge of unknown biodiversity more quickly, lest much of it is lost without even being discovered,” says Dr. Miloslavich. “International sharing of data, expertise and resources, as has been accomplished through the Census of Marine Life, is the most cost-effective way of achieving this.”

The Census papers collection, freely available Aug. 2 at *PLoS ONE* (www.coml.org/plos-one-collections), includes two overview articles and links to maps, databases and a suite of the first ten regional papers on which the summary drew, with several more to be added in weeks to come.

And there are Census reports on several more regions anticipated in years to come .

A exploration currently underway in the species-rich Timor and Arafura Seas, facilitated by Dr. Antonio (Tonny) Wagey, leader of the Census’ National Committee in Indonesia, will enrich the Indonesian report.

Another this past spring, led by Philippe Bouchet of the Muséum National d'Histoire Naturelle, Paris, discovered a vast array of marine life in the Deep South of Madagascar.

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Appendix 1:

Table: In 25 key marine areas, the percentage of species per taxonomic group. Groups that contributed more than 10% of the species in a region are indicated in red, and more than 20% in bold. (Note: many of the 25 regions share many species in common.)

Percentage of Areas >10%	plants and animals	Total # of species --													
		Crustacea	Mollusca	Pisces	Protozoa	Plants and algae	Annelida	Cnidaria	Other invertebrates	Platyhelminthes	Echinodermata	Porifera	Bryozoa	Other vertebrates	Tunicata
Australia	32,889	19	26	16	2	6	5	5	3	2	5	5	3	1	3
Japan	32,777	19	26	12	14	7	3	6	4	1	3	2	1	0	1
China	22,365	19	18	14	21	5	5	6	2	2	3	1	3	1	1

Mediterranean	16,848	13	13	4	24	7	7	4	13	6	1	4	2	0	1
Gulf of Mexico	15,374	17	16	10	14	13	6	5	4	5	3	2	2	3	1
New Zealand	12,780	17	18	10	12	11	4	6	4	2	4	4	5	1	1
South Africa	12,715	18	24	15	2	7	6	7	5	3	3	3	2	2	2
Atlantic Europe	12,270	18	11	9	4	28	13	4	0	2	2	4	3	2	1
Caribbean	12,046	24	25	11	7	5	5	8	3	1	4	4	1	0	1
Humboldt Current	10,186	31	12	11	7	5	6	5	8	2	4	2	4	2	1
USA	10,160	26	7	9	9	9	8	4	7	1	3	1	1	1	1
California										4					
Korea	9,900	14	19	11	3	9	5	3	25	1	2	3	1	2	1
Brazil	9,101	22	20	14	3	9	11	6	3	0	3	4	1	2	1
Hawaii	8,244	16	16	15	10	12	4	6	3	8	4	2	2	1	1
Antarctica	8,200	35	9	4	8	4	7	6	7	2	7	3	4	3	1
SA Trop East Pacific	6,696	13	13	18	14	5	28	2	1	0	3	1	1	1	0
Alaska	5,925	26	8	7	13	7	9	4	10	2	3	3	6	2	1
Baltic	5,865	10	5	3	20	30	7	2	13	5	1	0	1	2	0
USA NE	5,045	16	17	19	1	12	14	4	3	2	3	1	3	4	1
USA SE	4,229	16	17	28	4	8	9	9	1	0	0	3	2	2	1
Patagonian Shelf	3,776	16	22	14	0	7	5	7	5	1	5	7	4	5	1
Canada Eastern	3,160	23	7	17	19	12	14	3	2	0	2	0	0	1	0
Canada Arctic	3,038	24	5	6	12	36	11	2	2	0	1	0	0	1	0
SA Trop West	2,743	19	16	32	2	5	6	5	2	0	4	1	0	8	1
Atlantic															
Canada Western	2,636	18	7	14	4	38	14	0	2	0	1	0	0	1	0
Mean	10,759	19	17	12	10	10	7	5	5	3	3	3	2	2	1

Appendix 2

Census of Marine Life: Final summaries and reports

Started in the year 2000, the Census of Marine Life is a decade-long international collaboration uniting thousands of scientists worldwide to assess and explain the diversity, distribution and abundance of life in the seas. The private sources and government agencies the world over listed online at <http://www.comlsecretariat.org/about/partners-and-sponsors/> have supported the Census.

The Census of Marine Life will present and discuss its final results in London in October as follows:

Monday Oct. 4

Royal Institution of Great Britain, 21 Albemarle St., London

News Conference (new time)

1:30 to 2.30 pm local time (GMT+1)

Panel Presentations

3:00 to 4:30 pm local time (GMT+1)

Audio of the panel presentations and news conference will be available worldwide.

Questions from abroad and/or News Conference accreditation requests may be sent in advance to:

Terry Collins, tc@tca.tc, +1-416-538-8712

or Darlene Crist, darlene.crist@cox.net, +1-401-295-1356

Tuesday Oct. 5 and Wednesday Oct. 6

The Royal Society, 6-9 Carlton House Terrace, London

Science Symposium

A review of scientific results and accomplishments during the decade of discovery, and a discussion of marine biodiversity research priorities in years ahead.

Oct. 5: 8:30 am- 5:00 pm (GMT+1)

Oct. 6: 8:30 am- 3:00 pm (GMT+1)

For symposium accreditation requests may be sent in advance to:

Terry Collins, tc@tca.tc, +1 416-538-8712;

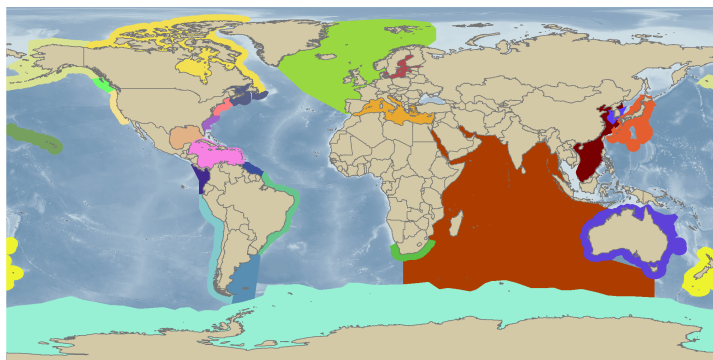
Darlene Crist, darlene.crist@cox.net, +1 401-295-1356; or

Kristen Yarincik, kyarincik@oceanleadership.org, +1 202-448-1237;

Please note: on-site accreditation numbers will be limited by space.

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Appendix 3



NRIC Regions and Sub-Regions

The links below provide more information on CoML's 13 national and regional activities:

- [Australia](#) (contact Annabel Ozimec, Annabel.Ozimec@csiro.au)
- [Canada](#) (contact: Philippe Archambault, philippe_archambault@uqar.qc.ca)
- [Caribbean](#) (contact: Patricia Miloslavich, pmilos@usb.ve)
- [China](#) (contact: Xiao-xia Sun, xsun@ms.qdio.ac.cn)
- [Europe](#) (contact: Bhavani Narayanaswamy, Bhavani.Narayanaswamy@sams.ac.uk)
- [Japan](#) (contact: Katsunori Fujikura, fujikura@jamstec.go.jp)
- [Indian Ocean](#) (contact: Dr. P. A. Lokabharathi, loka@darya.nio.org)
- [Indonesia](#) (contact: Tonny Wagey, t.wagey@fisheries.ubc.ca)
- [Republic of Korea](#) (contact: Youn-Ho Lee, ylee@kordi.re.kr)
- [South America](#) (contact: Diego Rodríguez, dhrodri@bart.mdp.edu.ar)
- [Sub-Saharan Africa](#) (contact: Charles Griffiths, Charles.Griffiths@uct.ac.za)
- [USA](#) (contact: Michael Feldman, mfeldman@OceanLeadership.org)
- Arabian Sea (Michel Claereboudt, michelc@squ.edu.om)

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Appendix 4

The PLoS ONE Collection

To view full text versions of the following articles visit
www.ploscollections.org/coml/marine_biodiversity

Overview Articles:

Marine Biodiversity and Biogeography – Regional Comparisons of Global Issues, An Introduction

Ron O’Dor, Patricia Miloslavich, Kristen Yarincik (contact: rodor@oceanleadership.org)

A Census of Marine Biodiversity Knowledge, Resources, and Future Challenges

Mark John Costello, Marta Coll, Roberto Danovaro, Pat Halpin, Henn Ojaveer, Patricia Miloslavich (contact: m.costello@auckland.ac.nz)

Research Articles:

Marine Biodiversity in the Australian Region

Alan J. Butler, Tony Rees, Pam Beesley, Nicholas J. Bax (contact: alan.butler@csiro.au)

Marine Biodiversity of Aotearoa New Zealand

Dennis P. Gordon, Jennifer Beaumont, Alison MacDiarmid, Donald A. Robertson, Shane T. Ahyong (contact : d.gordon@niwa.co.nz)

Marine Biodiversity in Japanese Waters

Katsunori Fujikura, Dhugal Lindsay, Hiroshi Kitazato, Shuhei Nishida, Yoshihisa Shirayama (contact: fujikura@jamstec.go.jp)

Deep-Sea Biodiversity in the Mediterranean Sea: The Known, the Unknown and the Unknowable

Roberto Danovaro, Joan Batista Company, Cinzia Corinaldesi, Gianfranco D’Onghia, Bella Galil, Cristina Gambi, Andrew J. Gooday, Nikolaos Lampadariou, Gian Marco Luna, Caterina Morigi, Karine Olu, Paraskevi Polymenakou, Eva Ramirez-Llodra, Anna Sabbatini, Francesc Sardà, Myriam Sibuet, Anastasios Tselepides (contact: danovaro@univpm.it)

The Biodiversity of the Mediterranean Sea: Estimates, Patterns, and Threats

Marta Coll, Chiara Piroddi, Jeroen Steenbeek, Kristin Kaschner, Frida Ben Rais Lasram, Jacopo Aguzzi, Enric Ballesteros, Carlo Nike Bianchi, Jordi Corbera, Thanos Dailianis, Roberto Danovaro, Marta Estrada, Carlo Froglija, Bella S. Galil, Josep M. Gaso, Ruthy Gertwagen, João Gil, François Guilhaumon, Kathleen Kesner-Reyes, Miltiadis-Spyridon Kitsos, Athanasios Koukouras, Nikolaos Lampadariou, Elijah Laxamana, Carlos M. López-Fé de la Cuadra, Heike K. Lotze, Daniel Martin, David Mouillot, Daniel Oro, Saša Raicevich, Josephine Rius-Barile, Jose Ignacio Saiz-Salinas, Carles San Vicente, Samuel Somot, José Templado, Xavier Turon, Dimitris Vafidis, Roger Villanueva, Eleni Voultziadou (contact: mcoll@icm.csic.es)

Marine Biodiversity in the Caribbean: Regional Estimates and Distribution Patterns

Patricia Miloslavich, J.M. Díaz, E. Klein, J.J. Alvarado, C. Díaz, J. Gobin, E. Escobar-Briones, J.J. Cruz, E. Weil, J. Cortés, A.C. Bastidas, D.R. Robertson, F.A. Zapata, A. Martín, J. Castillo, A. Kazandjian, M. Ortiz, M. (contact : pmilos@usb.ve)

Antarctic Marine Biodiversity – What Do We Know About the Distribution of Life in the Southern Ocean?

Huw J. Griffiths (hjg@bas.ac.uk)

An Overview of Marine Biodiversity in United States Waters

Daphne Fautin, Penelope Dalton, Lewis S. Incze, Jo-Ann C. Leong, Clarence Pautzke, Andrew Rosenberg, Paul Sandifer, George Sedberry, John W. Tunnell, Jr., Isabella Abbott, Russell E. Brainard, Melissa Brodeur, Lucius G. Eldredge, Michael Feldman, Fabio Moretzsohn, Peter S. Vroom, Michelle Wainstein, Nicholas Wolff (contact: fautin@ku.edu)

Marine Biodiversity in South Africa: An Evaluation of Current States of Knowledge

C.L. Griffiths, T.B. Robinson, L. Lange, A. Mead (contact: Charles.Griffiths@uct.ac.za)

Canada's Three Oceans of Biodiversity

P. Archambault, P. V. R. Snelgrove, J. A. D. Fisher, J.-M. Gagnon, D. J. Garbary, M. Harvey, E. Kenchington, V. Lesage, M. Levesque, C. Lovejoy, D. Mackas, C. W. McKindsey, J. Nelson, P. Pepin, L. Piché, M. Poulin (contact: philippe_archambault@uqar.qc.ca)

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At various stages of preparation are additional papers by the Census of Marine Life National and Regional Committees:

Western European Margin

Bhavani E Narayanaswamy, Paul E Renaud, Gerard CA Duineveld, Jørgen Berge, Marc SS Lavaleye, Henning Reiss, Torleiv Brattegard (contact: Bhavani.Narayanaswamy@sams.ac.uk)

Baltic Sea

Henn Ojaveer, Andres Jaanus, Brian R. MacKenzie, Georg Martin, Sergej Olenin, Teresa Radziejewska, Irena Telesh, Michael L. Zettler, Anastasija Zaiko (contact Henn.Ojaveer@ut.ee)

Indian Ocean

M. Wafar, K. Venkataraman, B. Ingole, S. Ajmal Khan & P. A. Lokabharathi (contact: wafar@darya.nio.org; wafar@csnio.ren.nic.in)

Atlantic and Pacific coasts of South America

Patricia Miloslavich, Eduardo Klein, Julio Castillo, Juan Manuel Díaz, Cristián Esteban Hernández, Gregorio Bigatti, Lucia Campos, Felipe Artigas, Pablo Penchaszadeh, Paula Emily Neill, Alvar Carranza, María Valeria Retana, Juan Manuel Díaz de Astarloa, Mirtha Lewis, Pablo Yorio, María Luz Piriz, Diego Rodríguez, Yocie Yoneshigue-Valentin, Luiz Gamboa, Alberto Martín (contact : pmilos@usb.ve)

China Seas (Ruiyu Liu, J.Y. Liu, in preparation)

Korea (Youn-Ho Lee, in preparation)

Indonesia (Tonny Wagey, in preparation)

and

Arabian Sea (Michel Claereboudt, in preparation)

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