Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

Workshop

Building Capacities for Regional Ocean Governance: Marine Genetic Resources and Area-based Management Tools

New York, 25 August 2019

Marine Genetic Resources: from Sampling to Commercialisation

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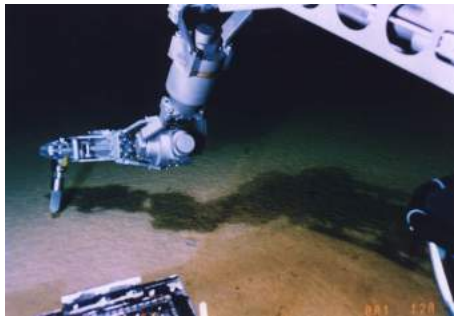
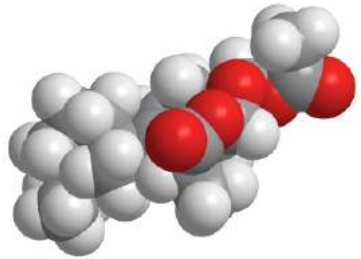
Bioprospecting

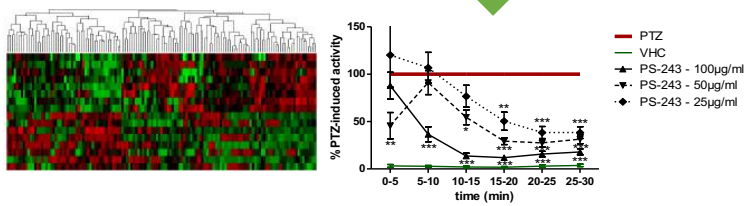


Sampling

Bioresources



New Materials



Testing

Commercialisation

Product

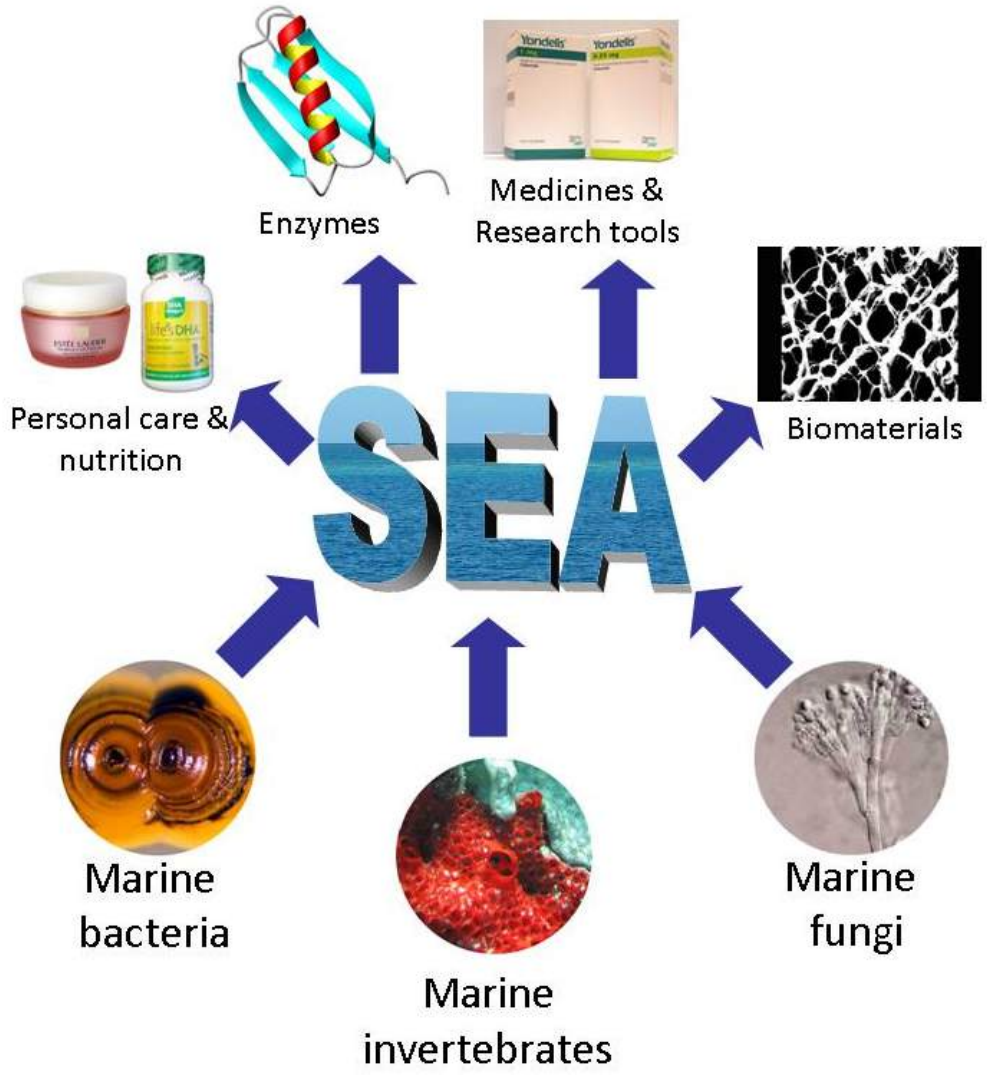
Potential Benefits of Marine Bioprospecting

Offers advantage over comparable terrestrial resource:

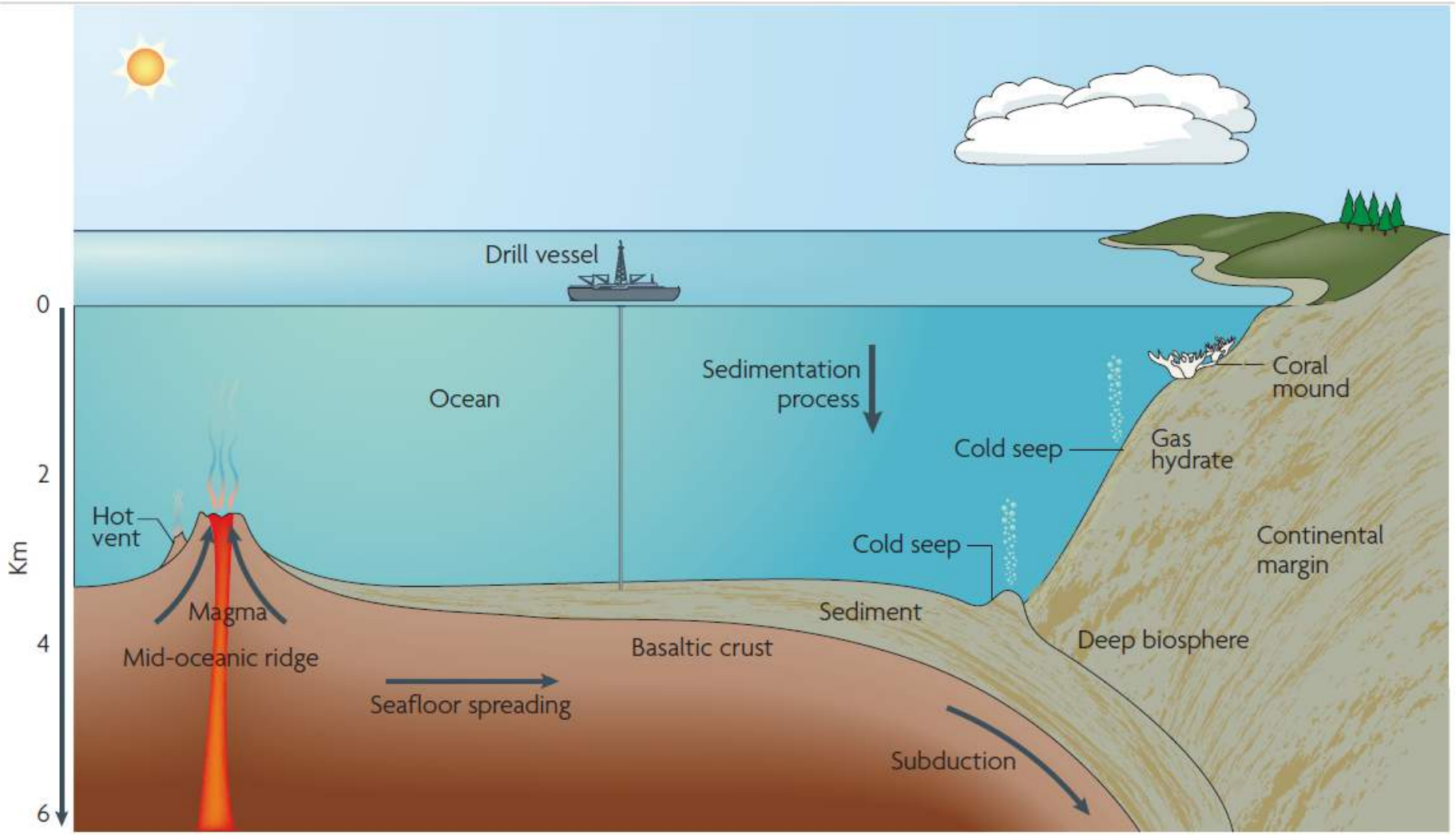
- Superior performance
- Better economics

Unprecedented activity in particular application:

- Enzymes: new reactivity/new biotransformation
- Small molecules: novel chemical structures & new mechanism of action
- Materials: new properties



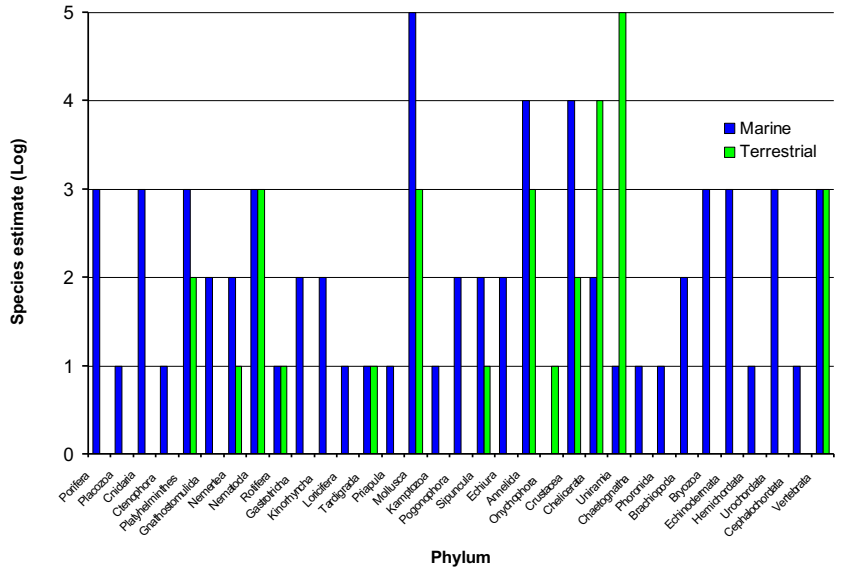
Marine Environments



Jørgensen *Nat Rev Microbiology*, **2007**, *5*, 770

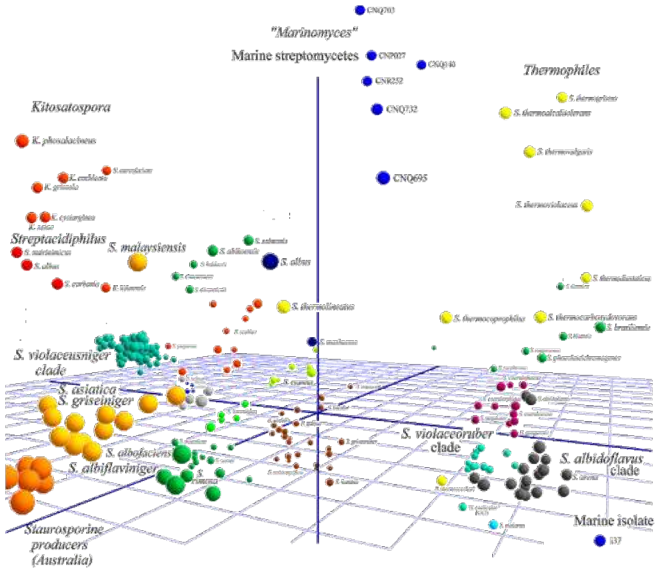
Marine Environments are Rich in Genetic Diversity

Animal Diversity



Of the major divisions of animal life ~20 have no representatives on land

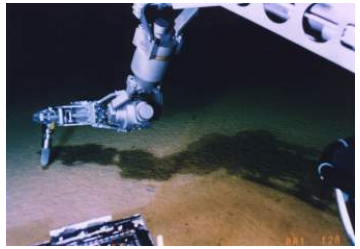
Microbial Diversity



There is no clear estimate of marine microbial diversity or its economic value

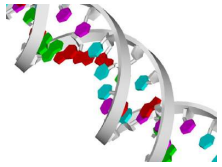
The Biodiscovery Pipeline

Sampling
In situ



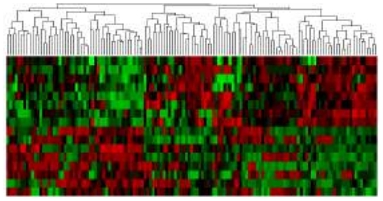
Bioresource Repository (*Ex situ*)

Species identification can take long time
Limited number of taxonomists globally



Genetic Sequence Data (*In silico*)

Chemistry



Biological screening
Functional testing

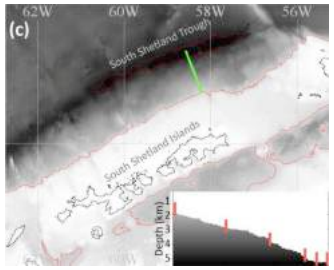
Product

Each step may take a significant period

In addition, there may be periods of inactivity/waiting for a variety of reasons

Marine Scientific Research Planning

Application
- Cruise plan



Award
- Feasibility
- Checks

After Cruise
- Cruise report

MSR
- Most cruises are for basic research
- Freedom of MSR
- File cruise report to funder

How Might Bioprospecting be Accommodated?

- Require updates on cruise report to alert to change of use
- Notify when commercialisation occurs

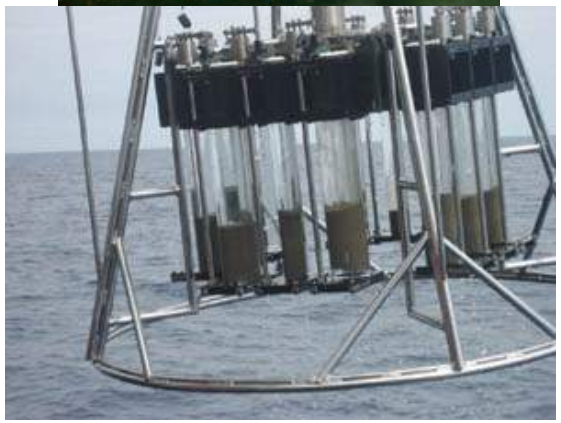
Opportunity – Global cruise data available in consistent format will benefit scientific community

Collecting Materials

RRS Discovery (UK)

ROV Isis (UK) (6500 m)

Sampling Devices

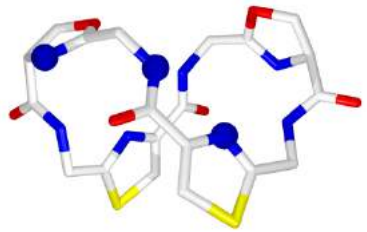


Biomass – Invertebrates and Microorganisms

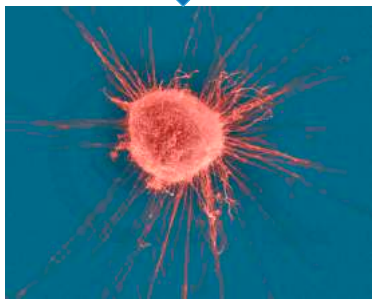
Chemistry

Extraction

Compound Isolation

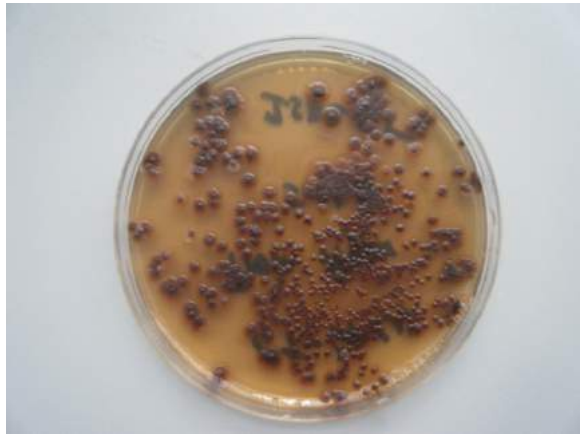


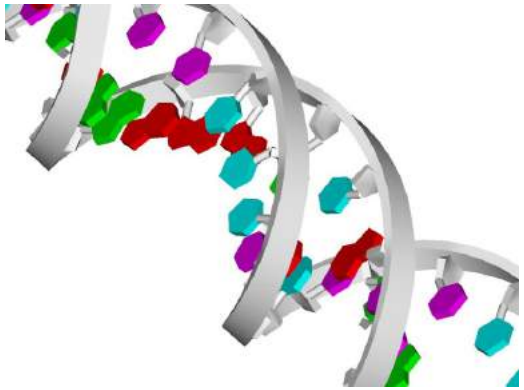
Compound Identification



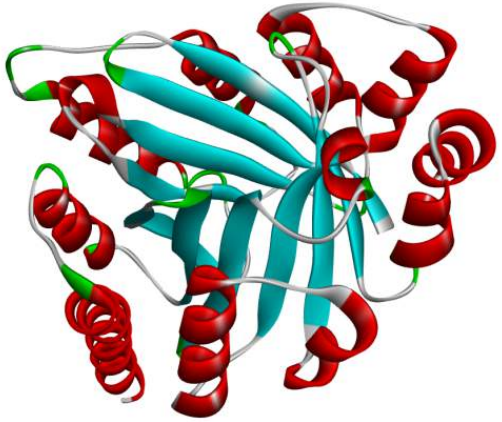
Biological Testing

Alternative - Using Genetic Sequence Data

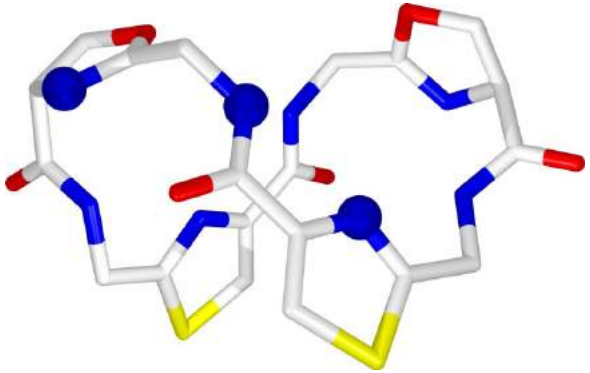




DNA

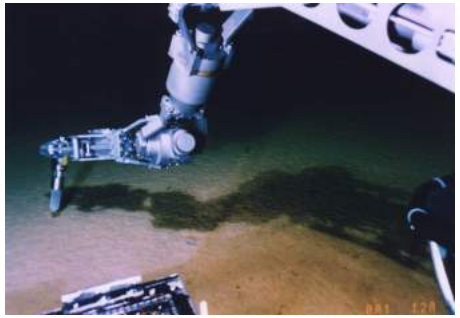


Protein

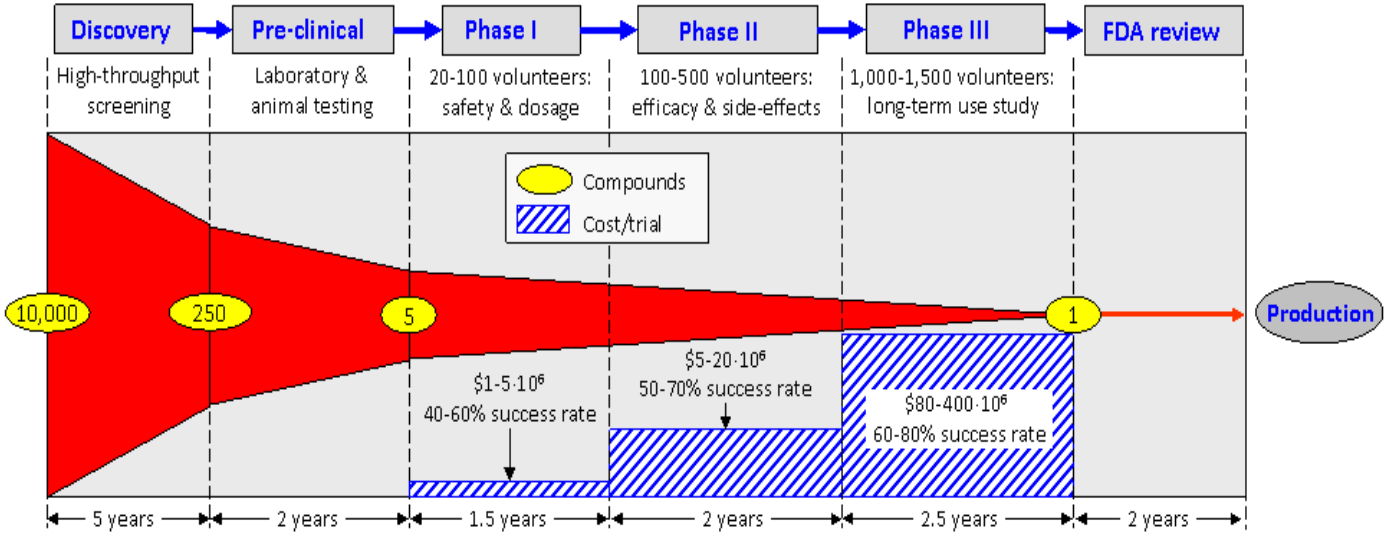


Compound

The Biodiscovery Timeline



Sampling in ABNJ



Universities

Large companies

Universities and SME's

Scientific knowledge & data

Commercial

'Potential' value

Actual value

Thomas Vanagt

The Marine Pharmaceutical Pipeline

Mainly derived from shallow reef dwelling organisms

Mainly anti-cancer with a few analgesics and antivirals

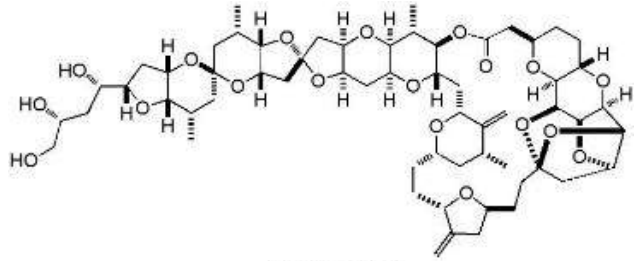
Mainly start-ups at early stage with large pharma at late stage

http://marinepharmacology.midwestern.edu/

Case study: Halaven

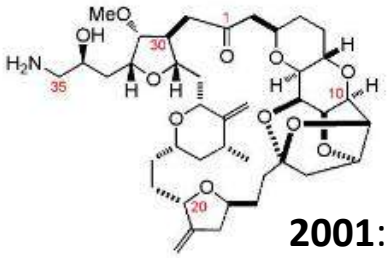
Bioprospecting

Pre 1986: Screening
Isolation & Structure



Halichondrin B

1996: Synthesis



E7389 Eribulin

2001: Derivative synthesis

Laboratory tests
and clinical trials
2010: approval by
US FDA)

Current sales
Ca US$ 350 M pa

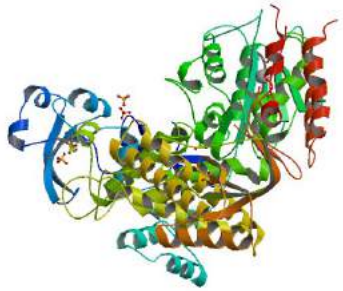
(Usual Royalty
Rates are 1-3%)

Pharmaceutical Products

Yondelis
Cancer treatment
Origin: Seasquirt
Location: Caribbean Mangroves
Production: Semisynthesis
Owner: PharmaMar

Prialt
Intractable pain
Origin: Cone snail
Location: Philippines
Production: Recombinant
Owner: Neurex/Elan

Non-Pharmaceutical Products



Vent Polymerase
DNA amplification
Origin: Vent bacterium
Location: Naples, Italy
Production: Recombinant
Owner: New England Biolabs

Venuceane
Cosmetic screening infra-red rays
Origin: Vent bacterium
Location: Unknown
Production: Fermentation
Owner: Sederma (Croda)

Fuelzyme
Enzyme used in biodiesel production
Origin: Deep sea bacterium
Location: Unknown)
Production: Recombinant
Owner: Verenium (BASF)

Brominated Furanones
Anti biofilm agents
Origin: Red seaweed
Location: Australia
Production: Synthesis
Owner: Unilever

Mare Geneticum

Balanced benefit sharing must consider:

Size and timing of benefits accrued by user(s)

Cost and burden of benefit-sharing to the user

Burden of benefit-sharing to the regulator – institutional cost

Who are the beneficiaries?

How many beneficiaries are there?

Impact of benefit-sharing on the beneficiary

Timing of the transaction

Requirements:

Inclusivity of developing states

Facilitated access for the scientific community

Legal certainty, predictability and stability for industry

Enforceability for the regulator

Mare Geneticum

Access:

Online notification system: OPEN

Free but conditional access

Exclusivity period

Benefit-Sharing:

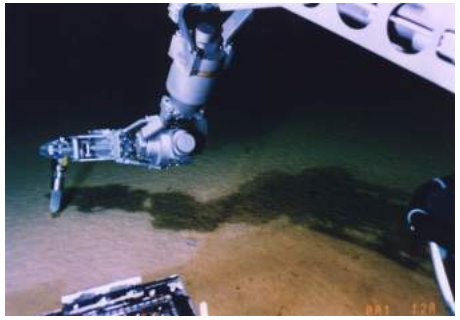
Mandatory deposit of material in biorepositories

Mandatory sharing of meta data and raw data (including GSD)

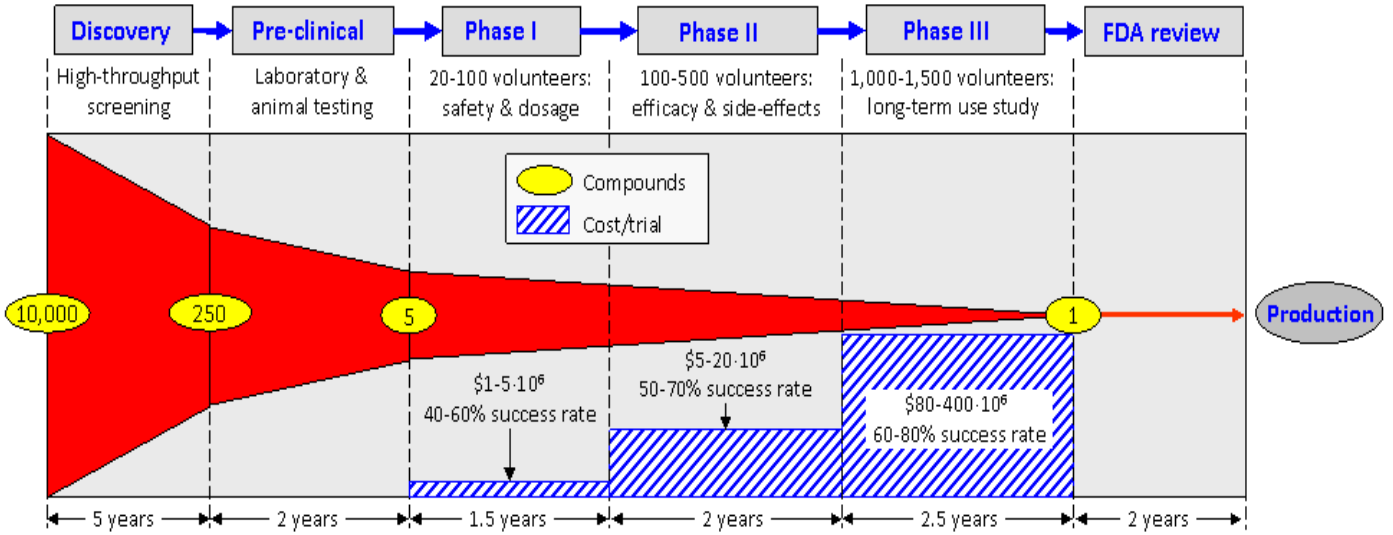
Possibility of extending exclusivity period in return for a fee

If monetary benefits are requested: at the point of commercialization, and not negotiated

Biodiscovery Pipeline and Benefit-sharing



Sampling in ABNJ



Scientific knowledge & data

Commercial

Embargo period (fee)

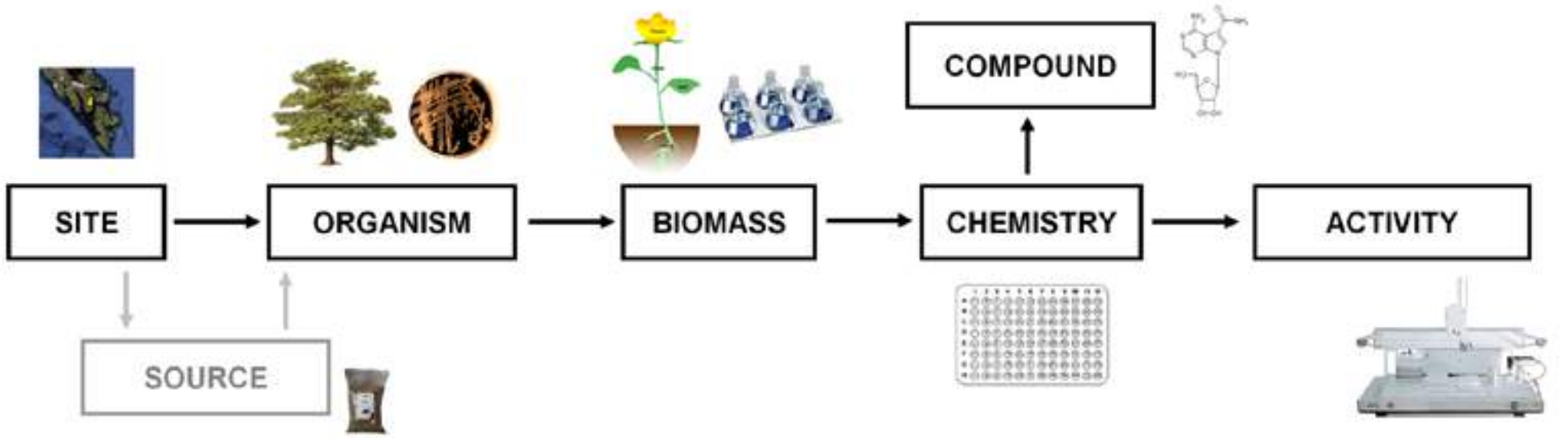
Deposit in biorepository
Sharing of metadata

Sharing of MGR data

Monetary BS ?

Thomas Vanagt

Sample and Data Management

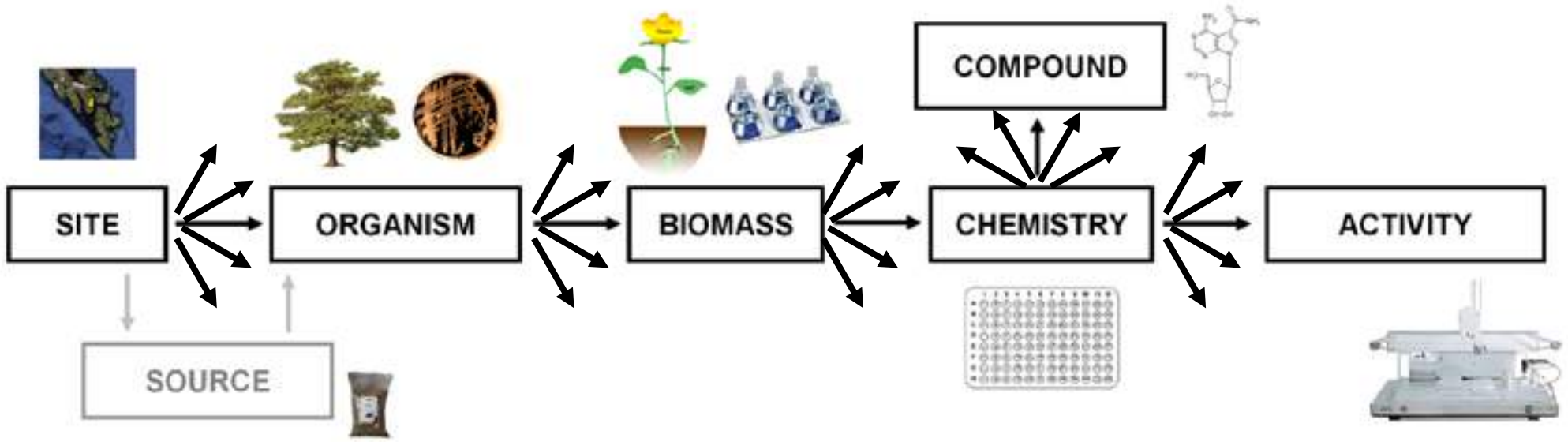


Sample and data management from origin to exploitation is possible
Already part of good scientific practice but needs standards & improved data infrastructure

Source: OpenNAPIS, White Point Systems

Real World Example

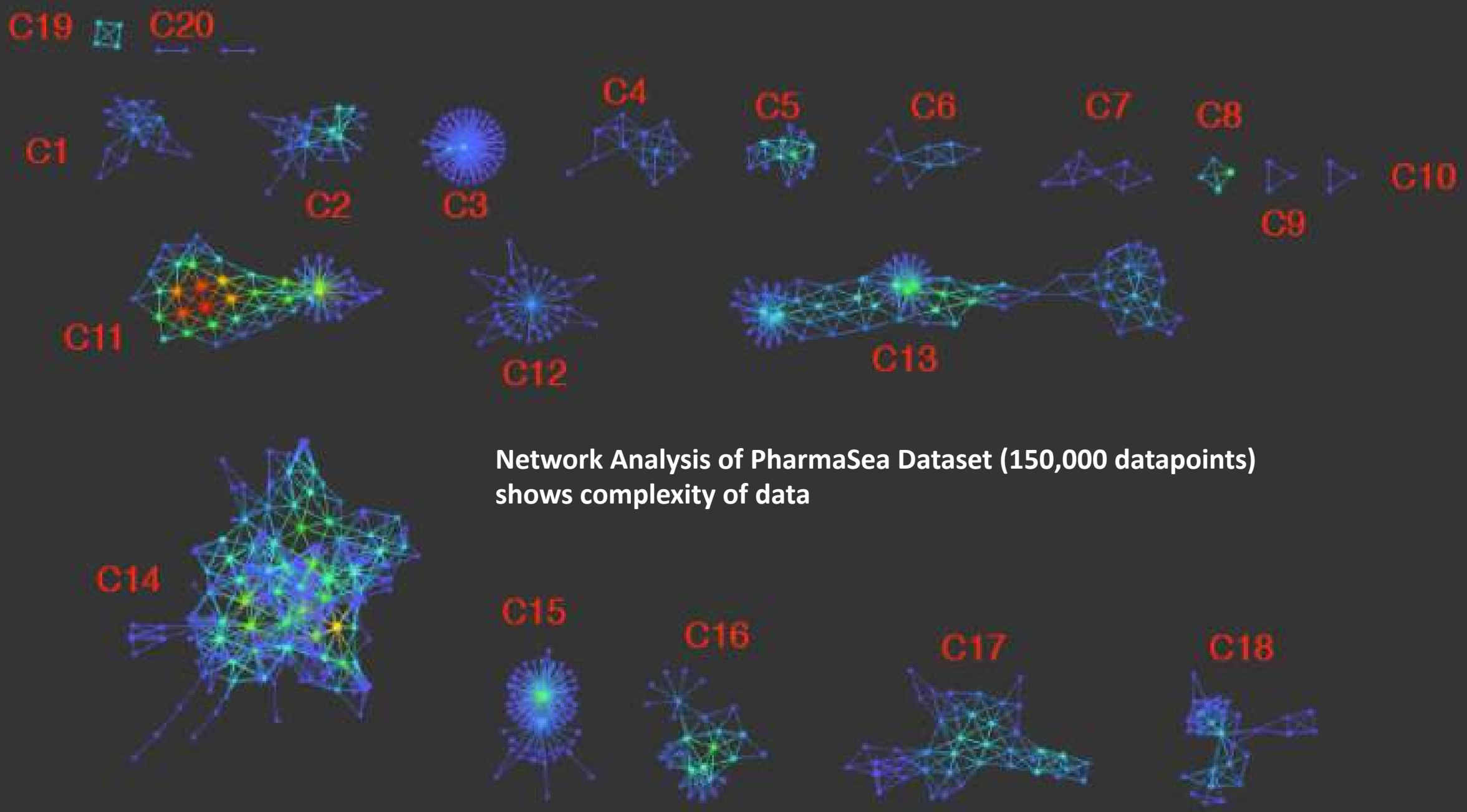
25 Compounds



Example	**1 sample of sediment**	**100 new microbes (10 used)**	**Each microbe grown in 4 different media**	**Each one gives 8 fractions**	**Each fraction tested in 10 assays**
	1	**10**	**40**	**320**	**3200**

Total 3596 datapoints – for 1 sample

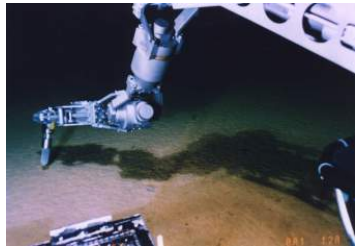
& Genetic Sequence Data



Network Analysis of PharmaSea Dataset (150,000 datapoints) shows complexity of data

Obligatory Prior Electronic Notification (OPEN)

Sampling
In situ

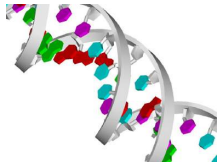


Submit OPEN
Obtain Unique Identifier

Bioresource
Repository
(*Ex situ*)

Update OPEN
(Location, metadata, species etc)
Share Materials

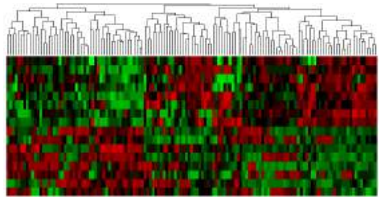
Researchers accessing material
provided with Unique Identifier



Genetic
Sequence
Data
(*In silico*)

Share
Data

Chemistry



Biological screening
Functional testing

Unique
Identifier
Needed for
Publication/IP

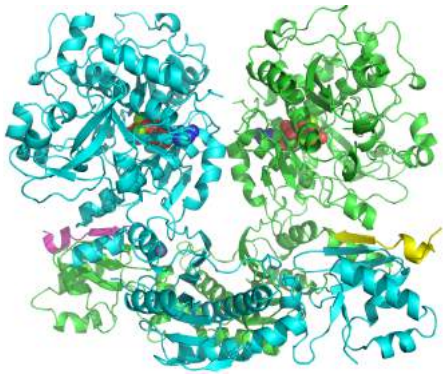
Product

Online Prior Electronic Notification

- Use of cruise plans and cruise reports builds on existing practice.
- Agree on minimal dataset to accompany each sample collected.
- Share materials, but have processes to ensure maximum value is obtained from rare samples.
- Develop unique identifier to work with existing ex situ collection data infrastructure and digital sequence information databases
- Fee-free access to materials and raw data – scope to be clarified but initially intended to mean nucleotide sequence data (DNA/RNA sequences).
- Possibility for exclusivity period on samples/data to enable scientific research to be completed, or for commercial research to be protected. Exclusivity period can be granted without fee for defined period, after which payment to central fund must be made.

Exclusivity Periods in Scientific Practice

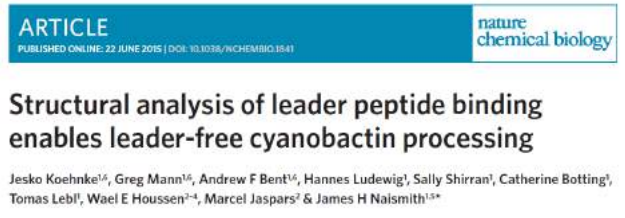
- Protein Data Bank entries are placed on hold for one year from the date of deposition. They may be released earlier on a date specified by the Contact Author. When the corresponding electronic or paper publication occurs, the entry must be released if the journal policy requires release upon publication.



Solve protein crystal structure

RCSB PDB PROTEIN DATA BANK

Deposit data
Get PDB ID



1 Year

Data Released

http://www.rcsb.org/pdb/home/home.do

Current Thinking on Exclusivity Periods for DSI

INSIGHTS

POLICY FORUM

DATA ACCESS

Toward unrestricted use of public genomic data

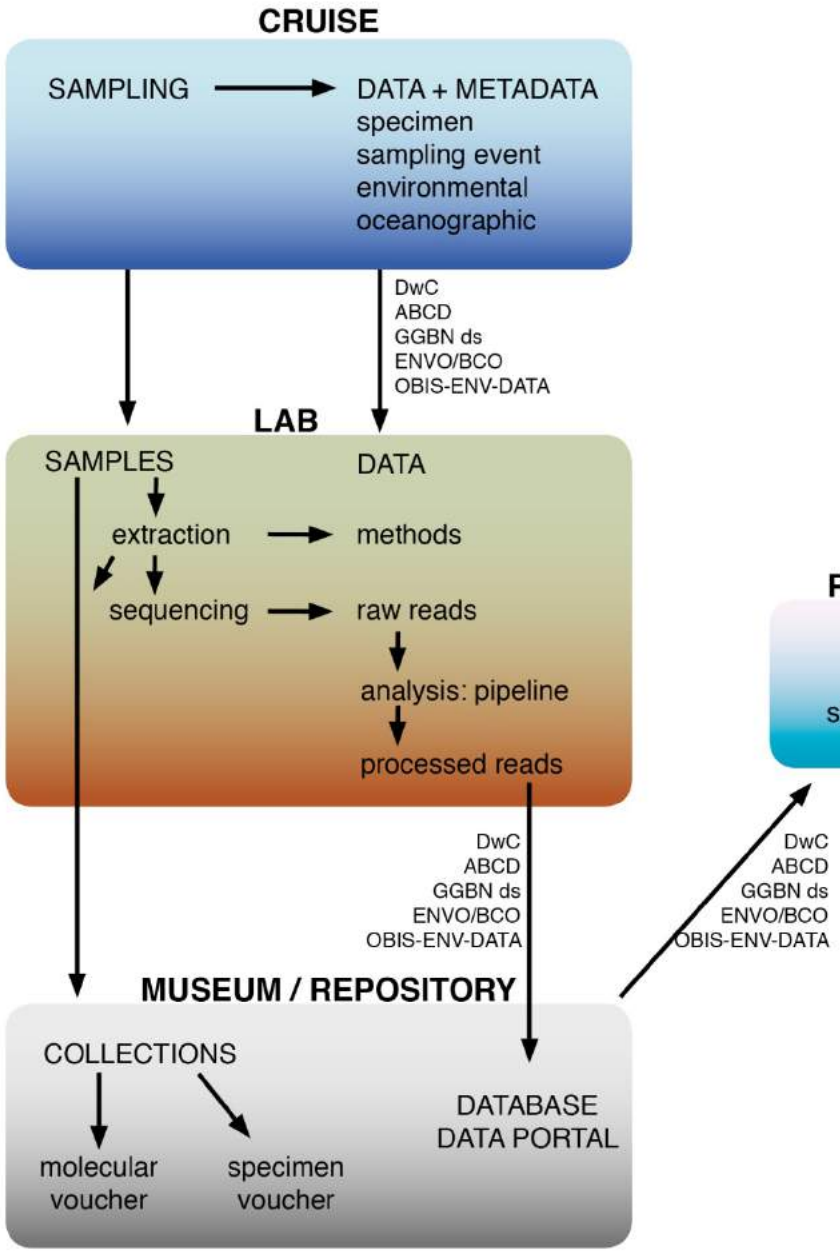
Publication interests should not limit access to public data

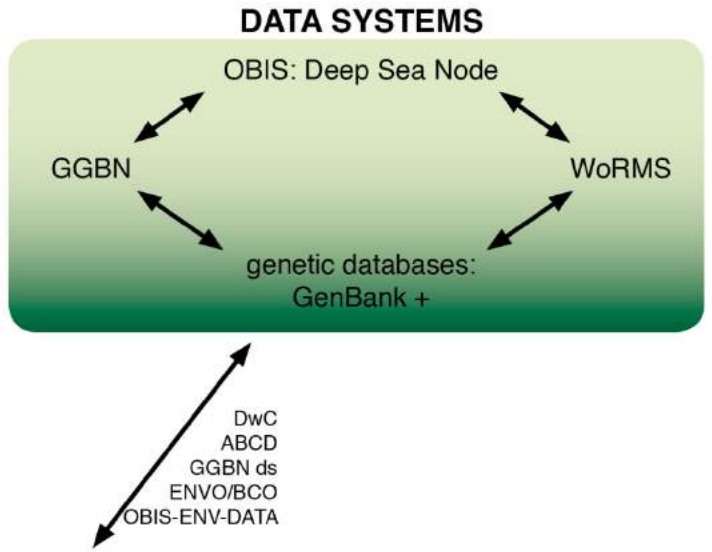
By **Rudolf I. Amann, Shakuntala Baichoo, Benjamin J. Blencowe, Peer Bork, Mark Borodovsky, Cath Brooksbank, Patrick S. G. Chain, Rita R. Colwell, Daniele G. Daffonchio, Antoine Danchin, Victor de Lorenzo, Pieter C. Dorrestein, Robert D. Finn, Claire M. Fraser, Jack A. Gilbert, Steven J. Hallam, Philip Hugenholtz, John P. A. Ioannidis, Janet K. Jansson, Jihyun F. Kim, Hans-Peter Klenk, Martin G. Klotz, Rob Knight, Konstantinos T. Konstantinidis, Nikos C. Kyrpides, Christopher E. Mason, Alice C. McHardy, Folker Meyer, Christos A. Ouzounis, Aristides A. N. Patrinos, Mircea Podar, Katherine S. Pollard, Jacques Ravel, Alejandro Reyes Muñoz, Richard J. Roberts, Ramon Rosselló-Móra, Susanna-Assunta Sansone, Patrick D. Schloss, Lynn M. Schriml, João C. Setubal, Rotem Sorek, Rick L. Stevens, James M. Tiedje, Adrian Turjanski, Gene W. Tyson, David W. Ussery, George M. Weinstock, Owen White, William B. Whitman, Ioannis Xenarios**

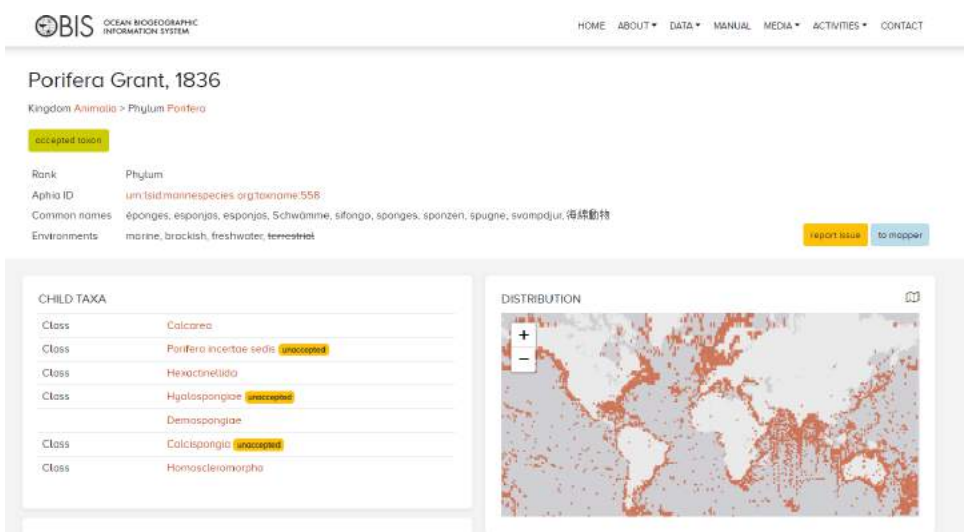
Science **2019**, *363*, 350

Build on Science Good Practice

Data Must Be:
Findable
Accessible
Interoperable
Reusable

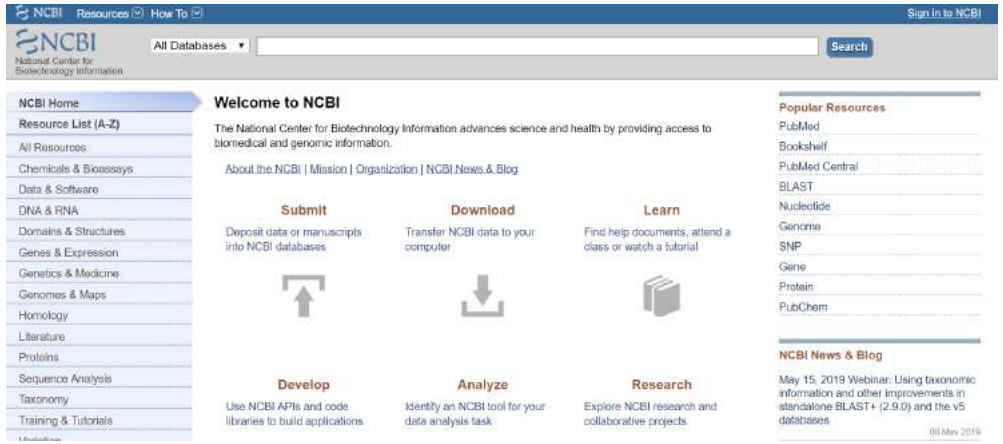






Muriel Rabone
Natural History Museum, London

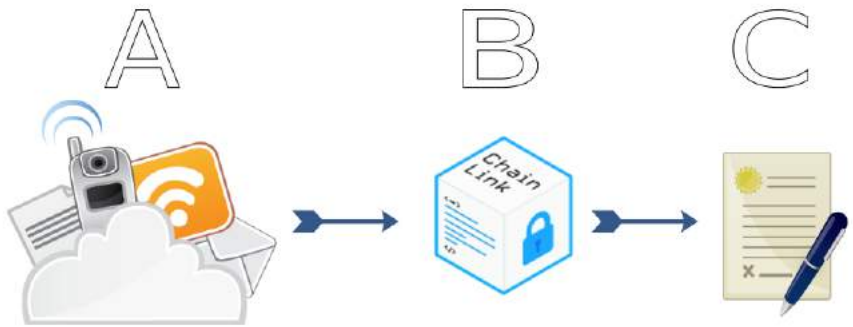
IT Solutions (e.g. Blockchain)



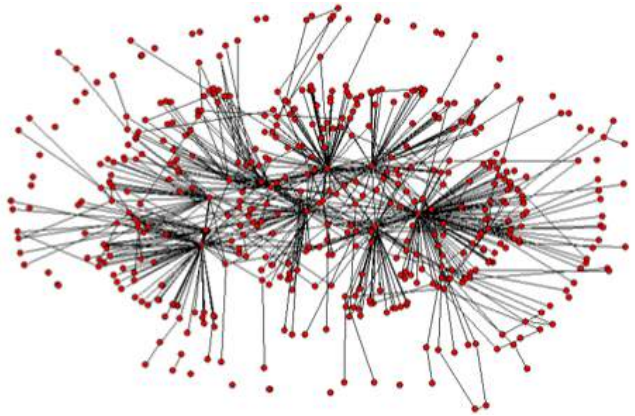
Build on existing data infrastructure
(Data Curation Essential)

But: Human Compliance main issue
Feasibility Study?
Marine Science
Collections/Curation
Marine Bioprospecting
Computing Science
Behavioural Science
Law/Policy

&



Blockchain adapters



Decentralised/Minimal traceability requirement

Prof. Pete Edwards, Computing, Aberdeen University

Acknowledgements

PharmaSea & MarPipe

Arianna Broggiato, Thomas Vanagt, Laura E. Lallier, Geoff Burton, Dominic Muyldermans, Jane Collins, Torsten Thiele, Isabelle Huys

& the rest of both consortia

Deep Ocean Stewardship Initiative

Muriel Rabone, Tammy Horton, Maria Baker, Harriet Harden-Davies & many others

University of Aberdeen

Law: Abbe Brown, Anne-Michelle Slater

Chemistry: Rainer Ebel (& the Marine Biodiscovery Centre)

Biological Sciences: Frithjof Kuepper, Ursula Witte

Computing: Pete Edwards

Search '*Mare Geneticum*'

www.abdn.ac.uk/bbnj

m.jaspars@abdn.ac.uk

The Zoology Room

Dr. Judith Gobin
Faculty of Science and Technology,
Dept. of Life Sciences,
University of the West Indies,
Trinidad and Tobago

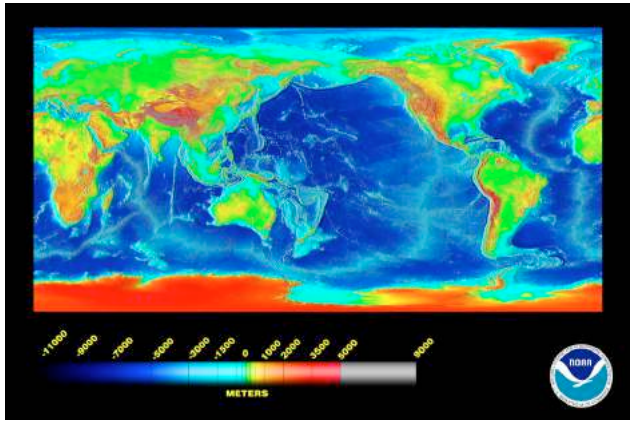
DEEP-OCEAN STEWARDSHIP INITIATIVE
Deep-sea Genetic Resources

Depth

Light

Pressure

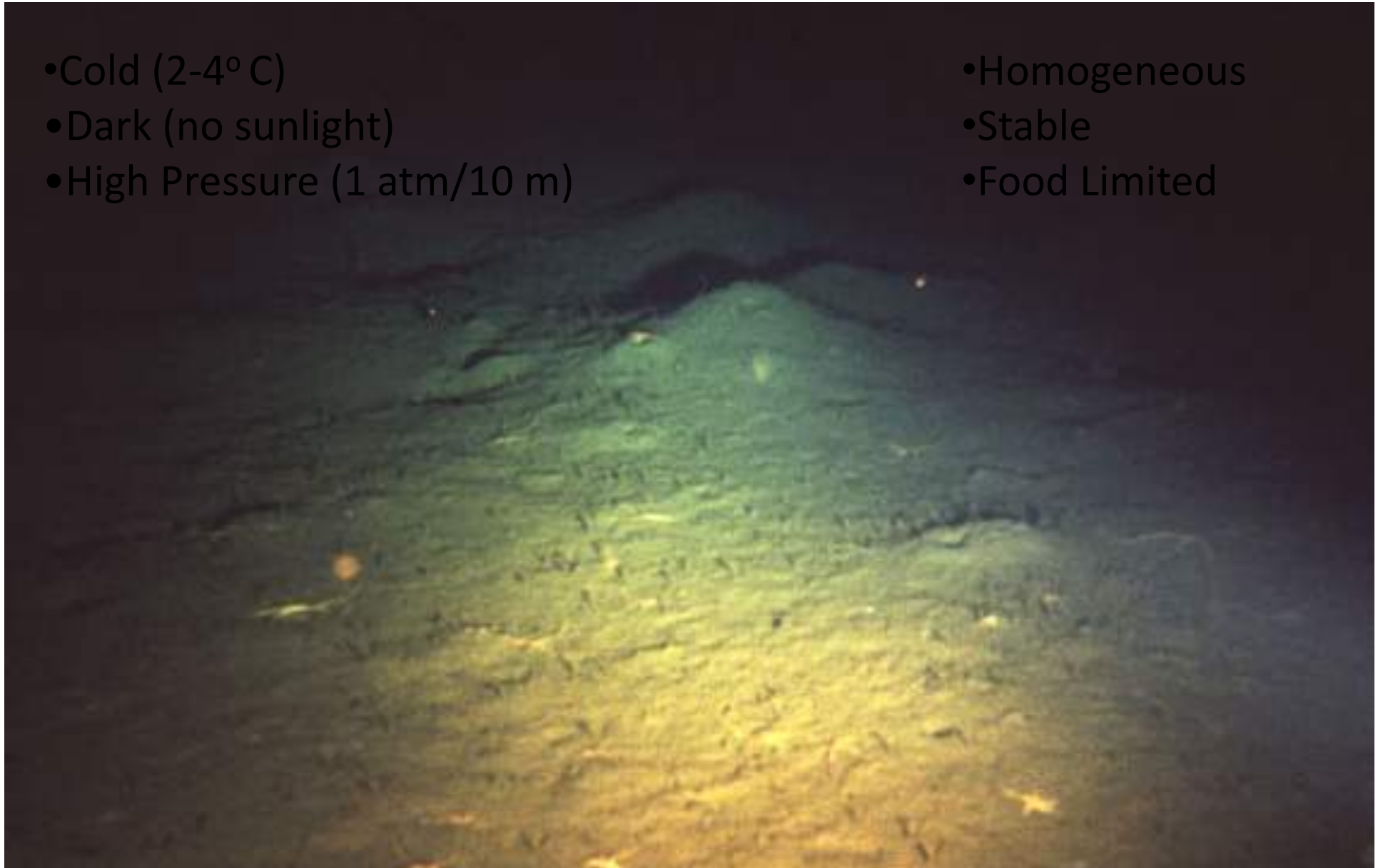
Size



Science & Technology

"We know there are some things we do not know; but there are also unknown unknowns -- the ones we don't know we don't know."

--U.S. Secretary of Defense, Donald Rumsfeld (2002)


•Cold (2-4^{o} C)
•Dark (no sunlight)
•High Pressure (1 atm/10 m)
•Homogeneous
•Stable
•Food Limited

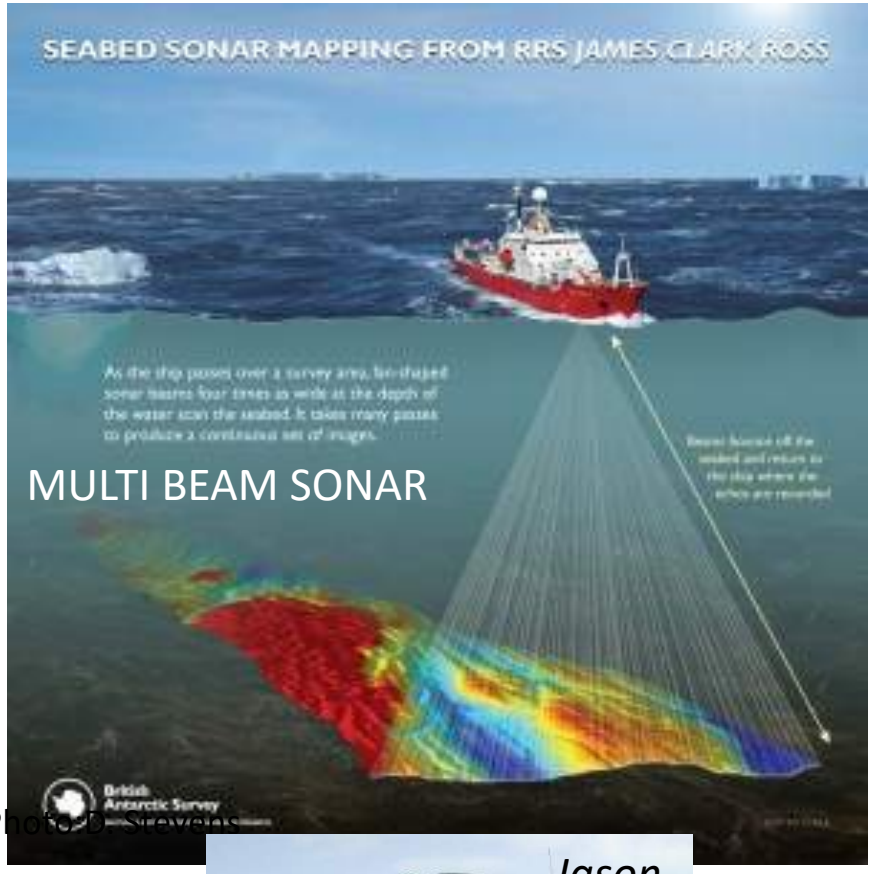
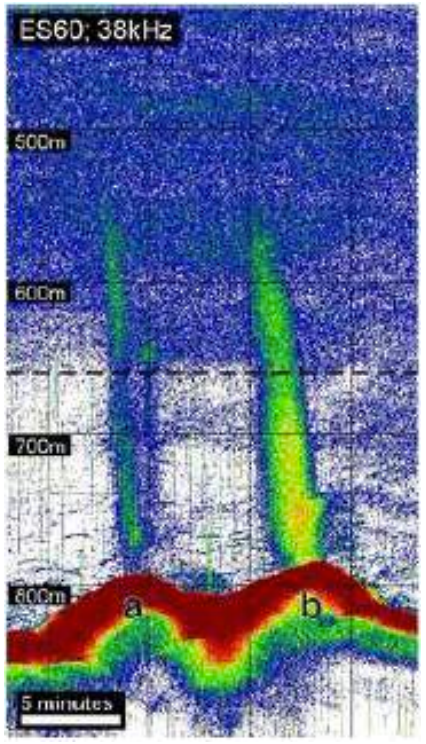
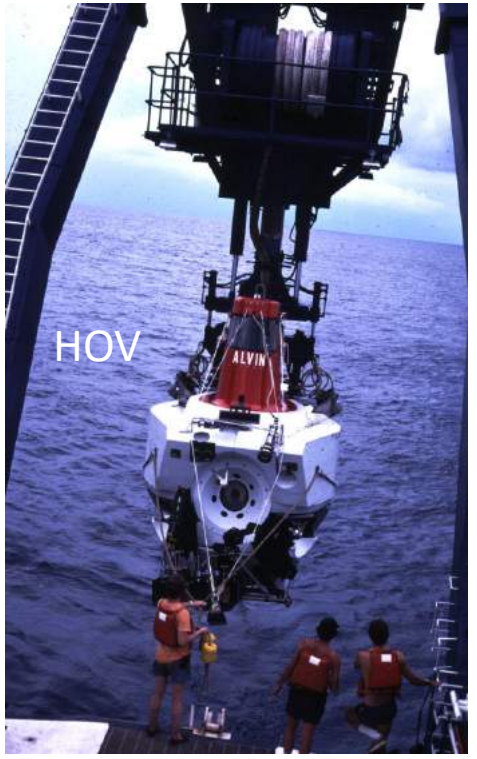
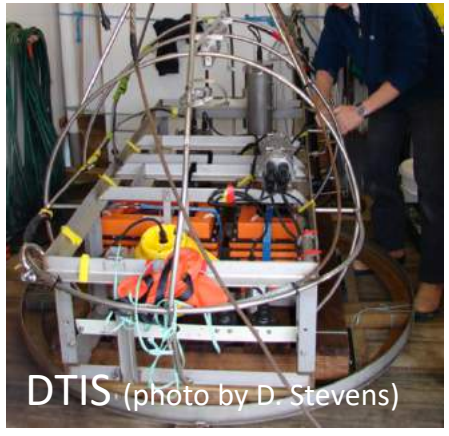
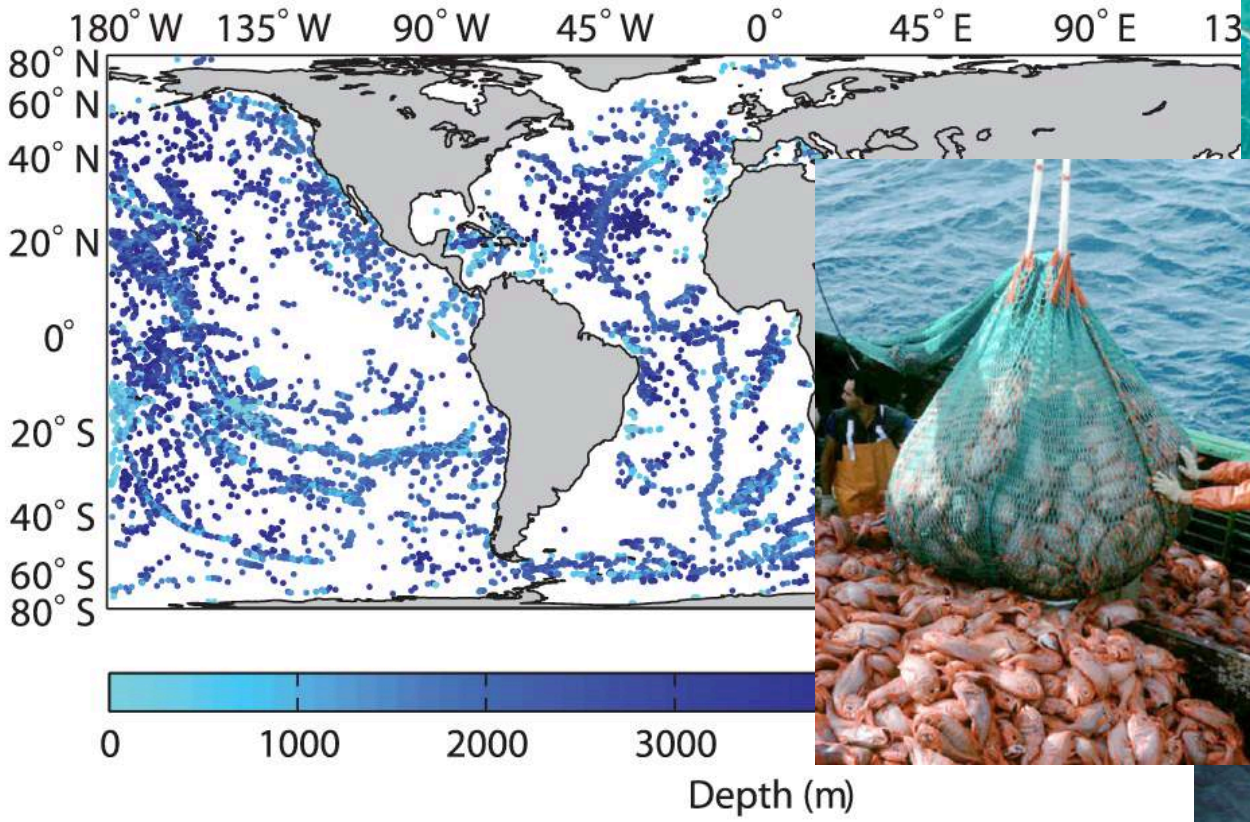


Photo: D. Stevens



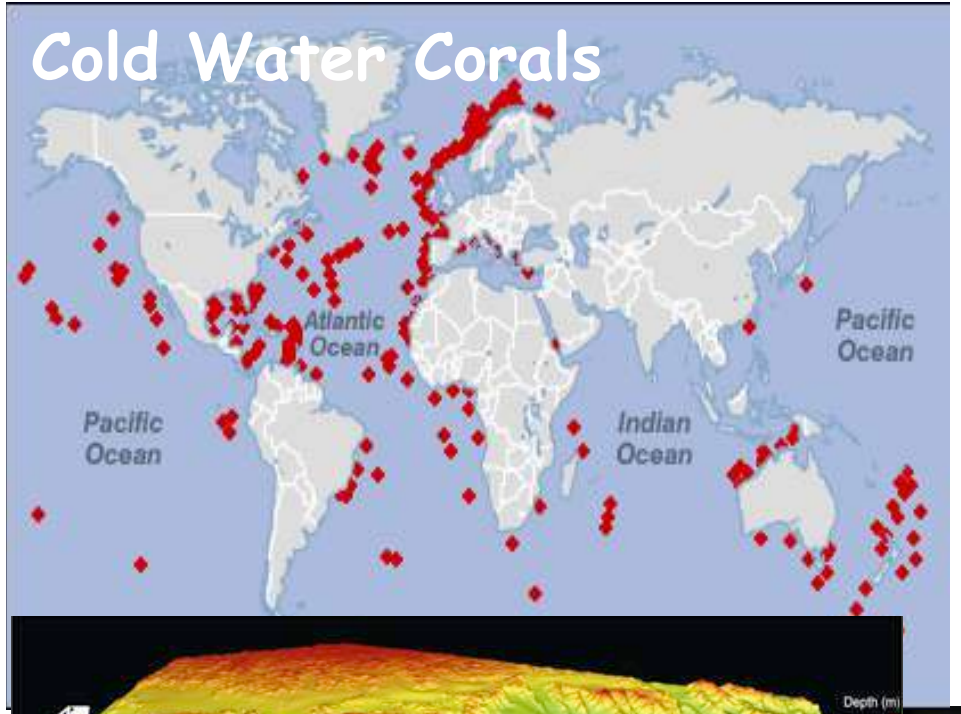


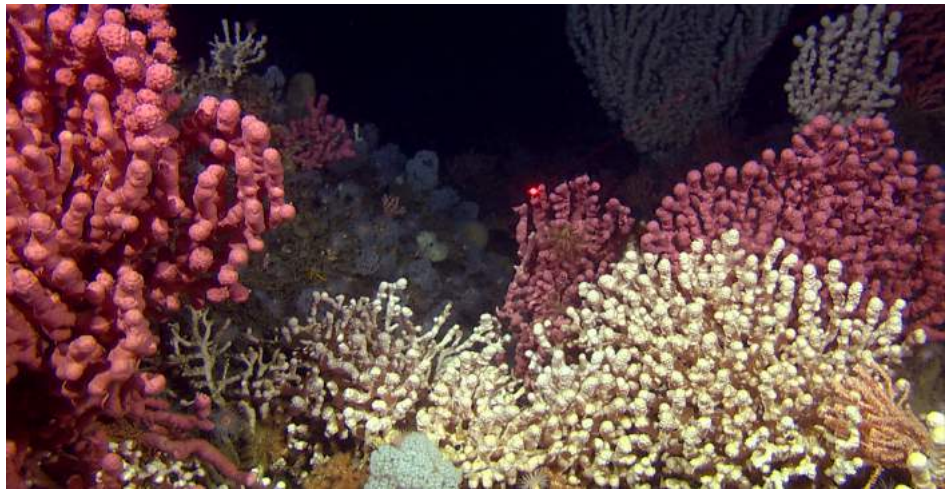


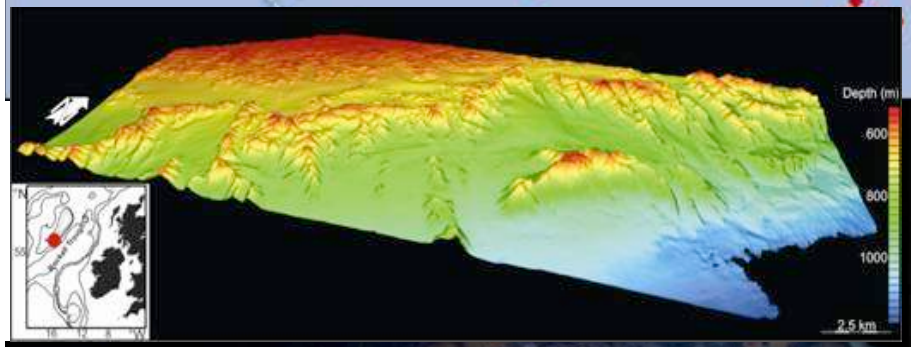

180° W
135° W
90° W
45° W
0°
45° E
90° E
80° N
60° N
40° N
20° N
0°
20° S
40° S
60° S
80° S
0
1000
2000
3000
Depth (m)


Lush invertebrate populations

Cold Water Corals



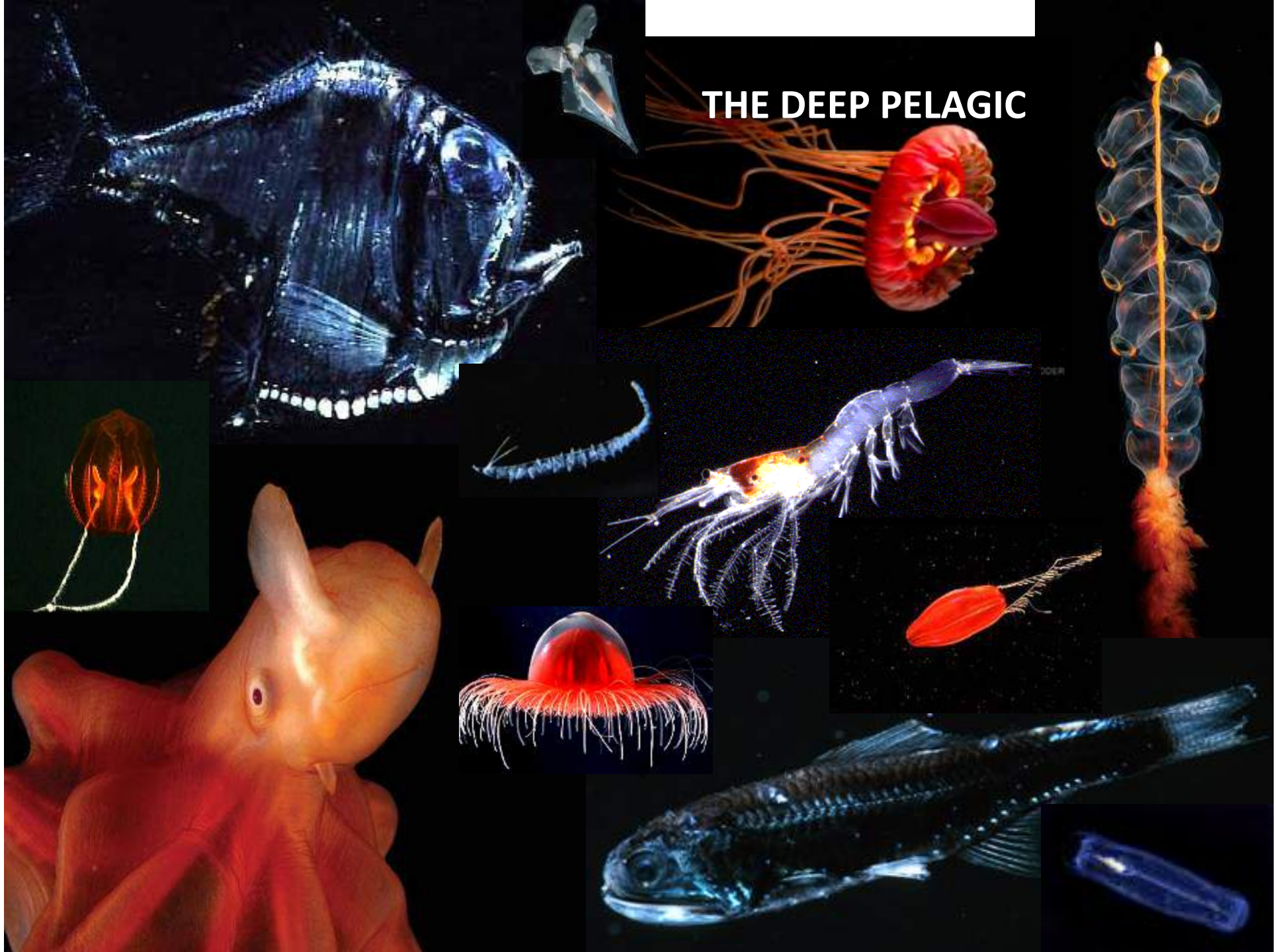


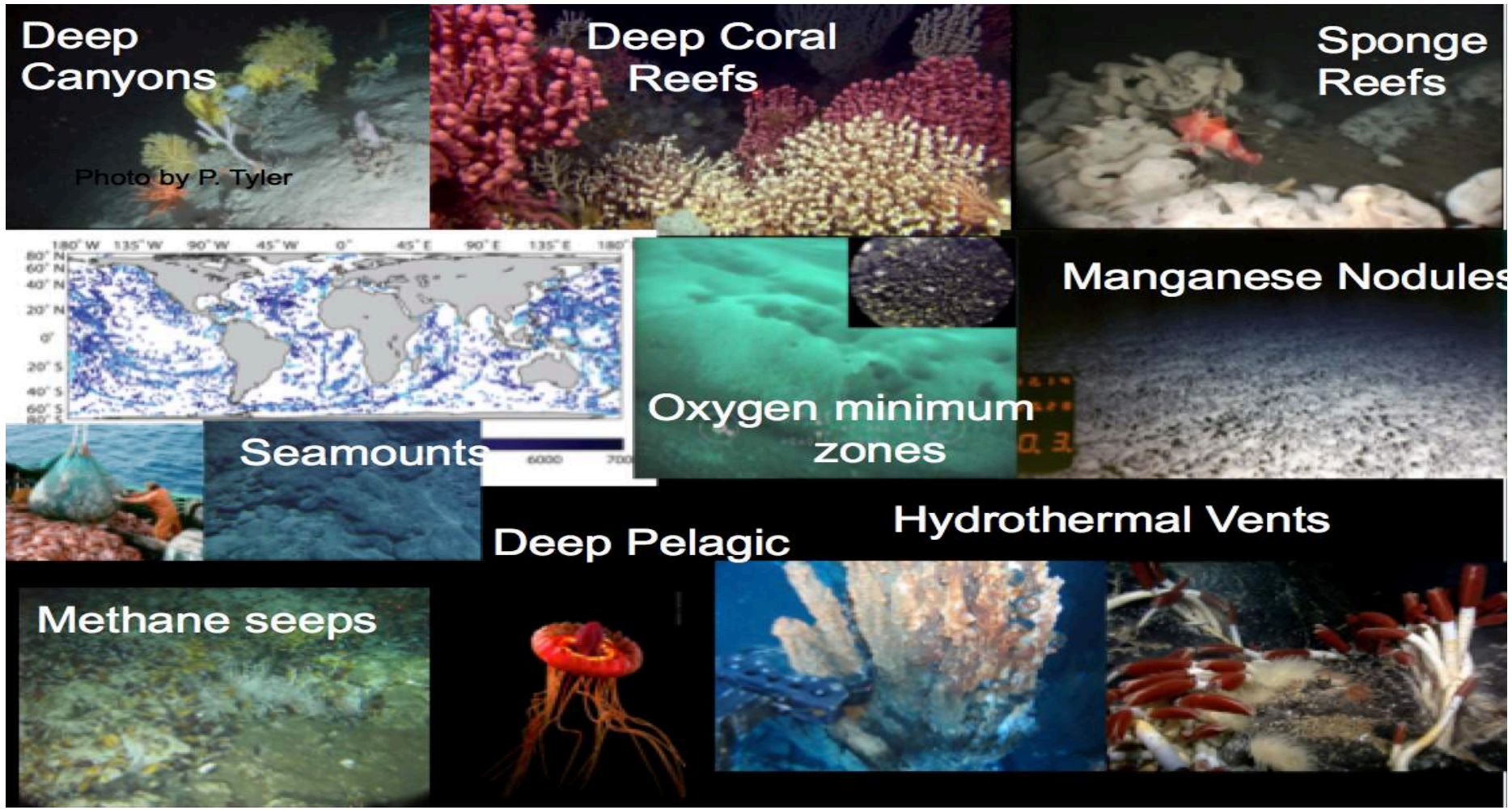


SPONGE REEFS

Gas Hydrates

THE DEEP PELAGIC




Deep Canyons
Photo by P. Tyler
Deep Coral Reefs
Sponge Reefs
Manganese Nodules
Oxygen minimum zones
Seamounts
Deep Pelagic
Hydrothermal Vents
Methane seeps

Provisioning Services:

Support Functions:

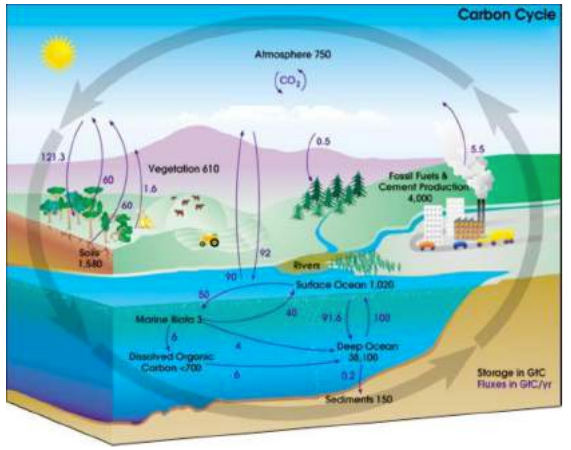
Regulating Services:

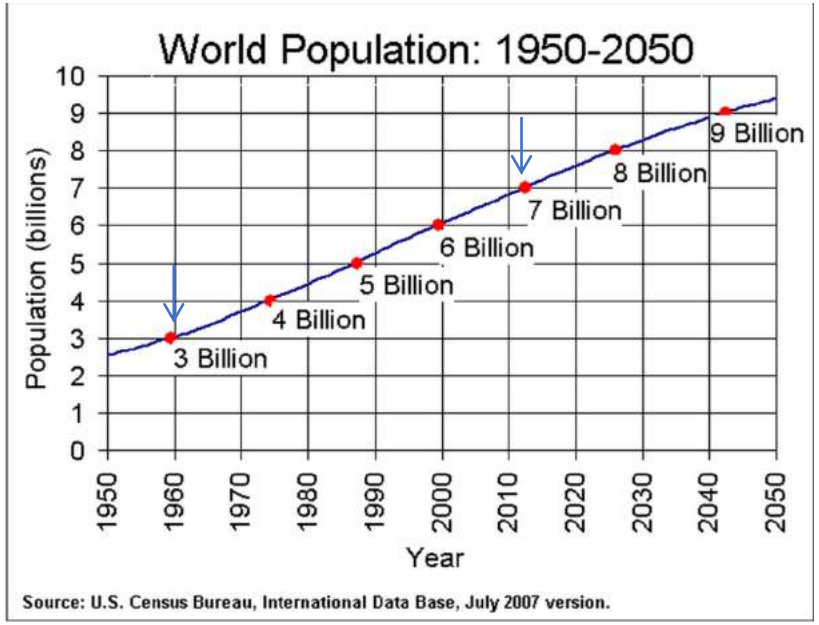
Biodiversity:

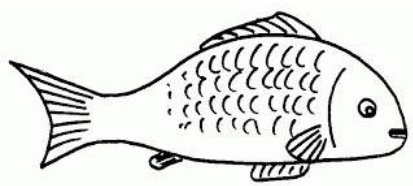
Scientific Research

Communications

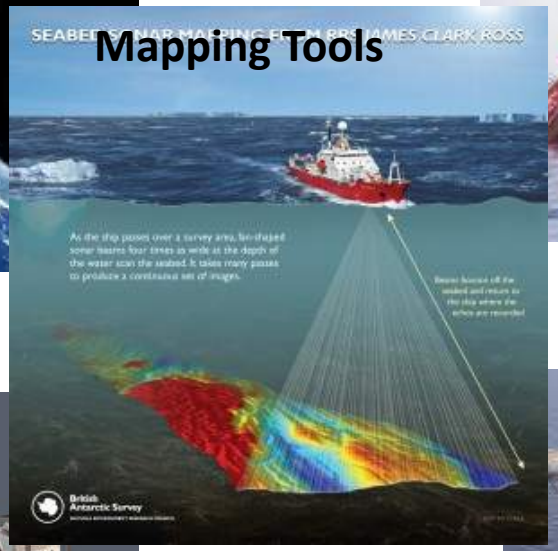
Artistic Inspiration




World Population: 1950-2050
Population (billions)
Year
3 Billion
4 Billion
5 Billion
6 Billion
7 Billion
8 Billion
9 Billion
Source: U.S. Census Bureau, International Data Base, July 2007 version.




Satellite guided GPS
en.wikipedia.org


Mapping Tools
British Antarctic Survey

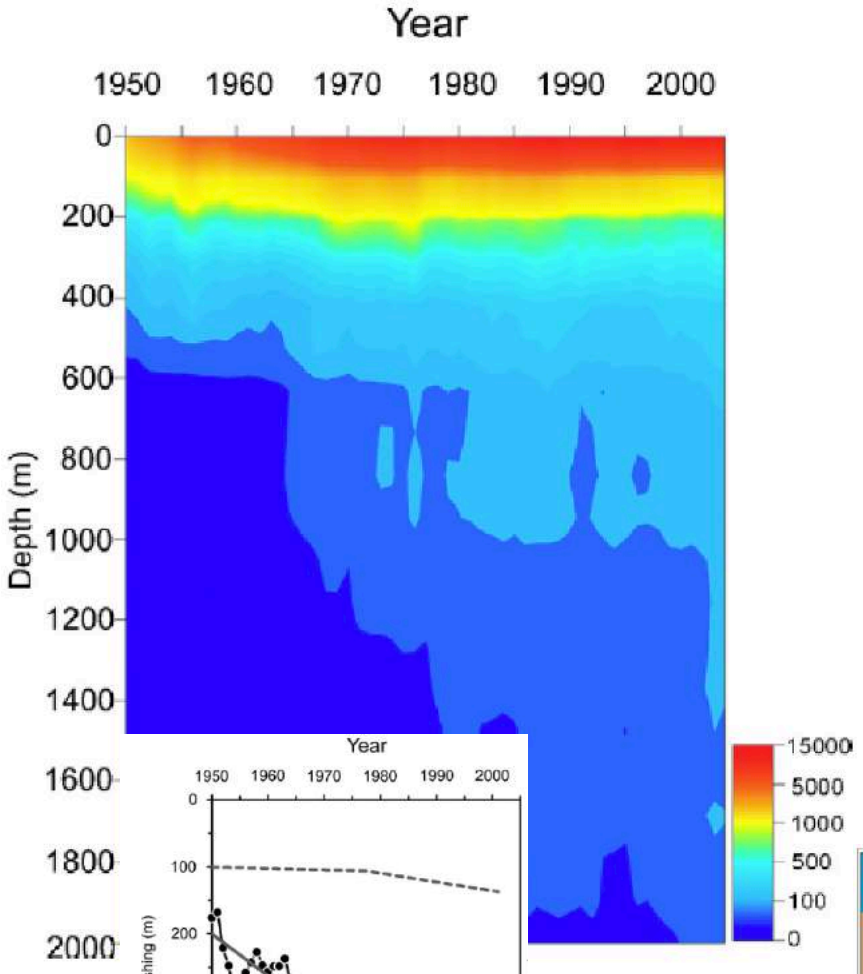

Nature.com


New mining tools
deepseanews.

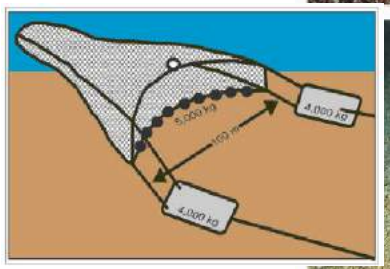
Overfishing

Ghost Fishing

Endangered Species via Bycatch

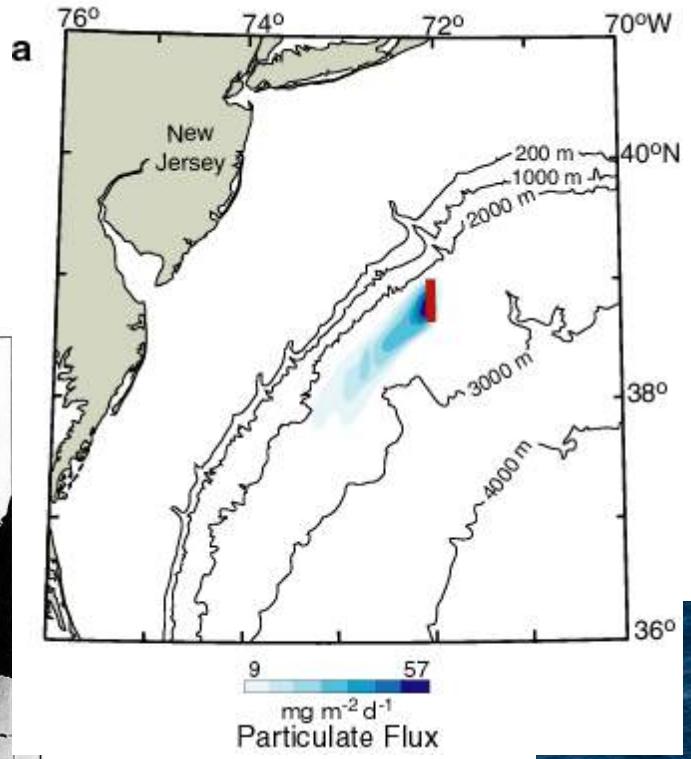


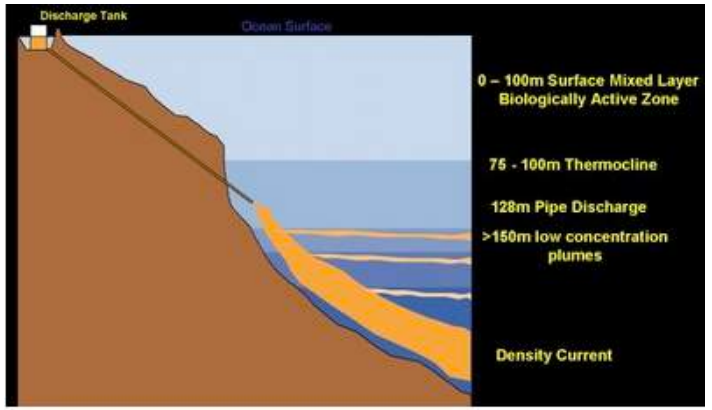
Watson and Morato 2013

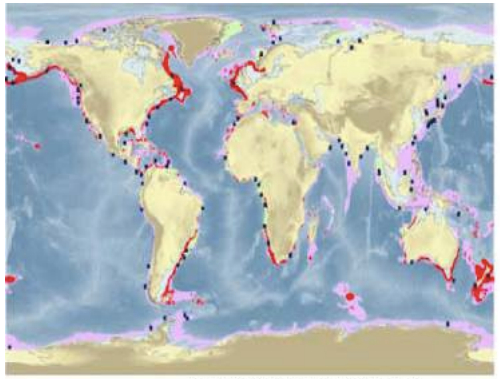


Waste Disposal in the Deep Sea

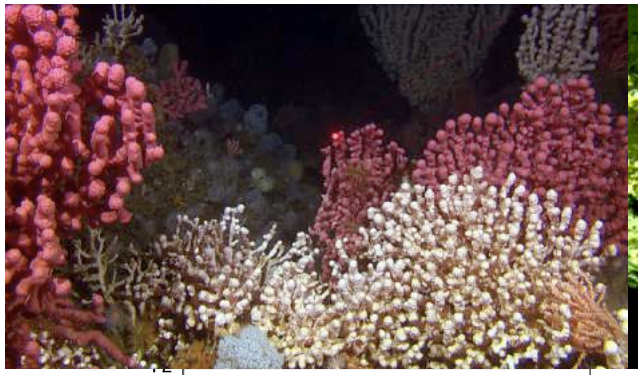
Figure 12.1 Locations of radioactive waste disposal sites in the North-East Atlantic Ocean (from NEA 1985).

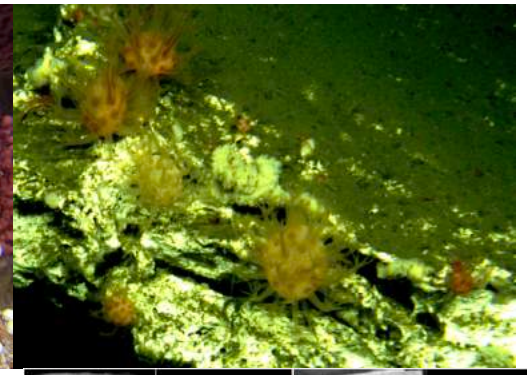


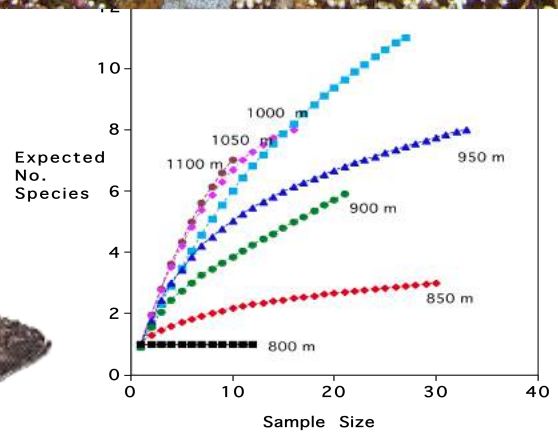


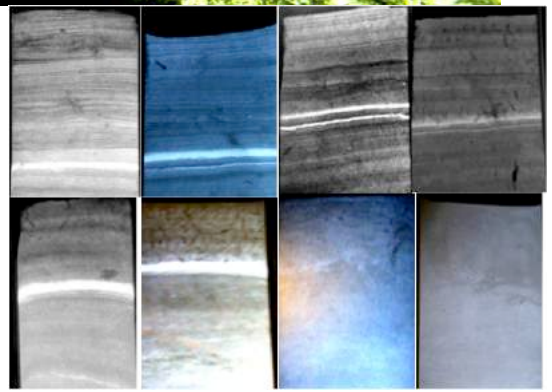


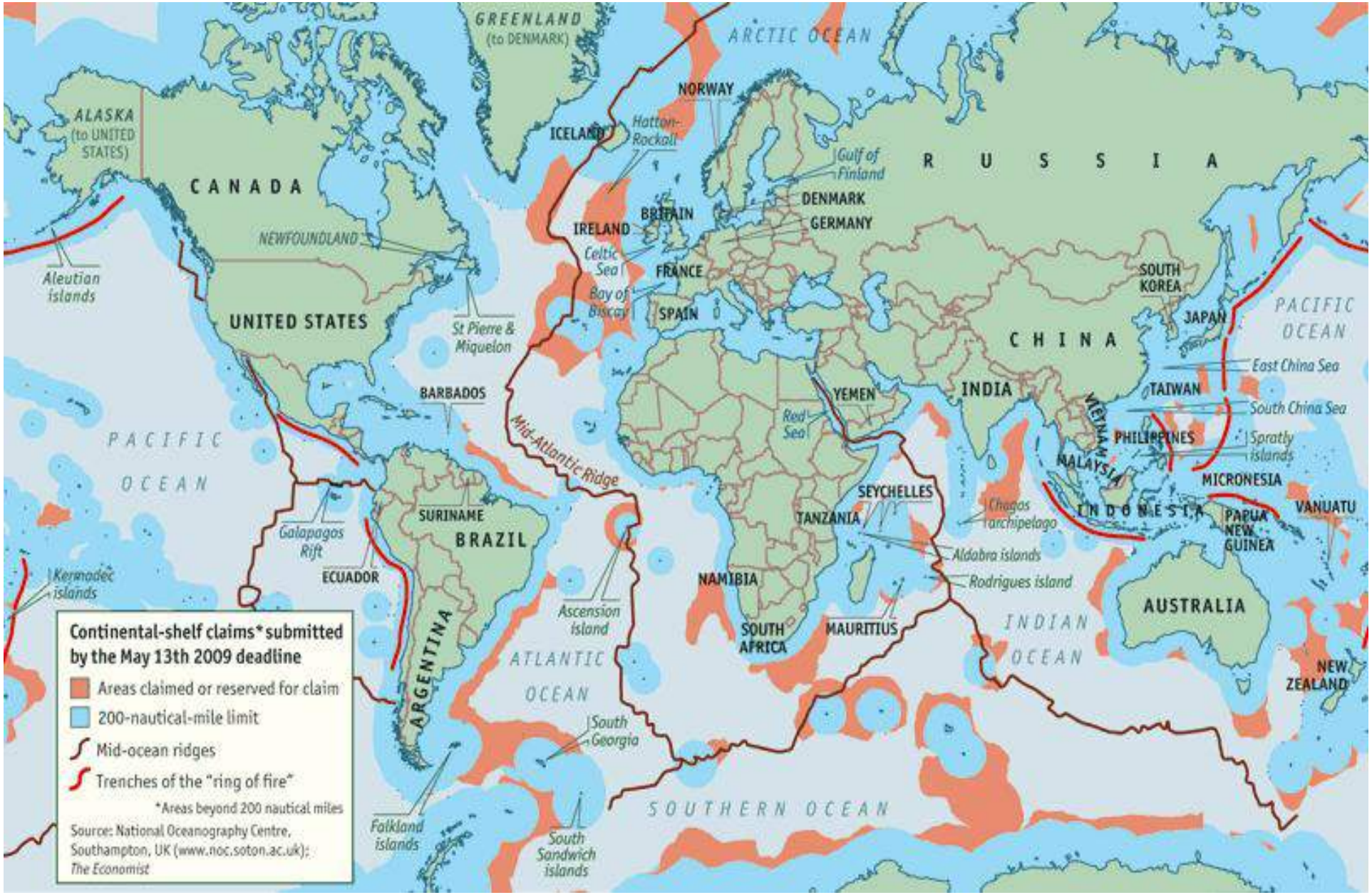
Living and energy resources on continental margins



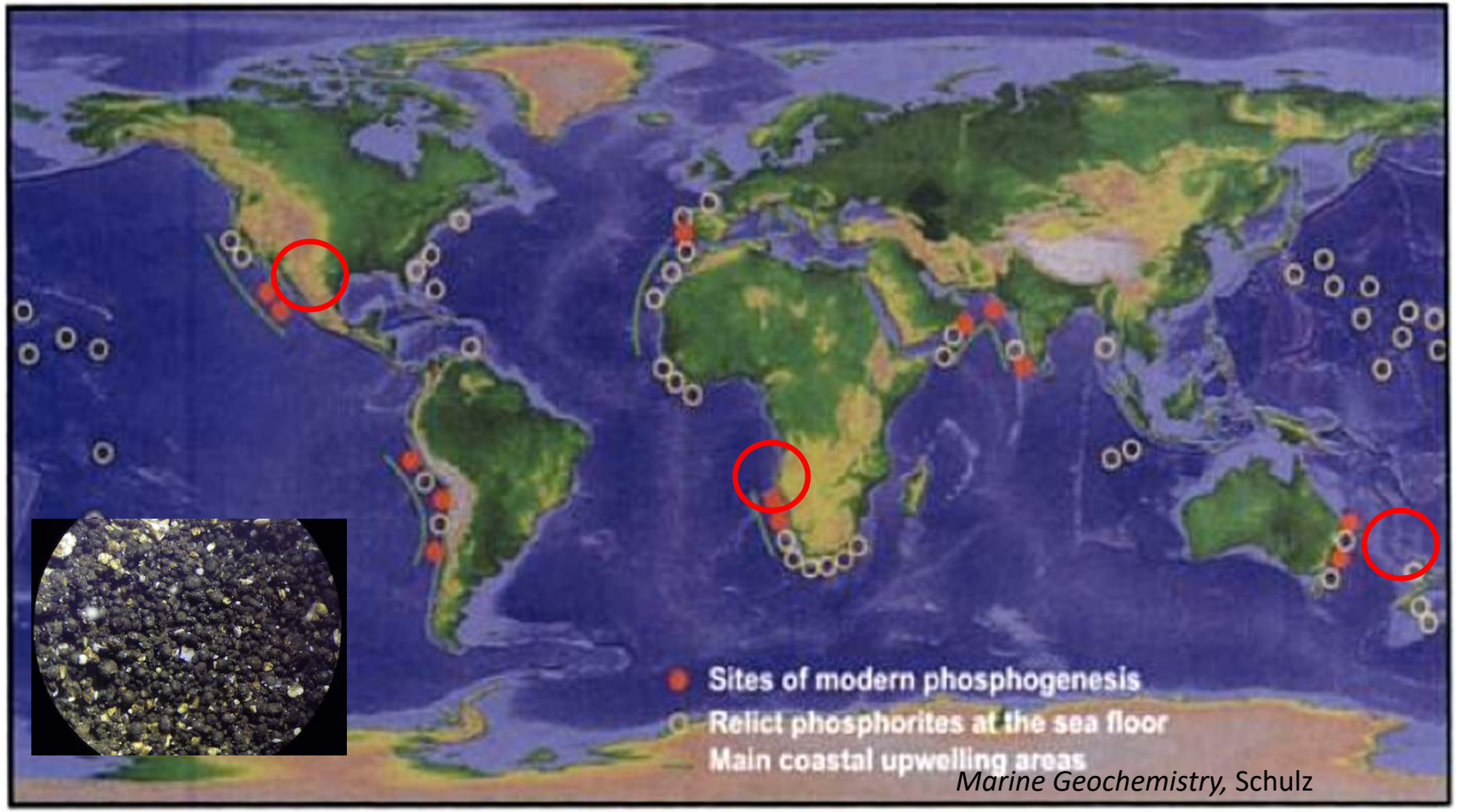






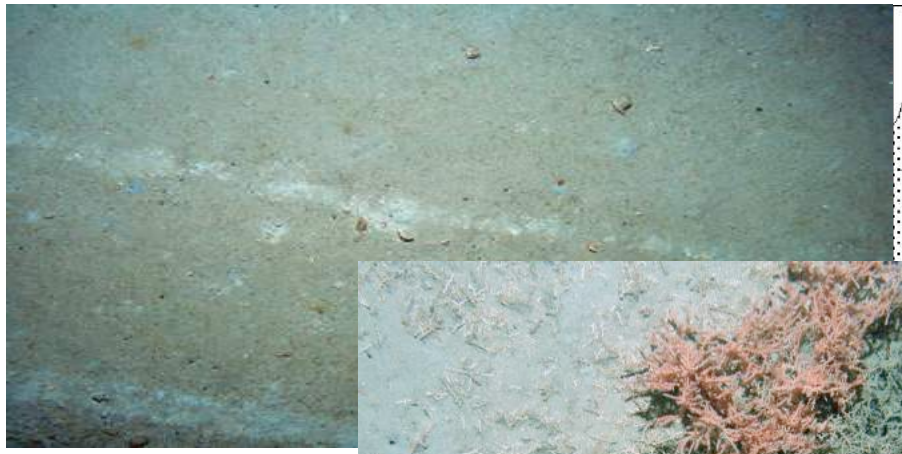

GREENLAND
(to DENMARK)
ARCTIC OCEAN
ALASKA
(to UNITED STATES)
CANADA
NORWAY
ICELAND
Hatton-Rockall
Gulf of Finland
R U S S I A
DENMARK
GERMANY
BRITAIN
IRELAND
NEWFOUNDLAND
Celtic Sea
FRANCE
Bay of Biscay
SPAIN
Aleutian islands
St Pierre & Miquelon
UNITED STATES
SOUTH KOREA
JAPAN
PACIFIC OCEAN
C H I N A
East China Sea
INDIA
TAIWAN
South China Sea
YEMEN
Red Sea
BARBADOS
VIETNAM
PHILIPPINES
Spratly islands
MALAYSIA
MICRONESIA
Mid-Atlantic Ridge
PACIFIC OCEAN
SEYCHELLES
Chagos archipelago
SURINAME
TANZANIA
I N D O N E S I A
PAPUA NEW GUINEA
VANUATU
Galapagos Rift
BRAZIL
Aldabra islands
Rodrigues island
Kermadec islands
ECUADOR
NAMIBIA
AUSTRALIA
Ascension island
SOUTH AFRICA
MAURITIUS
INDIAN OCEAN
ATLANTIC OCEAN
NEW ZEALAND
ARGENTINA
South Georgia
SOUTHERN OCEAN
Falkland islands
South Sandwich islands
Continental-shelf claims* submitted by the May 13th 2009 deadline
Areas claimed or reserved for claim
200-nautical-mile limit
Mid-ocean ridges
Trenches of the "ring of fire"
*Areas beyond 200 nautical miles
Source: National Oceanography Centre, Southampton, UK (www.noc.soton.ac.uk); The Economist

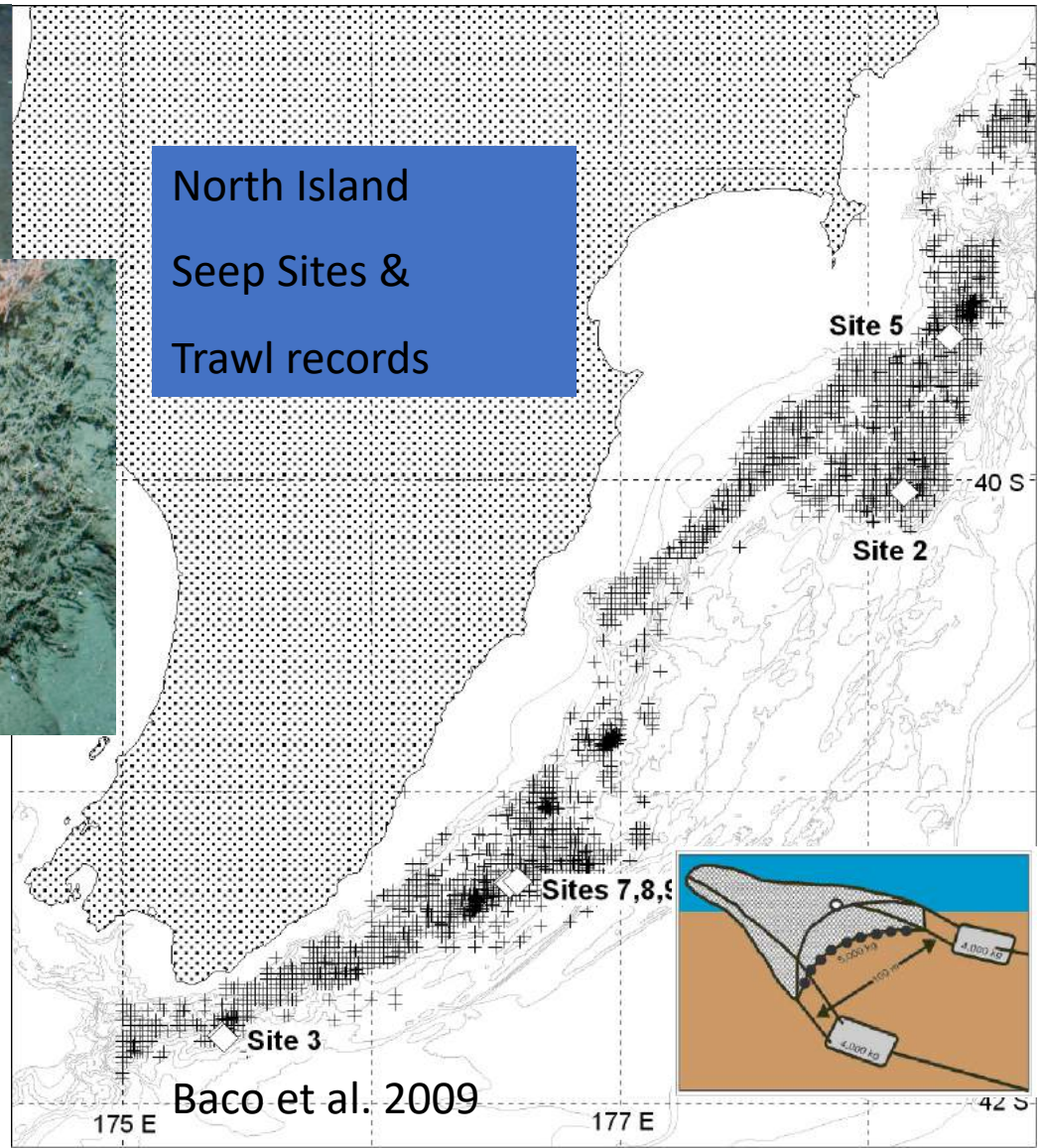
We are Leasing even before Learning



Marine Geochemistry, Schulz

"9 new seep sites discovered off New Zealand in 2006, all trawled & disturbed"





Baco et al. 2009

Voluntary code of conduct)

BIODIVERSITY AND HABITATS: Convention on Biological Diversity (CBD) & UN General Assembly

MINERALS: United Nations Convention on the Law of the Sea (UNCLOS) International Seabed Authority

SHIPPING & POLLUTION: International Maritime Organization

FISHING: Regional Fisheries Management Organizations/ FAO

CABLE & PIPELINES, BIOPROSPECTING: Unregulated

"Despite over 200 research expeditions and 40 years of work in the Clarion- Clipperton Zone (CCZ1) there are almost no published taxonomic records of animals living in the (CCZ1). This is remarkable given the intensity of work there, and the widespread knowledge that the abyssal Pacific is one of the most biodiverse regions of our deep-seafloor, based on macrofaunal community studies".

Deep-Ocean Stewardship Initiative (DOSI's *Briefing Note: Taxonomic Knowledge of the Clarion-Clipperton Zone)*

Precautionary Approach - minimization of human impact

Lack of knowledge requires mechanisms to improve deep ocean research

Require preservation as key form of restoration unless and until appropriate restoration mechanisms established.

Science and Technology-key Governance enablers

Science & Technology needs are global

Deep Sea (DSea) challenges = ABNJ challenges

Unknown Deep Sea & ABNJ biodiversity

Funding -DSea/ABNJ scientists, sophisticated & high-tech equipment

Scientific opportunities (DSea research vessels)

Access to data

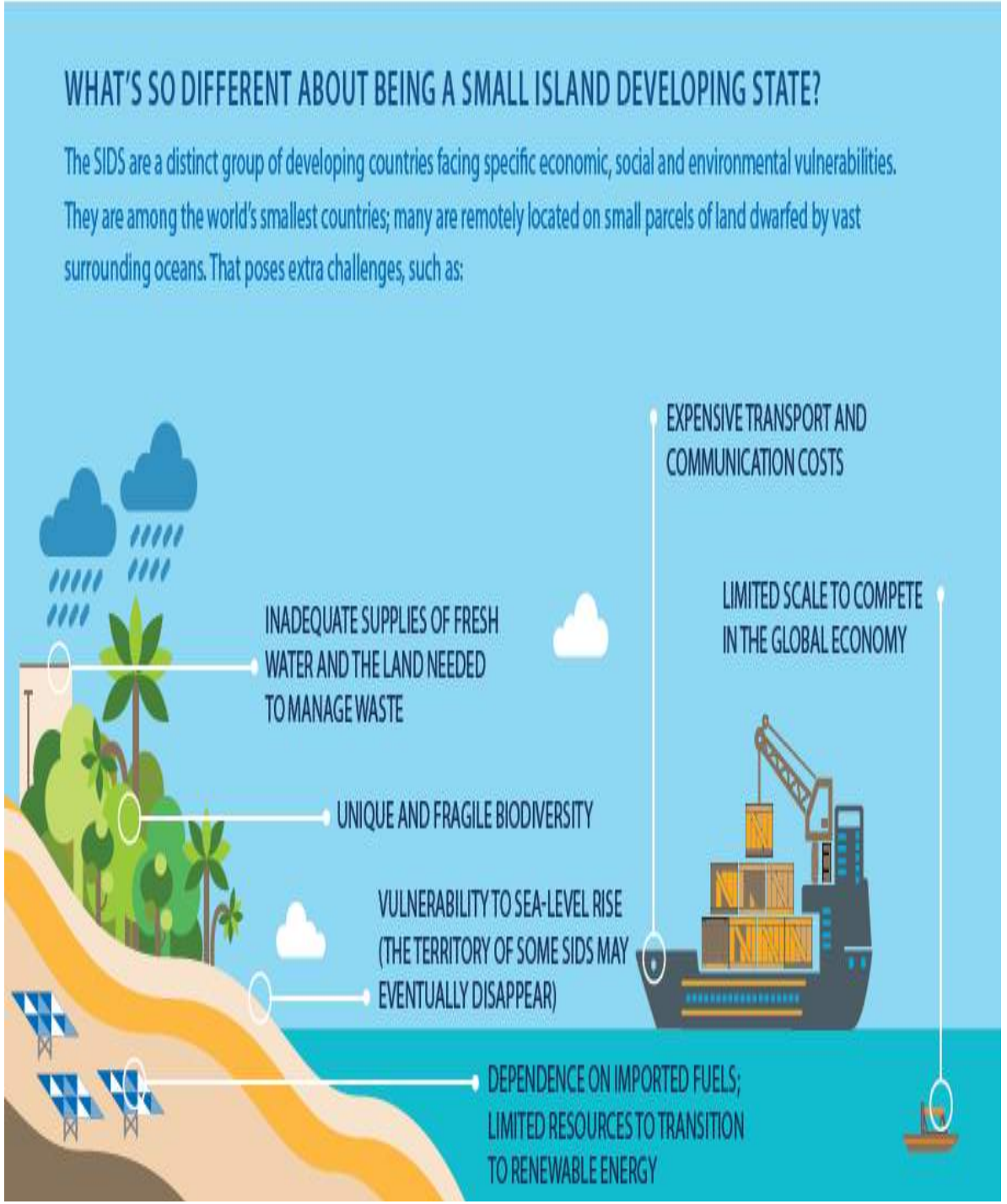
SIDs challenge- competing in the global environment: Science and Technology

DSea & ABNJ access- limited opportunities on ocean-going ships

Data availability- lacking

Data storage- lacks IT infrastructure for big data needs

Data analysis – computationally demanding with significant advances in data analyses



- **Initiate strategic environmental assessment**

- **Generate baseline data to characterize natural variability**

- Early engagement of stakeholders with outcomes that bind

- **Develop research funding sources**
- **Strengthen legal framework & regional agreements –**

- Take advantage of **global expertise**:

DEEP-OCEAN STEWARDSHIP INITIATIVE
Deep-sea Genetic Resources

Global effort- includes network of scientists, lawyers, economists (9 working groups)

eg. DOSI Deep-Sea Genetic Resources Working Group (2013)

- GOAL: Explore and identify options to:

  Conserve and sustainably use deep-sea marine genetic resources (MGR)

  Include **access and benefit sharing** of marine genetic resources in **areas beyond national jurisdiction (ABNJ)**

  Can assist at a regional level

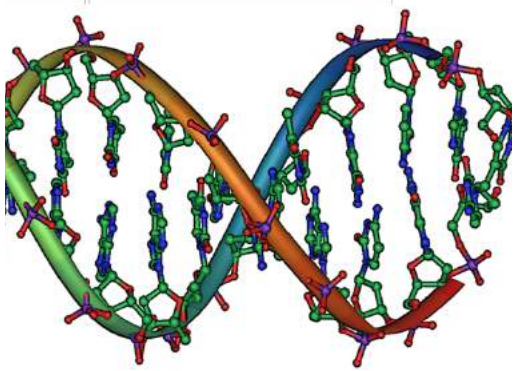
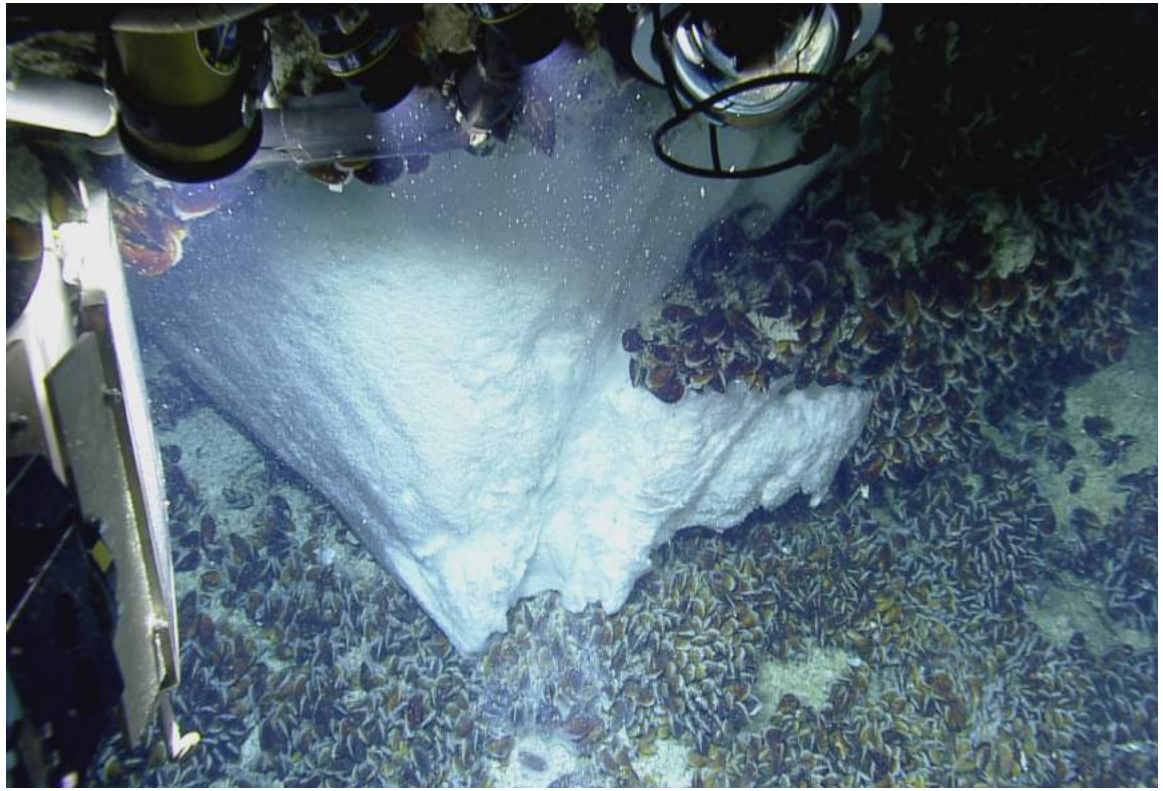


Image credits: Michael Ströck via Wikimedia Commons (top); H Harden-Davies, 2016 (middle); Shealah Craighead, 2006, via Wikimedia Commons (bottom)

Building Capacity in Science & Technology



Financial support for research, development & innovation

Bridge gaps between science, industry & education

Improved understanding of the value of ecosystem services

Improved understanding of seabed resource mapping for sustainable exploitation of marine resources

Scientists, engineers & skilled workers who are able to apply new technologies

(

Regional Strategies

- **Active networking** to involve *regional scientists* in large deep-sea research projects; Global assessments
- Innovative ***regional funding*** mechanisms to address knowledge gaps
- Advance progress towards *regionally coordinated sampling* eg. mapping of the deep sea floor and Research Projects
- **Promote *regional programs*** *for communication* and education on the importance of the Deep Sea. Educated communities will connect and better understand the need for investment in Deep Sea research towards conservation & management
- **Corporate responsibility**
- **National & Regional Policy including Legislation**

Regional Strategies- building Capacity

- Research clusters (international) to achieve internal & external integration (industry, government, research institutes, universities etc.)
- Promote/expand training & career opportunities for scientific research, policy & industry
- Financing & Funding mechanisms; scholarships, training workshops, exchange research visits
- Develop Science & Technical/IT expertise

Range: Education & institutional capacity-building to more specific training (eg. MGRs)

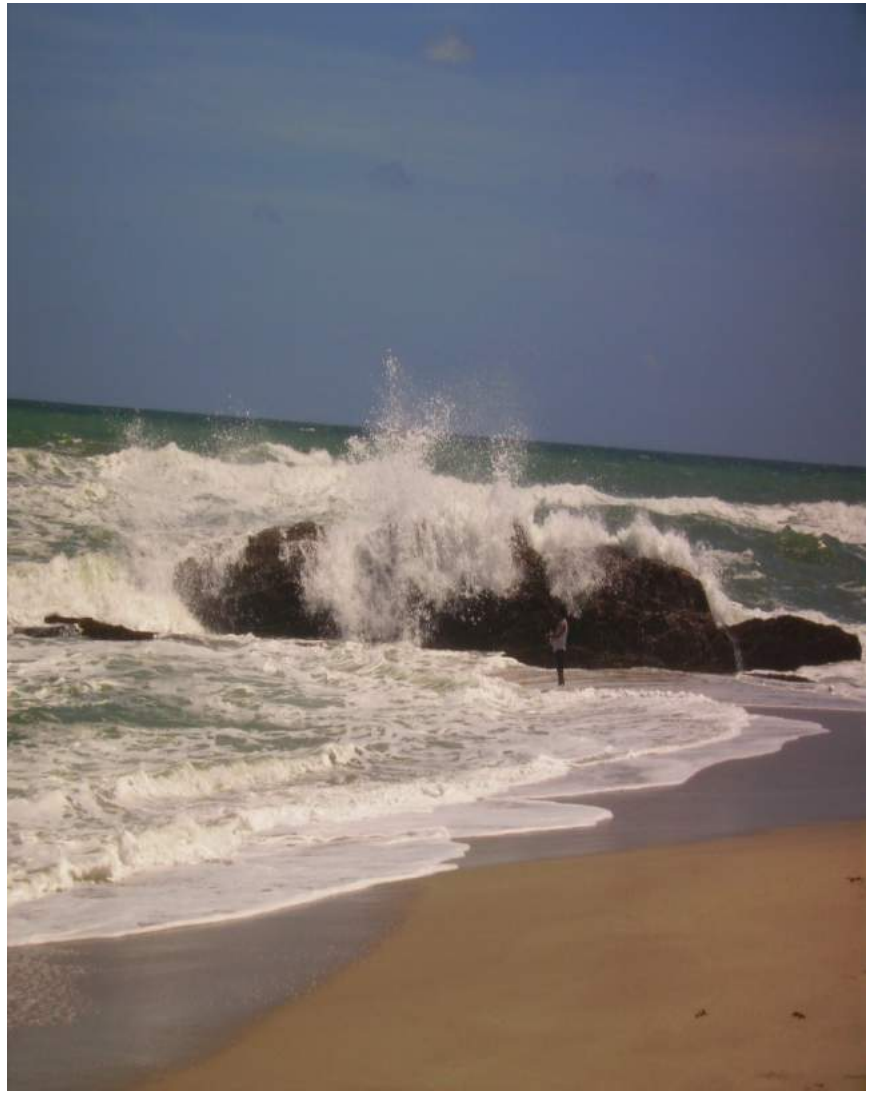
Successful Regional Partnerships: Caribbean Fisheries Management

- **United Nations University, University of the West Indies**
- **IOI/Dalhousie: Marine Law and Policy**
- **ANCORS, Univ. of Wollongong, Australia, VIMS – Univ. of Virginia, Univ. of Florida, Univ. of Belize**
- **IOC/UNESCO**
- **Public & private sector including fishers (CNFO)**

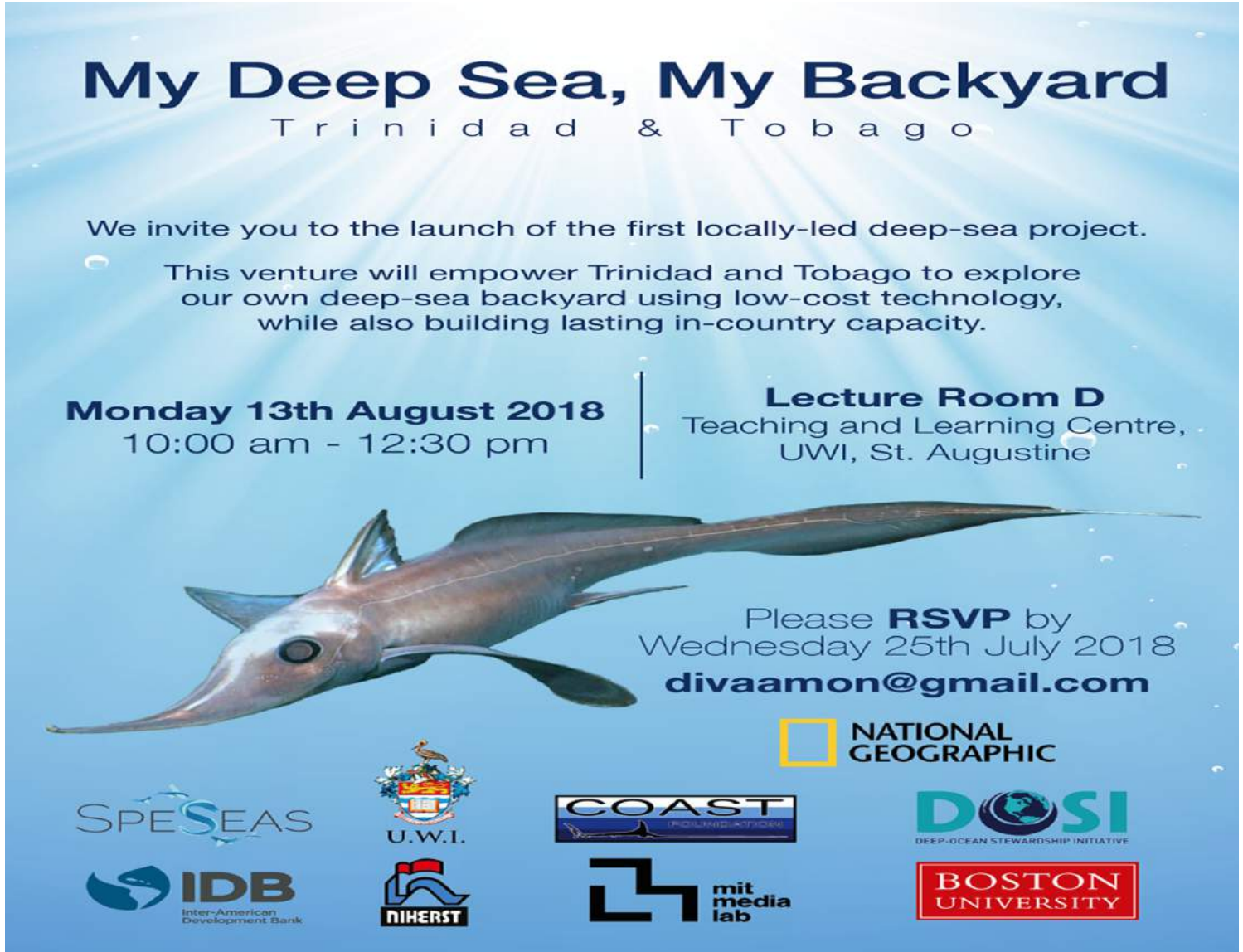
- **WECAFC 16, July 2016:**

The Commission agreed to launch a process to establish RFMO in the WECAFC area of

competence, and to collaborate in fisheries management and conservation in the Areas Beyond National Jurisdiction (ABNJ) of straddling stocks, deep sea fish stocks and highly migratory species that are not under the mandate of ICCAT (**International Commission for the Conservation of Atlantic Tuna)**



Partnerships and alliances including Regional



Continued attempt to fill gaps in knowledge

Enabling a science-based approach to conservation & sustainable use of biodiverstity in the deep sea & ABNJ

2018 32°C Overcast

TRINIDAD and TOBAGO NEWSDAY

3 Days Ago Marlene Augustine

TT's ocean to be explored

LET'S GO: Alan Turchik (right) mechanical engineer for National Geographic shows off a deep-sea camera, which can be used up to 6000 metres deep, to ecologist Dr Diva Amon (middle) and The UWI's lecturer Dr Judith Gobin (left) at the launch of SPESEAS's My deep sea, My back yard project at UWI. PHOTO BY SUREASH CHOLAI

- **Grenada - 1st in the world to initiate a pro-active & comprehensive national coastal master-planning approach to Blue Growth.**

- **Grenada follows the Maldives as the 2nd global SIDs & 1st Caribbean SIDs to** *"join in partnership with Parley for the Oceans to adopt and implement Parley's AIR (Avoid, Intercept and Redesign) strategy – to end ocean plastic pollution"*!

- **Grenada & The Blue Innovation Institute-working** with Parley for the Oceans, Adidas (using recycled plastics to produce athletic shoes), UN-OHRLLS and UN Environment (AIR)

The Tide is turning – the GRENADA success story:

1st OECS (Organisation for Eastern Caribbean States) to have Developed a Blue Growth Master Plan

Thank you

Special thanks to
DOSI and
Dr. Lisa Levin of
Scripps Oceanographic
Institute and DOSI
(for the majority of
Deep Sea slides)

Photo credit: EV Nautilus