Biodiversity in deep sea
Research drivers for biological sciences: Biodiversity

• What are the patterns of biodiversity in the deep-sea?

• How do deep-sea ecosystems function and what ecosystem services do they provide?

• What are the patterns of connectivity between deep- and shallow-sea ecosystems and between the deep and shallow water?

• What are the patterns of connectivity between deep-sea ecosystems and between the Earth system and to humankind?

• What ecosystem services are provided by the deep-sea and how important are they to the Earth system and to humankind?
How does biodiversity in the deep oceans compare to that of shallower seas and terrestrial environments? The answer is fundamental to understanding how many species exist because the deep sea is widely regarded as one of the largest reservoirs of undiscovered biodiversity on Earth. But there is a wide range of estimates of just how many species there are left to be discovered. To help decide which of these is likely to be correct we must understand the large scale patterns of diversity in the oceans.

One of the most basic properties of biodiversity patterns is the size of species' geographical range, i.e. their distribution across the face of the Earth. What we know about this feature of deep-sea species is summarised in an excellent review by Craig McClain and Sarah Mincks Hardy. Current evidence suggests that species seem to be broadly distributed across the deep sea in general, compared to their shallow water relatives. If correct, this suggests that species density is probably lower on average than in shallower waters. In our paper Biases in biodiversity: wide-ranging species are discovered first in the deep sea we set out to test whether this prevailing view is representative of reality or whether we might have a biased view of deep sea biodiversity.

During my masters research I examined the relationship between a single dimension of species ranges (depth) and patterns of diversity in deep-sea brittle stars. I soon began to realise that it is quite difficult to know what the true geographical range of a species is. There are all sorts of problems, especially related to sampling. How can you be sure that you have sampled enough to truly capture the full range of a species? This leads on to bigger questions about how good our knowledge of species distributions really is and how this might affect our picture of biodiversity.

It was several years later that I began thinking about these questions again. I saw a tweet from marine macroecologist Tom Webb, asking if anyone knew of a study demonstrating that wide-ranged species are discovered earlier than narrow-ranged species. While I didn't immediately have a reference to hand, we had a short exchange where I suggested that you could use geographical data from OBIS to look at this.

This got me thinking about how species range size might have affected species discovery, particularly in the deep-sea. I had recently been working to create a deep-sea subsection of the World Register of Marine Species using depth data from OBIS. I knew that you could extract geographic data on species occurrences from OBIS and the date that species was described from WoRMS. I did just this and the data showed a strong negative correlation between the date that a species is described and its geographic range (actually a rough proxy of range-size).

This raises an interesting paradox because the direction of causality in this relationship can work both ways. Usually, the correlation is taken to show that widespread species are discovered earlier than geographically restricted species, because they are more likely to come up in samples (the ‘encounter hypothesis’). But the relationship could be equally explained if recently described species have simply not been around long enough to be recorded enough times to have the true extent of their ranges determined (the ‘records hypothesis’).

Understanding which of these two mechanisms is the dominant cause of the correlation is important because it changes how we view undiscovered species diversity. The diagram below illustrates why. It shows trends in the mean range size of newly described species over time. The solid red line shows an apparent decrease in the mean range size of newly discovered species over time as did our data. The encounters hypothesis suggests that the trend will continue into the future (solid grey line) and that more and more of the newly described species will have (on average) smaller ranges.
Cruises and projects

A lot of cruises were operated by many countries, both at abyssal plains.

USA, France, Germany, P.R. China, Russia and other major countries

- Danish HADES cruise Tangaroa (Kermadec Trench, 2017)
- FISH „2017 Shinyo-maru (Marianas Trench, Challenger Deep, 2017)
- ICT36 James Cook (Rockall Trough, 2016)
- KURMAMO II SO 250 (Kurile Trench, 2016)
- SOKHODO Labrador (Sea of Okhotsk, 2015)
- IOE-II EXP 3 Sagar Kenya (Bay of Bengal, 2016)
- IOE-II EXP 2 Sagar Kenya (Bay of Bengal, 2016)
- IOE-II EXP 1 Sagar Kenya (Indian Ocean, 2015)
- PAP sustained Observatory Discovery (NE Atlantic, 2016)
- HADES Falkor (Marianas Trench, 2015)
- HADES T.G. Thompson (Kermadec Trench, 2014)
- QUELLE 2013 Yokosuka (mid-Indian T’ off Brazil, Caribbean Sea, Tonga-Kermadec Trench, 2013)

(blue) and continental margins (red).
Many of cruises have not operated for Blue Sky Science, but for Mission-oriented Science.

- Climate changes: Climate systems, Climate variability, Ocean acidification, Oceanic hypoxia,
- Anthropogenic disturbances: Deep-sea mining and disposal, Geo-engineering, deep-sea mining and disposal, Geo-engineering, oil and gas extraction, waste bio-prospecting, oil and gas extraction, waste disposal, geo-engineering, deep-sea mining and disposal, Geo-engineering, oil and gas extraction, waste bio-prospecting, oil and gas extraction, waste disposal, geo-engineering, deep-sea mining and disposal.
Flow chart for Disaster Risk Management (Prevention, Reduction, Mitigation and Restoration)
Flow chart for Disaster Risk Management

Trans-disciplinarity

Inter-disciplinarity

Stakeholders

Action
Delivery

Data & Observation

Synthesis & Modelling

(Information products: habitat maps)

Social Applications of Scientific Results

Scientific activities

Others
restoration, advanced and sustainable fisheries and
(ex. ecosystem managements, socio-ecological

Prevention, Reduction, Mitigation and Restoration)
Disaster Risk Managements at Deep-sea realms

(Data & Observation, Modeling & Synthesis, Action & Delivery, Habitat Mapping, Open Science & Open Data, OBIS & other multi-functional cruise)

(Ecosystem Managements, Strategic Sea area managements, MPA's)

(Prevention, Reduction, Mitigation and Restoration)
Relevant platforms, sensors, networks for observation

• Planktons, sensors, networks for observation

  with morphological diversity, but easy to construct Big Data

  and other genetics, molecular biodiversity (discrepancy

  analytical methods: DNA barcoding, environmental DNA-RNA

  • Planktons: research vessels, HOVs, ROVs, AUVs, Gliders, hadal drone

  • Networks: cable networks (NEPTUNE, DONETS, EURONETS

  • Sensors: biogeochemical sensors (C, H, O, N, S, P, Cl, and

  other gases, development of ultra-sensitive sensors (O2, Cl2, etc)

  • Analytical methods: DNA barcoding, environmental DNA-RNA

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Where are sensitive areas for monitoring human activities and their impacts?

Where are sensitive areas for monitoring global climate changes?

Where are hotspots for biotic evolution?

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Global climate changes?

Where are sensitive areas for monitoring

vent and seeps, sediment-water interface

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Symbioses have accelerated at chemoclinal such as

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Polar region (Arctic / Antarctic), oxygen minimum zone

hadal trenches and others

( Arabian Sea, Bay of Bengal, off Peru), CCD + lysocl ine,

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Disaster Risk Managements at deep-sea realms

(Mitigation, Reduction, Action)

Open Science

Database

Habitat mapping

Information products

Delivery

Action

# Strategic Sea area managements
# Ecosystem managements
# MPA's

# Novel methods (platforms, sensors, analyses)
(DNA barcoding, networks)

# Multi-functional cruise (Observation-Experiment-Measurement-Observation)

OBIS and other open data

# Strategic Sea area managements
# Ecosystem managements
# MPA's

# Novel methods (platforms, sensors, analyses)
(DNA barcoding, networks)

# Multi-functional cruise (Observation-Experiment-Measurement-Observation)
Need to construct database networking among different countries.

Database: species distributions from HOV-ROV dive video records.
Both natural and societal data integration: Habitat mapping.

For keeping sustainable use of the seas, distribution of organisms, environments and land use information are projected on one map as Habitat Map.

Differences in garbage removal speed:

GIS vs. NO GIS

- Topography
- Geology
- Substrate
- Debris distribution

Compilating map of different data on map.

Defining debris distribution map.
time scales for monitoring

- Short term changes: daily, weekly, monthly, seasonal
- Rapid changes in deep-sea internal waves, oxygen depletion, food supply, and others
- Long-term monitoring: 10~100 years or historical
- Natural and anthropogenic changes
- Accidental events: natural and anthropogenic
- Industrial Revolution (1850~)
- „Anthropocene“ (1950~)
- Human impacts (fishing, gas and oil exploration, deep-sea mining, waste disposal and others)
- Natural hazards (Earthquake and Tsunami, volcanic activities)
Natural hazard: Earthquake and Tsunamis (2011, Mar. 11)

Open cracks and muddy nepheloid layer at epicenter

Kawagucci et al., 2012

Benthic nepheloid layer: huge slope destructions?

2011.4.16 (36 days after 311 Earthquake)
We have not observed this type of bacterial mat before. From dead organisms also a stinky smell of hydrogen sulfide and a distinct smell of hydrogen sulfide.

Depth 3551m. Patchy microbial mat with 3m wide thick mat. Depth 5341m. 20m wide, 20m x 20m wide bacterial mat with 3m wide thick mat.

Dead Sea urchin (Aeropsis fulva). The species live 2870-5680m (82mm diameter). The species usually live in 2870-5680m. The species live 1465-5200m depth ranges in the Pacific. Dead ophiuroid specimens (Ophiura) 130 specimens in one push core.

Bacterial mats formed on bio-mound.
Mass extinction → Rotten (smell of H₂S)

Well sorted dead organisms

August, 2011

Well sorted dead organisms

Mass extinction introduced down slope turbidity current
Slope destruction introduced down slope of steep escarpment on the bacterial mat formed on the bio-mound related bacterial mat

Big turbidites produced in 2011
Bacterial mat disappeared after August, 2011. No additional deposition of mud occurred, and a lot of ophiuroid skeletal fragments are accumulated in mud. A lot of ophiuroid skeletal fragments are accumulated in mud.


Succeessive changes in microbial mat on biomound.
Foraminiferal assemblage at ophiuroid mound (2000–3500m) has changed after one year.

<table>
<thead>
<tr>
<th>Changes in Foraminiferal assemblage at EQ epicenter</th>
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August, 2011
5348m ophiuroid mound

- Normal sediment
- Foraminiferal tests
  - *Reophax sp.*
  - *Elphidium patellum*
  - *Oridorsalis umbonatus*
  - *Globobulimina affinis*
  - *Nonionella globosa*
  - *Chilostomella ovoides*
  - *Globobulimina affinis*
  - *Uvigerina sensu lato*
  - *Recurvoides subglobosus*
  - *Tecnitella sp.*
  - *Nonionellina labradica*
  - *Saccammina spp.*
  - *Rutherfordoides rotundata*
  - *Foraminidina complanata*
  - *Elphidium ba?alis*
  - *Reophax micaceous*
  - *Reophax sp.*

August, 2012
5348m ophiuroid mound

- Agglutinated taxa
- Foraminiferal tests
  - *Reophax sp.*
  - *Elphidium patellum*
  - *Oridorsalis umbonatus*
  - *Globobulimina affinis*
  - *Uvigerina sensu lato*
  - *Recurvoides subglobosus*
  - *Tecnitella sp.*
  - *Nonionellina labradica*
  - *Saccammina spp.*
  - *Rutherfordoides rotundata*
  - *Foraminidina complanata*
  - *Elphidium ba?alis*
  - *Reophax micaceous*
  - *Reophax sp.*

Foraminiferal assemblage at ophiuroid site is the same as those from lower bathyal depth (2000–3500m).

*Pioneer species (Kitazato 1995) were found in surface sediment after one year.

Foraminifera had been dislocated from lower bathyal to abyssal depths with turbidite.

Planktonic foraminifers tests
- *Elphidium patellum*
- *Oridorsalis umbonatus*
- *Globobulimina affinis*
- *Uvigerina sensu lato*
- *Recurvoides subglobosus*
- *Tecnitella sp.*
- *Nonionellina labradica*
- *Saccammina spp.*
- *Rutherfordoides rotundata*
- *Foraminidina complanata*
Natural laboratory gives case studies to solve anthropogenic disturbances

• Sediment disturbances

• Calcareous fauna below CCD ocean (human impacts)

• Sediment disturbances manganese nodules

• Acidification (global changes)
Some recommendations

@ Need more monitoring with multi-platforms, multi-sensors,
  More mobile monitoring than fixed monitoring.

More understanding of biodiversity of eukaryotic and prokaryotic microorganisms at strong chemocline sites.

Continental margins should belong to EEZ of coastal countries.

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Thank you for your kind attention.