Breakout Session 1

Plankton
Gaps

Diversity, vertical structure

Temporal and spatial variability (different scales: temporal/spatial)

Ecosystem structure and function and connection to the physical and biogeochemical environment (at a global scale)

Energy flow: link between plankton and fish and apex predators. Importance of export (Particulate Organic Matter - POM)

The Deep Scattering Layer (DSL): function and productivity – mesopelagic populations --models between the surface and subsurface biomass

Autotrophy in the dark ocean. Non-sunlight fueled production
Focused topics: relevant to societal needs

Drivers of biological productivity change at regional/ global scales and how we can project this to the future

Energy transfer (flow---trophic efficiency) from phytoplankton to fisheries in the shelf zone, in the DSL (structure, function, impact on fisheries) and relationship to fluxes.

Ecosystem structure and function ---support ecosystem assessments (e.g. biodiversity for CBD, IPBES, WOA...)
Topic 1. What are the drivers of changes in biological productivity at a regional scale and how we can predict these into the future?

<table>
<thead>
<tr>
<th>Discussion Topic</th>
<th>Key points from Breakout discussions</th>
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<tbody>
<tr>
<td>Societal impact(s) of the project(s)</td>
<td>There is no doubt the ocean is changing and these changes will impact on global issues such as biological production including food security. A predictive capability (model) will enable us to quantify the impacts and focus mitigation in the most appropriate regions.</td>
</tr>
<tr>
<td>Gap assessment(s)</td>
<td>The majority of methods are operational today. There is a need to collect and analyze samples for genomics (microbial processes and players) although this technology is not yet fully mature.</td>
</tr>
<tr>
<td>Technology requirements</td>
<td>Most of the technologies exist although there may be some advantages of newer technologies when the regions are selected.</td>
</tr>
<tr>
<td>Financial feasibility</td>
<td>Expensive, bring as many of the groups together as possible.</td>
</tr>
<tr>
<td>Any new observations, data and modeling requirements</td>
<td>The proposal is to sustain a time series of observations across several regions of rapidly rising PP, some control regions and several regions of declining PP. These might span from shore, across the shelf, through a boundary current to the edge of the open ocean. If possible some of these would extend into a region of declining DO.</td>
</tr>
<tr>
<td>Identifying possible implementation challenges</td>
<td>It would best if all appropriate observations were made. This may require working cooperatively &amp; collaboratively with our physical and chemical colleagues. Other challenges include funding.</td>
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Topic 2. What are the similarities and differences in trophic efficiency (energy transfer) in shelf and oceanic systems (e.g. the Deep Scattering Layer) and how does this influence living marine resources?

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<td>Societal impact(s) of the project(s)</td>
<td>Food security; Supporting Marine Management - Ecosystem Approach to Fisheries; Global carbon cycle</td>
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<td>Gap assessment(s)</td>
<td>Although more productive areas generally have more fish, the relationship is relatively weak. We currently do not have a good idea of how biological productivity feeds into fish biomass and how this varies in different systems. We suggest a comparative meta-analysis of biological productivity and fish biomass around the world. How many fish are there in the world? Research suggests that there might be 10x as much fish in the world because of recent bioacoustic estimates of mesopelagic fish. This is an outstanding questions. If this is true, oceanic systems could be much more productive than we currently think. New fishery resource?</td>
</tr>
<tr>
<td>Technology requirements</td>
<td>Biogeochemical data, Satellite information, Nets, CPR, LOPC, microbial data, bio-acoustics, fish tagging?, UVP?</td>
</tr>
<tr>
<td>Financial feasibility</td>
<td>Mainly existing data. Cost effective methods. Need more information on microbes, phyto and zooplankton functional groups in some regions, mesopelagic fish</td>
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### Discussion Topic

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| **Identifying possible implementation challenges** | Availability of fish biomass data  
Less data in tropical systems |
### Topic 3. Improved understanding of ecosystem structure and function

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<td>Societal impact(s) of the project(s)</td>
<td>Incidence of HABs / Global carbon cycle / Global biodiversity/ Food Security Address needs of CBD / IPBES / WOA ecosystem assessments</td>
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| Gap assessment(s)                          | Baseline of phyto and zooplankton diversity (including microzooplankton)  
Key important regions are not sampled, or undersampled (to be defined: e.g. Tropical and subtropical / EBSAS)  
Need to understand both standing stock and rates, rates are more difficult, but could be related to stocks using information gained from process-oriented “calibration” cruises.                                                                                                                                          |
| Technology requirements                    | Some phytoplankton data can be got by satellites, some zooplankton information from active acoustics but both still require ground-truthing e.g. by CPR, or cruises (operational, at least at regional scales) or genomics (pilot) and potentially autonomous vehicles (concept). Space Agencies (e.g. NASA, JAXA) are interested in developing phytoplankton community structure from space. IOCCG also interested in bringing it to the operational level, especially for HABS.  
Also depend on scale of project: vary from local to regional to global (from shelf to open ocean, ships to satellites). Regional studies need to be upscaled to global level.                                                                                               |
| Financial feasibility                      | The more we have, the more we can do!                                                                                                                                                                                                 |
| Any new observations, data and modeling requirements | Zooplankton community structure, including microzooplankton, not well considered in models.                                                                                                                                                                                                |
| Identifying possible implementation challenges | Level of maturity: still in concept and pilot stages globally. Mostly just a financial challenge.                                                                                                                                                                                                 |
**MERGED TOPIC:** Measuring ocean health through plankton: how and why is plankton changing at regional and global scales due to anthropogenic drivers and climate variability

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<td>Societal impact(s) of the project(s)</td>
<td>A predictive capability (model) on primary and secondary plankton production will enable us to quantify the impacts and focus mitigation in the most appropriate regions. Incidence of HABs / Global carbon cycle / Global biodiversity Address needs of CBD / IPBES / WOA ecosystem assessments</td>
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<tr>
<td>Gap assessment(s)</td>
<td>Baseline of phyto and zooplankton diversity (including microzooplankton) and zooplankton biomass Key important regions are not sampled, or undersampled (to be defined: e.g. Tropical and subtropical / EBSAS) There is a need to collect and analyze samples for genomics (microbial processes and players) although this technology is not yet fully mature</td>
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### Discussion Topic

#### Technology requirements

- Majority of methods are operational today. Most of the technologies exist although there may be some advantages of newer technologies when the regions are selected.
- Biogeochemical data, Satellite information, Nets, CPR, LOPC, microbial data, bio-acoustics, fluorocytometer, ecosounders, UVP. All remote sensing techniques still require ground-truthing e.g. by CPR, or cruises (operational, at least at regional scales) or genomics (pilot) and potentially autonomous vehicles (concept).
- Space Agencies (e.g. NASA, JAXA) are interested in developing phytoplankton community structure from space. IOCCG also interested in bringing it to the operational level, especially for HABS.
- Also depend on scale of project: vary from local to regional to global (from shelf to open ocean, ships to satellites). Regional studies need to be up-scaled to global level.

#### Financial feasibility

- Mainly existing data. Most are cost effective methods, but expensive platforms.
Merged Topic. Measuring ocean health through plankton: how and why is plankton changing at regional and global scales due to anthropogenic drivers and climate variability

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<td>Any new observations, data and modeling requirements</td>
<td>Zooplankton community structure, including microzooplankton, not well considered in models. Compare shelf systems and oceanic areas with existing plankton data and supplement these data with new data. Modeling the link to fisheries?</td>
</tr>
<tr>
<td>Identifying possible implementation challenges</td>
<td>Unsampled areas (e.g. tropical) Achieving all appropriate observations for which collaborative work is required with physical and chemical colleagues. Funding (and funding capacity development).</td>
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Breakout Session 2

Merged topic: Measuring ocean health through plankton: how and why is plankton changing at regional and global scales due to anthropogenic drivers and climate variability.
Measuring ocean health through plankton: how and why is plankton changing at regional and global scales due to anthropogenic drivers and climate variability

Major discussion points related to the topic:

• Identify near-term innovation priorities for observing platforms and sensors, data and modeling to enable multi-disciplinary observations

• Identify programmatic and professional expertise necessary to support specific project/activity (organizations, projects)

• Scope an implementation plan for the project(s): begin discussions of how we might actually make the projects a reality
Measuring ocean health through plankton: how and why is plankton changing at regional and global scales due to anthropogenic drivers and climate variability

Major discussion points related to the topics:

- Identify near-term innovation priorities for observing platforms and sensors, data and modeling to enable multi-disciplinary observations

**Modelling**
1. Regional models provide adaptive sampling strategy – where and how often to deploy assets
2. Model assimilation of plankton data for forecasting in ecosystem models

Meta-analysis of existing data – learn and highlight gaps
Help to fill gaps: Instrumentation of hydrographic surveys – UVP, genomics
Select representative regions for higher intensity observations - open ocean, shelf, EBC, WBC, tropical

- **Databases**: Easy to upload data, QC, meta data including uncertainties, personnel, accessible to modellers
- **Sampling protocols**: Well defined and known uncertainties
- **Satellites**: Physics (SSH, SST), Biology (ocean colour, LIDAR) – P biomass & diversity
- **Genomic**: Functional groups, Ecological diversity (parasites, mixotrophs, symbionts, autotrophs) – P & Z diversity
Measuring ocean health through plankton: how and why is plankton changing at regional and global scales due to anthropogenic drivers and climate variability

Major discussion points related to the topics:

• Identify near-term innovation priorities for observing platforms and sensors, data and modeling to enable multi-disciplinary observations

• **BGC Argo and gliders**: BGC sensors, In the Future to measure zooplankton: Miniaturise and low energy, UVP, LOPC, acoustics (P & Z biomass)

• **Bio-acoustics**: ecosounders and calibrate ADCPs on research vessels and SOOPs for acoustic backscatter (Z biomass)

• **In-line instrumentation (clean lines)**: optical sensors, spectral absorption, automated microscopy (Phyto and small zooplankton biomass and diversity)

• **Hydrographic surveys and sampling at moorings**: Bottles (P biomass and diversity – microscopy and HPLC), fluorocytometers, Nets (Z biomass and diversity), UVP (Underwater Video Profiler) on rosettes (Z biomass and diversity)

• **Towed instruments on SOOPs and RVs**: CPR (Larger P biomass and diversity, Z biomass and diversity)

• **Moorings**: Automated water samplers (weekly to monthly with adaptive sampling), LOPCs (Z biomass)

• CPRs on commercial vessels
Breakout Session 3

Measuring ocean health through plankton: how and why is plankton changing at regional and global scales due to anthropogenic drivers and climate variability
Open Ocean and Shelf activities were considered separately

1. Open Ocean
Coincident measurements that are needed to support plankton are T, S, O₂, Nutrients (N, P, Si), pH and if possible Fe.

Project/Activity milestones for both a 2 year and a 5 year project
• **Within 2 years** - Ask to be on the GO SHIP steering committee to pursue augmenting the cruises:
  Add a UVP to the rosette for zooplankton/particles $135k per ship
  Additional water samples for flow cytometry, phyto pigments (HPLC), POC, genomics for micro-orgs. $30k per voyage, $250k per voyage for additional on-shore analysis and data delivery.
  Potentially optics (transmissometer, fluorometer, back scatter).
  Possibly in-line imaging cytometry $135k per ship

This would provide a spatially intensive snapshot, i.e. a biodiversity census every 7-8 years. Great vertical resolution. Costs for augmenting are relatively small (270k for instrumentation, <300k per voyage for additional sampling and data delivery.)
1. Open Ocean

- **Within 5 years** - Move towards sustainable funding for the BGC Argo network and ensure the database and dissemination infrastructure are in place.
  Advocate that BGC Argo floats incorporate a UPV. The community has already agreed the 6 important measurements to be added – O$_2$, Nitrate, Chl-a, pH, backscatter and down-welling irradiance. Goal is for 1000 floats with 4 yr life span, and so 250 floats per year. **$25,000,000 per year** including database and data distribution.

  Long term wishes may be passive acoustics (for marine mammals) and active acoustics (zooplankton biomass)

  Go Ship is very accurate but long time between observations, BGC Argo less accurate but every 10 days – need to connect these approaches and optimize the BGC Argo data.

- Open Ocean time series stations (e.g. HOTS, BATS, OSP) could be augmented to have a UVP on every CTD cast. Tropical arrays could also be augmented.
1. Open Ocean

- **Existing.** Continue existing CPR to provide large scale context for zooplankton. Adding additional transects would be $250k for between 10,000 and 20,000 miles of transect (plus additional capacity building costs of $50k per new region). Eventually possible to compare and integrate CPR and UVP (each tells you something different about the plankton).

- Include use of satellites to provide large scale context for phyto - functional group information is in development. Satellite data essential for defining seasonality.

**Other discussion points:**
- Data products and data access are important, not to be diminished. Needs to be discussion with modelers to optimize the inputs to models.
- Underway ADCP from ships also provides high resolution biomass data, but need to be calibrated so data can be compared and integrated.
- We’re presented with a challenge to produce a uniform dataset or product from the different data types this approach would generate, but it would be of great value to an Ocean Health Index. Need to consider how this would influence policy. **Within 2 years:** Define Ocean Health Index (through a convened workshop).
1. Coastal/Shelf

Sampling needs are monthly, more frequent inshore – can we move to adaptive sampling? Transect from shore to open ocean or stations.
Coincident measurements that are needed to support plankton are: $O_2$, inorganic carbon, ocean colour (includes light), nutrients, suspended particles, wind, ice, T, S, currents, Continental/riverine input (EOV from GCOS).

- **Within 2 years** - Meta-analysis of existing data and encouraging the community to move towards free and open data access. E.g identify gaps - overlay existing 300+ time series stations (including CPR), GO SHIP and distribution of BGC Argo to show the global coverage.

- **Within 5 years** - Filling gaps in coastal observing, with an emphasis on developing nations, especially SIDS. Potentially each region would require $3-5000,000$ per year for the EOVS discussed here.

Other Issues:
- Improved coastal (type 2) algorithms for algae [HPLC]. HABS in particular. Toxin detection. (near term objective to report in the assessment on biomass related to eutrophication) SDG14.1
- Phytoplankton biomass/species from cell counts, flow cytometer, genomics, fluorescence (or % transmission) profile or high frequency (gliders or other) – potentially gliders programmed to explore blooms.
- Capacity building especially for HABs - IOC WESTPAC an example.
Haiku by LuAnne Thompson

Miami is hot
Interdisciplinary
Ocean health appears
Breakout Session 4

Measuring ocean health through plankton: how and why is plankton changing at regional and global scales due to anthropogenic drivers and climate variability
1. Work across gradients of anthropogenic impact. Eutrophication and other pressures. Review the available stations against pressures. Publication. 2 year goal.

2 Year GOALS
1. Coordination – engagement - outreach
   A. Opportunity to co-locate with OMZ and Boundary Current IMSOO
   B. Marine Stations of the world, bring them together should help with access to data and implementation of standard methods (where appropriate).
   C. Map with stations that share data identified. Encourage sharing.
   D. Richardson and Thompson agree to take the global sharing initiative to the IOC IGMETS WG. Review the availability of data. Which data series are freely available. Joint international effort to make this better.
   E. POGO ?
   F. IOC Henrik Enevoldsen Global HABS, TrendsPO, IGMETS
   G. Others!
Coastal plankton

5 year GOALS

Design, propose (implement?) a coastal observing program inside GOOS

Develop and produce a Health Check report for coastal ecosystems
Discover Ocean Time Series

NOAA

Todd O’Brien

IOC IGMETS

~ 340 global
Coastal Ocean
Plankton

GOA-ON
Coastal Plankton

Areas of the world with significant harmful algal blooms
Coastal Plankton

Known areas of hypoxic and eutrophic conditions
Open Ocean

Within 5 years - Move towards sustainable funding for the BGC Argo network and ensure the database and dissemination infrastructure are in place.
Advocate that BGC Argo floats incorporate a UPV. The community has already agreed the 6 important measurements to be added – O2, Nitrate, Chl-a, pH, backscatter and down-welling irradiance. Goal is for 1000 floats with 4 yr life span, and so 250 floats per year. $25,000,000 per year including database and data distribution.

Long term wishes may be passive acoustics (for marine mammals) and active acoustics (zooplankton biomass)

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Open Ocean time series stations (e.g. HOTS, BATS, OSP) could be augmented to have a UVP on every CTD cast. Tropical arrays could also be augmented.
Major discussion points related to the topics:
• Create a consolidated project/activity plan
• Identify opportunities for ongoing collaborations and communication
• Identify potential opportunities for funding support for integrated multi-disciplinary projects/activities
Open Ocean

Existing. Continue existing CPR to provide large scale context for zooplankton. Adding additional transects would be $250k for between 10,000 and 20,000 miles of transect (plus additional capacity building costs of $50k per new region). Eventually possible to compare and integrate CPR and UVP (each tells you something different about the plankton).

Include use of satellites to provide large scale context for phyto-functional group information is in development. Satellite data essential for defining seasonality.

Other discussion points:
Augment other ocean time series (Ocean SITES)
  tropical ocean moorings as pilot for plankton EOVs
  calibrate existing acoustic instruments (zoo biomass)
Within 2 years: Define Ocean Health Index (through a convened workshop).