REPORT OF THE POGO TASK FORCE ON OCEAN BIOLOGICAL OBSERVATIONS

Published June 2018

Task Force Members

Margaret Leinen, UC San Diego/Scripps Institution of Oceanography US, ***Chair***
Jesse Ausubel, Rockefeller University, USA
Jules Jaffe, UC San Diego/Scripps Institution of Oceanography, US
Chris Scholin, Monterey Bay Aquarium Research Institute, US
Yoshihisa Shirayama, JAMSTEC, Japan
Willie Wilson, MBA, UK

Guest Contributors

Francisco Chavez, Monterey Bay Aquarium Research Institute, US
Neil Davies, UC Berkeley and Gump Station/Moorea, US
Julie Robidart, National Oceanography Centre, UK

pogo

Partnership for
Observation of the Global Oceans

Contents

REPORT OF THE POGO TASK FORCE ON OCEAN BIOLOGICAL OBSERVATIONS

INTRODUCTION

The POGO Task Force on Biological Observations was charged with answering a number of questions for the POGO membership:

1) What is the policy rationale for biological observations of the ocean and what are the entities that we want to endorse such observations?
2) Develop a census of approaches to ocean biological observation
    a. Which of the approaches already have a community that interacts regularly (e.g., working groups of other organizations, groups that propose symposia, groups that hold sessions at international meetings)? What are those entities and how does POGO connect to them?
    b. Which of the approaches are not already well organized and would benefit from support from POGO for a workshop or other organizational activity? Can we co-sponsor with other entities for such activities?
3) How can we foster intercalibration, intercomparison and linkage to existing time series of ocean biological observations?
4) Is there potential for an array of techniques to recover the overall ecosystem at a location?

The POGO task force met six times by conference call and once in person over November 9-10, 2017 at Scripps Institution of Oceanography. We invited three members of the ocean biological observations community to join our meeting in November to hear about developments in the field of ocean biological observation and to have them assist us in thinking about the questions posed by POGO.

This report consists of three sections and an appendix.

Section I discusses the scientific and societal questions that require the development of large scale and/or long-term ocean biological observation capabilities and how POGO might assist the ocean observational community in developing this capability.

Section II outlines the state of development of various ocean biological observation techniques and issues.

Section III discusses some of the issues associated with the development of large scale and/or long term biological observations.

Appendix I includes information and references used in our discussion and deliberation.

SECTION I:

What are the factors that argue for development of large scale and/or long term biological observation of the ocean and what role should POGO play?

Oceanographers are now challenged with a number of important and broad questions that require much greater understanding of the biology and ecology of the ocean than we currently have. This more sophisticated level of understanding requires much greater density and duration of observation than can be achieved with the campaign-style process studies than we currently undertake, as well as greater geographic coverage than is possible with individual oceanographic cruises or studies.

Some of these questions are basic research questions, for example:

- What is the scale of coherence in marine biological systems?
- How does biodiversity affect ocean ecological processes?
- What is the relationship between the biology of the surface ocean and that of the deep interior and benthic environments?

Some of the questions being asked of oceanographers are driven by societal concerns, for example:

- How will ecological and/or biogeochemical regions shift due to climate change?
- How will such changes influence the distributions of harmful algal blooms, invasive species or the occurrence of other biological events that affect our health and food supply?
- Are regime shifts on the way as a result of climate change?
- What is the fate of excess CO2 in the ocean and its impact on ocean ecosystems?

Some questions are ones the public asks in response to perceived risk, for example:

- Is the ocean dying?
- Will unsustainable fishing practices result in a major crash in the stocks of food fish?

And some are concerns of policymakers, for example:

- Are marine protected areas actually working to protect biodiversity and abundance?
- Would rigs to reef programs actually enhance biological resource production?
- Could we sequester carbon in the ocean?

An appropriate opportunity for POGO

The kinds of questions we have provided examples of above are important for scientists, for the public and for policymakers. They cannot be answered with any certainty using our current style of biological observation. A decade ago, physical oceanographers were confronted by similar challenges. Basic science questions like *'how is the upper ocean affecting seasonal to interannual weather prediction?'*, societal questions like *'how much is the ocean warming?'*, and policy questions like

'what magnitude of emission reduction is needed to prevent harmful acidification?' were impossible to answer. The physical oceanography community rose to this challenge by proposing a distributed physical measurement network - the ARGO array - that POGO advocated and fostered. We believe that it is necessary for POGO to prepare to foster and advocate for a new era of ocean biological observing capability.

The oceanographic community is beginning to develop sensors, instruments, platforms and systems that will eventually make large scale and long-term ocean biological observation possible. There are developments in imaging, acoustic measurement and genomic sensing that show great promise for the future. Each development is in a different stage of maturity and there is great enthusiasm within the communities for investment in these capabilities. But we see no organization that is consistently fostering these capabilities. We believe that POGO has the long-term perspective, the ocean observation focus, the international scope, and the organizational convening power to take on a focus on ocean biological observation. And our institutions represent the scientists who will develop and deploy these capabilities. This capability is not an alternative to the ocean physical observation capability that POGO has fostered for 20 years. Instead, these ocean biological observations will depend on and build on physical observations to provide a new and more comprehensive understanding of the ocean.

Fostering biological observation of the ocean will require a different approach than POGO took in fostering physical observation of the ocean. When POGO was formed to advocate for observation of the basic physical characteristics of the ocean, we were dealing with an existing platform concept and set of sensors that were fairly well developed. Our challenge was to ensure that oceanographic institutions and their funding agencies came together to endorse a single concept and set of measurements that could fulfil the promise of dense measurement of the upper ocean. The situation for biological observation is different: there are multiple sensing tools, often adapted to observe specific components of ocean biology. And these tools are in far different stages of development.

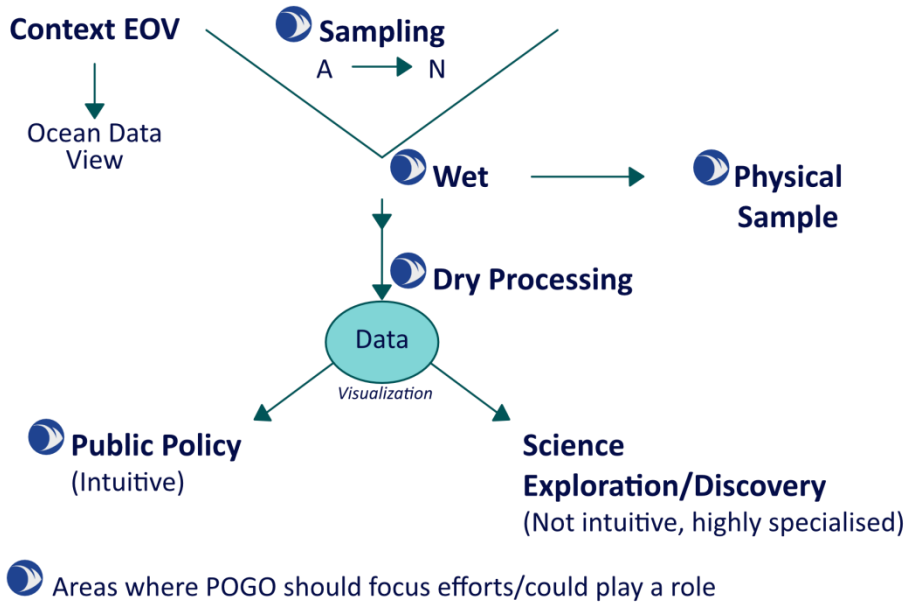
What should POGO do to foster biological observation?

We believe that broader and more consistent coordination by POGO with its long-term partners in fostering ocean observation (e.g., Blue Planet, SCOR, IOC, GEO) in addition to new partners (e.g., ICES, PICES), could dramatically accelerate the process of developing ocean biological observing capabilities for large scale and long term observation. We believe that POGO should consciously commit to taking a leadership role in providing this coordination. POGO can do this by fostering dialogues that will increase the pace of capability development, for example, dialogues on:

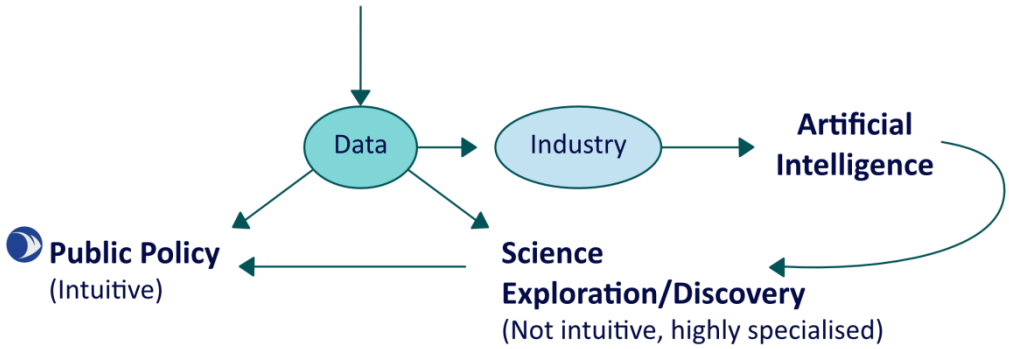
- standards for biological measurement
- validation, verification and intercalibration of techniques
- sampling strategies
- development of data repositories

The issues surrounding data coordination (standards, data repositories, tools for use of data, etc., are particularly important and provide an opportunity for POGO. Task force member Chris Scholin developed a visual image to help us think about the roles that POGO could serve in data issues:

Presentation & Discussion – Data Visualization – How to Integrate and Display Data



We subsequently expanded the lower part of the diagram to show additional partners:



POGO has also played a critical role in the development and implementation of training programs to expand the use of observational technology. We believe that POGO has a role here as well – in training new researchers, both in the developed and the developing world.

How could POGO proceed?

We believe that POGO should establish a longer-term group or subcommittee to continue discussion, set an agenda for moving forward and ensuring that POGO is informed on the state of development of ocean biological observing systems. This group could partner with other organizations to foster workshops and other activities. It could also ensure that POGO is represented in international discussion of ocean biological observing capabilities and systems. It is essential that we be able to go from biological observation to ecosystem understanding. Therefore, we will need to include member representatives who are ecologists in this group.

They can help POGO ensure that we foster what *should be* observed, not just what *could be* observed.

How should we use the opportunity provided by the Lounsbery funds?

During our meeting we were able to discuss the potential use of the Lounsbery funds for a ocean biological observation workshop. While there are many topics that we covered and that could be candidates for a POGO-sponsored workshop, the task force members believe that a topic that would enhance the capability of the ocean biological observations community to use existing large-scale data that is coming online – and a topic that is not currently being discussed by other groups – would be a workshop to connect the community with practitioners of artificial intelligence and machine learning. This is an area where a few members of the community have started working, but many are interested in learning how to move forward within their own groups. Providing information and the first steps toward training our community would be appropriate given POGO's interest in training.

SECTION II:

A brief summary of the state of ocean biological observation

We conducted an initial overview of the techniques that are currently being used and developed for ocean biological observation. We asked a series of questions for each topic:

1. Is it appropriate for POGO to be involved in this topic?
2. Are there other organizations that are also/more appropriate?
3. How urgent is the need for action?
4. How big an effort is required?
5. Would this require a short-term (1-2 year) or long-term effort?
6. Would POGO need/want other partners?
7. Would POGO be able to fund the activity or would we need other funders?

We present our results in an outline format to shorten this section.

Established techniques for ocean biological sensing

- Satellite sensing—acoustic surveys
- Fisheries surveys

POGO roles

- Improve the dialogue between fisheries surveys and satellite sensing and communities looking at new techniques
- Fisheries and acoustics/optics—encouraging acoustics work on the fisheries surveys
- Encouraging AUVs, etc. on those surveys
- Foster use of other ocean biological observing data together with the survey data
- Begin emphasizing machine learning
- Foster understanding of the importance of the data for other uses
- Importance of annotation of the data

Partners for POGO to engage

- ICES, PICES
    - Consider POGO sessions at ICES/PICES + more
    - Consider requesting that POGO be a formal observer

Focus

- Improving their understanding of the importance and use of ocean biological observing techniques in addition to their existing techniques
- Segue to new techniques
- Relationship-building
- Medium-length effort

Urgency

- Good will related to public questions—high
- Scientific discovery—medium

New Techniques

1) Samples for genomic analysis—we can now sample from AUVs and other platforms; high resolution

POGO roles

- Scientists in POGO institutions will drive the state of the art framework for how we establish "equivalency" of data from genomic analysis and from traditional organismal studies
- Foster analysis at multiple sites
- Foster linkage between these analyses and physics
- There will be different partners for different sites: blue ocean, nearshore; fixed sites (e.g. existing moorings oil/gas platforms), drifting platforms
- There will be different partners for strategy v. action

Urgency

- High, timely

2) Microscopic techniques/imaging techniques—critical for equivalency, etc. of techniques like CPR and of genomic techniques.

- Knits other techniques together to provide ground-truth validity
- Real time observation will still be important

Partners

- International groups are interested—SCOR working group
- Private sector may be interested

Urgency

- High, timely

3) Acoustics/Soundscapes

Passive

- A POGO-sponsored group, The International Quiet Ocean Experiment (IQOE), has started work on this topic, but they haven't looked at it as part of a system of observations
- An opportunity for POGO because little is going on in this field and sources/ signal processing has improved very much
- Need to foster use at sites where other work is going on

Active Acoustics

- Fisheries
- Encourage use of autonomous platforms combined with images and genomics

Partners

- Private sector (e.g. mineral resources extraction industry)
- ICES for use with fisheries
- Not many existing partners

Urgency

- High, timely, inexpensive

4) Genomics Method Development and Standards

POGO Roles

- Foster curated reference material—tissue, water, extracted DNA
- Foster development of international association of marine labs that can work on this topic
- Biomed is the big player here – there is a rapid evolution of methods, standards; we need to watch and deal with that evolution

Partners

- SCOR working group
- Marine labs
- Genomics Standards Consortium
- NIST
- Natural History Museums
- Earth Cube
- Earth Microbiome

Urgency

- Slow and steady

5) Deep Ocean Biological Observations

- Potential test site: North Sea (Conserve v. resource extraction). This is an unaddressed opportunity
- There will be 200 platform shutdowns in the North Sea by 2028
- 200 sites between 1000-2000m at which deep biological observations could take place will be available from platforms
- Many deep ocean sites (2000m+) will become available
- There are also moorings that are very deep – 6000m+
- We need to start accessing deep sites for biological observation
- Are we making use of assets? We do have:
    - Cabled observatories
    - Moorings
- New Deep ARGO Technology
- There is a lack of information even in twilight zone
- There is also problem urgency associated with deep sea mining environmental assessment

POGO roles

- Development of patrol & docking to transfer samples/information
- Foster eDNA imaging at these locations
- Foster use of communication cables for observations
- POGO institutions have an obligation here because of our expertise with deep physical observation
- There may be an X-Prize opportunity here for development of technology to use on deep moorings or platforms
- Another prize opportunity is the Australian Innovation Exchange Prize

Data-Related Issues for Biological Observations

Repositories for samples and data

- POGO could foster development of repositories, including making the information/samples in the repositories broadly available
    - We need a census of what POGO institutions do already to curate data and samples from biological observation
    - Metadata standards need to be used more routinely
    - POGO could engage GSC to work on this topic
- Data repositories
    - Issue of dealing in terabytes for "small" big data sets
- Workflows
    - Collection → Validation & Annotation → Storage
        - POGO could foster work on annotation
    - The continuum is a challenge
    - How do you get to data products?
- Artificial Intelligence / Machine Learning
    - Use of AI/Machine Learning will require curated, well documented, large data/reference sets
    - There is rapid progress in the commercial sector
        - POGO could foster connections between these sectors and ocean biological observation scientists
    - New efforts are seeking to not only identify the objects/organisms in images but their relationship to other objects/organisms
    - Domain adaptation is another topic for which AI/Machine Learning can be valuable: the environment around the organism is changing & the community is changing as well

Partners

- IT community, natural history museums, existing oceanographic collections

Urgency

- High

System Issues related to ocean biological observation

- Many issues systemic to ocean biological observation are related to the length/extent of observation, e.g.:
    - Biofouling
    - Energy
    - Computation onboard
    - Novel methods and materials
- Other issues are related to size constraints of platforms, e.g., miniaturization needs for ocean biological observation techniques
- Training sets, reference library

POGO roles

- We can highlight how specific use cases drive needs for addressing system issues through some examples
- We should foster collaborations between oceanographic instrument development and biomed instrument development
- We could highlight our challenges and opportunities at the Catch the Next Wave conference (HHMI)

Urgency

- Slow and steady

Sites for experimentation and verification/validation (long term vs areal coverage)

- Coastal labs
- Existing long-term open ocean time series sites: L4, K2, HOT, BATS, CalCOFI, etc.
- Established long term moorings arrays, e.g., TOGA-TAO.
- Cabled ocean observation systems.
- Rigs/Commercial platforms.
    - Use of these platforms would require several years to approve. It would therefore be appropriate to begin conversations with rig operators. This could be a major component of global ocean observation systems.
- Ships of opportunity: commercial, ferries, research vessels.

Partners

- All of the operators of sites listed above

POGO role:

- Foster dialogues

Urgency:

- High priority - long lead time

SECTION III:

Crosscutting issues in ocean biological observations and observation technologies

As we explored the developments in biological observation and observation technologies, we found a set of issues that apply to all observation technologies. It is worth highlighting these issues as ones that will need to be addressed in order to make ocean biological observing systems fulfil their promise. We present this discussion in outline form to make a shorter document for members.

System Issues

I. Standardization and quality control of data
II. Common issues experienced by most in situ systems:
    a. biofouling
    b. size of sensors versus space on platform
    c. therefore, need for miniaturization
    d. move to GPUs for increased computational power on board the platform
    e. need for increased storage space on instrument – especially for biological samples
    f. need for improved energy efficiency for longer deployments
    g. sensitivity
    h. accuracy/precision of data acquisition
    i. training sets, labelled reference libraries
        i. standards for labelling
        ii. centralized repositories needed
III. The key limitation of a given system is a function of the specific use case
    a. System issues a function of deployment strategy, location, etc.
        i. E.g., surface tropics v. deep ocean
    b. Accessibility
        i. E.g., shore station v. open ocean
IV. Prototyping efforts in different regions could help localize commonalities and thus identify solutions

Sensor Issues

POGO could sponsor meetings with biomedical, criminal justice, etc. communities to encourage co-development of sensors, e.g.,

I. miniaturization
    a. Researchers involved in miniaturization and microfluidic systems could be helpful to our community
    b. Biomedical community in general is moving quickly in developing small biological sensors
II. NYC Crime Lab for genomics
    a. rapid turnaround on genetic analysis
    c. Tap into communities that have more resources at their disposal?

The Deep Ocean

The biological oceanography community often uses the term 'deep ocean' to refer to depths greater than about 200 m (i.e., below the photic zone). We are using the term in a sense that would include depths below the twilight zone (i.e., 1000m+). We use the term 'very deep' to refer to depths of 4000m+.

I. There is some overlap between deep sea systems and shallow water environments. We could foster the extension of shallow water technologies for use in deeper environments

II. Biologists and ecologists cannot currently use classical techniques in the very deep ocean. As a result, there is a lack of information about these ecosystems.

III. We should determine whether we are using the assets we now have. For example, are there efforts to integrate new systems onto existing platforms:
   a. cabled observatories
   b. moorings
   c. ARGO/deep-ARGO

IV. We have not explored the potential of transocean cables. For example, there is a new transarctic cable for telecommunication between Japan and UK
   a. Could there be nodes for science applications?
   b. Could we foster contact with telecommunication companies?
   c. At a corporate level, we want companies to support environmental initiatives

V. We could foster conversations with X-Prize organizers to encourage contests targeting development of biological sensors for the deep ocean
   a. imaging challenge
   b. eDNA
   c. miniaturization
   d. docking stations for extended deployment/data transfer

VI. Underwater autonomous systems with distributed docking stations for data acquisition and recharging are being developed
   a. JAMSTEC, WHOI, MBARI are working on something like this
   b. Could address limits with respect to battery life and data storage for autonomous vehicles

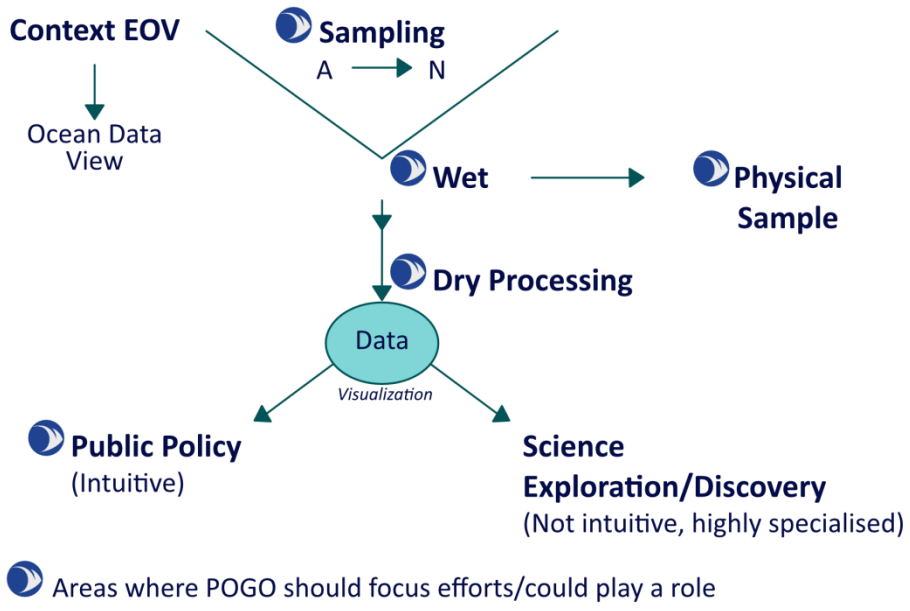
VII. One approach to ensure that observations were focused in a way to develop data sets that could be used to answer larger questions is to frame the study in terms of big problems
   a. deep ocean biology as a carbon export problem (how do modellers parameterize biological component of carbon export?)
   b. Frame deep ocean biology as sustainable fisheries issue
   c. Frame deep ocean biology as oil rig decommission study
   d. North Sea (but this is not truly a deep ocean area except at quite high latitudes)
      i. is nexus of chemical/biological sensing and industry interests
      ii. system requirements are pretty stringent for such an application area
      i. 200+ fixed platform shut downs per year projected by ~2030
      ii. 100+ fixed platform shut downs per year projected by ~2020

Data and Related Issues

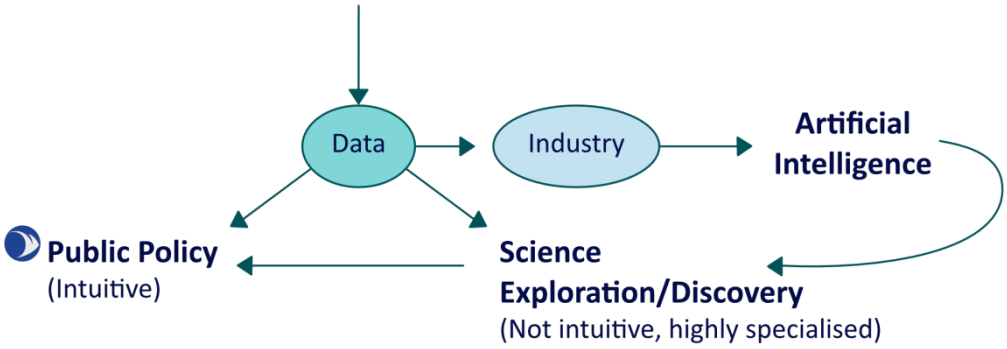
I. Focus on developing centralized repositories
II. Make information/samples broadly available
III. Accessibility
IV. Accounting for future scaling
V. Connect with museum repositories (Natural History Museum, etc.)
VI. Codify metadata requirements for such data hubs
VII. Focus energy on automated annotation
VIII. How to go from data collection —> data products
IX. Conduct census of what POGO institutions do already
X. Machine learning, pattern recognition, artificial intelligence
XI. Domain adaptation
    a. shifting underlying populations that are being sampled
    b. changing environmental parameters affect sampling and the computer's ability to recognize new data
    c. explore how machine classifiers handle such variability
XII. Commercial and academic computer science collaborations
    a. broad interest in those communities for new data streams for experiments
XIII. Curated, well-documented, large, labelled reference sets for training
    a. publically available
    b. training sets that span many areas to improve scalability to new environments
XIV. Area that needs rapid development

Task Force member Chris Scholin presented a visual perspective on the data-related issues. The task force members identified areas in which POGO could make a difference in fostering development of this area:

Presentation & Discussion – Data Visualization – How to Integrate and Display Data



Suggested alteration to the flow chart that was presented above:



Sites for Experimentation, Verification and Validation

a. Coastal labs
b. Existing long term open ocean time series
    i. L4, K2, HOT, BATS, CalCOFI, other LTER sites, etc.
c. Moorings
    i. TOGA-TAO
d. Cabled systems
e. Rigs/platforms
    i. decommissioned and otherwise
f. Ships of opportunity
    i. super yacht and other private vessels
    ii. ferry box for local surveys
    iii. commercial vessels
g. Partners? all of the above
h. POGO members could work with:
    i. personnel resources
        1. research vessels at university
        2. marine labs
        3. moorings, etc.
    ii. external:
        1. shipping
        2. oil and gas
        3. decommissioned oil rigs for research platforms
            a. huge opportunities starting in the 2020s
            b. no time like present to begin talking with these companies

APPENDIX I:

Background information used by the Task Force.

The following is a link to a Google drive that contains all of the materials used by the task force. This includes peer reviewed articles, workshop reports, other informal articles, and presentations from the workshop.

https://drive.google.com/drive/folders/0B49wnCVN6ICaZVRPY0d5R2VDNEk?usp=sharing