CENSUS OF MARINE LIFE

UNITED STATES

Biological Ocean Observing:

Exploring Components of the Integrated Ocean Observing System (IOOS®) from the Perspective of the Census of Marine Life

Workshop sponsored by the U.S. National Committee of the Census of Marine Life
January 14-15, 2008 • Washington, D.C.

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UNITED STATES

About the Census of Marine Life

The United States Census of Marine Life (U.S. CoML) was established in 2002 in consultation with the National Academy of Sciences, the National Research Council, the National Oceanic and Atmospheric Administration (NOAA) and the International Scientific Steering Committee (SSC) of the Census of Marine Life (CoML). The U.S. component, led by a National Committee (USNC), seeks to build broad U.S. community support to establish CoML as a sustained national research and monitoring program for marine and coastal biodiversity in support of its mission.

The U.S. CoML's mission is to serve as an unbiased source of sound scientific information to support the needs of the nation by assessing and explaining the changing diversity, distribution, and abundance of marine species in the past, present, and future, as well as the functional role of marine biodiversity in the U.S. and its territories and commonwealths.

CONSORTIUM FOR
Ocean Leadership

About the Consortium for Ocean Leadership

The Consortium for Ocean Leadership is a Washington, D.C.-based nonprofit organization that represents 95 of the leading public and private ocean research education institutions, aquaria, and industry with the mission to advance research, education and sound ocean policy. The organization also manages ocean research and education programs in areas of scientific ocean drilling, ocean observing, ocean exploration, and ocean partnerships.

Introduction

Observations of living marine organisms are important components toward understanding ocean health. Consequently, biological information and biodiversity data must be integrated with physical and chemical parameters such as temperature, salinity, and currents data to effectively assess and predict the overall health and sustainability of our nation's ocean ecosystems, as well as the entire global marine ecosystem. These data are needed to describe the marine environment and evaluate the effects, response and resilience of marine species and their environments to activities such as fishing and bycatch, and short-term events such as harmful algal blooms (HABs). In fact, the Joint Subcommittee on Ocean Science and Technology (JSOST) released *Charting the Course for Ocean Science in the United States for the Next Decade: An Ocean Research Priorities Plan and Implementation Strategy*, an interagency effort that identified biological ocean observing as one of the United States' most compelling national research priorities. With changes to the Magnuson-Stevens Fishery Conservation and Management Act and greater emphasis from federal agencies to comply with the National Environmental Policy Act, there is a need for marine ecosystem data to meet such legal mandates.

The Integrated Ocean Observing System (IOOS) is a significant driver of this strategy. A sustained and coordinated observation program, IOOS is an inter-disciplinary system of systems comprised of remote and in-situ global and regional observations and data transmission, data management and communications (DMAC), and data modeling and analysis. It routinely and continuously acquires and disseminates quality controlled data and information on present and future states of the oceans and Great Lakes in formats and at time scales required by user groups and decision makers. IOOS depends on ocean observations to support applications that address seven societal needs and goals:

- Improve predictions of climate change and weather and their effects on coastal communities and the nation;
- Improve the safety and efficiency of marine operations;
- Mitigate the effects of natural hazards;
- Improve national and homeland security;
- Reduce public health risks;
- Protect and restore healthy coastal marine ecosystems; and
- Enable the sustained use of marine resources.

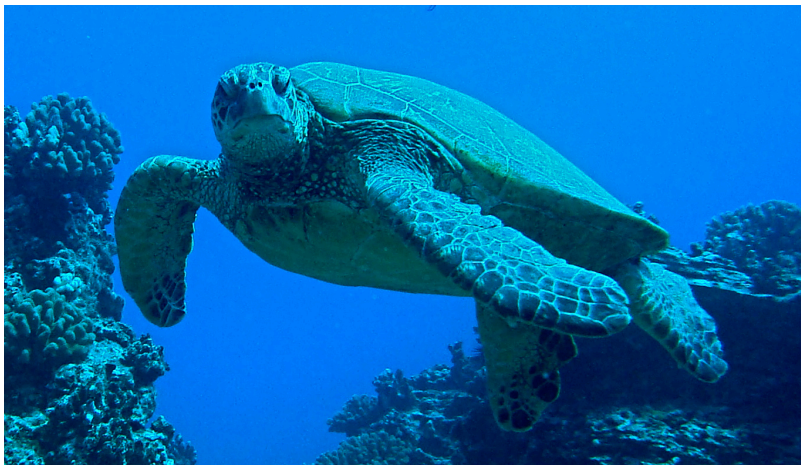
The Census of Marine Life (CoML) is a growing global collection of biological information used to assess and explain the diversity, distribution, and abundance of marine life in the oceans. The data and information CoML collects provide new insights into ocean biodiversity and therefore are an important component of IOOS. These data help identify sentinel species that enhance our ability to monitor, predict and evaluate changing climate and environmental conditions.

To ensure that the data are captured and made available to the broadest extent possible, the CoML has established the Ocean Biogeographic Information System (OBIS). OBIS is intended to be an archive for the results of the CoML projects as well as a mechanism for the sharing of marine biodiversity data with the broader scientific community and the public. It currently integrates data from a large number of different sources with the help of an extensive network of Regional OBIS Nodes (RONs), which facilitate capture of data globally. OBIS currently provides biogeographical information - taxonomic name, position in three dimensions, time and date (and several auxiliary fields including collector, identifier and project information) - and makes the data freely and openly available online through a single user interface. OBIS also facilitates analysis across the various national and international datasets. Coupled with other components of the IOOS, its contents will become a powerful tool for resource management and policy development.

In an effort to garner support for the importance of incorporating biological data – particularly CoML data – into IOOS, the United States National Committee of the Census of Marine Life organized a biological ocean observing workshop in Washington, D.C. from January 14 to 15, 2008. The workshop brought together experts from academia, management agencies, industry, and the IOOS Regional Associations to share information and stress the importance of including the biological data collected by CoML and contained in OBIS in IOOS (a list of workshop steering committee members, speakers, participants, and support staff is found on page 10).

Workshop Approach

During the workshop, participants addressed four central questions. Multiple plenary sessions held before each breakout group helped to establish the context for these questions and the issues they highlighted. Four concurrent working group discussions followed each plenary talk to examine issues related to the central questions. The following is a brief listing of the four objectives/questions, a listing of the plenary sessions' key points, and a summary of the discussions.



Workshop Results

Question 1 Discussion Summary:

What types of biological data are needed to ensure the success of IOOS goals related to ecosystem health and living marine resources; what existing data from CoML would be appropriate to integrate into IOOS?

Biological Data Sets Critical to the Success of IOOS
Dr. Tom Malone, OCEAN.US and the University of Maryland

- IOOS is envisioned as a sustained system of systems that are end-to-end, user-driven, interdisciplinary, and integrated. IOOS provides data and information at rates and in forms required by those who use, depend on, manage or study marine systems; performs functions that can only be achieved through integrated approaches; and continually evolves as user needs change and expand and technology improves.
- The U.S. Commission on Ocean Policy called for an integrated observation system for oceans. IOOS is the U.S. contribution to Global Ocean Observing System (GOOS), which is the oceans and coasts part of the Global Earth Observing System of Systems (GEOSS).
- Implementation of the initial IOOS is focused on physical oceanographic and meteorological data and model-based predictions of physical states of the oceans (surface current and wave fields, heat content,

etc.), marine weather, climate, and coastal inundation. The priority now is to incorporate biological and ecological observations needed for model-based predictions of changes in the state of marine ecosystems that affect public health risks and ecosystem goods and services.

- For the purposes of fisheries and protected species management and monitoring the "top-down" effects pertaining to how large marine animals use the ocean ecosystem are critical to understand not only ocean health but the health of marine wildlife. Pacific Ocean Shelf Tracking (POST) and Tagging of Pacific Predators (TOPP) are research projects that should be transitioned into pilot projects for IOOS and GOOS with the goal of improving operational capabilities of ocean observing systems.
- Major challenges to establishing and sustaining IOOS and GOOS are the lack of government policies and procedures for transitioning capabilities developed through research into an operational system (in the same sense that atmospheric observations are sustained for the purposes of nowcasting and forecasting the weather), and for creating synergy between ocean research, operational observing and predicting systems such as IOOS and GOOS.

After Dr. Malone's presentation, workshop participants listed a plethora of biological data that would contribute to addressing the IOOS goals. While some participants mentioned very specific types of data – including relative abundance estimates of species; species size, age, and life history characteristics; species distribution and migrations; taxonomic information; trophic composition; and species biomass – many focused on broader data characteristics.

The breakout groups repeatedly cited the importance of data transparency, accessibility, and availability and noted the need for quality-controlled data (peer-reviewed and verified). The value of gathering historical and time-series data was also emphasized. Data interoperability, which the group defined as data that can relate to or with other datasets, was of paramount concern. Several breakout groups cited the ability to link biological data with physical data as a key component to understanding how the overall system responds. One participant also suggested that having relevant and accessible data was more important than having real-time data. Another offered that any biological data integrated into IOOS or OBIS should be transformed into a format useful for users such as agencies, students, and researchers. Participants also noted that biological data should have a role and importance that specifically relates to IOOS and they identified that the IOOS goal(s) pertaining to: "protect and restore healthy coastal marine ecosystems; and enable the sustained use of marine resources" are the goals best served by greater integration of biological data.

When addressing what existing CoML data should be integrated into IOOS, participants' responses echoed a common refrain – any biological data that is integrated should ultimately improve IOOS. They listed several datasets that would help promote this objective, including Pacific Ocean Shelf Tracking Project (POST) and Tagging of Pacific Predators (TOPP), the Ocean Tracking network (OTN), the Census of Marine Zooplankton (CMarZ), the Bar Code of Life (BoL), and the International Census of Marine Microbes (ICoMM). The group mentioned Arctic Ocean Diversity (ArcOD) and Census of Antarctic Marine Life (CAML) datasets, which address data coverage from pole to pole. The Census of Continental Margins (COMARGE) was another potentially useful dataset that was discussed, as it provides records at greater depths than most available datasets.

Question 2 Discussion Summary:

What gaps exist in current biological data collections that must be filled to establish an IOOS that is effective in meeting its societal goals; and how can future biological observation programs be better designed to facilitate integration into IOOS (e.g., sampling/data collection design, planning, analysis, models)?

Several speakers offered insight into critical data gaps in data collection, analysis, and management. The following is a synopsis of the three presentations.

Application of Information Products for the Public and Policymakers – Broad Community Case
Dr. Steve Murawski, National Oceanic and Atmospheric Administration

- Policymakers address legal mandates and public needs, so they need abundant, scientifically credible data and improved means to use that data to better manage living marine resources. It is important that the data is topically and geographically relevant and sustained over time for long-term trend analyses.

- Integrated Ecosystem Assessment (IEA) is a tool that establishes target levels and thresholds for the conservation and management of important ecosystem components. The goal of IEA is to evaluate the impacts of management options and the risks of not attaining target ecosystem states.
- Integrating and combining data sets in new ways can provide new insights into ecosystem function and natural history.

Application of Information Products for the Public and Policymakers – Specific Technology Case
Dr. Pat Halpin, Duke University

- There is a need to maximize the interaction between ocean observing and ecological analysis of information systems.
- Specifically, decision-makers require integrated ocean observing data to improve protected species management and so there is a need to integrate protected species observations with ocean observing systems to more fully understand protected species habitat use and the risk associated with certain human-activities in protect species habitat.
- Studies are fusing marine mammal and ocean observing data to support risk assessment models to help avoid marine mammal.
- Animals can be a significant source for undersea data as autonomous ocean observers (using satellite-relayed tags).
- As regional and global ocean observing systems are developed, there will be a need to look for partnerships to co-develop oceanographic and animal observing instrumentation to capitalize on animals as living ocean observing systems.

Examples of Large Biological Databases – Ocean Biogeographic Information System
Dr. Edward Vanden Berghe, Rutgers University

- OBIS publishes primary data on marine species distributions online through *www.iobis.org*. OBIS integrates data over themes and from many sources and enables data capture for re-use.
- OBIS develops standards for data management and exchange and makes data freely accessible online. It is the database management component of CoML.
- OBIS is limited by a lack of knowledge of total biodiversity, selective sampling in geography, and selective sampling in taxonomy.
- The current priorities of OBIS include: filling gaps; completing marine species inventory; creating inventory of existing data; and making OBIS sustainable.

During the breakout discussions, participants overwhelmingly agreed that there are existing gaps in all major categories of biological data and that no categories are sampled adequately. In addition, attendees acknowledged that much of the biological data needed to ensure IOOS' effectiveness – especially in regards to the two societal goals of protecting and restoring healthy coastal marine ecosystems and enabling the sustained use of marine resources – fall within these gaps.

Lack of data on ecosystem structure, natural history, biodiversity, taxonomy, and individual species distribution, density, and habitat use were all issues attendees listed as impeding IOOS' effectiveness in reaching its living marine resource and ecosystem goals. Participants also attributed missing biological data to the fact that many species surveys are not systemically comprehensive and are not completed with sufficient frequency to detect biological trends. In addition, current long-term monitoring systems do not include biological data to the extent necessary nor is that data paired with physical and chemical data that might be sampled during portions of those surveys.

The group also identified the lack of time series data for non-commercial marine species and the effects of ocean acidification as other data voids that should be filled. Due to the difficulty in collecting data in deeper and harder to access waters, participants also acknowledged the existence of data gaps in the types of sampling between surface/nearshore and offshore waters, with offshore habitats being under sampled. In addition, participants also noted that under-utilization of bycatch data (e.g. for abundance, natural history information and long-term biodiversity trends) when scientists conduct studies targeting specific species further contributes to data gaps and our better understanding the biodiversity of the ocean.

The lack of specific records and time series data discussed by the groups was noted as a problem related to a much larger issue – the inaccessibility to long-term biological data. It was agreed that it is an issue that can be resolved relatively easily. Much of the long time series data exists, but are simply not currently available to other users. Workshop attendees agreed that integration of these data sets into OBIS, and by extension IOOS, is a high priority.

The group suggested that following the data management and communication (DMAC) structure of IOOS during future biological observing programs could make it easier to integrate these data into IOOS. They also offered that various technologies – such as DNA/genome-based technology, molecular probes, biosensors on nets, nitrate sensors, and Acoustic Doppler Current Profilers (ADCPs) for plankton biomass added to moorings – could be developed to fill some data gaps. However, attendees acknowledged that in many cases the ability to process data is a limiting factor in collecting information. One attendee noted that in many instances, data have been collected but have remained unused and suggested that this older data could possibly be mined to help fill in some of these data gaps.

Question 3 Discussion Summary:

What must be done to facilitate the interoperability of existing biological monitoring and baseline databases (e.g., OBIS) with IOOS. How can the various scales and resolution of the static biological data be integrated with the dynamic chemical and physical oceanographic data in the Integrated Ocean Observing System (e.g., spatial data vs. temporal data)?

Interoperability Among Heterogeneous Data Streams: Developing Common Interfaces & Standards
Dr. Roy Mendelssohn, National Oceanic and Atmospheric Administration

- If the "container" holding the data is well defined and standardized then the data can be interoperable regardless of the type of data (e.g., profiles can be either physical or biological data, but profiles are defined in the same way).
- Physical data is more widely accepted because these data are readily available and the data follow standards for names, units and formats, whereas biological information tends to be confidential, harder to access, and with no particular standard.
- With well-defined data standards, interoperability between physical and biological data is not that difficult. The greatest hurdle is that important biological datasets are not publicly available.
- The main OBIS works as a cache service, which is not the IOOS system (web services). DiGIR is a well-defined service, but needs to be expanded and sites made more stable.

During this session, participants listed several significant challenges to the facilitation of biological monitoring and database interoperability. One challenge is the lack of current standards for IOOS biological data. While attendees noted that NOAA's DMAC is attempting to address this problem, it still remains a concern and an impediment to the integration of biological data. Attendees suggested that a toolkit, or set of software applications, for data standards could be developed and applied on a national scale. Participants also offered that if IOOS developed full DMAC standards and a single front-end interface, it could possibly spur agencies, academics, and others to contribute their data. Several individuals also supported protocols and standards for future data use, including requiring quality assurance and quality control data standards through IOOS.

Reluctance to share data was also listed as one of the major hurdles to facilitating data interoperability. Specifically, participants claimed that it is extremely difficult to get researchers and scientists to share their data with others. Citing many researchers' fear that their work will be used without acknowledgment or for another's benefit, participants stated that many researchers are reluctant to disclose their data. Consequently, several individuals suggested offering academic promotion and/or recognition (citation in other works) to scientists who shared data as a potential incentive. It was also agreed that clear requirements for data use and citation must be provided.

In regards to data integration, participants mentioned that OBIS – the information technology component of CoML which facilitates data discovery and operation, integrates data over marine themes and from different sources, and enables data capture for reuse – is a known standard platform

for publishing biological observations. With the acquisition of the new key identified datasets, OBIS holdings might be more complete, and be more useful for nation-wide analysis of ocean ecosystem health, conservation and management, and biodiversity assessments. OBIS can be used to identify biodiversity hotpots and document the distribution of endangered species, both of which can help with the creation of Marine Protected Areas (MPAs) and Environmental Impact Assessment studies. Participants also noted that one of OBIS's unique attributes is its ability to provide a controlled vocabulary for species taxonomy, a critical issue in quality control when integrating data from different sources.

Other participants argued that while standardization and integration of data are challenges, the greater challenge is to describe data in a manner that allows users to access them. These individuals suggested a database's ability to communicate with another might be more important than physically bringing all available data into one single database. The discussion highlighted the need and value for metadata (i.e. descriptive information on source, collector, georeferencing, data-processing and validation). Metadata acknowledges the data sources, but can also serve as a tool for determining 'fitness for use' of the data itself. The lack of adequate metadata is a critical barrier to sharing and applying biological data to ecosystem-based management. Currently, standards exist or are emerging to solve this issue and it was agreed that the support of the biological community is needed to further address and resolve this crucial issue.

Question 4 Discussion Summary:

How can biological data be used in predictive models to assist decision-makers in meeting their conservation and management mandates and in developing end products to meet user needs?

Using Predictive Modeling to Foster Ecosystem Management

Dr. Jeff Polovina, National Oceanic and Atmospheric Administration

- Scientists are using predictive modeling from the Pacific Islands using IOOS-collected data, protected species data, and fisheries observer data.
- NMFS effectively used data from these sources to predict when sea turtles would overlap with pelagic longline fisheries. Disseminating this information allows these fisheries to take action to avoid entanglements of sea turtles.
- Developing predictive models for ecosystem management has several uses, including providing:
  - Clear management objectives with predictable indicators
  - Dissemination of timely and high-quality biological data
  - Biological data from various trophic levels
  - Models to compare and extend data to make predictions
  - A statistical framework to convey prediction uncertainty

One breakout group suggested that taking concurrent observations of environmental and ecological data (description of habitat, physical oceanographic parameters such as temperature, salinity, pH and dissolve oxygen concentration) is of the utmost importance. These measurements, made together with the biological observations, ensure compatible space and time scales of data and would result in much stronger analyses and interpretation of data, both of which would ultimately aid decision-makers.

According to participants, biological data can also provide a better understanding of the ecological relationships of marine species and assist management actions (i.e., establishing marine protected areas). Several individuals noted that resource agencies collecting biological information should retain all survey data for future use, not just data on the target species.

Participants also suggested identifying 10 national datasets and making them more usable through interagency cooperation, OBIS and DMAC enhancements, and the development of data wrappers to provide data in appropriate formats for product development. To make these datasets more useful, the group decided that interagency cooperation should be a top priority and suggested that NOAA should take the lead on the integrated system, with OBIS and USGS serving as partners.

Recurring Themes

During the workshop, most dialogue revolved around five major interwoven themes:

- **Sampling protocols**
- **Data standards**
- **Data accessibility**
- **Data interoperability**
- **Data applications**

In order for data to become more useful and interoperable, the group noted that there must be a shift in the culture of sampling. Specifically, several breakout sessions discussed the need for establishing sampling protocols. Participants stressed that it is crucial for physical, chemical, and biological data to be collected simultaneously. Over the long term, this change in sampling protocol should lead to more efficiency, better data interaction, and lower sampling costs.

In addition to addressing the need for sampling protocols, many breakout discussions focused on data standards. Attendees emphatically agreed that there is an urgent need to advance an agreed-upon core set of national data standards and pushed for a move toward standardized best data practices. The group also insisted on the development of consistent and transparent quality assurance/quality control approaches in data and believed that defining a schema (vocabulary, etc.) and data model would be useful.

Discussions of data standards also led to dialogue on the second major theme – data accessibility. During the workshop, participants explained that an initial data standard agreement would provide guidance for people to make data available and in particular formats. According to the group, this data accessibility – making pre-existing data sets that have been particularly elusive open and accessible to the ocean community – is a vital aspect of ocean observing.

According to the group, physical/chemical/biological data systems would need to become interoperable with other systems to best use these improved sampling protocols, core data standards, and newly available key data sets.

Data application, the fifth and final theme, tied the discourse together. Once sampling protocols are in place, data standards, data accessibility, and data interoperability can aid in the sharing of data, which then allows scientists to develop or apply applications. The group noted that data must be applied in a manner that will best influence policy and decision-makers, Group on Earth Observations (GEO)/Global Earth Observation System of Systems (GEOSS), and other necessary stakeholders and organizations.

Recommendations for OBIS and the Future of Biological Ocean Observing Programs

The workshop concluded with a moderated discussion designed to evaluate the previous days' breakout sessions. During the final discussion, attendees arrived at several conclusions and made the following recommendations for future biological observing programs. It is vitally important that these recommendations be acted upon quickly to establish the biological components of ocean observing in a manner that makes the best use of the OBIS data and structure.

- Improve interaction between researchers, data collectors, data managers, and user groups. A culture shift must occur, encouraging a unified effort towards developing a successful national observing system.
- Create a core national set of data standards (this is an issue that must be resolved within months, not years). These data standards should build as much as possible on existing standards that are widely used by the scientific community.
- Expand OBIS schema to incorporate data standards that allow OBIS to capture different types of biological and physical information (e.g. stock assessment, density and line transect data). Collaborate on this with existing initiatives such as Ecological Metadata Language (EML), the Marine Metadata Initiative (MMI), and the European SeaDataNet Consortium.
- Attempt to either integrate or make interoperable five to ten historical datasets, surveys, and records that span both coasts and several agencies within the next six to twelve months. Suggestions included: Marine Resources Monitoring Assessment Prediction Program (MARMAP), Southeast Area Monitoring and Assessment Program (SEAMAP), and California Cooperative Oceanic Fisheries Investigations (CalCOFI) datasets; U.S. Environmental Protection Agency (EPA) water quality, National Estuarine Research Reserves (NERR), U.S. Geologic Survey (USGS), and fisheries/trawl surveys; habitat characterization data; and protected species stock assessments.
- Incorporate environmental data into the OBIS schema and develop products (i.e., maps and summary statistics) to illustrate data applications and the utilization of OBIS for managers and policy makers.
- Publicly share the status of initiatives, integration, and product development to help reduce the chance of multiple groups "reinventing the wheel" when collecting and processing data.
- Have data producers and OBIS provide ongoing web service and tools training to address the use of existing tools and services to help determine capacity building needs. This should also include training in metadata preparation.
- Implement Regional Pilot Studies to illustrate the benefits of IOOS and OBIS to the marine community; demonstrate that data can be interoperable; market why IOOS is economically important; and capitalize on regional opportunities in communication.

Appendix A: Workshop Agenda

U.S. CoML Sponsoring Agencies:

National Oceanic and Atmospheric Administration
The Gordon and Betty Moore Foundation
Alfred P. Sloan Foundation

The Latham Hotel • 3000 M Street, NW, Washington, DC 20007 • January 14-15, 2008

Monday, January 14

9:00	Coffee/Breakfast and Registration
9:40	Welcome/ Goals of the Workshop Dr. Andrew Rosenberg, University of New Hampshire Dr. Ned Cyr, NOAA NMFS
10:00	Plenary Speaker: Review of Biological Data Sets Critical to the Success of IOOS Dr. Tom Malone, Ocean.US/ University of Maryland
10:45	BREAK (15 MIN)
11:00	Breakout Session – Central Question 1: What types of biological data are needed to ensure the success of IOOS goals related to ecosystem health and living marine resources; what existing data from CoML would be appropriate to integrate into IOOS
12:30	LUNCH (45 min)
1:15	Plenary Speaker: Application of Information Products for the Public and Policy-Makers – Broad Community Case Dr. Steve Murawski, NOAA
2:00	Plenary Speaker: Application of Information Products for the Public and Policy-Makers – Specific Technology Case Dr. Pat Halpin, Duke University
2:45	Plenary Speaker: Examples of Large Biological Databases--Ocean Biogeographic Information System Dr. Edward Vanden Berge, Rutgers University
3:30	BREAK (15 mins)
3:45	Breakout Session – Central Question 2: What gaps exist in current biological data collections that must be filled to establish an IOOS that is effective in meeting its societal goals; and how can future biological observation programs be better designed to facilitate integration into IOOS (e.g. sampling/data collection design, planning, analysis, models)?
5:30	Plenary Summary of Central Questions 1 & 2
6:00	End of Day 1

Tuesday, January 15

8:30	Breakfast
9:00	Day 1 Summary/Goals for Day 2 Dr. Andrew Rosenberg, University of New Hampshire Dr. Ned Cyr, NOAA NMFS
9:30	Interoperability Among Heterogenous Data Streams: Developing Common Interfaces and Standards Dr. Roy Mendelssohn, NOAA
10:15	Breakout Session – Central Question 3: What must be done to facilitate the interoperability of existing biological monitoring and baseline databases (e.g. OBIS) with IOOS. How can the various scales and resolution of the static biological data be integrated with the dynamic chemical and physical oceanographic data in the Integrated Ocean Observing System? (e.g. spatial data vs. temporal data)?
12:00	LUNCH (45 min)
12:45	Plenary Speaker: Using Predictive Modeling to Foster Ecosystem Management Dr. Jeff Polovina, NOAA
1:30	Breakout Session – Central Question 4: How can biological data be used in predictive models to assist decision-makers in meeting their conservation and management mandates and in developing end products to meet user needs?
3:15	BREAK (15 mins)
3:30	Plenary Summary of Central Questions 3 & 4
4:00	Moderated Discussion: Recommendations for Future Biological Observing Programs - Measurements, Analysis, Data Management and Communications Dr. Ru Morrison, University of New Hampshire
5:00	BREAK (15 mins)
5:15	Plenary and Workshop Summary Dr. Andrew Rosenberg, University of New Hampshire Dr. Ned Cyr, NOAA NMFS
5:45	Meeting Adjourns

Appendix B: Participant List

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Appendix C: Acknowledgments and Thanks

We gratefully acknowledge the support for the workshop provided by the following organizations:

The National Oceanic and Atmospheric Administration (NOAA) is a federal agency focused on the condition of the oceans and the atmosphere. NOAA's mission is "to understand and predict changes in the Earth's environment and conserve and manage coastal and marine resources to meet our nation's economic, social, and environmental needs." Support for this workshop was provided by the NOAA Fisheries Office of Science and Technology, NOAA Research (Office of Ocean Exploration and Research), and the NOAA IOOS office.

The Gordon and Betty Moore Foundation, established in September 2000, is dedicated to advancing environmental conservation and cutting-edge scientific research around the world, as well as helping to improve quality of life for future generations in the San Francisco Bay area.

The Alfred P. Sloan Foundation is a philanthropic nonprofit institution established in 1934 by Alfred P. Sloan, then President and chief Executive Officer of General Motors Corporation. The organization offers grants in several fields of interest, including science and technology.

We also thank all workshop participants for their enthusiastic engagement and we thank the following rapporteurs who provided yeoman service during the workshop sessions: Melissa Brodeur, Allison Byrd, Heather Mannix, and Colin Reed.

Special thanks to writer Sara B. McPherson and designer Jason Mallett.

UNITED STATES

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