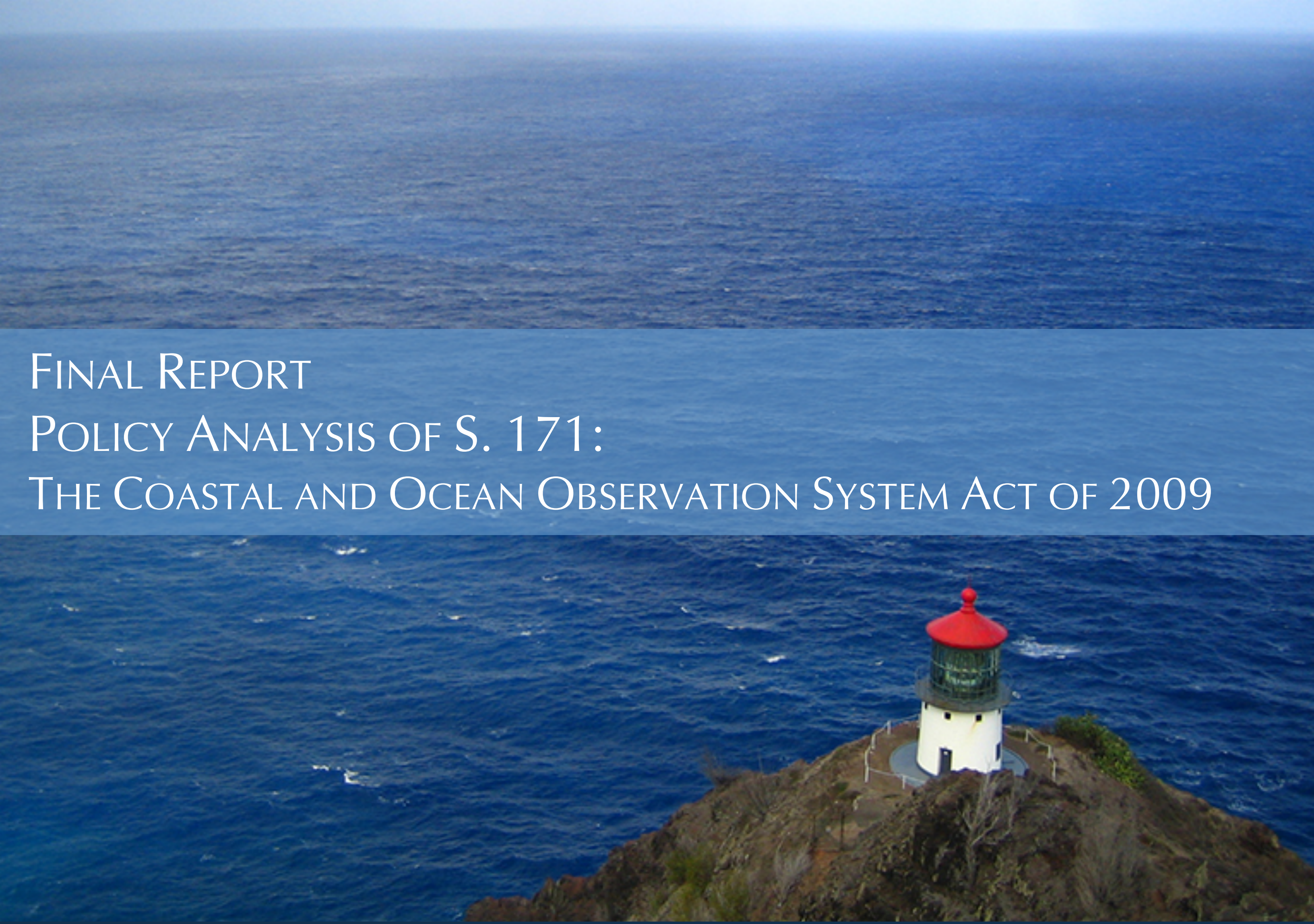

Final Report
Policy Analysis of S. 171:
The Coastal and Ocean Observation System Act of 2009

Summer Workshop in Applied Earth Systems Management

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Executive Summary

Evidence of worsening environmental problems, such as global climate change, marine biodiversity loss, and ocean-based threats, has alerted national leaders to the urgent need to improve data collection, integration, and modeling systems.[1] Global climate change is now unequivocal, as is evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.[2] There is already evidence that global warming leads to biodiversity loss and more severe storms. Improved data management can help experts to predict weather events more accurately, and can help to better assess the status of coastal ecosystems, which many Americans rely on for their livelihoods. A better understanding of marine, coastal, and Great Lakes systems will equip agencies to prevent and mitigate risks rooted in these environmental problems.

The Coastal and Ocean Observation System Act (S.171) authorizes an integrated national observation system to gather and disseminate data on a set of variables from the coasts, oceans, and Great Lakes. The Act would promote basic and applied research to improve observation technologies, modeling systems, and data management. S.171 would also require administrative restructuring to improve interagency communication and coordination.

S.171 would give the National Oceanic and Atmospheric Administration (NOAA) primary responsibility for the Integrated Coastal and Ocean Observing System (ICOOS) under the oversight of a designated committee ("the Committee"). In cooperation with the Committee, NOAA would develop a data management and communication system to integrate marine data collected across federal, state, and regional agencies, create a certification process for regional associations, and establish a process for administering grants and contracts to regional associations for data collection.[3] A budget for ICOOS would be set by NOAA and approved by the Committee.

Should this bill pass, the administrators of S.171 would likely encounter some implementation challenges, including complex challenges to data management and communication, as well as uncertainty regarding local, state, regional and private entities' willingness to participate. Measuring the effectiveness of the ICOOS would present another challenge. It is expected that the program would be monitored and evaluated by federal staff surveys, and measured against pre-determined evaluation indicators.

"The opportunity is here and the time to act is now. A new national ocean policy can be implemented that balances ocean use with sustainability, is based on sound science and supported by excellent education, and is overseen by a coordinated system of governance with strong leadership at national and regional levels."

-Final Report of the US Commission on Ocean Policy, 2003[4]

I. Challenges Addressed by S. 171

S.171 addresses a dual challenge. First, research has identified several interconnected environmental problems as threatening to public health and welfare, the economy, and ecological resources. Second, inadequacies in database information science, management structures, and communication hinder agencies' ability to mitigate the effects of environmental problems. These two challenges define the interrelated problems and solutions addressed by S.171.

S.171 authorizes the President to establish and maintain an integrated observation system to monitor ocean and coastal environments in an effort to enhance homeland security, support maritime operations, improve management of coastal marine resources, and increase accuracy and effectiveness of warnings about ocean-based threats. This report has focused its analysis on threats and solutions regarding global climate change, marine biodiversity, and ocean-based threats, as these are the fundamental research areas that should be investigated in order to best protect human and natural resources.

To address these environmental threats, S.171 authorizes the National Oceanic and Atmospheric Association (NOAA) to organize an interagency network of ocean-observing and communication systems along the Nation's coastlines. This project would present a unique challenge to improving the existing data management and interagency communication network.

II. Why Is Data Integration and Communication Necessary?

The oceans cover three-fourths of the globe's surface, yet relatively little is known about them. Changes in oceanic events over the past decades have highlighted three pressing environmental problems in marine and Great Lakes systems--changes in the climate system, a loss of biodiversity, and more intense and possibly more frequent ocean-based threats. Each of these problems has the potential to significantly impact American lives and livelihoods on a massive scale.

Federal agencies, including NOAA, US Fish and Wildlife, and the Army Corps of Engineers, collect data on twelve core variables to assess the state of our oceans. These variables include data such as: temperature, sea level, surface currents, dissolved nutrients, and pathogens (*see Appendix A for a full list*). Scientists in government and academia have created modeling tools that utilize these data, enabling government agencies to predict and respond to climate change, marine biodiversity loss, and ocean-based threats. However, these models cannot be successfully utilized unless data are integrated and disseminated to those that need it most. By improving data integration, scientists may better understand and predict environmental changes in oceans. By coordinating these data and disseminating them more rapidly, policymakers may craft policies that sustain and restore marine biota, aid marine navigation safety, and contribute to homeland security and economic development. Through new and improved policies, leaders can help to predict and respond to urgent environmental problems. Below is a more in-depth treatment of these environmental problems, existing data collection efforts, some relevant modeling tools, and a description of the missing link: data integration and communication.

Environmental Problem I: Global Climate Change

There is unequivocal evidence that our climate system is warming-- global average air and ocean temperatures are increasing, and as a result, polar ice cap and glacier melting is accelerating, and global average sea level is rising.[5] According to the Intergovernmental Panel on Climate Change (IPCC), global sea levels have risen at an average rate of 1.8 millimeters per year from 1960 to 2003.[6] Additionally, the increase in global sea surface temperatures results in thermal expansion of the oceans, which in turn contributes to the net rise in sea level. Furthermore, increases in ocean temperatures have been detected at depths of at least 3000m.[7] Additionally, polar ice caps are melting, contributing to this detected rise in sea levels. Based on satellite imagery data, the annual average Arctic sea ice extent has diminished by 2.7% per decade since 1978.[8] Although these changes to the climate system have been observed and measured, the implications of these changes are not fully understood. These facts suggest the urgency of mitigating global climate change, and the following case study will illustrate a local example of the significant effects of this environmental problem.

Case Study: Lobster Kills

Climate change is observably impacting coastal marine life. A dramatic example of such an impact occurred off the coast of Long Island, NY in the fall of 1999. As lobster pots were harvested that season, fishers found them to contain 95-99% dead lobsters.[9] This struck a blow to New York's fishing industry. The waters of the lobster habitat were tested for a range of contaminants including pesticides, herbicides, PCBs, and heavy metals. Test results were negative. Scientists found that the water temperature had increased by 1-2°C, and determined that this change was sufficient to drive lobsters to deeper waters. This exposed the lobsters to contaminants located in the sediment, which they normally would not have encountered. This migration had caused the lobster kill.[10] Although this devastating event happened off the coast of New York, it generated a large study by the State of Maine due to Maine's economic dependence on coastal and marine resources. Based on the results of this study, Senator Snowe (R-ME) used this lobster kill as a platform to launch S.171 in 2009.

Environmental Problem II: Marine Biodiversity Loss

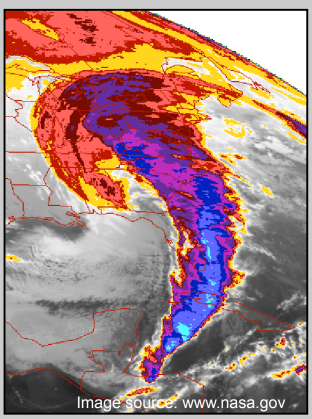
Marine biodiversity loss has resulted from the effects of ocean warming and associated sea level rise. The IPCC estimates that sea level could rise between 0.6 and 2 feet in the next century.[11] According to the US Environmental Protection Agency, approximately 5,000 square feet of dry land nationwide are within two feet of high tide.[12] Therefore, sea level rise could result in land loss through submergence, coastal erosion, coastal habitat displacement, and flooding.[13] Coastal areas are rich in unique wetland biodiversity, and would be altered and diminished in species richness as a result of sea level rise.

Another cause of marine biodiversity loss in recent decades has been the proliferation of marine algal blooms. The frequency of algal blooms (known as harmful algal blooms or HABs) has increased recently. Fertilizers and other highly nutrient-rich materials run off watersheds onto coastlines, oceans, and lakes. These nutrients can cause significant algal growth that, in turn, utilizes a large amount of the oxygen dissolved in the water, creating hypoxic (low-oxygen) or anoxic (extremely low-oxygen) conditions, toxic for many species. These conditions can result in toxin bioaccumulation in shellfish, and cause human illness through direct contact or ingestion of contaminated seafood.[14] Improved algal bloom prediction and monitoring would result in both public health and ecological benefits.

Over time, carbon dioxide absorption in the oceans has the potential to result in great changes in pH.[15] These changes would result in acidification of the ocean, which would substantially impact marine biodiversity, particularly coral reefs. A more acidic ocean would dissolve the calcium carbonate skeletons of coral reefs and deter formation of new coral skeletons.[16] This effect, in conjunction with increased oceanic temperature, variable salinity, and changing optical properties (as coral require particular light conditions), would result in mass bleaching of existing coral reefs and a reduced likelihood for habitat recovery. Coral reefs are valued not only aesthetically and economically, but also for the integral role they play in tropical ocean ecosystems.[17] Coral reefs are also an indicator of general ocean health and water quality, and degradation of this habitat suggests deleterious effects at higher trophic levels.

ENVIRONMENTAL PROBLEM III: OCEAN-BASED THREATS

More than half of the US population lives on or near the coasts.[18] Hurricanes, storm surge flooding, and tsunamis are significant threats to the lives and livelihoods of millions of Americans. In 2005 alone, hurricanes accounted for over $1B in damages and close to 2,000 deaths in coastal communities. Hurricanes are large cyclonic windstorms that form over tropical waters in the Atlantic Ocean. They are fueled by the latent heat energy released by condensing water vapor. The latent heat required for a hurricane's creation is only possible over warm, tropical oceans during summer.[19] Severe hurricanes can produce damaging winds, torrential rainfall, tremendous waves and massive flooding. In an effort to mitigate these destructive effects, scientists have modeled hurricane systems. Data collected over the past decades are now being used to forecast potential changes in hurricane frequency, intensity and location. Based on the latest IPCC projections, future hurricanes will likely become "more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures of about 0.5°C by 2200."[20] Modeling helps to mitigate potential damage, and can incentivize improved responses following an ocean-based threat. Better-integrated and more transparent information systems could help decision-makers take immediate actions to significantly mitigate the consequences of dangerous storms.



Case Study: The No-Name Hurricane

The No-Name Hurricane, also known as the Perfect Storm, struck New England on October 31, 1991. No warnings were issued prior to the hurricane's approach, and extensive damage resulted. There were 12 fatalities, and storm damage cost the federal government $208 million. It was not until after the storm that it was classified as a hurricane. A lack of available data factored into an inability to predict the hurricane.

S. 171 seeks to implement an integrated coastal and ocean observation system that would provide a more efficient transition from data collection to data utilization. Although great advancements have been made in the methods of oceanic data collection and the development of predictive models, there is still a lack of integration and standardization among government and research institutions that collect oceanic data. With better data integration and communication, the effects of storms such as the Perfect Storm of 1991 could be mitigated, saving not only livelihoods, but lives as well.

III. The Solution: An Integrated Coastal and Ocean Observation System

S.171 proposes to address climate change, biodiversity loss, and ocean-based threats by strengthening the Integrated Coastal and Ocean Observing System. This proposal stems from the recommendations of the US Commission on Ocean Policy in 2004, which underscored the need for the US to review and update its current database systems and management of national coastal systems and waterways.[21]

The solution proposed by S.171 recognizes that many integral components of a national coastal and ocean management system are already in place at the federal, state, and regional levels. Government agencies such as NOAA, the US Department of Commerce, the US Department of Defense, as well as independent research institutions, have made great advancements in methods of data collection and oceanic exploration. However, methods and data cannot be utilized to their full potential if agencies and institutions are not coordinating their efforts. S.171 proposes to maximize the benefits of oceanic research by:

- Transmitting information in a timely manner to those who need it for immediate and long-term planning and management decisions,
- Facilitating sharing and coordination among data-collection institutions, and
- Creating a standardized pool of data for use in predictive models.

A New Administrative Framework

An oversight body would be created to facilitate the integration and standardization of oceanic data. Such a body would oversee the agencies and associations involved in collecting oceanic data, establish and enforce standard methods for data collection, and implement a system for integration of data. S.171 proposes the creation of the Interagency Ocean Observation Committee ("the Committee") to execute these functions. The Committee would be responsible for these efforts and charged with establishing priorities for the ICOOS, and implementing them.[22]

As the leading national agency in oceanic research, NOAA would have primary responsibility for the functional implementation of this improved system, through the oversight of the Committee. NOAA's responsibilities would include:

- Technical and administrative oversight of the Committee,
- Development of a data management and communication system to integrate coastal and oceanic data collected across all state, regional, and federal agencies,
- Creation of a process for certifying regional associations to ensure compliance with mandated standards and protocol for data collection,
- Establishment of a process for administering grants and contracts to regional associations for data collection efforts, and
- Funding research on new data collection technologies.[23]

In addition to the Committee and NOAA, regional associations would also play an integral role in managing the collection of essential oceanic data, coordinating their efforts with other institutions, and making their data available for use by institutions that could benefit from it.

Existing Oceanic Exploration and Data Collection Elements

The benefits of access to continuous data observations of oceanic and atmospheric conditions have driven the development of new technologies such as satellites and ocean sensor buoys. The drive to understand unknown ocean territory has resulted in the development of vessels able to reach depths of more than 20,000 feet.[24] These technological advancements contribute to more accurate assessments of oceanic conditions, which in turn contribute to more accurate predictive models. The following are examples of data collection parameters and methods that would be particularly effective in the mitigation and prevention of the environmental problems described earlier, namely, global climate change, biodiversity loss, and ocean-based threats.

Data Utilization for Global Climate Change

Atmospheric general circulation models (AGCMs), coupled with oceanic general circulation models, form what is called Atmospheric-Oceanic General Circulation Models (AOGCMs). AOGCMs use knowledge of the major components of the climate system in conjunction with other measured components, such as sea ice models, to create full climate models. These models are used by scientists to study the response of the climate system to various scenarios. For example, such a model can illustrate how oceanic temperature increases would change ocean volume through thermal expansion.

Data Utilization for Biodiversity Loss

Several different types of robotic data-collection vehicles and undersea habitats for scientists are under development and in use by NOAA (*see Appendix B*). NOAA's Center for Coastal Monitoring and Assessment (CCMA) utilize these data to assess the condition of coastal ecosystems, forecast future ecological health, and evaluate potential management strategies and impacts on the ecosystem. An example of an integrated ecosystem assessment performed by CCMA is one completed for the Olympic Coast National Marine Sanctuary in Washington State. The goal of the assessment is to characterize oceanographic and climatic processes in this marine ecosystem. Some of the variables that CCMA has identified as necessary for understanding the environment and how it affects the ecosystem are: sea surface temperatures, ocean color, turbidity, surface current vectors, oceanographic fronts, and surface winds.

Data Utilization for Ocean-Based Threats

Tsunami forecast models aim to estimate wave arrival time, wave height, and inundation area resulting from a tsunami event. The Method of Splitting Tsunami (MOST) model is used by the NOAA Center for Tsunami Research to simulate three processes of tsunami evolution: earthquake, transoceanic propagation (wave generation), and inundation of dry land. MOST uses the parameters of bathymetry (ocean depth) and topographic data to develop coastal inundation maps. In addition to providing warnings of tsunamis, forecast modeling can be used to create coastal inundation maps, which are essential for long term planning of evacuation routes for coastal communities.

The Missing Link: Data Integration and Communication

Integration of oceanic data is important for two reasons:

- A large, integrated, standardized pool of oceanic data can provide more timely and accurate predictions from models, and
- Integrated data can be more efficiently communicated to those who need it for management and planning decisions.

The existing Integrated Ocean Observing System (IOOS) of NOAA is currently developing a data integration framework that aims to improve the management and delivery of the core oceanographic variables. A few examples of data delivery servers that are currently in their testing phase are described below. Because these databases integrate oceanic data collected from multiple sources and by multiple agencies, they serve as good examples of how an integrated observing system might function better after passage of S. 171:

- *National Data Buoy Center (NDBC) Sensor Observation Service* provides in-situ temperature, salinity, current, water level, wave and wind data from the NDBC moorings, Deep-ocean Assessment and Reporting of Tsunamis buoys, and Tropical Atmosphere Ocean (TAO) buoys.

- *Center for Operational Oceanographic Products and Services* provides in-situ temperature, conductivity, current, water level, and wave data from the National Water Level Observing Network and the Physical Oceanographic Real-Time System.

- *Southeast Coastal Ocean Observing Regional Association* provides many in-situ parameters, culling from a collection of other databases.

A current cooperative effort between NOAA and the US Coast Guard exemplifies how integrated data might be shared for multiple uses. New data sets are being compiled by NOAA that include surface current maps made from high frequency radar systems, a technology that measures speed and direction of ocean surface currents in "near real-time."[25] These data will feed directly into the Coast Guard data servers. The Coast Guard can then use these environmental data to perform search–and-rescue operations with greater accuracy. The surface current maps can also be used to address ocean-based threats; for instance, by monitoring oil spills or HABs.[26]

Case Study: Hurricane Warning System

Hurricane destructiveness has increased substantially since the mid-1970s.[27] Additionally, the IPCC predicts that storms will increase in intensity over the 21st century. Therefore, a national hurricane warning system is essential to enable appropriate government intervention and response.

Remediation of hurricanes, moreover, is costly. In September 2008, Hurricane Ike struck Galveston, Texas and caused $22 billion in damages. NOAA's National Data Buoy Center, Center for Oceanographic Products and Services, Climate Prediction Center, National Hurricane Center, as well as the Hurricane Research Division, the US Coast Guard, university research centers, and various regional associations are all collecting data relevant to hurricane warning.

Several tools are being used to collect data, including satellites such as the Geostationary Operational Environmental Satellite (GOES-O) and moored buoys. Variables collected include: sea surface temperatures, precipitation, wave height and wind speeds. Although some collaboration already occurs between agencies in order to integrate data, the Committee proposed by S. 171 would improve agency coordination by standardizing incoming data. Moreover, the central data collection agency that would be created by S. 171 would disseminate data more effectively and in a timelier manner. Overall, official data dissemination and more integrative models would help improve government response to hurricanes.

Data Integration and Communication

A key challenge of the existing observing system is improving data integration and communication, the focus of S.171. Data integration involves implementing a standardized system for data collection, as well as physically updating the information technology infrastructure in order to integrate data collected by different agencies and allow sharing among these agencies.

Although great advancements have been made in the methods of oceanic data collection and the development of predictive models, there is still opportunity for better integration and standardization of data. An improved data system such as that proposed by S. 171 would increase the knowledge base available for strategic planning.

IV. Shortcomings and Potential Implementation Challenges

With the passage of S. 171, administrators would likely encounter a number of implementation challenges, including those involving complex data management and communications as well as uncertainty as to the cooperation and participation of local, state, regional and private institutions. These two challenges are examined below.

Data Management and Communications

This legislation would establish a "standardized system of information dissemination and management on national and regional levels."[28] The Committee and NOAA would be responsible for developing a standard-setting process to build upon NOAA's pre-existing observing system. This process could become controversial because data-collecting entities may have to compromise on the types of data they report to the system.[29]

Defining clear guidelines and standards could result in issues of:

- Quality control,
- Different methodologies of scientific analysis,
- Different data-set versions,
- Inconsistent metadata products and services,
- Data discovery,
- Network data transport,
- Varied file formats, and
- Different data archiving methods.[30]

Unless a formal and comprehensive process for data management and communications is established and followed, mismatched methods of data collection and differences in data models could limit integration among data collectors. This might lead to data redundancies and gaps among institutions.

Uncertain Cooperation and Participation

Communication and collaboration among data collecting institutions and personnel are critical to the success of S.171. However, some institutions may be reluctant to collaborate due to security concerns or lack of staff and resources. S.171 would involve "regional associations of coastal and ocean observing systems," including federal, state, regional, and local government agencies, private corporations, non-governmental organizations, Tribal authorities, and universities.[31] When the IOOS was initially designed and implemented, some of the aforementioned entities were raised concerns about their respective roles in the planning process. Consequently, these associations were hesitant to participate and, as a result, the IOOS struggled to obtain sufficient funding.[32] A similar challenge could occur in the implementation of S.171.

The certification process proposed by S.171 would determine whether a regional association has "an organizational structure capable of supporting and integrating all aspects of a coastal and ocean observing and information program."[33] Subscription and compliance to a new, integrated system would be contingent upon the administrator's ability to achieve the desired interoperability while preserving the integrity of unique datasets and observation techniques.

V. Measuring Success

The challenge of S.171 is to integrate a high volume of complex information and to adroitly share the data with appropriate agencies under the National Ocean Research Leadership Council. This bill addresses this challenge by outlining the public policy and management aspects of data collection and integration. However, the bill does not clearly identify indicators that would be used to measure the success of data integration and distribution. This section focuses on the management tools and indicators that could potentially monitor the bill's effectiveness at improving a data integration system, and in improving administration of interagency communication to respond to environmental threats.

Participation and Compliance

The standards and protocols established by ICOOS would be a comprehensive, standardized guide for researchers and data providers. In terms of an evaluation process for the ICOOS, stakeholders would evaluate the ease of transitioning to the new standards set forth by ICOOS, and its ability to access and distribute information. This would be evaluated through annual surveys measuring parameters such as system utility, quality, and reliability. Identification of the number of data providers that adopt standards developed by the system would help to evaluate the system's effectiveness.

To measure success of regional associations, participating federal agencies would be surveyed on their overall satisfaction with the regional associations and whether associations share and integrate their data with the ICOOS. Identifying stakeholders, as well as identifying stakeholder data needs and measuring stakeholder satisfaction, will help to evaluate the effectiveness of regional association collaboration and communication.

Utilization of Best Practices and Technologies

The Committee will select effective technologies and methodologies to collect ocean, coastal and Great Lakes data. These technologies and subsequent data modeling systems must also include a successful combination of the twelve key scientific variables, and demonstrate their applicability to a wide range of needs. The Committee must apply standards to technologies and enable local- and federal-level compatibility of data collection and utilization methodologies. By measuring the number of new or improved methodologies that are developed, as well as by measuring the increase in adaptation and use of the centralized system, evaluators will be able to discern the effectiveness of new technologies.

Resiliency and Responsiveness of System

The Committee would be responsible for disseminating data into a management framework for public projects such as mitigation plans and warning systems. Once data are collected, the Committee would gauge their relevance, prioritize them, and channel them to participating agencies for utilization in a timely manner. These actions are expected to increase the resiliency of coastal, ocean and Great Lakes ecosystems, and mitigate the effects of climate change, biodiversity loss and ocean-based threats.

In addition to the indicators mentioned above, the Committee should evaluate the program based on questions such as:

- Do stakeholders find standardization and integration efforts necessary and useful?
- Do regional associations share information with other entities and federal agencies?
- Has the new database system improved data quality and access?
- Can the system be used for creating a disaster response management framework?

Evaluations of these questions should provide evidence as to whether the ICOOS and the Committee are successful, and highlight areas needing improvement. If the established system does not aid the appropriate agencies in mitigation and response to environmental threats, the framework will have to be restructured. This bill provides a long-term vision for better understanding and responding to oceanic, coastal and Great Lakes threats. Therefore, choosing a timeframe for measuring success would be an important decision to be made by participating government agencies.

VI. Looking Forward

The introduction of S. 171 represents a strong, activist approach to improve data integration and lack of administrative coordination of the Nation's marine and Great Lakes data, identified in 2004 by the US Commission on Ocean Policy.[34] Military and intelligence planners have been aware of the challenge posed by climate change for some years, but the current federal Administration has been the first to make it a policy focus.[35] This year (2009), the Pentagon and the State Department have begun to consider the effects of global warming in their long-term planning documents. Similarly, other government agencies should focus on improving data collection and management of our coasts, oceans, and Great Lakes. By proposing a new administrative structure to be led by a governing Committee and NOAA, S. 171 seeks measurable, science-based solutions to address environmental threats like climate change, marine biodiversity loss, and ocean-based threats. In doing so, the desired outcome is that implementation of S.171 would provide policy-makers with the tools they need to prevent and mitigate threats to our Nation's coasts, oceans, and Great Lakes. Whether or not this legislation will reach its goals depends on the effectiveness of its implementation.

APPENDIX A: TWELVE CORE DATA COLLECTION VARIABLES

- *Salinity* is the dissolved salt content of a water mass, often measured in parts per thousand (ppt). The average salinity of the world's oceans is approximately 35 ppt[36], but there can be considerable variations in salinity values spatially, temporally and vertically. Salinity values and ranges often determine organism and species distribution. Variations in salinity can therefore degrade ecosystem health. Salinity can be collected in real-time using a shipboard sensor instrumentation integrated with NOAA's Scientific Computer System (SCS).[37]

- *Temperature* is a measure of how warm or cold the ocean water is, typically recorded by buoys, but also collected via ships instrumentation. Ocean temperature monitoring is important for establishing trends related to global warming. This information is also used to monitor ecosystem health since some organisms and entire ecosystems (e.g., coral reefs) can only survive in a relatively narrow temperature range.

- *Bathymetry* is the measuring of bottom depth relative to sea level. The measurements are almost always derived indirectly by measuring the time required for a signal to travel from a transmitter located at the surface, to the bottom, and back to a receiver. This travel time is then converted to a depth based on a variety of estimations of the signal speed through the water column. Bathymetric data are useful in creating navigational charts important to all ships navigating oceans, the Great Lakes, and the Nation's coastal waterways.

- *Sea Level* is the average height of the sea measured between the crests and troughs of sea waves. The sea level data are important in terms of global warming. As water warms it expands, causing a rise in sea levels. In addition, the monitoring of fluctuating sea levels is essential in modeling the deleterious effect global warming may have on our nation's coastlines.[38]

- *Surface Waves* can be generated in any body of water by wind blowing horizontally across the water's surface. The measurement of sea waves is important to all ships navigating the waters. These data can be used to predict transport and distribution of organisms, nutrients, energy, and pollution.[39]

- *Surface Currents* are the manner in which water moves across the ocean's surface. Primarily, surface currents are driven by winds caused by the earth's rotation and its effect on wind directions. These data can be useful to predicting the distribution of organisms or migration pathways of pollutants. Surface currents influence sea-surface temperatures and the biological productivity of the oceans and can also be used to forecast ecological health bloom trajectory.[40]

- *Dissolved Nutrients* are chemicals dissolved in water that are important to the biology of oceans and the Great Lakes. Two primary nutrients are Nitrate (NO_3) and Phosphate (PO_4), which are essential to biological production.

- *Optical Properties* are the visible characteristics of the ocean, including light scatter and intensities, irradiance and radiance distribution, and clarity.[41] Measurements are taken by ocean profiling packages in a variety of units, including wavelength and degree of scatter. This information is used to determine general characteristics of the ocean environment required for ecological habitats.

- *Ocean Color* is a measurement of the ocean's visible and near-visible spectral optical characteristics from which variables (e.g., chlorophyll-A concentrations, turbidity, and dissolved organic matter) can be estimated. Measurements are taken by satellite and can be extrapolated to give information regarding primary productivity in the ocean.[42]

- *Bottom Character* describes the material composition of the ocean and lake floor (e.g., rock, sand, and mud). Benthic habitats are important food sources for fish and a profitable market and food source for humans.

- *Pathogens* are agents that cause disease, including microorganisms like bacteria, fungi, viruses, and parasites. They can enter the ocean via storm water runoff, sewage treatment plants, or illegal dumping, or they can already exist and proliferate under particular ocean conditions (e.g., harmful algal blooms). Pathogens, typically measured in parts per million (ppm), can bioaccumulate in marine species, including those harvested for human consumption. They can contaminate beaches and ocean water to unhealthy levels.[43]

- *Dissolved Oxygen* (DO) is a measure of oxygen (O_2) dissolved in the water. DO is often measured as milligrams per liter (mg/L).

APPENDIX B: UNDERSEA DATA COLLECTION

SUBMERSIBLE VEHICLES

- *Human Occupied Vehicles* (HOVs) are capable of carrying scientists to depths greater than 6,500 feet.

- *Remotely Operated Vehicles* (ROVs) are unmanned underwater robots controlled by a pilot and fitted with a camera, lighting and sampling systems, allowing scientists to be "virtually transported" to depths greater than 21,385 feet.

- *Autonomous Underwater Vehicles* (AUVs) are the most recent form of deep-sea technology. AUVs can be preprogrammed to conduct measurements and perform video surveillance. Because they are battery powered and controlled by computers, AUVs can be operated at depths, ranging distances, and over time spans that couldn't be economically achieved using human-guided vehicles. The most recent AUVs used by NOAA are capable of reaching depths of 7,217 feet.

- *NOAA Aquarius* is an undersea habitat located at a depth of 64 feet below sea level, at the base of a coral reef in the Florida Keys National Marine Sanctuary. Aquarius provides life support systems that allow up to four scientists and two technicians to live and work underwater for missions lasting up to 30 days. In this amount of time, scientists are able to obtain ten times the research that they can normally achieve through conventional surface-based dives.

References

1 Panetta, Leon E., chair. "America's Living Oceans: Charting a Course for Sea Change. A Report to the Nation." Recommendations for a New Ocean Policy, May 2003. Pew Oceans Commission.

2 Intergovernmental Panel on Climate Change, "2007: Summary for Policymakers." In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY.

3 S.171. Coastal and Ocean Observation System Act of 2009. Library of Congress. Accessed on August 2, 2009, from http://thomas.loc.gov/cgibin/bdquery/z?d111:SN00171:@@@L&sum2=m&/.

4 Panetta, Leon E., chair. America's Living Oceans: Charting a Course for Sea Change. A Report to the Nation. Recommendations for a New Ocean Policy, May 2003. Pew Oceans Commission.

5 Intergovernmental Panel on Climate Change. "Climate Change 2007: Synthesis Report." Accessed on August 2, 2009, from http://www.ipcc.ch/ipccreports/ar4-syr.htm.

6 *Ibid.*

7 *Ibid.*

8 *Ibid.*

9 Ain, Stewart. "Threat to Lobster Way of Life." New York Times. December 19, 1999. Accessed on August 2, 2009, from http://www.nytimes.com/1999/12/19/nyregion/threat-to-lobster-way-of-life.html?pagewanted=all.

10 Pearce, Jack et al. "The 1999 Long Island Sound Lobster Mortality Event: Findings of the Comprehensive Research Initiative." Journal of Shellfisheries Research Oct 2005. Accessed on August 2, 2009, from http://findarticles.com/p/articles/mi_m0QPU/is_3_24/ai_n15800370/.

11 Intergovernmental Panel on Climate Change. "Climate Change 2007: Synthesis Report." Accessed on August 2, 2009, from http://www.ipcc.ch/ipccreports/ar4-syr.htm.

12 Environmental Protection Agency. "Coastal Sensitivity to Sea Level Rise: A Focus on the Mid-Atlantic Region." Accessed on August 1, 2009, from http://www.epa.gov/climatechange/effects/coastal/index.html.

13 Environmental Protection Agency. “US Climate Change Science Program.” Accessed on July 9, 2009, from http://www.epa.gov.

14 National Oceanic and Atmospheric Administration. “Harmful Algal Blooms Observing System.” Accessed on August 3, 2009, from http://habsos.noaa.gov/.

15 Caldiera, Ken, and Michael Wickett. “Anthropogenic Carbon and Ocean pH.” Nature 425(2003): 365.

16 Schenider, Steven. ”The Worst Case Scenario.” Nature 458(2009): 1105.

17 Hoegh-Guldberg, Ove. “Climate Change, Coral Bleaching and the Future of the World.” Marine and Freshwater Research 50(1999): 839-866.

18 Crossett, K. M., T. J. Culliton, P.C. Wiley, T. R. Goodspeed. “Population Trends Along the Coastal United States.” 1980-2008. Coastal Trends Report Series. NOAA, National Ocean Service, Management and Budget Office, Special Projects, 2004.

19 Philander, George S. “Is the Temperature Rising?:The Uncertain Science of Global Warming.” Princeton, NJ: Princeton University Press, 1998.

20 Intergovernmental Panel on Climate Change. “Climate Change 2007: Synthesis Report.” Accessed on July 10, 2009, from http://www.ipcc.ch/ipccreports/ar4-syr.htm.

21 An Ocean Blueprint for the 21st Century: Final Report of the US Commission on Ocean Policy. Executive Summary.

22 S.171. Coastal and Ocean Observation System Act of 2009. Library of Congress. Accessed on August 4, 2009, from http://thomas.loc.gov/cgibin/bdquery/z?d111:SN00171:@@@L&summ2=m&/.

23 *Ibid.*

24 National Oceanic and Atmospheric Administration. “Underwater Technology and Development.” Accessed on August 5, 2009, from http://explore.noaa.gov/advanced-underwater-technology.

25 National Oceanic and Atmospheric Administration. “NOAA, US Coast Guard: New Ocean Current Data to Improve Search and Rescue Activities.” Accessed on May 4, 2009, from http://www.noaanews.noaa.gov/stories2009/20090504_ioss.html.

26 *Ibid.*

27 Intergovernmental Panel on Climate Change. “Frequently Asked Question 3.3: Has there been a Change in Extreme Events like Heat Waves, Droughts, Floods and Hurricanes?” Accessed on August 7, 2009, from http://ipcc- wg1.ucar.edu/wg1/FAQ/wg1_faq-3.3.html.

28 S.171. Coastal and Ocean Observation System Act of 2009. Library of Congress. Accessed on August 4, 2009, from http://thomas.loc.gov/cgibin/bdquery/z?d111:SN00171:@@@L&summ2=m&/.

29 National Oceanic and Atmospheric Administration. ”IOOS-DMAC Guidelines/Standards Adoption Process.” Silver Springs, MD: GPO, 2006.

30 *Ibid*.

31 The National Office for Integrated and Sustained Ocean Observations. “Regional Coastal Ocean Observing Systems. Accessed on August 4, 2009, from http://www.ocean.us/coastal_component/.

32 US Commission on Ocean Policy. Preliminary Report. Governor’s Draft, Washington, DC, 2004.

33 S.171. Coastal and Ocean Observation System Act of 2009. Library of Congress. Accessed on August 4, 2009, from http://thomas.loc.gov/cgibin/bdquery/z?d111:SN00171:@@@L&summ2=m&/.

34 Panetta, Leon E., chair. “America's Living Oceans: Charting a Course for Sea Change.” A Report to the Nation. Recommendations for a New Ocean Policy, May 2003. Pew Oceans Commission.

35 Broder, John M. “Climate Change Seen as Threat to National Security.” New York Times. August 8, 2009. Accessed on August 9, 2009, from http://www.nytimes.com/2009/08/09/science/earth/09climate.html?_r=1&scp=1&sq=Climate%20Change%20Seen%20as%20Threat%20to%20National%20Security&st=cse.

36 Kump, Lee R., James F. Kasting, and Robert G. Crane. “The Earth System.” 2nd. Upper Saddle River, NJ: Pearson Education, 1999.

37 US Department of Commerce. “NOAA. Shipboard Sensor Database (SSD).” Accessed on August 4, 2009, from http://www.nodc.noaa.gov/ssd/.

38 Houghton, John. “Global Warming.” 4th. Cambridge: University Press, 1994.

39 Kump, Lee R., James F. Kasting, and Robert G. Crane. “The Earth System.” 2nd. Upper Saddle River, NJ: Pearson Education, 1999.

40 *Ibid*.

41 Maffione, Robert. “Evolution and Revolution in Measuring Ocean Optical Properties.” Oceanography 14.3(2001): 9-14.

42 National Aeronautics and Space Administration. “Ocean Color.” Accessed on August 4, 2009, from http://oceancolor.gsfc.nasa.gov/.

43 National Oceanic and Atmospheric Association. “National Ocean Service Education.” Accessed on August 4, 2009, from http://oceanservice.noaa.gov/education/kits/estuaries/media/supp_estuar09c_pathogens.html.