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The Mid-Atlantic Regional Coastal Ocean Observing System (MARCOOS):

Economic Estimate of Benefit Pathways

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Disclaimer:
This paper illustrates and, where possible, measures the economic value of information generated by MARCOOS. Information from ocean observing systems (OOS) is extremely difficult to measure in monetary terms, and attempting to trace and measure all pathways of actual or potential benefits is prohibitively costly. As a result, earlier attempts to assign value to OOS information employ simple "rules of thumb". In the United States, such attempts include the development by NOAA of an IOOS Business Case in 2008, and a set of studies that estimate regional OOS systems in other parts of the United States that were published as peer reviewed papers in a 2008 issue of *Coastal Management*. This paper describes these rules of thumb that have become the default methodology for assigning dollar values to OOS information, reviews previous applications of them, and uses them to estimate the value of MARCOOS information. The results presented here are consistent with the results of previous applications using the same approach, but should still be viewed as first-order approximations of the benefits of MARCOOS information in selected sectors in the MARCOOS region. A more comprehensive assessment of benefit pathways and applications of more precise valuation methodologies, if that ever becomes affordable, could result in higher or lower benefit estimates than those presented here.

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EXECUTIVE SUMMARY

This report examines and attempts to estimate the economic value of ocean information generated as part of a multi-institutional effort funded by the National Oceanic and Atmospheric Administration (NOAA) called the Mid-Atlantic Coastal Ocean Observing System (MARCOOS).

The ocean area covered by MARCOOS reaches from Cape Cod, Massachusetts in the north to Cape Hatteras, North Carolina in the South and encompasses nine states, 66 million people, four major estuaries (including the world's largest estuary), many military bases (including the world's largest Navy base), and several important seaports (including the second largest U.S. port). MARCOOS provides data on ocean currents, winds, temperature, salinity, barometric pressure and digital images of the shoreline using high-frequency radar and deployed gauges. In the private sector, routine or occasional end users of this information include energy, transportation, fishing, and aquaculture industries; public sector users include ocean and coastal resource managers, emergency managers, leaders of search and rescue operations, homeland security/national defense staff, research, and education.

This report will use available data to attempt to quantify the value of MARCOOS information for these sectors, building upon approaches used in previous studies in other regions. Since at least the mid-1980s, researchers who have attempted to develop estimates of the overall economic value of weather and climate observations have concluded that it is too difficult and costly to trace and measure all the relevant benefit pathways with precision (Nordhaus 1986, IOOS 2008). With the advent of the Integrated Ocean Observing System (IOOS) and its regional U.S. components, including MARCOOS, a number of studies have attempted to trace and quantify economic benefits along various pathways on a regional scale (Dumas and Whitehead 2008; Kite-Powell and Colgan 2001; Kite-Powell, et al. 2008; Lynch et al. 2008; Pendleton 2008; Richert et al. 2008; Wellman and Hartley 2008).

A review of this literature indicates that while many provide illustrations of how ocean observing systems generate some values, nearly all of them eventually rely on “rules of thumb” based on results of previous studies indicating that the availability of data from ocean observations increases the value (or decreases the cost) of goods and services linked to affected economic sectors on the order of one percent. As crude as such a rule of thumb is, it has been generally accepted by those who have made an attempt to develop more precise estimates and concluded that the time and effort required would be prohibitively expensive. Because our research resulted in the same conclusion, the economic benefit estimates presented in this report for many sectors follow the “one percent rule” valuation method. The availability of ocean observations that allow decision makers to take advantage of favorable ocean and weather conditions and avoid unfavorable conditions, in other words, is assumed to result in a 1% increase in the dollar value of the output generated by affected ocean/coastal sectors (or lower the costs of producing them by one percent). This follows the methodology used for estimating the benefits of regional ocean observation systems that was used in many of the articles in a special peer-reviewed issue of *Coastal Management* devoted to the topic in 2008.

In this report, we focus primarily on seven sectors: energy (offshore wind energy), transportation (commercial marine shipping and the cruise industry), fishing (commercial and recreational), coastal resource management (recreational boat use, beach use, and beach nourishment), ocean resource management (aquaculture), emergency management (storm response), and at-sea search and rescue operations.

Applying the rule of thumb described above to the output value or input costs of most sectors/end users in the MARCOOS "information value chain," we estimate that the annual value of MARCOOS information, including reduced costs and/or risks and increased benefits, is on the order of approximately $255 million. For specific sectors, these benefit estimates include, for example, an estimated $10 million in annual benefits to commercial fisheries due to higher allowable harvests; $5 million in annual benefits to the commercial shipping industry because of reductions in transit time, fuel, and labor costs; and $1 million in benefits to beach-nourishment efforts due to more efficient project design and scheduling. Once adjusted for relative size of various sectors in the MARCOOS region compared to other IOOS regions, these estimates, not surprisingly, are comparable to value estimates published in the 2008 special issue of *Coastal Management*.

It is important to emphasize that these are first-order approximations of benefits to selected sectors only; and that a more comprehensive assessment of benefit pathways in these sectors could result in higher or lower benefit estimates. However, the inclusion of some sectors that could not be addressed as part of our analysis would most certainly increase overall benefit estimates. Some of the information presented in this report indicates that if a detailed and comprehensive analysis of MARCOOS benefits were conducted, a task that would be enormously costly and time consuming, the resulting estimate of annual MARCOOS benefits would exceed the roughly $255 million that were developed using rules of thumb in this brief study.

TABLE OF CONTENTS

EXECUTIVE SUMMARY ii
TABLE OF CONTENTS iv
LIST OF FIGURES vi
LIST OF TABLES vii
INTRODUCTION 1
  IOOS Background 1
  MARCOOS Region 2
  Cost of Risk and Value of Information 2
FOCUS 4
  Energy Industry 6
  Transportation Industry 6
    Marine Transportation 6
    Shore-based Transportation 6
  Fishing Sectors 7
    Commercial Fishing 7
    Recreational Fishing 7
  Ocean Resource Managers 7
    Fisheries 7
    Aquaculture 8
    Marine Mammals and Endangered Species 8
    Habitat Conservation/Restoration 8
  Coastal Resource Managers 8
    Beach Use 8
    Recreational Boating 8
  Emergency Managers 9
    Health and Safety 9
    Storm Response 9
    Spill Response 9
  Search and Rescue 9
  Homeland Security/National Defense 9
  Research 10
  Education 10
LITERATURE REVIEW 10
  Economic Value from Regional Ocean Observing Systems 12
    The Gulf of Maine: 12
    Southeast Atlantic Case Study 12
    Florida Case Study 13
    California Case Study 14
    Alaska Case Study 14
USE AND ECONOMIC BENEFITS 15
  Energy Industry 15
  Transportation Industry 18
    Commercial Marine Shipping 18

Cruise Industry 18
Fishing Sectors 19
Commercial 19
Recreational 21
Ocean Resource Managers 21
Fisheries 21
Aquaculture 22
Marine Mammals and Endangered Species 23
Coastal Resource Managers 23
Recreational Boating 23
Beach Use 23
Beach Erosion 25
Beach Nourishment 25
Emergency Managers 26
Storm Response 26
Spill Response 28
Spill Response 28
Search and Rescue 29
CONCLUSIONS 31
REFERENCES 33

LIST OF FIGURES

Figure 1. Map of the MARCOOS Region showing major ports. 3
Figure 2. The ocean value chain. Source: NOAA 2008. 11
Figure 3. Wind energy potential in the United States, showing the MARCOOS region in the "outstanding" category (Source: AWEA 2008). 17
Figure 4. Wind development needed by 2030 to reach 20% wind energy goal (Source: AWEA 2008). 17

LIST OF TABLES

Table 1. Users and potential users of MARCOOS data and related work products. 5
Table 2. Potential wind energy generation in the Mid-Atlantic region (Sources: AWEA; Robinson and Musial 2006) 16
Table 3. Annual maritime commercial shipping benefits in the MARCOOS region. 18
Table 4. Annual recreational cruise industry benefits in the MARCOOS region. 19
Table 5. Annual commercial fishing values in the MARCOOS region (Source: Hagan, King and Price 2009). 20
Table 6. Daily commercial fishing values in the MARCOOS region. 20
Table 7. Recreational fishing trip benefits in the MARCOOS region. 21
Table 8. Responses to survey of fishery scientists conducted by Hagan, King and Price (2009). 22
Table 9. Annual value of aquaculture production in the MARCOOS region. 22
Table 10. Annual benefits of recreational boating in the MARCOOS region. 23
Table 11. Annual benefits of beach use in the MARCOOS region. 25
Table 12. Annual benefits of beach erosion prevention in the MARCOOS region. 25
Table 13. Value of annual beach nourishment benefits in the MARCOOS region. 26
Table 14. Hurricane prediction benefits in the MARCOOS region (using Hurricane Isabel as an example) 28
Table 15. Fatalities during Hurricane Isabel. 28
Table 16. Annual oil spill response benefits in the MARCOOS region. 29
Table 17. Annual value of search and rescue benefits in the MARCOOS region. 30
Table 18. Summary of MARCOOS benefits. 32

INTRODUCTION

IOOS Background

The Integrated Ocean Observing System (IOOS) provides continuous, quality-controlled ocean monitoring data collected at numerous geographic locations by collaborating organizations (National Office for Integrated Ocean Observations 2006a). By linking three subsystems – data analysis and modeling, data management and communications, and observations and data telemetry – IOOS brings an enormous amount of information together in an efficient, streamlined, and accessible resource. As part of the Global Ocean Observing System (GOOS) and Global Earth Observation System of Systems (GEOSS), IOOS provides a national and global infrastructure for many different users to monitor coastal and ocean environments (IOOS 2009). Ocean and coastal resource managers benefit from information about ocean conditions that affect fish larval transport and mortality. Emergency responders, such as at-sea search and rescue teams, use wind and current data to locate targets. Scientists who study ocean and coastal ecosystems, policy makers who manage them, and educators and the general public all have access to IOOS information and benefit from using it in various ways.

More specifically, IOOS provides information and data to help achieve seven national goals: 1) Improve predictions of climate change and weather and their effects on coastal communities and the nation; 2) Improve the safety and efficiency of maritime operations; 3) Allow more effective mitigation of the effects of natural hazards; 4) Improve national and homeland security; 5) Reduce public health risks; 6) Allow more effective protection and restoration of healthy coastal ecosystems; and 7) Enable the sustained use of ocean and coastal resources (IOOS 2009).

IOOS was first conceived and implemented in the 1990s as a way to increase the value of physical and environmental observations about ocean conditions. In 1990, the Intergovernmental Oceanographic Commission passed a resolution establishing GOOS. The U.S. began taking the first steps to establishing their own GOOS in 1992 and by 2000, IOOS planning and development had begun in earnest between NOAA, the National Science Foundation (NSF), National Aeronautics and Space Administration (NASA), the U.S. Geological Survey (USGS), the Department of Energy (DOE), the U.S. Coast Guard (USCG), the Army Corps of Engineers (USACE) and Environmental Protection Agency (EPA). In 2003, the structure and function of the regional associations (RCOOS) and their contribution to the U.S. IOOS were established. Over the next several years, various workshops and reports at the regional, national and international level helped prepare the IOOS program. In February 2007 NOAA launched the official IOOS program and in March 2009, the President authorized it as a formal program.

In 2010 there are eleven regional associations that comprise the IOOS network: 1) Alaska, 2) Pacific Northwest, 3) Central and Northern California, 4) Southern California, 5) Hawaiian Islands, 6) Great Lakes Region, 7) Gulf of Mexico, 8) Caribbean, 9) Southeast, 10) Mid-Atlantic, 11) Northeast. Each region operates its own Regional

Coastal Ocean Observing System (RCOOS) that provides data relevant to stakeholders in that region (The National Office for Integrated Ocean Observations 2006a).

This report focuses on the Mid-Atlantic Regional Coastal Ocean Observing System (MARCOOS) which is part of the Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA), one of the eleven regional associations listed above that comprise IOOS.

MARCOOS Region

MARCOOS was formed within MACOORA in order to "to generate quality controlled and sustained ocean observations and forecasts that fulfill user needs." There are many different users and user needs in the MACOORA/MARCOOS region which reaches from Cape Cod, Massachusetts to Cape Hatteras, North Carolina (See Figure 1). The MARCOOS region encompasses nine states, 66 million people, four major estuaries (including the world's largest estuary), many military bases (including the world's largest Navy base), and several important seaports (including the second largest U.S. port). The region also contains some of the most actively used coastal beaches and recreational boating areas in the United States. All of these industrial, military, and recreational activities are affected in one way or another by ocean and coastal sea conditions and the impacts of wind, surge, tides, currents, and precipitation. Decision-makers involved in all these activities, therefore, are active, occasional, or potential users of information provided by MARCOOS.

There are several sub-regional groups within MARCOOS, including the Chesapeake Bay Observing System (CBOS), Long Island Sound Coastal Observatory, Coastal Ocean Observation Lab (RU COOL), and New York Harbor Observing and Prediction System (NYHOPS). MARCOOS' goals are to support MACOORA's efforts in coastal inundation and water quality, while also focusing on their own themes of maritime safety and ecological decision support. MARCOOS coordinates existing observational, data management and modeling assets to generate and disseminate real-time data, now-casts and forecasts of the ocean (MARCOOS 2008).

Cost of Risk and Value of Information

Our analysis of the potential value of MARCOOS information is ultimately an assessment of how it can be used to manage risk. Defined generally as the volatility of potential outcomes, risk cannot always be controlled, but information can sometimes be used to improve how risk and exposure to risk are managed. What is generally called "integrated risk management" is a three step process that includes 1) managing controllable risk, 2) monitoring leading indicators of uncontrollable risk, and 3) modifying decisions when a leading indicator of uncontrollable risk meets some predefined threshold. All three steps require the collection and analysis of information. In the final analysis, however, the value of information depends on how information can be used at various stages to make or modify decisions in ways that either reduce costs or risks or increase some measure of benefits.

If decision-makers are aware of how information can be used to reduce costs or increase benefits, one potential measure of the dollar value of information is the amount of money they are willing to pay for it (Katz and Murphy 1987). However, information is actually only valuable if it changes the actions the decision-maker takes, and if those actions lead to benefits or cost reductions that offset the cost of acquiring and using the information. At some point, therefore, the cost of acquiring and interpreting additional information will exceed the marginal value of that information and some kind of cost/benefit trade off must be made (Anderson et al. 2003).

To understand the benefits of ocean-observing systems, and to justify continued public investment in them, attempts have been made to demonstrate and, where possible, quantify and monetize the value of the information they generate. As a result, a small body of literature has emerged that deals with methods of tracing how this information is used, and estimating the value of IOOS in general, and of various regional observing systems that are part of IOOS. In some cases studies have been used to estimate the value of specific upgrades or expansions of those systems.

In general, these studies first trace and measure how data from observing systems are used to generate information that improves two kinds of decisions: those made in industrial/commercial sectors, such as commercial and recreational fishing, shipping, offshore energy, beach use, and tourism; and those made in the public sector, such as improving search-and-rescue operations and oil spill responses and better identifying sources and expected distributions of contaminant and harmful algal blooms. The value of the data is then measured by comparing how those improved decisions result in higher benefits or lower costs and/or risks.

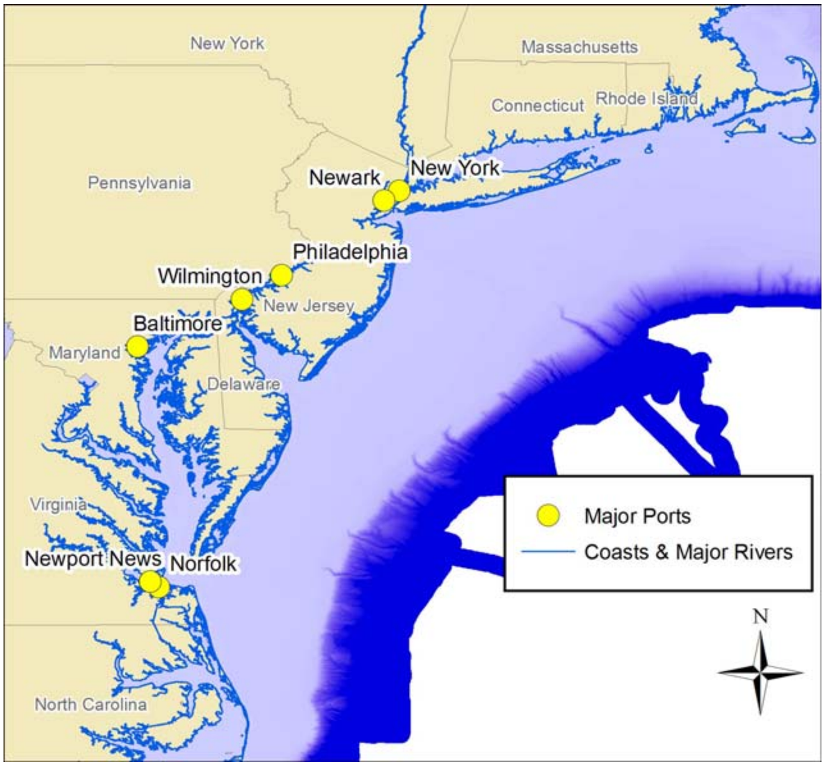


Figure 1. Map of the MARCOOS Region showing major ports.

FOCUS

This report examines various sectors that use data from IOOS and how they might benefit from the additional information provided by an IOOS network in the MARCOOS region (See Table 1).

Table 1. Users and potential users of MARCOOS data and related work products.

Energy Industry	a) Shore-based (facilities/equipment at risk) b) Offshore (rigs, wind/wave energy)
Transportation Industry	a) Shore-based (ports, roads, waterways) b) Offshore (ships)
Fishing Sectors	a) Commercial (search efficiency/vessel safety) b) Recreational (search efficiency/vessel safety)
Ocean Resource Managers	a) Fisheries (population dynamics, migrations, etc.) b) Aquaculture (location decisions/risk assessment) c) Marine Mammals (threats, resiliency, migrations) d) Endangered Species (threats, resiliency, migrations) e) Habitat Conservation/Restoration
Coastal Resource Managers	a) Beach Use (closures/openings) b) Recreational Boating (safety at sea, improved planning) c) Other Coastal Recreation (better planning, less risk)
Emergency Managers	a) Health and Safety (plumes) b) Storm Response (surge, waves, inundation) c) Spill Response (targeting containment/clean up efforts)
Search and Rescue	a) Assessing Risks (before and during operations) b) Targeting Operations (reduced search time) c) Managing Operations (manpower/asset deployment
Homeland Security/National Defense	a) Vulnerability Assessments b) Response Planning
Research	a) Climate Change b) Other
Education	a) K-12 b) Undergraduate/Graduate

Energy Industry

MARCOOS ocean observations have a number of important applications for the energy industry and many more potential applications associated with new and future investments in various types of renewable energy. For onshore power production and delivery, more precise weather forecasts or severe weather alerts provide important benefits by preventing damage to power plants themselves (Willis 2008) and by allowing energy companies to pre-position trucks and personnel to deal more efficiently with threats to their infrastructure. This information also allows them to restore power more quickly, limiting the impact to their customers. Also, offshore oil and gas companies use improved ocean and weather data to make decisions that minimize damage to drilling infrastructure and from potential spills (IOOS 2008).

Research into alternative energy sources, such as wind and wave energy, will also benefit from MARCOOS data. For example, currently there are gaps in the knowledge of the offshore wind field which require a significant amount of modeling and correlation extrapolation to fill (Atkinson et al. 2009). Existing wind observations and data supplied by MARCOOS can be used in running these models and calculations, which in turn determine the optimal placement of wind turbines in off-shore wind farms. MARCOOS data can also be used to help determine if any adverse or, perhaps, positive ecological changes should be expected to result from various types of proposed ocean energy projects.

Transportation Industry

Marine Transportation

NOAA's National Ocean Service (NOS) offices, such as the Office of Coast Survey, supply electronic navigation charts, coast pilots, and navigation response teams to meet the increasing challenges associated with marine navigation. IOOS can provide real-time observations and predictions of water levels, coastal currents, and other meteorological and oceanographic data for these marine transportation products (NOAA 2009).

Shore-based Transportation

Many ports are currently instituting new navigation systems that maximize cargo loads and rely on the availability of real-time tides and currents, as well as other ocean information. One additional foot of draft may allow for an increase in vessel-profit of between $36,000 and $288,000 for each trip. Knowledge of the currents, water levels, winds, and density of the water can increase the amount of cargo moved through a port and harbor by enabling mariners to safely utilize every usable inch of dredged channel depth (NOAA 1999). Enhancing marine forecasts of winds and waves saves up to $95 million/year for commercial shipping based on transit time savings and cargo loss reductions (NOAA 2004a).

Real-time data can assist boaters (and sometimes cargo ships) in determining if water level/currents are favorable in waterways. This prevents accidents (groundings, collisions) and decreases the response time to such accidents (e.g., oil spills) (USCG

2007). Ocean data can also help estimate flooding potential along coastal roads, which can save time and money when constructing roadways.

Fishing Sectors

Commercial Fishing

Fisheries-related economic values of MARCOOS data are increasing rapidly for five reasons: 1) Growing interest in "ecosystem-based fishery management" and "spatial planning of ocean uses" that require more information about variability in ocean conditions; 2) Expectations that changing ocean conditions associated with global warming will significantly affect fish population dynamics and the abundance, availability, catchability, and spatial distribution of fish stocks; 3) Improvements in computing capacity, data storage and retrieval systems, and web-based communication are dramatically reducing the cost of using ocean observations in fishery research and allowing it to be analyzed more effectively and incorporated more usefully in fishery science; 4) Coupled physical-biological models that require ocean observations are evolving quickly and proving their value in many fishery applications that directly affect fishery values; and 5) Real-time observations about ocean conditions are easily accessible on-line to fishermen and allow them to find targeted fish stocks more effectively which reduces search time and related costs and energy use and also allows them to minimize by-catches of at-risk fish stocks, marine mammals, and sea birds (Hagan, King and Price 2009).

Recreational Fishing

Ocean data can be used by recreational and charter boats to decide when and where to operate in order to avoid dangerous conditions and improve search and catch efficiency. They can also use real time data about ocean conditions to improve their fishing success, and to target desirable species and avoid incidental catches of prohibited or undesirable species.

Ocean Resource Managers

Fisheries

Changes in ocean conditions can have an enormous impact on the survival of fish eggs and larvae, the abundance and distribution of fish stocks, and the availability of fish stocks to fishing gear and the catchability of fish. As a result, there are many reasons to expect that observations about changing ocean conditions would be useful as "leading indicators" of fishery conditions that can be used to establish and, where necessary, adjust fishery management decisions. However, physical and environmental data are not usually used in fishery models and are only rarely used to interpret or predict changes in catch per unit effort statistics. As a result, misunderstandings about ocean-fish interactions are a significant and chronic source of uncertainty in fishery science and fishery management (Hagan, King and Price 2009).

Aquaculture

Aquaculture in the MARCOOS region (including shellfish, salmon, etc.) would greatly benefit from access to real-time water quality data. For example, elevated temperatures can increase mortality in oysters as well as trigger outbreaks in bacteria (National Estuarine Research Reserve System 2007). Spawning can also be triggered by elevated temperatures. As temperature increases, the resistance of oysters to low salinities decreases, as well. Dissolved oxygen, turbidity, chlorophyll and pH are all other parameters that affect aquaculture success and can be provided by IOOS.

Marine Mammals and Endangered Species

A major threat to large marine mammals is the collision with ships in coastal marine transportation corridors along the MARCOOS region. IOOS data such as wind speed, air and water temperature and tide elevation can all help support the management of shipping waterways that are also home to large marine mammals (Raytheon Corporation 2006). For example, NOAA has recently instituted a plan to reduce ship strikes of the endangered North American right whale. Water quality data provided by IOOS can also assist ocean resource managers in determining marine mammal migration routes and patterns.

Habitat Conservation/Restoration

IOOS data can help define environmental patterns and variations that in turn can assist ocean resource managers in making and implementing ecosystem-based management decisions (NOAA 2008). Information on fish populations, storm and weather data and water quality can all help in the management of marine protected areas (MPAs). IOOS data can be especially useful when initially designating an area as an MPA.

Coastal Resource Managers

Beach Use

Beach closures are often a direct result of poor water quality within a region. Water quality data provided by IOOS allow coastal resource managers to more accurately and efficiently make beach closure decisions (National Office for Integrated and Sustained Ocean Observations 2006b). This reduces human health risk from exposure to unsafe beaches as well as reduces economic loss from unnecessary beach closures. Other data provided by IOOS that contribute to beach closures include wave, wind and current information.

Recreational Boating

Recreational boaters will benefit from wave speed and direction, as well as wind data from IOOS (IOOS 2009). Real-time data will allow boaters to make safer decisions and plan trips according to IOOS spatial and temporal data.

Emergency Managers

Health and Safety

Weather data from IOOS can be expected to lead to improve predictions of when and where severe weather events will occur, thus allowing more time to get people out of harm's way. IOOS data will also allow for earlier and more accurate predictions of environmental hazards (e.g. harmful algal blooms), thus allowing decision-makers to take earlier and more targeted action to prevent human exposure to these hazards (Pendleton 2008). Protection of water quality and in turn public health can also be achieved through the delivery of real-time IOOS data.

Storm Response

IOOS data will provide climate variability information, thus providing more accurate data on storm surges and inundation (NOAA 2004b). This will allow emergency managers to be better prepared with a faster response and earlier mitigation actions.

Spill Response

By providing real-time surface current data, IOOS can assist in response and trajectory forecasting to accurately predict the fate and transport of oil or chemical spills (IOOS 2008).

Search and Rescue

Real-time IOOS data such as weather conditions and wave heights allow search and rescue teams to assess accurately the risks involved with any given search and rescue mission before and during operations (IOOS 2008). This also helps teams in managing operations, so that they can determine the manpower needed for a particular mission. Data such as surface current speed and direction allow search and rescue teams to more accurately track people lost at sea, targeting operations and reducing search time. This added efficiency not only saves time and money, it also saves lives.

Homeland Security/National Defense

Inundation and erosion due to hurricanes or other natural disasters are currently on the forefront for several federal agencies (NOAA 2006). America's coastline and transportation hubs (airports, subway tunnels, ports, etc.) will all be affected by coastal inundation, making it a matter of national defense. IOOS data can help make America's coastline stronger and more resilient to natural disasters by providing real-time data on weather conditions and currents, allowing more accurate predictions of when and where a coastal inundation will occur; and thus a more efficient allocation of resources that could potentially save lives as well as money.

Research

IOOS data can be used for many research initiatives. Climate change research, especially, can benefit from the long-term continuous data provided by IOOS (AOOS 2007). The Department of Energy's (DOE) Carbon Sequestration Program is currently examining the feasibility of ocean carbon sequestration, a task for which IOOS data will be particularly beneficial. DOE is also involved in creating global climate simulation models. These will further benefit from IOOS, which is equipped with the latest high performance computing and information technologies. IOOS data can also aid in research of ecological events such as coral bleaching, fish and shellfish spawning, and onshore flux (IOOS 2009).

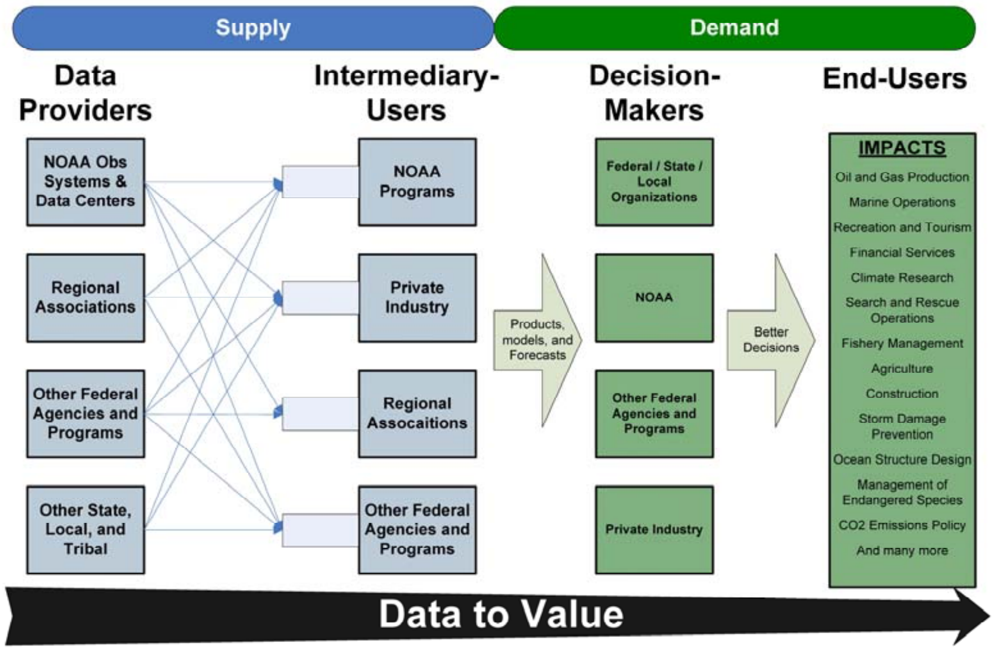
Education

IOOS data can be used for a variety of educational purposes. Potential educational audiences include undergraduate education, adult/continuing education, informal learning centers, radio programs, K-12 education, internet programs, parks/sanctuary/reserve programs, youth and community centers and TV programs (National Office for Integrated Ocean Observations 2007). Training a community of educators that use IOOS information to achieve their educational objectives is a primary goal of IOOS.

LITERATURE REVIEW

The economic literature identifies four general factors that determine the value of information: 1) how it differs from the next best available information, 2) how much more it costs, 3) how it can be used to improve decision making, and 4) what is at stake in those decisions (Macauley 2005). Since the late 1970s a number of studies have examined and presented conclusions about the economic value of improved earth-science information in general. (This literature is summarized in Macauley 2005 and IOOS 2008). Since the 1990s several studies have been undertaken to assign economic value specifically to information generated by IOOS, including some general studies that attempt to sum across various types of information users and economic value pathways (Kite Powell and Colgan 2001) and some that focus on particular benefit pathways, such as fisheries (Wellman and Hartley 2008 and Adams et al. 2003).

In 2008, much of this value of IOOS information research was presented or summarized in a special issue of *Coastal Management Journal* that included six articles describing case studies of IOOS values for Florida, the Southeast, the Gulf of Maine, California, and Alaska. This work was used later in 2008 by NOAA to generate an overall assessment of IOOS benefits in the United States, which was presented in a NOAA report, "The Business Case for Improving NOAA's Management and Integration of Ocean and Coastal Data." The NOAA 2008 IOOS Business Case report adapted the concept of a "value chain," initially developed to describe how an organization creates and uses business intelligence (Brackett 1999), to create an "Ocean Data Value Chain" that describes how ocean observation data and communications capabilities generate value to intermediary users (such as fisheries scientists or meteorologists), decision makers (such as fisheries managers or emergency managers), and end-users (such as commercial fishermen or search and rescue teams) (Figure 2).



Note: NOAA Obs Systems and Data Centers refers to providers of ocean data, data centers and centers of data, including National Data Buoy Center (NDBC), National Oceanographic Data Center (NODC), National Climatic Data Center (NCDC), National Geophysical Data Center (NGDC), CO-OPS, CoastWatch, and NOAA Fisheries Science Centers (NFSC).

Figure 2. The ocean value chain. Source: NOAA 2008.

Kite-Powell et al. (2008) assessed the economic value of two different types of IOOS-derived information: forecasts, which usually involve historical ocean data being fed into models) and now-casts, which involve real-time or near real-time information being used by decision-makers. These researchers note that the appropriate measure of economic value from these two types of information would be the change in "social surplus," which is a term economists use to refer to the sum of producer surplus (the difference between business costs and revenues) and consumer surplus (the difference between what a consumer is willing to pay and what he or she actually pays). However, they also note that the change in social surplus from IOOS would be nearly impossible to estimate. So, following a convention initiated in a 1986 study of the value of weather forecasts (Nordhaus 1986) they simply assume that the "social surplus" benefit of IOOS information is one per cent of the total value of the output of industries that use IOOS information. This "one-percent rule" is applied frequently to generate aggregate estimates of IOOS values, with the important caveat that it is a first-order approximation. Several of the studies mentioned below attempt to illustrate how more refined estimates of IOOS values can be generated for specific industries and end users. However, it is generally recognized that attempting to estimate precisely the full range of IOOS values for benefit pathways involving fishing, shipping, search and rescue, etc. would be prohibitively costly.

Economic Value from Regional Ocean Observing Systems

Several recent studies have attempted to quantify economic benefits of regional ocean observing systems that make up a significant portion of the United States IOOS. Similar studies have addressed marine observations in the United Kingdom (U.K. IACMST 2004) and from a European perspective (Flemming 2001). Our review of the literature focused on U.S. regional studies is described below.

The Gulf of Maine:

The Gulf of Maine Ocean Observing System (GoMOOS) is one of the oldest regional ocean observing systems, having come on line in 2001. Its 40 members include academic, industry, nonprofit, and governmental representatives (Richert et al. 2008). Kite-Powell and Colgan (2001) examined five activities in the Gulf of Maine: maritime transportation, commercial fishing, recreational fishing and boating, search and rescue operations, and oil spill management and prevention. For each activity, they defined the source of benefits and estimated the size of activity from which benefits may be derived. The authors note the difficulty in developing precise estimates of the value of information. Relying largely on the one-percent rule suggested by Nordhaus, the authors estimate a first-order annual potential benefit of more than $33 million from GoMOOS data management and communications.

Kite-Powell and Colgan make some important points relevant to studies of the value of ocean information in other regions and for fisheries in particular. First, while they note that setting up and operating the observing systems will be expensive, the development of these systems is taking place during a period when the cost of distributing the information is falling “essentially to zero” because of the development of the World Wide Web and other technologies. They note that, while this can greatly increase the access to—and demand for—this information, it also increases the distance between the producers (at one end of the ocean data value chain) and consumers (the “end-users” at the other end of the chain).

With regard to managed commercial fisheries, the authors note that the only path to economic benefits resulting from improved ocean information is indirectly through the regulators, who must find ways to use the ocean observation information to improve regulation and fishery yields. With such information, and reduced uncertainty, it may be possible to allow increased numbers of days at sea or permit yields.

In 2005, Richert et al. conducted an on-line survey of GoMOOS users in order to construct a user profile, including an initial assessment of the overall qualitative value of GoMOOS information by these users. Twenty-nine percent of the respondents indicated that they visit the GoMOOS web site daily, and an additional 33% said they visit it at least weekly. Fishermen (55%) and commercial mariners (53%) were among the most prevalent daily users of the site, typically looking for below-the-surface data.

Southeast Atlantic Case Study

Dumas and Whitehead (2008) examined the potential economic benefits of the Southeast Atlantic Coastal Ocean Observing System (SEACOOS), which covers North Carolina, South Carolina, Georgia, and Florida. The authors applied generally the approach taken in previous studies of the Gulf of Maine (Kite-Powell and Colgan 2001) and Gulf of Mexico (Lynch et al. 2003)**,** examining several categories of quantifiable benefits, including maritime transportation, commercial fishing, recreational fishing and boating, search and rescue operations, oil spill management and prevention, hurricane evacuation warning systems, beach recreation opportunities, cruise line operations, and beach erosion management. They estimate the annual economic benefit of SEACOOS information to be on the order of $170 million.

Dumas and Whitehead use the Nordhaus one-percent rule of thumb and apply that to transit time for maritime commercial shipping and recreational cruise voyages, with transit time reduced by one percent and operating costs reduced proportionally. For commercial fishing, they noted that increases in trip scheduling efficiency decrease the average cost per pound of fish landed. For fishery management, they note that better information from SEACOOS may improve the efficiency of regulations, eventually leading to larger fish stocks that could permit regulators to increase the size of the sustainable catch, and thus increase future revenues per trip. Following the approach taken in the Gulf of Maine and Gulf of Mexico studies, they assume that SEACOOS information will lead to one additional favorable fishing day per season.

Florida Case Study

Wieand (2008) applied a Bayesian methodology to estimate the impacts of improved coastal information on the marine recreational fishing industry, using a hypothetical computation for Florida's west coast that compares baseline data sources (such as current hydrographic models based on data from the National Weather Service) to better information that would be provided through IOOS. Wieand found in his hypothetical example that more accurate information provided by IOOS on two selected Gulf of Mexico parameters – ocean currents and water quality – would alter the decisions of recreational fishermen, lowering the expense and effort and increasing the expected catch. Current data would allow recreational fishermen to locate and fish in the more nutrient-rich offshore current. Once fishermen arrive at the fishing site, they could make a determination regarding fishing strategy by assessing fish concentrations that depend on water quality (temperature, nutrients, current, salinity, water clarity, and absence of pollutants). If fish concentrations were high, the fishermen would stay put and allow more time for fishing. If not, the fishermen would change locations (Wieand 2008).

Wieand estimated the value of the increase in fish caught in this hypothetical IOOS scenario by utilizing a previously published estimate of willingness to pay for recreational fish (Haab et al. 2000). The authors valued an additional fish caught at $9.77. Wieand multiplied that by 0.3, the increase in fish caught using (more accurate) IOOS data, and derived a value of $2.93, as measured by willingness to pay, for IOOS data. He then linked that to survey results for the Florida watercraft-based saltwater recreational fishery from the NOAA report, *Current Participation Patterns in Marine Recreation* (Leeworthy and Wiley 2001), which estimates a total of more than 31 million watercraft-based saltwater recreational fishery days in Florida per year. Wieand determined that the value to boat-based saltwater anglers of an increase in the expected catch from use of the IOOS data would be more than $91 million annually.

California Case Study

Pendleton (2008) examined the potential economic benefits of a regional ocean observation system for California, in this case focusing on the benefits of more accurate beach-closure decisions due to possibly contaminated water. Pendleton estimated the lost recreational value from both “Type 1” errors (in which clean beaches are closed due to uncertainty about the spatial extent of water contamination) and “Type 2” errors (in which contaminated beaches remained open because of delays in data management and communication). Pendleton used previous economic estimates of the value of beach use in Southern California to estimate that reducing the number of beaches closed unnecessarily could increase economic well-being of beach-goers by more than $2 million annually and lead to an additional $4 million in beach-related spending; and that the potential public health savings from improved data management and communications could exceed $3 million annually.

Alaska Case Study

Wellman and Hartley (2008) assessed the potential value of information from an enhanced Alaska Ocean Observation System (AOOS) to select Alaskan commercial fisheries. As Kite-Powell et al. (2008) note in an introductory article in the same issue of *Coastal Management Journal*, the Alaska ocean observing system provides a particularly good example of a case where possible benefits can be measured somewhat precisely for an industry—in this case, to the commercial fishing industry. Because of the short time the Alaska fishery is open, and its remoteness, companies must estimate carefully the labor and capital needed. Because of this situation, the companies would have direct benefit from better information derived from AOOS, and cost data would also be readily available to estimate changes in producer surplus (Kite-Powell et al. 2008).

Wellman and Hartley discuss the role of “ABCs,” or allowable biological catches (determined by fishery scientists, species by species), and “TACs,” or total allowable catches (determined by the Council Advisory Panel, consisting of representatives from the public and seafood industry), which are often very similar to ABCs. These stock assessments and harvest quotas factor in the amount of uncertainty for each species, with relatively low ABCs in cases of high uncertainty, and high ABCs where there is less uncertainty. The authors note that the National Marine Fisheries Service is correct only 60% of the time in its annual Pollock stock assessment.

While reduced uncertainty can help bring ABCs and TACs more in line, and conceivably increase TACs, Hellman and Hartley also describe a situation where physical ocean-observation data might play a role in reducing TACs, citing the example of the collapse of the Kodiak crab fishery in 1983. As they point out, even though spawning biomass was adequate for sustainable harvest, fishery managers realized after the fact that ocean temperature and currents caused reproduction failures.

USE AND ECONOMIC BENEFITS

As discussed previously, there are at least ten sectors that include actual or potential users of MARCOOS data (Table 1). In this section we analyze the potential economic benefits of MARCOOS data to those sectors, with the exception of Homeland Security/National Defense, Research, and Education.

Homeland Security/National Defense (with the exception of natural disasters, such as hurricanes), Research, and Education are not valued here, although it is important to note that they would likely receive important benefits from MARCOOS data. MARCOOS data is already providing important benefits to climate change research along the Mid-Atlantic coast, where sea level rise is expected to have a greater impact than elsewhere on the coast (Titus et al. 2009). And real-time data provided by MARCOOS can also be used in educational settings, allowing teachers and students to increase their knowledge of ocean processes.

In order to estimate the value of those sectors that are examined here, we generally follow the commonly-used "One percent rule"; that is, MARCOOS data increases total output (or decreases costs) for particular subsets of each sector by 1%. We estimate the total value (or costs) to each affected sector, multiply by 1%, and total the results for all sectors we analyzed to arrive at a first approximation of MARCOOS value.

Energy Industry

Here we specifically looked at the potential impact of MARCOOS data on the wind energy industry. MARCOOS information regarding offshore wind and waves can be used to determine the optimal placement of wind turbines in order to generate the most energy at the lowest possible cost. Using potential energy generation by offshore placement distance and a production cost of $0.05 per kilowatt (Robinson and Musial 2006), we use the 1% metric to calculate the estimated cost savings due to MARCOOS data in the Mid-Atlantic region (Table 2). Overall, the use of MARCOOS data could decrease the cost of wind energy production for the region by $132,900 annually.

The American Wind Energy Association has identified the mid-Atlantic region as an area with particularly good potential for provision of energy from offshore wind resources, with 600-800 W/m^3 in offshore wind energy potential and wind speeds close to 20 miles per hour at a distance of 50 meters offshore (Figure 3). If the United States were to reach the goal of producing 20% of its energy consumption using wind power by 2023, the MARCOOS region would most likely be a significant source of that energy (Figure 4).

Table 2. Potential wind energy generation in the Mid-Atlantic region (Sources: AWEA; Robinson and Musial 2006)

Miles offshore	GW Produced	KW Produced	Value Based on Production Cost Estimate	1% Cost Reduction
0-30	64.3	64,300,000	$3,215,000	$32,150
30-60	126.2	126,200,000	$6,310,000	$63,100
60-900	45.3	45,300,000	$2,265,000	$22,650
>900	30	30,000,000	$1,500,000	$15,000
TOTAL	265.8	265,800,000	$13,290,000	$132,900

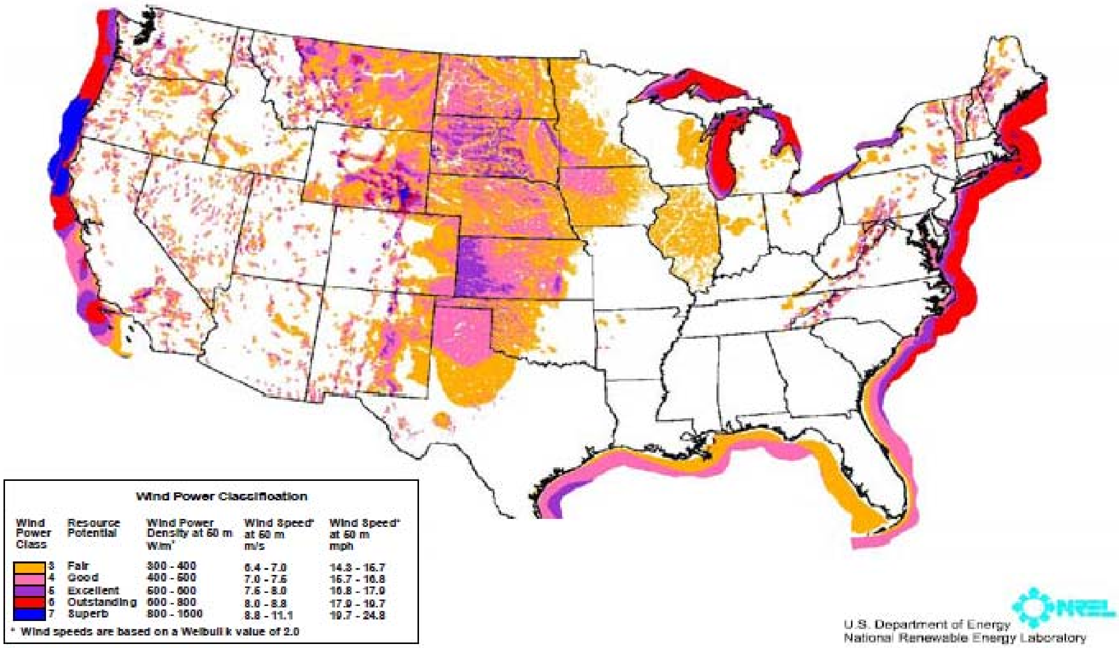


Figure 3. Wind energy potential in the United States, showing the MARCOOS region in the "outstanding" category (Source: AWEA 2008).

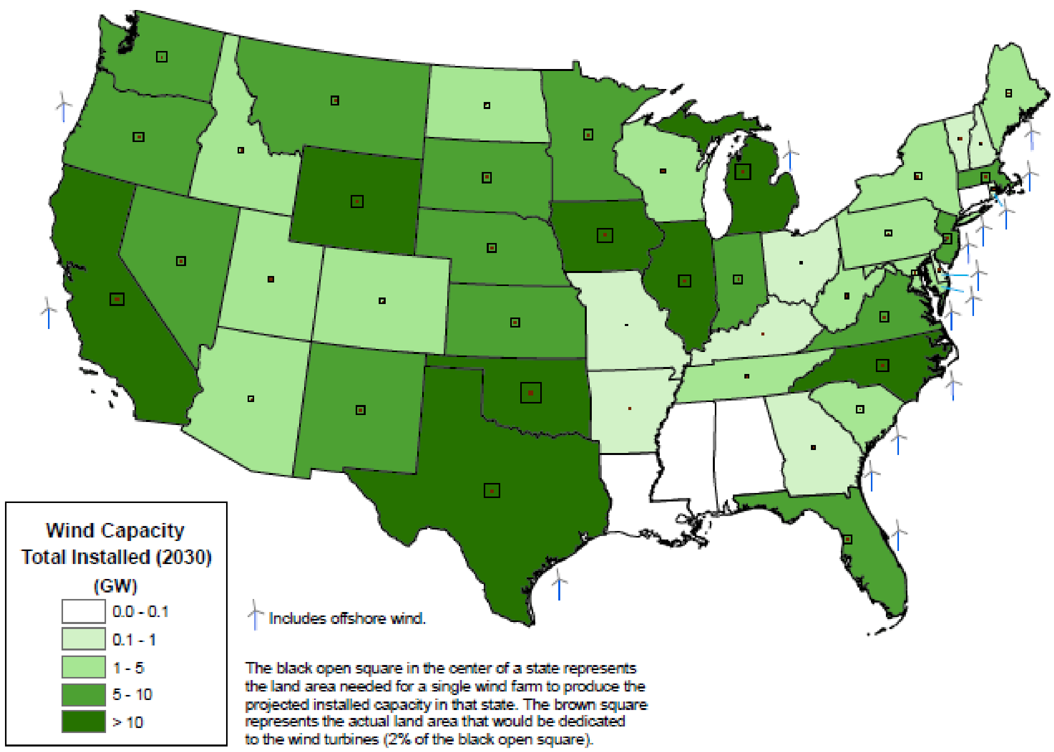


Figure 4. Wind development needed by 2030 to reach 20% wind energy goal (Source: AWEA 2008).

Transportation Industry

Commercial Marine Shipping

The commercial shipping industry benefits from COOS information on currents, winds, waves and fog to help minimize transit time and reduce fuel and labor costs. Using vessel calls at MARCOOS ports (Hood and Matsuda 2008) and average operating costs for four different ship types, both foreign and domestic (MSI 2007), we estimate the total operating costs for each ship type at each port. Using an approach similar to studies of the Gulf of Maine and Southeast regions, we assumed three things: 1) MARCOOS information will reduce average transit time by 1%; 2) the reduction in transit time is proportional to a reduction in operating costs; and 3) the average transit time of a commercial vessel operating in the coastal MARCOOS region is 2 days. Using MARAD data, we also assume that 12% of all vessels entering MARCOOS ports are U.S. vessels (which have higher operating costs, according to MSI data). Thus, MARCOOS data could save approximately $5.6 million in transit time costs (Table 3).

Table 3. Annual maritime commercial shipping benefits in the MARCOOS region.

Foreign Vessels

Ship Type	MA	RI	CT	NY	PA	MD	VA	NC	Total
Containership	$58,793	$0	$0	$980,829	$202,329	$156,916	$20,273	$45,413	$1,464,553
Tanker	$104,484	1279.397	$30,279	$637,993	$660,595	$82,734	$74,205	$117,278	$1,708,848
Bulker	$33,217	$431	$25,452	$112,594	$112,594	$236,404	$262,287	$27,178	$810,157
General Cargo	$0	$984	$9,514	$22,966	$152,230	$32,808	$16,732	$21,981	$257,216
TOTAL	$196,494	$2,695	$65,246	$1,754,381	$1,127,748	$508,863	$373,498	$211,850	$4,240,774

Domestic Vessels

Ship Type	MA	RI	CT	NY	PA	MD	VA	NC	Total
Containership	$19,448	$0	$0	$324,440	$66,927	$51,905	$6,706	$15,022	$484,447
Tanker	$37,867	$464	$10,974	$231,218	$239,410	$29,984	$26,893	$42,503	$619,312
Bulker	$9,239	$120	$7,079	$31,316	$31,316	$65,752	$72,951	$7,559	$225,333
General Cargo	$0	$226	$2,185	$5,273	$34,954	$7,533	$3,842	$5,047	$59,060
TOTAL	$66,553	$810	$20,237	$592,248	$372,606	$155,174	$110,392	$70,131	$1,388,152

Total Vessels

Ship Type	MA	RI	CT	NY	PA	MD	VA	NC	Total
Containership	$78,241	$0	$0	$1,305,269	$269,256	$208,821	$26,980	$60,434	$1,949,001
Tanker	$142,351	$1,743	$41,253	$869,211	$900,005	$112,719	$101,098	$159,781	$2,328,160
Bulker	$42,456	$551	$32,531	$143,910	$143,910	$302,156	$335,239	$34,737	$1,035,490
General Cargo	$0	$1,210	$11,699	$28,239	$187,184	$40,341	$20,574	$27,029	$316,276
TOTAL	$263,047	$3,505	$85,483	$2,346,629	$1,500,354	$664,037	$483,890	$281,981	$5,628,926

Cruise Industry

MARCOOS information would enable cruise ships to avoid rough seas during a cruise as well as reduce idle time in port. In this instance we estimate the total size of the cruise industry by state (Business Research and Economic Advisors 2009) and a value-added of $0.53 for every dollar spent (Braun et al. 2002). Using this we then estimate the total benefits to the cruise industry in the MARCOOS region to be approximately $16 million (Table 4).

Table 4. Annual recreational cruise industry benefits in the MARCOOS region.

State	Expenditures (Millions)	Value Added (Millions)	Benefits (1% of Value Added, in Millions
Massachusetts	$434	$230	$2.30
Rhode Island	$25	$13	$0.13
Connecticut	$143	$76	$0.76
New York	$1,143	$606	$6.06
New Jersey	$387	$205	$2.05
Pennsylvania	$368	$195	$1.95
Delaware	$26	$14	$0.14
Maryland	$153	$81	$0.81
Virginia	$153	$81	$0.81
North Carolina	$214	$113	$1.13
TOTAL	$3,046	$1,614	$16.14

Fishing Sectors

Commercial

In 2008, the U.S. commercial fishing fleet landed 8.3 billion pounds of fish and shellfish with an ex-vessel value of $2.2 billion (NMFS 2009a). Information from COOS, such as weather and sea conditions, benefit commercial fishermen in many ways as described in previous sections. Additionally, COOS data can lead to improved fishery management and result in less risk to fish stocks and higher allowable and sustainable commercial harvests. Hagan, King and Price (2009) estimated the impact of MARCOOS information on the value of the finfish and shellfish catch using the methodology of a 1% increase in total value. Based on commercial fish landings in MARCOOS states (NMFS, 2009b), MARCOOS information is estimated to result in an increase in total value of more than $10 million as shown in Table 5.

An alternate approach would be to calculate the increase in value associated with one additional commercial fishing day due to more accurate weather forecasts as a result of MARCOOS data. Using the value of commercial landings by state and assuming a 60-day season for finfish and a 120-day season for shellfish, the total value of one additional fishing day in the MARCOOS region would be almost $23 million (Table 6).

Table 5. Annual commercial fishing values in the MARCOOS region (Source: Hagan, King and Price 2009).

State	Finfish ($)	Shellfish ($)	Total ($)	1% Increase
Massachusetts	109,161,589	311,015,875	420,177,464	4,201,774.64
Rhode Island	24,961,633	48,577,449	73,539,082	735,390.82
Connecticut	3,270,438	38,782,110	42,052,548	420,525.48
New York	19,979,274	39,633,895	59,613,169	596,131.69
New Jersey	24,171,423	127,281,222	151,452,645	1,514,526.45
Pennsylvania	126,872	0	126,872	1,268.72
Delaware	1,256,927	6,637,266	7,894,193	78,941.93
Maryland	11,925,260	46,755,787	58,681,047	586,810.47
Virginia	45,737,549	86,874,770	132,612,319	1,326,123.19
North Carolina	36,208,007	46,123,792	82,331,799	823,317.99
TOTAL	276,798,972	751,682,166	1,028,481,138	10,284,811.38

Table 6. Daily commercial fishing values in the MARCOOS region.

	MA	RI	CT	NY	NJ	PA	DE	MD	VA	NC
2007 Value	420,177,464	73,539,082	42,052,548	59,613,169	151,452,645	126,872	7,894,193	58,681,047	132,612,319	82,331,799
1% Increase	4,201,774.64	735,390.82	420,525.48	596,131.69	1,514,526.45	1,268.72	78,941.93	586,810.47	1,326,123.19	823,317.99
Value of 1 Additional Fishing Day (Finfish)	7,002,957.73	1,225,651.37	700,875.80	993,552.82	2,524,210.75	2,114.53	131,569.88	978,017.45	2,210,205.32	1,372,196.65
Value of 1 Additional Fishing Day (Shellfish)	3,501,478.87	612,825.68	350,437.90	496,776.41	1,262,105.38	1,057.27	65,784.94	489,008.73	1,105,102.66	686,098.33
Total Value of 1 Additional Fishing Day	10,504,436.60	1,838,477.05	1,051,313.70	1,490,329.23	3,786,316.13	3,171.80	197,354.83	1,467,026.18	3,315,307.98	2,058,294.98

Recreational

Recreational fisheries may benefit from COOS data for the same reason that commercial fisheries benefit, but these benefits are not measured in terms of increases in the expected market value of the harvest. Instead, we estimate the annual benefits to recreational fisheries on the basis of a 1% increase in fishing trips per year due to MARCOOS information. Using the number of trips (NMFS 2009b) and the estimated benefit per trip (Norton et al. 1983 and McConnell and Strand 1994); we estimate that the annual benefits to recreational fishermen in the MARCOOS region are on the order of $58.8 million (Table 7).

In the MARCOOS region, annual spending on saltwater fishing, including expenditures on party and charter boat trips, private and rental boats, shore-based fishing, and equipment/durable goods, is estimated to be $7.4 billion (see King, Wainger and Cantrell 2008, based on data from the National Ocean Economics Program). Under certain assumptions this spending reflects "revealed willingness to pay" for saltwater fishing. If we assumed MARCOOS information used by recreational fishermen and the recreational fishing industry results in 1% of this value it would be worth $74 million per year. However, for our purposes we will use the lower $58.8 million that is based on assumed impacts of MARCOOS data on number of trips and benefits per trip as shown in Table 7.

Table 7. Recreational fishing trip benefits in the MARCOOS region.

State	Trips	Benefits per Trip	Additional Trips	Annual Benefits
MA	2,557,708	$207.26	25,577	$5,301,105.60
RI	842,675	$207.26	8,427	$1,746,528.21
CT	1,348,672	$207.26	13,487	$2,795,257.59
NY	3,588,270	$407.29	35,883	$14,614,664.88
NJ	3,955,108	$407.29	39,551	$16,108,759.37
DE	598,919	$407.29	5,989	$2,439,337.20
MD	2,106,869	$215.85	21,069	$4,547,676.74
VA	2,400,692	$215.85	24,007	$5,181,893.68
NC	2,833,165	$215.85	28,332	$6,115,386.65
TOTAL	**20,232,078**		**202,321**	**$58,850,610**

Ocean Resource Managers

Fisheries

In addition to the value of MARCOOS data for commercial fisheries, which we estimated in the previous section using fishery landings data, we also considered the value of such data for ocean resource managers, who are essentially one step back from fishery landings on the value chain (Figure 2). A survey of fishery scientists conducted by Hagan, King and Price (2009) showed that the majority of information provided by

MARCOOS would be important in assessing fish abundance and population dynamics, as well as strengthen confidence in recommendations by fishery managers (Table 8). Ultimately, in terms of economic value, these benefits to ocean resource managers would most obviously be demonstrated through data from commercial fishery landings.

Table 8. Responses to survey of fishery scientists conducted by Hagan, King and Price (2009).

	% respondents who agreed or strongly agreed	
Data Category	**If reliable data were available, it would be important in assessment of fish abundance and population dynamics**	**If reliable data were available to fishery scientists, it would strengthen confidence in recommendations to fishery managers**
Surface Currents	92%	71%
Subsurface Currents	90%	68%
Wave Height	16%	22%
Water Temperature	98%	80%
Salinity (Density)	86%	78%
Dissolved Oxygen	84%	76%
Chlorophyll a	75%	55%

Aquaculture

MARCOOS information could aid in aquaculture production by providing real-time water quality data such as water temperature, salinity and chlorophyll concentration. Here we again apply the 1% metric to estimate the increase in aquaculture revenues (USDA 2009) due to MARCOOS data, for a total of more than $1.7 million (Table 9).

Table 9. Annual value of aquaculture production in the MARCOOS region.

State	Total Revenue	Increased Revenue
MA	$18,443,000	$184,430
RI	$0	$0
CT	$15,010,000	$150,100
NY	$16,458,000	$164,580
NJ	$17,025,000	$170,250
PA	$33,040,000	$330,400
DE	$0	$0
MD	$1,890,000	$18,900
VA	$41,358,000	$413,580
NC	$32,175,000	$321,750
TOTAL	$175,399,000	$1,753,990

Marine Mammals and Endangered Species

Improved knowledge about real time ocean conditions, under some circumstances, can be used by commercial and recreational fishermen to avoid incidental catches of prohibited species. As a result, MARCOOS information has potential to generate benefits associated with the conservation of these species and reduced costs to fishing industries of avoiding them. Hagan, King and Price considered this benefit pathway in their survey of fishery scientists, but the results were inconclusive (based on a survey question regarding by-catch). Though MARCOOS information most likely would provide benefits to this sector, we did not estimate the value of such benefits. This would require a benefit estimation method such as a contingent valuation or contingent choice survey, which was beyond the scope of our study.

Coastal Resource Managers

Recreational Boating

MARCOOS information includes tide, current, and other observations and predictions that benefit recreational boaters in many ways that lead to better, safer boating experiences, and lead to potential increases in revenue and/or decreases in costs in the recreational boating industry in the MARCOOS region. Here, the number of annual recreational motorboat trips in the MARCOOS region is estimated based on data from 2001 (Leeworthy and Wiley 2001), and the average value per motorboat trip is estimated using a national average of $33.83 (estimated by Sommer and Sohngen 2002). Assuming 1% of the value of recreational boating is based on improved decisions by recreational boaters that are due to MARCOOS information, the value of that information is estimated at about $10.7 million (See Table 10).

Table 10. Annual benefits of recreational boating in the MARCOOS region.

State	Motorboating Trips	Per Trip Value	Total Revenue	Increased Value
MA	3,026,000	$33.83	$102,369,580	$1,023,696
RI	2,184,000	$33.83	$73,884,720	$738,847
CT	3,378,000	$33.83	$114,277,740	$1,142,777
NY	4,741,500	$33.83	$160,404,945	$1,604,049
NJ	6,223,500	$33.83	$210,541,005	$2,105,410
DE	2,278,000	$33.83	$77,064,740	$770,647
MD	4,065,000	$33.83	$137,518,950	$1,375,190
VA	2,271,500	$33.83	$76,844,845	$768,448
NC	3,626,500	$33.83	$122,684,495	$1,226,845
TOTAL	31,794,000		$1,075,591,020	$10,755,910

Beach Use

COOS information will allow for more accurate water quality measures on which to base beach-closure decisions. Here we estimate the value of MARCOOS benefits for recreational beach use by using beach visitation days by state (Leeworthy and Wiley 2001) and an average value of benefits per beach visitation day for the MARCOOS region (NOEP 2009). By assuming a 1% increase in beach visitation days as a result of more targeted beach closures the annual value of MARCOOS information in terms of beach use would be $18.4 million (Table 11).

Table 11. Annual benefits of beach use in the MARCOOS region.

State	# of Visitation Days	Benefits per Day	Additional Days	Annual Benefits
MA	28,681,000	$8.80	286,810	$2,523,928
RI	17,865,000	$8.80	178,650	$1,572,120
CT	14,065,000	$8.80	140,650	$1,237,720
NY	29,225,000	$8.80	292,250	$2,571,800
NJ	40,881,000	$8.80	408,810	$3,597,528
DE	12,877,000	$8.80	128,770	$1,133,176
MD	18,696,000	$8.80	186,960	$1,645,248
VA	18,749,000	$8.80	187,490	$1,649,912
NC	27,936,000	$8.80	279,360	$2,458,368
TOTAL	208,975,000		2,089,750	$18,389,800

Beach Erosion

Beach erosion management would benefit from COOS information regarding the likely impact of ocean and coastal conditions on erosion rates. Here we estimate the benefits of COOS data by first making several assumptions: 1) the population living within 500 feet of the shoreline in the MARCOOS region is proportional to the number of structures within 500 feet of the shoreline; 2) the regional percentage of structures within 500 feet of the shoreline that are also in the 60-year Erosion Hazard Area (EHA) is applicable across all states in the MARCOOS region; and 3) the total cost of the loss of structures and land in each state is proportional to the structures within the EHA. Using population estimates by state, a regional structure estimate, a regional percentage estimate for EHA structures, and a regional cost estimate for loss of land and structures in the EHA (Heinz Center 2000), assuming 1% of erosion control costs are saved (or 1% of erosion damage is avoided) as a result of having MARCOOS information, we estimate the total annual cost savings from COOS information in the MARCOOS region to be $2.7 million (Table 12).

Table 12. Annual benefits of beach erosion prevention in the MARCOOS region.

State	Structures	Erosion Costs	Annual Benefits
MA	34,000	$118,636,364	$1,186,364
RI	5,100	$16,477,273	$164,773
CT	6,800	$23,068,182	$230,682
NY	5,100	$19,772,727	$197,727
NJ	18,700	$62,613,636	$626,136
DE	1,700	$3,295,455	$32,955
MD	1,700	$3,295,455	$32,955
VA	3,400	$9,886,364	$98,864
NC	5,100	$16,477,273	$164,773
TOTAL	**81,600**	**$273,522,727**	**$2,735,227**

Beach Nourishment

MARCOOS may also reduce erosion costs by ensuring more efficient beach nourishment project design. Here we estimate cost savings due to MARCOOS data by annualizing total beach nourishment costs across states during the period from 1921 to 1998 (Heinz Center 2000). Using a 3% discount rate and assuming MARCOOS information will provide a 1% costs savings, we estimate the total savings across all states to be approximately $926,000 (Table 13).

Table 13. Value of annual beach nourishment benefits in the MARCOOS region.

State	Cumulative Costs	Annualized Costs	Annual Benefits
MA	$76,659,487	$2,299,784.61	$22,997.85
RI	$4,424,574	$132,737.22	$1,327.37
CT	$65,583,121	$1,967,493.63	$19,674.94
NY	$710,875,211	$21,326,256.33	$213,262.56
NJ	$424,977,053	$12,749,311.59	$127,493.12
DE	$63,729,923	$1,911,897.69	$19,118.98
MD	$89,660,605	$2,689,818.15	$26,898.18
VA	$107,106,426	$3,213,192.78	$32,131.93
NC	$191,350,065	$46,290,492	$462,905
TOTAL	$1,734,366,465	$92,580,984	$925,810

Emergency Managers

Storm Response

In addition to the health-and-safety benefits discussed previously with regard to beach closures due to water-quality threats, MARCOOS information has significant potential to improve hurricane prediction capabilities. In doing so, it will prevent property damages and save lives. Here we estimate the benefits of MARCOOS by using the most recent severe hurricane to hit the MARCOOS region, Hurricane Isabel. Though it made landfall as a Category 2 on the Saffir-Simpson scale; the subsequent freshwater flooding that occurred after the majority of the hurricane passed caused extensive damage and was responsible for most of the deaths resulting from the hurricane (NOAA 2003). It is important to note here that these are not annual benefits, as most of the other estimations presented in this report; they might only accrue when a significant hurricane makes landfall in the MARCOOS region, which is not necessarily every year.

Based on an approach used by the National Weather Service, overall property damage from hurricanes is typically estimated to be twice reported damage to insured property. For purposes of estimating the value of lives saved, the value of a statistical life, as estimated by EPA, is $6.9 million. For purposes of this exercise we again assumed that with the benefit of MARCOOS information, there would be a 1% reduction in property damage and lives lost as a result of a hurricane. Using estimates of hurricane damage associated with Hurricane Isabel which struck the MARCOOS region in 2003 this amounts to total savings of $34.6 million dollars (See Table 14). Although we applied the 1% rule across the board for this estimate it is important to mention that several of the deaths during Hurricane Isabel would not necessarily be avoided by better predictions, as this analysis assumes (See Table 15). For example, better MARCOOS-based information about hazards posed by wave and storm surge during and after Hurricane Isabel would not necessarily have prevented the 5 canoers/ kayakers who were killed during Hurricane Isabel from going out.

Table 14. Hurricane prediction benefits in the MARCOOS region (using Hurricane Isabel as an example).

State	Total Damages ($)	Deaths	Monetary Value of Lives ($)	Total Value Saved ($)
NY	$90,000,000	1	$6,900,000	$969,000
NJ	$50,000,000	2	$13,800,000	$638,000
PA	$160,000,000	0	$0	$1,600,000
DE	$40,000,000	0	$0	$400,000
MD	$820,000,000	1	$6,900,000	$8,269,000
VA	$1,850,000,000	10	$69,000,000	$19,190,000
NC	$340,000,000	1	$6,900,000	$3,469,000
RI		1	$6,900,000	$69,000
TOTAL	$3,350,000,000	16	$110,400,000	$34,604,000

Table 15. Fatalities during Hurricane Isabel.

Cause of Death	# of Deaths
Surge Drowning (coast)	1
Falling Trees/Branches	7
Freshwater Drowning (inland)	4
Recreational (Canoes/Kayaks)	5
Total	16

Spill Response

Spill Response

MARCOOS information related to surface and subsurface currents and water transport helps emergency managers respond more effectively to oil and toxic spills by helping them predict how a spill will behave. We estimated potential annual benefits due to potentially-reduced oil spill response costs using the National Response Center database for oil spills occurring in the year 2009 (NRC 2009). This data was sorted by state and totaled by gallon. Gallons of oil spilled were converted to barrels (assuming 42 gallons per barrel) and then, using an approach used in other regions (Dumas and Whitehead 2008, Lynch et al. 2003, Kite-Powell and Colgan 2001, and Volpe 2001), was multiplied by $10,000 to determine the total cost of oil spilled in each state,. Assuming a 1% reduction in costs of cleanups, we then estimate the total potential benefit from MARCOOS information in the MARCOOS region to be approximately $35.5 million annually (Table 16).

Table 16. Annual oil spill response benefits in the MARCOOS region.

State	Gallons	Barrels	Costs	1% Reduction
Massachusetts	1,577,211	37,553	$375,526,360	$3,755,264
Rhode Island	126,112	3,003	$30,026,577	$300,266
Connecticut	33,647	801	$8,011,095	$80,111
New York	529,163	12,599	$125,991,158	$1,259,912
New Jersey	8,152,611	194,110	$1,941,097,794	$19,410,978
Pennsylvania	436,036	10,382	$103,818,006	$1,038,180
Delaware	1,263,536	30,084	$300,841,964	$3,008,420
Maryland	165,797	3,948	$39,475,373	$394,754
Virginia	2,518,189	59,957	$599,568,847	$5,995,688
North Carolina	107,364	2,556	$25,562,932	$255,629
TOTAL	14,909,664	354,992	$3,549,920,107	$35,499,201

Search and Rescue

Benefits of MARCOOS information associated with search and rescue operations are estimated in terms of both cost savings and the increase in lives saved as a result of more effective targeting of search and rescue operations. Here we use state boat registration data (NMMA 2008) to estimate the percentage of national boating activity that takes place in the MARCOOS region (based on the percent of boat registrations in the region) and then estimate the number of lives saved in each state based on the regional total number of lives saved (USCG 2009). Assuming a 1% increase in lives saved due to MARCOOS data and using the EPA-determined value of a statistical life ($6.9 million), we estimate the total benefits of MARCOOS information resulting from its use in search and rescue operations to be approximately $60 million (Table 17).

Table 17. Annual value of search and rescue benefits in the MARCOOS region.

	MA	RI	CT	NY	NJ	PA	DE	MD	VA	NC	TOTAL
Lives Saved*	58	18	44	198	73	137	23	77	96	143	868
Increase in Lives Saved	0.58	0.18	0.44	1.98	0.73	1.37	0.23	0.77	0.96	1.43	8.68
Increased Value**	$4,023,939	$1,207,630	$3,001,830	$13,662,961	$5,065,241	$9,470,400	$1,619,808	$5,337,850	$6,615,091	$9,887,251	$59,892,000

*Used Boat registrations by state (NMMA 2008) to estimate the number of lives saved in each state, based on USCG SAR statistics (1997-2001).

**Used EPA value of a statistical life: $6.9 million in 2008 $.

CONCLUSIONS

This paper identifies several economic sectors that might especially benefit from a coastal ocean observing system in the mid-Atlantic region. It also provides very crude estimates of the economic benefits and potential economic benefits in these sectors from the use of MARCOOS information. In most cases these benefits were estimated by applying a widely used rule of thumb that the type of information generated from MARCOOS data results in either a 1% increase in the economic value of the total output of an affected sector (e.g., commercial fisheries) or a 1% reduction in costs (e.g., for search and rescue or spill response operations). These estimates are useful primarily to illustrate that the economic value of MARCOOS information to these sectors, although difficult or impossible to measure precisely, is not zero. However, because of the simplifying assumptions on which they were based they should not be considered as firm and reliable valuation estimates.

Table 19 summarizes the benefit estimates developed in this paper. Our initial study suggests that, of the sectors we analyzed, the search and rescue sector might stand to benefit the most from MARCOOS data, followed closely by recreational and commercial fishing sectors.

We estimate the total annual benefits across all sectors in the MARCOOS region that were analyzed as part of this study to be approximately $255 million. This places the value of coastal and ocean observing information in the MARCOOS region in between the value of $170 million estimated for the Southeast region (Dumas and Whitehead 2008) and $381 million estimated for the Gulf of Mexico (Lynch et al 2003). Since these other studies and this study applied the same 1% rule of thumb to estimate the value of coastal and ocean information to various sectors, differences in the size of various sectors in different regions can be assumed to account for most, if not all, of the differences in these value estimates.

Table 18. Summary of MARCOOS benefits.

Benefit	MA	RI	CT	NY	NJ	PA	DE	MD	VA	NC	MARCOOS Region
Wind Energy	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$132,900
Commercial Shipping	$263,047	$3,505	$85,483	$2,346,629		$1,500,354		$664,037	$483,890	$281,981	$5,628,926
Cruise Industry	$2,300,200	$132,500	$757,900	$6,057,900	$2,051,100	$1,950,400	$137,800	$810,900	$810,900	$1,134,200	$16,143,800
Commercial Fishing	$4,201,775	$735,391	$420,525	$596,132	$1,514,526	$1,269	$78,942	$586,810	$1,326,123	$823,318	$10,284,811
Recreational Fishing	$5,301,105.60	$1,746,528.21	$2,795,257.59	$14,614,664.88	$16,108,759.37	0	$2,439,337.20	$4,547,676.74	$5,181,893.68	$6,115,386.65	$58,850,610
Aquaculture	$184,430	$0	$150,100	$164,580	$170,250	$330,400	$0	$18,900	$413,580	$321,750	$1,753,990
Recreational Boating	$1,023,696	$738,847	$1,142,777	$1,604,049	$2,105,410	$0	$770,647	$1,375,190	$768,448	$1,226,845	$10,755,910
Beach Use	$2,523,928	$1,572,120	$1,237,720	$2,571,800	$3,597,528	$0	$1,133,176	$1,645,248	$1,649,912	$2,458,368	$18,389,800
Beach Erosion Management	$1,186,364	$164,773	$230,682	$197,727	$626,136	$0	$32,955	$32,955	$98,864	$164,773	$2,735,227
Beach Nourishment	$22,998	$1,327	$19,675	$213,263	$127,493	$0	$19,118.98	$26,898.18	$32,131.93	$462,905	$925,810
Storm Response	$0	$69,000	$0	$969,000	$638,000	$1,600,000	$400,000	$8,269,000	$19,190,000	$3,469,000	$34,604,000
Oil Spill Response	$3,755,264	$300,266	$80,111	$1,259,912	$19,410,978	$1,038,180	$3,008,420	$394,754	$5,995,688	$255,629	$35,499,201
Search and Rescue	$4,023,939	$1,207,630	$3,001,830	$13,662,961	$5,065,241	$9,470,400	$1,619,808	$5,337,850	$6,615,091	$9,887,251	$59,892,000
TOTAL	$24,786,745	$6,671,886	$9,922,061	$44,258,617	$51,415,422	$15,891,002	$9,640,204	$23,710,218	$42,566,522	$26,601,407	$255,596,986

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