# The Potential Economic Benefits of Coastal Ocean Observing Systems:

## The Gulf of Maine

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# *Preface*

In August of 2000 we released a joint NOAA/Navy publication **The Economics of Sustained Ocean Observations: Benefits and Rationale for Public Funding.** That report detailed the findings of a Panel of economic experts called together to assess the economics of the proposed Integrated Sustained Ocean Observing System (ISOOS), a joint initiative of Federal agencies, academic groups, and industry. The primary focus was on the link between improved ocean observations and better short and long term weather and climate forecasts across a wide range of both private and public economic sectors and activities.

The Panel concluded that ISOOS benefits will exceed costs significantly and that the network externalities and public-goods characteristics of ISOOS argue for Federal support to achieve the full economic benefits.

Concurrent with the global ocean observing initiative is a new focus on local and regional observing systems. An example is planning for the Gulf of Maine Ocean Observing System (GoMOOS). Regional ocean observing systems, however, must be evaluated under different criteria. Accordingly, NOAA and ONR asked the Panel to begin analyzing the economic benefits of regional systems, starting with the proposed Gulf of Maine Ocean Observing System.

Hauke Kite-Powell at WHOI's Marine Policy Center and Charlie Colgan at the University of Southern Maine agreed to undertake the analysis.

In this publication**, The Potential Economic Benefits of Coastal Ocean Observing Systems: The Gulf of Maine,** Kite-Powell and Colgan focused on five important activities in The Gulf of Maine:

- maritime commerce,
- commercial fishing,
- recreational fishing and boating,
- search and rescue, and
- pollution management, specifically oil spill management.

For each area, the sources of benefits were defined and estimates were made of the size of the activity in the region from which benefits may be derived.

The results of their analysis suggests strongly that the benefits from a regional ocean observing system in the Gulf of Maine will exceed its costs, although more precise measurement is required before the actual magnitude of benefits can be estimated.

In addition to supporting the GoMOOS initiative, we hope this analysis can serve as a useful template for analyzing the economic benefits and costs of other proposed regional ocean and coastal observing systems.

Mel Briscoe of ONR initiated and secured funding for this Report. Philip Bogden, Executive Director of GoMOOS, provided helpful advice during the analysis.

We welcome comments and suggestions.

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# The Potential Economic Benefits of Coastal Ocean Observing Systems: The Gulf of Maine as an Example

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The ocean remains one of the least-measured major ecosystems on the planet, but this has begun to change. A major effort to instrument the Pacific Ocean over the past fifteen years has resulted in significantly improved ocean and meteorological data, and improved forecasts of the El Niño-Southern Oscillation (ENSO) weather phenomenon. Efforts to extend the concept of sustained ocean observing systems have arisen at the global, regional, national, and sub-national levels. An international coordinating organization for a Global Ocean Observing System (GOOS) was formed in 1991 (International Oceanographic Commission 1998). Recent efforts to develop the US portion of GOOS have been endorsed and supported by the National Oceanographic Partnership Program (National Ocean Leadership Program 1998).

Improved deep ocean observation represents one part of the effort to develop sustained ocean observing systems. Another key part is the development of coastal ocean observation systems. In the coastal ocean, the challenge is two-fold. Depending on the region, there may already be a number of observing stations whose data are collected but not integrated into a coherent whole. At the same time, existing observing stations may not be placed at optimal locations to develop complete pictures of the regional ocean system, and so additional observing stations may be required.

As a result, most regional observing systems are likely to evolve as a combination of existing and expanded observing stations. Some of the latter will be fixed buoys deployed to supplement existing infrastructure such as the National Weather Service weather buoys. Radar systems capable of measuring offshore currents (CODAR) will be included, as well as technologies for the remote control of observing stations. Some systems, such as the Gulf of Maine Ocean Observing System (GoMOOS), will be general purpose in nature, designed to collect and provide data for a variety of users (GoMOOS 2001). Others, such as the Harmful Algal Blooms Observing System in the Gulf of Mexico, will be designed to address specific recurring events that have potentially harmful effects.

A major question confronting development of the GOOS concept is the cost of such systems. Estimates of the deployment and operating costs of ocean observing systems are very uncertain, but run from the tens of millions to billions of dollars per year. In seeking to justify this level of expense to governments who must provide the major share of the funding, question arise regarding the benefits that may be expected, and their magnitude relative to the costs. The usefulness of undertaking economic analyses of the benefits of ocean observing systems has been demonstrated in studies of the improved predictions of ENSO (Weiher 1999).

Following the seminal work on the economics of ENSO prediction, Adams *et al.* (2000) examined more broadly the potential benefits of global ocean observing systems. This review of the economics of an integrated sustained ocean observing system focused primarily on the link between improved ocean observations and the potential for better short and long term weather and climate forecasts. As the focus moves from global scale to local and regional levels, the types of benefits considered in such studies must be adjusted. While the benefits of global observing systems can be tied easily to improved weather forecasts involving large-scale phenomena such as ENSO, regional ocean observing systems must be evaluated under different criteria. This paper identifies general categories of benefits that may result from the implementation of a regional observing system, and uses figures from the Gulf of Maine to suggest orders of magnitude for those benefits. More precise measurement is required before the actual magnitude of benefits can be estimated and used in policy decisions, but the results of the reconnaissance-level analysis reported here suggest that economic benefits of such regional observing systems may be more than adequate to justify their costs.

Economic benefits are manifested as an increase in the real value of goods and services: more goods or services produced, goods or services of a higher value, or at lower production cost. Benefit-cost analysis seeks to determine whether the benefits of a proposed investment outweigh its cost.

The benefits of a regional ocean observing system, such as the proposed Gulf of Maine Ocean Observing System (GoMOOS), must derive from the information the system provides. Improved ocean observation produces data on ocean conditions (waves, currents, water temperature, etc.). These data are used to develop and operate better nowcast and forecast models. Decision makers in a variety of activities make use of the output of these models. Under the "value of information" framework, the economic value of GoMOOS is the sum across all individuals/organizations of the difference between economic outcomes (net benefits) of these decisions with and without GoMOOS data.

Many commercial and recreational activities can make use of better marine conditions information in the Gulf of Maine. We focus here on five of these activities:

- maritime transportation
- commercial fishing
- recreational fishing and boating

- search and rescue operations
- pollution management, specifically oil spill management and prevention.

For each of these areas, we define the source of benefits and estimate the size of activity in the Gulf of Maine region from which benefits may be derived.

*Maritime transportation:* Oceangoing ships make use of information on currents, winds, and waves to optimize their routes for minimal transit time and exposure to severe weather. Part of the cost of delays in ocean transport can be seen in representative daily operating costs shown in Table 1.

| cargo type | ship type | representative size | typical charter rate ($/day) | typical operating cost incl. fuel ($/day) |
|---|---|---|---|---|
| dry bulk | handysize | 27,000 dwt | 6,500 | 7,000 |
| | handymax | 43,000 dwt | 8,000 | 8,000 |
| | Panamax | 59,000 dwt | 9,500 | 9,000 |
| | Cape | 150,000 dwt | 14,000 | 12,000 |
| liquid bulk | product | 45,000 dwt | 12,000 | 10,000 |
| | Aframax | 90,000 dwt | 13,000 | 12,000 |
| | Suezmax | 140,000 dwt | 16,500 | 14,000 |
| | VLCC | 280,000 dwt | 22,000 | 18,000 |
| general cargo | container | 400 TEU* | 5,000 | 4,000 |
| | container | 1000 TEU | 9,000 | 7,000 |
| | container | 1500 TEU | 13,500 | 8,000 |
| | container | 2000 TEU | 18,000 | 9,000 |
| | container | 3000 TEU | -- | 10,000 |
| | container | 4000 TEU | -- | 11,000 |

*TEU = twenty-foot equivalent unit

**Table 1: Shipping costs.**
Source: Kite-Powell (2000).

Some 50 million short tons of maritime cargo move through US ports in the Gulf of Maine each year. More than 80% of this is oil and petroleum products (US Army Corps of Engineers 2001). This cargo is associated with some 2000 port call by self-propelled vessels (mostly foreign flag) and 1500 barges (mostly domestic) per year. Gulf of Maine cargo represents about 4% of total US oceangoing cargoes.

If a significant number of Gulf of Maine transits make use of improved marine conditions information to shorten their transit by even a fraction of an hour, this can result in operating cost savings. Table 2 provides an estimate of total operating costs for marine transportation in the Gulf of Maine. Because there are no data to match vessel types in the Gulf of Maine precisely with the operating costs shown in Table 1, we use the following assumptions. (1) The lowest cost in Table 1 is used for each vessel type, except for tankers where we use a figure of $12,000 per day. Barges are assumed at $2000 per day. (2) Each transit (round trip) of the Gulf of Maine takes 2 days. Based on these assumptions, a 1% improvement of transit times would yield benefits of about $500,000 per year.

In addition, vessel operators can use information about wave conditions at harbor entrances to plan ahead for pilot boarding, and additional benefits may be realized from avoided losses due to heavy weather exposure.

| | transits/year (1999) | operating cost estimate ($/day) | annual operating cost ($/year) |
|---|---|---|---|
| foreign dry cargo and passenger | 835 | 7,000 | 11,690,000 |
| foreign flag tanker | 817 | 12,000 | 19,608,000 |
| foreign flag barge | 54 | 3,000 | 324,000 |
| US flag dry barge | 59 | 3,000 | 354,000 |
| US flag tanker | 203 | 10,000 | 4,060,000 |
| US flag tank barge | 1,199 | 3,000 | 7,194,000 |
| **total** | -- | -- | **43,230,000** |

**Table 2: Estimated operating costs of maritime transportation in the Gulf of Maine, assuming average total transit time of 2 days.**
Sources: US Army Corps of Engineers Waterborne Commerce of the United States 1999 and Kite-Powell (2000).

*Commercial fishing:*

The economic benefits to fisheries of improved ocean observing systems differ depending on the type of fishery. For benthic and pelagic fisheries using mobile gear and subject to fishery management regimes of either the state or federal governments, the principal benefits will likely be derived indirectly from improved management decisions. Improved understanding of oceanographic conditions may be linked to improved fisheries management decisions that in turn permit increases in the number of days at sea or allowable catch in an effort-limited fishery. In such cases, the economic benefits may be viewed as a function of the value of a day at sea. Table 2 shows the average value per day for the Gulf of Maine commercial finfish and shellfish fisheries. This is an approximation, since the real value of benefits must be the marginal rather than average value.

For a fixed gear fishery, such as the lobster fishery, additional instrumentation may provide local weather observations that are of use to fishers. Lobstermen have suggested that information about local variations in fog may be particularly valuable. Many lobster boats do not carry radar, and the large variability in fog patterns across even a relatively small area makes real time information potentially beneficial. The measure of these benefits must come from value of information models that must be empirically specified before benefits can be estimated.

A third category of potential beneficiaries is aquaculture. Two types of aquaculture are currently practiced in the Gulf of Maine: net pen culture of Atlantic salmon and bottom culture of shellfish (primarily mussels). Both are currently undertaken almost exclusively in protected embayments, primarily in Maine. These waters permit easy access and protect from the vagaries of weather. However, protected embayments raise issues about competition for near-shore space and environmental damage from nutrient discharges. These disadvantages have led to growing interest in open ocean aquaculture as an alternative (Bridger and Reid 2001). Open ocean operations may benefit from improved understanding of ocean circulation, chemistry, and temperature. But it is too early to say how extensive open ocean aquaculture will become in the Gulf of Maine, and these benefits must be considered too speculative for inclusion here.

The fourth category of potential beneficiaries from improved regional oceanographic data is participants in mobile gear fisheries, primarily those involved in the groundfish and pelagic fisheries. As with the fixed gear fishery, there may be some benefits from improved local weather and ocean condition information in deciding whether and how long to fish. A more complex problem arises, however, because the majority of these fisheries, particularly in the Gulf of Maine, are managed fisheries. In these fisheries, federal or state regulators impose limitations on fishing effort. Limited effort translates into limited income potential, which means that some economic benefits from improved understanding and observation of the ocean environment must be mediated through the fisheries management regime.

This makes the estimation of benefits from improved ocean observing systems to the managed commercial fisheries very difficult. The only path to economic benefits lies through the regulators, who must find ways to use the information in order to improve regulation and fishery yields. This connection requires that the environmental characteristics monitored by the ocean observing system provide data that result in management decisions that permit more fish to be caught. It must be shown that environmental determinants of stock levels can be better understood and predicted, and that once these environmental determinants are controlled for, increases in fishing effort can be permitted.

For example, better observations of temperature and salinity may permit a connection between these factors and the abundance of species X, a commercially valuable species managed through a seasonal restriction on allowable catch. Prior to the establishment of this connection, regulators were able to permit only very short catch seasons in order to be “on the safe side”. But the development of additional information showed that stock abundance grew when certain temperature/salinity characteristics were present, and models developed from the larger base of available observations showed some degree of regularity in the fluctuations of those relevant characteristics. This permitted regulators to allow somewhat longer fishing seasons in certain years.

Such longer seasons would result in an increase in the sustainable harvest of the commercially important species. The measure of such benefits is an increase in profit to fishers and a lower price to fish consumers. Estimation of such benefits requires detailed models of the fishery production and consumption markets, but a first order approximation of the size of such benefits may be obtained by looking at the overall size of the Gulf of Maine fishery.

As an indicator of the approximate size of potential benefits, Table 3 shows an estimate of the average value added per day in the New England finfish and shellfish fisheries. These estimates are based on total landed values adjusted for the costs of inputs, estimated by the National Marine Fisheries Service. Annual values were then adjusted to average daily values based on an estimated 60-day finfish season and 120-day shellfish season. These are obviously only preliminary estimates, and value added is an approximation of the correct measure of economic benefits. Nonetheless, there appears to be a significant potential benefit.

| fishery | state/region | estimated average value added per fishing day ($) |
|---|---|---:|
| finfish | Maine | 339,975 |
| | New Hampshire | 57,685 |
| | Massachusetts | 1,151,355 |
| | Rhode Island | 285,919 |
| | ***New England*** | ***1,834,934*** |
| shellfish | Maine | 1,218,079 |
| | New Hampshire | 36,793 |
| | Massachusetts | 787,628 |
| | Rhode Island | 271,668 |
| | ***New England*** | ***2,314,168*** |
| **combined** | **New England** | **4,149,102** |

**Table 3: Estimated average value added per fishing day.**
Assumes a 60 day finfish season and 120 day shellfish season.
Source: National Marine Fisheries Service Fisheries Statistics of the US 1999
and NMFS Estimates of Fisheries Value Added.

### *Recreational fishing and boating*

Both marine recreational fishing and boating are important ocean activities throughout the coastal United States. Participation in these activities depends very much on local weather and sea conditions, which can vary greatly throughout a region as large as the Gulf of Maine. Increases in monitoring stations and the availability of real time or near-real time information could provide the information to increase both the quantity and quality of recreational boating and fishing activity.

The quantity could be increased by allowing boaters to identify weather and sea conditions that are favorable for boating, and thus encourage additional activity. Such a system is partly in place with the NWS weather buoy system, but coverage from these stations is often spotty. Rutgers University has established a more extended system of coastal weather and sea observations available in near-real time on a website through their Coastal Ocean Observations Laboratory (see http://marine.rutgers.edu/coolroom/).

Table 4 shows estimated daily recreation values for marine fishing in the Gulf of Maine region and in the United States as a whole. These estimates use the proportion of recreational fishing trips conducted from either private or charter boats rather than from shore, and the effect of a 1% increase in fishing trips in each state that might occur if more accurate ocean/weather information were available.

| | angler trips, 1999 (1000s) | number of marine recreational anglers | estimated total willingness to pay ($million) | value of 1% increase in trips ($) |
|---|---|---|---|---|
| Maine | 629 | 216,007 | 136.8 | 1,368,000 |
| New Hampshire | 285 | 122,901 | 18.2 | 182,000 |
| Massachusetts | 2,983 | 470,570 | 179.1 | 1,791,000 |
| Rhode Island | 1,262 | 321,201 | 90.4 | 904,000 |
| Gulf of Maine | 5,159 | 1,130,679 | 424.5 | 4,245,000 |
| United States | 61,807 | 7,822,048 | 702.5 | 61,807,000 |

**Table 4: Marine recreational fishing values.**
Sources: National Marine Fisheries Service (1999) and Hicks *et al.* (1999).

An improvement in the quality of recreational boating and fishing activities is also possible with improved weather and sea information. Knowing when conditions are unfavorable for planned activities means that people can avoid being caught in unpleasant or dangerous conditions. This would result in a reduction of the number of trips, but an increase in the value of those trips taken. This value would be measured by assessing boater's willingness to pay for improved information.

### *Search and rescue (SAR) operations:*

The US Coast Guard conducts some 6000 SAR missions and saves more than 500 lives each year in the Gulf of Maine region. This represents about 15% of the Coast Guard's total SAR activity. Significantly, some 28 lives are lost each year in the Gulf of Maine region after the Coast Guard has been notified that they are at risk. Perhaps the most critical factor determining the success of SAR is the time it takes the Coast Guard to get to the person at risk. The SAR success rate is only about 4% when this time exceeds 2 hours.

Understanding the currents and winds in the vicinity of the SAR target is critical to locating and reaching the person quickly. Improved nowcasts of these parameters from GoMOOS can improve SAR effectiveness. For example, a 1% improvement in SAR effectiveness (from 90% to 91% lives-at-risk saved) in the Gulf of Maine would result in an additional 6 lives saved per year, with an economic value of some $24 million. (We assume here a conservative value for a human life of $4 million; see Viscusi (1993).) Additional benefits can be realized from reduced SAR costs and reduced risk to SAR personnel.

### *Pollution Management and Prevention*

Improved understanding of the fate and effects of marine pollutants is likely to have major economic benefits. Two examples from the Gulf of Maine illustrate the types of benefits that may be derived. One is better understanding of the effects of sewage and other land-based sources of effluents into the marine environment, and the other is the prediction and management of oil spills. An order of magnitude estimate for the latter may be made.

#### *Boston Harbor*

The activation in September 2000 of a new sewage outfall tunnel (and sewage treatment plant) in Boston has removed a long-standing source of pollution from Boston Harbor and contributed to the successful remediation of its water quality. The new outfall tunnel extends 9.5 miles into Massachusetts Bay, and has changed the focus of Boston metropolitan sewage nutrient input from the immediate vicinity of Boston Harbor to greater Cape Cod Bay and its coastal towns. In particular, there is concern about the possible enhancement, by sewage nutrients, of harmful algal blooms that “migrate” seasonally into Cape Cod Bay from the Gulf of Maine. Understanding the interaction of coastal currents, harmful algal blooms, and sewage nutrients is important to the proper management of coastal waters as a sink for human waste. This understanding can only be developed through sustained programs of coastal ocean observation.

#### *Oil Spills*

The subject of oil spills in the marine environment is often discussed only in connection with the exploration and development of offshore oil and gas resources, something that is currently prohibited in the US Gulf of Maine. But the risks of oil spills in the Gulf of Maine, and in all regions of the United States, arise as much from the transport of oil across the oceans as from its extraction from beneath the oceans. The Gulf of Maine is a good example of where these transportation risks are barely visible, but still significant.

Over 2000 oil tanker and barge transits of the Gulf of Maine are made each year. Over 960 million barrels of oil were imported into the US side of the region in 1998, accounting for more than 5% of all oil moved by ocean in the United States. Portland, Maine was the largest oil port in the region, and the third largest (after New York and

Philadelphia) on the east coast. In addition to the activity on the US side of the Gulf of Maine, Saint John in New Brunswick is also a major oil refining and port center, where VLCCs service the largest oil refinery in Canada.

The risks of oil spills have, fortunately, declined over the past thirty years. The frequency of spill incidents and the volume of oil spilled have dropped significantly. However, vessels still account for the majority of spills, and also for the majority of large (>1000 gallon) oil spills (Table 5). The number and magnitude of "routine" spills has declined, but the risks of large scale catastrophic spills will never be eliminated entirely. In the past decade, major spills have occurred in Naragansett Bay and in Portland Harbor.

| | Number of Spills | | Volume of Oil (in gallons) | |
|---|---|---|---|---|
| Year | <1000 Gals | > 1000 Gals | <1000 Gals | > 1000 Gals |
| 1973 | 8,473 | 541 | 578,836 | 14,674,744 |
| 1974 | 9,157 | 842 | 680,065 | 15,018,666 |
| 1975 | 8,647 | 645 | 664,535 | 20,855,547 |
| 1976 | 8,812 | 610 | 586,471 | 17,931,477 |
| 1977 | 8,912 | 547 | 587,321 | 7,601,812 |
| 1978 | 10,061 | 583 | 635,945 | 10,228,163 |
| 1979 | 9,277 | 557 | 605,849 | 20,287,705 |
| 1980 | 7,931 | 452 | 529,915 | 12,067,055 |
| 1981 | 7,421 | 390 | 456,993 | 8,464,002 |
| 1982 | 7,032 | 452 | 460,706 | 9,884,090 |
| 1983 | 7,503 | 413 | 424,558 | 7,955,289 |
| 1984 | 7,841 | 417 | 441,075 | 17,564,804 |
| 1985 | 5,824 | 345 | 356,165 | 8,080,082 |
| 1986 | 4,853 | 140 | 238,888 | 4,043,091 |
| 1987 | 4,698 | 143 | 210,428 | 3,398,456 |
| 1988 | 4,850 | 148 | 215,358 | 6,370,645 |
| 1989 | 6,462 | 151 | 258,181 | 13,220,514 |
| 1990 | 7,988 | 189 | 238,901 | 7,676,106 |
| 1991 | 8,419 | 150 | 238,306 | 1,637,646 |
| 1992 | 9,340 | 151 | 276,005 | 1,599,663 |
| 1993 | 8,840 | 132 | 203,431 | 1,863,957 |
| 1994 | 8,811 | 149 | 208,940 | 2,280,333 |
| 1995 | 8,938 | 100 | 164,076 | 2,474,153 |
| 1996 | 9,226 | 109 | 158,265 | 2,959,566 |
| 1997 | 8,542 | 82 | 120,977 | 821,597 |
| 1998 | 8,221 | 94 | 124,699 | 760,604 |
| 1999 | 8,452 | 87 | 125,649 | 1,046,800 |

**Table 5: Oil spill trends, 1973-1999.**
Source: US Coast Guard.

More importantly, however, the cost of oil spills has risen dramatically. Strict liability standards in the Oil Pollution Act of 1990; increased requirements for training, preparedness, and mitigation; and provisions for recovery of damages to natural resources from oil spills have pushed the cost of oil spills up by over 700% according to one industry estimate. British Petroleum estimates the total cost of an oil spill to be $10,000 per barrel spilled. Table 6 provides a list of the types of costs involved in oil spills.

| **direct expenses:** | **indirect expenses** |
|---|---|
| · cost of personnel and their expenses during cleanup | · increased attention by regulators |
| · cost of contractors and other direct cleanup | · permits for new activities cost more and take longer |
| · reimbursed cost for USCG and USCG fines | · more drills and exercises |
| · fees and fines from state agencies | · increased cost of new equipment and other preparation costs |
| · cost of litigation and litigation defense | · new local, state, and federal laws |
| · costs associated with residual damages | · new local, state, and federal taxes and fees |
| · economic losses | · business cost from diverting key personnel to spill control |
| · environmental damage | · stock price and stockholder pressure |
| · mitigation expense | · higher insurance costs |
|  | · loss of sale of products |

**Table 6: Oil spill cost categories.**
Source: Gandhi and Chennoju.

All major oil handling ports must have an oil spill response plan in place. That plan varies in detail from port to port, but each plan includes deployment of oil spill containment and clean-up equipment. Oil spill containment and cleanup remains a poor substitute for prevention; once a spill has occurred, adverse effects can be generally be reduced by only five to fifteen percent. One potential key to improving the effectiveness of containment and cleanup operations is to deploy the appropriate equipment in a timely manner. Spill response coordinators often rely on fate and effects models based on models of currents, which are in turn derived from the best available data. While good data on tidal currents are usually available, larger regional circulation patterns may be imperfectly predictable because of a lack of observations. Regional ocean observing systems are likely to develop significantly improved data bases from which new models can be estimated. The result may be significant improvements in spill response time and effectiveness.

Table 7 shows estimates of the reduction in Gulf of Maine and national oil spill costs that could have occurred over 1990-2000 if improved oil spill fate and effect predictions were available and reduced the costs of oil spilled by only one percent.

As Table 7 shows, the estimation of benefits related to improved oil spill clean up varies greatly from year to year. For most years, the effects are not particularly large because of the increased effectiveness of oil spill prevention. The size of benefits is primarily determined by rare catastrophic events, such as the 1986 *Julie N* spill in

Portland harbor. Estimation of such benefits thus requires a probability model to estimate the possibility of such events.

| | New England | United States |
|---|---|---|
| 1990 | 2,827,676 | 18,276,443 |
| 1991 | 341,817 | 3,899,157 |
| 1992 | 413,760 | 3,808,721 |
| 1993 | 317,657 | 4,437,993 |
| 1994 | 205,817 | 5,429,364 |
| 1995 | 178,360 | 5,890,840 |
| 1996 | 2,526,031 | 7,046,586 |
| 1997 | 242,957 | 1,956,183 |
| 1998 | 232,464 | 1,810,962 |
| 1999 | 179,495 | 42,492,381 |

**Table 7: Estimated value ($) of 1% reduction in oil spill costs.**

## Conclusions

A preliminary analysis of likely benefits in these five sectors suggests strongly that the benefits from a regional ocean observation system in the Gulf of Maine will exceed its costs. To test the validity of this claim, it will be necessary to look in more detail at how GoMOOS information will be used in at least some of the most promising sectors: search and rescue, oil spill management, and fisheries. Table 8 summarizes the value of the various benefit types discussed here.

| application | nature of benefit | annual potential benefits ($million) |
|---|---|---|
| search and rescue | lives saved* | 24 |
| | reduced operating costs | ? |
| pollution mitigation | oil spills** | 0.75 |
| | other | ? |
| commercial fisheries | improved weather information | ? |
| | improved management*** | 4 |
| | aquaculture | ? |
| recreation | additional recreational fishing days**** | 4 |
| | improved weather information | ? |
| maritime transportation | lower vessel operating costs***** | 0.5 |
| **total** | | **33+** |

*based on improved SAR effectiveness from 93% to 94% success
**based on 10 year average annual oil spill costs
***based on 1 additional fishing day per year for shellfish and finfish
****based on 1% increase in recreational fishing trips
*****based on 5% savings in annual operating costs

**Table 8: Summary of estimated Gulf of Maine benefits.**

To produce accurate estimates of benefits, it will be necessary to define more carefully the new data and information that GoMOOS will produce. Here, economic analysis can serve a double purpose: it can describe the benefits that result from additional ocean observing capacity, and it can inform the design of this capacity to maximize its usefulness.

Economic evaluations of oceanographic research and monitoring have been few, but the need for such assessments may be more critical now than at any time in the past for three reasons:

- First, as is the case with GOMOOS, there is a very strong orientation towards specific user communities beyond the traditional marine science community. Once data is to be directly used by groups such as the marine transportation or commercial fishing industries, or even more broadly by millions of recreational boaters, questions about the value that such users place on available information become critical to assuring their continued involvement and satisfaction.

- Second, well-designed and functional coastal observing systems will be expensive to set up and run. In a period of limited resources, state and federal governments will be asking what they can expect in return for their investment. Perhaps even more importantly, a thorough understanding of the economic benefits will be essential to allocate the costs of such systems efficiently between the public and private sectors, and within the public sector, among federal, state, and local governments.

- Finally, the development of coastal ocean observing systems is taking place at a time when the cost of distributing such information is falling essentially to zero. The World Wide Web and associated information technologies make possible the dissemination of information from monitoring systems in ways that are entirely unprecedented. The web sites of GoMOOS and COOL make information available to literally millions of potential users who have never been part of the marine science community. This greatly broadens the demand for (and thus the economic benefit of) such information, but it also greatly increases the distance between producers and consumers of the information.

Economic evaluation of this connection provides the most complete picture of the link between users and producers of regional ocean information, thus assuring both the best service to users and the most efficient and effective coastal ocean observing systems.

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