# The Potential Economic Benefits of Integrated and Sustainable Ocean Observation Systems: The Southeast Atlantic Region

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## Executive Summary

The ocean is one of the least measured and observed regions of the planet. Better ocean information provides many benefits to society, and efforts are underway to improve our understanding. The South East Atlantic Coastal Ocean Observing System (SEACOOS) consists of a three-pronged program of observation, modeling, and data management. SEACOOS collects, manages, and disseminates oceanic and atmospheric observation data and information products. SEACOOS data are collected off the coasts of North Carolina, South Carolina, Georgia and Florida.

The costs of deploying and operating coastal observing systems nationwide are uncertain, but range from tens of millions to billions of dollars per year. It is likely that the government rather than the private sector will provide the major share of funding to support these systems. Determining the magnitude of the potential economic benefits of coastal observation data relative to costs is a major policy issue.

Many economic activities may benefit from improved SEACOOS information. For consistency with other regional studies of SEACOOS benefits, we consider five benefit categories: maritime commercial transportation, commercial fishing, recreational boating and fishing, search and rescue operations, and oil spill prevention. In addition, we consider additional benefit categories of particular importance within the SEACOOS region: beach recreation, coastal erosion control, hurricane prediction and evacuation, recreational cruises, commercial fishing vessel accidents, and maritime shipping accidents.

Better SEACOOS data drive better ocean and weather forecast models, which in turn improve management and operational efficiency in coastal-dependent sectors of the economy. Improved efficiency produces benefits in terms of higher value products and lower costs. The full, eventual impacts of improved SEACOOS information are difficult to estimate. Following the methodology used in similar studies of other regions, we evaluate the impacts of assumed, conservative changes in economic activity or costs in each sector. Typically, a one percent change in activity or cost is considered.

The estimated total annual benefits of SEACOOS information across all states in the SEACOOS region and across all benefit categories are $170 million (2003 $'s). Beach recreation, search and rescue operations, and recreational cruises receive the largest annual benefits, $88 million, $40 million, and $27 million. Annual benefits in the remaining categories are: maritime commercial shipping transit time, $4.6 million, maritime commercial shipping grounding reduction, $0.13 million, marine recreational fishing, $3 million, commercial fishing, $3.3 million, beach erosion management, $2.0 million, hurricane evacuation, $0.9 million, and oil spills, $0.6 million.

Comparing across states within the SEACOOS region, Florida receives more than 67% of the estimated SEACOOS region benefits, due to disproportionately large benefits in the beach recreation and recreational cruise categories. North Carolina and South Carolina each receive approximately 13% of regional benefits, while Georgia receives approximately 8%. The categories receiving the largest benefits in North Carolina, South Carolina, and Georgia are beach recreation and search and rescue operations.

The SEACOOS region annual benefit estimate of $170 million falls between estimates of $33 million for the Gulf of Maine and $381 million for the Gulf of Mexico. The major drivers of regional differences are the large beach recreation and recreational cruise benefits in the SEACOOS region and the large offshore oil and gas extraction benefits in the Gulf region.

**1. Introduction**

The ocean is one of the least measured and observed regions of the planet. Better ocean information has many beneficial applications, and efforts are underway to improve our understanding. In 1991, the Intergovernmental Oceanographic Commission (IOC) of UNESCO, the World Meteorological Association, and the United Nations Environment Program (UNEP) formed the Global Ocean Observing System (GOOS) (IOC 1998). In 2000, the Chief of Naval Research (CNR), the Administrator of the National Oceanic and Atmospheric Administration (NOAA), and the President of the Consortium for Ocean Research and Education (CORE) announced the formation of OCEAN.US (http://www.ocean.us/), an organization dedicated to the formation of an Integrated and Sustainable Ocean Observation System (ISOOS) for the United States (SEACOOS 2004). ISOOS is the U.S. contribution to GOOS and the U.S. ocean contribution to the Global Earth Observing System (GEOSS) (OceanUS 2004). International agreements calling for actions addressed by ISOOS include the Safety of Life at Sea (SOLAS) Convention, the Framework Convention on Climate Change, Convention on Biodiversity, and the Program of Action for Sustainable Development. Development of ISOOS influences and is guided by the design and implementation of GOOS.

The South East Atlantic Coastal Ocean Observing System (SEACOOS, http://www.seacoos.org) is one of the regional (see Figure 1.1) observing systems ringing the U.S. that will form ISOOS. SEACOOS is an umbrella organization that seeks to coordinate coastal observing system activities in four southeastern states, including the efforts of NCCOOS (northern and central North Carolina), Caro-COOS (southern North Carolina and South Carolina), SABSOON (Georgia), and EFSIS and COMPS (Florida), the U.S. Army Corps of Engineers, state port authorities, and emergency management agencies.

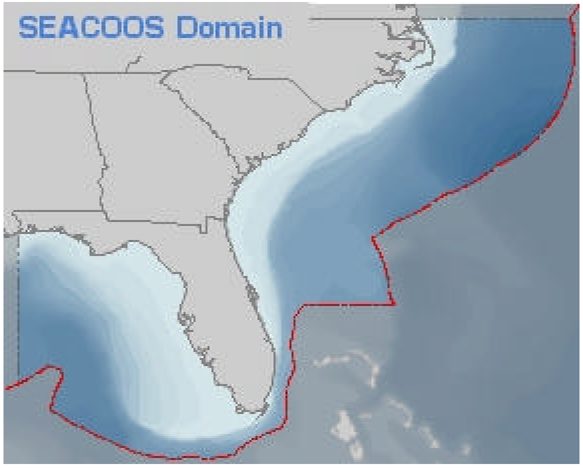


Figure 1.1 The SEACOOS region.
(Graphic used by permission: SEACOOS, http://www.seacoos.org)

SEACOOS consists of a three-pronged program of observation, modeling, and data management. SEACOOS collects, manages, and disseminates oceanic and atmospheric observation data and information products. The instruments that collect coastal ocean and atmospheric measurements, the platforms that host them, and the supporting communications and power systems comprise the observing subsystem of SEACOOS. SEACOOS data are collected off the coasts of North Carolina, South Carolina, Georgia and Florida (Figure 1.2).

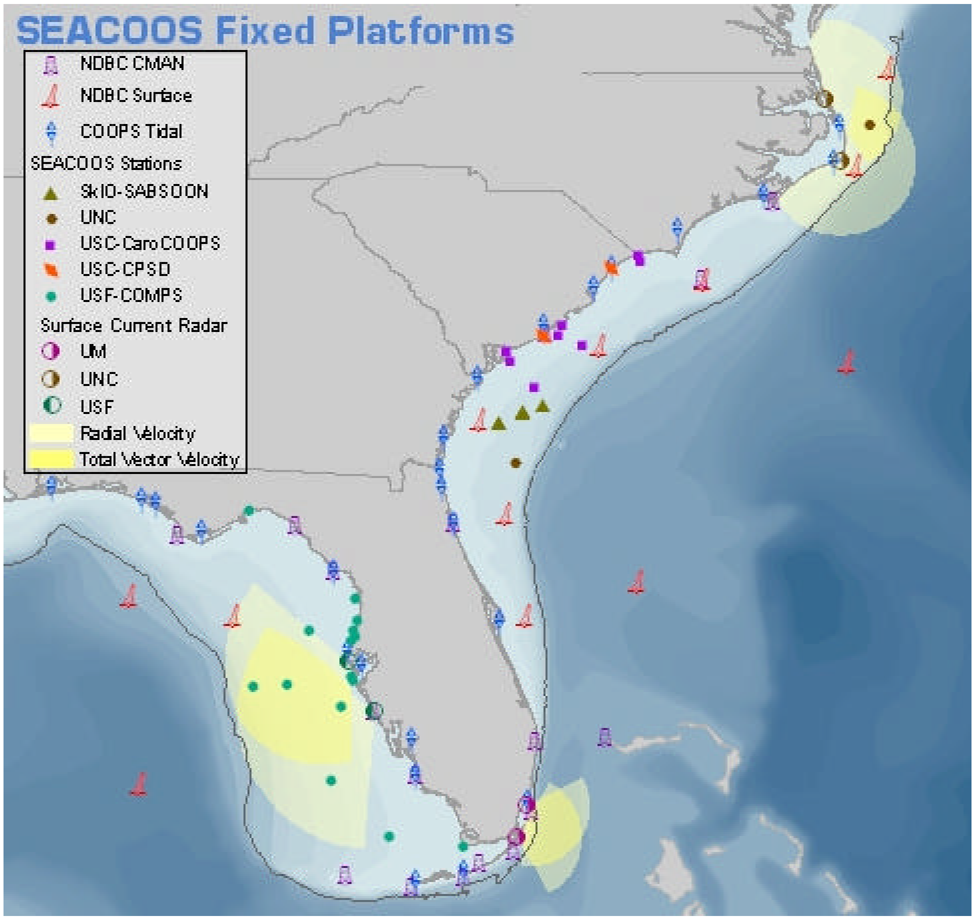


Figure 1.2 The SEACOOS data collection network.
(Graphic used by permission: SEACOOS, http://www.seacoos.org)

The costs of deploying and operating ISOOS nationwide are uncertain, but range from tens of millions to billions of dollars per year (Kite-Powell and Colgan 2001). It is likely that the government rather than the private sector will provide the major share of funding to support ISOOS. Such a program will probably consist of a combination of existing and new technologies and equipment, including buoys, radar systems, tide gauges, and satellite observation. Determining the potential economic benefits of ISOOS and the magnitude of these benefits relative to costs is a major policy issue. Better ISOOS data drives better ocean and weather forecast models, which in turn improves management and operational efficiency in coastal-dependent sectors of the economy. Improved efficiency produces economic benefits in terms of higher value products (e.g., higher success rates in life-saving search and rescue missions, cruise trips with calmer seas and more sunny days) and lower costs (e.g., shorter detours around bad weather for maritime shipping, fewer oil spills and related costs).

This report complements a series of region-specific reports on the economic benefits of ISOOS in the United States (NOAA-ONR 2002). Other research has considered the benefits of ISOOS in the Gulf of Maine and the Gulf of Mexico. Research in these regions identified five major categories of quantifiable benefits: (1) maritime transportation, (2) commercial fishing, (3) recreational fishing and boating, (4) search and rescue operations, and (5) pollution management, specifically oil spill management and prevention. In the Gulf of Maine, the annual benefits are estimated to be more than $33 million with most of these benefits in the category of lives saved (Kite-Powell and Colgan 2001). In the Gulf of Mexico, Lynch, Harrington and O'Brien (2003), using similar methodology and assumptions, find that the annual benefits of ISOOS for the same five benefit categories are $97 million/yr., with more than $25 million/yr. in benefits attributable to each of the maritime transportation, recreational fishing and search and rescue benefit categories.

This report develops estimates of ISOOS economic benefits for the southeast Atlantic, SEACOOS region--from North Carolina through Florida's Gulf coast. The research is intended to complement related research currently underway at the national and regional levels. In addition to the five benefit categories addressed in the Gulf of Maine and Gulf of Mexico studies, we estimate the benefits of ISOOS for hurricane evacuation warning systems, beach recreation opportunities, cruise line operations, and beach erosion management. Benefit estimates are developed for each state in the SEACOOS region and for the SEACOOS region as a whole. A brief literature review of the potential economic benefits for agriculture is also presented, although it is outside the scope of this study to provide a quantitative benefit estimate for the farm sector. We find that the potential economic benefits of ISOOS for the SEACOOS region amount to $171 million per year for the benefit categories considered.

This report does not represent a comprehensive benefit analysis of ISOOS in the SEACOOS region. Rather, it provides a preliminary assessment of the potential economic benefits for the economic sectors most likely to benefit from ISOOS information. In cases where hard data are not available, professional judgment is used to estimate potential economic impacts under typical circumstances. Where feasible, estimates of the potential variation in economic benefits are provided.

## 2. Theory

Two economic principles, network externalities and public goods, support government involvement in ISOOS data collection and distribution. The collection of ISOOS data is subject to network externalities--the benefits of the whole are greater than the sum of the benefits of the individual parts. For example, it is valuable to each individual to know the temperature and wind speed in his backyard, but if all such measurements are collected and analyzed, then projections of weather fronts and forecasts of changes in the weather can be made. The economic value of such projections and forecasts cannot be obtained from the individual measurements in isolation; additional value is created beyond the value of the individual measurements when they are combined and analyzed as a whole. Unfortunately, the direct incentive for a private firm to pay for information collection, combination and analysis is usually limited to the value received by the firm. Although an individual firm may benefit from weather forecasts, it is not likely that the benefits would be large enough for the firm to undertake the costs of establishing a national weather data collection network all by itself. Acting independently, firms would likely under-invest in the development of the system, relative to the efficient level of development, the level that would maximize the net economic benefits to society as a whole.

In addition to the problem of network externalities, the public good nature of ISOOS information works against its development by the private sector. Once produced, the economic net benefits of ISOOS information are maximized by distributing the information to all who might benefit, because the information is almost costless to copy and distribute. While this public good characteristic of low cost distribution is desirable from a societal perspective, it reduces the incentive for the private sector to pursue system development, because results are easily copied and distributed by business rivals, and initial investments by industry pioneers may not be recovered. Businesses that pay the large, up-front investment costs necessary to develop "name brand" ISOOS information would find it difficult to protect their product from infringement by business competitors selling "generic" versions of their information products. The potential of copy-cat rivals to dissipate the value of large initial investments often stifles the development of products with public good characteristics.

When a government project or policy is implemented there are economic benefits and costs. The economic efficiency criterion requires that for a project to be desirable, the benefits must outweigh the costs. Economic efficiency is one of several criteria (others include equity and risk) used to assess the desirability of government projects. Benefit-cost analysis is a method used to calculate and compare monetary benefits and costs for the purpose of assessing efficiency (Boardman et al. 2001). Cost estimation is typically straightforward. Engineers can provide estimates of the cost of mooring and maintaining a buoy in an inlet. However, benefits are often difficult to measure, especially when government agencies produce and distribute the products to end users "free of charge" or at subsidized prices. When the products involve network externalities or public good characteristics, benefit valuation is even more difficult.

The following discussion reviews the basic principles of economic benefit valuation for producers and consumers. The concepts of value-added and producer surplus are used to measure the net economic benefits of products and services to producers (business owners and their employees). Value-added is the net economic benefit accruing to business owners and their employees from producing goods and services. Value-added may be divided into producer surplus and employee wages and salaries. Producer surplus is equal to sales revenue minus all variable production costs (costs that vary with the amount of product produced). Producer surplus is the amount of money that a business has "left over" after it pays all variable costs. This "left over" money is used to pay fixed costs and profit to owners. That is, "Produce Surplus = Fixed Costs + Profit." Producer surplus is used as an indirect measure of changes in firm profits because (1) producer surplus can be measured using non-proprietary data on market prices and quantities and (2) producer surplus varies dollar-for-dollar with firm profit. If firm profit increases by a dollar, then producer surplus must increase by a dollar, because Fixed Costs are exactly that--fixed. As a result, if one is interested in measuring the change in firm profits resulting from a change in the firm's operating environment, say an improvement in ISOOS information, then all that is needed is a measurement of the change in the firm's producer surplus, because changes in producer surplus track changes in profit dollar-for-dollar. To estimate the full economic value of an improvement in ISOOS information for a producer and its employees, we calculate the change in value-added, which is simply the change in the producer surplus plus any changes in employee wages and benefits.[1] Improvements in ISOOS information may increase value-added in two ways: (1) improved ISOOS information may increase the value of the product to the consumer, which will allow the producer to charge higher prices, increasing revenues, producer surplus, and value-added, and (2) improved ISOOS information may decrease the producer's variable costs, increasing producer surplus and value-added.

The concept of consumer surplus is the basis for measuring the net economic benefits of products and services to consumers.[2] The consumer surplus is the difference between what the consumer is willing (and able) to pay for a product and the price actually paid (amount actually spent) for the product. Consumer surplus is also called net willingness to pay (net WTP) since it is willingness to pay net of costs. For example, suppose a consumer of ISOOS information services, say a commercial fisher, may be willing and able to pay $50 for ISOOS data. However, suppose the government makes the data available to her for a monthly fee of $10 set to just cover costs, then the consumer surplus is $50 - $10 = $40 – the difference between the consumer's maximum willingness to pay and the amount actually paid. Consumer surplus is the correct measure of the net economic benefit enjoyed by the consumer of the information. It is important to note that the price paid, $10, is *not* the correct measure of economic benefit and may in fact significantly underestimate benefits. Furthermore, suppose an improvement in ISOOS information services increases the fisher's willingness to pay for the information to $75, and the government increases its monthly fee to $20 to cover the cost of additional data acquisition. The increase in the amount of money collected by the government for its services, $20 - $10 = $10, is *not* the correct measure of economic benefit to the consumer. Rather, it is the change in consumer surplus, ($75 - $20) - ($50 - $10) = $55 - $40 = $15. Measuring benefits in terms of changes in fees collected may significantly underestimate consumer benefits.

It is important to note that consumer surplus exists as well for "non-market goods" such as beach recreation and recreational fishing (Freeman, 1993). Beach recreation and recreational fishing are non-market goods because consumers typically do not pay directly for the goods themselves. For example, although a recreational angler may pay for gasoline, food and lodging in order to access a fishing location, in most cases she does not pay for the actual fish caught. Suppose the angler is willing and able to pay up to $125 for a good day of fishing. If the cost of the day trip is $25, then her consumer surplus is $125 - $25 = $100. Now suppose that improved ISOOS information leads to better fishery management that, in turn, increases the angler's expected catch per trip. With the increase in expected catch, the angler's willingness to pay might increase to say, $160. However, suppose as well that in order to take advantage of the additional fish, the

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[1] This assumes that any additional employees hired (or any additional pay raises) as a result of ISOOS would be unemployed (would not occur) without ISOOS. If employees have a "fall back" job, then the full economic value is less by the difference between the wages of the job with ISOOS and the wages of the "fall back" job without ISOOS, assuming that the jobs are similar in all other non-monetary aspects. This report attempts to account for this possible discrepancy by making very conservative assumptions regarding any changes in employment or wages caused by ISOOS.

[2] In practice, changes in consumer surplus have been found to be good approximations of more theoretically-precise measures of economic benefit (Willig 1976, Randall and Stoll 1980).

angler must travel to a slightly different location costing $27 per day. If so, the consumer surplus per trip is now $160 - $27 = $133. The angler's economic gain from improved ISOOS information is the change in her consumer surplus, or $133 - $100 = $33. (It is important to note that the change in the angler's expenditures, $27 - $25 = $2, is *not* the correct measure of economic benefit.) The empirical challenge, of course, is to determine the angler's willingness to pay and consumer surplus before and after the change in ISOOS information.

Estimation of consumer surplus is relatively straightforward if market data exist. Typically, a demand curve equation is estimated statistically using data on market prices, quantities purchased by consumers, and other related variables such as consumer incomes and prices of related goods. Consumer surplus estimates are then derived from the demand curve equation. Without market data, a number of methodologies have been developed to estimate consumer surplus, including the hedonic pricing method, the travel cost method, and the contingent valuation method. These methods are described briefly below and are simply referenced when cited later in this report.

The hedonic price method (Palmquist 1991, Freeman 1993) exploits relationships between characteristics of land or labor markets. For example, land parcels in close proximity to water bodies with high erosion risk command lower prices than parcels adjacent to water with lower erosion risk. Job markets with greater safety risk (such as commercial fishing) pay higher wages relative to other job markets. All else equal, differences in land prices or wages across locations or jobs with different risks can signal the value of improved safety. Such housing or labor market data can be used to indirectly estimate demand curve equations and associated consumer surplus for information that reduces risk.

The travel cost method (Bockstael 1995) begins with the insight that the major cost of outdoor recreation is the travel and time costs incurred to get to the recreation site. Since individuals reside at varying distances from the recreation site, variations in travel distances and the number of trips taken are used to trace out a demand curve for the recreation site. The demand curve is then used to derive the consumer surplus associated with using the site.

The contingent valuation method (Mitchell and Carson 1989, Bateman and Willis 1999) involves the development of a hypothetical market via in-person, telephone, mail, or other types of surveys. In the hypothetical market respondents are informed about the current problem and the policy designed to mitigate the problem. The situations before and after the policy are described. Other contextual details about the policy are provided such as the policy implementation rule (e.g., majority voting) and the payment vehicle (e.g., increased taxes or utility bills). Finally, a hypothetical question is presented that asks respondents to choose between the proposed policy (typically with associated costs) and the status quo. The choice is often framed as a referendum vote in order to make the situation more realistic. Respondents can be presented with multiple scenarios and make multiple choices. Statistical analysis of these data leads to the development of demand curve equations and consumer surplus estimates.

## 3. Categorical Benefits of SEACOOS

Many commercial, recreational and governmental activities may benefit from improved ISOOS information in the SEACOOS region. For consistency with other regional studies of ISOOS benefits (Kite-Powell and Colgan 2001; Lynch, Harrington and O'Brien 2003), we consider the following five benefit categories:

- maritime commercial transportation
- commercial fishing
- recreational boating and fishing
- search and rescue operations
- oil spill prevention and management

In addition, we consider the following benefit categories of particular importance within the SEACOOS region:

- beach recreation
- coastal erosion control
- natural hazard (i.e., hurricane) prediction and evacuation
- recreational cruises
- commercial fishing vessel accidents
- maritime shipping accidents

For each benefit category, we describe the source of benefits and estimate the change in net economic benefits attributable to improved ISOOS information. The full, eventual impacts of improved ISOOS information are difficult to estimate. Following the other regional ISOOS studies, we evaluate the impacts of assumed, conservative changes in economic activity or costs in each sector. Typically, a one percent change in activity or cost is assumed.

Finally, we present a literature review of the economic benefits of improved climate and weather information for agriculture. An assessment of the impact of ISOOS information on agriculture in the SEACOOS region is beyond the scope of this report.

### 3.a. Maritime transportation

Two categories of maritime transportation may be affected by SEACOOS information: maritime commercial shipping and recreational cruise voyages. We follow the methodology of Kite-Powell and Colgan (2001) for maritime commercial shipping. Kite-Powell and Colgan (2001) did not address the benefits of recreational cruise voyages in their study. We estimate the benefits of cruise voyages using two alternative methodologies. We find that the two methodologies produce similar results.

### 3.a.1. Maritime commercial shipping

Oceangoing ships use ISOOS information on currents, winds, waves and fog to improve routing efficiency, minimize transit time, and reduce fuel and labor costs. Availability of ISOOS information may also improve docking, berthing and loading efficiency, and reduce cargo damage due to storms and rough seas (Kite-Powell and Colgan 2001). In addition, the use of ISOOS information on visibility and water depth in conjunction with electronic chart/navigational system technology may help vessels avoid damage and injuries to crew and passengers from groundings, collisions, ramming and other accidents (Kite-Powell et al. 1997, 1999; Talley 2001, 2002).

Cargo vessels (mainly foreign), cargo barges (mainly domestic) and tankers (both foreign and domestic) make thousands of visits to SEACOOS region ports each year. Table 3.a.1.1 presents information on the number of trips by vessel type for SEACOOS region ports in 2002 (only inbound trips are measured to avoid double-counting) (USACE 2002a, 2002b).

We first consider benefits attributable to reduced transit time. Following Kite-Powell and Colgan (2001) we assume that (1) a reduction in transit time results in a proportional reduction in operating costs, (2) the average transit time of a commercial vessel in coastal waters is two days (round trip), and (3) the availability of ISOOS information reduces average transit time by 1%.

Table 3.a.1.2 presents conservative estimates of the daily operating costs (fuel, crew, lube & stores, maintenance & repair, insurance, and administration costs) by vessel type for both foreign and domestic vessels (USACE 2000, 2003c; Kite-Powell, et al. 2001). Operating costs of foreign vessels are typically lower due to lower crew wages. The operating costs presented in Table 3.a.1.2 for ships in the Passenger and Dry Cargo vessel category reflect moderate size (24,000-28,000 deadweight tonnes, dwt) "Handysize/Handymax" vessels.[3] The operating costs for ships in the Tanker category reflect tankers approximately 90,000 dwt in size.[4]

Table 3.a.1.3 presents estimates of the potential annual maritime transportation transit time benefits attributable to improved ISOOS information in the SEACOOS region by state and vessel type category. Annual benefits across all states and vessel categories total approximately $4.58 million/yr. (2003 $'s)[5].

[3] Approximately 65% of the world's dry cargo vessels are in the "Handysize" and "Handymax" size categories, while the remaining vessels are in the larger "Panamax" and "Capesize" size classes (Intercargo 2004). An assumption of Handysize/Handymax operating costs is conservative because vessels in this size class have lower operating costs, and SEACOOS benefits are calculated as a percentage of operating costs.
[4] In terms of ship numbers, approximately 2/3 of all tankers are smaller than 90,000 dwt, and 1/3 are larger (Intertanko 2004). On the other hand, in terms of ship tonnage, approximately 1/3 of all tankers are smaller than 90,000 dwt, and 2/3 are larger. When selecting a representative tanker size class, 90,000 dwt appears to achieve a reasonable balance between numbers and tonnage.
[5] Excludes benefits to the recreational cruise ship industry considered in section 3.a.2 below.

Table 3.a.1.1 Maritime Commerce Trip Statistics 2002, Southeast U.S. Region (including Florida)
Source: USACE 2002a, 2002b.

| | | Number of Trips (b), Foreign Vessels, Inbound | | | | Number of Trips (b), Domestic Vessels, Inbound | | | |
|---|---|---|---|---|---|---|---|---|---|
| Port | State | Passenger & Dry Cargo (a) | Tanker | Barge Dry Cargo | Barge Tanker | Passenger & Dry Cargo (a) | Tanker | Barge Dry Cargo | Barge Tanker |
| Morehead City Harbor | NC | 69 | 38 | 0 | 0 | 2 | 1 | 147 | 203 |
| Wilmington Harbor | NC | 302 | 189 | 2 | 0 | 23 | 29 | 1009 | 400 |
| Georgetown Harbor | SC | 96 | 0 | 0 | 0 | 0 | 0 | 487 | 18 |
| Charleston Harbor | SC | 2089 | 140 | 1 | 0 | 0 | 35 | 2021 | 276 |
| Savannah Harbor | GA | 1785 | 245 | 0 | 0 | 0 | 50 | 197 | 360 |
| Brunswick Harbor | GA | 481 | 2 | 0 | 0 | 0 | 0 | 150 | 92 |
| Fernandina Harbor | FL | 161 | 0 | 8 | 0 | 0 | 0 | 8 | 87 |
| Jacksonville Harbor | FL | 1132 | 191 | 32 | 5 | 121 | 59 | 471 | 1016 |
| Canaveral Harbor | FL | 648 | 40 | 48 | 7 | 0 | 5 | 0 | 345 |
| Palm Beach Harbor | FL | 146 | 15 | 10 | 7 | 0 | 0 | 67 | 52 |
| Port Everglades Harbor (Ft. Lauderdale) | FL | 1630 | 154 | 38 | 5 | 53 | 249 | 1 | 288 |
| Miami Harbor | FL | 2389 | 15 | 24 | 4 | 0 | 0 | 8 | 317 |
| Tampa Harbor | FL | 717 | 252 | 9 | 1 | 23 | 369 | 506 | 886 |
| Panama City Harbor | FL | 72 | 7 | 0 | 0 | 0 | 0 | 717 | 254 |
| Pensacola Harbor | FL | 38 | 0 | 6 | 0 | 0 | 9 | 116 | 387 |
| Atlantic Intracoastal Waterway (c) | | 0 | 0 | 0 | 0 | 0 | 0 | 1533 | 599 |
| TOTALS | | 11755 | 1288 | 178 | 29 | 222 | 806 | 7438 | 5580 |

Notes:
(a) Includes vessels 19+ ft in draft.
(b) Excludes tug and tow boat traffic.
(c) Excludes Gulf Intracoastal Waterway from AL-FL border to Apalachee Bay FL.

Table 3.a.1.2 Maritime Commerce Operating Costs (2003 $'s / day)
Sources: USACE. 2000., USACE. 2003c., Kite-Powell, et al. 2001. (Costs converted from 1999 $'s to 2003 $'s using CPI.)

| | Foreign Vessels | | | | Domestic Vessels | | | |
|---|---|---|---|---|---|---|---|---|
| | Passenger & Dry Cargo (a) | Tanker | Barge/Tow Dry Cargo | Barge/Tow Tanker | Passenger & Dry Cargo (a) | Tanker | Barge/Tow Dry Cargo | Barge/Tow Tanker |
| Operating Cost (2003 $'s / day) | $12,000 | $14,000 | $3,300 | $3,300 | $23,000 | $26,000 | $3,300 | $3,300 |

Table 3.a.1.3 Estimated Annual Maritime Commerce Reduced Transit Time Benefits 2002, Southeast U.S. Region (including Florida)(b)
Source: USACE 2002a, 2002b; Kite-Powell et al. 2001.

| | | Benefits (2003 $'s), Foreign Vessels | | | | Benefits (2003 $'s), Domestic Vessels | | | |
|---|---|---|---|---|---|---|---|---|---|
| Port | State | Passenger & Dry Cargo (a) | Tanker | Barge Dry Cargo | Barge Tanker | Passenger & Dry Cargo (a) | Tanker | Barge Dry Cargo | Barge Tanker |
| Morehead City Harbor | NC | $16,560 | $10,640 | $0 | $0 | $920 | $520 | $9,702 | $13,398 |
| Wilmington Harbor | NC | $72,480 | $52,920 | $132 | $0 | $10,580 | $15,080 | $66,594 | $26,400 |
| Georgetown Harbor | SC | $23,040 | $0 | $0 | $0 | $0 | $0 | $32,142 | $1,188 |
| Charleston Harbor | SC | $501,360 | $39,200 | $66 | $0 | $0 | $18,200 | $133,386 | $18,216 |
| Savannah Harbor | GA | $428,400 | $68,600 | $0 | $0 | $0 | $26,000 | $13,002 | $23,760 |
| Brunswick Harbor | GA | $115,440 | $560 | $0 | $0 | $0 | $0 | $9,900 | $6,072 |
| Fernandina Harbor | FL | $38,640 | $0 | $528 | $0 | $0 | $0 | $528 | $5,742 |
| Jacksonville Harbor | FL | $271,680 | $53,480 | $2,112 | $330 | $55,660 | $30,680 | $31,086 | $67,056 |
| Canaveral Harbor | FL | $155,520 | $11,200 | $3,168 | $462 | $0 | $2,600 | $0 | $22,770 |
| Palm Beach Harbor | FL | $35,040 | $4,200 | $660 | $462 | $0 | $0 | $4,422 | $3,432 |
| Port Everglades Harbor (Ft. Lauderdale) | FL | $391,200 | $43,120 | $2,508 | $330 | $24,380 | $129,480 | $66 | $19,008 |
| Miami Harbor | FL | $573,360 | $4,200 | $1,584 | $264 | $0 | $0 | $528 | $20,922 |
| Tampa Harbor | FL | $172,080 | $70,560 | $594 | $66 | $10,580 | $191,880 | $33,396 | $58,476 |
| Panama City Harbor | FL | $17,280 | $1,960 | $0 | $0 | $0 | $0 | $47,322 | $16,764 |
| Pensacola Harbor | FL | $9,120 | $0 | $396 | $0 | $0 | $4,680 | $7,656 | $25,542 |
| Atlantic Intracoastal Waterway (c) | | 0 | $0 | $0 | $0 | $0 | $0 | $101,178 | $39,534 |
| TOTALS | | $2,821,200 | $360,640 | $11,748 | $1,914 | $102,120 | $419,120 | $490,908 | $368,280 |

Notes:

(a) Includes vessels 19+ ft in draft.

(b) Excludes tug and tow boat traffic.

(c) Excludes Gulf Intracoastal Waterway from AL-FL border to Apalachee Bay FL.

Kite-Powell et al. (1999) note that grounding of commercial ships accounts for about one-third of all commercial maritime accidents. Groundings can result in damage to vessels and cargo, obstruction of waterways, environmental damage, injuries, and loss of life. Kite-Powell et al. (1999) estimate average grounding rates for five U.S. ports based on U.S. Coast Guard groundings data from 1981 to 1995 (Table 3.a.1.4).

Table 3.a.1.4 Ship groundings and average grounding rates per 1000 transits by vessel type, 1981-1995, for five U.S. ports. (Source: Kite Powell et al. 1999)

| Port | Ship Groundings (1981-1995) | Grounding Rates (Groundings / 1000 Vessel Transits) | |
|---|---|---|---|
| | | Ships | Barge Trains |
| Boston, MA | 9 | 0.32 | 0.37 |
| New York, NY | 107 | 0.72 | 0.18 |
| Tampa, FL | 74 | 1.32 | 1.84 |
| Houston/Galveston, TX | 134 | 0.89 | 1.28 |
| San Francisco, CA | 76 | 0.65 | 2.28 |

Kite-Powell et al. (1999) find that poor visibility and to a lesser extent wind speed significantly influence the probability of grounding. For example, poor visibility increases the probability of grounding in Houston/Galveston, TX, and Tampa Bay, FL, by a factor of four to nine. Kite-Powell et al. note that better data on wind, visibility, water level, and currents are needed to improve the accuracy of grounding risk studies.

Estimates of the average total cost (2003 $'s) per grounding presented in Kite-Powell et al. (1997)[6] are $386,352, $869,291, $24,147, and $808,924 for dry cargo, tanker, dry cargo barge, and tanker barge vessels, respectively.

Based on the grounding rates for ships and barges in Tampa, FL, and Houston/Galveston, TX, in Table 3.a.1.4, we assume a grounding rate of 1/1000 vessel transits for ships and 1.5/1000 vessel transits for barges. Not all groundings are due to poor weather conditions (e.g., some are caused by engine or rudder failure), and not all groundings due to poor weather could be prevented by better ISOOS information. Assuming that improved ISOOS information would reduce the number of groundings by one percent, using the vessel transit data in Table 3.a.1.1, and using the grounding cost estimates described in the preceding paragraph, we estimate the annual reductions in commercial maritime grounding costs as $12,206, $15,325, $17,987, $89,775, and $135,294 for NC, SC, GA, FL and the SEACOOS region, respectively.

[6] The Kite-Powell et al. (1999) grounding cost estimates are based on data from a 1991 port needs study (Maio et al. 1991). The estimates for the dry cargo and tanker vessels reflect medium size class vessels, and the estimates for the dry cargo and tanker barges reflect small size class barges, as no estimates for medium size class barges were available. The grounding cost estimates have been converted to 2003 $'s using the CPI.

### 3.a.2. Recreational cruise voyages

ISOOS information provides benefits to the recreational cruise voyage industry. This category of benefits is not addressed in the Kite-Powell and Colgan (2001) report but is important in the southeast Atlantic region. As other ISOOS regional reports have not addressed this benefit category, somewhat more extensive background information is provided.

The worldwide recreational cruise industry hosted almost 10 million passengers and generated approximately $13 billion in revenues in 2000 (Kester 2002). The world fleet consists of 183 cruise ships supplying 213,000 berths. The industry grew rapidly in recent decades, doubling its berthing capacity in the 1980s and again in the 1990s. There are 37 additional cruise ships currently under construction. These ships will increase industry capacity by 80,000 berths by 2006. Cruise ship occupancy rates are high (typically 90-100%), and industry analysts believe that the additional berth capacity will be easily absorbed by the market, which analysts believe has yet to reach maturity (WTO 2003). Although growth in leisure travel was restrained in 2002 by continued global tensions, health concerns raised by the Norwalk virus, and a weak global economy, the number of passengers carried by the North American cruise industry increased 9.8 percent from the previous year (ICCL 2003).

The modern cruise industry began in the early 1970s in the Caribbean region of North America (Kester 2002). Demand and supply are still relatively concentrated in the region. North American consumers accounted for 72% of worldwide cruise passengers in 2000 (Kester 2002), and North America hosted 43 to 68% (depending on season) of worldwide cruise trips taken in 2002. Within North America, the Caribbean/Gulf of Mexico/East Coast of Mexico region is still the most important cruise location, accounting for 23% of worldwide summer cruise trips and 61% of winter trips in 2002. Schumacher et al. (1998) and WTO (2003) provide additional detail on the North American cruise industry.

U.S. ports handled 6.5 million cruise embarkations during 2002, accounting for 71 percent of global embarkations and representing an increase of 10.2 percent from 2001. Florida ports handled approximately 4.4 million embarkations and accounted for 68 percent of U.S. cruise embarkations (ICCL 2003). The cruise lines and their passengers directly spent $10.9 billion on goods and services in the United States in 2002, a 9.1 percent increase over 2001. The cruise lines spent $8.8 billion while passengers and crew spent $2.1 billion (ICCL 2003). See WTO (2003) for additional detail on cruise passenger demographics and expenditures.

Most cruise trip passengers travel to a base port to embark on a vessel that sails to a number of ports of call, where passengers disembark to visit land-based sites before returning by ship to the base port. Florida hosts the most important base ports in the Caribbean/Gulf of Mexico/East Coast of Mexico region: Miami, Port Everglades (Ft. Lauderdale), Port Canaveral and Tampa (Kester 2002), while Key West serves as an important port of call. Miami, FL, and Port Canaveral, FL, are the busiest cruise ports in the Western Hemisphere, serving 3.4 million and 3.8 million passengers, respectively, in 2000 (Braun et al. 2002; WTO 2003).

The cruise industry heavily impacts the onshore economy by stimulating port service industries and shore excursion tourism (Braun et al. 2002). Some cruise passengers make additional economic contributions to base port cities when they use the cities as "staging areas," lodging, eating and shopping overnight in the base port before and after the cruise. Braun et al. (2002) find that every dollar of expenditures by cruise line companies and cruise ship passengers in the Port Canaveral base port county (Brevard County, FL) generates $0.53 in direct value added (excluding economic multiplier effects) within the base port community. The ICCL (2003) developed estimates of direct expenditures by cruise line companies and passengers by state in 2002 (Table 3.a.2.1). We assume that Braun et al.'s direct value added multiplier estimate of $0.53 is applicable to all U.S. ports within the SEACOOS region. Multiplying each dollar of direct expenditure by the $0.53 value added multiplier produces estimates of direct value added by state (Table 3.a.2.1).

Table 3.a.2.1 Estimated Cruise Industry Benefits, SEACOOS Region 2002 (2003 $'s)
Sources: ICCL (2003), Braun et al. (2002).

| State | 2002 Direct Expenditures by Cruise Industry and Passengers (2003 $'s) | 2002 Direct Value Added (a) (2003 $'s) | Annual COOS Benefits (1% of Value Added) (2003 $'s) |
|---|---|---|---|
| NC | 146,841,001 | 77,825,730 | 778,257 |
| SC | 64,954,352 | 34,425,807 | 344,258 |
| GA | 334,772,607 | 177,429,482 | 1,774,295 |
| FL | 4,626,224,347 | 2,451,898,904 | 24,518,989 |
| Total | 5,172,792,307 | 2,741,579,923 | 27,415,799 |

(a) Assumes $0.53 in direct value added per dollar of direct expenditure (Braun et al. 2002). Excludes economic "multiplier" effects (indirect and induced impacts).

ISOOS information might benefit the cruise industry in two primary ways. First, such information might improve the scheduling efficiency of cruise operations, reducing idle time in port by making use of improved weather forecasts. Altalo et al. (2002) report that severe weather conditions can develop fairly rapidly in the Caribbean region. Although cruise ships can "out-run" storms, this is not desirable from the perspective of passenger comfort. Ship captains make routing decisions to avoid major storms by using 7-10 day weather forecast information. Ships also use weather information to plan routes that minimize fuel consumption expense. Altalo et al. (2002) find that cruise lines use NOAA's advanced forecasting and storm tracking facility, NOAA's wave height and wind speed data, hurricane advisory charts, the Canadian Hydrographic Service's search and rescue satellite data, the National Ocean Service's (NOS) website-based weather reports, and the Dutch Royal Institute's METEO weather service information (including ocean surface temperature, cloud conditions, precipitation, fog, wind speed and direction, ocean/wave conditions, and swell data). Cruise lines report that when hurricanes are present, ships require information with the highest spatial resolution available.

Second, if ISOOS information improves the experience of cruise passengers at sea by enabling cruise ships to better avoid rough seas and bad weather, then passengers may enjoy more satisfaction per trip, and demand for cruise trips may increase. The additional value arising from increased passenger satisfaction would be divided between passengers and cruise line owners, depending on the degree of competition in the cruise line industry and the impact of increased demand on cruise trip prices. However, to our knowledge, the impact of cruise passenger weather/rough seas experience on demand for cruise trips has not been quantified. Although the effect seems very plausible, it remains speculative.

To estimate the economic benefits of ISOOS to the cruise industry, we assume that ISOOS information would increase cruise industry-related direct value-added in the SEACOOS region by 1% through some combination of the two effects described above. Estimated annual cruise industry benefits are $27.4 million (2003 $'s) (Table 3.a.2.1).[7] The estimate is conservative in that it does not include economic multiplier effects, expected deployment of new cruise ships currently under construction, any reductions in insurance costs due to increased safety from access to ISOOS data, or any increases in consumer surplus received by cruise ship passengers.[8]

The benefits of ISOOS to the cruise industry may be calculated by an alternative method that limits the analysis to the Florida base ports and calculates value-added accruing to cruise industry owners and crew separately from value-added resulting from base port expenditures by passengers. The estimate produced by the alternative method is similar in magnitude to the estimate given previously. The alternative estimate is based on cruise passenger trips/embarkations for the top four Florida cruise ports in 2002 presented in Table 3.a.2.2.

Table 3.a.2.2 Cruise passenger trips/embarkations by port, Florida, 2002 (ICCL. 2003)

| | |
|---|---|
| Miami | 1,821,000 |
| Port Canaveral | 1,197,000 |
| Port Everglades | 1,105,000 |
| Tampa | 290,000 |

Average North American cruise ship industry revenues per passenger per trip were $1,549 in 2002, and operating expenses were 58.5% of revenues (ICCL 2003). Schumacher et al. (1998) cite Peisley's (1992) finding that crew wages comprised 38% of world cruise industry operating expenses in 1991. Assuming that the proportion of crew wages to revenues is similar in 2002, crew wages would be approximately 22.2% of revenues. Cruise line operating income amounts to approximately 15.7% of revenues (ICCL 2003). Defining a conservative measure of cruise industry value-added as simply crew wages plus operating income, value-added amounts to 37.9% of revenues, or $587 (2002 $'s) per passenger per trip. Multiplying by the number of passenger trips and adjusting for inflation (using the CPI), Florida cruise industry owners and crew receive approximately $2.65 billion (2003 $'s) in value-added per year. Assuming that ISOOS information increases cruise industry value-added by 1%, annual value-added increases by $26.5 million (2003 $'s) (excluding multiplier effects).

[7] Although not included in this report, the U.S. Virgin Islands and Puerto Rico would also benefit from any increases in cruise ship visits, hosting 1.9 million and 1.4 million cruise ship visitors, respectively, in 2001 (Kester 2002).
[8] Although some portion of the increase in value-added attributable to increases in crew wages and passenger expenditures may occur in the absence of improved ISOOS (i.e., crew may get jobs in onshore hotels instead, and passengers may take vacations elsewhere), and, if so, this portion of value-added should not be included in our estimate of net (national) benefits, a conservative estimate of the impact of improved ISOOS (i.e., 1%) is selected to account for this consideration. The value-added benefit estimates are considered to be *net* of any "transferred" value-added.

In addition to the value-added received by cruise industry owners and crew, onshore spending by cruise ship passengers in the base port creates additional value-added. Approximately 31% of cruise industry passengers stay overnight in the base port before embarking (ICCL 2003). The ICCL (2003) reports that passengers who lodged in the base port on the night before a cruise spent on average $181.11 per passenger per trip in 2002, while non-overnight passengers spent on average $15.42 per passenger per trip. Braun et al. (2002) find that every dollar of expenditures by cruise ship passengers in the Port Canaveral base port county (Brevard County, FL) generates $0.53 in direct value-added (excluding economic multiplier effects) within the base port community. Assuming the value-added figures for other Florida base ports are similar to that of Port Canaveral, multiplying the number of passenger trips in each port by the proportions of overnight and non-overnight passengers, multiplying by the respective passenger expenditure values, multiplying by the value-added estimate, adjusting for inflation, and summing over all four Florida base ports yields an estimate of $159.8 million (2003 $'s) in base port value-added.[9] Assuming that ISOOS information increases base port value-added by 1%, annual value-added increases by $1.60 million (2003 $'s) (excluding multiplier effects). Hence, the alternative method produces an estimate of ISOOS benefits to the cruise industry and base ports of $26.5 million in cruise line profits and crew wages plus $1.60 million in direct value-added attributable to passenger spending in base ports, for an alternative estimate of $28.1 million (2003 $'s), similar in magnitude to the initial estimate of $27.4 million.

### 3.b. Pollution and oil spill prevention and mitigation

#### 3.b.1 Pollution prevention and mitigation

Access to ISOOS weather data will likely improve our ability to avoid coastal pollution events associated with high winds, rainfall and stream flow, such as municipal sewage treatment plant overflows, and non-point runoff from land-applied agricultural fertilizers, pesticides and treated animal wastes. Reducing sewage overflows would reduce health-related closures of coastal swimming areas, and reducing non-point runoff would likely benefit aquatic ecosystem health. In addition, improved understanding of the transport and fate of pollutants in estuarine and coastal ocean environments will improve our ability to mitigate the effects of any runoff events that do occur. Better ISOOS information might also allow better prediction and management of coastal biological hazards such as red tides and Pfiesteria. Coastal pollution prevention benefits, other than oil spill reduction, are not pursued further in this report.

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[9] That is: $\$159.8\text{million} = \sum_i [c \cdot v \cdot (p_o \cdot e_o + p_n \cdot e_n) \cdot T_i]$, where, i = 1 . . . 4, is a variable indexing the four Florida base ports (Table 3.a.2.2), $T_i$ = passenger trips in port i (Table 3.a.2.2), $p_o$ = 0.31 = proportion overnight passengers, $p_n$ = 0.69 = proportion non-overnight passengers, $e_o$ = $181.11 = base port expenditures per trip for overnight passengers, $e_n$ = $15.42 = base port expenditures per trip for non-overnight passengers, v = base port value-added per dollar of base port expenditures by cruise passengers, c = 184/179.9 = deflation factor used to adjust from 2002 $'s to 2003 $'s (based on CPI).

### 3.b.2 Oil spill prevention and mitigation

Improved ISOOS information may reduce costs associated with oil spill prevention and mitigation. Although there are currently no offshore oil extraction, drilling or exploration activities off the Atlantic coast of the SEACOOS region (Luger 2004), data on vessel transits presented in Table 3.a.1.1 indicate that over 2,000 tanker vessels and over 5,000 tanker barges passed through SEACOOS region harbors in 2002. Significant oil spills can occur when vessels load or unload oil, or when vessels sink, run aground or collide. In addition to oil tanker vessels, oil barges and even non-oil transport vessels (e.g., freighters) that simply carry oil in their bunkers to fuel their own engines can be sources of significant oil spills (Talley et al. 2001). Although the amount of oil spilled per year in the U.S. has declined steadily over the last thirty years, the amounts spilled in SEACOOS region states have varied erratically (Table 3.b.2.1). Fortunately, large oil spills are relatively low frequency events, and most years are characterized by relatively small spills associated with unloading and offloading operations and minor accidents. However, the risk of occasional, catastrophic spills remains. For example, a spill released 728,000 gallons of crude oil off the coast of Georgia in 1995, and a spill off the coast of South Carolina released 959,921 gallons of oil in 1996 (Luger 2004).

The cost of oil spills has risen dramatically since the catastrophic 1989 Exxon Valdez oil spill in Alaska and the subsequent passage of the Oil Pollution Act (OPA) of 1990 (Volpe 2001). OPA-1990 increased requirements for oil spill training, preparedness, mitigation and natural resource damage assessments (Wood 1995). As summarized by Kite-Powell and Colgan (2001) and Lynch, Harrington and O'Brien (2003), all major oil handling ports must develop oil spill response plans, including provisions for deployment of oil spill containment and clean-up equipment. However, because the effectiveness of containment and cleanup is limited, the adverse effects of any spill can be reduced by only five to fifteen percent (Kite-Powell and Colgan 2001). Hopkins (1992) found that oil spill clean up costs ranged from $205/barrel to $5,184/barrel (1990 $'s). In a report following the Exxon Valdez spill, the National Research Council (1991) found that estimates of the environmental cost of oil spills, beyond clean up costs, ranged from $205/barrel to $1,432/barrel (1990 $'s). Kite-Powell and Colgan (2001) and Lynch, Harrington and O'Brien (2003) cite a British Petroleum estimate of the total cost of an oil spill of $10,000 (2000$'s) per barrel spilled.[10] Luger (2004) cites a clean-up cost estimate of $27,426 per barrel developed by D.F. Dickens Associates, Ltd. in 2000. A recent Programmatic Regulatory Assessment (PRA) of the OPA prepared for the U.S. Coast Guard (Volpe 2001) finds that although the cost of removing spilled oil from the water is approximately $210 per barrel spilled, the *least cost* combination of actions necessary to *prevent* an oil spill or remove oil from the water *before damage to the environment occurs* is approximately $8,657 per barrel in 1996 dollars, equivalent to $10,152 in 2003 dollars. This cost reflects the least cost package of eleven regulatory actions selected from an analysis of over 2,000 combinations of oil spill prevention actions considered in the PRA analysis.[11]

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[10] One barrel equals 42 gallons.

[11] The least cost regulatory package includes the following eleven actions: establishing legal financial responsibility for oil spill costs, requiring double hulls on oil tanker vessels, requiring oil handling facility spill response plans, requiring spill source control and containment, requiring operational measures for single hull vessels, requiring licenses, certificates and mariners' documents, requiring overfill devices, additional regulation of lightering of single hull vessels, requiring special equipment and personnel in Alaska, and requiring deck spill control.

There is evidence to support the assertion that improved ISOOS information may help prevent oil spills. Jin et al. (1994) find that ISOOS information in combination with electronic charts may be a far more cost-effective approach than requiring double hulls on oil tankers to reduce oil spills. In addition, the use of ISOOS information on visibility and water depth in conjunction with electronic chart/navigational system technology may help vessels avoid damage from grounding, collisions and ramming when approaching and maneuvering in port (Kite-Powell et al. 1997, 1999). Talley et al. (2001) find that high winds are likely to increase the risk of oil spills. Seemingly counter-intuitively, oil spillage is lower under poor visibility conditions (Talley et al. 2001) or during precipitation (Talley et al. 2000); however, this may be an indirect effect of vessel operators taking extra precaution under poor weather conditions or of port closures at times when wind speeds are high (Kite-Powell et al. 1999).

In the event that oil spill prevention fails, the effectiveness of oil spill containment and clean-up can be improved by more rapid and accurate response. Better response can be achieved through more accurate models of oil spill fate and effects, which depend on ISOOS information such as current and tide data (Kite-Powell and Colgan 2001). Better ISOOS information will likely significantly improve spill response time and effectiveness.

Table 3.b.2.1 Oil spill data, SEACOOS states, SEACOOS region and U.S. total, 1973-2001. (Source: USCG. 2004)

| | NC | | SC | | GA | | FL | | SEACOOS Region | | Total U.S. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | # Spills | Gallons | # Spills | Gallons | # Spills | Gallons | # Spills | Gallons | # Spills | Gallons | # Spills | Gallons |
| 1973 | 27 | 12,619 | 48 | 36,744 | 57 | 82,033 | 335 | 49,765 | 467 | 181,161 | 9,014 | 15,253,580 |
| 1974 | 23 | 48,838 | 31 | 42,316 | 52 | 49,104 | 376 | 90,102 | 482 | 230,360 | 9,999 | 15,698,731 |
| 1975 | 67 | 46,214 | 63 | 17,353 | 50 | 62,698 | 357 | 83,536 | 537 | 209,801 | 9,292 | 21,520,083 |
| 1976 | 81 | 79,033 | 96 | 15,789 | 52 | 16,349 | 468 | 34,484 | 697 | 145,655 | 9,422 | 18,517,949 |
| 1977 | 57 | 57,451 | 152 | 33,629 | 77 | 322,069 | 621 | 192,786 | 907 | 605,935 | 9,459 | 8,189,133 |
| 1978 | 124 | 70,936 | 132 | 30,133 | 78 | 44,563 | 649 | 162,681 | 983 | 308,313 | 10,644 | 10,864,108 |
| 1979 | 101 | 56,351 | 72 | 65,460 | 96 | 397,607 | 683 | 163,410 | 952 | 682,828 | 9,834 | 20,893,558 |
| 1980 | 62 | 21,365 | 54 | 19,673 | 76 | 38,724 | 577 | 304,582 | 769 | 384,344 | 8,383 | 12,596,970 |
| 1981 | 42 | 17,268 | 34 | 1,402 | 40 | 9,265 | 464 | 47,195 | 580 | 75,130 | 7,811 | 8,920,995 |
| 1982 | 42 | 72,187 | 30 | 16,292 | 37 | 388,267 | 373 | 49,048 | 482 | 525,794 | 7,484 | 10,344,797 |
| 1983 | 34 | 54,599 | 50 | 4,466 | 52 | 6,418 | 574 | 43,078 | 710 | 108,561 | 7,916 | 8,379,848 |
| 1984 | 71 | 718,828 | 63 | 1,534 | 35 | 4,781 | 529 | 176,631 | 698 | 901,774 | 8,258 | 18,005,878 |
| 1985 | 66 | 5,629 | 35 | 2,995 | 45 | 2,633 | 298 | 28,830 | 444 | 40,087 | 6,169 | 8,436,248 |
| 1986 | 47 | 15,879 | 61 | 5,626 | 67 | 503,872 | 453 | 46,476 | 628 | 571,853 | 4,993 | 4,281,979 |
| 1987 | 51 | 8,063 | 67 | 2,471 | 55 | 6,912 | 463 | 142,590 | 636 | 160,036 | 4,841 | 3,608,885 |
| 1988 | 36 | 872 | 83 | 2,387 | 57 | 1,184 | 436 | 177,220 | 612 | 181,663 | 4,998 | 6,586,004 |
| 1989 | 59 | 1,682 | 103 | 5,738 | 50 | 3,672 | 674 | 34,358 | 886 | 45,450 | 6,613 | 13,478,695 |
| 1990 | 73 | 4,266 | 113 | 4,336 | 54 | 1,823 | 972 | 51,965 | 1,212 | 62,390 | 8,177 | 7,915,007 |
| 1991 | 59 | 6,236 | 114 | 3,286 | 110 | 2,394 | 1,093 | 31,772 | 1,376 | 43,688 | 8,569 | 1,875,953 |
| 1992 | 42 | 1,355 | 161 | 4,561 | 146 | 61,150 | 837 | 170,473 | 1,186 | 237,539 | 9,491 | 1,875,668 |
| 1993 | 64 | 7,886 | 125 | 2,026 | 82 | 3,272 | 800 | 432,489 | 1,071 | 445,673 | 8,972 | 2,067,388 |
| 1994 | 68 | 8,911 | 81 | 3,441 | 89 | 18,841 | 894 | 34,284 | 1,132 | 65,477 | 8,960 | 2,489,273 |
| 1995 | 136 | 2,709 | 100 | 2,980 | 99 | 728,337 | 976 | 68,992 | 1,311 | 803,018 | 9,038 | 2,638,229 |
| 1996 | 246 | 4,000 | 85 | 959,921 | 65 | 4,979 | 861 | 23,083 | 1,257 | 991,983 | 9,335 | 3,117,831 |
| 1997 | 157 | 31,167 | 90 | 3,377 | 46 | 511 | 798 | 16,424 | 1,091 | 51,479 | 8,624 | 942,574 |
| 1998 | 170 | 1,678 | 110 | 3,515 | 45 | 2,875 | 804 | 25,896 | 1,129 | 33,964 | 8,315 | 885,303 |
| 1999 | 154 | 3,528 | 106 | 1,232 | 25 | 24,009 | 716 | 13,664 | 1,001 | 42,433 | 8,539 | 1,172,449 |
| 2000 | 145 | 7,258 | 86 | 1,863 | 34 | 1,276 | 647 | 23,302 | 912 | 33,699 | 8,354 | 1,431,370 |
| 2001 | 126 | 2,399 | 58 | 1,227 | 20 | 47 | 554 | 11,508 | 758 | 15,181 | 7,559 | 854,520 |

Although Kite-Powell and Colgan (2001) and Lynch, Harrington and O'Brien (2003) note that oil spills are probabilistic events that are best assessed using a probabilistic model, for a first-order estimate each chooses to examine the impact of a one percent reduction in oil spills and associated costs. Kite-Powell and Colgan (2001) assess the impact of the reduction from a baseline of the ten-year (1990-1999) average annual cost of oil spills, while Lynch, Harrington and O'Brien (2003) assess the impact from a baseline of year 2000 oil spill costs. Luger (2004) employs a very basic probabilistic modeling approach to estimate the benefits of oil spill reduction for Virginia, North Carolina, South Carolina and Georgia based on the last ten years of oil spill data. (Luger reasonably uses only the most recent ten years of data in order to capture post-OPA 1990 conditions. Data from earlier years would not reflect current regulatory conditions.) Luger develops benefit estimates for three cases: a three percent reduction in the oil spill costs of the "average" year (mean value of 10 year time series), a three percent reduction in oil spill costs for a "typical" year (median value of 10-year time series), and a three percent reduction in oil spill costs for the "once-in-ten-years event" (maximum value of 10-year time series).

Following Kite-Powell and Colgan (2001) and Lynch, Harrington and O'Brien (2003), we estimate the economic benefits of a one percent reduction in oil spills and associated costs. We assume that the reduction results from the combination of improved prevention and better mitigation due to improved oil spill fate and effect modeling. However, following Luger (2004), we develop estimates for an average (mean) year, a typical (median) year, and a "once-in-ten-years" event. Table 3.b.2.2 presents the mean, median and maximum amounts of oil spilled in the SEACOOS region (all states combined) for the ten year period 1992-2001. Oil spill volumes are converted to estimated costs by multiplying by $10,000 (2003 $'s) per barrel of oil spilled, following Kite-Powell and Colgan (2001) and Lynch, Harrington and O'Brien (2003). We note that the $10,000 per barrel cost number can also be interpreted as the approximate per barrel cost of preventing an oil spill using the cost-effective combination of regulatory actions identified by Volpe (2001).

Table 3.b.2.2 Oil spill reduction benefits in SEACOOS region (2003 $'s).

| | Average (Mean) Year[4] | Typical (Median) Year[4] | "Once-in-ten-years" Event[4] |
|---|---|---|---|
| Oil Spilled (gallons) | 272,045 | 58,478 | 991,983 |
| Oil Spilled (barrels)[1] | 6,477 | 1,392 | 23,619 |
| Oil Spill Costs @ $10,000/barrel[2] | $64,772,524 | $13,923,333 | $236,186,429 |
| SEACOOS Benefits[3] | $647,725 | $139,233 | $2,361,864 |

[1] Based on 42 gallons/barrel.
[2] Based on $10,152 (2003 $'s) per barrel of oil not spilled or spilled and recovered (Volpe 2001).
[3] Based on 1% reduction in oil spill costs.
[4] Based on 1992-2001 annual data.

Oil spill reduction benefits by SEACOOS region state are presented in Table 3.b.2.3. These values reflect the oil spill reduction benefits that would have been achieved assuming (1) ISOOS information had been available 1992-2001, (2) the information resulted in a one percent reduction in oil spills, and (3) oil spill costs amounted to $10,000 per barrel spilled.

Table 3.b.2.3 Oil spill cost reduction benefits in SEACOOS region by state (2003 $'s).

| | North Carolina | South Carolina | Georgia | Florida | SEACOOS Region |
|---|---|---|---|---|---|
| | (2003 $'s) | (2003 $'s) | (2003 $'s) | (2003 $'s) | (2003 $'s) |
| 1992 | $3,226 | $10,860 | $145,595 | $405,888 | $565,569 |
| 1993 | $18,776 | $4,824 | $7,790 | $1,029,736 | $1,061,126 |
| 1994 | $21,217 | $8,193 | $44,860 | $81,629 | $155,898 |
| 1995 | $6,450 | $7,095 | $1,734,136 | $164,267 | $1,911,948 |
| 1996 | $9,524 | $2,285,526 | $11,855 | $54,960 | $2,361,864 |
| 1997 | $74,207 | $8,040 | $1,217 | $39,105 | $122,569 |
| 1998 | $3,995 | $8,369 | $6,845 | $61,657 | $80,867 |
| 1999 | $8,400 | $2,933 | $57,164 | $32,533 | $101,031 |
| 2000 | $17,281 | $4,436 | $3,038 | $55,481 | $80,236 |
| 2001 | $5,712 | $2,921 | $112 | $27,400 | $36,145 |
| Average (mean) Yr | $16,879 | $234,320 | $201,261 | $195,265 | $647,725 |
| Typical (median) Yr | $8,962 | $7,568 | $9,823 | $58,569 | $139,233 |
| "Once in ten years" | $74,207 | $2,285,526 | $1,734,136 | $1,029,736 | $2,361,864 |

**3.c. Commercial fishing**

The commercial fisheries of the United States landed approximately 9.3 billion pounds of fish and shellfish worth $3.1 billion in 2002 (NMFS 2003). As described by Kite-Powell and Colgan (2001), ISOOS information may benefit commercial fisheries in several ways. First, ISOOS information may decrease fishing costs by increasing the efficiency of trip scheduling. Many commercial fishing trip departures are based on predicted weather conditions days to weeks in the future. Better weather and sea condition information means that a greater proportion of fishing trips will be taken at times when conditions at sea turn out to be favorable for fishing, and a smaller proportion of trips will be taken at times when conditions turn out to be unfavorable. Such increases in trip scheduling efficiency decrease the average cost per pound of fish landed.

Second, better ocean information may improve the efficiency of fishery management regulations, eventually leading to larger fish stocks. In turn, larger fish stocks may permit fishery regulators to increase the sustainable number of trips allowed per year and may increase fish catch and revenue per fishing trip. For example, Costello et al. (1998) find that improvements in the ability to forecast El Nino weather events in the Pacific Ocean could lead to economic welfare gains on the order of $1 million per year in the coho salmon fishery.

Kite-Powell and Colgan (2001) and Lynch, Harrington and O'Brien (2003) develop a conservative estimate of the impact of ISOOS information on the efficiency of commercial fishing trip scheduling and fishery management regulations by assuming that such information will allow one additional fishing day per year. Tables 3.c.1 and 3.c.2 (NMFS 2004) present information on landings and ex-vessel (dockside market) values for the commercial finfish and shellfish industries in SEACOOS region states for the last ten years (1993-2002). Because annual landings and ex-vessel values vary substantially from year to year, we consider 10-year mean values. The 10-year mean ex-vessel values are converted to value-added estimates by multiplying the ex-vessel values by the National Marine Fisheries Service's estimate of the average value-added[12] percentage for edible domestic commercial marine fishery products in the United States in 2002, or 63.2% (NMFS 2003). We follow Kite-Powell and Colgan (2001) and Lynch, Harrington and O'Brien (2003) and assume a 60 day finfish fishing season and a 120 day shellfish season. Dividing each value-added estimate in Tables 3.c.1 and 3.c.2 by the appropriate number of fishing days per season produces estimates of value-added per fishing day. Adding one additional fishing day to each of the finfish and shellfish fishing seasons produces an estimate of the benefit of ISOOS information for commercial fisheries of $2.8 million/yr. (2003 $'s) in value-added.[13]

Alternatively, one might estimate the impact of ISOOS information on the efficiency of commercial fisheries by assuming a net increase in value-added of 1%. This assumption produces an estimate of the benefit of ISOOS information for commercial fisheries of $2.6 million/yr. (2003 $'s) in value-added (see Tables 3.c.1 and 3.c.2).

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[12] For commercial fisheries, value-added is a measure of the additional net economic value added to the fish product by the fish harvesting sector of the economy. Value-added is calculated as ex-vessel price per unit of fish minus the cost of additional, purchased goods and services needed to harvest the additional unit of fish. Value-added includes wages, salaries, interest, depreciation, rent, taxes and profit (NMFS 2003).

[13] This estimate considers the value-added accruing to the harvest sector only; it does not include the value of any onshore economic multiplier effects.

Table 3.c.1 Finfish harvest (pounds) and ex-vessel/dockside value (constant 2003 $'s) by state. (Source: NMFS 2004)

| Year | NC Pounds | NC Dollars | SC Pounds | SC Dollars | GA Pounds | GA Dollars | FL (east) Pounds | FL (east) Dollars | FL (west) Pounds | FL (west) Dollars | SEACOOS Region Total Pounds | SEACOOS Region Total Dollars |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1993 | 118,359,170 | 37,768,487 | 4,235,449 | 7,820,902 | 766,526 | 1,097,303 | 26,320,068 | 31,042,049 | 78,445,121 | 74,985,857 | 228,126,334 | 152,714,598 |
| 1994 | 132,132,038 | 45,049,952 | 3,854,451 | 7,381,684 | 866,703 | 1,268,217 | 24,443,330 | 28,960,786 | 72,588,911 | 70,263,115 | 233,885,433 | 152,923,753 |
| 1995 | 123,369,586 | 53,579,746 | 4,100,671 | 6,752,563 | 837,019 | 1,295,256 | 19,272,132 | 26,813,994 | 43,717,675 | 56,896,065 | 191,297,083 | 145,337,624 |
| 1996 | 117,365,451 | 46,908,337 | 3,495,522 | 5,929,164 | 721,988 | 1,024,567 | 16,243,007 | 22,478,864 | 36,980,460 | 52,981,673 | 174,806,428 | 129,322,605 |
| 1997 | 163,505,987 | 47,365,697 | 3,572,364 | 6,225,731 | 569,024 | 780,421 | 17,511,996 | 21,905,348 | 40,282,668 | 53,995,155 | 225,442,039 | 130,272,353 |
| 1998 | 111,413,684 | 41,492,823 | 2,787,180 | 4,997,826 | 528,050 | 785,891 | 17,137,993 | 20,379,896 | 39,014,751 | 49,578,013 | 170,881,658 | 117,234,450 |
| 1999 | 85,917,420 | 36,916,448 | 2,947,723 | 5,957,512 | 549,220 | 913,669 | 15,175,736 | 19,864,750 | 43,041,807 | 54,678,984 | 147,631,906 | 118,331,364 |
| 2000 | 102,071,046 | 40,465,946 | 3,076,797 | 5,704,729 | 556,691 | 989,279 | 13,920,966 | 19,872,376 | 39,351,225 | 51,734,510 | 158,976,725 | 118,766,839 |
| 2001 | 99,350,901 | 35,196,415 | 3,152,484 | 5,965,181 | 544,064 | 989,090 | 12,694,879 | 15,787,423 | 44,487,742 | 54,694,045 | 160,230,070 | 112,632,154 |
| 2002 | 110,496,876 | 34,939,971 | 3,052,406 | 5,497,117 | 594,832 | 981,787 | 12,177,729 | 15,009,483 | 43,558,235 | 52,713,324 | 169,880,078 | 109,141,682 |
| 10-yr Mean | 116,398,216 | 41,968,382 | 3,427,505 | 6,223,241 | 653,412 | 1,012,548 | 17,489,784 | 22,211,497 | 48,146,860 | 57,252,074 | 186,115,775 | 128,667,742 |
| Value-Added (VA) | | 26,524,017 | | 3,933,088 | | 639,930 | | 14,037,666 | | 36,183,311 | | 81,318,013 |
| VA of 1 Add'l Fishing Day[1] | | 442,067 | | 65,551 | | 10,666 | | 233,961 | | 603,055 | | 1,355,300 |
| 1% Increase in VA | | 265,240 | | 39,331 | | 6,399 | | 140,377 | | 361,833 | | 813,180 |

[1] Assumes 60-day finfish fishing season.

Table 3.c.2 Shellfish harvest (pounds) and ex-vessel/dockside value (constant 2003 $'s) by state. (Source: NMFS 2004)

| Year | NC Pounds | NC Dollars | SC Pounds | SC Dollars | GA Pounds | GA Dollars | FL (east) Pounds | FL (east) Dollars | FL (west) Pounds | FL (west) Dollars | SEACOOS Region Total Pounds | SEACOOS Region Total Dollars |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1993 | 52,338,120 | 44,495,147 | 16,765,604 | 29,920,048 | 16,444,261 | 27,636,636 | 15,777,297 | 34,389,580 | 44,705,154 | 98,186,737 | 146,030,436 | 234,628,148 |
| 1994 | 62,544,532 | 67,140,694 | 14,778,252 | 30,758,529 | 16,831,314 | 31,685,180 | 24,457,124 | 55,517,424 | 44,100,703 | 115,431,612 | 162,711,925 | 300,533,438 |
| 1995 | 57,367,778 | 78,548,973 | 20,354,114 | 39,032,352 | 21,312,105 | 40,169,623 | 18,234,670 | 47,783,433 | 48,472,835 | 132,509,306 | 165,741,502 | 338,043,688 |
| 1996 | 73,772,759 | 73,756,126 | 12,430,701 | 22,488,304 | 12,916,032 | 24,275,017 | 34,339,302 | 50,681,420 | 56,961,364 | 137,407,622 | 190,420,158 | 308,608,488 |
| 1997 | 65,074,720 | 72,001,380 | 13,774,202 | 31,062,944 | 13,942,347 | 30,630,983 | 15,282,207 | 34,204,637 | 47,004,982 | 116,596,156 | 155,078,458 | 284,496,101 |
| 1998 | 68,824,162 | 70,430,803 | 14,864,766 | 27,606,032 | 12,668,057 | 26,365,975 | 12,795,219 | 29,793,954 | 60,843,578 | 141,006,487 | 169,995,782 | 295,203,251 |
| 1999 | 67,648,152 | 71,291,629 | 15,625,357 | 29,524,103 | 11,670,220 | 24,442,454 | 15,417,948 | 34,846,121 | 47,100,218 | 125,247,260 | 157,461,895 | 285,351,568 |
| 2000 | 52,065,004 | 73,348,609 | 12,820,190 | 26,920,083 | 9,284,276 | 22,169,803 | 17,479,584 | 35,955,413 | 38,117,948 | 118,995,986 | 129,767,002 | 277,389,895 |
| 2001 | 39,115,935 | 54,076,024 | 11,120,167 | 18,873,961 | 8,663,661 | 14,766,178 | 14,646,497 | 28,746,759 | 36,392,458 | 97,536,445 | 109,938,718 | 213,999,366 |
| 2002 | 49,059,762 | 66,033,030 | 10,506,818 | 16,328,942 | 8,511,292 | 13,898,618 | 9,544,495 | 20,251,193 | 38,187,075 | 93,758,624 | 115,809,442 | 210,270,408 |
| 10-yr Mean | 58,781,092 | 67,112,242 | 14,304,017 | 27,251,530 | 13,224,357 | 25,604,047 | 17,797,434 | 37,216,993 | 46,188,632 | 117,667,623 | 150,295,532 | 274,852,435 |
| Value-Added (VA) | | 42,414,937 | | 17,222,967 | | 16,181,758 | | 23,521,140 | | 74,365,938 | | 173,706,739 |
| VA of 1 Add'l Fishing Day[1] | | 353,458 | | 143,525 | | 134,848 | | 196,009 | | 619,716 | | 1,447,556 |
| 1% Increase in VA | | 424,149 | | 172,230 | | 161,818 | | 235,211 | | 743,659 | | 1,737,067 |

[1] Assumes 120-day shellfish fishing season.

A third source of commercial fishery benefit lies in the area of vessel safety. ISOOS weather and sea condition information may increase fishing vessel safety at sea, reducing costs associated with on-deck and overboard injuries and fatalities, and ship sinkings, capsizings and collisions. Commercial fishing is one of the most dangerous occupations. Jin et al. (2001) find that the U.S. commercial fishing fatality rate was 16 deaths per 10,000 fishers, a rate 16 times higher than that for fire and police protective services. Jin et al. (2002) find that between 1984 and 1998, 2,074 U.S. commercial fishing vessel accidents resulted in total loss of the vessel. The annual property, injury, and other costs associated with these accidents are estimated at more than $240 million (2002 $'s), more than three times the cost of tanker accidents. This amounts to an average cost of $116,000 (2002 $'s) per fishing vessel accident. Ocean conditions influence the likelihood of fishing vessel accidents. Jin et al. (2001) and Jin et al. (2002) find that the likelihood of fishing vessel accidents is greater during precipitation, rough seas, and higher wind speeds. In addition, the expected number of fatalities is larger during precipitation (Jin et al. 2001).

Table 3.c.3 presents data on the annual number of commercial fishing vessel trips by state in the SEACOOS region in 2002. Jin et al. (2002) find that over the period 1981 to 1993, the average accident rate per 1000 vessel days ranged from 0.48 to 1.99, with a mean of 0.96, in the Northeast statistical fishing area off New England. In the absence of similar estimates for waters off the coast of the southeastern U.S., we assume that the accident rate in the SEACOOS region is similar to that of New England. If we further assume that each vessel trip corresponds to one vessel day (on average), then dividing the annual number of vessel trips by 1000 and multiplying the result by 0.96 produces estimates of the mean number of fishing vessel accidents per year by state in the SEACOOS region (Table 3.c.3). Multiplying the mean number of accidents by Jin et al.'s (2002) estimate of costs per accident and deflating to 2003 $'s using the CPI produces estimates of the average annual costs of fishing vessel accidents by state (Table 3.c.3). Assuming that the availability of ISOOS information reduces commercial fishing vessel accidents by 1%, the estimated annual reductions in accident-related costs are $256,816, $46,378, $18,931, $289,220, and $611,345 for NC, SC, GA, FL, and the SEACOOS region.

Table 3.c.3. Estimated commercial fishing vessel accident cost reduction benefits, by state, SEACOOS region.

| State | Commercial Fishing Vessel Trips/Yr, 2002 | Estimated Fishing Vessel Accidents/Yr, 2002 | Estimated Accident Cost/Yr (2003 $'s) | Estimated ISOOS Accident Cost Reduction Benefits/Yr.[5] (2003 $'s) |
|---|---|---|---|---|
| NC[1] | 230,618 | 221 | $25,681,620 | $256,816 |
| SC[2] | 41,647 | 40 | $4,637,810 | $46,378 |
| GA[3] | 17,000 | 16 | $1,893,120 | $18,931 |
| FL[4] | 259,716 | 249 | $28,921,974 | $289,220 |
| Totals | 548,981 | 526 | $61,134,524 | $611,345 |

[1]North Carolina Commercial Fishing Trips 2002, North Carolina Division of Marine Fisheries Trip Ticket Program (April 2004).
[2] South Carolina did not collect commercial fishing vessel trip data before 2003, and representative data are not yet available (Jenkins 2004). We estimate the number of South Carolina commercial fishing vessel trips based on the number of trips in North Carolina and Georgia by assuming that the number of trips by sector in each fishery is proportional to landings in the sector. South Carolina's largest commercial fishery sectors are shrimp, crabs, oysters & clams, and snapper/grouper. The oyster & clams and snapper/grouper sectors are similar to corresponding sectors in North Carolina, while the shrimp and crab sectors are similar to corresponding sectors in Georgia (Jenkins 2004). We estimate the number of South Carolina commercial fishing vessel trips in the shrimp sector by multiplying South Carolina shrimp landings by the ratio of Georgia vessel trips in the shrimp sector to Georgia shrimp landings. Estimates for the remaining sectors are made in a similar manner, and trips are summed over sectors to arrive at an estimate of 41,647 South Carolina commercial vessel fishing trips in 2002.
[3]Georgia Department of Natural Resources, Coastal Resources Division.
[4]Florida Commercial Fisheries Total Trips 2001, Florida Fish and Wildlife Conservation Commission, Marine Fisheries Information System, 2001 Annual Landing Summary.
[5] Assumes one percent reduction in vessel accidents per year.

### 3.d. Recreation

There are a large number of coastal recreational activities that might be affected by SEACOOS. We focus on two of the most important: saltwater boat fishing and saltwater beach activities. Boat fishing includes private boats, charter boats and party/head boats. We follow the methodology of Kite-Powell and Colgan (2001) for recreational boat `fishing. Beach activities include swimming, fishing, beachcombing, etc. Kite-Powell and Colgan (2001) did not address the benefits of beach recreation in their study. The value of SEACOOS for recreation is the product of the net increase in the number of days engaged in the activity and the consumer surplus per day.

The number of days engaged in recreational boat fishing is measured by the number of fishing trips. This is a conservative estimate of the number of days since overnight fishing trips may be longer than one day. Saltwater recreational fishing data are from the Marine Recreational Fisheries Statistics Survey (MRFSS) conducted annually by the National Marine Fisheries Service (http://www.st.nmfs.gov/st1/recreational/index.html). We obtain the number of fishing trips from the private/rental and party/head boat fishing modes with a destination of ocean waters from each state during 2002 (pers. comm., National Marine Fisheries Service 2004). A total of 8.55 million days of recreational boat fishing occurred in the southeastern U.S. in 2002.

(Table 3.d.1). Fifty-four percent and 32 percent of these boat trips originated from the Gulf coast and Atlantic coasts of Florida, respectively.

Table 3.d.1. Benefits of Marine Recreational Boat Fishing

| State | Days | Consumer Surplus per Day | Additional Trips | Additional Consumer Surplus |
|---|---|---|---|---|
| NC | 878,868 | 18.52 | 8789 | $162,776 |
| SC | 249,501 | 7.84 | 2495 | $19,558 |
| GA | 34,827 | 3.02 | 348 | $1,051 |
| FL-Atlantic | 2,732,934 | 14.05 | 27,329 | $384,024 |
| FL-Gulf | 4,658,445 | 53.68 | 46584 | $2,500,635 |
| Total | 8,554,575 | | 85,546 | $3,068,044 |

Haab, Whitehead, and McConnell (2000) use the travel cost method with MRFSS data to estimate the economic value of marine recreational fishing in the southeastern U.S. Using their estimate of the "mean value of access per trip by state", the value of Florida Gulf, North Carolina, Florida Atlantic, South Carolina and Georgia fishing days are $54, $19, $14, $8, and $3 (2003 dollars) (Table 3.d.1). Assuming a one percent net increase in the number of fishing trips resulting from ISOOS information, the additional consumer surplus is $3 million. Ninety-four percent of this value would occur in Florida. Eighty-one percent of the total benefits would occur in the Gulf coast of Florida.

An estimate of the number of days of saltwater beach visitation is obtained from the 2000 National Survey of Recreation and the Environment (Leeworthy and Willis 2001). The total number of days spent at the beach in 2000 is 247 million with 72 percent of these days spent in Florida (Table 3.d.2). According to the MRFSS, only a small portion of these beach days were spent fishing from the shore. Three million, 0.58 million, 63 thousand and 5 million shore fishing trips were taken in North Carolina, South Carolina, Georgia, and Florida.

Table 3.d.2. Benefits of Beach Recreation

| | Days/Yr. (in millions) | Consumer Surplus per Day | Additional Trips | Additional Consumer Surplus |
|---|---|---|---|---|
| NC | 27.94 | $35.75 | 279,360 | $9,987,120 |
| SC | 33.30 | $35.75 | 333,020 | $11,905,465 |
| GA | 8.48 | $35.75 | 84,830 | $3,032,673 |
| FL | 177.15 | $35.75 | 1,771,530 | $63,332,198 |
| Total | 246.87 | | 2,468,740 | $88,257,455 |

Surprisingly, there are few existing studies of the economic value of beach trips in the southeastern U.S. Of these, none focus on North Carolina, South Carolina, or Georgia beaches although research is currently being conducted to value North Carolina and Georgia beach trips. In early valuation research, Bell (1986) uses the contingent valuation method and estimates a value of a beach day of $3.10 per person (2003 dollars) for 115 square feet of beach. Bell and Leeworthy (1990) use the travel cost method and estimate the value of a beach day of $68.40 per tourist (2003 dollars). This large difference in values may be due to several factors (e.g., methodology, populations). Since there is no reason to prefer one estimate over the other, we employ the average value of a Florida beach day ($35.75) and apply it to each of the four southeastern states. Assuming a one percent net increase in the number of beach trips resulting from ISOOS, the additional consumer surplus is $88 million/yr. Seventy-two percent of this value would occur in Florida. Unfortunately, since the data on beach trips is not divided by the Gulf and Atlantic coasts of Florida, separate estimates are not possible.

Beach recreation benefits estimates are highly speculative due to the paucity of value estimates for beach recreation days. More reliable estimates must await the appearance in the literature of additional estimates of consumer surplus per beach day for the southeastern states.

### 3.e. Search and Rescue

Search and rescue benefits are estimated as an improvement in the percentage of lives saved by U.S. Coast Guard search and rescue missions. Search and rescue data for incidents reported to the U.S. Coast Guard are provided by the U.S. Coast Guard (http://www.uscg.mil). The data are aggregated by Coast Guard regions. Region 7 is the southeast Atlantic region and consists of North Carolina, South Carolina, Georgia, and the Atlantic coast of Florida. Region 8 consists of the Gulf of Mexico. Lives saved, lives lost after Coast Guard notification, and the percentage of lives saved for 1997-2001 are reported in Table 3.e.1 for Regions 7 and 8. The five year average of lives saved in the southeast Atlantic and the Gulf of Mexico is 704 and 595. The percentage of lives saved is 93.74% and 88.87% in the southeast Atlantic and the Gulf of Mexico. The Search and Rescue Program goal is 93% of lives saved.

Table 3.e.1. U.S. Coast Guard Search and Rescue Summary by District

| | Southeast Atlantic (Region 7) | | | Gulf of Mexico (Region 8) | | |
|---|---|---|---|---|---|---|
| | Lives Saved | Lives Lost* | % Saved | Lives Saved | Lives Lost* | % Saved |
| 1997 | 560 | 28 | 95.24% | 626 | 90 | 87.43% |
| 1998 | 491 | 38 | 92.82% | 427 | 110 | 79.52% |
| 1999 | 900 | 31 | 96.67% | 810 | 85 | 90.50% |
| 2000 | 825 | 58 | 93.43% | 504 | 53 | 90.48% |
| 2001 | 743 | 80 | 90.28% | 609 | 73 | 89.30% |
| Average | 704 | 47 | 93.74% | 595 | 82 | 87.87% |

*After Coast Guard Notification

An estimate of state-level boating activity is applied to the aggregate statistics in order to develop estimates of search and rescue benefits at the state level. The estimate of state-level boating activity employed is the number of registered recreational boats in each state. These statistics are from the National Marine Manufacturers Association (http://www.nmma.org). The latest available data are for 2002 (Table 3.e.2). The total number of boat registrations in Florida is divided in half to obtain estimates of boating activity in the southeast Atlantic and Gulf of Mexico for Florida. According to this measure of boating activity in the southeast Atlantic region, Florida accounts for 30% of boating activity, South Carolina 25%, North Carolina 23%, and Georgia 21%. Florida accounts for 25% of the boating activity in the Gulf of Mexico.

Table 3.e.2. State Recreational Boat Registrations: 2002

| | NC | SC | GA | FL-Atlantic | | Total |
|---|---|---|---|---|---|---|
| Total | 353,625 | 383,971 | 325,135 | 461,299 | | 1,524,030 |
| Percentage | 23.20% | 25.19% | 21.33% | 30.27% | | |
| | | | | | | |
| | FL-Gulf | AL | MS | LA | TX | Total |
| Total | 461,299 | 264,191 | 199,037 | 327,272 | 624,390 | 1,876,189 |
| Percentage | 24.59% | 14.08% | 10.61% | 17.44% | 33.28% | |

The estimates of boating activity by state are used to partition the average lives saved and lives lost data to obtain estimates of lives saved and lives lost by state (Table 3.e.3). Of the 47 annual average lives saved in the southeast Atlantic region, 14 are saved off the east coast of Florida, 12 in South Carolina waters, 11 in North Carolina, and 10 in Georgia. Of the 82 annual average lives saved in the Gulf of Mexico, 20 are saved off the gulf coast of Florida. Following Kite-Powell and Colgan (2001) we assume that the percentage of lives saved with ISOOS will increase by one percentage point. That is, the percentage of lives saved would increase from 93.74% to 94.74% in the southeast Atlantic. Similarly, the percentage of lives saved in the Gulf of Mexico would increase from 87.97% to 88.97%. With rounding, two additional lives would be saved with ISOOS in each southeast Atlantic state and two on the gulf coast of Florida. The total expected number of additional lives saved per year is 9.17.

Table 3.e.3. Additional Lives Saved with SEACOOS by State

| | | Without SEACOOS | | With SEACOOS | | |
|---|---|---|---|---|---|---|
| | Lives Saved | Lives Lost | % Saved | Lives Lost | % Saved | Additional Lives Saved |
| NC | 163.35 | 10.91 | 93.74% | 9.16 | 94.74% | 1.74 |
| SC | 177.37 | 11.84 | 93.74% | 9.95 | 94.74% | 1.89 |
| GA | 150.19 | 10.03 | 93.74% | 8.42 | 94.74% | 1.60 |
| FL-Atlantic | 213.09 | 14.23 | 93.74% | 11.95 | 94.74% | 2.27 |
| Atlantic-Subtotal | 704.00 | 47.00 | 93.74% | 39.49 | 94.74% | 7.51 |
| FL-Gulf | 146.29 | 20.00 | 87.97% | 18.34 | 88.97% | 1.66 |
| FL-Total | 359.38 | 34.23 | 91.30% | 30.29 | 92.30% | 3.94 |
| Total | 850.29 | 67.00 | 92.70% | 57.83 | 93.70% | 9.17 |

There is a vast literature that develops estimates of the value of a statistical life (VSL) (Viscusi 1993). These estimates are used in benefit cost analyses of policies that impact human health and safety. The VSL is estimated by the hedonic wage method, the averting behavior method and the contingent valuation method. The hedonic wage method exploits the fact that jobs with higher safety risks pay higher incomes. The averting behavior method exploits the fact that consumers tend to spend money to protect themselves from risk. For example, households faced with contaminated drinking water will purchase bottled water. The contingent valuation method develops VSL estimates from answers to survey questions regarding averting behavior or willingness to pay to avoid hypothetical risky situations. In this study, hedonic analysis of labor market data and the results of averting behavior studies are used to develop estimates of VSL.

Kite-Powell and Colgan (2001) rely on a literature review in Viscusi (1993) to develop a VSL estimate of $4 million per life saved by U.S. Coast Guard search and rescue activities. More recently, Blomquist (2004) concludes that "the best estimate of VSL from averting behavior in consumption is probably close to $4 million in year 2000 dollars." This estimate is within the $4 million to $5 million range of VSL estimates from a review of labor market studies using the hedonic wage valuation method (Mrozek and Taylor 2002). Miller (2000) finds that estimates of VSL from contingent valuation studies are greater than those from labor market and averting behavior studies. Collectively, these studies support a conservative VSL estimate of $4 million, or $4.35 million in 2003 dollars.

Applying the $4.35 million VSL to the estimates of additional lives saved from ISOOS leads to benefits of $17 million, $8 million, $8 million, and $7 million in Florida, South Carolina, North Carolina and Georgia (Table 3.e.4). Benefits are $33 million in the south Atlantic and $7 million on Florida's Gulf coast. Total benefits from North Carolina through the Florida Gulf coast are almost $40 million/yr.

Table 3.e.4. Search and Rescue Value of SEACOOS (in millions 2003 $'s/yr.)

| | NC | SC | GA | FL-Atlantic | Atlantic Total |
|---|---|---|---|---|---|
| Lives Saved | 1.74 | 1.89 | 1.60 | 2.27 | 7.51 |
| Value | $7.58 | $8.23 | $6.97 | $9.89 | $32.67 |
| | | | | | |
| | FL-Gulf | FL-Total | | | Total |
| Lives Saved | 1.66 | 3.94 | | | 9.17 |
| Value | $7.23 | $17.12 | | | $39.90 |

### 3.f. Natural hazard prediction

A category of benefits not addressed by Kite-Powell and Colgan (2001) but important in the SEACOOS region is improved natural hazard (e.g., hurricane) prediction. Improved hurricane forecasts will generate benefits for recreational boaters, commercial fishers, cruise ships, the maritime transportation industry, and the military. These benefits include reduced costs of avoiding forecast storms that do not materialize and reduced damages from avoiding storms that are forecast with greater accuracy. Benefits in the maritime transportation, recreational cruise, commercial fishing, and recreational boating industries arise from more efficient route scheduling and fewer cancelled trips due to better weather information; these benefits are addressed in sections 3.a.1, 3.a.2, 3.c, and 3.d of this report. We do not attempt to quantify benefits to the military.

It is possible to quantify the hurricane forecast benefits of ISOOS for onshore hurricane evacuation because data for hurricane evacuation rates, strikes, and costs are available. Improved information from ISOOS will lead to improved information for emergency managers. With improved hurricane forecasting ability the width of forecast hurricane paths will narrow, allowing emergency managers to make better judgments about evacuation orders. We assume that better forecast information will lead to a one percent reduction in the number of households that must evacuate. Since hurricane evacuation generates economic costs, a reduction in the number of evacuees will lead to avoided costs. These avoided costs are a component of the total economic benefits of ISOOS.

In the event of a hurricane, and without ISOOS information, the number of evacuated households is the product of the evacuation rate and the number of households. With ISOOS information, the number of reduced household evacuations is the product of the number of evacuated households in the absence ISOOS information and a one percent reduction in evacuations.

Since hurricane strikes are uncertain, we calculate expected evacuation benefits. Expected evacuation benefits are the product of the probability of a hurricane strike, the cost per evacuated household and the number of reduced household evacuations. Estimates of expected benefits are made for minor and major hurricanes. Minor hurricanes are defined as Saffir-Simpson category 1 and 2 storms. Major hurricanes are defined as Saffir-Simpson category 3, 4, and 5 storms. The total expected hurricane evacuation benefits are the sum of the expected benefits for minor and major hurricanes.

First, we develop an estimate of the number of evacuated households for minor and major hurricanes. During the late 1990s, three hurricanes landed on the Atlantic coast. Hurricane Floyd (1999) represents a major hurricane, and hurricanes Dennis (1999) and Bonnie (1998) represent minor hurricanes. In 1999 category 4 Hurricane Floyd approached the southeast U.S. and led to what has been called the biggest peacetime evacuation in U.S. history. Hurricane Floyd eventually landed as a category 3 storm, but the evacuation behavior reflected expectations of a category 4 storm.

Data on recent hurricane evacuation is available from several sources (Table 3.f.1). Whitehead et al. (2000) estimate that 41 percent of coastal North Carolina residents evacuated for hurricane Floyd. Similarly constructed estimates for South Carolina, 66%, and Florida, 13%, are from the Hazards Research Lab (2000) and the Institute for Public Opinion Research (1999). Baker (2000) reports the evacuation rate for Georgia was 90% for hurricane Floyd. Evacuation rates for hurricane Bonnie and hurricane Dennis are from Whitehead et al. (2000) for North Carolina and Dow and Cutter (2000) for South Carolina. Evacuation rates for North Carolina, South Carolina and Georgia are for the coastal county population. The evacuation rate for Florida is for the entire state.

Table 3.f.1. Hurricane Evacuation Rates

| State | Bonnie (1998) Category 2/3 | Dennis (1999) Category 1 | Floyd (1999) Category 3/4 |
|---|---|---|---|
| NC | 26% | 17% | 41% |
| SC | 44% | 17% | 66% |
| GA | 51%* | 33%* | 90% |
| FL | 8%* | 5%* | 13% |

*Extrapolated from existing data.

Evacuation rates for hurricane Bonnie and hurricane Dennis for Georgia and Florida are estimated from the relationship between evacuation for hurricanes Bonnie, Dennis and Floyd for North Carolina and South Carolina. The percentage change in evacuation from hurricane Floyd to hurricane Bonnie and hurricane Floyd to hurricane Dennis is averaged for North Carolina and South Carolina and used to adjust the hurricane Floyd evacuation rates for Georgia and South Carolina for the lower intensity storms.

The number of evacuated households for hurricane Floyd is 76,000, 252,800, 160,414, and 782,360 for North Carolina, South Carolina, Georgia, and Florida. The estimates for North Carolina and Florida are obtained from Whitehead et al. (2000) and Institute for Public Opinion (1999). The estimate of households evacuated for South Carolina is obtained from the estimate of individuals evacuated (Hazards Research Lab 2000) and divided by 2.5 individuals for each household. The estimate for Georgia is obtained from 2000 U.S. Census estimates of population for the Georgia coastal counties of Bryan, Camden, Chatham, Glynn, Liberty and McIntosh (total population = 445,595) and dividing by 2.5 individuals for each household. The number of evacuations for a minor hurricane is the product of the average evacuation rates for hurricane Bonnie and hurricane Dennis and the household population of each state.

The avoided evacuations for minor and major hurricanes are obtained by multiplying the evacuation estimates by one percent (Table 3.f.2). Avoided evacuations are then multiplied by the hurricane risk and an estimate of the household cost of an evacuation to obtain the hurricane evacuation benefits of ISOOS information. The hurricane risk measures are developed from historical hurricane strike data provided by the National Hurricane Center (http://www.nhc.noaa.gov). From 1900 to 1996, a period of 97 years, North Carolina experienced 25 hurricane strikes with 14 and 11 of these minor and major hurricanes. The chance of a hurricane strike is the ratio of the number of hurricane strikes to the number of years (e.g., $(14 \div 97) \times 100 = 14.43\%$). Similar estimates are developed for the other states.

Estimates of hurricane evacuation costs from North Carolina are obtained from Whitehead (2003). The total household cost includes expenditures on lodging, food, entertainment, travel and time. The total household cost is $211, $233, $273, $256, and $292 for category 1, 2, 3, 4, and 5 hurricanes. The cost for a minor hurricane is the average of the costs of category 1 and 2 hurricanes ($222). The cost for a major hurricane is the average of the costs of category 3, 4, and 5 hurricanes ($274). We assume that household evacuation costs for South Carolina, Georgia, and Florida are the same as for North Carolina.

Table 3.f.2. Hurricane Evacuation Benefits

| | Category 1 or 2 Hurricane | | | Category 3, 4 or 5 Hurricane | | |
|---|---|---|---|---|---|---|
| | Avoided Evacuations | Strike Probabilities | Costs Avoided | Avoided Evacuations | Strike Probabilities | Costs Avoided |
| NC | 57.73 | 14.43% | $12,816 | 86.19 | 11.34% | $23,615 |
| SC | 120.44 | 10.31% | $26,737 | 104.25 | 4.12% | $28,564 |
| GA | 38.69 | 5.15% | $8,590 | 0.00 | 0.00% | $0 |
| FL | 1399.52 | 34.02% | $310,693 | 1935.74 | 24.74% | $530,392 |
| Total | 1,616 | | $358,837 | 2,126 | | $582,570 |

The annual total hurricane evacuation cost avoided with ISOOS is approximately $940,000. Sixty-two percent of these costs are for a major hurricane. Most of these benefits occur in Florida – 87 percent and 91 percent for minor and major hurricanes – for two reasons. Both the affected population and strike probabilities are much larger in Florida. Annual costs avoided in North Carolina, South Carolina, and Georgia are $36 thousand, $55 thousand, and $9 thousand.

The hurricane evacuation benefits are underestimates of the true values for several reasons. First, we do not include the hurricane evacuation costs imposed on tourists. Much of hurricane season occurs during tourist season in states with popular beaches. Improved hurricane evacuation orders would reduce the number of tourists that must be evacuated. Second, we do not include the additional "shadow evacuations," evacuations in non-coastal counties, for all states but Florida. We do not include tourist and shadow evacuations because there are no reliable estimates of these numbers. Third, we do not include the economic costs of business interruptions (Burrus et al. 2002) due to evacuations.

Another hurricane evacuation benefit of ISOOS information is the avoidance of the costs of the "crying wolf" effect. The crying wolf effect is the incentive for coastal residents to stay home in the face of an approaching hurricane because they have evacuated in the past without a hurricane strike. The crying wolf effect leads to increased hurricane damages as these residents are exposed to unnecessary hurricane risks to life and limb. Improved information would reduce the number of false alarm evacuations and reduce the crying wolf effect.

### 3.g. Beach erosion

Reduction of beach erosion damage costs represents another category of ISOOS benefits important in the southeast Atlantic region. As this benefit category is not addressed in other ISOOS regional reports, somewhat more extensive background information is provided here.

Driven by a rising sea level, large storms, flooding, and powerful ocean waves, erosion wears away the beaches along the coast of the United States. Erosion undermines waterfront houses, businesses, and public facilities, eventually rendering them uninhabitable or unusable. By moving the shoreline inland, erosion also brings nearby structures ever closer to the water, putting them at greater risk. The 1990s saw the publication of two major reports by the National Research Council (NRC) on the problems of coastal erosion and beach protection (NRC 1990; NRC 1995). While coastal erosion is generally recognized as a costly problem, opinions differ regarding the best management solution. Some find beach sand renourishment to be cost effective in some locations (e.g., Hillyer et al. 1997; Wakefield 2001; Houston 2002), while others oppose renourishment and find alternative management policies such as zoned setbacks more attractive (e.g., Pilkey and Dixon 1996). ISOOS information would likely reduce the costs of implementing any of these erosion management measures. After presenting background information on the problem of beach erosion and associated costs, this section of the report develops estimates of ISOOS benefits for two benefit categories: improved efficiency in coastal land-use and setback planning, and improved efficiency in beach nourishment project design.

*Magnitude of the Erosion Problem*

The National Flood Insurance Reform Act of 1994 mandated that the Federal Emergency Management Agency (FEMA) submit an independent report to Congress evaluating the extent and economic impact of erosion along the shorelines of the United States (Crowell et al. 1999a). The report was conducted in two phases. Phase 1 consisted of an effort by state coastal zone management agencies to "map a statistically valid and representative number of communities with erosion hazard areas throughout the United States . . . ." Results for the sample communities were then extrapolated to the coastal region as a whole. Phase 1 sample communities located in the SEACOOS region are listed in the table below.

Table 3.g.1. SEACOOS region counties included in FEMA/Heinz Center erosion study sample.

| State | Counties |
|---|---|
| NC | Dare, Brunswick |
| SC | Georgetown |
| GA | Glynn |
| FL | Brevard, Lee, Escambia |

Phase 1 results for the sample communities are summarized in Special Issue #28 of the *Journal of Coastal Research* (Crowell et al. 1999b). Representative results of the Phase I mapping effort for the SEACOOS region are described in Overton et al. (1999) and Dean et al. (1999). The Phase 1 effort obtained baseline shoreline imagery, updated existing shoreline maps, calculated average annual erosion rates, and plotted current and future (60 years hence) flood zone boundaries while taking expected erosion into account.[14]

Through a competitive selection process, FEMA selected the H. John Heinz III Center for Science, Economics and the Environment to conduct the Phase II research effort, culminating in the report *Evaluation of Erosion Hazards* (Heinz 2000). The Heinz Center Phase II report was based on analysis of data from a field survey of over 10,000 structures located in the 60-yr erosion hazard areas of the Phase I sample communities. The Heinz Center analysis evaluated the economic impact of erosion hazard on coastal communities and the National Flood Insurance Program (NFIP). The analysis included an evaluation of policy responses and a cost-benefit analysis of erosion hazard mapping (Crowell et al. 1999a). Much of the following information on the magnitude of the erosion problem, current erosion management policy, and potential policy reform relies on the findings of the Heinz Center Phase II report.

Both the Atlantic and Gulf coasts are bordered by a chain of roughly 300 barrier islands, which are composed primarily of loose sand and are the most dynamic land masses along the open-ocean coast. Barrier island coastlines have been retreating landward for thousands of years in response to slowly rising sea levels. The average annual erosion rate on the Atlantic coast is roughly 2 to 3 feet/year (Heinz 2000). States bordering the Gulf of Mexico have the nation's highest average annual erosion rates (6 feet/year). The rates vary greatly from location to location and year to year.

Within the first few hundred feet bordering the Nation's coasts, property owners face as large a risk of damage from erosion as they do from flooding. Approximately 350,000 structures are located within 500 feet of the 10,000-mile ocean and Great Lakes shorelines of the lower 48 states and Hawaii (Heinz 2000). (This estimate does not include structures in the densest areas of large coastal cities, such as New York, Chicago, Los Angeles, and Miami, which are heavily protected against erosion.) Of these, about 87,000 homes are likely to erode into the ocean or Great Lakes over the next 60 years. Houses near a rapidly eroding shore are worth less today than otherwise identical houses located near non-eroding shorelines due to the risk of future erosion damage. Today's property values within the areas most susceptible to coastal erosion are \$3.3 billion to \$4.8 billion lower than they would be in the absence of the erosion threat, equivalent to a reduction in property values of about 10 percent (Heinz 2000). Assuming no additional beach nourishment or structural protection, roughly 1,500 homes and the land on which they are built will be lost to erosion each year for the next several decades (Heinz 2000). Costs to coastal property owners will average \$530 million per year including both damage to structures and loss of land. At current insurance enrollment levels, it is estimated that the National Flood Insurance Program will pay \$80 million per year for erosion-related damage (Heinz 2000). Additional beach nourishment or structural protection may reduce losses; but additional anticipated development in many erosion prone areas may lead to higher losses.

[14] Future shoreline positions and erosion hazard zones are typically defined for periods 30 and 60 years into the future for two primary reasons: the expected lifetime of new coastal structures is typically estimated at 30 or 60 years, and discounted benefits and costs beyond this time horizon are typically negligible using customary discount rates.

*Current Erosion Management Policy*

Currently, erosion is addressed in a piecemeal manner by Federal, state, and local governments as well as private landowners (Heinz 2000). Federal activities and programs include: the NFIP, which reimburses policyholders for erosion losses; coastal engineering projects, such as beach nourishment, that help protect against erosion; funding and technical assistance to states; and the purchase of coastal areas for public ownership. The Coastal Barrier Resources Act restricts federal expenditures, including flood insurance and disaster assistance, within designated Coastal Barrier Resources System Units. The system encompasses nearly 1.3 million acres and approximately 1,200 miles of shoreline. State-level responses to erosion range from doing nothing to restricting the use of hard structures and enforcing erosion-rate based setbacks (e.g., North Carolina), to providing no-interest loans and grants to stabilize the shoreline through cliff-hardening (e.g., the Maryland side of the Chesapeake Bay). In other areas, groins, seawalls, bulkheads, and other measures are used to prevent erosion of the coastline.

The U.S. Army Corps of Engineers spent about $700 million between 1950 and 1993 (in 1993 dollars) to nourish beaches along approximately 200 miles of U.S. coastline (Heinz 2000). Continued beach maintenance and renourishment costs total approximately $300,000/year per mile of nourished beach. In densely developed areas, such as Ocean City, Maryland, or Miami Beach, Florida, some economists find that beach nourishment may be worth the cost for the foreseeable future (Parsons and Powell, 1998). However, expected annual erosion damage exceeds nourishment costs in only one of the ten less urbanized Atlantic and Gulf coast counties in the Heinz Center sample (Heinz 2000). It appears that nourishment of additional stretches of the coast, if desired at all, will likely pass a benefit-cost test for federal funding only in limited areas with relatively high population densities.

*Potential Policy Reform*

The Heinz Center Report (Heinz 2000) makes only two major recommendations:

> (1)--Congress should instruct FEMA to develop erosion hazard maps that display the location and extent of coastal areas subject to erosion. The erosion maps should be made widely available in both print and electronic formats.
>
> (2)--Congress should require FEMA to include the cost of expected erosion losses when setting flood insurance rates along the coast.

Currently, the NFIP does not map erosion hazard areas to inform homeowners of the erosion risk they face, nor does it directly incorporate erosion risks into its flood insurance ratemaking procedures. Current rates are primarily based on flood risk alone. Flood insurance rate maps do not inform current and prospective coastal property owners of erosion risks. Without such information, state and local decision makers and the general public are not fully aware of the coastal hazards they face, nor do they have this information available for land-use planning and erosion hazard mitigation. Despite facing higher risk, homeowners in erosion-prone areas currently pay the same amount for flood insurance as do policyholders in non-eroding areas. The

Heinz Center report recommended that FEMA should incorporate erosion risk into the cost of insurance along the coasts in order to discourage development in erosion-prone areas.

While it is difficult to estimate the effects that erosion map information might have on future development decisions, the effects would not have to be large to justify the costs. FEMA estimates that a nationwide erosion hazard mapping program would cost $44 million (Heinz 2000). Assuming that a map is useful for 10 years, annual costs would be roughly $5 million per year. For comparison, if all currently empty lots in areas most susceptible to erosion are developed, structural damage from erosion would rise by roughly $100 million per year. If the availability of erosion maps lowers future structural damage by just a few percent, the savings would exceed the costs. Alternative federal erosion-related expenditures are unlikely to be more cost-effective. For example, spending an equivalent amount on beach nourishment would protect only 10 additional miles of shoreline (Heinz 2000). In addition to the use of erosion maps by individual homeowners and communities, FEMA will need such maps should it decide to include the costs of erosion losses in the coastal insurance rate determination process.

*Benefits of ISOOS Information for Erosion Cost Reduction*

The two major recommendations of the Heinz Center erosion report highlight erosion rates and erosion hazard maps as critical elements of erosion management policy. Indeed, recent field research in both Delaware (Wakefield 2001; Parsons and Powell 2001) and Georgia (Landry, Keeler and Kriesel 2003) indicates that selection of the efficient erosion management policy (nourishment vs. beach retreat, etc.) depends crucially on estimates of erosion rates. As well, Crowell et al. (1997) and Houston (1996) find that accurate determination of erosion rates is necessary for designing either cost-effective building setback regulations (a method of implementing beach retreat) or cost-effective nourishment projects. Hence, we base our benefit estimates on the improvements in erosion management efficiency that would result from improved estimates of erosion rates made possible by the availability of ISOOS data.

Accurate calculation of erosion rates depends on the availability of a variety of high quality ISOOS data. The 1990 NRC report *Managing Coastal Erosion* finds that the availability of long-term oceanographic data would improve the accuracy of shoreline prediction. The NRC report calls for more research on (1) long-term wave climatology through field data collection, (2) beach response to wave climate variations and episodic events, and (3) use of remote sensing resources in order to improve the methodology for assessing beach erosion. Erosion and shoreline position estimates depend on shoreline response models such as the U.S. Army Corps of Engineers' GENESIS model (Hanson and Kraus 1989) or regression analysis of historical shoreline position data (Crowell et al. 1991). The GENESIS model relies on ISOOS data such as mean breaking wave heights, while shoreline position regression models require ISOOS data such as shoreline positions (e.g., the National Ocean Service's coastal topographic maps and vertical aerial photographs) and sea level (e.g., tide gauge data) (Crowell et al. 1997). The 1995 NRC report *Beach Nourishment and Protection* finds that shoreline location prediction is limited by the accuracy of available ocean information. The NRC report recommends the collection and analysis of directional wave data, cross-shore and alongshore transport rates of sediments, tide data, storm data, and sea level data to support beach nourishment design and prediction. The NRC report also finds that data on offshore shoal locations can help predict erosion hotspots.

The NRC notes that ISOOS equipment such as wave gauges, current meters, surface-piercing gauges, pressure gauges, accelerometer buoys, inverted echo sounders, deep water directional buoys, multiple gauge arrays and shallow water pressure-gauge slope arrays can provide appropriate ocean data. Houston (1996) reports that efficient beach nourishment project design depends on data describing offshore bathymetry; sediment sources, sinks and characteristics; longshore sediment movement rates; sediment fall velocities (which in turn depend on sediment diameter and water temperature data); and mean annual significant wave heights and standard deviations. Wave height predictions depend on historical wave data and forecasts of future climate, storm frequencies, and wind speeds, which in turn depend on ISOOS atmospheric and oceanic data. Houston (1996) also reports that improvements in nourishment project design depend on post-project beach monitoring data and data on the fate of beach-fill sediment offshore. Finally, Crowell et al. (1997) and Douglas et al. (1998, 2000) find that long-term data collection is necessary due to the existence of quasiperiodic, interannual and interdecadal variations in the data (such as large storm events) that tend to obscure underlying long term trends in erosion.

Erosion costs may be reduced by several means, including better allocation of new development to less erosion-prone areas (Heinz 2000), more efficient estimation of erosion set back locations Crowell et al. (1997), and more efficient beach nourishment project design (Houston 1996) and location (Ofiara and Psuty 2001). We consider two benefit categories, reduced beach nourishment costs in more densely populated areas currently protected by beach sand nourishment, and reduced costs of alternative management measures (such as reduced costs of development restrictions and beach retreat) in less densely populated areas.

Estimates of the efficient size and cost of a beach nourishment project can vary widely depending on estimates of the beach erosion rate (Wakefield 2001). The availability of ISOOS data would allow more accurate estimation of beach erosion rates and more efficient design of beach nourishment projects. For consistency with the assumptions made in the other regional ISOOS benefit assessment reports, and to facilitate benefit comparisons across benefit categories and regions, we consider a 1% reduction in beach nourishment costs due to the availability of ISOOS information. Table 3.g.2 presents data on the cumulative costs of beach nourishment by state from 1921 to 1998. These costs are annualized using a 3% discount rate. The annual benefits of ISOOS information are calculated as a 1% reduction in annualized nourishment costs, or $174,151/yr for the SEACOOS region. These estimates may be conservative, as future sea level rise may significantly increase nourishment costs and the benefits of cost reduction (Yohe 1990; Leatherman et al. 2000).

Table 3.g.2. Benefits of beach nourishment cost reduction (high-population density areas)

| State | Cumulative Beach Nourishment Costs (1921-1998) (a) (2003 $'s) | Annualized Beach Nourishment Costs (b) (2003 $'s) | Annual SEACOOS Benefits (c) (2003 $'s) |
|---|---|---|---|
| NC | $171,400,530 | $5,142,016 | $51,420 |
| SC | $105,585,103 | $3,167,553 | $31,676 |
| GA | $39,945,591 | $1,198,368 | $11,984 |
| FL | $263,572,173 | $7,907,165 | $79,072 |
| SEACOOS Region Total | $580,503,398 | $17,415,102 / yr. | $174,151 |

(a) Source: Heinz (2000). (b) Assumes 3% discount rate.
(c) Assumes 1% reduction in annualized nourishment costs.

In addition to the beach nourishment cost reduction benefits described above, the availability of ISOOS data improves the efficiency of alternative beach erosion management measures in less densely populated areas where nourishment may not be cost effective. For example, improved erosion rate estimates made possible by ISOOS data might indicate that development should be discouraged in an area that otherwise would be fully developed. The avoided costs of erosion-related property losses are benefits of ISOOS.

Table 3.g.3 presents data necessary for developing estimates of erosion cost reduction benefits in low-population density areas. For low-population density areas in the Atlantic and Gulf regions, the Heinz (2000) report provides 1990 state level data on population living within 500 feet of the shoreline and estimates of the number of structures located within 500 feet of the shoreline. We assume that shoreline structures are allocated across states in proportion to shoreline population. Regional estimates of the proportion of structures located within 500 feet of shore that are also located within the 60-year Erosion Hazard Area (EHA) (Heinz 2000) are used to estimate the number of structures located within the 60-year EHA. Regional estimates of the average annual cost of erosion to land and structures located within the 60-year EHA (Heinz 2000) are translated to state-by-state costs by allocating regional costs to states in proportion to the allocation of EHA structures across states. Costs are deflated to 2003 using the CPI. Assuming that improvements in erosion management efficiency due to the availability of ISOOS information reduce the costs of alternative erosion management measures by 1 percent results in an average annual benefit estimate of $1,811,886 (2003 $'s) for the SEACOOS region. However, this value may underestimate benefits because it does not account for the additional coastal development that has occurred since 1990. Although we have no estimate of the number of structures added to the 60-year EHA since 1990, the Heinz (2000) report provides estimates of the number of vacant lots by region in 1990 (On average across all regions, vacant lots accounted for approximately 30 percent of total lots in 1990.) and regional estimates of the average annual costs of erosion to land and structures, were all lots to be developed. An upper-bound benefit estimate may be derived by assuming that all lots are developed. Assuming that additional structures and associated erosion costs would be allocated across states in proportion to the allocation of EHA structures across states in 1990 allows estimation of the number of structures and associated erosion costs by state under "full build" conditions. Under "full build" conditions, the estimate of average annual benefits is $2,328,812 (2003 $'s).

Table 3.g.3. Benefits of alternative beach erosion management cost reduction (low-population density areas)

| State | Population w/n 500 ft of Shoreline (1) 1990 | Structures w/n 500ft of Shoreline (2) 1990 Properties | Structures w/n 60-yr EHA (3) 1990 Properties | Average Annual Erosion Costs (2003 $'s) to Properties located w/n 60-yr EHA (4) 1990 Properties | Structures w/n 60-yr EHA Full Build (5) | Average Annual Erosion Costs (2003 $'s) to Properties located w/n 60-yr EHA (4) Full Build (5) |
|---|---|---|---|---|---|---|
| NC | 5,000 | 4,830 | 1,449 | $7,603,514 | 2,072 | $9,769,766 |
| SC | 6,000 | 5,795 | 1,739 | $9,124,217 | 2,486 | $11,723,719 |
| GA | 1,000 | 966 | 290 | $1,520,703 | 414 | $1,953,953 |
| FL Atlantic | 81,000 | 78,239 | 23,472 | $123,176,932 | 33,564 | $158,270,202 |
| FL Gulf | 41,000 | 32,214 | 9,664 | $39,763,256 | 16,332 | $51,163,562 |
| SEACOOS Region | 134,000 | 122,044 | 36,613 | $181,188,622 | 54,869 | $232,881,201 |
| Annual SEACOOS Benefits (6) | N/A | N/A | N/A | $1,811,886 | N/A | $2,328,812 |

(1) Source: Heinz (2000), Table 2.3. Numbers rounded to nearest thousand. Data exclude densely populated portions of urban areas, assumed protected by nourishment projects or hardened structures.

(2) Assumes structures are distributed across states in proportion to population w/n 500 ft. of shoreline.

(3) The 60-yr Erosion Hazard Area (EHA) is determined by multiplying local erosion rates by 60 years (Heinz 2000).

(4) Reflects average annual cost of structures and land lost to erosion over next 60 years, not including any "amenity value" of the oceanfront. Any amenity value is assumed to transfer to the next house inland. Source: Heinz (2000), Tables 5.6 and 5.7.

(5) Assumes all open lots within 60-year EHA are filled. Source Heinz (2000).

(6) Based on assumed 1% reduction in average annual erosion costs.

**3.h. Agriculture**

A full assessment of the impact of ISOOS information on agriculture in the SEACOOS region is beyond the scope of this report. However, the following literature review provides a general introduction.

Oceanic and atmospheric conditions impact agriculture by influencing temperature and precipitation. For example, the North Atlantic Oscillation has been found to exert a "dominant influence on wintertime temperature and precipitation across the North Atlantic basin and thus has major impacts on marine and terrestrial ecosystems" (Marshall et al. 1997, p.8). Relationships between sea surface temperature in the North Atlantic and inter-annual precipitation in the southeastern United States have been found (Enfield 1996). A recent NOAA-ONR (2000) report finds that incorporation of additional types of ocean observation information into weather forecasts will improve the predictability of precipitation and air temperature over the southeastern United States.

Fluctuating weather can cause large variations in crop yields and farm profits. When crop management decisions are based on incorrect weather expectations, impacts on farm productivity can be significant. Many studies have found that improvements in weather information can improve the productivity of agriculture (Wilcox and Cochrane 1960; Hashemi and Decker 1972; Stewart et al. 1984; Tice and Clouser 1982; Byerlee and Anderson 1969). Better weather and climate predictions based on ISOOS information may help farmers plan crop choice, irrigation, fertilizer, and pesticide decisions more efficiently. Studies of the economic impacts of better weather information in agriculture appear to vary in two primary dimensions: scale of the driving weather process (i.e., global climate processes, such as El Nino-La Nina or the North Atlantic Oscillation, *versus* regional and local weather conditions), and scope of economic impact (i.e, national impact *versus* impacts on particular crops or agricultural regions).

In terms of economic impacts at the national level, a recent study by Brunner (2002) finds that the El Nino-Southern Oscillation (ENSO) cycle has significant medium-run impacts on U.S. food prices. In a multidisciplinary study, Solow et al. (1998) estimate the potential annual benefits of perfect ENSO information for U.S. agricultural to be $230-320 million/yr. (1995 $'s). Adding the effects of international trade and improvements in crop storage decisions, Chen and McCarl (2000) raise the benefit estimate to $400 million/yr. Of course, less than perfect information would produce smaller benefits, and only a portion of these benefits would accrue to the SEACOOS region. Still, these estimates give some indication of the potential agricultural benefits of ISOOS information in the SEACOOS region.

Several studies consider the benefits of improved weather information for specific crops or agricultural regions. Although most of these studies address areas located outside the SEACOOS region, some address crops grown within the SEACOOS region, and all provide guidance on the nature and potential magnitude of agricultural benefits. Nicholls (1996) reports that better weather information would improve the planting decisions of Missouri cotton farmers and improve irrigation decisions in Nebraska. McNew (1999) finds that such information would improve corn farmers' inter-annual crop storage decisions. Mjelde et al. (1997a) find that the value of ENSO-based weather forecasts for east-central Texas farmers varies by crop, with little value for grain sorghum producers, but a value of $1.08-$2.15 per acre for corn producers. Hill et al. (1998) report that the value of ENSO-based forecasts varies by region for U.S. winter wheat producers, with producers in Illinois gaining little value from improved forecasts, while producers in Oklahoma gain $1.20 per acre. Mjelde et al. (1998) note that the value of ENSO forecasts to Oklahoma farmers increases to $3.40 per acre when more refined forecasting methods are used. Bosch and Eidman (1987) find that Oklahoma farmers pay agricultural consulting companies around $5.00 per acre for irrigation scheduling information based on weather and soil moisture information. Kenkel and Norris (1995) find that Oklahoma farmers and livestock producers are willing to pay an estimated $352,488 to $1,949,064 per year for real-time meso-scale weather information, and from $419,316 to $2,236,368 for this information plus decision support software. Cohen and Zilberman (1997) believe that Kenkel and Norris' benefit estimate is too low, as experience with the CIMIS regional network of weather stations in California has shown that farmers may not be able to estimate the full benefits of weather information for irrigation timing and pest control decisions until after they have had some experience with the new technology. CIMIS is a network of weather stations managed by the California Department of Water Resources that provides daily and historical weather data to farmers, irrigation and pest control consultants, and others throughout California (Parker and Zilberman 1996). Current CIMIS users number in the thousands, and the economic benefits of CIMIS to agricultural and other users in California are estimated to be in the tens of millions of dollars per year (Parker et al. 1996). Farmers reported an average willingness to pay of almost $3 per acre for CIMIS information. Some farmers have even purchased their own CIMIS weather stations at an initial cost of $1,500 to $5,000 and an additional $200 per year in maintenance costs. The availability of CIMIS information has reduced pesticide use and cost in some counties by facilitating better pesticide application timing, and CIMIS temperature information is used in some counties to better control mosquito populations. Kenkel and Norris (1997) reply that although the eventual benefits of weather information to Oklahoma farmers may be larger than their initial survey results indicate, farmers may be slow to adopt the new technology, and public funds may be needed to support the program until full benefits become more apparent to farmers.

Sherrick (2002) finds that Illinois grain farmers located within the territory covered by a NOAA weather reporting station hold systematically biased beliefs regarding the probabilities of rainfall events. Such biased beliefs can lead to costly mistakes in terms of crop choice, planting date, fertilizer use, pesticide application, and crop insurance selection. Sherrick's results reemphasize the need to publicize ISOOS information in a form that is meaningful and persuasive to potential users. Better information is valuable only to the extent that it influences the behavior of end users.

Improvements in weather information may enhance the profitability of other agricultural technologies. For example, recent studies (e.g., Isik and Khanna 2003) indicate that precision agriculture (NRC 1997) methods using site-specific technologies (SSTs) based on sub-field level soil and crop yield monitors may be more profitable when combined with more accurate weather information.

Many existing studies assume that the market prices of farm products will remain unchanged as farmers adjust their operations in response to improved weather information. In an early study of the value of improved weather information to farmers when changes in market prices are considered, Lave (1963) found that the profits of California raisin producers could decrease when better weather information is supplied to the industry. This counter-intuitive result is driven by two features of the raisin industry: it is very competitive, and small increases in production drive down market prices by a relatively large amount (i.e., consumer demand for raisins is "inelastic"). Although it is in each farmer's individual self interest to make use of improved weather information in order to compete with other farmers, if all farmers make use of such information, then large increases in crop production may result, depressing market prices and aggregate industry profits. If farmers could act "collusively" as a cartel (e.g., via marketing boards) to restrain production after receiving more accurate weather information, then industry profits might rise, but this is unlikely in very competitive industries, because it is difficult to prevent members of the "cartel" from "cheating" on the agreement. Babcock (1990) shows that the impact of improved weather information on farm profits under competitive conditions with inelastic consumer demand may be negative even when farmers realize that this will be the case (i.e., even when farmers have rational expectations).

Weather information initially targeted to agricultural users may find other beneficial uses outside agriculture. Parker et al. (1996) find that California golf courses realized an average annual benefit of $20,000 each through better irrigation management based on CIMIS information originally intended for agricultural users. Several large municipal parks each saved $1.75 million per year on average through more efficient irrigation practices based on CIMIS information.

In a recent review article on the value of climate forecasts for U.S. agriculture, Mjelde et al. (1998) note that while estimates of the value of current ENSO-based weather forecasts to Oklahoma farmers are about $3-$4 per acre, the value of perfect weather forecast information would be around $20/acre. The large difference is a measure of the potential benefits of improved weather information for agriculture. Indeed, Mjelde et al. (1997b) estimate that the value of perfect weather forecasts for midwestern corn production alone could amount to $1.2-2.9 billion over just a ten year period. Mjelde et al. (1998) find that among the various agricultural production decisions, improvements in crop selection due to better weather information appear to provide the greatest value to farmers, with improvements in fertilizer decisions ranking second. The review authors report that more research is needed on the impacts of improved weather information on pesticide and pest management decisions. Mjelde et al. note that a substantial portion of the economic benefits of improved weather information in agriculture may not accrue to farmers but instead may be passed on to consumers through lower food prices due to strong competition among farmers. They note as well that additional research is needed to determine the impacts of better weather information on agricultural environmental impacts, such as fertilizer and pesticide runoff. Finally, Mjelde et al. emphasize that farmers will need additional training in the interpretation of probabilistic weather information, and additional research is needed on ways to speed the adoption of weather-based decision tools by agricultural end users.

## 4. Total Benefits

The estimated total annual benefits of ISOOS information across all states in the SEACOOS region and across all benefit categories considered in this study are $170 million/yr (2003 $'s). Estimated annual benefits by state and by benefit category are presented in Table 4.1 below.

Table 4.1 Summary of Annual SEACOOS Benefits (2003 $'s).

| Benefit Category | NC | SC | GA | FL (Atlantic coast) | FL (Gulf coast) | SEACOOS Region Total |
|---|---|---|---|---|---|---|
| Maritime Commercial Shipping Transit Time Benefits[1a] | $305,315 | $791,125 | $713,680 | $2,076,254 | $689,556 | $4,575,930 |
| Maritime Commercial Shipping Grounding Cost Reduction[1b] | $12,206 | $15,325 | $17,987 | $89,775 | | $135,294 |
| Recreational Cruise Benefits[2] | $778,257 | $344,258 | $1,774,295 | $24,518,989 | | $27,415,799 |
| Oil Spill Cost Reduction[3] | $16,879 | $234,320 | $201,261 | $195,265 | | $647,725 |
| Commercial Fishing Benefits (Finfish)[4] | $442,067 | $65,551 | $10,666 | $233,961 | $603,055 | $1,355,300 |
| Commercia l Fishing Benefits (Shellfish)[4] | $353,458 | $143,525 | $134,848 | $196,009 | $619,716 | $1,447,556 |
| Commercial Fishing Vessel Accident Cost Reduction[5] | $256,816 | $46,378 | $18,931 | $289,220 | | $611,345 |
| Marine Recreational Fishing Benefits[6] | $162,776 | $19,558 | $1,051 | $384,024 | $2,500,635 | $3,068,044 |
| Beach Recreation Benefits[7] | $9,987,120 | $11,905,465 | $3,032,673 | $63,332,198 | | $88,257,455 |
| Search & Rescue Cost Reduction[8] | $7,580,000 | $8,230,000 | $6,970,000 | $9,890,000 | $7,230,000 | $39,900,000 |
| Hurricane Evacuation Cost Reduction (Cat 1 & 2)[9] | $12,816 | $26,737 | $8,590 | $310,693 | | $358,837 |
| Hurricane Evacuation Cost Reduction (Cat 3-5)[9] | $23,615 | $28,564 | $0 | $530,392 | | $582,570 |
| Beach Nourishment Cost Reduction[10] | $51,420 | $31,676 | $11,984 | $79,072 | | $174,151 |
| Other Beach Erosion Mgmt. Cost Reduction[11] | $76,035 | $91,242 | $15,207 | $1,231,769 | $397,633 | $1,811,886 |
| Agriculture Benefits | Not quantified in this study. | | | | | |
| Total Annual Benefits | $20,046,574 | $21,958,399 | $12,893,185 | $115,308,440 | | $170,341,892 |

[1a] Assumes 1% decrease in commercial vessel transit time in coastal waters. Assumes Atlantic Intracoastal Waterway benefits are distributed across states in proportion to distribution of benefits by harbor across states. [1b] Assumes 1% decrease in vessel groundings. [2] Assumes 1% increase in direct expenditures by cruise line companies and passengers. [3] Assumes 1% decrease in oil spills and associated costs. [4] Increase in value-added. Assumes one additional fishing day per year. [5] Assumes 1% decrease in commercial fishing vessel accidents per year. [6] Annual increase in consumer surplus. Assumes 1% net increase in recreational fishing trips per year. [7] Annual increase in consumer surplus. Assumes 1% net increase in recreational beach trips per year. [8] Assumes one percentage point increase in lives saved. [9] Assumes 1% decrease in hurricane evacuations. [10] Assumes 1% decrease in annualized nourishment costs. [11] Assumes 1% decrease in average annual erosion costs.

Beach recreation, search and rescue operations, and recreational cruises receive the largest estimated annual benefits, $88 million/yr., $40 million/yr., and $27 million/yr. Estimated benefits in the remaining benefit categories are: maritime commercial shipping transit time, $4.6 million/yr., maritime commercial shipping grounding reduction, $0.13 million/yr., marine recreational fishing, $3 million/yr., commercial fishing, $3.3 million/yr., beach erosion management, $2.0 million/yr., hurricane evacuation, $0.9 million/yr., and oil spills, $0.6 million/yr..

Comparing across states within the SEACOOS region, Florida receives more than 67% of the estimated SEACOOS region benefits, due to disproportionately large benefits in the beach recreation and recreational cruise categories. North Carolina and South Carolina each receive approximately 13% of regional benefits, while Georgia receives approximately 8%. The categories receiving the largest benefits in North Carolina, South Carolina, and Georgia are beach recreation and search and rescue operations.

Comparing across regions, Kite-Powell and Colgan (2001) find that the annual benefits of ISOOS in the Gulf of Maine region for the five benefit categories: (1) maritime transportation, (2) commercial fishing, (3) recreational fishing and boating, (4) search and rescue operations, and (5) pollution management (specifically oil spill management and prevention) are more than $33 million/yr., with most of these benefits in the category of search and rescue.

In the Gulf of Mexico, Lynch, Harrington and O'Brien (2003) find using similar methodology and assumptions that the annual benefits of ISOOS for the same five benefit categories are $97 million/yr., with more than $25 million/yr. in benefits attributable to each of the maritime transportation, recreational fishing, and search and rescue benefit categories. Lynch, Harrington and O'Brien consider additional benefit categories including: construction, $779 million, coastal recreation (beach visits, canoeing, bird watching, waterfowl hunting), $40.36 million, agriculture, $314 million, military, $18 million, onshore oil and gas refining, $1.134 billion, offshore oil and gas extraction, $217 million, storm damage mitigation, $27 million, coastal water quality management, $1.5 million, and water supply management, $7.4 million. However, some of the additional benefit estimates are based on changes in economic activity rather than changes in net economic value. Of the additional estimates, the military, storm damage mitigation, offshore oil and gas extraction, and coastal water quality management estimates appear to be appropriate. Although the estimate of onshore oil and gas refining benefits is possible, it seems somewhat large and likely requires further substantiation.

Table 4.2 below categorizes the estimated SEACOOS benefits by type of beneficiary: public, public/private, or private. An estimated $132,166,906 in annual benefits, or 77.5% of the estimated $170,341,892 in total annual SEACOOS benefits, accrues to the "public" sector. These benefits reflect savings in government expenditures for search and rescue operations, beach nourishment, etc., as well as benefits available to the public at large, such as recreational fishing and beach recreation benefits. An estimated $2,732,676 in annual benefits, or about 1.5% of estimated total benefits, accrue to public/private sectors of the economy, such as reductions in costs of commercial fishing vessel groundings, which would accrue partially to private fishing vessel owners, and partially to government rescue programs. Finally, an estimated $35,442,310 in annual benefits, or 21.0% of estimated total benefits, accrues primarily to private sectors of the economy, such as maritime commercial shipping and commercial fishing.

Table 4.2 Public vs. Private Benefits (2003 $'s).

| Benefit Category | Public or Private Benefits? | SEACOOS Region Total |
|---|---|---|
| Maritime Commercial Shipping Transit Time Benefits[1a] | Private | $4,575,930 |
| Maritime Commercial Shipping Grounding Cost Reduction[1b] | Public/Private | $135,294 |
| Recreational Cruise Benefits[2] | Private | $27,415,799 |
| Oil Spill Cost Reduction[3] | Private | $647,725 |
| Commercial Fishing Benefits (Finfish)[4] | Private | $1,355,300 |
| Commercial Fishing Benefits (Shellfish)[4] | Private | $1,447,556 |
| Commercial Fishing Vessel Accident Cost Reduction[5] | Public/Private | $611,345 |
| Marine Recreational Fishing Benefits[6] | Public | $3,068,044 |
| Beach Recreation Benefits[7] | Public | $88,257,455 |
| Search & Rescue Cost Reduction[8] | Public | $39,900,000 |
| Hurricane Evacuation Cost Reduction (Cat 1 & 2)[9] | Public | $358,837 |
| Hurricane Evacuation Cost Reduction (Cat 3-5)[9] | Public | $582,570 |
| Beach Nourishment Cost Reduction[10] | Public/Private | $174,151 |
| Other Beach Erosion Mgmt. Cost Reduction[11] | Public/Private | $1,811,886 |
| Agriculture Benefits | Not quantified in this study. | |
| Total Annual Private Benefits | | $35,442,310 (21.0%) |
| Total Annual Public/Private Benefits | | $2,732,676 (1.5%) |
| Total Annual Public Benefits | | $132,166,906 (77.5%) |
| Total Annual Benefits | | $170,341,892 (100%) |

# 5. Conclusions

## 5.a. Summary

Initial studies of the economics of integrated and sustainable ocean observing systems (ISOOS) in the U.S. (e.g., NOAA-ONR 2000) found that benefits were likely to significantly exceed costs and that work on such systems should move forward. It was recognized that Federal support of ISOOS was needed due to the existence of market failures (such as network externalities in ISOOS data acquisition and the public good nature of ISOOS information) that prevent the private market from developing and implementing ISOOS at an efficient level. Benefit-cost analysis would be necessary to determine the efficient level of government program support. However, a full cost-benefit analysis was beyond the scope of the initial assessment effort due in large part to a lack of benefit estimates for the full range of projected ISOOS applications.

This report identifies general categories of economic benefits that may result from the implementation of ISOOS in the southeastern United States and develops initial, order of magnitude benefit estimates. The results of the initial analysis indicate that the economic benefits of the regional observing system likely justify the costs. The estimated total annual benefits of ISOOS information across all states in the SEACOOS region and across all benefit categories considered in this study are $170 million/yr. Of these total annual benefits, approximately 77.5% accrue to public sectors of the economy, 1.5% accrue to mixed public/private sectors of the economy, and 21% accrue to largely private sectors of the economy.

Beach recreation, search and rescue operations, and recreational cruises receive the largest estimated annual benefits, $88 million/yr., $40 million/yr. and $27 million/yr.. Estimated benefits in the remaining benefit categories are: maritime commercial shipping transit time, $4.6 million/yr., maritime commercial shipping grounding reduction, $0.13 million/yr., marine recreational fishing, $3 million/yr., commercial fishing, $3.3 million, beach erosion management, $2.0 million/yr., hurricane evacuation, $0.9 million/yr., and oil spills, $0.6 million/yr. These estimates reflect the direct, net economic benefits (increases in producer value-added and consumer surplus) of ISOOS. Economic "multiplier" effects (indirect and induced economic impacts) are not included in these estimates.[15] Multiplier effects are omitted in order to produce conservative benefit estimates; if multiplier effects were included, benefit estimates would be larger.

Comparing across states within the SEACOOS region, Florida receives more than 67% of the estimated SEACOOS region benefits, due to disproportionately large benefits in the beach recreation and recreational cruise benefits categories. North Carolina and South Carolina each

[15] The additional value-added resulting from additional direct expenditures by recreational cruise ship passengers in base ports the day before and the day following a cruise are included in the net benefit estimates, but the indirect and induced impacts of these expenditures are not. Although some portion of the increase in value-added attributable to increases in crew wages and passenger expenditures may occur in the absence of improved ISOOS (i.e., crew may get jobs in hotels instead, and passengers may take vacations elsewhere), and, if so, this portion of value-added should not be included in the estimate of net (national) benefits, a conservative estimate of the impact of improved ISOOS (i.e., 1%) is selected to account for this consideration. The value-added benefit estimates are considered to be *net* of any "transferred" value-added.

receive approximately 13% of regional benefits, while Georgia receives approximately 8%. The benefit categories receiving the largest benefits in North Carolina, South Carolina, and Georgia are beach recreation and search and rescue operations.

Comparing across regions, the SEACOOS region benefit estimate of $170 million/yr. falls between estimates of $33 million/yr. for the Gulf of Maine and $381/yr. for the Gulf of Mexico (where Gulf of Mexico benefit categories include the Gulf of Maine benefit categories, plus benefits to coastal recreation, storm damage reduction, and offshore oil and gas). Although there are some differences in the definitions of benefit categories across regions, the major drivers of regional differences appear to be the large beach recreation and recreational cruise benefits in the SEACOOS region and the large offshore oil and gas extraction benefits in the Gulf region. The estimates of recreational cruise industry benefits presented in this report are somewhat speculative, but the magnitude of the cruise industry's role in Florida's economy indicates that even small improvements in industry efficiency (or improvements in the satisfaction of cruise passengers) resulting from the availability of ISOOS information could lead to relatively large economic benefits.

Results indicate that coastal recreation and tourism, including recreational boating safety (search and rescue) and recreational cruises are large beneficiaries of improved ISOOS information in the SEACOOS region. These results reflect demographic and economic trends in coastal regions. Colgan (2004) notes in his recent summary of trends affecting the coastal economy of the United States that employment along the coast is rising much more rapidly than the national average. Tourism and recreation account for essentially all of this employment growth. The share of coastal economic activity attributed to recreation and tourism is growing rapidly, and these industries are highly influenced by weather and the accuracy of weather information.

### 5.b. Additional Research Needs

The NOAA-ONR (2000) report on the economics of ISOOS recommended that a portion of ISOOS funding be set aside for monitoring and evaluating economic benefits. It noted that several efforts are currently underway, including studies to further our understanding of the economic benefits of improved satellite images and weather forecasts, the National Ocean Economics Project, and a multi-national study of the value of maritime industries across Europe under the auspices of EuroGOOS. This report has identified numerous areas where additional study is needed to refine estimates of ISOOS benefits at the regional level.

The benefit estimates related to maritime shipping rely on assumptions regarding improvements in transit time. Pilot studies demonstrating transit time improvements would aid benefit assessment. The work of Kite-Powell et al. (1997) on the benefits of electronic charting represents a step in this direction.

More detailed studies of the best uses of ISOOS information within the cruise industry are needed to fully assess benefits. In particular, estimates of improvements in scheduling efficiency and fuel efficiency would be useful, as would better understanding of the impact of improvements in weather and sea conditions (calmer waters, sunnier days, more comfortable air temperatures) on passenger demand for cruise trips.

In commercial fisheries, Colgan (2004) stresses the need for systematic and consistent measures of employment in the commercial fisheries industry in order to better assess economic impacts. Studies of the potential improvements in fish stock assessment, fisheries management, and sustainable catches that may result from the use of ISOOS information are needed. Estimates of reductions in fish location costs and "bad weather avoidance" costs are needed.

In the category of recreational fishing, it would be useful to determine whether and how improvements in ocean and weather data (1) improve the recreational fishing experience and (2) improve the ability of fishers to avoid scheduling trips on bad weather days.

Colgan (2004) emphasizes the need to better understand the seasonal nature of many coastal recreation industries. A study of the potential benefits of improved weather forecast information to beach recreationists appears to be needed. If such information were available, could recreationists better avoid scheduling trips on overcast days? Would this increase congestion on good weather days?

A cross-sectional study that compares the success rates of search and rescue operations utilizing different levels of ISOOS data would be useful to determine the marginal impact of such information on success rates.

Researchers need to investigate the ways in which better ISOOS information could reduce the costs associated with hurricane evacuations. In addition, the ability of improved ISOOS information to reduce other tropical storm-related costs, such as costs imposed on tourists, “shadow evacuations” made by residents of non-coastal counties, and the economic costs of business interruptions, require further assessment.

Better understanding of the coastal land development process and the impacts of improved erosion rate and erosion hazard zone forecasts on development activities are needed to better estimate the benefits of ISOOS. Results from the recent Heinz Center (2000) erosion study were based on field observations from a relatively small sample of coastal counties. Region-specific studies are needed of the potential cost savings in beach nourishment and alternative erosion management program design due to better ISOOS information.

There would appear to be significant benefits to the construction and agriculture industries from better ISOOS information (Lynch, Harrington and O’Brien 2003). Although consideration of the potential benefits of ISOOS information to the construction industry was outside the scope of this report, an initial literature review of potential benefits to agriculture was conducted. There has been some initial work on the value of improved regional weather forecast information for particular crops and regions. The primary benefits of better weather information in agriculture appear to be improvements in crop selection and in the efficiency of irrigation and fertilization. Studies indicate that the value of weather information can vary significantly by crop and by region. Most of the existing studies estimate the impacts of weather information on farm input selection, costs, and profits while assuming no changes in crop prices, but recent research indicates that El-Nino, for example, has significant impacts on farm prices at the national level. When price changes are considered, farm profits may either increase or decrease with better weather information (however, when profits decrease due to falling prices, consumers benefit). Studies find that farmers will need additional training in the interpretation of probabilistic weather information, and additional research is needed on ways to speed the adoption of weather-based decision tools by agricultural end users.

In all areas, researchers need to develop estimates of the uncertainty surrounding economic values and forecasts. Similarly, while many existing studies have compared the benefits of perfect weather information with the status quo in order to produce "upper bound" estimates on the value of weather information, more work needs to investigate the value of improved but imperfect forecast information (cf. Barrett 1998).

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**Appendix A -- List of acronyms.**

| | |
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| CEFA | Center for Economic Forecasting and Analysis, Florida State University |
| COOS | Coastal Ocean Observing Program |
| CORE | Consortium for Ocean Research and Education |
| FEMA | Federal Emergency Management Agency |
| GOOS | Global Ocean Observing System |
| CPI | Consumer Price Index |
| EHA | Erosion Hazard Area |
| ISOOS | Integrated and Sustainable Ocean Observation System |
| NFIP | National Flood Insurance Program |
| NOAA | National Oceanic and Atmospheric Administration |
| NOPP | National Ocean Partnership Program research project on Regional Benefit Studies of Coastal Ocean Observing Systems http://www.whoi.edu/science/MPC/dept/research/NOPPproject.html |
| OPA, OPA-1990 | Oil Pollution Act of 1990 |
| PRA | Programmatic Regulatory Assessment |
| SAIC | Science Application International Corporation |
| SEACOOS | Southeast Atlantic Coastal Ocean Observing System. SEACOOS is a consortium of 11 institutions from the four coastal Southeastern states: North Carolina State/Sea Grant ; University of North Carolina System; South East Center for Ocean Sciences Education Excellence; University of South Carolina; South Carolina Sea Grant Consortium; South Carolina Department of Natural Resources; Skidaway Institute of Oceanography; University of Georgia/Sea Grant; University of Florida/ Sea Grant; University of Miami; University of South Florida. These institutions initiated SEACOOS with funding from the Office of Naval Research beginning in September 2002. |

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