NOAA Technical Report NOS CO-OPS 044

Estimating Economic Benefits from NOAA PORTS® Installations:

A Value of Information Approach

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noaa National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services

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National Ocean Service (NOS)

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The CO-OPS mission is to deliver the operational environmental products and services necessary to support NOAA's Environmental Stewardship and Environmental Assessment and Prediction Missions. CO-OPS provides the focus for operationally sound observation and monitoring capability coupled with environmental predictions to provide the quality data and information needed to support the cross-cutting NOS Primary Goals of Navigation, Coastal Communities, Habitat, and Coastal Hazards.

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Estimating Economic Benefits from NOAA PORTS® Installations:

A Value of Information Approach

Report prepared for the Center for Operational Oceanographic Products and Services (CO-OPS), National Ocean Service, NOAA

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SUMMARY

This report describes a methodology for valuing the benefits from information provided by a Physical Oceanographic Real-Time System (PORTS®) installation. We describe an approach to estimate benefits in dollar terms to the extent possible, and also discuss ways to treat non-quantifiable benefits.

Potential sources of economic benefit from PORTS® information include:

- Greater draft allowance/increased cargo capacity and reduced transit delays for commercial maritime transportation (water level information)
- Reduced risk of groundings/allisions for maritime traffic (currents and wind information)
- Enhanced recreational use of coastal waters boaters, windsurfers, etc. (winds, weather forecasts, and other information)
- Improved environmental/ecological planning and analysis, including hazardous material spill response

In the table on the following page, we summarize typical (potential) benefits from PORTS® data. We categorize these benefits according to the extent to which they typically can be quantified with varying degrees of confidence. For some benefits, there is direct observable evidence and benefits can be quantified with a high degree of confidence. Other benefits are likely realized at present but direct evidence is lacking and/or significant assumptions are required to derive quantitative estimates. Yet other benefits are more speculative or potential, and could perhaps be realized with the fuller utilization of the PORTS® data by all potential users.

Most of these benefits are in the nature of avoided costs (increased producer surplus, or profit) for commercial operations and avoided costs or increased consumer surplus, including non-market benefits, for recreational users.

Confidence level	*Source of benefit*	*Nature of benefit*
Usually quantifiable with high degree of confidence reasonably good confidence and/or direct evidence for benefits	avoided groundings, commercial vessels	avoided costs (surplus)
	increased draft, cargo loading	efficiency (surplus)
	reduced delays, commercial vessels	avoided costs (surplus)
	improved spill response (present practice)	avoided costs (surplus)
Usually quantifiable with lower degree of confidence more significant assumptions required to estimate benefits; less direct evidence	reduced distress cases, recreational boats	avoided costs (surplus, value of life)
	improved weather forecasts	non-market consumer surplus
	improved storm surge forecasts	avoided costs (surplus)
Potential or speculative these benefits could be realized with additional investment or a higher level of utilization of PORTS® data	improved spill response (with add'l models & infrastructure)	avoided costs (potential; not realized at present)
	enhanced recreational boating	non-market consumer surplus
	enhanced recreational fishing	non-market consumer surplus (potential; not realized at present)
	enhanced beach recreation	non-market consumer surplus
Non-quantified benefits	educational use	non-market
	scientific research	non-market

INTRODUCTION

NOAA Physical Oceanographic Real-Time Systems (PORTS®) are near-shore ocean observing systems now operating in a dozen locations around the United States (http://co-nos.noaa.gov/d_PORTS®.html). PORTS® installations provide near-real time information and, in some cases, forecasts about water levels and currents at specific points in a coastal water body. In some instances, they also provide information on wind speed and direction, salinity, bridge clearance (air gap) and on water temperature. In addition, co-located sensors (i.e., possibly operated by other parties and not part of the official NOAA PORTS® installation) may provide information on wave height, visibility, and other parameters, as well as digital still or video images of portions of the waterbody.

The information made available by PORTS® results in economic benefits because it is used by decision makers to make choices that affect economic well-being. To estimate the benefits that may accrue from a PORTS® installation, it is necessary to compare the outcome of these choices under two scenarios: the PORTS® scenario, in which the PORTS® data are available to decision makers; and a non-PORTS® scenario, in which these data are not available. The data and products enabled or affected by the PORTS® installation influence decisions made in industry, recreation, the research community, and public administration, changing the economic outcome from these activities, and thereby affecting economic well-being. The difference in outcome under the two scenarios is the benefit derived from the investment in PORTS®.

The most accurate measure of this benefit is the marginal increase in what economists call consumer and producer surplus. Consumer surplus is the difference between what consumers are willing to pay and what they actually pay. Producer surplus is the difference between the price received for a good or service sold and the costs of producing that good or service. Because this surplus is often difficult to estimate, economists also use other measures of benefit, such as the change in value added (contribution to GDP), or reduction in cost to achieve the same level of output. These measures typically are less precise estimates of true social surplus. Usually, these measures are estimated as annual values at the level of a firm or other economic unit, and then aggregated over geographic regions and industries to estimate total annual benefits.

Benefits represent only one side of the investment decision. To estimate net benefits, or rates of return, it is necessary to have information on costs as well. In the case of PORTS®, there are two main categories of costs: the cost of data collection, processing, and archiving; and the cost of generating from these data the products that decision makers ultimately use. In the case of PORTS®, the first component (the direct capital and operating cost of the PORTS® installation) is usually well understood. The second component generally includes activities carried out by both public and private sector organizations, and these costs are likely to be more difficult to specify. The analysis of costs associated with the generation and use of PORTS® data is outside the scope of this report.

ECONOMICS OF INFORMATION

A product, such as a real-time water level report for a harbor, represents information about the ocean environment. This information has value when it can be used by an individual or an organization to make a better decision – that is, a decision that results in an outcome that is economically superior. The standard economic approach to valuing information requires:

- A description of the information being valued and of the state of knowledge about the phenomena or conditions it describes. Typically, information is useful because it reduces uncertainty about the present or future state of nature in a particular context – for example, the location of a particular depth contour, or the exact water level in a dredged channel.

- A model of how this information is used to make decisions. Most decisions are made in the face of imperfect information, or uncertainty about how conditions will in fact develop and what the exact outcome will be. For many CO-OPS products, including those based on PORTS® data, the relevant decisions involve the navigation of commercial or recreational vessels. Here, the critical information concerns water depth, current speed and direction, wind speed and direction, or other information needed for the safe and efficient operation of a vessel.

- A model of how these decisions affect physical outcomes. Modeling the difference in outcome with and without the product in question usually requires making assumptions about how the decision makers will respond to the lack of the product in question.

- A model of how physical outcomes can be translated into economic outcomes. The value of a product is the difference between the expected value of the outcome of decisions using that product, and the expected value of the outcome without the product.

Most information-based products are valuable because they reduce the user's uncertainty about a factor that is important to the physical outcome (such as weather, waves, or water level). A standard Bayesian approach can be used to estimate the value of information contained in such products (see Berger 1995). In this model, a decision maker (user of the product) must choose among a range of actions represented by *A*. The outcome of each action depends on a "state of nature," *S*, which is not known precisely at the time of the decision but becomes manifest later. The manifestation of *S* is modeled as a random variable with probability density function *f(s)*. This probability density function (pdf) describes the probability that the condition (for example, the height of waves at a surfing beach) will lie within a particular range considering only what is known from past observation, and disregarding the new forecast.

Let *B(a,s)* be the consequence (net benefit) to the decision maker of pursuing action *a* if it turns out that *S=s*. The expected net benefit of pursuing action a is then the integral of the product of *B(a,s)* and *f(s)* (see Raiffa 1970):

$$E_o = \int B(a,s) f(s) ds$$

The optimal choice of action without the new information (a_0*) is that which produces the maximum expected net benefit (E_0*). If we now provide useful new information to the decision maker, the optimal choice of action and the associated expected net benefit will change. To determine the value of the new information, we need to know something about the accuracy of the information and something about the frequency with which different conditions arise on average. (For instance, a water level forecast may be more valuable if extreme deviations in water level are more frequent than if they only happen once a year.) How a decision maker revises her estimate of the likelihood of *s* is described by Bayes' Theorem:

$$f(s \mid x) = l(x \mid s) f(s) / p(x)$$

where *X* is the information in the forecast,
l(x|s) is the probability that *X* =*x* given *S*=*s*, and
p(x) is the probability that *X*=*x* :

$$p(x) = \int l(x \mid s) f(s) ds$$

In simple terms, Bayes' Theorem describes how the decision maker should adjust her prior expectation of the occurrence of event *s* when the new information says *x*, taking into account how "good" this information tends to be.

The new optimal action given information X is found be maximizing

$$E \ (a \mid x) = \int B(a,s) f(s \mid x) ds$$

The outcome of the optimal choice, *E*(x)*, now depends on *x*, and the expected value of net benefit is

$$E_X{}^* = \int E^*(x) p(x) dx$$

Since the decision maker could realize expected benefit E_0* without the new information and E_X* with it, the value of this new information to the decision maker is E_X* - E_0*.

QUANTIFYING ECONOMIC VALUE

The preceding discussion of the theoretical underpinning of the value of information does not address the question of how the net benefit (*E*) is quantified. Quantifying true economic benefits is difficult; and proxy measures are frequently used.

The most appropriate measure of economic value of information resulting from a change in user decisions or behavior is the change in what economists refer to as "social surplus." Social surplus has two components: producer surplus and consumer surplus. Producer surplus in this case is generally a reduction in costs to businesses. Consumer surplus, as in the case of the surfer, is the difference between what one would be willing to pay and what one actually pays for, for example, a recreational experience. "Social surplus" is the sum of producer and consumer surplus. It is the appropriate measurement because it assures that only the value in excess of costs is counted, making it a unique measure that avoid the artificial inflation of values by double counting.

The problem with social surplus and both of its elements is that they can only be measured using exacting, time-consuming, and costly techniques. Other measures of economic activity (broadly termed "economic impacts") such as the value of sales at the wholesale or retail level, or value added (the most common example of which is the Gross Domestic Product, or GDP), are widely available, but measure social surplus in a rather imperfect manner.

In other situations, estimates of social surplus may be available but data to support an explicit model of how PORTS® information is used in economic decisions are lacking. In such cases, an order-of-magnitude estimate of potential value of PORTS® data may be obtained by applying a rule of thumb developed by Nordhaus (1996) and others: the value of weather and climate forecasts to economic activities that are sensitive to weather/climate tends to be on the order of one percent of the economic activity in question.

Studies of economic values from investments such as PORTS® thus often face a dilemma due to data constraints. The most appropriate measure is the least available, while the most available measures are the least appropriate. This is a major reason why these estimates of economic benefits often must be considered approximate.

SOURCES OF ECONOMIC BENEFIT FROM PORTS®

PORTS® data, and products derived from PORTS® data, are used by a wide range of industrial, recreational, and public sector organizations and individuals. They include maritime shipping interests, recreational boaters and fishers, and marine resource and environmental managers.

For the purpose of this analysis, we use the following classification of benefits from PORTS® installations:

- Improved Safety of Shipping and Boating
  - Avoided groundings, commercial vessels
  - Avoided distress cases, recreational vessels

- Improved Efficiency of Marine Operations
  - Increased cargo carried per ship call (greater loaded draft)
  - Reduced delays (less allowance for error/margin in piloting decisions)
  - Improved SAR performance (surface currents)

- Improved Environmental Protection and Planning
  - Improved hazardous material spill response
  - Improved environmental restoration/conservation activities

- Improved Recreational Experiences
  - Enhanced value from boating decisions (power, sail, windsurfing, kayaking, etc.)
  - Enhanced value from fishing decisions
  - Enhanced value from beach visit decisions

- Improved Weather and Coastal Marine Conditions Products
  - Improved general weather forecasts
  - Improved coastal marine weather forecasts
  - Improved storm surge forecasts

- Science and Education
  - Use of PORTS® data in scientific research
  - Use of PORTS® data in secondary education

While this list is not exhaustive, it captures to the best of our knowledge all of the major benefits generated by PORTS® data.

GENERAL FRAMEWORK FOR ESTIMATING BENEFITS FROM PORTS®

In the following discussion of general approaches to estimating particular benefits from PORTS® data, we describe a process for estimating annual benefits in present dollar terms. These are most useful for comparison with annualized costs of the PORTS® installations. For longer time horizon analyses, annual values can be aggregated over time to produce discounted present value numbers.

MARINE SAFETY

Avoided groundings, commercial vessels

Better information about water levels, currents, and winds can reduce the risk of grounding for commercial vessels. If it is possible to determine the reduction in grounding risk (Δr_c) due to availability of PORTS® data for a particular class of vessels c, then the annual economic value of PORTS® data for that vessel class is

$$AV = T \times \Delta r_c \times AC$$

where

AV = annual benefit ($)
T = annual number of transits for vessel class c
Δr_c = reduction in grounding risk due to PORTS® (groundings/transit)
AC = average cost associated with a grounding for vessel class c

Δr_c can be estimated from historical data or from a risk model. The US Coast Guard keeps records of vessel accidents in US waters, and often local port authorities keep their own data on accidents. If sufficient historical data are available, it is possible to estimate risk reduction due to PORTS® by comparing accident rates before and after PORTS® data come into use. Any such analysis must recognize that several factors determine grounding risk, in addition to environmental data, including channel depth and configuration, vessel characteristics, and port-specific operating procedures and constraints. The analysis must attempt to isolate, so far as possible, the effect of a change in available information. If the necessary historical data are not available, it may be preferable to estimate grounding risk from first principles. For an example of such an exercise, see Amrozowicz (1996).

Avoided distress cases, recreational vessels

Recreational boaters can reduce the risk of weather-related distress situations if they have better information about conditions such as wind speed and direction, waves, and severe precipitation events in the waters they intend to visit. If it is possible to determine the reduction in this risk (Δr_c) due to availability of PORTS® data for a particular class of recreational boaters c, then the annual economic value of PORTS® data for these boaters is

$$AV = T \times \Delta r_c \times AC$$

where

AV = annual benefit ($)
T = annual number of boating days involving recreational boaters c
Δr_c = reduction in distress situation risk due to PORTS® (incidents/boating day)
AC = average cost associated with a distress situation for boater group c

Specific data on recreational boating accidents are difficult to obtain. The US Coast Guard (2004) maintains some data on recreational vessel accidents, and other local organizations that respond to boater distress calls may also have such data. If data are available, it may be possible to estimate Δr_c from the fraction of distress cases involving boaters who should not have been on the water given the weather conditions. For all US waters in 2003, the Coast Guard (2004) recorded 5,438 accidents resulting in 703 fatalities, 3,888 injuries, and about $40 million in property damage (the data do not include accidents resulting in less than $2,000 worth of damage). "Hazardous waters" and "weather" were causal factors in 356 and 184 of these accidents, respectively. About 12.8 million recreational boats were registered in the United States in 2003.

The average cost associated with a distress situation (AC) is, at minimum, the incremental cost to the search and rescue organizations of assisting the boaters in question. Average property damage per accident in the 2003 USCG data is about $7,350.

EFFICIENCY

Increased cargo (draft) per transit

Real-time information and accurate forecasts of water level (tide plus meteorological forcing) can allow draft-constrained vessels to enter or depart a port safely with a greater draft than they might otherwise. A good proxy for the economic benefit derived from this ability to carry increased draft is the expected cost savings associated with moving a fixed cargo volume with a reduced number of reduced voyages. For each trade (e.g. phosphate, petroleum) and vessel type:

$$AV = (AD \times TPI \times NC / AC) \times ((RT \times SC / KTS) + (DOC + (2AC / LR)) \times PC)$$

where

AV = annual benefit ($)
AD = additional draft enabled by PORTS® information (inches)
TPI = tons per inch immersion
AC = average cargo carried per ship transit without PORTS® (tons)
NC = number of transits/year affected by PORTS®
RT = average round trip distance (nm)
SC = operating cost at sea ($/hr)
KTS = vessel speed (knots)
DOC = docking and undocking time per transit (hours)
LR = loading/unloading rate (tons/hr)
PC = operating cost in port ($/hr)

The data to support this calculation are specific to the vessels, cargos, port facilities, and local conditions of each trade and port. Typical cost and speed data for broad categories of commercial ship in the international trades are shown in Table 1. Additional information on vessel costs can be found in US Army Corps of Engineers reports (http://www.usace.army.mil/inet/functions/cw/cecwp/cecwp_temp/egm00-6.htm).

vessel category		*operating cost, $/24 hours*	*time charter cost, $/24 hours*	*operating speed, knots*
dry bulk	*handy*	3,000	6,000	14.0
	handymax	4,000	8,000	14.0
	Panamax	5,000	9,500	14.5
	Cape	7,000	14,000	14.5
tanker	*product*	6,000	12,000	14.0
	Aframax	7,000	13,000	15.0
	Suezmax	8,000	16,500	14.5
	VLCC	10,000	22,000	13.0
container	*1000 TEU*	5,000	9,000	15.0
	1500 TEU	7,000	13,500	15.0
	2000 TEU	10,000	18,000	24.0
	3000 TEU	13,000	27,000	24.0
	4000 TEU	16,000	35,000	24.0
LNG		15,000	50,000	20.0
car carrier/RoRo		8,000	16,000	16.0
cruise		20,000	40,000	25.0
tug/barge	*dry*	4,000	8,000	12.0
	tank	4,000	8,000	12.0

Table 1: Typical vessel cost and operating speed parameters. Cost data are rough averages, 1980-2000, in 2001 dollars, for vessels in the international trades (typically non-US flag).

Reduced delays

Commercial ships sometimes encounter delays entering or exiting a port. These may be due to draft constraints and tide windows, port operating rules governing minimum visibility or maximum wind or current conditions, or other factors. In some instances, PORTS® data may allow operators to reduce these delays. For example, specific knowledge about water levels or current speed may increase pilots' comfort level with a transit and allow a vessel to move sooner than the absolute high water or slack tide window would otherwise suggest.

The annual benefit from such reduced delays for vessel class c is given by

$$AV = T \times \Delta t_c \times AC$$

where

AV = annual benefit ($)
T = annual transits by vessel class c for which PORTS® data reduce delays
Δt_c = reduction in delay due to PORTS® data (hours/transit)
AC = average hourly operating cost for vessel class c

As with increased draft, these benefits are generally port- and trade-specific. Representative operating costs are shown in Table 1.

Improved SAR performance

The effectiveness and efficiency of search and rescue (SAR) operations often depend critically on knowledge of surface currents and wind speed and direction in the area where a search is being orchestrated. This is relevant only if knowledge of currents and wind are known to be a factor in local SAR operations. This is generally the case offshore (see Allen 2004), and may be the case in some regions served by PORTS®. If PORTS® data can contribute to better SAR performance in a region, the benefit can be estimated as follows:

$$AV = I \times \Delta t \times OC$$

where

AV = annual benefit ($)
I = annual number of SAR cases in which PORTS® data improve effectiveness
Δt = average time savings per SAR operation due to PORTS® data (hours)
OC = average hourly operating cost for SAR assets during a SAR operation

If the greater effectiveness of SAR operations leads to a reduction in lives lost after SAR notification, this is a quantifiable benefit as well and can be estimated as the product of the expected annual number of lives saved and the statistical value of life. The US Coast Guard typically uses $3 million for the value of a statistical life; studies suggest that values as high as $7 million may be appropriate; we recommend using $4 million based on a review by Viscusi (1993).

Note that any estimation of benefits due to improved SAR performance must take into account the reduction in recreational boating distress cases described above.

ENVIRONMENTAL PROTECTION: IMPROVED SPILL RESPONSE

More effective spill response, including deployment of spill response equipment and dispersants or other measures, can result in reduced environmental cost from hazardous material spills. Booms and skimmers can be deployed to limit the transport of spilled material and to recover the material from the water. Dispersants may be used to separate spilled petroleum into smaller droplets, reducing shoreline impact, but leaving the material in the water column for longer periods. Decisions about dispersant use, for example, therefore involve tradeoffs between exposure of shoreline or benthic communities, and exposure of organisms in the water column; and models that predict contaminant concentrations with and without dispersant use are of value in spill response. *In situ* burning of spilled materials raises similar issues, with one of the tradeoffs being air quality effects.

To estimate accurately the value of PORTS® data in spill response and planning, it is necessary to carry out extensive simulations of likely spill scenarios and responses with and without PORTS® data. These simulations typically require circulation models, transport and fate models for the spilled material, environmental resource data, and physical/biological damage models, and economic damage models. Natural resource damage assessment models include the Natural

Resource Damage Assessment (NRDA) Process (http://www.darp.noaa.gov/about/nrda.html) of NOAA's Damage Assessment and Restoration Program. The benefit derived from the PORTS® data is given by:

$$AV = \sum_{ST} \left[(R_0 + E_0) - (R_P + E_P) \right] \times PR$$

where

AV = annual benefit ($)
ST = range of representative hazardous material spills
R = spill response costs incurred by responding agencies
E = environmental damage cost due to spill
PR = expected number of spills per year
0 subscript = without PORTS® data
P subscript = with PORTS® data

ENHANCED VALUE OF RECREATION ACTIVITIES

Information about marine conditions can enhance recreational activities in several ways, as the following example illustrates (the example is adapted from Kite-Powell *et al.* 2004). While the subject here is a surfer's decision, similar arguments hold go/no go decisions by boaters, fishers, and other beach visitors.

Consider a surfer who wants to go to the beach for a day's surfing. Her decision to actually go depends on knowing whether the beach is open for swimming and what is the current state of the surf. General weather forecasts are available, as is information about whether the beach is closed or not. (Beach closures usually follow from sewage overflows that may increase the presence of pathogenic bacteria in the water, or from severe harmful algal blooms.)

The decision about whether to travel to the beach can be depicted as the interaction between two factors, each of which has two possible outcomes. One is whether the beach is open or closed, and the other, which applies only if the beach is open, is whether the surf conditions are good or bad.

The decision to open or close the beach rests not with the surfer but with public health officials who monitor the presence and location of pathogenic bacteria that could pose a threat to health. The presence of pathogens generally results from overflow of sewage systems from storm events. The location and concentration of the bacteria depends on the location of the sewage outfalls and local tidal and other currents. Based on sampling data and information on currents, the public health official must decide whether to close a beach, post it as potentially hazardous, or take no action (leave the beach open). This decision depends on the information from the sampling regimen and predictions of currents, both of which have elements of uncertainty in them. Because of those elements, the public official faces the probability that the decision to close a beach will be in error. The beach may be safe for swimming, but the official closes it (a false positive outcome, since the data indicates a positive result for pathogenic exposure, leading to a closure decision). Or the beach may actually be unsafe for swimming and kept open in error (a false negative outcome). Since the official is likely to be risk averse, more beaches are likely to be closed when they could be open if uncertainty were reduced.

The decision to open or close the beach is influenced strongly by knowledge of local conditions in the vicinity of sewage outfalls and storm drains. PORTS® can provide fine scale (both temporal and spatial) information on physical conditions, and thereby significantly alter the public health official's decision problem. By reducing uncertainty, the length of beaches that must be closed can be reduced, as can the risk of false positives or false negatives. A reduction in false positives increases the amount of time beaches are open for recreation, while a reduction in false negatives decreases the risks to swimmers' and surfers' health and safety.

For the surfer, the question of conditions is a subjective one that depends on wind and wave conditions, which may be unique to the particular destination beach. Again, finer temporal and spatial scale oceanographic and meteorological information provides the information the surfer needs to decide whether to make the trip to the beach.

The economic value at stake in these decisions is the value received from safely enjoying the recreational activity. That value is the amount the surfer would be willing to pay for the opportunity to go surfing less the amount that is actually paid (usually transportation costs). If the surfer makes the trip only to find the beach closed or to find surf conditions too large or too small for enjoyable surfing, then there is a loss of value. It is thus the value to the surfer (or other recreationist) that is at stake in this use of the PORTS® data. The reduction in uncertainty for the public health official creates value to the extent that it increases the value of recreation to those who use the beach.

Boating

Boaters' decisions potentially affected by PORTS® information include (a) the decision not to go boating on a given day because PORTS® data suggest that conditions are unfavorable, (b) the decision to go boating on a given day when they might otherwise not have because PORTS® data suggest that conditions are favorable, and (c) the decision to change the timing or destination of a boating trip.

The value of decisions not to go boating is captured in part by the preceding discussion of boating safety benefits. Decisions of type (b) and (c) can be valued according to the economic surplus generated by a boating day in the region of interest. [Citations.] The value of PORTS® to these boating decisions is

$$AV = NBD \times SBD$$

where

AV = annual benefit ($)
NBD = number of additional positive boating days/year due to PORTS® data
SBD = economic (consumer) surplus generated by one boating day

Fishing

Similar to boating, a fishing experience (whether from shore or from a boat) can be enhanced by PORTS® data if these data permit an improvement in the probability of catching a fish. Fish capture probabilities can be related to currents and to water temperature, among other factors. For an application to Florida salt water fishing, see Wieand (2004). As with boating, the important parameters are the number of fishing days enhanced by PORTS® data, and the incremental economic surplus associated with this enhancement.

The incremental benefit derived from recreational fishing activities due to PORTS® data can be estimated as follows:

$$AV = NFD \times ICV$$

where

AV = annual benefit ($)
NFD = number of fishing days/year on which catch probability is enhanced
ICV = economic (consumer) surplus generated by enhanced catch probability

Beach visits

The derivation of value for beach visits follows closely the surfer example described above. For an application of this approach to valuing improved information for beach use decisions in California, see Pendleton (2004).

The benefit due to enhanced beach recreation resulting from PORTS® data can be estimated as follows:

$$AV = NBD \times BDV$$

where

AV = annual benefit ($)
NBD = number of additional beach days/year enabled by PORTS® data
BDV = economic (consumer) surplus generated by one beach day.

ENHANCED WEATHER FORECASTS

General Weather and Coastal Marine Forecasts

Observations of atmospheric conditions, such as winds, are an input to general weather forecast models. As such, PORTS® data may be used by the National Weather Service to improve both general weather forecasts and coastal marine weather forecasts for the region surrounding the PORTS® installation. The value of improved coastal marine forecasts is reflected in the improved recreational boating experience of local boaters, as discussed above. The improved general weather forecasts benefit all users of weather forecasts in the area.

Estimates of the value of significant increases in weather forecast quality lie around $16 per household per year (Lazo and Chestnut 2002). However, these estimates assume significant improvements in weather forecast quality over present baselines, which may be difficult to achieve in general: 12 updates/day instead of 4, one-day forecast accuracy 95% instead of 80%, and geographic resolution of 3 miles instead of 30 miles. Also, it may be difficult to attribute specific improvements in local or regional weather forecasts to PORTS® data. On the other hand, in some nearshore locations, conditions over the water have significant effects on local weather, and PORTS® observations may play a critical role in local forecasts.

Storm Surge Forecasts

Storm surges are associated with large storm events, such as hurricanes, and can cause extensive damage. Much of this damage cannot be avoided by an improved forecast, but marginal improvements in response activities (securing boats and structures, evacuating areas) may be possible or less costly with a more accurate and timely forecast.

NOTES ON APPLYING THE FRAMEWORK

In each of the benefit categories discussed above, it is possible to estimate the potential value of PORTS® data by assuming that all potential users of the information in fact make use of it as described. This potential value is an upper bound of sorts on what is likely to be the value actually realized during a given year, since the number of actual users is likely to be less than 100% of potential users, 100% of the time. Potential value is often easier to estimate than actual value because estimating potential value does not require data on how many users actually use the PORTS® data, and how often.

In situations where data or model limitations do not permit the application of the benefit frameworks described above, it may be possible to estimate at least the general scale of potential benefit by applying a "one percent proxy rule." Formulated by Nordhaus (1986) and other economists on the basis of experience with a number of forecast/nowcast value of information studies of industries and activities sensitive to weather, this rule suggest that the value of weather nowcast/forecast information to economic activity sensitive to weather conditions is generally on the order of one percent of the economic value generated by the economic activity. There is, of course, no guarantee that this rule will hold in all cases; but where no better estimate can be constructed, it provides an order of magnitude estimate of value that is likely to be reasonable.

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