# MID-ATLANTIC BLUE OCEAN ECONOMY 2030

Exploring the prospects and challenges for emerging ocean industries to 2030

*The Marine Science & Policy Series*

The Rockefeller University | MONMOUTH UNIVERSITY

October 12-13, 2017 | Monmouth University | West Long Branch, NJ

.

## ECOSYSTEM SERVICES AND NATURAL RESOURCES

Porter Hoagland[1]*, Hauke Kite-Powell[1], Di Jin[1], and Charlie Colgan[2]

[1]Marine Policy Center
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

[2]Center for the Blue Economy
Middlebury Institute of International Studies at Monterey
Monterey, CA 93940

*Corresponding author. This working paper is a preliminary draft for discussion by participants at the *Mid-Atlantic Blue Ocean Economy 2030* meeting. Comments and suggestions are welcome. Please do not quote or cite without the permission of the authors.

## 1. Introduction

All natural resources, wherever they are found, comprise physical features of the Earth that have economic value when they are in short supply. The supply status of natural resources can be the result of natural occurrences or affected by human degradation or restoration, new scientific insights or technological advances, or regulation. The economic value of natural resources can expand or contract with varying environmental conditions, shifting human uses and preferences, and purposeful investments, depletions, or depreciation.

It has now become common to characterize flows of goods and services from natural resources, referred to as "ecosystem" (or sometimes "environmental") services (ESs). The values of ES flows can arise through direct, indirect, or passive uses of natural resources, in markets or as public goods, and a variety of methodologies have been developed to measure and estimate these values. Often the values of ES flows are underestimated or even ignored, and the resulting implicit subsidies may lead to the overuse or degradation of the relevant resources or even the broader environment (Fenichel *et al*. 2016). Where competing uses of resources are potentially mutually exclusive in specific locations or over time, it is helpful to be able to assess—through explicit tradeoffs—the values of ES flows that may be gained or lost when one or more uses are assigned or gain preferential treatment over others.

In this paper, we examine the status and trends for the valued services arising from natural resources located on the coasts and in the ocean of the US Mid-Atlantic region. In line with related work for the Mid-Atlantic Regional Ocean Council (MARCO), we concentrate on coastal and ocean resources from Long Island, NY to Hampton Roads, VA, representing the southern section of the Northeast Shelf Large Marine Ecosystem. The Mid-Atlantic is the most densely populated region along the US East Coast, and the resources of the coast and ocean are used very intensively there.

We present a qualitative representation of the potential "vulnerabilities" of ES flows to climate changes, including the consequences of increases in ocean temperatures, changes in ocean chemistry, and increases in sea-level rise. We include attention also to other pressures, including anthropogenic releases of macronutrients, such as nitrogen compounds, and growing densities of human populations in coastal environments. These latter phenomena may interact with climate changes in ways that could affect ES flows adversely.

We take as an underlying assumption that achievement of the full potential for a "blue economy" in the Mid-Atlantic region implies the *sustainable* use of the region's coastal and ocean resources. Accordingly, where possible, we attempt to characterize the value of ecosystem services as economic surpluses. In theory, if economic surpluses could be optimized, through planning, judicious trade-offs, assignments of property rights, or regulation, and if these surpluses were to be reinvested in economically or socially productive activities, a sustainable (*i.e*., blue) economy could be realized. The promotion of a blue economy would be sustainable in the sense that economic surpluses could be realized and invested such that future generations would be at least as well off as today's generation.[1]

[1] *N.b*, the instructions for this white paper call for forecasts of future ES flows out to the year 2030, which constitutes only about one-half of the duration of a modern generation (about 25 years).

## 2. Socio-economic significance

Following current thinking in environmental economics (*e.g*., Boyd and Banzhaf 2006; Lipton *et al*. 2014), we focus this assessment mainly on the ecosystem "endpoints" linked to specific human uses (or non-uses) of the Mid-Atlantic's coast and ocean. Table 1 presents some of the most important endpoints, indicating the relevant resources, the existence of estimates and sources of ES values, qualitative assessments of the extent to which those estimates provide coverage of ES values for the region, and discussions of some of the gaps in valuation.

Importantly, we do not explicitly consider values for "supporting" services, such as, for example, salt marshes, seagrass beds, and intertidal waters in their specific role as habitat for juvenile striped bass, because doing so could lead to double counting when both the habitat value of the marsh and the recreational or commercial values of striped bass are assessed (*cf*., Freeman 2013). (A salt marsh may provide other types of services for which double counting would not occur, such as for recreation, macronutrient assimilation, or flood protection.) Thus, following the typology developed through the United Nation's Millennium Ecosystem Assessment (MEA) (Fig. 1), we focus on provisioning, regulating, and cultural ecosystem services.

There is a long record, dating back at least 30 years, of economic valuation studies focused on non-market ES endpoints in the Mid-Atlantic region, including those for saltwater recreational fishing, beach uses, improvements in water quality, wildlife viewing (birdwatching), and the total economic values of estuaries and associated upland watersheds. Some of the most important of these studies are listed in Table 2. ES values from these and other studies have been compiled in various online databases (*e.g*., de Groot *et al*.2012), including most recently the US Geological Survey's "Benefits Transfer Toolkit" (USGS 2017). In such compilations, these values tend to be reported as or recalibrated into estimates of willingness-to-pay (WTP or consumer surpluses) per person per day. Table 3 presents Mid-Atlantic regional average use value estimates for some marine recreational endpoints as reported in the USGS benefits transfer database.

For purposes of coastal and ocean planning, however, it is valuable to know the spatial distributions of the underlying resources from which ecosystem services flow, the spatial patterns of human uses of the resources, and the spatial configurations of marginal ES values that arise from these human uses. With the advent of geographic information system (GIS) mapping, the spatial distributions of resources and human uses have been fairly well resolved in the Mid-Atlantic region. Less clear are the scales and spatial distributions of economic values associated with the region's ecosystem services. In many cases, it is necessary to transfer benefits from other locations and contexts. Two such examples from the region include the work of Costanza *et al*. (2006) and Liu *et al*. (2010) for ecosystem services in New Jersey, including coastal and estuarine services, and Koicin *et al*. (2016) for the ecosystem services and natural capital of Long Island Sound and its associated upland watershed. (Notably the latter study relies significantly upon the earlier work of Johnston *et al*. (1990) concerning the valuation of resource services in the Peconic Estuary, located at the eastern end of Long Island.)

Benefit transfer efforts are an important initial step, but spatially resolved estimates of ES values sometimes show widely divergent values when compared with the results of primary data collections and analysis. Fig. 2, for example, reveals very different average estimates of total economic value from the benefit transfer studies cited above when compared to a recent study of the nonmarket value of tidal marshes in the Delaware estuary, the latter comprising mainly cultural ES values such as the various recreational activities (Santoni *et al*. 2017).

A comprehensive understanding of ES values can help planners assess tradeoffs among human uses (or non-uses) that may be incompatible. Here, we characterize extant estimates without explicit consideration for how such estimates eventually would be used by planners. In practice, the separation of estimates and applications may be challenging to carry out, as many planning exercises need to consider not only the identity of relevant gainers and losers but also the nature of dynamic linkages among ecosystems and these stakeholders (Johnston and Russell 2011).

## 3. Current and emerging trends

Table 4 presents a qualitative assessment of trends for ES endpoints in the Mid-Atlantic region. Salient and publicly conspicuous recent developments include the impacts and recovery from Hurricane Sandy in 2012, the dredging of ship channels to 45-50 feet, especially in the Delaware River and in New York Harbor, deepening the entrances into the major ports, and the leasing of outer Continental Shelf lands for renewable energy (wind power) off New York, Delaware, Maryland, and Virginia. Other longer term trends include declining fish yields, losses of estuarine intertidal mudflats and salt marshes, increasing numbers of localized hypoxic events, and challenges in reestablishing the beds of the once-prolific native shellfish, especially those for the Eastern oyster. Trends for these and other endpoints may depend upon their sensitivities to the effects of climate change, pollution, and progressing human coastal habitation. We describe these challenges and threats in the next section. In this section, we focus on long-term historical data that describe two important but potentially vulnerable ES endpoint examples: commercial and recreational fishing.

Fig. 3 depicts the landings and exvessel value (gross revenues) from commercial fishing in the Mid-Atlantic region. Historically, ~\$0.5 ± \$0.07 billion in revenues have been realized annually from all commercial fisheries taken together, although the mix of species landed has been variable. These landings have been downward trending since the mid-1990s. Using rules of thumb for estimating resource rents (producer surpluses) in the Northeast fisheries, and based upon this record, we can expect rents in the future of ~\$0.2-0.3 billion annually, implying an asset value of ~\$7-10 billion (at 3 percent). Importantly, the surf clam/ocean quahog fishery is rationally managed with individual tradeable quotas (ITQs). Other species are important to the region, including sea scallops, weakfish, black sea bass, squids, scup, and filter feeders (menhaden). Important nearshore fisheries include those for striped bass, summer flounder, and blue crab. The regional Mid-Atlantic Fisheries Management Council (MAFMC) now is implementing an ecosystem "approach" to fisheries management in order to consider the effects of harvests on the larger ecosystem. Ocean temperature increases are an imminent concern, as they imply a northward migration for some commercial species and habitat changes—with uncertain biomass implications—for others.

Fig. 4 depicts participation and total WTP estimates for saltwater recreational fisheries in the Mid-Atlantic region. Historically, ~\$1.2 ± 0.5 billion in WTP (consumer surpluses) have been realized annually, which is 3-4 times larger than the region's commercial fishery rents. Saltwater recreational fishing activity appears cyclical and currently is in a trough. New York and New Jersey record the highest recreational fishing activity days. The charter/party business (headboats) is important, but their level of activity has not been shown in Fig. 4. Saltwater anglers target striped bass, bluefish, summer flounder, weakfish, and tautog, and the higher end anglers target offshore stocks of bluefin tuna, billfish, and sharks. As is the case with commercial fishing, ocean temperature changes are an imminent concern.

## 4. Challenges, threats, and impediments

We consider these underlying trends in the context of a qualitative assessment of what the future may hold, based upon underlying drivers and pressures, such as climate change, nutrient loadings, and human migrations to the coast. A conceptual context, such as the DPSIR framework (Driver-Pressure-Stressor-Impact-Response), which has gained wide use in Europe (Fig. 5), is useful in this regard.

In the Mid-Atlantic region, fundamental drivers and pressures relate to the effects of climate change, macronutrient releases, and human population increases near the coast. Specifically, increases in carbon dioxide levels are causing warmer coastal water temperatures, increases in sea levels, probable increased tropical cyclone severities, and, in the longer term, a more acidic ocean with lower carbonate levels. Releases of nitrogen compounds from coastal runoffs, including agriculture and septic systems, municipal wastewater treatment plants, and atmospheric deposition are causing increases in coastal primary production, thereby increasing the frequency of localized hypoxic or anoxic events, and degrading estuarine and ocean habitats, including seagrass beds and wetlands. Finally, the redistribution of human populations along the coast has led to an expansion of residential developments, encroachments on wetland habitats, and higher risks to public health and property from flooding and erosion, especially during extreme high tides and storm surges.

In order to begin to understand the stressors and impacts to ES endpoints, we develop a qualitative representation of their exposures and sensitivities to climate change (Fig. 6). This representation follows the vulnerability assessment developed by NMFS for the fisheries of the northeast shelf (Hare *et al*. 2016), which has been adopted by MAFMC in its ecosystem approach to fisheries management. Fig. 6 depicts the relationship between climate change effects and sensitivity. Though 2030, most of the Mid-Atlantic region's ES endpoints are expected to experience low exposures, and they will be insensitive to the effects of climate change, appearing in the dark green squares in the lower left. In contrast, some endpoints, including commercial and recreational fishing and wildlife viewing (perhaps limited to a subset of species in each case), may be more exposed and more sensitive, appearing in the dark red square in the upper right. Other endpoints fall somewhere in between.

An example with high exposure to climate change effects and medium sensitivity concerns the case of the so-called "living shorelines," such as salt marshes, which provide protection from flooding and erosion due to extreme high tides ("king tides"), waves and overwashes from nor'easters, and storm surges from tropical cyclones. In recent work, Narayan *et al*. (2016) found reduced coastal property damages in the Mid-Atlantic region on the order of $0.6 billion due to the presence of living shorelines during Hurricane Sandy. Across the entire US Northeast, the authors estimated an average of 10% reduction in losses. In Ocean County, NJ, using data on flooding from 2,000 historical storms dating back a century, the authors estimated an average of a 20% reduction in losses.[2] Living shorelines face stressors and impacts from both rising sea levels and encroaching human developments. In particular, the latter imply that wetlands may be unable to migrate inland with rising seas.

## 5. Key objectives and milestones to maximize economic benefits

The sustainable (*i.e*., "blue") use of the Mid-Atlantic region's coastal and ocean resources necessitates a proper pricing of the ecosystem services that flow from its valued natural resources. Where values are ignored or institutions for realizing or assigning prices are absent or flawed, then the overuse or degradation of natural resources is an inevitable result. The outcome in such a situation cannot be considered to be emblematic of a blue economy. As a consequence, a key objective for the region is to organize institutions to ensure that appropriate values are assigned to unpriced ecosystem services.

The Mid-Atlantic is not alone in facing the pressures of climate change effects, macronutrient releases, and human developments. Three of the states in the Mid-Atlantic region (New York, Delaware, and Maryland) already participate in the Regional Greenhouse Gas Initiative (RGGI), which implements a combined allowance auction and cap-and-trade approach to carbon dioxide emissions from fossil fuel power plants. Although the RGGI cap is designed to become more constraining over time, it applies only to fossil fuel plants exceeding 25MW of capacity. It may be necessary to apply a carbon tax on other sources of greenhouse gases. To be consistent with the core objective of the Paris Agreement of keeping temperature rise below 2 degrees, the Carbon Pricing Leadership Coalition (CPLC) has recommended establishing a carbon price in $40-$80 per metric ton range by 2020, which would be increased to $50-$100 by 2030.[3] Finally, offshore renewable energy areas have been leased already, and these could provide significant non-fossil fuel sources of electrical energy.

More attention should be directed at maintaining living shorelines, especially the extensive salt marsh wetlands of the Chesapeake and Delaware estuaries. As evidenced by the very large cultural ES values measured recently for the Delaware wetlands (Santoni *et al*. 2017), the very significant property value protections from flood and erosion afforded by living shorelines (Narayan *et al*. 2016), and the large carbon sequestration capabilities of salt marshes (Carr *et al*. 2017), these environments present a clear priority for further protection and restoration. The double threats of sea-level rise and human encroachments need to be curbed. Further research on the scales and spatial distributions of ES values for these environments also is warranted.

Progress has been made in establishing total maximum daily loads (TMDL) standards for nitrogen, phosphorous, and sediment for Chesapeake Bay and many of the region's other estuaries and local waters. Nutrient trading programs, involving market exchanges of pollution credits between point sources, between point and nonpoint sources, and between nonpoint sources, have been recommended for the Chesapeake. Intrastate nitrogen and phosphorous credit exchanges

[2] Annual flood control values would depend upon return intervals for storms (*e.g*., the risks of Sandy-type flood recurrence). Sweet *et al*. (2012) found that return intervals for Sandy-type floods were significantly shortened by sea-level rise.

[3] CPLC. Leading Economists: A Strong Carbon Price Needed to Drive Large-Scale Climate Action (May 29, 2017)

among wastewater treatment plants exist already in the Chesapeake's watershed states of West Virginia, Virginia, Maryland, and Pennsylvania. Nitrogen credit exchanges among publicly owned treatment works also have been established in the Connecticut portion of the Long Island Sound estuary. For the larger estuaries spanning multiple state jurisdictions, interbasin and interstate trading in nutrient credits should be promoted.

Existing institutions, such as the FEMA's National Flood Insurance Program (NFIP), offer flood insurance at below actuarial rates. Incredibly, nearly 60% of the nation's flood mapping has been found to be inaccurate, and all NFIP mapping fails to account for changes in flood risks due to sea-level rise. The NFIP is up for reauthorization by the end of 2017. While much attention has been directed at recouping the program's current $25 billion deficit, a much bigger priority is to eliminate the hidden subsidies entrenched in the program. These subsidies encourage human encroachments in coastal areas that heighten disaster risks and degrade living shorelines.

In the near-term, the commercial fisheries appear to the most sensitive of the region's ES endpoints to the effects of climate change, particularly those relating to warming ocean temperatures. As fish stocks redistribute themselves in response to environmental changes, it will become necessary for managers and fishing firms to think more broadly about mechanisms for shared management across regional management regimes. Such an approach may be easier for some institutions, such as the Atlantic States Marine Fisheries Commission, which comprises a collaboration among Atlantic coastal states, than for others, such as the MAFMC and the New England Fisheries Management Council (NEFMC). An important model for sustainable fishery management is the surf clam/ocean quahog fishery, which utilizes a market-based approach to assign a price to shellfish stocks that cover the entire Northeast Shelf.

## 6. Conclusions and Recommendations

Mid-Atlantic stakeholders and resource managers clearly recognize the importance of coastal and ocean ecosystem services to the region, and a solid foundation of ecosystem service valuation has been established already in the region. Prominent human activities include prospects for developing already leased renewable energy areas (wind farms), accommodating larger vessels in the region's ports, and increases in coastal recreation, tourism, and habitation. Salient environmental trends include rising sea levels, heightened risks of flooding and erosion, warmer oceanic and estuarine waters, ongoing degradations of coastal waters due to nitrogen and phosphorous releases, and, in the longer term, decreasing oceanic pH and carbonate levels.

Many of the ES endpoints are either not exposed or insensitive to the effects of climate change, but several important endpoints appear to be much more vulnerable. These include commercial and recreational fisheries, wildlife viewing, and living shorelines, including salt marshes, seagrass beds, and intertidal lands and resources, including oyster reefs. It will be important for the communities of the region to address these vulnerabilities on several fronts.

Increased investments in scientific research, environmental monitoring, and ecosystem service valuations are warranted. Further characterizations of the spatial distributions of services, human uses, and the values arising from those uses would be useful in assessing the extent of potential vulnerabilities and characterizing appropriate management responses. Primary valuation studies, such as those that have been undertaken for the Chesapeake, Delaware, and Peconic estuaries, will yield more accurate estimates of the economic values at stake.

Importantly, several examples exist or are under development in the region of market-based institutions for realizing the values of ecosystem services, including auctions of allowances to fossil fueled power plants based upon a regional $CO_2$ cap, intrastate credit exchanges for macronutrients based upon waterbody TMDLs, and an ITQ program for harvests of surf clams and ocean quahogs. These institutions provide a foundation for their further expansion to all of the states of the region and to a broader array of natural resources and their associated ecosystem services. A clear priority for the region will be the design of equally innovative institutions for conserving living shorelines, and ES valuation will comprise an important element of the argument for characterizing the relevant blue economy in this case, thereby moving such a policy forward.

## 6. References


Agnello RJ, Han Y. 1993. Substitute site measures in a varying parameter model with application to recreational fishing. *Marine Resource Economics* 8:65-77.

Bockstael NE, Strand IE, McConnell KE, Arsanjani F. 1990. Sample selection bias in the estimation of recreation demand functions: an application to sportfishing. *Land Economics* 66(1):40-49.

Boyd J, Banzhaf S. 2007. What are ecosystem services? *Ecological Economics* 63: 616-626.

Carr E, Shirazi Y, Parsons G, Hoagland P, Somerfield CK. 2017. The economic value of carbon sequestration by wetlands in the Delaware Estuary: historic estimates and future projections. *Journal of Environmental Management* (forthcoming).

Costanza R, Wilson M, Troy A, Voinov A, Liu S, D'Agostino J. 2006. *The Value of New Jersey's Ecosystem Services and Natural Capital*. Proj. Rep. for NJ Department of Environmental Protection. Burlington, VT: Gund Institute for Ecological Economics, University of Vermont, 177pp.

de Groot R, Brander L, van der Ploeg S, Costanza R, Bernard F, Braat L, Christie M, Crossman N, Ghermandi A, Hein L, Hussainj S, Kumar P, McVittie A, Portela R, Rodriguez LC, Brink, van Beukering P. 2012. Global estimates of the value of ecosystems and their services in monetary units. *Ecosystem Services* 1:50-61.

Fenichel EP, Abbott JK, Bayham J, Boone W, Haacker EMK, Pfeiffer L. 2016. Measuring the value of groundwater and other forms of natural capital. *PNAS* 113:2382-2387.

Freeman MA. 2010. The wealth of nature: valuing ecosystem services. *Proc. 2010 EEPSEA Impact Conference*. Hanoi: Environmental Economics Program for South East Asia (February 26-27).

Hare J, Morrison WE, Nelson MW, Stachura MM, Teeters EJ, Griffis RB, Alexander MA, Scott JD, Alade L, Bell RJ, Chute AS, Curti KL, Curtis TH, Kircheis D, Kocik JF, Lucey SM, McCandless CT, Milke LM, Richardon DE, Robillard E, Walsh HJ, McManus MC, Marancik KE, Griswold CA. 2016. A vulnerability assessment of fish and invertebrates to climate change on the northeast US continental shelf. *PLOS One* (Feb. 3, 2016). https://doi.org/10.1371/journal.pone.0146756.

Johnston RJ, Grigalunas TA, Opaluch JJ, Mazzotta M, Diamantedes J. 2002. Valuing estuarine resource services using economic and ecological models: the Peconic Estuary System Study. *Coastal Management* 30:47–65.

Johnston RJ, Russell M. 2011. An operational structure for clarity in ecosystem service values. *Ecological Economics* 70:2243–2249.

Kocian M, Fletcher A, Schundler G, Batker D, Schwartz A, Briceno T. 2015. *The Trillion Dollar Asset: The Economic Value of the Long Island Sound Basin*. Tacoma: Earth Economics.

Leeworthy VR, Wiley PC. 1991. *Recreational Use Value for Island Beach State Park*. Rockville, MD: Strategic Environmental Assessments Division, Office of Ocean Resource Conservation and Assessment, NOAA.

Lipton D. 2004. The value of improved water quality to Chesapeake Bay boaters. *Marine Resource Economics* 19:265-270.

Lipton D, Lew DK, Walmo K, Dvarskas A. 2014. The evolution of non-market valuation of US coastal and marine resources. *Journal of Ocean and Coastal Economics* 1:6.

Liu S, Costanza R. 2010.

McConnell KE, Strand IE, Valdes SK, Weninger QR. 1994. The economic value of mid and south Atlantic sportfishing. Report between the University of Maryland, EPA, NMFS, and NOAA. Coop. Agr. No. CR-811043-01-0. College Park, MD: University of Maryland.

Millennium Ecosystem Assessment Board (MEAB). 2003. *Ecosystems and Human Well-being: A Framework for Assessment*. Washington: Island Press.

Myers KH, Parsons GR, Edwards PET. 2010. Measuring the recreational use value of migratory shorebirds on the Delaware Bay. *Marine Resource Economics* 25:247-264.

Narayan S, Beck MW, Wilson P, Thomas C, Guerrero A, Shepard C, Reguero BG, Franco G, Ingram CJ, Trespalacios D. 2016. *Coastal Wetlands and Flood Damage Reduction: Using Risk Industry-based Models to Assess Natural Defenses in the Northeastern USA*. London: Lloyd's Tercentenary Research Foundation.

Pendleton LH. 2008. *The Economic and Market Value of Coasts and Estuaries: What's At Stake?* Arlington, VA: Restore America's Estuaries.

Santoni A, Arvay B, Scarborough R. 2017. *Delaware Tidal Wetland Ecosystem Services Valuation: Technical Report*. Dover, DE: Delaware Department of Natural Resources and Environmental Control.

Sweet W, Zervas C, Gill S, Park J. 2013. Hurricane Sandy inundation probabilities today and tomorrow. *Bulletin of the American Meteorological Society* (September): S17-S21.

US Geological Survey (USGS). 2017. Benefits Transfer Toolkit. USGS Sustaining Environmental Capital Initiative.

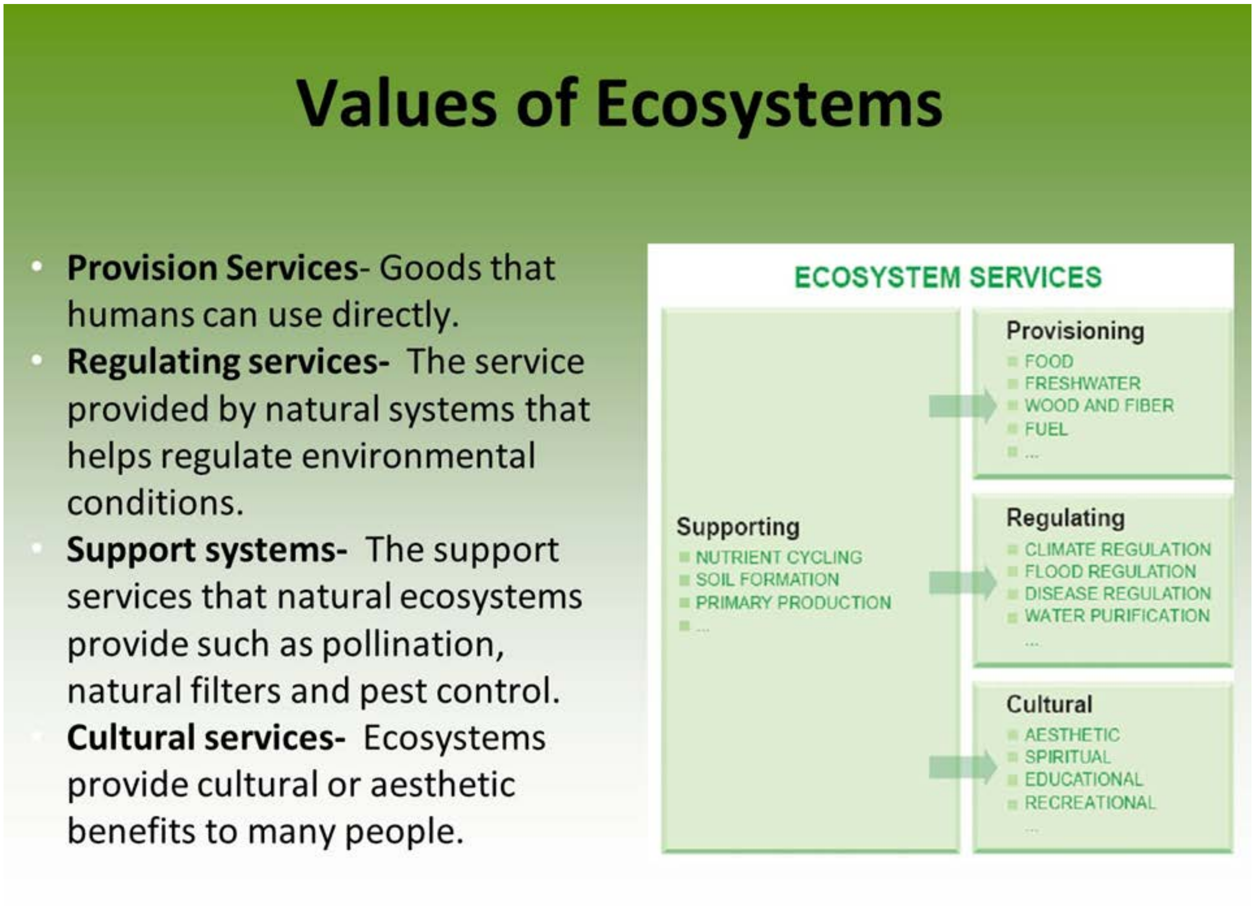



**Fig. 1**: Millennium Ecosystem Assessment (MEA) typology for ecosystem services.

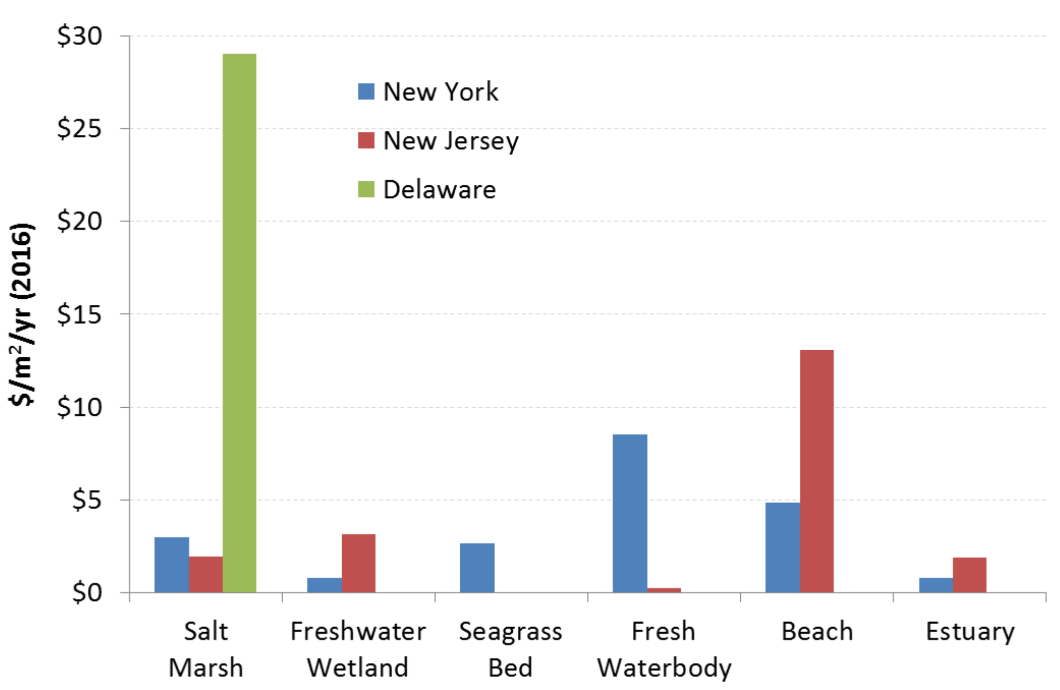
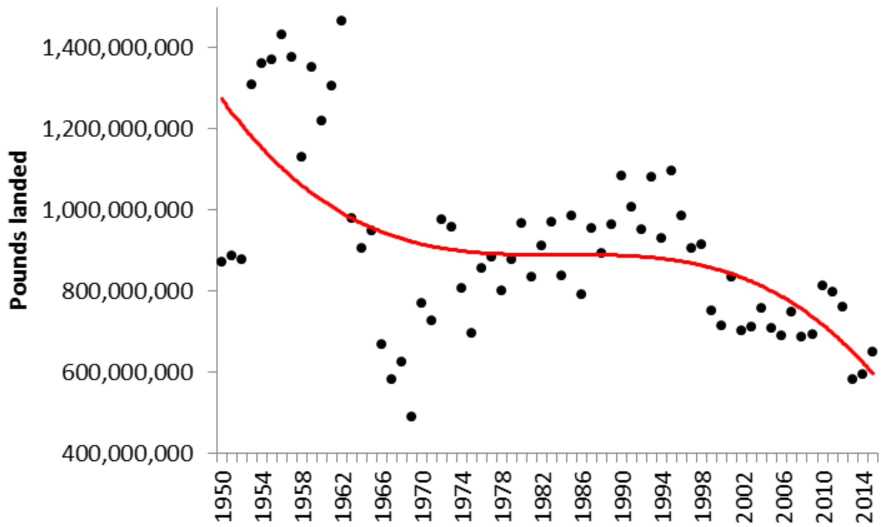



**Fig. 2**: Average total economic values for coastal resource categories ($/m$^2$/year). Sources: Koicin *et al*. (2016); Costanza *et al*. (2006); DNREC (2017).

a)




b)

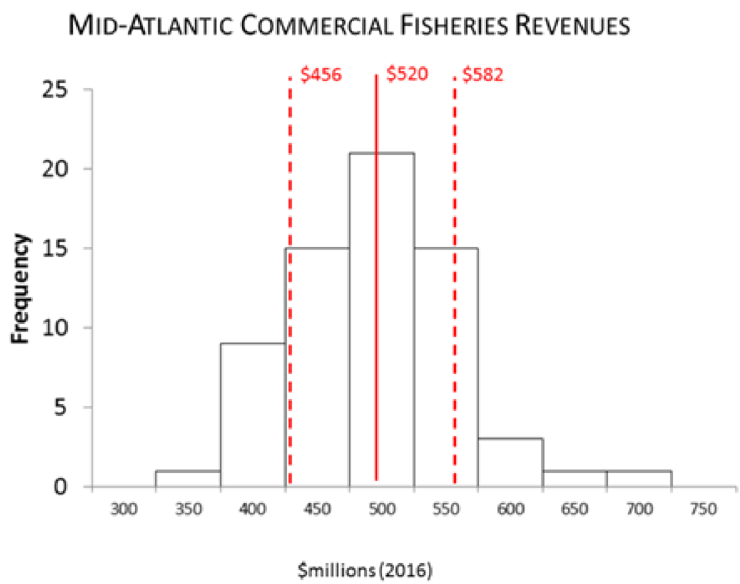
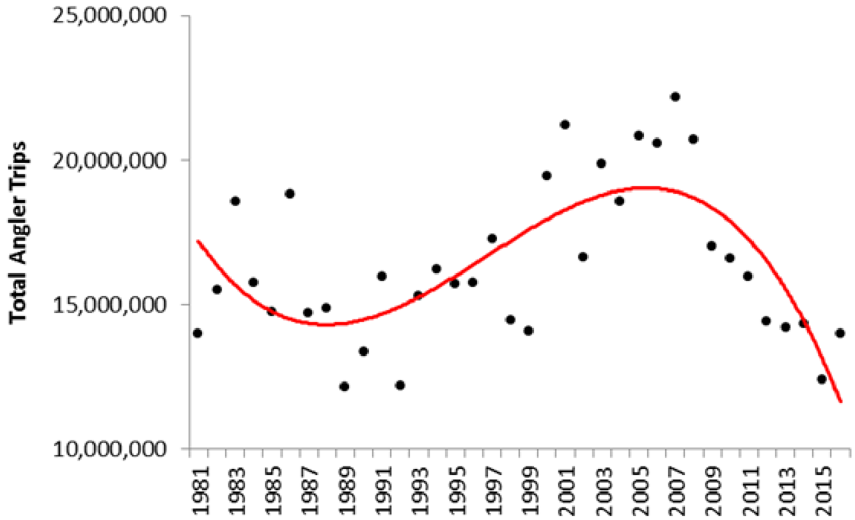



**Fig. 3**: Historical pattern in the Mid-Atlantic Region of commercial fish landings (panel a) and associated exvessel value of landings (panel 2) during 1950-2015. Values are gross revenues; the distribution shows the mean (solid red line) and one standard deviation (dashed red lines) above and below the mean. Source: NMFS (2017) Commercial Fisheries Statistics.

a)




b)

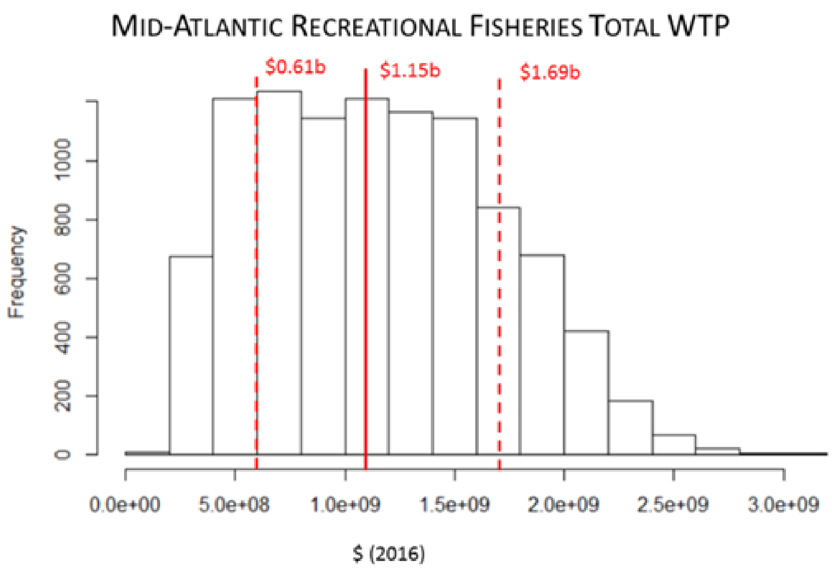



**Fig. 4**: Historical pattern in the Mid-Atlantic Region of participation in marine recreational fishing (panel a) and estimated total willingness-to-pay (WTP) (panel 2) during 1981-2015. Sources: MRIP (2017) for the participation data and Pendleton's (2008) compilation of values from WTP studies by state.

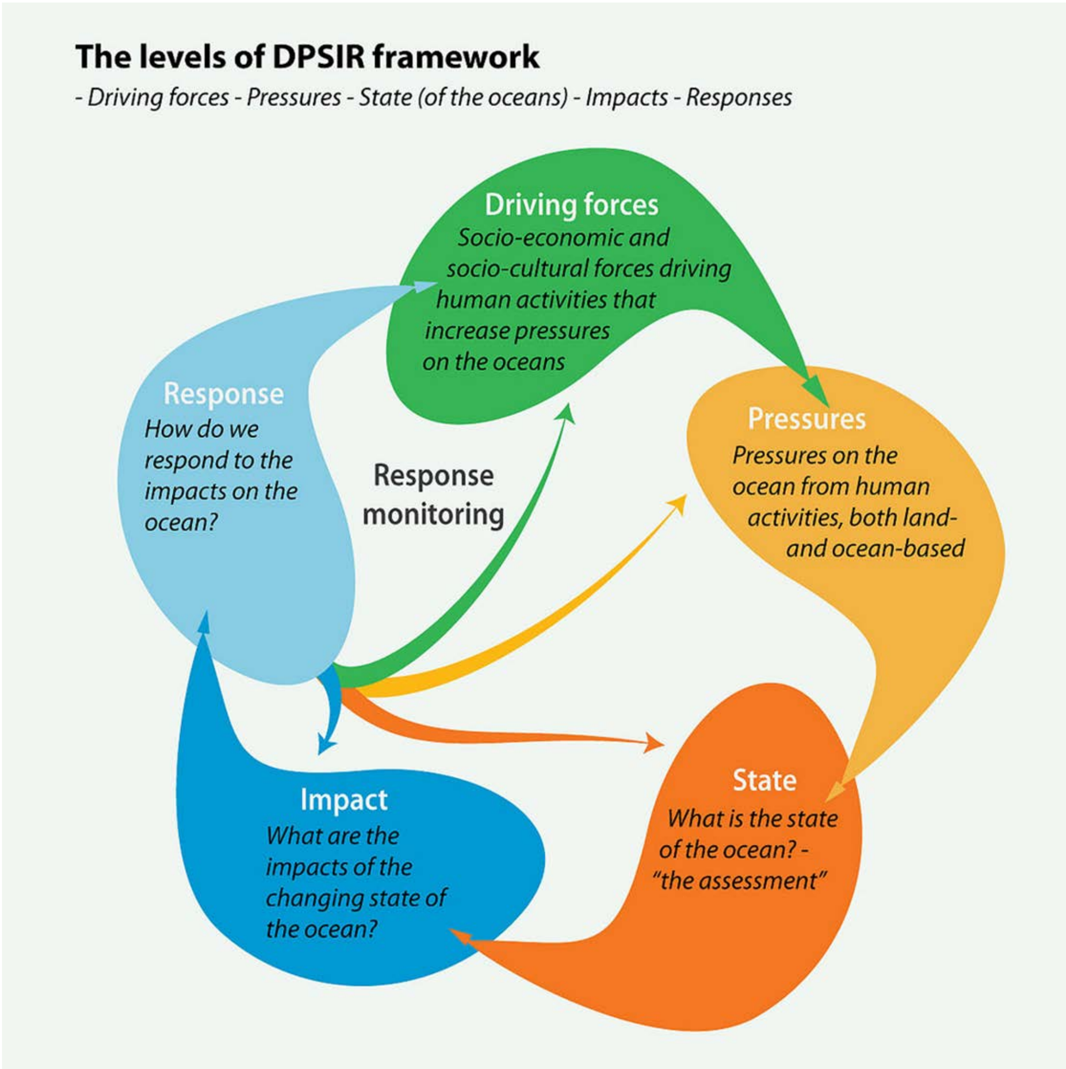



**Fig. 5**: The DPSIR (Driver-Pressure-State-Impact-Response) conceptual framework. Source: GRID Arendal (2016).

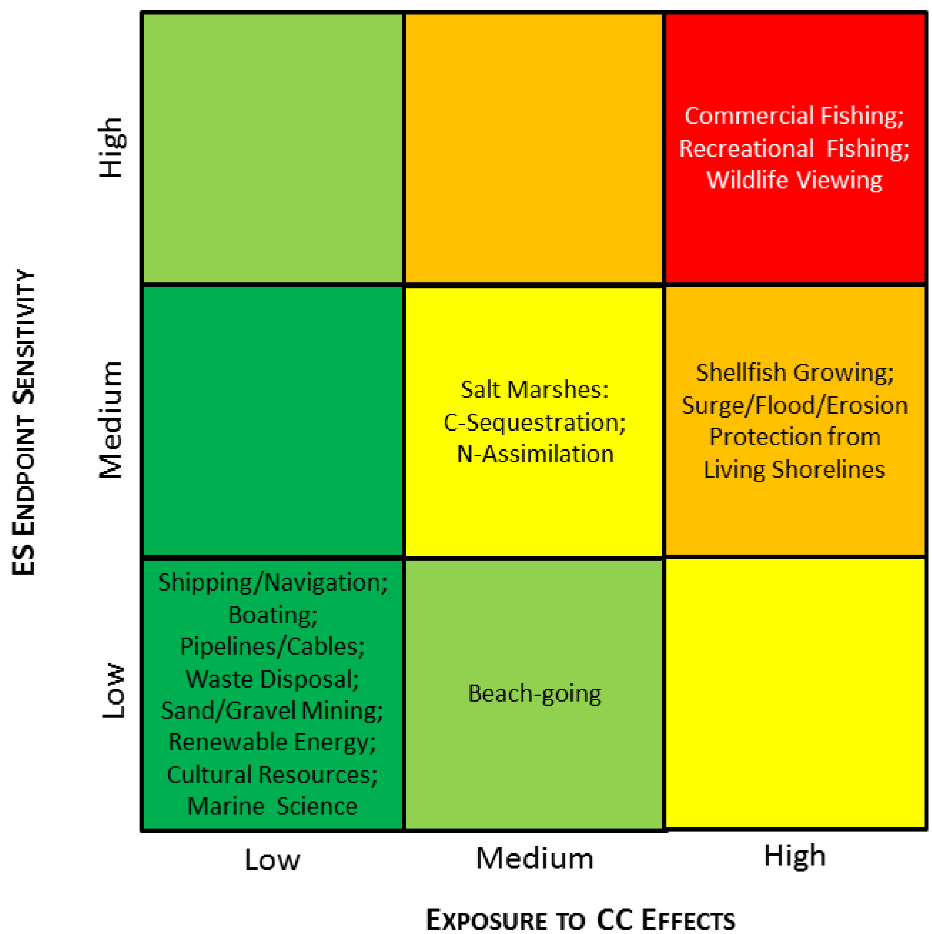



**Fig. 6**: Qualitative assessment of Mid-Atlantic Region ecosystem service (ES) endpoint exposures and sensitivities to climate change (CC).

**Table 1:** Mid-Atlantic Region ecosystem service (ES) endpoints, sources of value estimates, percent coverage, and gaps

| Endpoints | Valued Resource | ES Values | Sources | Est. % Coverage | Gaps |
|---|---|---|---|---|---|
| Navigation | Ocean area; channels; anchorages; ports | Yes | AIS data on shipping routes; avoided costs of route changes | ? | Valuation is limited to specific routing change scenarios |
| Pipelines and cables | Seabed area | -- | State submerged lands license fees | ? | Largely unexplored |
| Coastal tourism (beach visits, boating) | Sandy beaches, ocean area | Yes | New Jersey valuation studies of WTP for beach use | ? | Limited number of older use and valuation studies |
| Flood and erosion control | Salt marsh; dunes; physical structures | Yes | Models of value of coastal property protection with hard structures and living shorelines | ~100% | Effects of sea-level rise on value of living shorelines; threshold effects |
| Recreational fishing | Fish stocks | Yes | NMFS MRIP use data; NMFS headboat data; compilations of nonmarket estimates | ~100% | Spatial distribution of activity |
| Commercial fishing | Fish stocks | Yes | NMFS ex-vessel landings and value; VCR data and cost models | ~100% | Estimate is resource rents only; few consumer surplus estimates |
| Marine wildlife viewing | Birds, marine mammals | Yes | Delaware birdwatching studies | ~25% | Few studies; bird-watching is important; whale-watching exists but is small in scale |
| Sand and gravel production | Aggregate materials | -- | BOEM negotiated agreements with states to "donate" OCS materials for beach nourishment; some local ACoE dredge and fill activities | 0% | Value of unpriced resource |
| C-sequestration | Salt marsh | Yes | Carbon price and sequestration potential of alternative environmental features (salt marshes, seabeds, etc.) | ~25% | Sequestration estimates exist for salt marshes; sequestration potentials of other coastal and ocean areas are uncertain |
| N-, P-assimilation | Salt marsh, ocean and seabed | -- | Valuation studies of WTP for improved water quality; avoided costs of sewering or water treatments | ~50% | Some estuarine environments (e.g., Hudson, Passaic, Raritan, inland waterways) are not covered |
| Aquaculture | Ocean and seabed area | Yes | State estimates; NMFS commercial fishing data; USDA shellfish surveys (last in 2009); some DCF models exist | ~100% | USDA surveys of nearshore shellfish growing are infrequent |
| Underwater cultural resources | Archaeological or historical artifacts | -- | State historic preservation officers for some location data; geographic distribution data are low-resolution | 0% | Few non-market values; may be incorporated into recreational boating estimates |
| Renewable energy | Ocean and seabed area | Yes | Lease bonuses | 100% | Leasing, but no actual developments to date |
| Ocean science | Ocean and seabed area | -- | MARACOOS; NSF; NOAA; university oceanographic laboratories | 0% | no valuation estimates |

**Table 2**: Some important ecosystem service valuation studies for the Mid-Atlantic Region

| Year | Authors | Focus |
|---|---|---|
| 1990 | Bockstael et al. | Chesapeake Bay striped bass recreational demand |
| 1991 | Leeworthy & Wiley | New Jersey recreational beach use value |
| 1994 | McConnell et al. | Mid- and South Atlantic sportfishing value |
| 2002 | Johnston et al. | Peconic Estuary (Long Island, NY) resource services |
| 2004 | Lipton | Chesapeake Bay improved water quality value |
| 2006 | Costanza et al. | New Jersey value of ecosystem services and natural capital* |
| 2010 | Myers et al. | Delaware Bay recreational bird watching value |
| 2015 | Koicin et al. | Long Island Sound Basin total economic value* |
| 2015 | Walsh et al. | Chesapeake Bay adaptation to sea-level rise |
| 2015 | Moore et al. | Chesapeake Bay and watershed lakes improved water quality value |
| 2017 | Santoni et al. | Delaware tidal wetlands ecosystem services valuation |

*Benefit transfers.

**Table 3**: Average use values (WTP/person/day) for coastal and ocean recreation (2016 $)

Source: USGS (2017)

| | **Northeast*** | **Southeast**** |
|---|---|---|
| **Beach Use** | $36 | $77 |
| **Boating (motorized)** | $101 | $23 |
| **Boating (non-motorized)** | $18 | $87 |
| **Fishing (saltwater)** | $63 | $118 |
| **Swimming** | $28 | $14 |
| **Wildlife Viewing** | $63 | $62 |

*Includes NY, NJ, DE, MD.
**Includes VA.

**Table 4:** Mid-Atlantic Region ecosystem service (ES) endpoints and trends

| ENDPOINTS | TRENDS |
|---|---|
| Navigation | Region's channel deepening projects now complete; larger tankers and container ships |
| Pipelines and cables | No apparent trend |
| Coastal tourism (beach visits, boating) | Increasing with increased coastal populations |
| Flood and erosion control | Increased need for living shorelines, hard structures due to sea-level rise, storms |
| Recreational fishing | Cyclical; currently in a trough |
| Commercial fishing | Cyclical; currently trending down |
| Marine wildlife viewing | Increasing with increased coastal populations |
| Sand and gravel production | Expect increased activity due to need for beach replenishment |
| C-sequestration | Declining with the loss of wetlands due to sea-level rise and increased development |
| N-, P-assimilation | Loss of wetlands implies lower assimilation capacity |
| Aquaculture | Possible small upward trend in shellfish growing |
| Underwater cultural resources | No apparent trend |
| Renewable energy | Expect leased areas to begin to be developed over the next decade |
| Ocean science | Increased need for OOS; expansion depends upon public sponsorship |