Benefits of Water Quality Policies: The Chesapeake Bay

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Abstract

The Chesapeake Bay is a unique and treasured natural resource. It is the largest estuary on the Atlantic coast and one of the largest estuaries in the world. The Chesapeake drains portions of six states: Virginia, Maryland, Delaware, Pennsylvania, New York, and West Virginia and the District of Columbia. As testimony to its importance, the US Congress issued a directive in 1976 to the Chesapeake Bay Program to examine and identify the factors that were altering the conditions of the Bay. Nutrient delivery to the Bay, which has increased dramatically over time, was identified as one of the factors and has been the primary focus of research and policy efforts related to achieving water quality improvements.

The purpose of this paper is to estimate the benefits of water quality legislation in the Bay region from 1972, the year the Clean Water Act was promulgated, to 1996. Nutrients, nitrogen and phosphorous, are the dominant criteria addressed by this case study. Benefits are assessed from a "with-without" perspective. That is, 1996 water quality is compared with what it would have been in 1996 without the Clean Water Act and related legislation. The US EPA Chesapeake Bay Program Watershed and Water Quality Models were used to determine the distribution of nutrient loadings from point and non-point sources and characterize water quality.

Modeling results indicate that conditions in the Bay are improved in some areas for some pollutants. Total phosphorus has decreased dramatically from "without" concentrations in all major tributaries and segments of the Chesapeake Bay. The monetized annual boating, fishing, and swimming benefits of water quality improvements in the Chesapeake Bay range from $357.9 million to $1.8 billion. These benefit estimates represent use values for persons living in the

District of Columbia, and portions of Maryland and Virginia. Residents of Delaware, New York, and Pennsylvania, which are also part of the Bay Watershed, are not included in this analysis. As such, this range likely underestimates the true benefits of Bay water quality improvement

Key words: benefit analysis, Chesapeake Bay, nutrients, water pollution

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In 1972, Congress enacted the first comprehensive national clean water legislation, the Federal Water Pollution Control Act (FWPCA). Today, the Clean Water Act (CWA) of 1977, which amends FWPCA, is the primary federal law that protects our nation's waters. This Act and policies and regulations resulting from it are generally credited with reversing the downward trend in the quality of U. S. waters. One body of water that has undergone a remarkable transformation as a result of the Clean Water Act and resulting regulations and policies is the Chesapeake Bay.

The Chesapeake Bay is a unique and treasured natural resource and is the largest estuary on the Atlantic coast and is one of the largest estuaries in the world. The Chesapeake Bay covers portions of Virginia, Maryland, Delaware, Pennsylvania, New York, and West Virginia, as well as the District of Columbia. As testimony to its importance, the U. S. Congress issued a directive in 1976 to the Chesapeake Bay Program (CBP) to examine and identify the factors that were contributing to the decline of the Bay. Excessive nutrient delivery to the Bay, one of the recognized factors, has increased dramatically over time, and has been the primary focus of research and policy efforts related to restoring the Chesapeake Bay.

This paper presents estimates of the benefits of water quality regulation in the Bay region from 1972, the year the Clean Water Act was promulgated, to 1996. Unlike previous studies whose benefit estimates are based upon hypothetical changes in ambient water quality, the estimates in this paper are based upon modeled changes in ambient water quality, presenting a more accurate picture of changes in the Bay. Nitrogen and phosphorous are the criteria addressed in this case study. Understanding the value of the net benefits is useful in forming future water quality policies, particularly those affecting nutrients. In addition, this study also serves as an illustration of the types of information available to policy makers. The remainder of this paper first presents information on the Bay itself and the models used to evaluate the change in water quality. The benefit estimates related to this water quality change are then presented, and discussed.

The State and History of the Chesapeake Bay

More than 100,000 rivers and streams drain into the Chesapeake Bay (CBP, 1999a). Three rivers, the Susquehanna, the Potomac, and the James, supply over 75 percent of the freshwater delivered to the Bay, with the Susquehanna alone supplying approximately 50 percent (Alliance for the Chesapeake Bay, 1999). Figure 1 displays the 64,000 square-mile watershed. In the upper panel of Figure 1, the gray shading shows the extent of the watershed. The lower panel of the map displays 12 of the major sub-basins of the Chesapeake watershed.

The Chesapeake Bay is a commercial and recreational resource for the more than 15 million people living in the watershed (CBP, 1999a). The Bay has two of the five major North Atlantic ports in the United States and yields approximately 500 million pounds of seafood annually. The Bay is also a source of countless recreation services and tourism. Additionally, the area is home to a wide variety of agricultural activities.

These activities have affected the water, the air, and the ecosystem and led to a decline in the quality of the Chesapeake Bay. The top four stressors on the Bay's systems are excess nutrients, toxic chemicals, and air pollution changes, as well as those "brought about by humans" (CBP, 1999b). The main cause of the Bay's poor water quality and aquatic habitat loss is nutrients (CBP, 1999b). Elevated levels of nitrogen and phosphorus create algae blooms, which deplete oxygen and block sunlight, and have been linked to outbreaks of pfiesteria, a toxin which causes lesions on fish. These effects may result in physiological stress and death to fish species and other aquatic organisms. Excess algal growth may render the water unfit for marine recreational activities such as boating, fishing, and swimming by discoloring the water, killing fish and shellfish or making them unfit for human consumption, and causing human respiratory problems from toxins released in the air.

In an effort to curb, and ideally reverse, the decline in the Bay, the first Chesapeake Bay Agreement was signed in 1983 by Maryland, Virginia, Pennsylvania, the District of Columbia, the U. S. Environmental Protection Agency (EPA), and the Chesapeake Bay Commission, a tri-state legislative body. The Agreement made improvements to the Bay a high priority, explicitly recognizing that states share decisions because both the causes of and solutions to the pollution problems in the Bay transcend boundaries. In 1987, and again in 2000, these same states, the EPA, and the Chesapeake Bay Commission, renewed and expanded their commitments to the Bay, signing the 1987 and 2000 Chesapeake Bay Agreements.

Excess nutrients, including nitrogen and phosphorus, are delivered to the Bay through both point and non-point sources. Between 1985 and 1997, point source loads fell by 16 million and 5 million pounds annually for nitrogen and phosphorus respectively (CBP, 1999b). During the same time period, through the use of management practices and control techniques, annual non-point source loads of nitrogen and phosphorus fell by 16 and 1 million pounds, respectively (CBP, 1999b). This represents a decline in loads of more than 17 percent for nitrogen and more than 30 percent for phosphorus.

Toxic chemicals also impact the Bay system, although on a much more localized basis than nutrients. Many toxic chemicals, such as lead and mercury, occur naturally in the environment and, like nutrients, are delivered to the Bay through both point and non-point sources. Control of toxic substances is achieved through a variety of regulations and policies made possible by laws including, but not limited to, the Clean Water Act. The nature, extent and severity of effects from these chemicals vary widely. The Bay Program has designated three "Regions of Concern" (Baltimore Harbor, the Anacostia River, and the Elizabeth Rivers) because of their known toxic problems. Overall, however, there is no evidence of Bay-wide toxic problems. Since 1988, chemical releases and transfers of chemical contaminants have fallen by over 65 percent (CBP, 1999b).

Air pollution and water pollution have generally been considered separate problems, where air pollution is regulated by the Clean Air Act. The Chesapeake Bay airshed is approximately 6.5 times larger than the watershed (CBP, 1999b) and is a significant source of atmospheric deposition of pollutants such as nitrogen. The Bay Program models estimate that 25 percent of the nitrogen load to the Bay is attributable to atmospheric deposition.

The population in the Bay region has increased from 11.8 million in 1970 to 15.1 million people in 1997 (CBP, 1999b). This growth in population has put more stress on the Bay, from both increased use and from activities like construction. During this same time period, vehicle miles traveled, where exhaust emissions from cars add to nutrient pollution, increased at four times the rate of population in the Bay region (CBP, 1999b). Suburban sprawl is ranked as one of the top threats to the recovery of the Bay (CBP, 1999a).

Many of these improvements can be attributed to the CWA, the regulation that provides the framework for the Bay Program to address water quality problems in the Bay and its rivers.

For example, between 1985 and 1995, over one and half million acres of farmland in Maryland, Pennsylvania, and Virginia were placed under nutrient management plans which includes proper nutrient application rates to crops (CBP, 1999c). Point source controls include wastewater treatment plant upgrades such as installation of Biological Nutrient Removal equipment (CBP, 1999c). Nutrient reduction practices are also targeting animal waste management and management of urban areas. As nutrient levels entering the Bay decrease as the result of water legislation, the water quality of the Bay should continue to improve.

Chesapeake Bay Models

In order to assess water and habitat quality changes resulting from the CWA and ensuing regulations and management actions, the Bay Program developed the Chesapeake Bay Watershed and Estuary Models. These linked models, along with an Atmospheric Deposition Model which estimates nitrogen deposits from the atmosphere, track and predict the effect of nutrient and sediment reductions to the Bay. The Chesapeake Bay Watershed Model simulates the delivery of nitrogen, phosphorus, and sediments to the estuary from municipal, industrial, agricultural, urban, and forest sources. The Estuary Model estimates the impact of these load reductions on the concentrations of various water quality indicators as well as measures of habitat quality. These models were calibrated by comparing observed and predicted values over ten years of simulation (CBP, 2000).[1]

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[1]For an extremely detailed description of the airshed, watershed and estuary models, please see CBP, 2000. It should be noted that, although well suited to measuring the impact of nitrogen and phosphorus in the Bay, the models are not ideal since they are unable to take into account the impact of other contaminants such as toxics. As the majority of the decline in the Bay is attributed to nutrients, the Bay Program models are well suited for addressing the research question at hand. More appropriate models are not available.

The Bay proper, or the mainstem of the estuary, is composed of nine modeling segments: Susquehanna Flats (also labeled CB1), Tangier Sound, and the mainstem segments (CB2-CB8) (Figure 2). Recently, the Bay models were used to estimate changes in water and habitat quality attributable to the Clean Water Act and resulting legislation. In order to do so, changes in the concentrations of nitrogen, phosphorus, chlorophyll *a*, and dissolved oxygen, and in the densities of bay grasses for these segments were examined under two different scenarios. The first scenario ("with regulation") represents the baseline and is a depiction of Bay water quality and living resource conditions in 1996, after enactment of the CWA and other water quality regulations as well as voluntary pollutant control strategies undertaken by the Bay Program jurisdictions. The second model scenario ("without regulation") characterizes the counterfactual and is a simulation of conditions in 1996 if the CWA did not exist. In this case, nutrient discharges from both municipal and industrial sources were estimated as if the wastes were not treated to the extent they are today because of the CWA, and that the Phosphate Ban was not implemented in the Watershed states. This scenario also assumes no controls on nonpoint sources in the basin. The nutrient loads from the Air Deposition Model are held constant at baseline conditions. In other words, we are not taking into account any changes in atmospheric nitrogen resulting from the Clear Air Act.

The nutrient loads for the "without regulation" scenario (Pre-CWA) are approximately 345 million pounds of nitrogen and 83 million pounds of phosphorus. The nutrient loads for the "with regulation" scenario are estimated to be 295 million pounds of nitrogen and 17 million pounds for phosphorus. Most of the estimated improvement in nutrients in the "with regulation" scenario is due to improved point source controls (CBP, 2000).

Table 1 presents nutrient concentrations and percent improvement for the with-without regulation scenarios. Among the estuarine mainstem segments, the greatest decrease in phosphorus concentrations was seen in the upper Bay, reflecting the large reduction in phosphorous loads from the Susquehanna River which delivers about half of the freshwater flow to the Bay. Surprisingly, in this region, the average concentrations of nitrogen were actually greater in the post-CWA scenario. This counter-intuitive finding reflects the impact of hydroelectric dams at the base of the Susquehanna River. Before the Clean Water Act, the abundance of trapped phosphorus and sediment in these reservoirs, most likely, fed algae which, in turn, took up a large mass of nitrogen.

The primary factors that determine algal growth are nitrogen (N) and phosphorus (P). Either factor could be the limiting factor in the Chesapeake Bay. However, the nutrient which is the limiting factor may change based on changes in seasons, weather conditions, regional conditions, and land uses (EPA, 2000). Bockstael, McConnell, and Strand (BMS) (1988,1989) represent water quality as the product of total nitrogen and total phosphorus (TNP) because data suggests a high collinearity between nitrogen and phosphorus levels in the Bay. In other words, it is difficult to tell which nutrient is causing the deterioration in Bay water quality (i.e., can not determine if N or P is the limiting factor), which prevents treating the nutrients separately. The product of nitrogen and phosphorus assumes that the demand for recreational activities becomes more elastic as N or P increases. In other words, increases in either N or P do not have the same impact on water quality, and increases in either one of the nutrients has a greater impact on the slope of the demand curve. Another possible measure of water quality is the sum of N and P. However, using total nutrients as a measure of water quality assumes that the change in the slope of the demand curve for recreational activities at a site on the Bay is the same for changes in concentration of N or P, even though their impact on water quality may be different.

The product of nitrogen and phosphorus for each Bay segment is weighted by its respective area to obtain the overall change in TNP per segment and for the Bay proper. Table 2 presents the results. Estimates indicate that the CWA improved TNP by 60 percent. The greatest improvements occurred in the CB4, CB5, and CB7 segments of the Bay. Bay-wide aggregate benefits for a 60 percent improvement in water quality are presented in the next sections. Using these models to estimate the change in water quality in the Bay represents an improvement over previous studies that merely posited some hypothetical change in water quality, thereby providing a more policy relevant estimate of aggregate benefits.

Estimating Benefits

In order to measure the benefits of changes in water quality in the Chesapeake Bay we rely upon benefit transfer. Benefit transfer uses information from existing studies that have applied primary valuation methods to estimate benefits in other, yet related, contexts. Many applications of benefit transfer focus upon recreation demand. As the purpose of this paper is not to refine the benefit transfer methodology but to use the method, detailed information on the technique is not repeated here. More information on the benefit transfer technique can be found in a special issue of Water Resources Research (1992); Desvouges et al. (1998) and U.S. EPA (2000) also provide further information.

As with primary valuation methods, there are both advantages and disadvantages to using benefit transfer. The most oft cited drawback of the technique is that it may be less accurate than conducting original research. That said, original research is time consuming and expensive. Policy analysts supplying decision-makers with information on the benefits and costs of proposed regulations and policies must generally rely upon the technique for just these reasons.

Benefit estimates for this study are determined by combining the output of the water quality modeling runs with results from existing economic studies that recognize the link between these water quality parameters and service flows provided to humans by the Bay. As such, it is important for economic studies to be identified that employ water quality measures that are consistent with the output of the Chesapeake Bay Program Model. Otherwise, potentially valuable information from economic studies will not be transferable.

While a number of studies about the Bay have been conducted, some do not lend themselves to transfer to this study.[2] In order to appropriately use benefit transfer, high-quality studies dealing with applications similar to the new context must be available. Two such studies form the basis for the benefit transfer portion of this paper: Bockstael, McConnell, and Strand (hereafter BMS) (1988, 1989), and Krupnick (1988). Both BMS and Krupnick consider water quality improvements, as measured by levels of nitrogen and phosphorus, to the Chesapeake Bay thereby matching reasonably well the context of this study.

There are six major categories of benefits that are relevant for valuing water quality improvements in the Bay: (1) recreation (fishing, boating, swimming); (2) commercial fishing; (3) health; (4) nonuse value; (5) property values; and (6) regional economic impacts. However, recreation benefits likely represent the largest benefit category (although not necessarily the

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[2]For example, Norton, et al. (1983) focuses on the unit day values associated with marine recreation in the Chesapeake Bay region. Lipton, Lavan, and Strand (1992) develop an economic framework for considering the effects of molluscan introductions and transfers in the Bay.

majority of benefits) and, given model output and the results of BMS and Krupnick, represent the only quantified and monetized benefit category. Because BMS observe a positive relationship between N and P, they collapse their measure of water quality in the Bay into a single variable, TNP, the product of N and P. While there are other possible measures of the relationship between N and P, in order to use the benefit transfer method on BMS and Krupnick we use TNP, their measure of water quality.

BMS (1988, 1989) estimates willingness to pay for three activities: beach use, boating, and fishing.[3] They measure annual benefits for a hypothetical 20 percent improvement in water quality in the Bay for 1) the population of the Baltimore-Washington Standard Metropolitan Statistical Area (SMSA) who uses 10 public beach on Maryland's western shore, 2) boat owners in Maryland that trailered their boats to Maryland waters, and 3) Maryland fisherman who fished for striped bass in the Bay. The authors estimate the benefits of a hypothetical 20 percent improvement in water quality. Analytically, this is interpreted as a 20 percent decrease in TNP for beach use and boating and a 20 percent increase in catch rates for fishing.

Krupnick (1988) estimates the economic value of improving water quality in the Bay by 40 percent, the same percentage reduction called for by the 1987 Chesapeake Bay Agreement. His benefits estimates are based upon rescaling the BMS (1987) numbers to reflect a larger improvement in water quality (40 percent, the reduction called for by the Chesapeake Bay Agreement, versus 20 percent), to incorporate a larger population (Virginia residents and basin non-SMSA residents), and to include additional types of recreational fishing days. The author

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[3]Bockstael, McConnell, and Strand (1988) presents the details of the analysis, while Bockstael, McConnell, and Strand (1989) summarizes the results.

assumes a linear relationship between the benefits and percentage removal of nutrients to scale the 20 percent reduction estimates to reflect a 40 percent reduction. Representative surplus figures for each activity type are calculated based on "average" activity estimates and the estimated population of recreationists.[4] The striped bass estimate applies to all fishing days recorded in Maryland and Virginia. Of greatest relevance to the our study is the information used to scale the benefit estimates of BMS.

Calculating Benefits of Improvements in Water Quality

Both BMS's and Krupnick's benefit estimates are based on hypothetical change in ambient water quality and catch rate. Again, using the results from the Chesapeake Bay Watershed and Estuary models, we can paint a better picture of how ambient water quality has improved in the Bay. The predicted overall improvement in TNP in the Bay proper as a result of CWA is 60 percent rather than 20 percent and 40 percent, the proxies used by BMS and Krupnick, respectively.

Table 3 summarizes the BMS estimates of aggregate benefits for boaters, fishermen, and beach users. The annual benefits to beach users range from $15 million to $62.3 million which are much larger than trailered boating benefits (ranging from $.9 million to $11.2 million) and striped-bass fishing benefits (ranging from $.92 million to $2.9 million).

BMS benefit estimates are limited to the Maryland portion of the Chesapeake Bay. Krupnick scales the BMS benefits to Virginia's portion of the Bay and to other user populations

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[4]Krupnick employs the following "average" estimates : $17.61 per beach trip (12.7 million / 721,000 visits; 1984 $) and $51.25 per boat (4.1 million / 80,000 boaters; 1984 $). For sportfishing, he multiplies the original average estimate of 1 million by 4 because striped bass represent 25 percent of all fishing days in MD and then multiplies that result by 1.7 to reflect the ratio of Virginia anglers to Maryland anglers (680,000 to 400,000).

to obtain a rough estimate of Bay-wide benefits of water quality improvement. Table 4 summarizes the estimates of Bay-wide benefits for boating, fishing, and beach visiting for a 40 percent improvement in water quality and 40 percent increase in catch rate. The total benefits in 1996 dollars range from $43 million to $123 million annually.

We update the BMS aggregate benefits to reflect water quality conditions in 1996 and also expand the beach benefit estimates by including the entire 1996 Baltimore-Washington, DC SMSA who used western shore beaches in Maryland.[5] The BMS per boater estimates were expanded to 135,661 boaters trailering boats in Maryland (Maryland State Department of Natural Resource, Licensing and Registration Services). The sport fishing benefit estimates were expanded to 1996 Maryland fishermen (817,000) (US Fish and Wildlife Service, 1998a).

Following Krupnick, we extrapolated the 1996 BMS aggregate benefits to Virginia's portion of the Bay and to other user populations. Using the average benefit per trip to Maryland's beaches, the 1996 attendance (1,856,315, Virginia Park Attendance, 1991-1997) to two Virginia public beaches: First Landing and Kiptopeke, and an estimate that this attendance comprises 70 percent of total Virginia Bay Beach attendance we calculated the benefits to Virginia.[6] BMS benefits assume only people living in the Washington SMSA frequent the Bay beaches; however, we extend benefits to the Maryland non-SMSA by multiplying the population

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[5]Assumed 21 percent of the 1996 population, 7,164,519 (Census of the United States, 1996), used western shore beaches.

[6]This estimate was used by Krupnick and at this time, after speaking with representatives of Virginia's Department of Conservation and Recreation, we have no evidence that suggests a different estimate would be appropriate.

in this area by the estimate of trips per person and by the average benefit.[7] Virginia boating benefits were estimated by multiplying BMS estimates by the number of trailered boats in the Tidewater and the Eastern Shore area of Virginia (64,194, Virginia Department of Game and Inland Fisheries). Total fishing benefits were extended to all fish species and to Virginia's portion. In 1996 bass fishing represented 14 percent of fishing participation days in Maryland, thus we multiplied the BMS estimate by seven to capture all Maryland's fishing days. This estimate was multiplied by two to reflect the ratio of the Maryland and Virginia Bay fisherman (1,955,000) to the number of Maryland fisherman (817,000) (US Fish and Wildlife Service, 1998a). The fishing benefits may be overstated because all types of fishing are treated equally, whereas sports bass fishing is probably more valued than other types of fishing.

The Bay-wide aggregate benefits were then scaled to capture the additional benefits from the estimated 60 percent improvement in water quality as opposed to the 20 percent and 40 percent hypothetical improvement. Table 5 summarizes the estimates of Bay-wide benefits for boating, fishing, and beach visiting for a 60 percent improvement in water quality and 60 percent increase in catch rate. The annual benefits to beach users range from $288.8 million to $1.5 billion which dominate trailered boating benefits ($6.7 million to $83.6 million) and striped bass sport fishing ($62.4 million to $194.8 million). Total annual benefits range from $357.9 million to $1.80 billion.

The beach benefits represent the greatest percentage of the total benefits. However, it is likely the beach estimates understate benefits. The two public beaches used to calculate benefits

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[7]We used 0.127, the estimate used by Krupnick. A similar estimate was found in the 1996 Maryland Office of Tourism Development Annual Report.

in Virginia, First Landing and Kiptopeke, constitute a little over 2 miles of the 24 miles, or approximately 8 percent, of public beach in Virginia (The 1996 Virginia Outdoor Plan). Clearly, the attendance at these two beaches could represent much less than 70 percent of total Bay beach attendance. For example, if attendance were proportional to beach area, the beach estimates reflected in Table 5 may be understated seven fold.[8] Unfortunately refining these estimates is not possible as attendance figures are not available for other public Bay beaches or the many beaches on private lands in Virginia. These scaled estimates may also underestimate benefits because they do not take into account Bay use by those outside the District of Columbia, Maryland, and Virginia portions of the Bay.

Benefits may also be understated because the relationship between water quality, as represented by Q value, a measure of the biological and physico-chemical conditions of a water body, and benefits is not linear. At high levels of N and P, large reductions in nutrients result in little improvement in water quality (i.e., slope is less than -1). However, when nutrient levels in the water are low (i.e., less than 10 ppm) small reductions in the nutrient level result in large improvements in water quality (Mitchell and Stapp, 2000). For example, over the range of nitrogen concentration in the Bay, a small reduction in nitrogen results in a twofold improvement in water quality. A small change in phosphorus over the relevant range results in four times the improvement in water quality. The product of N and P falls somewhere between the two. Overall the average improvement in the TNP concentration in the Bay is approximately 0.04 ppm (Table 2). The benefits of this reduction in TNP may be two to four times greater than what we

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[8]Under the assumption that attendance is proportional to area, beach use benefit estimates range from $1.2 billion to $2.4 billion.

have estimated under the linearity assumption.

Missing categories of benefits

Recreation

In addition to swimming, trailered boating, and fishing, numerous other recreation activities take place on or near the Bay, not the least of which is non-trailered boating. Maryland requires only that trailered boats be registered. Therefore, it is likely in Maryland that trailered boating represents only a fraction of boating activity on the Bay and its tributaries. The Virginia Department of Conservation and Recreation, Planning Bureau, assumes that 15 percent of registered boats are non-trailered (approximately 11,000 in 1996). Clearly our benefit estimates do not capture benefits accrued to boat owners who live on the Bay or its tributaries or those owners who dock their boats.

Moreover, water quality has improved not only in the Bay proper, but also in the tributaries. These additional effects of water quality improvements were not captured in the previous section. Studies addressing willingness to pay for improvements to freshwater areas and for other recreation activities suitable for transfer to the case addressed in this paper are not available. However, "unit value" studies are available to provide some indication of the magnitude of this benefit category. Unit value studies are used to value access to recreation opportunities. These studies do not address the welfare gains or losses from a change in environmental quality. Rather, these studies assess the consumer surplus from participating in a recreation activity, or more broadly from having access to a recreation site. Studies like this are typically conducted when the elimination of a particular recreation site is a possible outcome due to pollution or other hazards.

Two studies that jointly address marine and freshwater recreation activities may shed some light on the magnitude of this benefit category. Walsh, Johnson and McKean (1990, 1992) compare studies that were done across the U.S. on many types of recreational uses. The authors compiled a total of 287 benefit studies, of which 156 were travel cost studies (TC) and 129 were contingent valuation studies, to assess unit-day values for major recreation activities in Forest Service Regions. Bergstrom and Cordell (1991) develop multi-site, multi-community demand models for 39 different recreation activities. The authors use data from the Public Area Recreation Visitors Study collected between 1985-1987 for 200 sites across the continental US. The study employs a regional zonal TC to accommodate data limitations such as the lack of destination information and amenity quality measures. A number of assumptions are made, including the establishment of a substitute index that was based upon a survey of site managers. Table 6 provides the net economic value of some activities relevant to the Bay.[9]

Real Estate Windfalls From Environmental Improvement

Using the benefit transfer technique, complete analysis of this benefit category is not possible. While a recent paper by Leggett and Bockstael (1998), suggests that premiums to Bay-contiguous home sellers from improved fecal coliform levels in the bay may be quite substantial,

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[9]Again, these estimates do not reflect the welfare gains associated with an increase in environmental quality. Nevertheless, when examined in conjunction with participation estimates they provide some information on the magnitude of this benefit category. As an example, approximately 6 million persons lived in Virginia in 1990 (U.S Census Bureau, 2000). In 1992, Virginia conducted a comprehensive survey asking residents about their participation in outdoor activities (Commonwealth of Virginia, 1992). According to the survey, 53 percent of residents swam away from home and of those, 83 percent swam primarily in Virginia and 18 percent, or over 400,000, swam in lakes or rivers, a large portion of which are Bay tributaries. It should be remembered that this only represents the number of participants engaging in this activity in the "with" scenario. Thorough examination of this benefit category would require an estimate of the number that would have participated in the "without" scenario; however, participation estimates expressed as a function of water quality are not available.

we are unable to evaluate the potential magnitude of this effect because fecal coliform counts are not included in the Chesapeake Bay models and they are not sufficiently correlated with any of the other indicators. Further complicating such an analysis is the reliance upon the assumption that both buyers and sellers are fully informed about both market conditions as well as environmental quality conditions and that the modeled water quality changes (a 60 percent improvement) can not be described as marginal changes.

Commercial Fishery

Valuation of commercial fishery benefits due to water quality improvements involves incorporating the effects from changes in water quality on the costs of production and the growth of the stock, and examining the changes in producer and consumer surplus. It is important to note that gains to producers are typically only realized in the short run. In the long run, quasi rents or profits are competed away in a perfectly competitive model, with the exception of rents accruing to fixed or specialized factors. As new firms enter commercial fishery, the welfare effects to producers from changes in factors such as water quality often dissipate (McConnell and Strand, 1989). Accordingly, changes in consumer surplus are often central to economic analyses of welfare gains associated with commercial fisheries. Studies that do evaluate changes in producer surplus often assume a short-run perspective or do not consider new entrants in estimating changes in welfare.

Benefits assessment involving commercial fisheries is further complicated by management and regulatory requirements. These policies introduce distortions that alter the structure and market responses of commercial fisheries. Large fluctuations in the stocks and harvest of commercial fisheries have had profound impacts on this industry. Since the 1987 Chesapeake Bay Agreement, 13 fishery management plans encompassing 19 species have been adopted (CBP, 1995). Management plans vary across species and rely on tools such as quotas, size restrictions, and/or technological requirements. All of these factors affect the way the markets adjust to factors such as changes in water quality and, in turn, complicate the valuation of commercial fishery benefits. However, examination of the commercial landings of some bay species may shed some light on the potential magnitude of this benefit category. Table 7 provides these estimates.

Human Health

A variety of human health effects are associated with swimming in contaminated waters and consumption of fish and shellfish from such waters. For example consumption of shellfish from waters contaminated with sewage, may be associated with hepatitis A and gastroenteritis (Leonard, et. al, 1989). Ingestion of sewage-contaminated water may also lead to gastroenteritis (Coye and Goldoft, 1989). Because the Bay models deal with nutrients, obtaining enough information about the number of illnesses in each scenario is virtually impossible. Counts of different types of bacteria are generally used to predict human health effects; however, no valid link between nitrogen and phosphorus and bacteria counts exists. Further complicating estimation of the human health benefits of improving Bay water quality is that when water quality is such that humans become ill upon contact with the water , the water body in question is generally closed for use. Therefore, often human health effects do not result, rather the welfare loss stems from the area not being in the population's choice set. Similarly, when water quality is such that consumption fish or shellfish from the area is hazardous to humans, the area is closed for fishing or shellfishing or limitations are placed on consumption.

Discussion of Benefits

The benefit estimates range from $357.9 million to $1.8 billion. These benefit estimates represent use values for persons living in the District of Columbia, and portions of Maryland and Virginia. The range of benefits likely underestimate the true benefits of Bay water quality improvement for several reasons noted previously in the paper. We were unable to attribute use benefits to boaters, anglers, and beach users that live outside of the District of Columbia, and tidal Maryland and Virginia. We were unable to quantify benefits associated with other recreation activities, such as hunting, swimming, and canoeing, that take place on the Bay proper.

We were also unable to quantify benefits associated with recreation activities associated with improvements in the tributaries. This component is likely to be significant as over 750,000 people participated in freshwater fishing and over 3.7 million days of fishing were spent on rivers or streams in Virginia in 1996 (U.S. Fish and Wildlife Service, 1998b). Similarly, in Maryland in 1996, 319,000 people participated in freshwater fishing, and over 2 million days of fishing were spent on streams or rivers (U.S. Fish and Wildlife Service, 1998c). While the former does not provide an indication of willingness to pay for improvements to Bay tributaries, it is offered to provide some indication of the magnitude of the omission of tributary benefits.

Non-use benefits are not included and are likely to be substantial. In 1996 dollars, Krupnick's rough annual non-use benefits (just taking into account the populations of Maryland, Virginia, and the District of Columbia) range from $180 million to $321 million. Other benefits which are not quantified are property value, commercial fishery, and health benefits. Benefits accrued from these categories are even more difficult to determine and not attempted in this analysis. Combined, these non-monetized benefits are likely to be large.

Overall, the net benefits associated with water quality initiatives in the Bay watershed are likely to be positive and substantial. Industrial Economics, Incorporated (IEc)(1998) developed cost estimates, where costs are equivalent to expenditures, not social costs, of water quality improvements in the entire Chesapeake Bay drainage basin attributable to water pollution control programs after 1972.[10] According to IEc's analysis, annual pollution control expenditures at municipal treatment facilities represent approximately 65 percent of total net annual costs of pollution control. Estimates of pollution control expenditures range from $1.0 to $1.3 billion, annually. Costs attributable to Virginia, Maryland and the District of Columbia range from $754 million to $926 million, annually. Even though the correlation between the cost and benefit analysis is less than exact, these estimates provide some indication that there may be positive net benefits associated with policies aimed at improving Bay water quality.

Conclusion

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[10] The analysis focused on three broad discharge sources: municipal treatment facilities, industrial treatment facilities, and non-point sources (primarily agricultural and forest runoff, and urban stormwater and other runoff). The difference between baseline and total costs, where baseline costs represent those costs expected to be incurred regardless of water quality initiatives, provides an estimate of the annual incremental cost associated (net costs) with pollution control in the Bay drainage basin.

Unfortunately, because of differences in methodology and data, we can not compare these cost estimates with our benefits estimates. The benefit analysis relies on water quality output from the Chesapeake Bay Watershed and Estuary Models. These models focus on water quality impacts from nutrient loadings to the Bay and tidal portions of rivers and streams, ignoring some upstream municipal and industrial facilities (IEc, 1998). The cost analysis reflects the direct compliance costs related to water pollution control initiatives, specifically wastewater treatment and Best Management Practice costs. The total compliance cost is for all municipal and industrial facilities in the basin and all pollutants, nutrients and toxics.

Again, these costs cover all expenditures made in the Bay watershed portion of the states and the District of Columbia, and include costs associated with decreasing loads of both nutrients as well as toxic and other contaminants.

This analysis characterizes the benefits of the water quality improvements to the Chesapeake Bay resulting from the Clean Water Act and other water quality policies from 1972 to 1996. The focus is on nutrients discharged to the Bay from point and non point sources. Chesapeake Bay water quality models are used to predict the nutrient reduction from these sources as the result of regulation. The benefit assessment relied on the water quality outputs from these models and the benefits transfer method to generate estimates of benefits from a 60 percent improvement in water quality. For persons living in parts of Virginia, Maryland, and the District of Columbia, annual benefits range from \$357.9 million to \$1.8 billion.

Because of time and resource constraints, it is often not feasible to conduct original studies in order to assess the benefits of proposed or existing regulations and policies and analysts must rely upon benefit transfer to generate such estimates. Policy makers must then frequently make decisions concerning resource allocations using this information. Our paper illustrates this point. The monetized benefits calculated in the paper are comparable to costs. This information coupled with the fact that monetized benefits may be understated by as much as four times, since it was not possible to monetize estimates for many benefit categories, and that costs are likely overstated, provides policy makers with enough information to make informed decisions.

Tables and Maps

Table 1. Chesapeake Bay Nutrient Concentrations and Improvements

Bay Segment	Total Nitrogen Concentration: Without	Total Nitrogen Concentration: With	Total Nitrogen Concentration: % Improvement	Total Phosphorus Concentration: Without	Total Phosphorus Concentration: With	Total Phosphorus Concentration: % Improvement
Susquehanna Flats	1.22 ppm	1.73 ppm	-42	0.14 ppm	0.03 ppm	81
CB2	0.98 ppm	1.21 ppm	-24	0.11 ppm	0.03 ppm	72
CB3	0.93 ppm	0.93 ppm	0	0.13 ppm	0.03 ppm	75
CB4	0.67 ppm	0.71 ppm	-6	0.08 ppm	0.03 ppm	66
CB5	0.54 ppm	0.53 ppm	1	0.07 ppm	0.02 ppm	66
Tangier Sound	0.65 ppm	0.62 ppm	5	0.06 ppm	0.03 ppm	47
CB6	0.44 ppm	0.41 ppm	5	0.05 ppm	0.02 ppm	55
CB7	0.41 ppm	0.39 ppm	4	0.05 ppm	0.03 ppm	50
CB8	0.42 ppm	0.38 ppm	9	0.06 ppm	0.03 ppm	47

Table 2. TNP Concentration in the Bay

Bay Segment	% of Total Bay Proper	Without (ppm)	With (ppm)	% Improvement in TNP	Area % change in TNP
Susquehanna Flats	1.57	0.18	0.05	73.51	1.15
CB2	2.63	0.10	0.04	65.84	1.73
CB3	6.70	0.12	0.03	74.95	5.02
CB4	12.80	0.05	0.02	63.60	8.14
CB5	24.76	0.04	0.01	66.41	16.44
Tangier Sound	13.97	0.04	0.02	49.74	6.95
CB6	10.73	0.02	0.01	57.54	6.17
CB7	21.09	0.02	0.01	52.17	11.00
CB8	5.77	0.03	0.01	51.22	2.96
Average		**0.067**	**0.022**		
Total	**100.00**				**60.0**

Table 3
Aggregate Benefits from a 20 percent Improvement in the Chesapeake Bay's Water Quality
(1996 dollars)

	Benefit Estimate		
Activity	*Low*	*Average*	*High*
Beach Use	$15.1 million	$48.0 million	$62.3 million
Trailered Boating	$.90 million	$6.5 million	$11.2 million
Striped Bass Sport Fishing	$.92 million	$1.89 million	$2.86 million
Totals	$16.9 million	$56.4 million	$76.4 million

Source: Bockstael, McConnell, and Strand, 1988.
Note: BMS estimates were updated to 1996 using Consumer Price Index.

Table 4
Aggregate Benefits from a 40 percent Improvement in the Chesapeake Bay's Water Quality
(1996 dollars)

	Benefit Estimate		
Activity	*Low*	*Average*	*High*
Beach Use	$36.2 million	$55.6 million	$89.9 million
Trailered Boating	$1.36 million	$9.97 million	$17.2 million
Striped Bass Sport Fishing	$5.13 million	$10.3 million	$15.4 million
Total	$42.69 million	$75.87 million	$122.5 million

Source: A. Krupnick, 1988.

Table 5
Aggregate Benefits[11] from a 60 percent Improvement in Chesapeake Bay Water Quality
(1996 dollars)

	Benefit Estimate		
Activity	*Low*	*Average*	*High*
Beach Use	$288.8 million	$824.9 million	$1.52 billion
Trailered Boating	$6.7 million	$ 48.5 million	$83.6 million
Striped Bass Sport Fishing	$62.4 million	$128.6 million	$194.8 million
Total	$357.9 million	$1 billion	$1.80 billion

[11]These estimates have the same limitations and errors as discussed in BMS and Krupnick.

Table 6
Net Economic Value Per Day
(1996 dollars)

Activity	Walsh, Johnson, and McKean	Bergstom and Cordell
Swimming	$31.72	$20.50 (stream/lake)
Motorized boating	$43.59	$22.53
Non-motorized boating	$67.24	—
Migratory waterfowl hunting	$49.22	—
Cold water fishing	$42.29	$24.57
Anadromous fishing	$74.60	$32.49
Warm water fishing	$32.52	$17.27
Canoeing/kayaking	—	$17.47

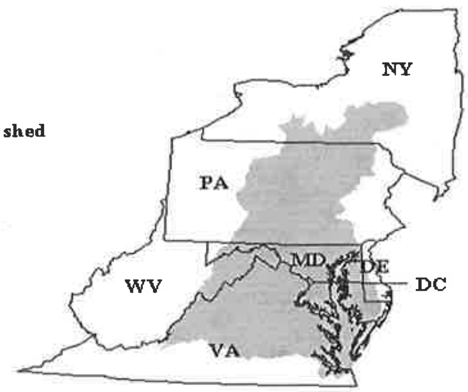
Table 7
Commercial Fishery Landings

Species	Pounds	Dollar Value (1996)
Maryland		
bass, striped	1,594,192	$2,606,511
clam, softshell	319,458	$1,476,533
clams or bivalves	6,443,962	$4,050,190
crab, blue	37,174,668	$26,170445
oyster, eastern	888,863	$2,852,786
Virginia		
bass, striped	1,608,898	$2,775,045
clam, quahog	788,523	$4,190,506
crab, blue	32,518,256	$19,718,691
oyster, eastern	159,606	$462,041

(source: National Marine Fisheries Service, 2000)

Figure 1
Chesapeake Watershed

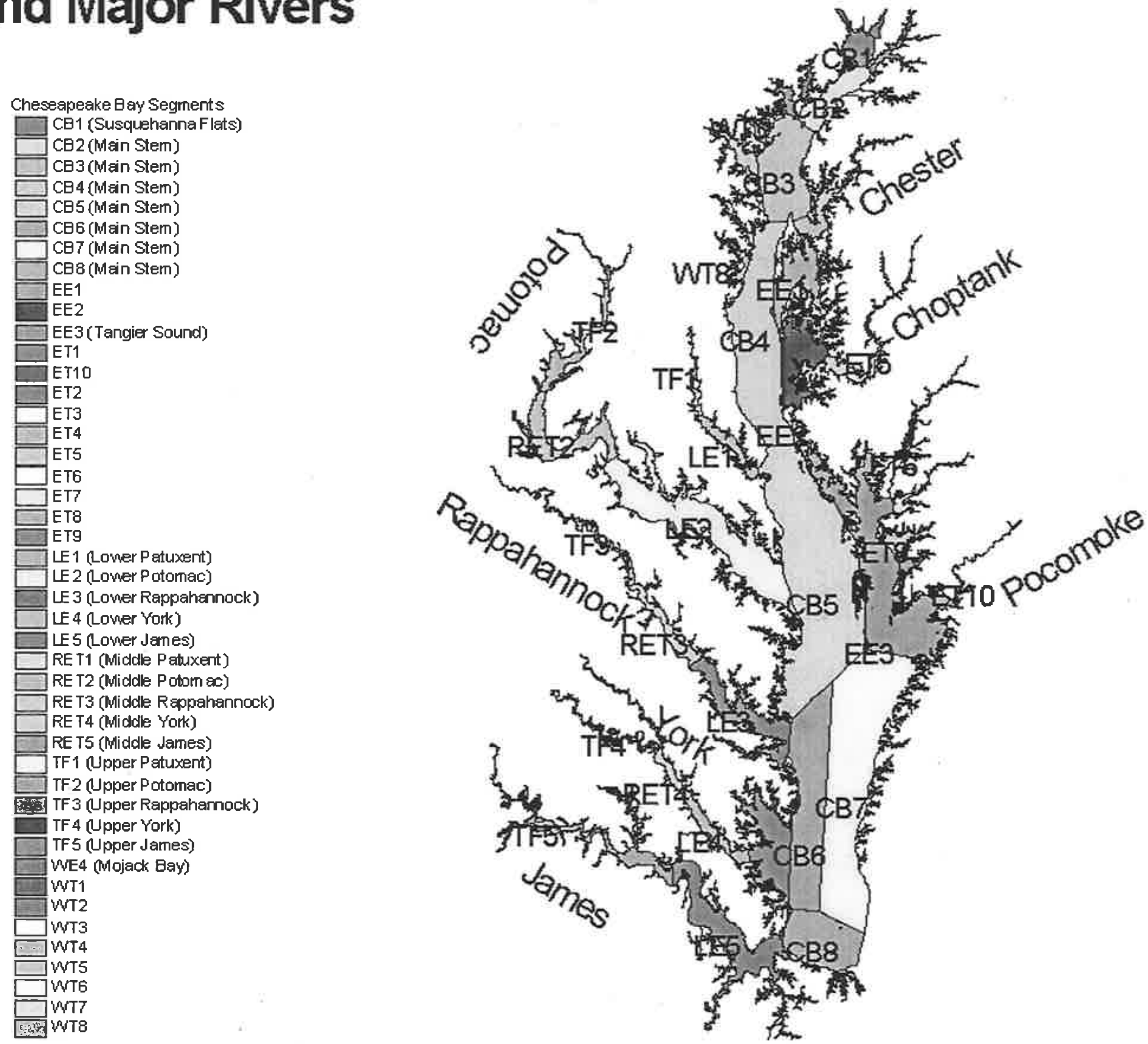
States and Watershed Boundary



Major Basins of the Watershed

1. Susquehanna
2. Potomac
3. James
4. Rappahannock
5. York
6. Patuxent
7. W. Shore - MD
8. E. Shore - MD
9. Choptank
10. Nantioke
11. E. Shore - VA
12. W. Shore - VA

Figure 2. Chesapeake Bay Model Segments and Major Rivers



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