DISCUSSION PAPER

September 2011 ■ RFF DP 11-31

The Benefits of Achieving the Chesapeake Bay TMDLs (Total Maximum Daily Loads)

A Scoping Study

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RESOURCES FOR THE FUTURE

The Benefits of Achieving the Chesapeake Bay TMDLs (Total Maximum Daily Loads): A Scoping Study

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Abstract

Concerns about nutrient pollution in the Chesapeake Bay have led to the establishment of pollution limits—total maximum daily loads (TMDLs)—which, by 2025, are expected to reduce nitrogen loadings to the Bay by 25 percent and phosphorous loadings by 24 percent from current levels. This paper outlines how the benefits associated with achieving the Chesapeake Bay TMDLs could be measured and monetized. We summarize studies that measure the benefits of improved water quality in the Bay and evaluate whether these studies could be used to value the water quality benefits associated with the TMDLs.In cases where studies conducted in the Bay watershed either do not exist or are out of date, we discuss whether results from studies conducted elsewhere could be transferred to the Chesapeake Bay. We also discuss original studies that would be useful to conduct in the future.

Key Words: Chesapeake Bay restoration, total maximum daily loads, benefits of water quality improvements

JEL Classification Numbers: Q51, Q53, Q57

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The Benefits of Achieving the Chesapeake Bay TMDLs (Total Maximum Daily Loads): A Scoping Study

Maureen L. Cropper and William Isaac*

I. Introduction

Concerns about nutrient pollution in the Chesapeake Bay have led to the establishment of pollution limits—total maximum daily loads (TMDLs)—which, by 2025, are expected to reduce nitrogen (N) loadings to the Bay by 25 percent and phosphorous (P) loadings by 24 percent from current levels. The TMDLs are expected to result in multiple benefits to residents of the Chesapeake Bay watershed and to people living outside of the watershed. By improving water quality in the Bay, the TMDLs will help restore various forms of aquatic life; this will, in turn, increase commercial fishery yields, which will benefit fishers in the Bay and consumers, regardless of where they live, and recreational fish catches, which will benefit anglers who visit the Bay. In addition, reducing levels of chlorophyll and improving water clarity will improve the quality of recreational experiences for boaters and swimmers. Improved water quality could potentially increase the value of property near the Bay, reflecting increases in both aesthetic and recreational values. In addition, restoring Bay ecosystems will benefit people who care about the natural environment, wherever they live.

But achieving the TMDLs will come at a cost. It is therefore appropriate to ask: What is the dollar value of the benefits that will result from achieving the TMDLs? In this paper, we define the value of benefits associated with the TMDLs as the amount that people would pay to achieve the resulting improvements in water quality, both in the Chesapeake Bay itself and in its tributaries.

The purpose of this paper is to outline how the benefits associated with achieving the Chesapeake Bay TMDLs could be measured and monetized. This paper focuses on six categories of benefits: benefits of improved water quality to homeowners who live near the Bay (amenity benefits), recreational benefits to fishers, recreational benefits to swimmers and boaters, commercial fishing benefits, and benefits to people who may never visit the Bay but care about protecting Chesapeake Bay ecosystems (nonuse benefits).In each case, we describe the methods

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we used to monetize benefits, summarize the state of the existing literature, and discuss whether the results of existing studies could be extrapolated to value the benefits of the TMDLs. In cases where the existing literature either does not exist or is out of date, we discuss whether results from studies conducted elsewhere could be transferred to the Chesapeake Bay. Finally, we discuss original studies that would be useful to conduct in the future.

This is preceded by a discussion of the decisions and noneconomic analyses that would need to be undertaken before measuring economic benefits. To examine the benefits of achieving the TMDLs, one must (a) specify what would happen in their absence (in the counterfactual scenario) and (b) translate the pollution levels achieved, at different dates, into ambient water quality, both for the TMDL scenario and the counterfactual scenario. We discuss what is involved in these analyses as well as the time interval at which benefits should be calculated.

II. Framework for a Study of the Benefits of Achieving the Chesapeake Bay TMDLs

The Chesapeake Bay TMDLs specify annual allocations of N, P, and total suspended solids (TSS) for watershed areas that drain into the 92 segments of the Chesapeake Bay. By 2025, total N will be limited to 185.9 million pounds per year (a 25 percent reduction from 2010 levels), total P to 12.5 million pounds (a 24 percent reduction from 2010 levels), and sediment to 6.45 billion pounds (a 20 percent reduction from 2010 levels).The TMDLs are designed to achieve ambient water quality standards for dissolved oxygen (DO), water clarity, and chlorophyll-a that were set for the Chesapeake Bay in 2003(U.S. Environmental Protection Agency 2010).

In calculating the benefits of the TMDLs, it is necessary to specify the levels of N, P, and sediment (TSS) that would occur without the TMDLs. Loadings of N and P to the Bay have fallen in absolute and in per capita terms since 1986.A possible counterfactual would be to assume that practices affecting loadings to the Bay would remain constant at 2010 levels, but to allow for growth in population and incomes in the Bay watershed. This would imply an absolute increase in N, P, and TSS from 2010 values in the year 2025.The percentage reduction in N, P, and TSS from the counterfactual would therefore be larger than the reductions from current values described in the previous paragraph.[1]

[1]The population in the Chesapeake Bay watershed is predicted to grow by about 15 percent between 2010 and 2025, implying a 15 percent growth in pollution loads if per capita loads were to remain at 2010 levels.

An estimate of economic benefits requires that reductions in loadings of N, P, and TSS to the Bay be mapped onto corresponding changes in ambient water quality. The studies reviewed below use a variety of measures of water quality, including ambient concentrations of N and P, DO, water clarity, chlorophyll-a, and submerged aquatic vegetation (SAV).The Chesapeake Bay Water Quality Model and the Chesapeake Bay Eutrophication Model (U.S. Environmental Protection Agency 2004) translate the impacts of the TMDLs and counterfactual scenarios into various measures of water quality. Model runs are available that translate the achievement of the TMDLs into the water quality measures listed in this paragraph. However, additional runs would be required to estimate water quality associated with the counterfactual scenario.

A challenge in any study will be to take the outputs from the Chesapeake Bay Water Quality Model and aggregate them to the level required to calculate economic benefits. Outputs from the Bay Water Quality Model are available at a fine level of spatial detail; they will need to be aggregated to the appropriate scale for each category of benefits analyzed.

Regarding the time frame for the analysis, the TMDLs are to be achieved by 2025, with 60 percent of reductions in pollutant loads achieved by 2017.A natural choice for the study timeline would be to calculate benefits in 2017 and 2025, with some interpolation of benefits in intermediate years. Calculating benefits in these years will necessarily require geographically detailed forecasts of population and income for the region, as well as forecasts of housing prices.

III. Benefits of Water Quality Improvements in the Chesapeake Bay and Its Tributaries

A. Impacts on Property Values

The fact that the benefits of environmental amenities are capitalized into property values provides a useful method of measuring environmental benefits: as long as a researcher can control for other factors affecting housing prices, it should be possible to infer the value of an amenity (such as water quality) from variation in the level of the amenity and in housing prices over space and time. Studies of the impact of water quality on housing prices typically use cross-sectional variation in water quality and housing prices to measure the benefits of improved water quality. As long as other location-specific amenities are adequately controlled for, so that water quality does not pick up their effect, coefficients from a hedonic property value equation should provide an unbiased estimate of the value of a marginal change in the level of the amenity.[2]

An issue that arises in using hedonic property value models to value water quality is how water quality should be measured. Many studies use water clarity—either objectively or subjectively measured—to assess water quality in rivers and lakes. Poor et al. (2001) measure water clarity in lakes in Maine using Secchi depth and compare this with residents' subjective estimates of clarity. They find that the two are highly correlated, although respondents tended to underestimate water clarity more often than they overestimated it. Poor et al. (2007) use TSS to measure water clarity along streams in St. Mary's County, Maryland. Other studies use variables that are likely to affect clarity but are not readily observable by homeowners—for example Poor et al. (2007) also use dissolved inorganic nitrogen (DIN) to measure water quality in tributaries to the Chesapeake. A possible drawback of using DIN is that it is a noisy measure of environmental quality as perceived by home buyers.[3] This may make it difficult to obtain precise estimates of its effect on home prices.

A second issue is what categories of benefits property values capture and whether these values should be added to other benefit estimates. Water quality near one's home has aesthetic value, which is unlikely to be captured in other ways. But it may also have recreational value (e.g., if water is used for swimming or boating).Whether this leads to double-counting of benefits depends on how other recreational values are measured. If the value of improved water quality to swimmers or boaters is measured based on visits to beaches and docks (primarily by visitors who are not local homeowners), then there is likely to be little double-counting, and property value estimates of benefits may be added to other recreational values.

Chesapeake Bay Literature

Two studies have measured the impact on home prices of water quality in tributaries to the Chesapeake Bay.[4] One is Poor et al.'s (2007) study of the impact of DIN and TSS on property values in St. Mary's County. This study is based on sales of 1,377 homes between 1999 and 2003.Most homes in the sample are located near the Patuxent River Naval Air Station; only

[2] If large changes are made that will affect housing market equilibrium in an area, these adjustments must be taken into account.

[3] That is, it measures what people care about with error, causing an error-in-variables problem.

[4] All Chesapeake Bay studies discussed in the text are summarized in Tables 1–4.

2 percent are waterfront properties. Poor et al. use annual average readings of TSS and DIN from the monitoring station closest to each house, in addition to housing and neighborhood characteristics, to explain variation in home prices. They find that a1-mg/L reduction in DIN (sample average DIN = 0.625 mg/L) is associated with an 8.8 percent increase in housing price, and a 1-mg/L reduction in TSS (sample average TSS = 13.3 mg/L) is associated with a 0.53 percent increase in housing prices.

The other study is Leggett and Bockstael's (2000) examination of the impact of fecal coliform counts on the values of waterfront properties in Anne Arundel County. This study, based on sales that occurred between 1993 and 1997, links housing prices to fecal coliform counts measured at 104 locations within the county. The authors find that a reduction in fecal coliform of 100 counts per 100 mL (sample average = 103 counts per100 mL) increases home prices by 1.5 percent.

Recommendations for Estimating Benefits

Both the Poor et al. (2007) and Leggett and Bockstael (2000) studies could be used to measure the benefits (and co-benefits) of reductions in pollutants targeted by the TMDLs. The contaminants studied by Poor et al. (2007) are directly addressed by the TMDLs. And, though the bacterial contaminants studied by Leggett and Bockstael (2000) are not addressed by the TMDLs, reductions in N and P loadings to the Bay from agricultural sources and combined sewer overflows (CSOs) may also reduce bacterial contamination, a potential co-benefit of achieving the TMDLs.

Using hedonic property studies to value water quality improvements requires data on property values for homes near the Bay, as well as estimates of the water quality indices used in each study, computed for the with- and without-TMDL scenarios. Property value data for the state of Maryland are available from the Maryland Property Tax Assessment (Property View) database (Maryland Department of Planning 2011).The database contains the location of each property (latitude, longitude, and street address), assessed value, acreage, and house and lot characteristics (including whether the property is a waterfront property).The database also contains the date of the most recent sale of the house and the most recent sale price. Although comparable data are not available from the state of Virginia, some Virginia counties bordering the Bay do have property value databases (see Appendix).Property value data for the year 2000 are available at the census block level from the 2000 Census of Housing (U.S. Census Bureau 2011).Projections of the rate of growth in property values will be required to estimate benefits in 2025.

Van Houtven and Clayton (2008) suggest that improvements in water clarity in the Chesapeake Bay could be valued by transferring results from studies of the impact of water clarity on lakefront properties in New England. These studies include the work of Poor et al. (2001) and Michael et al. (2000), who measure the impact of improved water quality on the prices of summer homes on lakes in Maine. In a third study, Gibbs et al. (2002) examine the impact of water clarity on lakefront homes in New Hampshire.

We believe that it would be difficult to transfer these studies to the Chesapeake Bay. The measure of water quality in all three studies is the product of water clarity (measured by Secchi depth) and the area of the lake near the house. Housing price is measured either in absolute terms or as price divided by feet of lakefront, which complicates benefits transfer.[5] Most importantly, the nature of the housing stock in these studies is quite different from the housing stock near the Bay. It would be preferable, in our view, to conduct an original study of the impact of water clarity on the prices of homes near the Chesapeake Bay. This could easily be done using the Maryland Property View database.

B. Impacts on Recreational Fishing

Improvements in water quality increase the number of fish that anglers are likely to catch on a fishing day, and thus increase the value of fishing trips. There is a large literature on the benefits of site characteristics to recreational fishermen, using both revealed and stated preference approaches. Revealed preference studies use data on fishing trips, together with the cost (including the travel cost) of visiting various sites, to estimate the value of a fishing day. This value will depend on the number of fish caught, which can, in turn, be linked to measures of water quality. Stated preference studies determine the value of increases in fish catch by asking fishers directly what they would pay for an increase in the size of their catch or how many additional trips they would take if the size of their catch were to increase. In both cases, increases in the number of fish caught must be linked to water quality measures through catch rate equations, which link the number of fish caught to the level of effort expended (number of hours spent fishing), angler experience, and measures of water quality. The measure of water quality most often used in these models is DO. The value of catching more fish and the impact of higher DO levels on catch rates varies with species, so separate studies are conducted for individual

[5] In most hedonic property value studies, the dependent variable is the logarithm of price, which implies that a one-unit change in a characteristic has a percentage impact on housing price. This facilitates benefits transfer.

species (e.g., striped bass vs. flounder).In addition, studies sometimes vary according to mode of fishing (pier, boat, or charter boat).

Increases in fish abundance may also increase the number of people who decide to fish at all and, for those who participate, the number of days spent fishing. Measuring the impact of water quality on participation requires estimating an equation to measure the impact of expected catch on whether a person fishes at all (i.e., a participation equation).The impact of expected catch on the number of days spent fishing (conditional on participation) is captured in some (but not all) recreation demand studies.[6]

Chesapeake Bay Literature

Lipton and Hicks (1999, 2003) have estimated the impact of DO on striped bass catch rates in the Chesapeake Bay, as well as the impact of higher catch rates on the value of a fishing day. Catch rate equations, based on data from the 1994 Marine Recreational Fisheries Statistics Survey (MRFSS) (National Oceanic & Atmospheric Administration 1994), link the logarithm of the number of fish caught per trip to hours spent fishing, angler experience, and water quality conditions including surface DO, bottom DO, bottom temperature, and surface temperature. Lipton and Hicks find that a 2.41-mg/L increase in DO (holding temperature constant) will increase striped bass catch rates by 95 percent. Based on average catch rates in 2001–2005, this translates into an increase in the number of fish caught per trip in Maryland and Virginia of 1.57 and 0.56 fish per trip, respectively (Van Houtven 2009).Using a travel cost model, Lipton and Hicks estimate the value of catching one more fish per trip of $11 (2007 dollars).

Studies by Lipton and Hicks are the only studies of which we are aware that value improvements in DO to recreational fishers in the Chesapeake Bay. However, Massey et al. (2006) value improvements in DO to fishers of summer flounder along the Atlantic Coast of Maryland. The authors estimate an equation linking DO levels to catch and estimate a travel cost model to gauge the value of improvements in catch to fishers.

[6] Models that explain the number of days spent fishing at different sites automatically capture this effect.When random utility models are estimated, an additional equation must be estimated to explain the number of days spent fishing, conditional on fishing at all.

Recommendations for Estimating Benefits

It is possible to estimate the effects of changes in DO levels associated with the TMDLs on striped bass and summer flounder using the studies by Lipton and Hicks (1999, 2003) and Massey et al. (2006).[7] These studies are limited, however, in that they cover only two species (striped bass and flounder) that are caught by recreational fishers in the Bay. Based on data from the U.S. Fish and Wildlife Service (Van Houtven and Clayton 2008), these species account for only about two-thirds of recreational fishing trips in the Bay. To cover more species, it is necessary to estimate equations relating catch rates to DO (or other water quality measures) for other species, and then to estimate the value attached to catching an additional fish from the recreation demand literature. An alternative (Van Houtven 2009) is to assume that the percentage change in catch corresponding to a 1-mg/L change in DO is the same for other species as it is for striped bass or flounder.

The literature linking water quality to catch rates by recreational fishers is small. Bricker et al. (2006) estimate equations relating chlorophyll-a, DO, and DO interacted with temperature to catches of bluefish, striped bass, and winter flounder in Mid-Atlantic estuaries.[8]They indicate that bottom water DO is positively, and chlorophyll-a negatively, related to striped bass and bluefish catches; however, they do not present quantitative estimates. Kaoru et al. (1995) relate total recreational catch per trip (no distinction by species) to N loadings in the Albemarle and Pamlico Sounds, but do not examine the impact of DO.

Currently, studies relating DO and other measures of ambient water quality to recreational fish catches are the binding constraint in estimating impacts of improved water quality on recreational fishing. Once this link in the analysis is complete, studies valuing the effects of increased catch are readily available (see Johnston et al. [2006] for a recent meta-analysis).[9]

[7] This assumes, of course, that the Bay Water Quality Model has been used to translate changes in loadings into changes in ambient water quality.

[8] The authors also have data on recreational catch and water quality in the Patuxent and Potomac Rivers. Equations were also estimated for all species.

[9] Poor and Breece (2006), using a combination of stated and revealed preference methods, estimate that the value of a 25 percent increase in the size of striped bass in the Chesapeake would be worth $75 per season to charter boat fishers.

Computing benefits associated with recreational fishing requires data on the number of fishing trips (by species) in different parts of the Bay and average catch. The annual MRFSS provides this information. This survey consists of an angler intercept survey that collects data on the number of fishing trips over the past two months, the duration and location of trips, and the number of fish caught. This is supplemented by a telephone survey to determine the percentage of the population who fish.

C. Impacts on Swimming

The revealed preference literature on the benefits of site characteristics to swimmers uses cross-sectional variation in the cost of visiting sites and in site quality to explain the choice of sites visited by beachgoers and/or the number of visits made to each site. The impact of changes in quality on the choice of site or number of visits made can be used to estimate what people will pay for improvements in site quality. Random utility models (e.g., Hicks and Strand 2000) explain which site a person will visit on a single recreation day and yield an estimate of the value of improvements in site quality per day. Benefits over the course of a season are computed by multiplying benefits per day by the number of visits per season.

Improvements in site quality may also increase the number of visits a household makes per season. Random utility models are often supplemented by an equation that estimates the impact of site quality on the total number of visits made during a season. Other models (e.g., the varying parameters model estimated by Bockstael et al. [1989]) explain the total number of visits made to each site over the course of a season and therefore incorporate the impact of site quality on the number of visits made, conditional on a person making any visits. But improvements in site quality may affect whether a family goes to the beach at all. Because random utility models and other recreation demand models are usually estimated based on a sample of beachgoers, rather than on a random sample of the population, an additional model must be estimated to measure the impact of water quality on whether a family goes to the beach at all.

An important issue is what site attributes matter to beachgoers. Many studies focus on beach width and depth, and on the availability of retail services (e.g., food), parking, and bathrooms. Total coliform and fecal coliform count are two measures of water quality that frequently appear in the literature. Water quality measures that are affected by eutrophication include water clarity and harmful algal blooms (e.g., red tide). Bockstael et al. (1988) report that the most important environmental disamenities to Chesapeake Bay beach users, based on a 1984 survey, are floating debris or oil, odors, jellyfish, cloudy water, and aquatic plants.

Chesapeake Bay Literature

Two studies by Strand and co-authors estimate the impact of water quality on beach visits in the Chesapeake Bay. Both studies are based on a 1984 survey of 484 visitors to 11 beaches on the western shore of the Chesapeake Bay. Bockstael et al. (1989) use the data to estimate the number of visits made to each beach as a function of the travel and out-of-pocket costs of visiting each beach and water quality. Water quality is measured as the product of N and P concentrations (TNP) in each location, based on 1977 readings. The authors calculate the average per-trip benefits of a 20 percent reduction in TNP to be $19.86 (1987 dollars).Hicks and Strand (2000) use the data to estimate a random utility model linking visits to fecal coliform counts at the beaches. This is supplemented by an equation to explain the number of visits made to all beaches. They report a mean seasonal benefit of $29 (1987 dollars) per beachgoer for a 40 percent reduction in fecal coliform from 1977 levels at all beaches studied.

Krupnick (1988) and Morgan and Owens (2001) use Bockstael et al. (1989) to estimate the benefits of larger improvements in water quality (40 percent reductions in TNP in the case of Krupnick and 60 percent in the case of Morgan and Owens) to residents of Maryland, Virginia, and the District of Columbia .Although these studies account for population growth, the benefit estimates do not reflect income growth. Although Bockstael et al. did not find income to be statistically significant in their original models, increases in income would affect the time cost of visits in a travel cost model, and this should be reflected in the calculations.

Recommendations for Estimating Benefits

The chief limitation of Bockstael et al. (1989) is the use of TNP as a measure of water quality. Although both N and P affect water quality (e.g., increasing algal blooms and lowering DO), the idea that it is the *product* of the two that matters is difficult to justify.[10] It can also lead to implausible results. To illustrate, Morgan and Owens (2001) use Bockstael et al. (1989) to measure the benefits of the Clean Water Act (CWA) on water quality in the Bay in 1996.In the main stem of the Bay the "without-CWA" concentrations of N and P are 0.98 and 0.11 ppm, respectively, whereas the "with-CWA" concentrations are 1.21 and 0.03 ppm, respectively. Although N concentrations increased by 24 percent, TNP decreased by 66 percent because of the

[10] In a personal communication, K.E. (Ted) McConnell, co-author of the Bockstael et al. (1989) study, suggested that it would not be appropriate to use this study to value the benefits of the TMDLs for this reason.

large percentage reduction in P. Unfortunately, this does not imply a 66 percent improvement in ambient water quality measures.

For these reasons, we would not recommend using Bockstael et al. (1989) to measure the benefits to swimmers of reductions in N and P achieved by the TMDLs. Hicks and Strand (2000) could be used to estimate the benefits of reductions in fecal coliform that might accompany improved agricultural practices and/or reductions in CSOs associated with achieving the TMDLs. But new studies need to be conducted to measure the benefits of improved water quality at beaches along the Chesapeake Bay.

Can studies from other locations be used in the interim to measure the benefits of improved water quality at beaches along the Chesapeake Bay? There is a sizable revealed preference literature that measures the value of a beach day (see Deacon and Kolstad [2000] for a summary), but much of this literature focuses on coastal beaches. And most of these studies do not explicitly relate beach visits to measures of water quality. A notable exception is Hanemann et al. (2005) who estimate the value of beach closures and degradation in water quality at beaches in Southern California; however, the emphasis in that study is on fecal coliform and other measures of bacterial contamination.

There is also a literature on recreational visits to lakes (e.g., Parsons and Kealy 1992; Phaneuf2002), including visits by swimmers, which does relate visits to DO and water clarity. However, it may not be appropriate to transfer the benefits of improved water quality in lakes in Wisconsin or watersheds in North Carolina to the Chesapeake Bay.

Even if the benefit of improved water clarity per visitor per day could be estimated, one still would need to estimate the number of beach visits made annually to the Chesapeake Bay. In contrast to data on fishing, data on beach visits are, in general, difficult to obtain. In Maryland, it is possible to obtain data on visits to state parks (see Appendix), although not on the number of persons who swim. The Virginia Outdoors Survey has information on the percentage of the population who visit beaches and on the annual number of visits made, but not on the location of the beaches visited (Virginia Department of Conservation and Recreation 2007).

One also faces the task of estimating the impact of water quality improvements on the annual number of beach visits. Neither Bockstael et al. (1989) nor Hicks and Strand (2000) estimate the impact of water quality on the probability that a household visits the beach at all. (Both studies estimate the impact of water quality on visits, conditional on making any visits.)Improvements in water quality will probably increase the percentage of households that go to the beach at all; however, studying this would require data on the general population.

D. Impacts on Boating

Revealed preference studies of recreation demand value water quality by observing the number of visits made to various sites as a function of the cost of visiting each site and site quality. A similar approach can be used to value water quality to boaters for boat owners who trailer their boats, and therefore choose where to launch their boats on each trip. The approach is more difficult to apply to boat owners whose boats are moored. This has led to the use of stated preference methods, which ask boat owners directly what they would pay for improvements in water quality.

Chesapeake Bay Literature

To our knowledge, the only revealed preference study of the value of water quality to boaters in the Chesapeake Bay is by Bockstael et al. (1989).Using data from a survey of 496 boat owners who trailer their boats, the authors estimate a model to explain the number of trips made to each of 12 county sites during a season as a function of the time and out-of-pocket cost of reaching each site and water quality, as measured by N and P loadings. As in their study of beach visits, the authors measure water quality by multiplying N times P concentrations in each location, based on 1977 readings, to produce TNP. They estimate that the value of a 20 percent reduction in TNP to trailered boat owners is approximately $59 (1987 dollars) per year.

Lipton (2004) uses stated preference methods to estimate what various categories of boaters will pay for an improvement in water quality in the Chesapeake. Boat owners are asked to rate water quality in the Bay on a five-point scale, and to indicate what they would pay for a one-unit improvement in water quality for a season. Based on 755 Maryland boat owners surveyed in 2000, the annual value of a one-unit improvement on the five-point scale ranges from $30 for trailered powerboat owners to $93 for sailboat owners (2000 dollars).Overall, mean willingness to pay was $63, with 38 percent of respondents reporting a willingness to pay of zero for water quality improvements.

Recommendations forEstimatingBenefits

Although Krupnick (1988) and Morgan and Owens (2001) have used Bockstael et al.'s (1989) analysis to measure the benefits of reductions in N and P to boaters, the use of TNP as a measure of improved water quality suffers from the same limitations as noted under the discussion of recreational benefits to swimmers. The Lipton (2004) study could be used to value water quality improvements to boaters if water quality changes could be mapped to the subjective water quality scale used in the study. Unfortunately the study does not report the impact of respondent income on willingness to pay, which makes adjustments for income growth difficult.

E. Impacts on Commercial Fisheries

Improvements in water quality can, by boosting harvests, increase fishers' incomes and also reduce the price paid by consumers for fish and seafood. Estimating these benefits requires that one estimate the impact of water quality on catch per boat. This can be done by estimating equations to measure the impact of water quality on fish populations and the impact of fish populations on yield (Kahn and Kemp 1985).Or one can estimate a reduced-form equation that relates catch per boat to water quality, the number of boats in a fishery, and other variables (Anderson 1989).[11]

The benefits to a fisher of an improvement in water quality equal the increase in catch per boat, multiplied by the price per pound of fish (i.e., the change in average revenue per boat).These benefits are likely to be greatest in the short run, before the number of boats in the fishery increases in response to increased revenue per boat. Estimating the long-run impact of improvements in water quality requires that one estimate an equation to explain the number of boats in the fishery as a function of average revenue per boat. Anderson (1989) is a nice example of this type of study. The author estimates the impact of SAV on catch per boat for the Virginia blue crab fishery and uses this to calculate average revenue per boat. He also estimates an equation to explain the number of boats in the fishery as a function of average revenue per boat. Because catch per boat depends on the number of boats in the fishery, entry reduces the increase in yield per boat in the long run. Anderson estimates that the increase in producers' surplus (profits) of fishers corresponding to full restoration of SAV to 1960 from 1987 levels would be $1.8 million (1987 dollars).

Increases in the size of the catch also benefit consumers by lowering the price of fish. Anderson (1989) estimates the demand curve for blue crabs, using national data, and then calculates the consumer surplus associated with a fall in the price of crabs due to increased production. The increase in consumer surplus is $2.4 million (1987dollars).The benefit to consumers of crabs is large—in fact larger than the increase in producer surplus—because of the high demand for the product.

[11] A complete bioeconomic model consists of equations to explain the size of the fish population, the size of the catch (or catch per unit of effort), and the level of effort (e.g., number of boats) in the fishery.

Chesapeake Bay Literature

In addition to the study by Anderson, Kahn and Kemp (1985) have studied the impact of changes in SAV on the striped bass fishery in the Chesapeake Bay. Using annual data from 1965 to 1979, Kahn and Kemp estimate a bioeconomic model of the striped bass fishery in which the population of striped bass depends on the carrying capacity of the environment, which is a function of SAV. The equilibrium catch in the fishery is a function of the striped bass population and SAV. The demand for striped bass is estimated as a function of regional population and per capita income. Kahn and Kemp simulate the model for various levels of SAV. They conclude that the sum of consumer and producer surplus associated with a 50 percent increase in SAV is approximately $5 million (1978 dollars), although they emphasize that the estimate is crude, given data limitations.

Mistiaen et al. (2003) examine the impact of DO levels on the trotline blue crab fishery in the Patuxent, Chester, and Choptank tributaries of the Chesapeake Bay. Similar to Anderson, the authors estimate blue crab catch as a function of bottom DO and the amount of effort (gear) in the fishery. However, they do not model the level of effort in the fishery, but instead analyze the impact of changes in DO, holding the stock of crabs and level of effort fixed. The authors assume that changes in DO have no effect above a level of 5 mg/L. They find that reducing bottom DO from 5.6 to 4.0 mg/L reduces crab harvests in the Patuxent River by 49 percent, a loss of about $200,000 in revenue to fishers (2000 dollars).As Van Houtven and Clayton (2008) emphasize, this study estimates the short-run benefits of a change in DO for a very localized area and does not allow for adjustment in the level of effort. Furthermore, the study assumes that there are no benefits to increasing DO above 5 mg/L.

Recommendations for Computing Benefits

The studies by Anderson (1989) and Kahn and Kemp (1985) are based on very old data. (Anderson uses data from 1960 to 1980; Kahn and Kemp use data from 1969 to 1975.) It would be a mistake to assume that the relationship among catch per boat, SAV, and the number of boats in a fishery would remain unchanged or that the equation explaining the number of boats in the fishery would be unaffected by policies to manage the level of effort in Chesapeake Bay fisheries. Thus, it is necessary to estimate the models in these papers using new data. This is also true on the demand side. Although both Anderson and Kahn and Kemp allow demand to depend on income, tastes may have changed. It is imperative that demand for the main species caught in the Bay also be reestimated.

In the interim, the benefits of improving water quality in the blue crab fishery could be simulated using a model similar to that developed by Smith (2007) for the North Carolina blue crab fishery. Smith constructs a bioeconomic model of the blue crab fishery and uses it to simulate the benefits of a 30 percent reduction in N loadings.[12]The benefits of pollution reductions are measured assuming that (a) the level of effort in the fishery is restricted and (b) the fishery continues to operate as an open-access fishery. However, the speed of entry in response to an increase in yields is allowed to vary. Biologic parameters and the price elasticity of demand for crabs are also varied in the simulations. The key results are that (a) the present value of the benefits of N reductions are small (regardless of how the fishery is managed) relative to the benefits of restricting entry into the fishery and (b) the present value of the benefits of reducing N decline more rapidly with faster entry into the fishery in response to an increase in yields. The present value of benefits of a 30 percent reduction in N range from $6 to $7.5 million (2002 dollars) when entry is restricted. Under open access, they range from $0.67 to 6 million (2002 dollars), depending on the speed of entry under open access.[13]

Also note that the benefits to consumers from increases in yields are much larger than the increased profits to fishers. Consumer benefits depend on the price elasticity of demand for crabs but vary less with how the fishery is managed. When the demand for crabs is price inelastic (–0.5), the present value of benefits to consumers is about $20 million per year; the benefit is about half of this when the price elasticity of demand equals –1.0.[14]

F. Nonuse Values for Water Quality Improvements

Many people who do not use the Chesapeake Bay for recreation may value reducing pollution to the Bay to restore Bay ecosystems. This may reflect a concern for nature or a desire to preserve the Bay for future generations. A large stated preference literature asks people what they would pay in the form of taxes or higher prices to improve water quality in lakes, streams, and estuaries. In most studies, respondents are shown a water quality ladder (or index), where higher values of the index correspond to a greater ability of the water body to support various

[12] Key parameters in the model are taken from a variety of sources and are varied to allow for parameter uncertainty.

[13] Both calculations assume a discount rate of 4.5 percent.

[14] In interpreting these results,one should remember that the 2009 blue crab harvest in North Carolina (25 million pounds) was about equal to the harvest in Virginia (24 million pounds) and about 60 percent of the harvest in Maryland (40 million pounds).

forms of marine life and to permit the water to be used for boating, fishing, and swimming.[15]Respondents are asked what they would pay for higher values of the index.

The answers to such surveys may capture use as well as nonuse values. Studies estimate nonuse values by asking respondents whether they use the lake or estuary for recreation; responses of nonusers are used to estimate nonuse values for improvements in water quality. Alternatively, stated willingness to pay by all respondents may be interpreted as a measure of the total (use and nonuse) value of improving water quality. The difficulty in using studies that value changes in a water quality index lies in linking improvements in water quality, measured in terms of water clarity or DO, to the water quality index.

Chesapeake Bay Literature

Bockstael et al. (1989) report the results of a telephone survey of 959 households in the Baltimore–Washington area in which respondents were asked, "Do you consider the water quality in the Chesapeake to be acceptable or unacceptable for swimming and/or other water activities?" The 57 percent of respondents who judged the water quality unacceptable were asked whether they would pay a stated amount to restore water quality to a level acceptable for swimming. Responses were used to estimate the distribution of willingness-to-pay values, by race and by user status (i.e., whether or not the respondent used the Bay for recreation).[16]Among users, mean willingness to pay was $183 for whites and $34 for nonwhites. The corresponding figures were $48 and $9 for nonusers (1987 dollars).Applying these figures to all residents of the Baltimore–Washington metropolitan area yielded a value of approximately $100 million for the total benefits of making the Bay swimmable. The nonuse component of these benefits was approximately $28 million.

Lipton et al. (2004) interviewed more than 8,000 households in Maryland, Virginia, Delaware, New Jersey, and North Carolina via telephone to determine their knowledge of the state of oyster fisheries in the Bay. This was followed by a mail survey in which 571 respondents indicated what they were willing to pay to restore oyster beds in the Bay.[17]Median willingness to

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[15] The origin of the water quality ladder lies in the goals of the Clean Water Act—to make navigable waters "boatable, fishable and swimmable."

[16] The impact of income on willingness to pay was not estimated.The mean income of white households in the sample was $40,000; it was $25,000 for black households.

[17] As the authors emphasize, respondents in the mail survey were self-selected.The questionnaire was mailed only to those households that indicated on the telephone that they were interested in receiving the mail survey.

pay for a 10,000-acre oyster sanctuary with 1,000 acres of constructed reef was $87 dollars (2000 dollars) per household.[18]

Recommendations for Computing Benefits

There are several difficulties in using the above studies to estimate the nonuse values of achieving the Chesapeake Bay TMDLs. The main difficulty with Bockstael et al. (1989) is the nature of water quality improvement valued (making the Chesapeake Bay “swimmable”).This does not readily map to the benefits of achieving the TMDLs. A second difficulty is that the authors do not provide an estimate of how willingness to pay varies with income, which is essential if the estimates in the study are to be used to estimate willingness to pay for water quality benefits today—or in 2025.Lipton et al. (2004) is suggestive of individuals’ willingness to pay for the restoration of Bay ecosystems, but was not administered to a random sample of the population. Most importantly, the study does not value a change in water quality.

Van Houtven (2009) suggests valuing water quality improvements in the Bay using meta-analyses of stated preference studies that value improvements in a water quality index. Meta-analyses by Johnston et al. (2005) and by VanHoutven et al. (2007) convert the water quality improvements valued in individual studies into a 10-point scale, based on the Resources for the Future water quality ladder (Vaughan 1986).Willingness-to-pay estimates from individual studies are explained as a function of the size of the water quality improvement valued, the nature of the water body (river, lake, estuary, or ocean), the size of the water body, and respondent characteristics (including income and whether the respondent uses the water body for recreation).Van Houtven uses these studies to estimate the average willingness to pay by nonusers for a one-unit improvement in the National Oceanographic and Atmospheric Administration’s Assessment for Estuarine Trophic Status(ASSETS) scale (from E=1 to E=2), which he estimates to be $16–$28 (2007 dollars) per household. The drawback to the Van Houtven benefits transfer is that the water bodies valued in the meta-analyses are quite different from the Chesapeake Bay. And the one-unit improvement in the ASSETS scale results in nonuser benefits substantially less than those reported by Bockstael et al. (1989).

For these reasons, the best that can be done in the short run is to use the estimate of nonuse values from Bockstael et al. (1989), drawing estimates of the income elasticity of

[18] The authors also estimated a travel cost model to calculate the recreational fishing benefits associated with reef restoration.

willingness to pay from the meta-analyses of Johnston et al. (2005) and Van Houtven et al. (2007).However, we strongly suggest that a new stated preference study be conducted in which the water quality improvements valued would more closely match those achieved by the TMDLs.

IV. Conclusions

A. General Conclusions

This review suggests, given information on water quality levels throughout the Bay with and without the TMDLs, that it would be possible to estimate some categories of water quality benefits using the existing literature. However, for some categories of benefits, new studies will be required. Of all categories of benefits, those associated with recreational fishing and impacts on property values can be estimated with the greatest confidence. Estimating the benefits of improved water quality to commercial fisheries will require estimating equations relating catch per boat to the number of boats in the fishery and water quality, but a simulation model developed by Smith (2007) for the North Carolina blue crab fishery could be adapted to blue crab fisheries in the Bay in the near term. Nonuse value estimates can be approximated based on Bockstael et al. (1989), but we suggest that a new stated preference study be conducted to measure nonuse values. The benefits of improved water quality to swimmers are also difficult to estimate using existing studies; however, the benefits of reductions in fecal coliform counts, which may accompany the achievement of the TMDLs, can be estimated from Hicks and Strand (2000). Conclusions about the possibility of estimating different categories of benefits are summarized below.

We emphasize that, even in cases where literature exists, it will be necessary to adjust benefit estimates for future increases in income and population. Although projections of income growth exist for the Bay region, estimates of the income elasticity of benefits are not always available in either revealed or stated preference studies. For example, in some travel cost models, the marginal utility of income is assumed constant, effectively assuming that the income elasticity of recreation demand is zero. The income elasticity of willingness to pay for water quality improvements is not estimated in Bockstael et al.'s (1989) stated preference study. Estimates of income elasticities from other sources should be used to adjust benefit estimates for income growth.

To estimate future use values, estimates of the number of persons who use the Chesapeake Bay for fishing, swimming, or boating will need to be projected. These estimates will depend on income and on the pattern of population growth within the watershed. They may also depend on water quality in the Bay. We emphasize that all recreation demand studies reviewed above are based on a sample of people who participated in water-based recreation (for example, visitors to beaches along the western shore of the Chesapeake Bay).Improved water quality may affect the participation decision—the decision to visit beaches or to go fishing in the Bay at all. We found no studies that estimated the impact of water quality on the decision to engage in water-based recreation in the first place.

B.Conclusions by Category of Benefits

What follows is a short summary of our recommendations for estimating benefits, by category of benefit.

Property Values

Studies that measure the impact of N and TSS concentrations on property values in St. Mary's County, Maryland (Poor et al. 2007), and the impact of fecal coliform on property values in Anne Arundel County, Maryland (Leggett and Bockstael 2000), could be used to measure the benefits (and co-benefits) of reductions in water pollution. In the authors' judgment it is preferable to use these studies rather than studies from other states that estimate the impact of water clarity on property values. The impact of water clarity on property values in the Bay could be estimated using the Maryland Property View database and data on water clarity from the 162 monitoring stations in the Bay.

Recreational Fishing

The water quality benefits of improved recreational fishing can be estimated by measuring the impact of changes in water quality on expected catch per day and by using recreation demand models to value the increase in the expected number of fish caught. Published estimates of the impact of DO on recreational catch rates in the Chesapeake Bay or Maryland coast exist for striped bass (Lipton and Hicks 2003) and flounder (Massey et al. 2006).Unpublished estimates are available for the impact of DO and chlorophyll-ain Bay tributaries on recreational catch rates for striped bass, flounder, and bluefish (Bricker et al. 2006).The value attached by anglers to increased catch can be obtained from studies conducted in the Chesapeake Bay (Lipton and Hicks [2003] and Poor and Breece [2006]for striped bass) and from meta-analyses of studies that value increases in expected catch associated with different species (Johnston et al. 2006).The value of increased recreational catches should be adjusted for income growth.

Swimming

A travel cost study by Hicks and Strand (2000) that estimates the value to swimmers of reducing fecal coliform levels at beaches in Maryland could be used to value the possible co-benefits of achieving the TMDLs. Bockstael et al.'s (1989) study relating TNP to beach visits is limited by the use of TNP as a pollution measure. The study suggests, however, that benefits to swimmers are large relative to benefits to boaters and recreational striped bass fishers. This highlights the value of conducting new studies of the benefits of water clarity to beachgoers in the Chesapeake Bay.

Boating

Lipton (2004) provides estimates of boaters' willingness to pay for improvements in water quality on a five-point water quality ladder. This study could be used to estimate the benefits of improvements in water quality resulting from the TMDLs if the water quality ladder could be translated into the index used in the survey. As in the cases of other recreational benefits, adjustments should be made to values to reflect income growth.

Commercial Fishing

A simulation model of the North Carolina blue crab fishery developed by Smith (2007) could be adapted to the Maryland and Virginia blue crab fisheries. Studies that estimate the impact of SAV on blue crab harvests in Virginia (Anderson 1989) and on striped bass in the Bay (Kahn and Kemp 1985) are out of date, and the Mistaien et al. (2003) study, which estimates the short-run impacts of DO on crab fishers, cannot be used to estimate the benefits of increases in DO above 5 mg/L. Given the results of previous studies, it is especially important to estimate the benefits to consumers of increased yields. These are likely to be at least as large as the benefits of increased yields to fishers.

Nonuse Values

The value of improving Bay water quality to nonusers of the Bay could be estimated in the near term using values estimated by Bockstael et al. (1989), adjusted for income growth. However, we strongly suggest that a new stated preference study be conducted to elicit willingness to pay for water quality improvements more closely linked to the TMDLs.

C. Some Concluding Thoughts

In estimating the benefits of the Chesapeake Bay TMDLs, priority should be given to the benefit categories that will yield the largest monetary benefits. The literature reviewed suggests that the largest categories of benefits are likely to be nonuse benefits, benefits reflected in property values, and benefits to recreational fishers and swimmers.

How the TMDLs are achieved is also important, as there are likely to be significant co-benefits associated with some control measures. Reductions in fecal coliform associated with improved agricultural practices or reduced CSOs will yield water quality benefits that can be evaluated using Leggett and Bockstael (2000) and Hicks and Strand (2000).There will also be significant co-benefits associated with reductions in atmospheric sources of N. Although reductions in N to be achieved under the Clean Air Act (CAA) do not count toward achieving the TMDLs, reductions in air emissions beyond what is required by the CAA do count, and are likely to yield significant health benefits through reductions in fine particles and ground-level ozone concentrations.[19]

In addition, achieving the TMDLs will yield significant upstream benefits in the form of improved water quality in tributaries to the Chesapeake Bay. These will yield recreational benefits as well as nonuse values. It is beyond the scope of this paper to review the literature on the benefits of reduced eutrophication in tributaries to the Bay. As Van Houtven and Clayton (2008) note, few studies have been conducted in the Chesapeake Bay watershed per se;[20] however, there are opportunities for transferring studies from other areas to the Bay to measure benefits.

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[19]As stated in the Maryland Watershed Implementation Plan (p. ES-8): "Reductions of atmospheric deposition from implementation of the federal Clean Air Act were 'taken off the top' before states were given their allocations by [the U.S. Environmental Protection Agency]. Maryland will separately take credit for the Healthy Air Act and adoption of the California low emission vehicle standards."

[20]A notable exception is von Haefen's (2003) study of the benefits of reduced eutrophication in the lower Susquehanna River.

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Tables

Table 1. Chesapeake Bay Property Value Studies

Study name	Geographic focus	Valuation method	Description	Measure of environmental quality	Value of benefits/loss (2010 dollars)
Leggett and Bockstael (2000)	Chesapeake Bay (Anne Arundel County, MD)	Hedonic property value	Estimates effect of FC levels on property values along the Chesapeake Bay	FC	Estimated $15.1 million for reduction in FC levels to 200 mg/L (Anne Arundel County)
Poor et al. (2007)	St. Mary's River watershed, adjacent to Chesapeake Bay	Hedonic property value	Estimates effect of differences in DIN and TSS levels on home values	DIN and TSS	Estimated decline of $1,140 in average housing price for 1-mg/L increase in DIN; decline of $18,530 in average housing price for 1-mg/L increase in TSS
Van Houtven (2009)	Chesapeake Bay (MD,VA,DC)	Benefits transfer	Uses Poor et al. (2007) to estimate benefits of reduced DIN along MD and VA portions of the Bay	DIN	Between $38.7 and $102.2 million in annual benefits to owner-occupied homes in Chesapeake Bay coastal areas

*Notes:*DIN, dissolved inorganic nitrogen;FC, fecal coliform; TSS, total suspended solids.

Table 2. Chesapeake Bay Recreation Activity Studies

Study name	Geographic focus	Valuation method	Description	Measure of environmental quality	Value of benefits/loss (2010 dollars)
Bockstael et al. (1988,1989)	Chesapeake Bay (MD)	Travel cost model	Estimates welfare effects of changes in TNP (and catch rates) in the Bay for different samples of recreational boaters, beachgoers, and fishers	TNP	Average of $77.1 million in recreational activity benefits annually for a 20% improvement in TNP and catch rate (Maryland residents only)
Krupnick (1988)	Chesapeake Bay (MD,VA)	Benefits transfer	Adapts and transfers results from Bockstael et al. (1988) to estimate Baywide benefits of the 1987 Chesapeake Bay Agreement.	TNP	Average of $103.9 million in recreational activity benefits annually for a 40% improvement in TNP and 20% in catch rate (MD,VA)
Lipton and Hicks (1999)	Chesapeake Bay (MD, VA)	Travel cost model	Measures effects of DO levels on striped bass catch rates and recreational consumer surplus	DO	$9.1 million in annual benefits for DO levels remaining above 3 mg/L(Chesapeake Bay and tributaries)
Hicks and Strand (2000)	Chesapeake Bay (MD)	Travel cost model (RUM)	Measures welfare effects of reduction in FC levels for the Chesapeake Bay area beaches	FC	Average of $3.05 per trip for 40% reduction in FC (Maryland residents only)
Morgan and Owens (2001)	Chesapeake Bay (MD,VA,DC)	Benefits transfer	Adapts and transfers results from Bockstael et al. (1988) and Krupnick (1988) to estimate Baywide benefits of large-scale changes in nutrient levels	TNP	Average of $1.25 billion annually for a 60% improvement in TNP (Chesapeake Bay proper)

Table 2. Chesapeake Bay Recreation Activity Studies, Continued

Study name	Geographic focus	Valuation method	Description	Measure of environmental quality	Value of benefits/loss (2010 dollars)
Lipton and Hicks (2003)	Patuxent River, MD	Travel cost model (RUM)	Measures effects of DO levels on striped bass catch rates and recreational consumer surplus	DO	$11,600 in annual damages when DO is constrained to 3 mg/L (Patuxent River, MD)
Lipton (2004)	Chesapeake Bay	Contingent valuation	Measures WTP by recreational boaters in the Bay for a one-unit improvement in general water quality (on a five-point subjective scale)	WQI	$7.3 million in annual benefits for one-step increase in water quality (Chesapeake Bay and tributaries)
Massey et al. (2006)	MD Coastal Bays	Bioeconomic model; travel cost model (RUM)	Measures dynamic interrelationships between DO, summer flounder stocks, catch rates, and recreational fishing preferences	DO	Average of $772,057 for 25% increase in DO levels in the MD Coastal Bays
Van Houtven (2009)	Chesapeake Bay (MD,VA,DC)	Benefits transfer	Estimates benefits of reduced nutrient deposition on various recreation services associated with the Chesapeake Bay—boating, beach use, and fishing—using Lipton (2004), Bockstael et al. (1989), and Lipton and Hicks (1999, 2003)	DO; WQI; TNP	$37.2 million in annual benefits for MD and VA striped bass anglers for a 2.41-mg/L decrease in DO (surface and bottom); $8.2 million in annual benefits for a one-unit increase in WQI for DC, MD, and VA boat owners in the Chesapeake Bay; $124 million in annual benefits for a 24% decrease in TNP for DC, MD, and VA beachgoers in the Chesapeake Bay

Notes: DO, dissolved oxygen; FC, fecal coliform; RUM, random utility model; TNP, total nitrogen and phosphorous; WQI, water quality index; WTP, willingness to pay.

Table 3. Chesapeake Bay Commercial Fishing Studies

Study name	Geographic focus	Valuation method	Description	Measure of environmental quality	Value of benefits/loss (2010 dollars)
Kahn and Kemp (1985)	Chesapeake Bay (MD,VA)	Bioeconomic model	Measures welfare effects of changes in SAV levels on commercial striped bass fishing	SAV	$26.4 million in annual damages for an 80% decrease in SAV (Chesapeake Bay proper)
Anderson (1989)	Chesapeake Bay (VA)	Dynamic market simulation model	Measures effects of SAV restoration on market surplus from hard-shell blue crab.	SAV	Estimated $8.04 million in net benefits annually for full recovery of SAV abundance to 1960 levels (VA Chesapeake only)
Mistiaen et al. (2003)	MD tributaries (Patuxent, Chester, Choptank) to Chesapeake Bay	Bioeconomic model	Estimates short-run effects of changes in DO (below 5 mg/L) on blue crab trotline fishery	DO	$269,539 in annual damages when DO falls below 4 mg/L (Patuxent River, MD)

Notes: DO, dissolved oxygen; SAV, submerged aquatic vegetation.

Table 4. Chesapeake Bay Nonuse Benefits Studies

Study name	Geographic focus	Valuation method	Description	Commodity valued	Value of benefits/loss (2010 Dollars)
Bockstael et al. (1988,1989)	Chesapeake Bay (MD)	Contingent valuation	Estimates willingness to pay to make Bay swimmable	Making the Bay "swimmable"	Average aggregate benefits of $44.6 million annually for swimmable water quality (Washington–Baltimore area nonusers)
Krupnick (1988)	Chesapeake Bay (MD,VA)	Benefits transfer	Adapts and transfers results from Bockstael et al. (1988) to estimate Baywide benefits of the 1987 Chesapeake Bay Agreement	Making the Bay "swimmable"	Average aggregate benefits of $85.3 million annually for swimmable water quality (MD, VA, and DC nonusers)
Lipton et al. (2004)	Mid-Atlantic Region (MD, VA, DE, NC, NJ)	Contingent valuation	Estimates the net economic benefits of oyster reef restoration in the Chesapeake Bay to nonusers	Restoration of oyster reef acreage	Estimated annual aggregate benefits of$131.5 million to Mid-Atlantic nonusers (MD,VA,DE,NC,NJ households) for a 10-year oyster reef project of 10,000 acres
Van Houtven (2009)	Chesapeake Bay (MD,VA,DC)	Benefits transfer	Estimates benefits of increase in WQI using Van Houtven et al. (2007) and Johnston et al. (2005)	WQI	$159.1 million in annual benefits for one-unit increase in WQI for DC, MD, and VA nonusers

Notes: WQI, water quality index.

Appendix

Table A-1.Virginia County Tax Assessment Data Availability

County	Property data location
Accomack	http://www.co.accomack.va.us/Assessment/Assessment.html
Alexandria*	http://alexandriava.gov/realestate/default.aspx
Arlington	http://www.arlingtonva.us/departments/realestate/reassessments/scripts/dreadefault.asp
Chesapeake*	http://www.chesapeake.va.us/services/depart/planning/index.shtml
Fairfax	http://icare.fairfaxcounty.gov/Search/GenericSearch.aspx?mode=ADDRESS
Gloucester	N/A
Hampton*	http://www.hampton.gov/ed/property/property_search.html
Isle of Wight	http://va-isleofwight-county.governmax.com/svc/default.asp?sid=A7226A6F24844986BA653D1F0E0460F9
James City	http://property.jccegov.com/parcelviewer/
King George	N/A
Lancaster	http://www.lancova.com/GIS/map.asp?agree=yes
Mathews	http://www.emapsplus.com/vamathews/maps/
Middlesex	N/A
Newport News*	http://www.nngov.com/assessor/resources/reis
Norfolk*	http://www.norfolk.gov/receivable/
North Cumberland	http://www.northumberlandco.org/default.asp?iId=MDDFE
Northampton	http://www.co.northampton.va.us/gov/real_estate.html
Portsmouth*	http://www.portsmouthva.gov/assessor/data/
Prince William	http://www04a.pwcgov.org/realestate/LandRover.asp
Stafford	N/A
Suffolk*	http://www.suffolk.va.us/realest/
Surry	http://www.surrycountyva.gov/departments/page/real-estate
Virginia Beach*	http://www.vbgov.com/e-gov/emapping/access/default.asp
Westmoreland	http://www.westmoreland-county.org/index.php?p=govt&c=publicRecords
York	http://www.yorkcounty.gov/Default.aspx?tabid=3626

* Indicates independent cities.

Table A-2.Chesapeake Bay Watershed State Beach Attendance, 2010

Park name	Total visitors	Day-use attendance
Calvert Cliffs (MD)	51,875	45,440
Elk Neck (MD)	279,483	224,977
First Landing (MD)	1,706,259	1,590,074
Gunpowder Falls (MD)	342,861	342,795
Hart-Miller (MD)	261,247	260,455
James Island (MD)	91,821	68,698
North Point (MD)	117,998	117,998
Point Lookout (MD)	370,416	342,724
Sandy Point (MD)	812,379	809,607
Kiptopeke (VA)	454,479	390,055
Westmoreland (VA)	123,486	50,770

Sources: Virginia Department of Conservation and Recreation; Maryland Department of Natural Resources.