Benefits of Improved Water Quality in the Delaware River Basin

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Abstract: The Delaware River has made a measureable recovery in the half-century since the authorization of the Delaware River Basin Commission Compact in 1961, EPA in 1970, and Federal Clean Water Act Amendments during the 1970s. A first-of-its-kind 1966 benefit-cost analysis by the Federal Water Pollution Control Administration concluded that a multi-million-dollar per year waste load abatement program to raise dissolved oxygen to boatable and fishable standards in the Delaware River would generate up to $350 million in annual benefits in $1964. While the Delaware has made one of the most extensive recoveries of any estuary in the world, scientists have called for raising the 1967 DO standard of 3.5 mg/l to a higher level of protection to provide for year-round protection of anadromous fish such as the recovering American shad and nearly extirpated Atlantic sturgeon. A more rigorous standard would also mitigate atmospheric warming that increases water temperatures, sea levels, and chloride levels that reduce DO saturation. This economic valuation research concludes that the benefits of improved water quality by increasing dissolved oxygen from existing criteria of 3.5 mg/l to a future DRBC year-round fishable standard of 5.0 mg/l in the Delaware River range from a low bound of $371 million to an upper bound of $1.1 billion annually. Recreational boating provides the greatest benefits ($46-$334 million) followed by recreational fishing ($129-$202 million), agriculture ($8-$188 million), nonuse value ($76-$115 million), viewing/boating/fishing ($55-$68 million),bird watching ($15-$33 million), increased property value ($13-27 million), municipal water supply ($12-$24 million), commercial fishing ($0-$17 million), and navigation ($7-$16 million). Future research would be useful to more precisely measure nonuse benefits through a stated preference survey to measure public willingness to pay for improved water quality in the Delaware River watershed.

1. Introduction

The Delaware River (Figure 1) has a long history of nutrient pollution (Sharp, Culberson, and Church 1982) but the estuary has recovered considerably in the last few decades largely due to restoration by the Delaware River Basin Commission (DRBC), Environmental Protection Agency, and the states (Bricker et al. 2007, Bain et al. 2010, and Sharp et al. 2009). Reconstruction of a century-long dissolved oxygen record (Figure 2) indicates the Delaware River has made one of the most extensive recoveries of any estuary in the world (Sharp 2010). While water quality has markedly improved in the Delaware Estuary since John F. Kennedy signed the 1961 DRBC Compact, DO levels still do not fully meet DRBC criteria (3.5 mg/l) during the summer when water temperatures rise close to 30°C (86°C) and DO saturation plunges below 50%. Scientists have concluded the DO criteria of 3.5 mg/l is not adequate to sustain anadromous fish such as Atlantic sturgeon and American shad (Ad-Hoc Task Force 1979, Delaware River Fish and Wildlife Management Cooperative 1982, Secor and Gunderson 1998, Campbell and Goodman 2004). The DRBC has discussed setting more protective DO criteria in the tidal Delaware River (to at least 5 mg/l) to sustain year-round propagation of anadromous fish and account for atmospheric warming and rising sea levels that increase water temperatures and salinity in the estuary. While recovery has been extensive, little is known about the modern economic benefits of pollution control efforts to improve water quality in the Delaware River and its tributaries.

2. Research Objective

The objective of this research is to estimate the economic benefits of pollution reduction strategies to restore the Delaware River and its tributaries to more protective year-round fishable water quality criteria in accordance with Federal, state, and Delaware River Basin Commission clean water standards.

3. Delaware River Basin

The Delaware River is the longest undammed river east of the Mississippi, extending 390 miles (628 kilometers) from the Catskill Mountains in New York to the mouth of the Delaware Bay at Cape May, New Jersey. The river is fed by 216 streams including the two largest tributaries - the Schuylkill and Lehigh River - and drains 13,539 square miles (35,077 square kilometers) in Pennsylvania (51% of the basin), New Jersey (23%), New York (18%), and Delaware (8%) and a small sliver of Maryland. The Delaware Basin covers just 0.4% of the continental U.S. yet supplies drinking water to 5% of the population and the 1st (New York City) and 7th largest (Philadelphia) metropolitan economies in the nation (Kauffman 2010). Over 16 million people rely on the Delaware Basin for drinking water including 8.2 million people who live in the basin and 8 million people who live outside the basin in New York City and central New Jersey. Between 2000 and 2010, the basin population increased by a half million people, or equal to the cities of Camden, Easton, Trenton, and Wilmington. The Delaware River watershed supports $21 billion in ecosystem goods and services and over 500,000 direct/indirect jobs in Delaware, New Jersey, New York, and Pennsylvania (Kauffman 2016).

Nutrient and DO levels are influenced by the freshwater flow balance in the Delaware Estuary. The freshwater Delaware Estuary extends 45 miles from the head of tide at Trenton to the Schuylkill below Philadelphia (Sharp 2006). High nutrient loads that flow from urban tributaries near Philadelphia, and rural agricultural streams along the bay are diluted by the large volume of saltwater as the bay widens and salinity increases toward the mouth of the Delaware Bay. Recirculation in the Delaware Estuary occurs once every 8 days with half mixing with freshwater from the Delaware River at Trenton, the Schuylkill, and other tributaries and the other half from the Atlantic Ocean through the bay mouth (Bricker et al. 2007). The estuary is relatively turbid with a light extinction coefficient from 0.3 to 7.0 (Roman et al. 2000). According to USGS stream gages, the basin's four largest rivers (Delaware, Schuylkill, Lehigh, and Brandywine-Christina) supply 93% of the freshwater to the Delaware Estuary.

The DRBC (2010) classifies the Delaware River/Bay by five non-tidal and five tidal water quality zones based on designated uses such as (1) Water Supply, Agricultural, Industrial, Public, (2) Wildlife, Fish and Aquatic Life, (3) Recreation (Primary Contact Swimming/Secondary Contact Boating, Fishing, Wading, (4) Navigation, and (5) Waste Assimilation. In the freshwater river above Trenton, 24 hour DO criteria vary from 6 mg/l and 7 mg/l for trout production at Narrowsburg-Hancock, New York to 5 mg/l between Narrowsburg and Trenton. In the tidal Delaware below Trenton, DO criteria range between 5 mg/l at Rancocas Creek (RM 108), 3.5 mg/l at Delaware Memorial Bridge, 4.5 mg/l at C&D Canal, to 6 mg/l near to the Atlantic Ocean. The DO criteria is 6.5 mg/l during spring/fall from Trenton downstream to the C&D Canal for seasonal propagation of resident and anadromous fish.

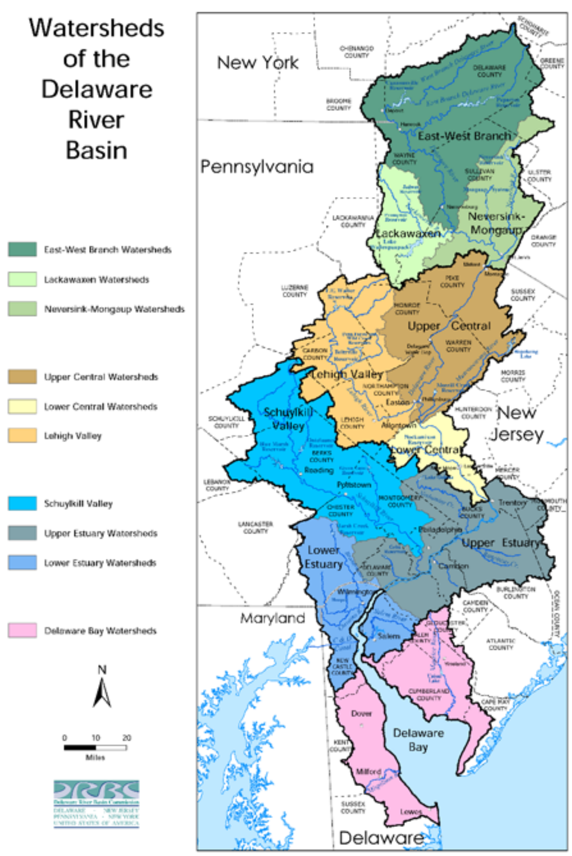

Figure 1. The Delaware River Basin (DRBC 2010)

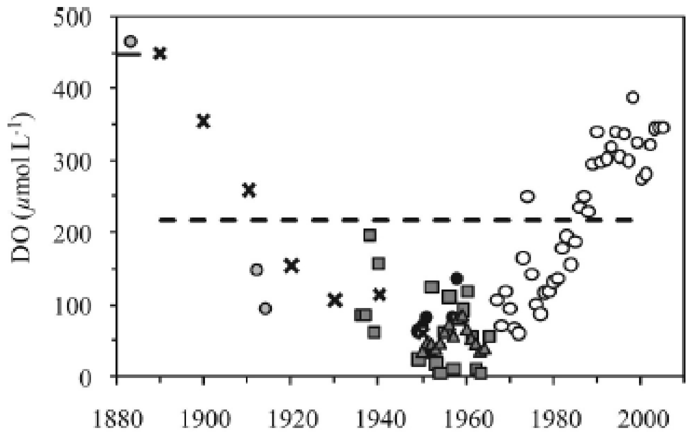

Figure 2. Dissolved oxygen in the Delaware River near Philadelphia from 1880 to present (Sharp 2010)

The Federal Water Pollution Control Administration (1966) reported that the Delaware Basin was the only watershed in the U.S. empowered by Federal/State law (the DRBC Compact) to implement regional, interstate water quality management. The FWPCA report described the Delaware River at Philadelphia as “a polluted waterway which depresses aesthetic values, reduces recreational, sport and commercial fishing, and inhibits municipal and industrial water uses.” This Delaware Estuary study was one of the first river basin economic analyses in the U.S. (Schaumburg 1967) and the report concluded the recreational benefits of swimming, boating, and fishing due to improved water quality in the Delaware Estuary would be substantial and ranged from $120-$280 million to meet DO criteria of 2.5 mg/l to $160-$350 million to meet DO criteria of 4.5 mg/l (Table 1). Marginal benefits were greatest for Objective Set II (DO = 4.0 mg/l) and ranged from $20-$30 million.

Table 1. Recreational benefits of improved water quality in the Delaware Estuary in $1964 (FWPCA 1966 and Thoman 1972)

Objective	**DO Summer (mg/l)**	**BOD/COD Residual (lb/day)**	**% Pollution Removal**	**Total Benefits ($ million)**	**Marginal Benefits ($ million)**
I	4.5	100,000	92%-98%	160-350	
II	4.0	200,000	90%	140-320	20-30
III	3.0	500,000	75%	130-310	10-10
IV	2.5	500,000	50%	120-280	10-30
V	0.5	status quo		0	0

During the 1960s, a few years before the 1970 birth of EPA and Congress passed the 1972/1977 Clean Water Act amendments, the DRBC was among the first in the U.S. to establish water quality standards on a watershed basis (Albert 1988). In January 1967, a DRBC water advisory committee of public, industry, government, recreation, conservation, and fish/wildlife stakeholders examined the FWPCA benefit-cost analysis to establish a water quality standard. Municipal/industrial interests recommended adopting Objective III (3.0 mg/l) with highest net benefits of $130 million (Figure 3). Conservationists and local officials recommended that DRBC adopt Objective II (4.0 mg/) as a more protective with the highest marginal benefits ($20-$30 million). Over 50 people testified at the hearings and the public debate was hailed as progressive for the time. In 1967, the DRBC adopted a combination of Objective Sets III (3 mg/l) and II (4 mg/l) as most cost-effective and as a compromise set a summer 24 hour DO criteria of 3.5 mg/l for the Delaware Estuary water quality zones near Philadelphia.

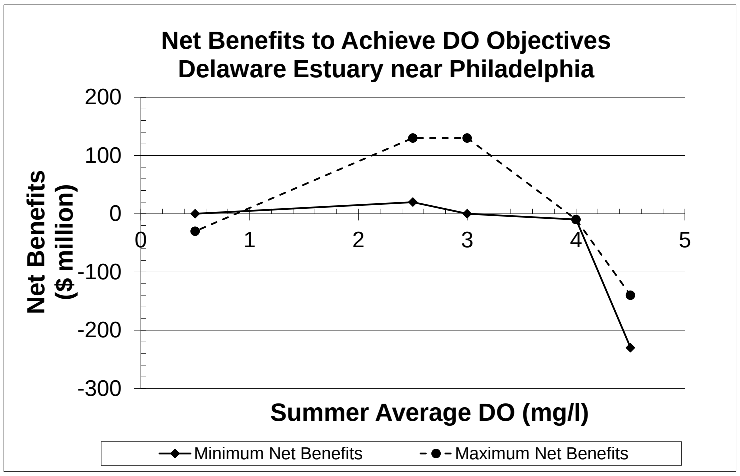

Figure 3. Net benefits to achieve DO objectives in Delaware Estuary near Philadelphia (FWPCA 1966, Kneese and Bower 1984)

In 2015, the Partnership for the Delaware Estuary Science and Technical Advisory Committee (STAC) advised the DRBC that the current DO criteria of 3.5 mg/l is too low to support year-round survival and growth of anadromous fish such as the American shad and juvenile sturgeon and recommended that the standard should be raised to a more protective level. A watershed program that reduces nutrient pollution would improve water quality and boost the tourism, fishing/hunting/bird watching, recreation, real estate, and water supply economies that depend on clean water. This research seeks to quantify the economic benefits of a Delaware River watershed restoration program that would reduce pollutant loads and improve water quality to a higher, more protective DRBC DO standard.

4. The Economic Approach

The concept of placing a dollar value on a natural resource goes back a century to economists Arthur Pigou in 1920 and John Hicks in 1939 who first outlined that individual preferences are based on individual willingness to pay for benefits (Kramer 2005). Willingness to pay for improved water quality in the Delaware River was first established for industrial, municipal, and recreational fishing, boating, and swimming uses during the 1960s (Hjalte et al. 1977). A half century ago, the Harvard Water Program (1971) advocated planning and design of water resources projects based on optimizing social, environmental, and economic costs/benefits (Maass et al. 1962, Dorfman et al. 1972),

Economic benefits are the maximum dollar value of goods and services that individuals are willing to pay (WTP) for improved water quality (Cech 2005). In environmental economics, WTP measures how much people are willing to pay for a given good or service regardless of whether they actually pay or not (Goulder and Kennedy 1997). Consumer surplus is the area under the demand (marginal benefit) curve above its price (or value) measured by the amount people are willing to pay for clean drinking water or enhanced fishing above the price they currently pay for it (Thurston et al. 2009). Marginal benefits are defined as the incremental change in value resulting from an improvement in an ecosystem service such as water quality (Dixon et al. 1994). The downward sloping demand curve traces marginal benefits (Figure 5) as the WTP for an additional unit of water quality (Koteen et al. 2002).

The benefits of improved water quality in river systems are difficult to assess due to externalities, the free rider effect, and lack of property rights. If the Delaware River is polluted by an upstream industrial discharge, then downstream residents in Philadelphia may be harmed by this negative externality because they are not compensated for impaired drinking water quality or reduced boating and fishing activity. A free rider is an individual such as a canoe livery that benefits from a public good such as improved water quality but does not pay to protect the watershed (Thurston et al. 2009). In contrast to land where property is bought and sold in the real estate market, water rights are not clearly asdefined and water flow may be overused with no incentive to conserve it (Libecap 2005).

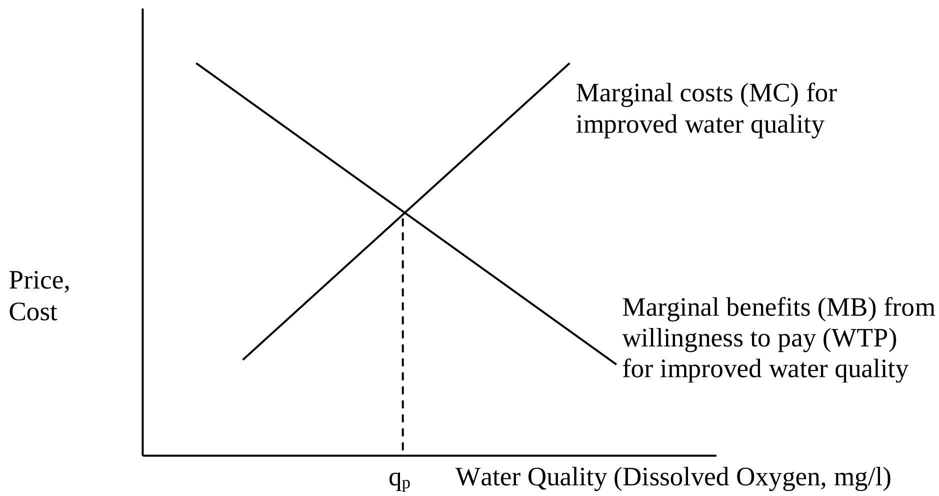

Figure 5. Optimal water quality (Hjalte et al. 1977)

Ecological valuation studies have found the benefits of improved water quality in the U.S. ranges from $0.8 to $42.3 billion per year (Table 2). Water pollution control programs authorized by the 1970s Clean Water Act Amendments have improved water quality with annual national benefits of $11 billion (Bingham et al. 2000). The gross domestic product (GDP) in 2004 for coastal and estuary tourism and recreation goods/services was $69.7 billion (Pendleton undated). Millions of jobs in the fishing, shipping, tourism, and transportation industries rely on coastal and estuary water resources according to the U.S. Bureau of Labor Statistics (NOEP 2010).

Table 2. Economic benefits of improved water quality in the United States

Location	Reference	Benefits ($ billion/yr)	Comments
U.S.	Freeman 1990	5.2	Water treatment/commercial fishing
Urban U.S.	EPA 1994	0.8-6.0	Pres. Clinton's Clean Water Initiative
U.S.	Bingham 1995	11.0	Clean Water Act of 1972/1977
U.S.	Carson & Mitchell 1993	39.1	WTP for boatable, fishable, swimmable
U.S.	Freeman 1982	39.6	1972 Clean Water Act base
Lower 48 states	Brown 2004	42.3	U.S. Forest Service value of streamflow
Oregon, Willamette R.	EPA 2002	0.12-0.26	Boatable, fishable, swimmable benefits

5. Methods

This analysis estimates the economic benefits of improved water quality in the Delaware Basin. Nitrogen load reductions are projected to increase dissolved oxygen levels from existing criteria (3.5 mg/l) to a future, more protective DRBC standard (5 mg/l) in the Delaware River that, in turn, would boost boating/fishing trip expenditures, raise property values, and reduce water treatment costs. This research estimates use and nonuse benefits (Hodge and Dunn 1992) of improved water quality in the Delaware River based on market and nonmarket valuation methods (Table 3). Use values include recreation (boating, fishing, and swimming), aesthetic (viewing), commercial fishing, hunting, navigation, water supply, and property ownership benefits. Nonuse values include existence and bequest benefits based on willingness to pay for improved water quality for existing/future generations.

This research conducts an analysis of benefits (U.S. Water Resources Council 1983, Lyon and Farrow 1995) of pollutant load reductions needed to improve water quality and meet a more protective DRBC DO standard to provide year-round propagation of diadromous fish in the tidal Delaware River. Use values are estimated for: (1) boating, fishing, bird/wildlife watching recreation from net factor income, productivity, and travel cost methods (Bockstael et al. 1989, Cordell et al. 1990, Leggett and Bockstael 2000, Johnston et al. 2002, EPA 2000, Leeworthy and Riley 2001, NOEP 2010, Griffiths et al. 2012), (2) commercial fishing using market price method from National

Marine Fisheries Service, (3) water supply (municipal/industrial) using market price and productivity methods due to decreased treatment costs, (4) viewing/aesthetics from willingness to pay and contingent valuation methods, and (5) increased property value using hedonic pricing methods for river-side parcels (EPA 1973). Nonuse benefits of existence and bequest values are from stated preference, contingent valuation surveys (Carson and Mitchell 1993).

Table 3. Benefits of improved water quality
(Carson and Mitchell 1993, EPA 2012, WBCSD 2011)

Benefit	Category	Examples	Method
Use	Recreation	Increased boating, fishing, swimming expenditures	Travel Cost
	Aesthetic/Viewing	Commuting, hiking, picnicking, photography	Travel Cost
	Fishing	Commercial	Market Price
	Water Supply	Lowered municipal/industrial water treatment costs	Avoided Cost
	Property Value	Increased river-side property value	Hedonic Price
	Ecosystem	Boating, fishing, bird watching, waterfowl Hunting	Travel Cost
	Navigation	Reduced dredging costs	Avoided Cost
Nonuse	Existence	Relatives, friends, American public	Contingent Valuation
	Bequest	Family, future generations	Contingent Valuation

The economic benefits from improved water quality are defined by the sum of use and nonuse values (Figure 6). Use values include direct market benefits such as sales of fish and drinking water and increased trip and equipment expenditures for recreational viewing, boating, fishing, and hunting (Hodge and Dunn 1992, Kramer 2005). Market benefits are derived from the price of goods and services by the sale of fish by commercial fisheries or purchase of drinking water by the public. Travel cost methods reveal use benefits from increased recreational participation in outings, boating, fishing, swimming, and bird/wildlife viewing that result in trip and equipment expenditures (Freeman 2003). Hedonic models indirectly reveal benefits by measuring increased waterfront property value due to improved water quality. Indirect use benefits may accrue from the increased value of properties along a restored river and waste treatment services by wetlands and forests (EPA 2012).

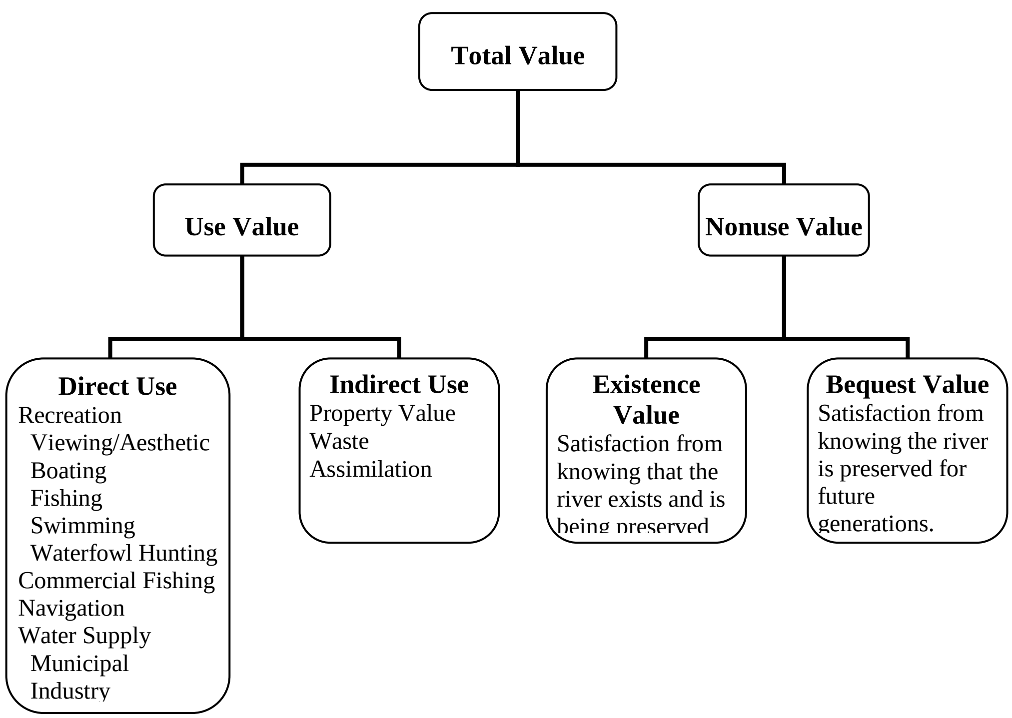

Figure 6. Economic benefits of improved water quality in the Delaware Basin

Nonuse values are defined as WTP to improve water quality and include existence values from the satisfaction that a water resource exists and is protected but may never be visited and bequest values from the satisfaction that the river will be preserved for future generations (Ingraham and Foster 2008). Nonuse values include existence and bequest values from stated preference studies and contingent valuation surveys that ask people how much they would be willing to pay for improved water quality for a river that they care about and may or may not visit (Krutilla 1967). Existence value is the satisfaction that people have knowing that the river exists and is being preserved even if they will never see it or use it (Freeman 2003). Bequest value is the value that people place on knowing the river is protected so future generations may enjoy it.

Benefit-cost analyses that rely solely on use benefits may underestimate total benefits because nonuse values can be significant (Loomis 2006). Because nonuse values rely on individual opinions or stated preferences and not hard market data, they are hard to precisely quantify yet contribute to a large portion of total benefits (Brown 2004). Nonuse values can be substantial because as University of Maryland economist Doug Lipton (2003) has observed "If everyone in the watershed has a small value for the restoration of the Bay, it ends up being a big number." Nonuse benefits were allowed in court to settle the 1989 Exxon Valdez oil spill in Alaska and can significantly exceed use (market) values but are difficult to quantify (Brown 2004).

If primary valuation data collected in the Delaware Basin were not available, then benefits transfer is utilized to translate data from other watersheds. Benefits transfer extrapolates benefits compiled from studies in other sites to the watershed in question with appropriate adjustments (EPA 2010). Benefits transfer is relatively inexpensive to implement, however, it must be applied carefully to avoid double-counting of benefits (Table 4). Benefits transfer is most reliable when: (1) the original site and watershed study site are similar in location and population characteristics, (2) water quality change is similar for the two sites, and (3) the original study used sound valuation techniques (WBCSD 2011). Benefits transfer is often used when too costly to conduct an original valuation study, yet measures of benefits are needed. EPA (2010) employs benefits transfer to estimate nonmarket benefits of proposed Federal Clean Water Act regulations. While it has shortcomings, benefit transfer is employed here to estimate benefits of improved water quality in the Delaware River by applying WTP data from similar watersheds.

The first step in benefits transfer is to identify existing study values that can be utilized for the site in question (EPA 2010). The second step is to decide whether existing values are transferable based on several criteria. Is the benefit valued comparable to the value in the existing studies? The third step is to evaluate the quality of transferred studies. If the quality of the initial study is good, then the transferred value will be more accurate. The final step is to adjust original values to reflect the characteristics of the study site. Due to uncertainty in the selection of parameters and transferring data to the Delaware River, lower and upper bound benefits are defined based on the population in the basin who benefit, assuming a range in the percent change in benefit due to improved water quality, and selecting low and high range unit values (WTP in $/person). Benefits are converted to 2010 dollars based on the average annual change (2.6% rounded to 3%) in the Consumer Price Index (CPI) in the Northeast Region from 1991-2010 as reported by the Bureau of Labor Statistics.

Table 4. Strengths and weaknesses of the benefits transfer approach (EPA 2010 and WBCSD 2011)

Strengths	**Weaknesses**
Relatively inexpensive and quick to implements	Must be applied transparently to avoid double counting
Most reliable when original site and study site are similar.	Benefits transfer only as good as the original study site
Used when too expensive or not enough time to conduct original valuation study for watershed	Higher degrees of uncertainty

The economic benefits of improved water quality for recreational boating, fishing, bird watching, waterfowl hunting, and beach going are estimated using a five-step approach. First, determine the number of visitors who participate in recreational activities in each state in the Delaware Basin. Second, scale statewide estimates of recreational participants to the watershed level by proportion of population and/or land area within each state. Third, review the literature to obtain unit day values per person for each recreation activity. Fourth, estimate the existing value of each activity by multiplying the unit day value by the number of recreation visits. Fifth, estimate the benefits by multiplying existing value by a percentage change in value due to improved water quality.

Travel cost models are employed to estimate the benefits of improved water quality to go from nonsupport (impaired) to viewing, boatable (3.5 mg/), and fishable (5.0 mg/l) uses in the Delaware River. Swimmable benefits are not considered as very few safe opportunities for swimming exist along the Delaware River due to strong tidal currents, lack of accessible beaches, and high bacteria levels that exceed DRBC primary contact recreation criteria (100#/100ml). Annual recreation benefits to achieve boating and fishing water quality are estimated by selecting per person values from travel cost studies and multiplying by the U.S. Census adult population (>18 yr old).

The Delaware River supports recreation where people go to view wildlife and birds, photograph scenery, boat, fish, and hunt waterfowl. Improved water quality increases user participation for recreational boating, fishing, swimming, waterfowl hunting, bird watching, photographing, and sailing. The enhanced recreational trip experience increases the value of trips and participation by visitors. The unit day value method estimates the value of recreation due to improved water quality by multiplying the number of visitor days by the unit value ($/day) of a recreation day. Recreation benefits of improved water quality are measured by the increase in the number of activity days by participants at the river. An activity day is "equal to one person doing an activity or visiting any setting for any part of a day" (Leeworthy and Wiley 2001). The unit day value method estimates the value of recreation due to improved water quality by multiplying the number of visitor days by the unit value ($/day) of a recreation day.

Markets do not adequately define economic benefits of improved water quality, therefore, environmental economists have defined nonmarket stated preference and revealed preference methods such as travel cost, hedonic pricing, and contingent valuation (Wilson and Carpenter 1999 and World Business Council for Sustainable Development 2011). Stated preference methods measure the economic value that individuals indicate they would assign to nonmarket ecosystem services (Kramer 2005). The stated preference approach includes the contingent valuation (CV) method that asks people how much they would be willing to pay for improved water quality for viewing, boating, fishing, and swimming (Emerton and Bos 2004 and Thurston et al. 2009). The utility of the contingent valuation method is often debated by economists because it is based on what people say they would pay (their stated preference), as opposed to what people actually pay (their revealed preference). Some economists are critical of CV because the surveyed individuals are stating willingness to pay even if they never do pay instead of buying or selling a good with real money based on the market price.

Revealed preference methods estimate the increased sale or purchase of goods or reduced costs that result from improved water quality and include the market price, productivity, damage cost avoided, travel cost, and hedonic pricing methods (Table 5). The market price method directly measures the higher prices of water resources good and services such as commercial fish or water purchased by consumers. The productivity method estimates economic value derived from improved water quality that results in decreased municipal water treatment costs or enhanced fishing productivity that boosts fishing jobs and wages. The damage cost avoided method estimates savings from ecosystems such as forests that provide water filtration benefits would need to be replaced by expensive water treatment plants (Emerton and Bos 2004). The travel cost method defines the higher costs that visitors are willing to pay for trip and equipment expenditures to participate in more frequent recreation tourism, boating, waterfowl hunting, fishing, and birding trips due to improved water quality (Smith and Desvousge 1986 and Freeman 2003). The hedonic pricing method indirectly measures benefits by recording the higher value of property close to rivers and bays with improved water quality (USDA 1995).

Table 5. Economic valuation methods to determine benefits of improved water quality

Method	Description	Benefits	Constraints
Contigent Valuation	Survey individual willingness to pay	Use (drinking water) and nonuse (recreation)	Hypothetical responses may introduce bias.
Productivity	Benefits from increased production of goods.	Commercial fisheries, drinking water	Dificult to obtain data relating change in market prices.
Property Value	Calculate property value near river	Water quality	Requires extensive parcel data base.
Travel Cost	Measure increased trip expenditures	Recreation boating, fishing, swimming	Only measures recreation benefits.

6. Results

At existing water quality levels, the Delaware River supports economic activity that ranges from $1.58 to $2.02 billion per year in $2010. The estimated benefits of improved water quality by increasing dissolved oxygen from the current standard of 3.5 mg/ to a future DRBC year-round fishable standard of 5.0 mg/l in the Delaware River range from a low bound of $370 million to an upper bound of $1.06 billion per year in $2010 (Table 6). Figure 7 illustrates recreational boating provides the greatest benefits ($46-$334 million) followed by recreational fishing ($129-$202 million), agriculture ($8-$188 million), nonuse value ($76-$115 million), viewing/boating/fishing ($55-$68 million),bird watching ($15-$33 million), increased property value ($13-27 million), municipal water supply ($12-$24 million), commercial fishing ($0-$17 million), and navigation ($7-$16 million). Recreational boating, fishing, and viewing provide 45% of the high bound benefits followed by agriculture (17%), nonuse (10%), wildlife/birdwatching, waterfowl hunting, and beach going recreation (6%), water supply (4%), and commercial fishing, navigation, and property value each provide 2% of total benefits (Figure 8). Swimming benefits are nill as very little swimming occurs in the Delaware River between Wilmington and Trenton due to dangerous currents and high bacteria levels. Figure 9 depicts a series of downward sloping marginal benefit curves defined by the change in economic value between existing water quality (DO 3.5 mg/l) and a future DRBC standard (DO 5.0 mg/l) for recreation, commercial fishing, agriculture, navigation, property value, water supply, and nonuse benefits.

Table 6. Benefits of improved water quality in the Delaware River in $2010

Category	**Activity**	**Existing WQ (DO 3.5 mg/l) ($M/yr)**		**WQ Benefits (DO 5.0 mg/l) ($M/yr)**	
		Low	**High**	**Low**	**High**
Use					
Recreation	Viewing, Boating, Fishing	4	6	55	68
	Boating	159	350	46	334
	Fishing	216	337	129	202
	Shad fishing	0	6.5	0	3.9
	Bird/Wildlife Watching	307	325	15	33
	Waterfowl Hunting	1.4	16	0.1	1.6
	Swimming	0	0	0	0
	Beach Going	6	50	2	16
Commercial	Fishing	34	34	0	17
	Agriculture	0	0	8	188
	Navigation	81	81	7	16
Indirect Use	Property Value	333	333	13	27
Water Supply	Municipal Water Supply	196	196	12	24
	Industrial Water Supply	140	140	8	17
Nonuse					
Existence/Bequest	WTP Boatable to Fishable WQ	102	151	76	115
Total		**1,580**	**2,025**	**371**	**1,063**

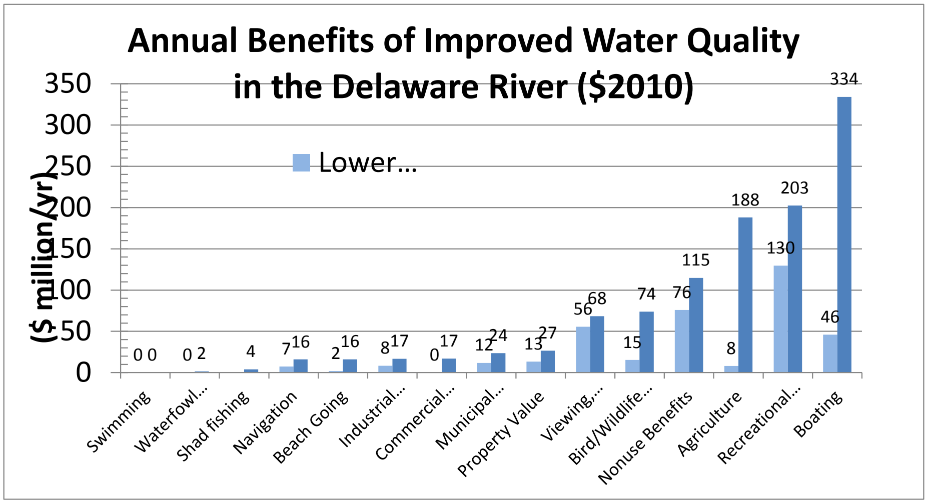

Figure 7. Lower and upper bound benefits of improved water quality in the Delaware River in $2010

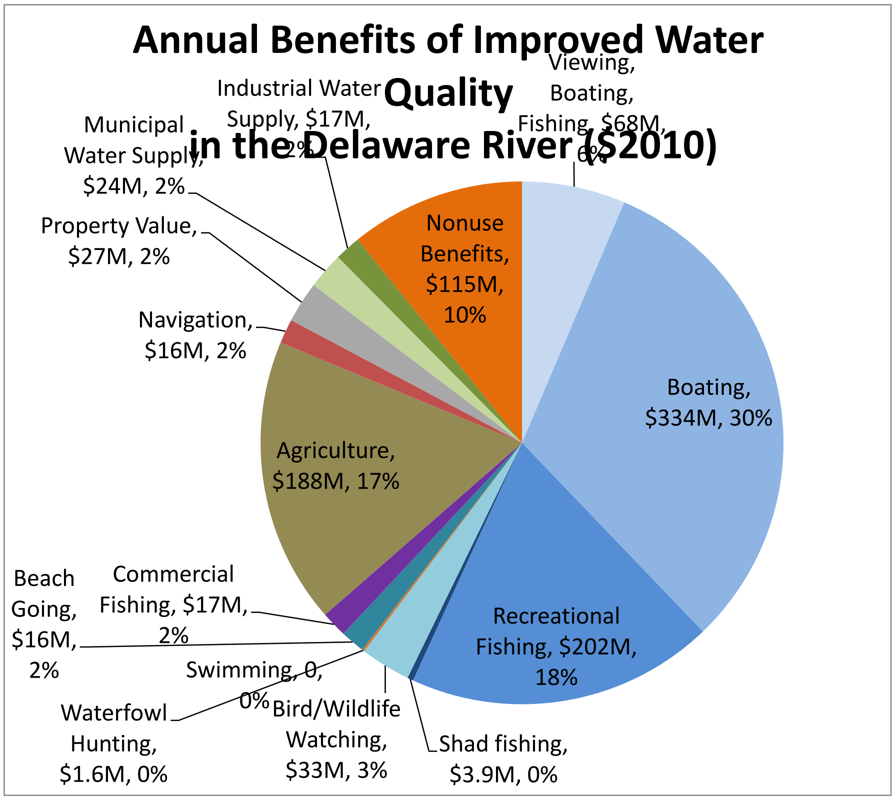

Figure 8. High bound benefits of improved water quality in the Delaware River in $2010

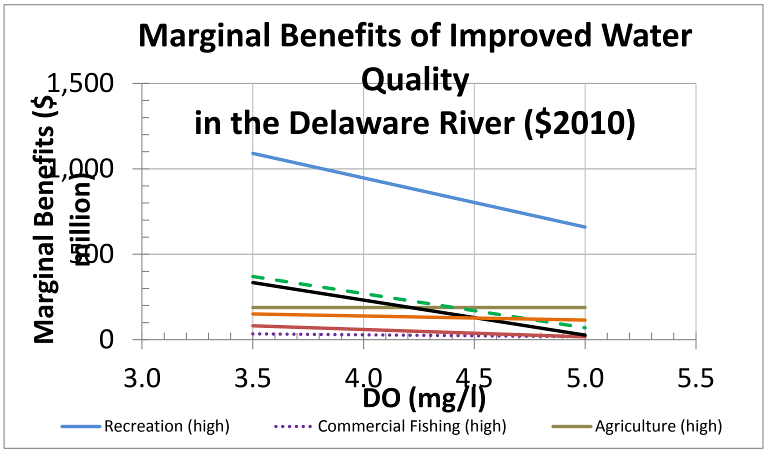

Figure 9. Marginal benefits of improved water quality in the Delaware River in $2010

Recreation (Viewing/Boating/Fishing/Swimming): Three Delaware Basin states (New Jersey, New York, and Delaware) ranked 4th, 7th, and 19th in coastal/estuary recreation activity with 6.2, 5.5, and 2.2 million annual participants respectively (Leeworthy and Wiley (2001). Travel cost values are selected from a study in six northeastern states (Parsons et al. 2003). Converting to $2010 based on a 3% annual change in the CPI, per person benefits to achieve high water quality are $3.61 for viewing, 4.03 for boating, and $2.98 for fishing (Table 7). Low bound and high bound annual benefits due to improved water quality are estimated by multiplying the per person benefit by the 2010 adult population (> 18 years old) in the Delaware Estuary (pop. 5,226,003) and Delaware River (pop. 6,438,910) watersheds. Annual benefits of attaining high water quality (DO 5 mg/l) range from $18.5 to $23.2 million for viewing, $21.0 to $25.9 million for boating, $16.0 to $19.2 million for fishing or $55.5 to $68.1 million in total (Figure 10).

Table 7. Recreation benefits due to improved water quality in the Delaware Basin in $2010

WQ Use	Adult Population[1]	WTP for High WQ[2] ($2010/person)	High WQ Benefits ($M)
Low Bound			
Viewing	5,226,003	3.61	18.5
Boating	5,226,003	4.03	21.0
Fishing	5,226,003	2.98	16.0
Total	**5,226,003**	**10.62**	**55.5**
High Bound			
Viewing	6,438,910	3.61	23.0
Boating	6,438,910	4.03	25.9
Fishing	6,438,910	2.98	19.2
Total	**6,438,910**	**10.62**	**68.1**

1. Adult population >18 years old (US Census) in the Delaware Estuary watershed (5,226,003) and Delaware River Basin (6,438,910). 2. Parsons et al. 2003 adjusted to $2010 based on 3% annual change in CPI..

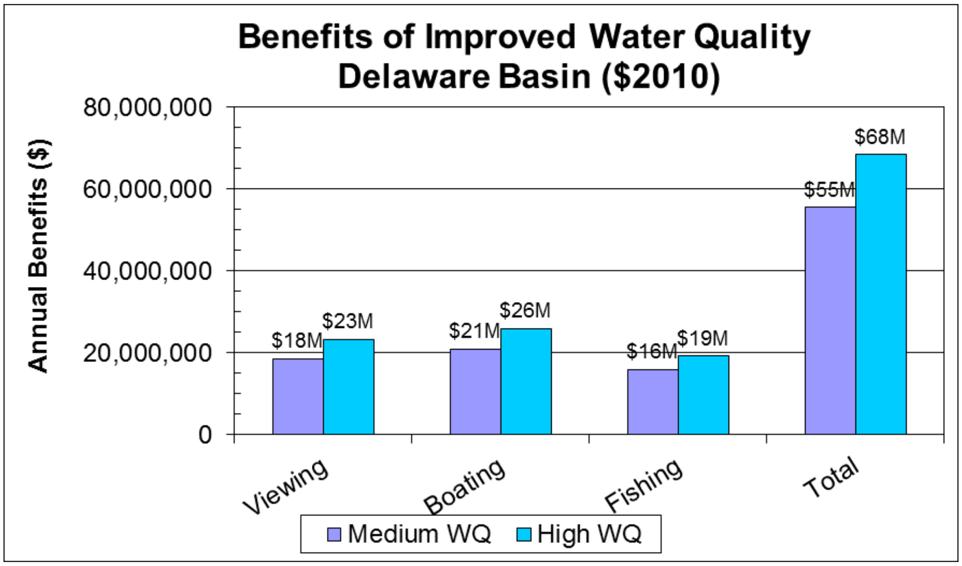

Figure 10. Recreation benefits of improved water quality in the Delaware River (Parsons et al. 2003 adjusted to $2010 based on 3% annually.)

Recreation and Tourism: In 2009, the recreation/tourism industry contributed $379 billion to the U.S. economy or 2.7% of total GDP. The American Sportfishing Association found more people in the U.S. fish (30 million) than play golf (24 million) or tennis (10 million). The 30 million anglers in the U.S. generate about one million jobs and over $45 billion in retail sales annually (Southwick Associates 2008). The Outdoor Industry Association (2006) found recreation contributed $730 billion annually to the national economy and supported 6.5 million jobs. In the Mid-Atlantic census division (NY, NJ, PA), the Outdoor Industry Association (2006) estimated fishing has 1.9 million participants who purchase $1.8 billion in gear/trip sales, paddling has 1.6 million participants who purchase $784 million in gear/trip sales, and wildlife viewing has 5 million participants who purchase $1.8 million in gear/trip sales (Table 8). The Delaware Basin is home of 7,611,595 people in New Jersey, New York, and Pennsylvania or 18.5% of the mid-Atlantic region's population of 40,800,000. Scaling by population, outdoor recreation in the Delaware Basin supports $797 million in economic activity in fishing ($327 million), paddling ($145 million), and wildlife viewing ($325 million).

Table 8. Outdoor recreation activity in the Delaware Basin

Recreation	Participants Mid-Atlantic[1]	Participants Delaware Basin[2]	Gear/Trip Sales Mid-Atlantic[1] ($M)	Gear/Trip Sales Delaware Basin[2] ($M)
Fishing	1,890,000	349,650	$1,768	$327
Paddling	1,586,000	293,410	$784	$145
Wildlife viewing	4,990,000	923,150	$1,756	$325
Total	**8,466,000**	**1,566,210**	**$4,308**	**$797**

1. Outdoor Industry Association (2006). 2. Scaled by proportion of population in the Delaware Basin in NJ, NY, and PA (7.6 million) to mid-Atlantic region (40.9 million) or 18.5%.

Boating: The U.S. Forest Service estimated 89 million people or 36% of the U.S. population participate in recreational boating such as kayaking, canoeing, sailing, and motorboating (EPA 2012). While water quality standards for non-contact recreation boating are not as stringent as fishing and swimming, the benefits are sizeable due to the many registered boats that cruise on estuaries (Cropper and Isaac 2011). The National Marine Manufacturers Association (2010) announced Delaware, Pennsylvania, and New Jersey were ranked 7th, 17th, and 23rd in the U.S. in powerboat expenditures and the value within the Delaware Basin is $392 million/year.

Recreational boating benefits are estimated by multiplying by the number of boating activity days in the Delaware Estuary by low and high bound estimates of daily recreation value and multiplying by an increase in benefits as water quality improves from existing DO (3.5 mg/l) to a future DRBC standard (5.0 mg/l). The low bound benefit of improved water quality is $46 million determined by multiplying 394,000 boaters (Leeworthy et al. 2001 and 2005) by $116/year per boater in $2010 transferred from Bockstael (1989). The high bound benefit is $334 million estimated by multiplying 5.3 million activity days (Leeworthy et al. 2001 and 2005) by $63/trip in $2010 from Smith and Desvouges (1986).

Table 9. Recreational boating benefits due to improved water quality in the Delaware Estuary in $2010

Estimate	Value ($2010/day)	Boating[3] (million days)	Existing Value ($M)	Boating[3] Participants	WQ Benefit ($2010)	Benefit ($M)
Low Bound	30[1]	5.3	159	394,000	$116/boater[4]	46
High Bound	66[2]	5.3	350	394,000	$63/trip[4]	334

1. Johnston et al. 2002. 2. Walsh et al. 1992. 3. Bockstael 1989. 4. Smith and Desvouges (1986). 5. Leeworthy et al. 2001 and 2005 scaled by percent of mariners in watershed and NMMA (2010) boat registrations.

Recreational Fishing: The U.S. Fish and Wildlife Service (2008) reported 25 million anglers took 337 million trips and spent $26 billion on travel/equipment at $78 per trip. If improved water quality led to just a 10% increase in fishing enjoyment and trip/equipment expenditures, then nation-wide benefits would be $2.6 billion. Recreational fishermen went on 4.5 million to 5.4 million trips per year to the Delaware Estuary (USFWS 2008, NMFS 2001, EPA 2002). Travel cost and contingent valuation models indicate the value of recreational fishing ranged from $40 to $75 per trip in $2010 (Rosenberger and Loomis 2000, Kaval and Loomis 2003, McConnell and Strand 1994, Walsh et al. 1992, EPA and NMFS 2002, Johnston et al. 2002, and USFWS 2008). Lipton and Hicks (1999 and 2003) found a 2.4 mg/l increase in DO in Chesapeake Bay increases recreational striped bass catch rates by 95%, therefore, a 1.0 mg/l improvement in DO increases recreational catch rates by 40%, therefore a 1.5 mg/l improvement in DO from 3.5 mg/l to future criteria of 5.0 mg/l increases benefits by 60%. The existing recreational fishing value in the Delaware Estuary ranges from $216 to $337 million/year at a low bound value of $40/trip during 5.4 million trip days and upper bound value of $75/trip on 4.5 million trip days. The existing value of recreational fishing in the Delaware Basin from the unit day model ($216-$337 million) compares with the Outdoor Industry Association (2006) estimate of $327 million for fishing gear/trip expenditures. If a 1.5 mg/l improvement in DO leads to a 60% increase in recreational fishing expenditures, then benefits range from $130 to $202 million/year (Table 10).

Table 10. Recreational fishing benefits due to improved water quality in the Delaware Estuary in $2010

Estimate	Unit Value ($2010/day)	Activity[3] (million days)	Existing Value ($M)	Benefit with Improved DO[4]	Benefit ($M)
Low Bound	40[1]	5,400,000	216	60%	130
High Bound	75[2]	4,500,000	337	60%	202

1. Rosenberger and Loomis 2000. 2. USFWS 2008. 3. USFWS 2000, NMFS 2001, and EPA 2002. Lipton and Hicks 1999 and 2003.

Recreational Shad Fishing: The Pennsylvania Fish and Boat Commission (2011) referenced a 1986 study of shad fishing on the Delaware River that estimated anglers spent $1.6 million during 63,000 trips or $25.40 per trip on gasoline, food, lodging, and tackle. Anglers were willing to pay $50 per day for shad fishing or $102 per day adjusted to $2010. During 63,000 angler days, annual willingness to pay for the Delaware River shad fishery was $3.2 million in 1986 or $6.5 million adjusted to $2010. If DO in the Delaware Estuary improves from 3.5 mg/l to a future standard of 5.0 mg/l, shad fishing activity is projected to increase by 60% with benefits of $3.9 million/year.

Wildlife and Bird Watching: The U.S. Fish and Wildlife Service (2008) reported that 71 million people or 22% of the U.S. population participated in bird and wildlife watching. In 1988, over 90,000 bird watchers spent $5.5 million in Cape May along Delaware Bay. Bombay Hook National Wildlife Refuge in Delaware was the 4th most popular refuge in the nation with 271,000 recreational visits in 2006 and contributed $13.4 million to the economy from food, lodging, equipment, and transportation expenditures for bird watching (Carver and Caudill 2007). The EPA (1994) estimated 1.4 million people took 5.1 million trips for recreational wildlife viewing in the Delaware Basin. Scaled data from the USFWS (2008) indicates 864,000 participants engaged in bird/wildlife watching in the Delaware Basin during 3.3 million visitor days in 2006 and spent $307 million/year for trip (food, lodging, transportation) and equipment expenditures or $68 to $154 per day. Scaled by basin population, the Outdoor Industry Association (2008) reported 923,000 people participating in wildlife viewing in a $325 million program in the Delaware Basin. User day values for wildlife viewing range from $43.94 (Kaval and Loomis 2003) to $92.00 (USFWS 2008) in $2010. The existing recreational value of bird and wildlife watching ranges from $307 to $325 million based on scaled data from the U.S. Fish and Wildlife service (2008) and the Outdoor Industry Association (2008). Bird and wildlife viewing benefits are estimated by multiplying existing recreation value by an estimated 5% and 10% increase in value due to improved water quality. Bird and wildlife watching benefits due to improved water quality along the Delaware Estuary range from $15 million to $33 million per year (Table 11).

Table 11. Recreational wildlife/bird watching benefits in the Delaware Estuary in $2010

Estimate	Participants	Existing Value ($M)	Increase Improved WQ	Benefit ($M)
Low Bound	864,000[1]	307[1]	5%	15
High Bound	923,000[2]	325[2]	10%	33

1. USFWS 2008. 2. Outdoor Industry Association 2008.

Waterfowl Hunting: Approximately 1.3 million people in the U.S. hunted for waterfowl on 13 million days and spent $900 million on trip/equipment expenditures in 2006 or $69 per trip (USFWS 2008). Along the Delaware Estuary, waterfowl hunters participated on 82,000 activity days with annual trip/equipment expenditures of $1.4 million or $17/trip (USFWS 2008). The National Survey of Coastal Recreation (Leeworthy et al. 2001) reported 16,347 people in Delaware and New Jersey hunted for waterfowl along the Delaware Estuary during 229,000 activity days. The value of waterfowl hunting ranges from $1.4 million to $15.8 million from lower/upper bound estimates of consumer surplus (Table 12). Waterfowl hunting benefits due to improved water quality range from $70,000 to $1.6 million per year at an estimated 5% and 10% increase in value due to improved water quality.

Table 12. Recreational waterfowl hunting benefits in the Delaware Estuary in $2010

Estimate	Unit Value ($2010/day)	Activity Days	Existing Value ($2010)	WQ Benefit	Benefit ($)
Low Bound	17[1]	82,000[1]	1,400,000	5%	70,000
High Bound	69[2]	229,000[2]	15,800,000	10%	1,600,000

1. USFWS 2008. 2. Leeworthy et al. 2001.

Swimming: Excellent water quality is necessary to support swimming. The Delaware River Basin Commission primary contact recreation (swimming) criteria is 100 #/100 ml of bacteria. High pathogen and bacteria levels can infect swimmers and cause gastrointestinal upset and diseases such as cholera, hepatitis, and dysentery. High nutrient loads can cause algae blooms that reduce water clarity and cause odor problems that are highly disagreeable to swimmers. Carson and Mitchell (1993) estimated nationwide Clean Water Act swimmable benefits ranged from $24 to $40 billion per year in $1990. Federal, state, and local governments and private marinas own 55 public access areas along 133 miles of the Delaware Estuary between Cape Henlopen and head of tide at Trenton or a density of one access point per 2 river miles. Recreational swimming benefits from improved water quality are not expected to be significant due to swift tidal currents, high bacteria levels, and lack of sandy beach access that hinder this activity along the Delaware River between Trenton and Wilmington.

Beach Going: Tourists account for 6.4 million beach visits in Delaware and 9.7 beach visits in New Jersey in the Delaware Estuary watershed and 5% of beach visits (854,000 in Delaware and New Jersey) occur on the Delaware River above the C&D Canal in the reach that benefits from improved water quality. The mean consumer surplus for a beach trip ranges from $5.36 to $31.45 per activity day or $7.29 to $58.81 per day in $2010 (Kline and Swallow 1998, Parsons et al. 1999, and Leeworthy and Wiley 1991). Bockstael et al. (1989) conducted a travel cost survey of visitors to beaches on the Chesapeake Bay and concluded that a 20% reduction in TNP results in a 20% increase in beachgoing activity or $19.86/trip in $1987 ($39.20/trip in $2010). Krupnick (1988) used Bockstael et al. (1989) to estimate a 40% reduction in TNP resulted in 40% increase in beach going activity. Morgan and Owens (2001) used Bockstael et al. (1989) to estimate a 60% increase in beach benefits due to a 60% reduction in TNP to residents of Maryland, Virginia, and District of Columbia. The existing value of beach going to the Delaware Estuary above the C&D Canal ranges from $6 to $50 million based on activity day estimates multiplied by a low and high estimate of daily use value/person from the literature. Improved water quality is estimated to increase beach going by 32% in the Delaware Estuary, therefore, benefits range from $2 to $16 million/year transferred from Bockstael et al (1989) where a 20% reduction in TNP resulted in a 20% increase in beach going activity. (Table 13).

Table 13. Recreational beach visitor benefits in the Delaware Estuary in $2010

Estimate	Unit Value ($2010/day)	Beach Activity Days[1]	Existing Value ($M)	WQ Benefit[3]	Benefit ($M)
Lower Bound	7.29[1]	854,000	6	32%	2
Upper Bound	58.81[2]	854,000	50	32%	16

1. Kline and Swallow 1998. 2. Leeworthy and Wiley 1991. 3 Bockstael et al. 1989.

Commercial Fishing: Commercial fishing benefits are calculated by estimating the increase in catch per unit effort from improved water quality. Improved water quality in estuaries can boost fish harvest, increase fishermen income, and reduce prices paid by the public for seafood (Cropper and Isaac 2011). In the Delaware Estuary from 1880-1980, Summers et al. (1987) found increased dissolved oxygen was positively correlated with fish abundance and accounted for at least 65% of stock variation for scup, white perch, summer flounder, bluefish, and oyster. A 50% increase in dissolved oxygen in the Delaware Estuary between 1980 and 1993 (Figure 11) correlated with increases in catch per haul of American shad, striped bass, and white perch (Weisberg et al. 1996). If water quality improves by 50% from the existing DO standard of 3.5 mg/l to future criteria of 5.0 mg/l, fish catch for these species is projected to increase by 50%. The NOEP (2010) reported the annual value of commercial fish landings in the Delaware Estuary was $25 million in $2000 or $34 million in $2010 (Table 14). The most valuable commercial fisheries in the Delaware Estuary are blue crab ($14.4 million), summer flounder ($5.3 million), Atlantic menhaden ($4.3 million), Eastern oyster ($3.7 million), striped bass ($2.3 million), and American eel ($0.8 million). If water quality improves by 50% from the existing DO standard (3.5 mg/l) to future criteria (5.0 mg/l) in the Delaware Estuary, then commercial fish landings may increase by 50% or by $17 million/year.

Table 14. Commercial fishery benefits from improved water quality in the Delaware Estuary

Species	2000 Landings[1] (lb)	2000 Value[1] ($)	2010 Value[2] ($)	WQ Benefit[3] ($)
Crab, Blue	8,436,188	10,800,000	14,472,000	7,236,000
Flounder, Summer	1,702,977	3,999,000	5,360,000	2,680,000
Menhaden, Atlantic	37,720,009	3,200,000	4,288,000	2,144,000
Oyster, Eastern	524,160	2,721,000	3,647,000	1,823,000
Bass, Striped	752,882	1,717,000	2,301,000	1,151,000
Eel, American	298,940	626,000	838,000	419,000
Herring, Atlantic	6,039,473	563,000	755,000	377,000
Bluefish	277,217	508,000	681,000	340,000
Whelk,Chan'd/Knob	1,423,282	511,000	685,000	342,000
Weakfish	189,110	261,000	350,000	175,000
Shad, American	130,426	119,000	160,000	80,000
Perch, White	88,060	84,000	113,000	57,000
Shellfish	30,130	76,000	102,000	51,000
Perch, Yellow	20,527	72,000	96,000	48,000
Snails (Conchs)	30,250	59,0006	79,000	39,000
Crab, Horseshoe	229,602	49,000	66,000	33,000
Carp. Common	10,488	28,000	37,0008	19,000
Drum, Black	39,230	22,000	30,000	15,000
Catfish, Channel	6,922	4,000	$5,000	2,500
Herring, Blueback	1,434	600	800	$40
Total	**57,951,307**	**25,422,000**	**34,066,000**	**17,033,303**

1. NMFS 2010. 2. Adjusted to $2010 by 3% change in CPI.
3. 50% increase in DO corresponds to 50% increase in fish catch

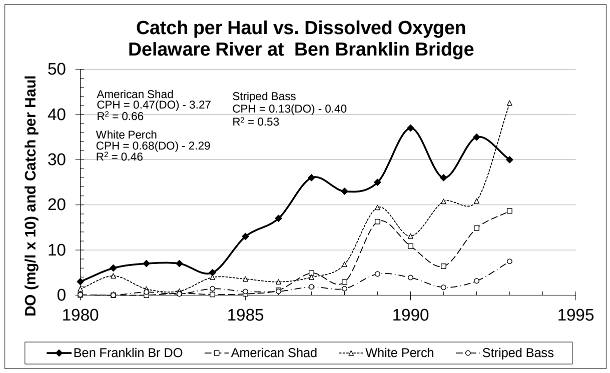

Figure 11. Relationship between dissolved oxygen and fish catch in the Delaware Estuary (Weisberg et al. 1996)

Agriculture: Soil erosion curtails agricultural production through reduced soil fertility and loss of crop production and sales. On 1.9 million acres of farmland in the Delaware Basin, the annual value of agricultural products sold was \$3.3 billion (Table 15). If soil erosion and sediment loss from cropland averages 1.2 ton/acre in the Chesapeake Bay watershed (USDA 2011), then soil erosion from 1.9 million acres of farmland in the Delaware Basin is estimated to deliver 2.3 million ton/year of sediment. If the average top soil thickness is 3 inches and loose soil density is 75 lb/ft^3, then the erosion rate of 2.3 million ton/year is equal to taking 5,600 acres of cropland out of production in the Delaware Basin. At a unit value of farm products sold (\$1,676/ac), the value of lost farm production due to loss of 5,600 acres from soil erosion in the Delaware Basin is \$9.4 million. If farm conservation BMPs reduce nitrogen and sediment loads by 90%, then the annual benefit of restoring cropland through soil erosion control programs is \$8.4 million.

In the U.S., 4 billion tons of soil are lost at a cost of \$7 billion per year (\$110/ac) due to water erosion and siltation damages at downstream recreation, water storage facilties, navigation, flood damages, and water treatment facilties (Pimentel et al. 1995). At \$110/ac, soil erosion damage due to sediment loss from 1.9 million acres of farmland in the Delaware Basin is \$209 million/year. If farm conservation BMPs reduce nitrogen and sediment loads by 90%, then agricultural benefits from reduced soil erosion damages in the Delaware Basin amount to \$188 million/year.

Table 15. Value of cropland and agriculture in the Delaware Basin

State	Farmland by state[1] (ac)	Products sold by state[1] ($ million)	Products sold by state[1] ($/ac)	Farmland in Del. Basin[2] (ac)	Products sold in Del. Basin[2] ($M)
Delaware	432,773	1,083	2,500	254,143	600
New Jersey	631,150	752	1,200	505,507	600
New York	503,151	282	500	187,561	100
Pennsylvania	1,290,796	2,672	2,000	979,313	2,000
Delaware Basin	**2,857,870**	**4,790**	**1,700**	**1,926,524**	**3,300**

1. Census of Agriculture 2007 (USDA 2009). 2. Scaled by ratio of farmland area in basin to state.

Navigation: The Delaware River port at Wilmington, Camden, and Philadelphia: (1) generates \$81 million in tax revenues, (2) imports 1/2 of the nation's cocoa beans, 1/3 of the bananas, and 1/4 of fruit and nuts, (3) ranks 5th among U.S. ports in import value and 20th in export value, and (4) handled 16% of U.S. container trade (The Economy League of Greater Philadelphia 2008). Pollutant load reductions in the watershed can decrease sediment loads which in turn can reduce navigation dredging costs in the Delaware River ship channel. From 1950-2009, sediment discharge to the Delaware Estuary averaged 2.2 million cubic yards or 1.3 metric tons (PDE 2012). The U.S. Army Corps of Engineers operates a Delaware River navigation channel dredging program that removes 4 million CY (Figure 12) at costs that range from \$3.75/CY in FY2005 to \$8.09/CY in FY 2010. Without watershed BMPs to reduce sediment loads, the annual cost to dredge 4 million CY from the Delaware River at costs of \$3.75 to \$8.09/CY ranges from \$15-\$32 million. If watershed BMPS reduce an annual 2.2 million CY sediment discharge to the Delaware River by 90%, then savings from avoided dredging costs range from \$7 to \$16 million (Table 16).

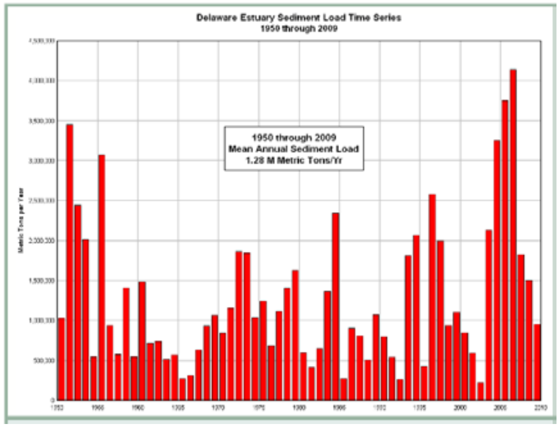

Figure 12. Delaware Estuary sediment load time series (PDE 2012)

Table 16. Navigation benefits due to avoided dredging costs in the Delaware River

	Without Watershed BMPs		With Watershed BMPS (reduce sediment by 90%)	
	Low	High	Low	High
Sediment Discharge (CY)	2,200,000	2,200,000	2,200,000	2,200,000
w/ 90% BMP Reduction (CY)	0	0	2,000,000	2,000,000
Required Dredge Volume (CY)	4,000,000	4,000,000	2,000,000	2,000,000
Unit Cost ($/CY)	3.75	8.09	3.75	8.09
Dredging Cost ($ million)	15	32	7	163
Benefits of Reduced Dredging ($ million)	7	16		

Property Value: Improved water quality produces amenity or indirect use benefits due to increased riverfront property value by enhancing aesthetic value to the owner (USDA 1995). Along the Chesapeake Bay, Leggett and Bockstael (2000) concluded that improved water quality increases property values with potential economic benefits of $12.1 million within a range of $3.8 to $20.5 million. Property values within 2000 feet of the shoreline are estimated to increase by a lower bound of 4% and an upper bound of 8% (Figure 13) due to improved water quality along the tidal Delaware River between Wilmington and Trenton (EPA 1973, Leggett et al. 2000, Poor et al. 2007). At an average real estate price of $192,000/ac, the annual value of 34,764 acres of riverfront property within 2000 ft of the Delaware River between the C & D Canal and Trenton is $334 million over a 20-year period. If property value within 2000 feet of the shoreline is boosted by 4% to 8% due to improved water quality in the Delaware River, then the amenity value ranges from $13 to $27 million/year Table 17).

Table 17. Increased property value due to improved water quality in the Delaware River

State	Shoreline Length[1] (ft)	Area within 2000 ft of water (ac)	Annual Value @ $192,000/ac ($M)	Annual Property Value ($M/yr)	Increased Property Value @ 4% ($M/yr)	Increased Property Value @ 8% ($M/yr)
Delaware	114,000	5,200	1,005	50	2	4
New Jersey	357,000	16,400	3,151	158	6	13
Pennsylvania	286,000	13,100	2,518	126	5	10
Delaware Estuary	**757,000**	**34,800**	**6,675**	**334**	**13**	**27**

1. Length of Delaware River shoreline between C&D Canal and Trenton.

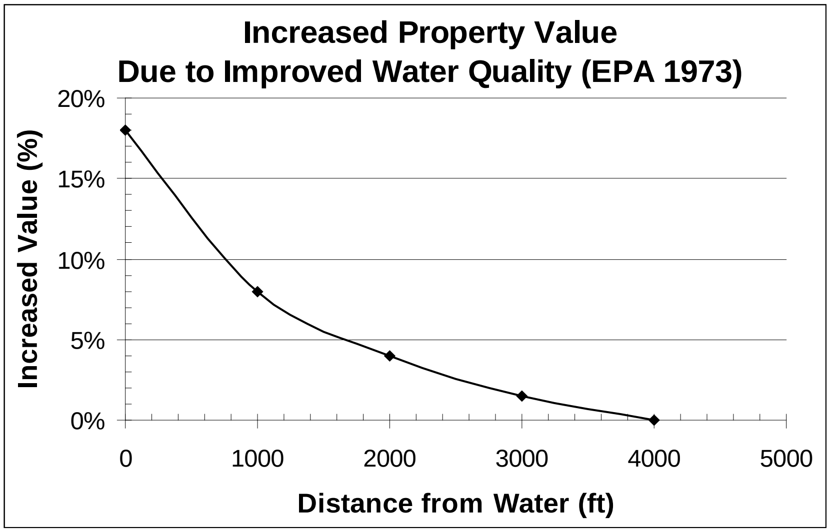

Figure 13. Increased property value due to improved water quality (EPA 1973)

Drinking Water Supply: Water treatment costs decline by 2% for every 1% increase in watershed forest area (Trust for Public Land and AWWA 2004). Texas A&M University found water treatment costs increase by 1% for a 4% decrease in turbidity (McCarl 1997). The Delaware River watershed provides drinking water (538 mgd) to Delaware (39 mgd), New Jersey (182 mgd), and Pennsylvania (317 mgd). A 50% increase in water quality from current criteria (3.5 mg/l) to a future DRBC DO standard (5.0 mg/l) can reduce water treatment costs by 6% to 12% (McCarl 1997 and Crocket 2007), therefore drinking water supply benefits range from $12 to $24 million/year (Table 18).

Table 18. Public water supply benefits due to improved water quality in the Delaware Basin in $2010

Water Purveyor	Water[1] Supply (mgd)	Treated Water[2] @ $1.00/1000 gal ($M/yr)	Benefit[3] @ 6% ($M/yr)	Benefit[3] @ 12% ($M/yr)
Delaware	38.9	14.2	1	2
New Jersey	182.5	66.6	4	8
Pennsylvania	316.9	115.7	7	14
Total	**538.3**	**196.5**	**12**	**24**

1. DRBC 2010. 2. UDWRA. 3. McCarl 1997 and Crocket 2007.

Industrial Water Supply: The median freshwater use value of industrial water supply is $132/ac-ft (Frederick et al. 1996) or $200/ac-ft ($0.61/1000 gal) in $2010. Industrial water allocations total 804 mgd in the Delaware Estuary watershed and at $0.61/1000 gal, the existing annual value is $140 million. If improved water quality in the Delaware River reduces industrial water treatment costs by 6% to 12%, benefits range from $8 to $16 million annually (Table 19).

Table 19. Industrial water supply benefits of improved water quality in the Delaware Basin in $2010.

Watershed	Industrial[1] Withdrawal (mgd)	Use Value[2] ($0.61/1000 gal) ($ million/yr)	Benefit @ 6% ($ million/yr)	Benefit @ 12% ($ million/yr)
Schuylkill Valley	40	9	0.5	1.1
Upper Estuary	132	29	1.8	4
Lower Estuary	446	99	6	12
Delaware Bay	12	3	0.1	0.4
Total	**630**	**140**	**8**	**16**

1. DRBC water allocations. 2. Frederick et al. 1996 adjusted to $2010 at 3% annually

Nonuse Benefits: Nonuse values are willingness to pay (WTP) for the preservation or improvement of natural resources (Haab and McConnell 2002). Nonuse benefits of actions to improve DO from the current 3.5 mg/l standard to meet a future year-round fishable DO standard of 5 mg/l in the Delaware River are based on contingent valuation surveys that define public WTP to improve water quality from nonsupport (impaired) to boatable and fishable uses. Swimmable benefits are not estimated because severe tidal currents impede this recreational use along the tidal Delaware River. Johnston et al. (2003) synthesized data on the benefits of improved water quality and concluded that a $1.00 increase in use value correlated to a $0.50 increase in nonuse values, therefore nonuse value is estimated to be 33% of the totsl use plus nonuse value from WTP stated preference surveys.

Carson and Mitchell (1993) asked 813 people their willingness to pay more taxes to achieve Clean Water Act goals based on a water quality ladder (Figure 14). Mean annual household WTP from Carson and Mitchell (1993) to improve water quality was $93 ($32/person) to go from nonsupported to boatable use and $70 ($24/person) to go from boatable to fishable uses in $1983. Adjusting for an annual 3% change in the CPI, annual WTP was $71/person for boatable and $54/person for fishable uses or a total of $125/person in $2010. This compares to a mean WTP of $83 within a range of $31-$331 as surveyed by Houtven et al. (2007). Annual nonuse benefits are estimated by multiplying WTP by the adult watershed population (78% of population > 18 yr old) in the Delaware Estuary watershed (5.2 million) and Delaware Basin (6.5 million) then by 33%. Low bound benefits are based on the Delaware Estuary watershed population (6.7 million) and high bound benefits are based on the Delaware Basin population (8.2 million) in Delaware, New Jersey, New York, and Pennsylvania. From the U.S. Census, 78% of the population is over 18, therefore the adult population in the Delaware Estuary watershed is 5.2 million and 6.4 million in the Delaware Basin. Nonuse benefits from WTP for improved water quality for boatable use (DO 3.5 mg/l) in the Delaware River range from $102 million to $151 million/year. To achieve fishable water quality (DO 5.0 mg/l), nonuse benefits ranges from $76 million to $115 million/year. Total WTP to improve from impaired to boatable and fishable uses in the Delaware River range from $178 million to $266 million/year in $2010 (Table 20 and Figure 15).

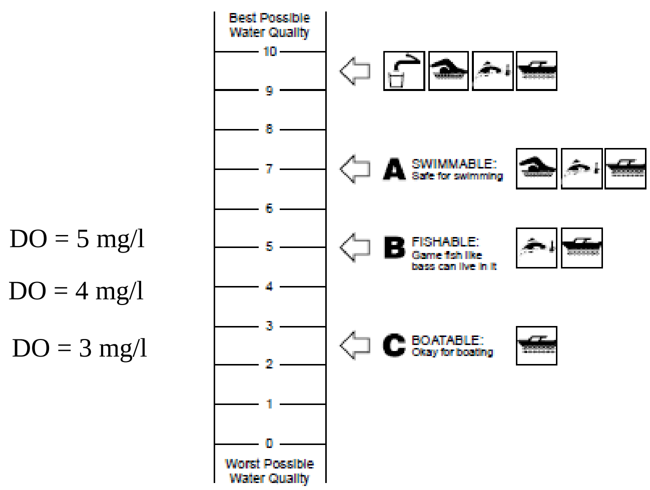

Figure 14. Water quality ladder
(Carson and Mitchell 1993 from Resources for the Future)

Table 21. Nonuse benefits of improved water quality in the Delaware Basin in $2010

WQ Use	Adult Population[1]	WTP[2] ($2010/person)	WTP ($M/yr)	Nonuse[3] ($M/yr)
Low Bound	**5,226,003**	**103**	**538**	**178**
Boatable	5,226,003	59	308	102
Fishable	5,226,003	44	230	76
High Bound	**6,438,910**	125	805	266
Boatable	6,438,910	71	457	151
Fishable	6,438,910	54	348	115

1. Adult population (>18 years old). 2. Carson and Mitchell 1993 adjusted to $2010 at 3% annually. 3. Nonuse benefits 33% of WTP.

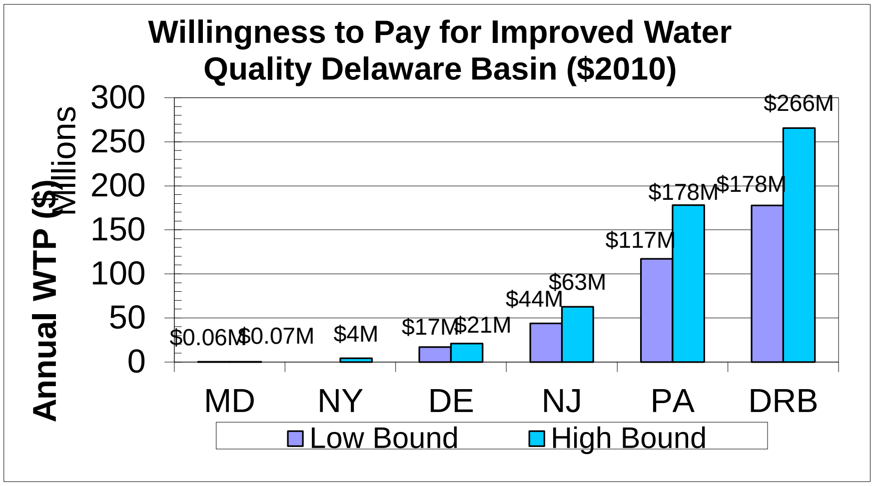

Figure 15. Nonuse benefits by state due to improved water quality in the Delaware Basin

7. Conclusions and Discussion

The Delaware River and its tributaries have made a measureable recovery in the half-century since the birth of JFK's Delaware River Basin Commission Compact (DRBC) in 1961, Richard Nixon's EPA in 1970, and Congressional approval of Clean Water Act Amendments during the 1970s. A first-of-its-kind 1966 benefit-cost analysis conducted by the Federal Water Pollution Control Administration concluded that a multi-million-dollar per year waste load abatement program to raise dissolved oxygen levels to boatable and fishable standards would generate up to $350 million in annual benefits in $1964. In 1967, the DRBC used this economic analysis to set dissolved oxygen criteria at 3.5 mg/l along the urban river from Philadelphia to Wilmington where the water quality standard has stood for over four decades. With improved water quality, anadromous American shad and Atlantic sturgeon have returned to the Delaware along with a growing river tourism and recreation economy.

While the Delaware has made one of the most extensive recoveries of any estuary in the world, scientists have called for raising the 1967 DO standard of 3.5 mg/l to a higher level of protection to at least 5.0 mg/l to provide for year-round protection of anadromous fish such as the recovering American shad and nearly extirpated Atlantic sturgeon, a species on the Federal Endangered Species List. This more rigorous standard would also mitigate atmospheric warming that increases water temperatures, sea levels, and chloride levels that, in turn, reduces DO saturation.

This economic valuation research concludes that the annual benefits of improved water quality by increasing dissolved oxygen criteria from 3.5 mg/l to a future DRBC year-round fishable standard of 5.0 mg/l in the Delaware River range from a low bound of $371 million to an upper bound of $1.1 billion. Recreational viewing, fishing, and boating provide 45% of benefits followed by agriculture (17%), nonuse (10%), birdwatching, waterfowl hunting, and beach recreation (6%), water supply (4%), and commercial fishing, navigation, and property value benefits (2%). Recreational boating provides the greatest benefits ($46-$334 million) followed by recreational fishing ($129-$202 million), agriculture ($8-$188 million), nonuse value ($76-$115 million), viewing/boating/fishing ($55-$68 million),bird watching ($15-$33 million), increased property value ($13-27 million), municipal water supply ($12-$24 million), commercial fishing ($0-$17 million), and navigation ($7-$16 million). Swimming benefits are nill as the urban Delaware River has dangerous currents and little public beach access.

Where available, benefits were derived from market/nonmarket data derived in the Delaware River watershed. If basin specific were not available, economic data for certain categories were transferred from other watersheds (such as Chesapeake Bay) to the Delaware River using principles of benefits (value) transfer. Benefits transfer is relatively inexpensive to implement, however, it must be carefully applied to avoid double-counting of benefits. In some cases, nonuse benefits may be unrealistic because the public is asked what they would be willing to pay but do not actually make a transaction in a market. However, EPA and Federal agencies include nonuse benefits in benefit cost analysis studies because if these were omitted then total benefits of improved water quality may be undercounted. Future research is need to more precisely measure nonuse benefits in the Delaware Basin through a stated preference survey to measure public willingness to pay for improved water quality in the river.

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