Dead Zone in the Delaware

Ocean Currents Series
Lewes, Del.
Jul 1, 2021

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What do these enterprises have in common?

- *Boeing*
- *Sunoco*
- *Campbell's Soup*
- *DuPont*
- *Wawa*
- *Astra Zeneca*
- *Crayola Crayons*
- *Starbucks*
- *Iron Hill Brewery*
- *Philadelphia Eagles*
- *Salem Nuclear Plant*
- *United States Navy*
- *Guggenheim Museum*

They all depend on the Delaware Basin!

Delaware River Basin

- Federalist model of shared power in water management
- 1961 DRBC Compact manages “without regard to political boundaries.”
- 4 states, 24 counties, and 838 municipalities
- 8 Senators, 25 Members of HR
- 19 federal, 43 state, 14 interstate agencies
- Use charges on water allocations ($0.10/1000 gal.).

The Great American Megabasin

Chesapeake and Delaware

Gerald J. Kauffman and Carol Collier

Linked by hydrology at the crossroads of American history, the Chesapeake and Delaware megabasin stretches 400 miles along the Atlantic seaboard in the most populous watershed in the United States (Figure 1). The American Revolutionary War and Civil War were fought along its rivers and John F. Kennedy, Richard M. Nixon and Barack H. Obama adopted federal programs to protect its rivers and watersheds.

While sharing similar geography and climate, these contiguous mid-Atlantic basins have contrasting demographic characteristics (see Table 1 on page 9). The Chesapeake and Delaware megabasin covers just 2% of the contiguous United States, yet is home to 8% of the nation's population and the nation's fifth- and seventh-largest metropolitan economies, the U.S. Capitol and five state capitals. The Chesapeake watershed (64,000 square miles) is four times larger than the Delaware watershed (13,500 square miles), which suggests the challenges of governing the nation's largest estuary are correspondingly complex. The Chesapeake is home to 16 million people — twice that of the Delaware basin — but the Chesapeake's population density (250 people per square mile) is less than the Delaware basin (590 people per square mile), which suggests less pressure per unit area from human pollution and water withdrawals.

Though each river is more than 300 miles long, the Chesapeake/Susquehanna and Delaware are merely the 42nd and 55th longest rivers in the United States. The Chesapeake is the longest estuary in the country (194 miles) and the Delaware estuary (96 miles) is the nation's third-longest navigable tidal river. Both estuaries are drowned river systems that evolved from rising sea levels that began 20,000 years ago during the end of the last ice age. While both estuaries have similar ratios of watershed to estuary surface area (18:1), the hydraulic retention time (HRT), measured by volume divided by median flow, is quite different. The approximate HRT of the Chesapeake is 812 days and that of the Delaware Bay is 443 days.

THE DELAWARE RIVER REVIVAL: FOUR CENTURIES OF HISTORIC WATER QUALITY CHANGE FROM HENRY HUDSON TO BENJAMIN FRANKLIN TO JFK

Gerald J. Kauffman Jr.
University of Delaware

Since Henry Hudson sailed to the bay 400 years ago in August 1609, water quality in the Delaware River has changed from pristine, to polluted, to partly recovered. Water pollution was so noticeable by 1769 that a visiting Englishman named Isaac Weld was moved to comment on the "mess" in the Delaware River at Philadelphia. Due to pollution in the river after the American Revolution, Ben Franklin left money in his will to build a drinking water supply system in America's largest city. In 1940 the Interstate Commission on the Delaware River called the tidal river at Philadelphia "one of the most grossly polluted areas in the United States." During the Second World War, water pollution was so bad that a newly painted ship faded to the colors of the rainbow as it sailed onto the river and Navy pilots were instructed to ignore the stench of the river as they flew a mile overhead.[1]

After the war, the urban Delaware River was one of most polluted in the world with zero oxygen levels during the summer.

PENNSYLVANIA HISTORY: A JOURNAL OF MID-ATLANTIC STUDIES, VOL. 77, NO. 4, 2010.

Environ Monit Assess (2011) 177:193–225
DOI 10.1007/s10661-010-1628-8

Water quality trends in the Delaware River Basin (USA) from 1980 to 2005

Gerald J. Kauffman · Andrew R. Homsey · Andrew C. Belden · Jessica Rittler Sanchez

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Abstract In 1940, the tidal Delaware River was "one of the most grossly polluted areas in the United States." During the 1950s, water quality was so poor along the river at Philadelphia that zero oxygen levels prevented migration of American shad leading to near extirpation of the species. Since then, water quality in the Delaware Basin has improved with implementation of the 1961 Delaware River Basin Compact and 1970s Federal Clean Water Act Amendments. At 15 gages along the Delaware River and major tributaries between 1980 and 2005, water quality for dissolved oxygen, phosphorus, nitrogen, and sediment improved at 39%, remained constant at 51%, and degraded at 10% of the stations. Since 1980, improved water-quality stations outnumbered degraded stations by a 4 to 1 margin. Water quality remains good in the nontidal river above Trenton and, while improved, remains fair to poor for phosphorus and nitrogen in the tidal estuary near Philadelphia and in the Lehigh and Schuylkill tributaries. Water quality is good in heavily forested watersheds (>50%) and poor in highly cultivated watersheds. Water quality recovery in the Delaware Basin is coincident with implementation of environmental laws enacted in the 1960s and 1970s and is congruent with return of striped bass, shad, blue crab, and bald eagle populations.

Keywords Water quality · Watersheds · Rivers/streams · Environmental regulations

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Introduction

In 1940, the Interstate Commission on the Delaware River Basin called the tidal Delaware River at Philadelphia "one of the most grossly polluted areas in the United States" (INCODEL 1940). By the 1950s, the urban estuary was noted as one of most polluted rivers in the world with zero oxygen levels during the summer (Dale 1996). American shad were unable to migrate through the anoxic barrier at Philadelphia leading to near extirpation of the species with genetic origins in the basin (Chittendon 1974). In 1973, a USEPA study concluded that the Delaware Estuary would never achieve fishable designated uses (USEPA 2000a).

Since then, environmental laws have led to water quality recovery in the Delaware Basin. In

Technical Summary

State of the Delaware River Basin Report

A Report on the Health of the 13,539-square-mile Delaware River Basin in Delaware, New Jersey, New York, and Pennsylvania

July 4, 2008

Delaware River Basin Partners

University of Delaware · Cornell University · Rutgers · Penn State

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SPECIAL ISSUE PAPER

WILEY

Economic benefits of improved water quality in the Delaware River (USA)

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Abstract
Water quality in the Delaware River, USA, has improved significantly since the Federal Water Pollution Control Act (1948), Clean Water Act of 1972, and authorization of the Delaware River Basin Commission Compact in 1961. Initial economic analysis by the Federal Water Pollution Administration in 1966 concluded the multimillion dollar pollution abatement programme would generate $350 million in annual benefits by improving dissolved oxygen levels to fishable standards in the Delaware River. Although water quality in the Delaware has improved substantially, scientists have called for raising the 1960s dissolved oxygen criteria from 3.5 mg/L to 5.0 mg/L to ensure year-round propagation of anadromous American shad and Atlantic sturgeon. This higher level would also mitigate atmospheric warming resulting in increased water temperatures and sea water incursion, both of which would lead to reductions in dissolved oxygen saturation in the river. Additional economic valuation of this water quality improvement shows direct use benefits in the Delaware River to range from $371 million to $1.1 billion per year. Other economic sectors benefiting from improved water quality include recreational boating ($46–$334 million), 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), property value ($13–27 million), water supply ($12–$24 million), commercial fishing (up to $17 million), and navigation ($7–$16 million). Future economic research is needed in the Delaware River watershed to more precisely measure nonuse benefits by public willingness to pay for improved water quality.

KEYWORDS
economics, river basin, water policy, water quality

1 | INTRODUCTION

The concept of placing a dollar value on natural resources goes back a century to economists Arthur Pigou (1920) and John Hicks (1939) who outlined that individual preferences are based on individual willingness to pay (WTP) for benefits (Kramer, 2005). 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 (Dorfman, Jacoby, & Thomas, 1972; Maass et al., 1962). In environmental economics, WTP measures how much people are willing to pay for a given service regardless of whether or not they actually use the service (Goulder & Kennedy, 1997). Economic benefits can be measured as the dollar value of services that individuals are willing to pay (WTP) for improved water quality (Cech, 2005). Marginal benefits are defined as the incremental change in value of ecosystem services that improve with enhanced water quality (Dixon, Scura, Carpenter, & Sherman, 1994). The downward sloping demand curve traces

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Benefit-cost analysis of water quality policy and criteria in the Delaware River

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Abstract

This research conducts a benefit-cost analysis of water policies to reach an optimal level of dissolved oxygen (DO) to meet year-round fishable water quality criteria in the Delaware River. A watershed pollutant load model is utilized to estimate marginal cost curves of water quality improvements to meet a more protective year-round fishable standard and annual benefits are defined to achieve future DO criteria in the Delaware River. The most cost-effective DO standard is 4.5 mg/L defined by the point where the marginal benefits of willingness to pay (WTP) for improved water quality equals the marginal costs of pollution reduction. This optimal criteria (4.5 mg/L) can be achieved at a cost of $150 million with benefits ranging from $250 to $700 million/year. While a future DO standard of 4.5 mg/L reflects an economically efficient level of water quality, this DO criteria is less protective than the level of 5–6 mg/L needed to protect anadromous fish such as the Atlantic sturgeon. The policy to reach a DO level of 6 mg/L (at 80% DO saturation) may be difficult to achieve at summer water temperatures that approach 30 °C in the Delaware River at Philadelphia.

Keywords: Benefit-cost analysis; Economics; River basin; Water quality

Introduction

Clean water is an environmental good that has the economic value because people are willing to pay for it (Thurston *et al.*, 2009). The benefit-cost analysis (BCA) is often employed in water resources management to determine whether a project should be done (Thacher *et al.*, 2011). BCA helps to determine whether it is worthwhile for governments to spend on watersheds and river basins (Douglas & Taylor, 1999). BCA is a decision tool employed by policymakers to measure the net gain or loss to society due to a certain policy or project (Thurston *et al.*, 2009). Goldberg (2007) offered BCA valuation as an efficient way to make cost-effective decisions by policymakers and create a market to fund watershed services. BCA evaluates the opportunity costs of policy actions and determines whether the benefits will leave everyone well off without harm, the Pareto criterion. Policies that maximize net benefits to

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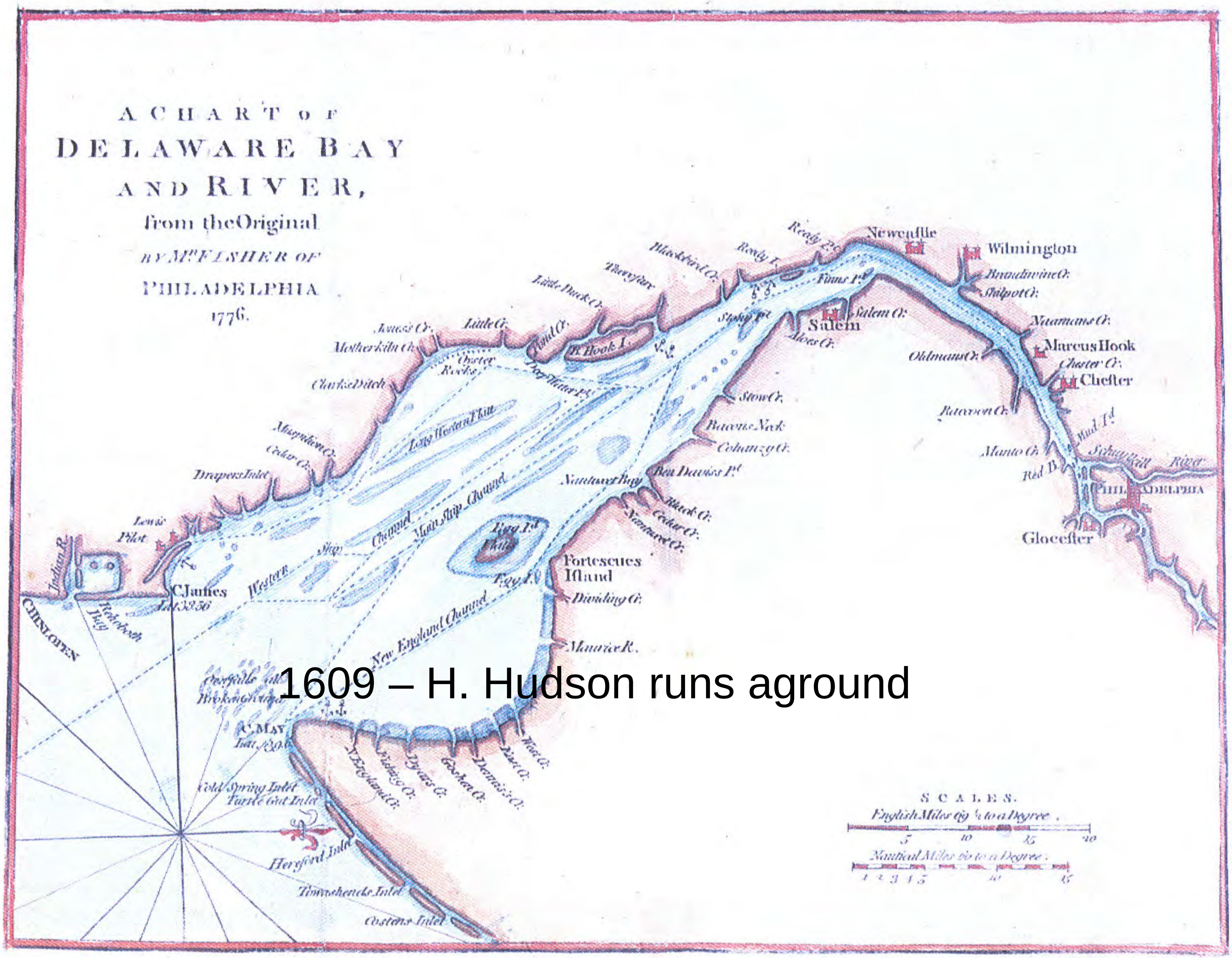


1609 – H. Hudson runs aground

1682 – W. Penn, oysters too big…. eaten whole.

1739 – B. Franklin petition remove tanneries. Creek choked w/ hair, horns, guts.

1790 – B. Franklin leaves funds for Phila. water system.

1832 – Cholera kills 900 in Philadelphia.

1885 – "Privies for 250 men over a brook 40th St. abv. Girard Ave.

1886 – Gloucester serves 10,000 planked shad dinners.

1897 – Phila. councilman thought Schuylkill water was lemonade.

1920's – Schuylkill so dirty, people emerged from tubs dirtier…

WWII – Pilots a mile up, rotten egg smell. Ship turns to rainbow. HMS Nelson

1952 - Delaware R. *"outstanding example of destruction of bass habitat…*

1961 – PA Gov. Lawrence convinces JFK to sign DRB Compact.

1968 – DRBC issues waste load allocations.

1971 - *"gross pollution …extirpated the striped bass…"*

1972 – Congress and McGovern overrode Nixon's veto of CWA.

1973 – EPA says "*extirpation of the…(shad) runs is distinct possibility".*

1945

HMS Nelson

FOUR STATES SIGN DELAWARE PACT

President Joins in Approving Vast Program for Basin Backed by Governors

COMMISSION IS SET UP

Developing of River Valley Will Use, Conserve and Protect Vital Supply

By RUSSELL BAKER
Special to The New York Times.

FRIDAY, NOVEMBER 3, 1961.

The New York Times.

Background

- Since 1961, water quality has improved in tidal Delaware River.
- Yet, DO doesn’t meet fishable standard (3.5 mg/l) in summer.
- American shad/striped bass abundance increasing in river.
- 2012, NOAA puts Atlantic sturgeon on Endangered Species list
- Atmospheric warming and sea level rise (increased salinity) may decrease DO saturation.
- Considering more protective DO criteria to 4.0 or 5.0 mg/l?

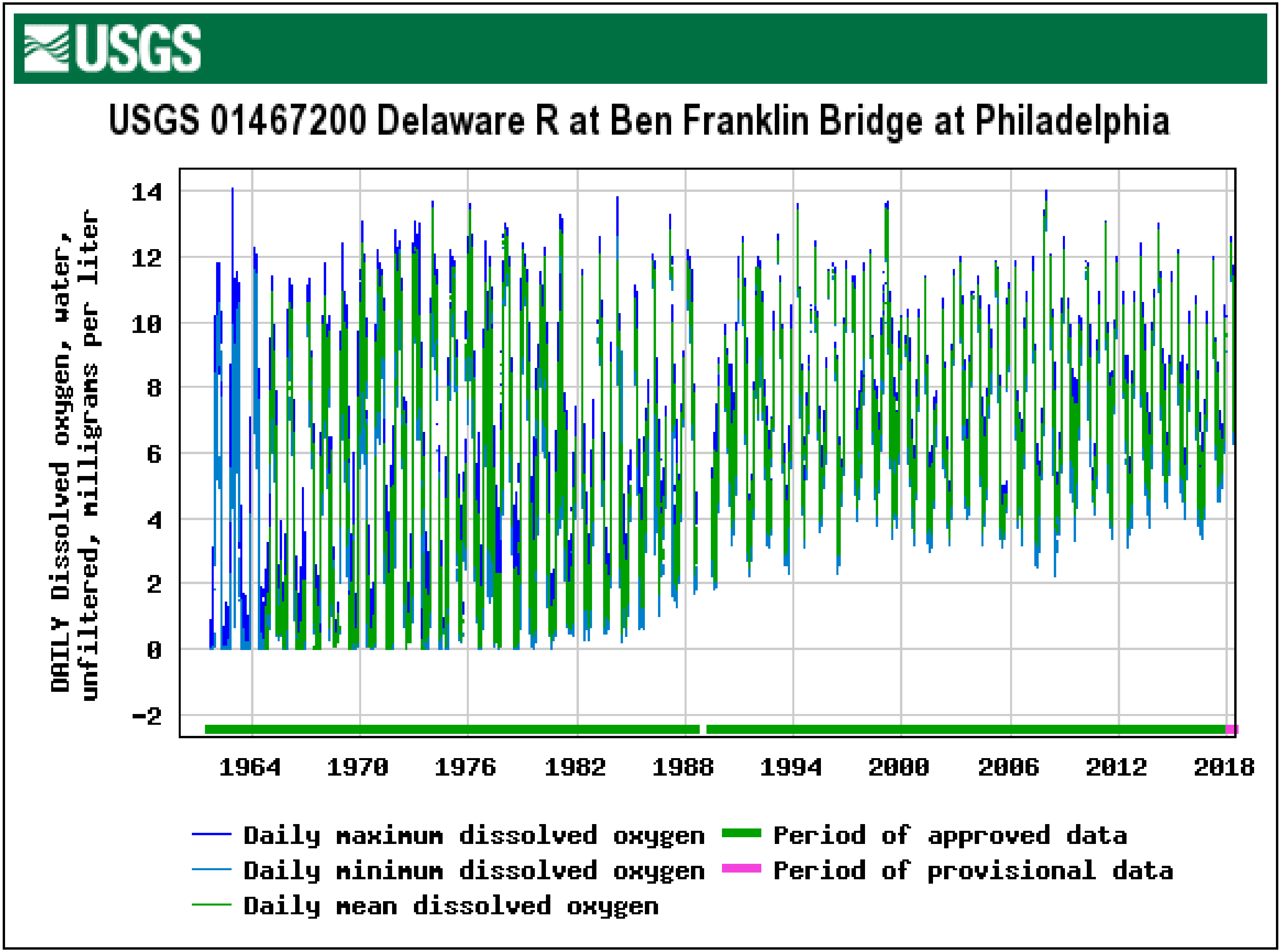
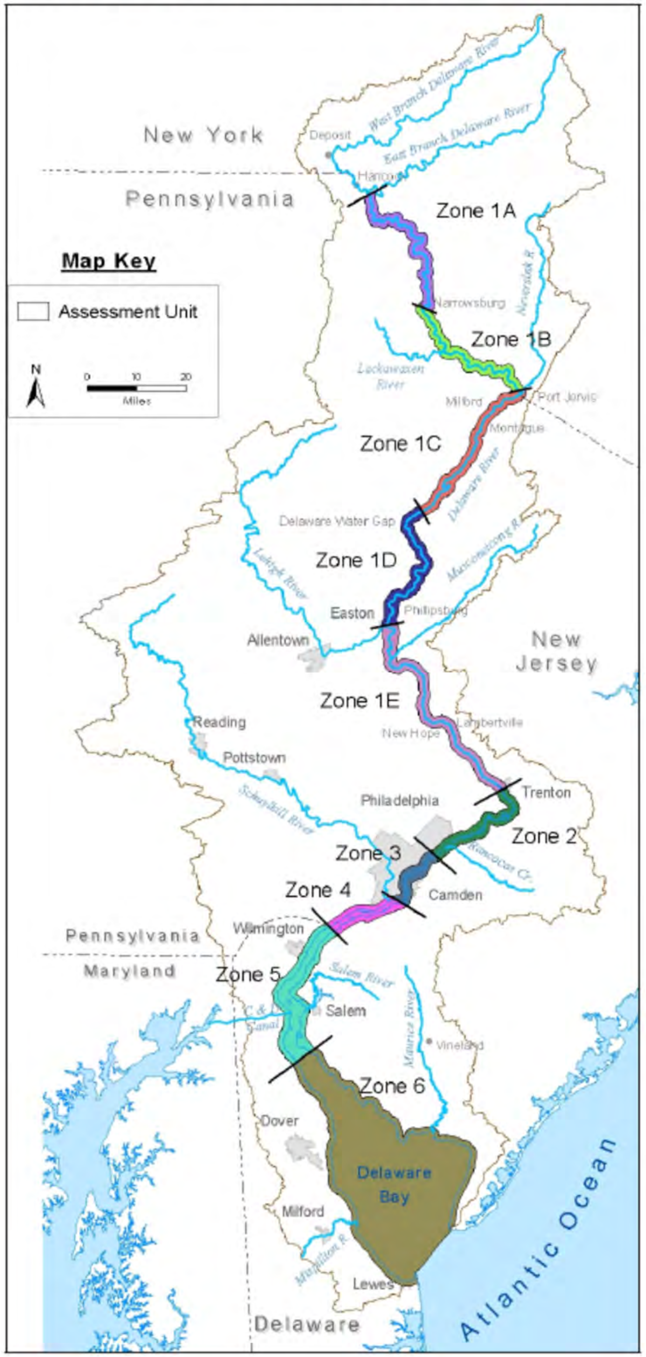

USGS
USGS 01467200 Delaware R at Ben Franklin Bridge at Philadelphia
DAILY Dissolved oxygen, water, unfiltered, milligrams per liter
14
12
10
8
6
4
2
0
-2
1964
1970
1976
1982
1988
1994
2000
2006
2012
2018
Daily maximum dissolved oxygen
Daily minimum dissolved oxygen
Daily mean dissolved oxygen
Period of approved data
Period of provisional data

Figure 2: Delaware River Water Quality Management Zones / Assessment Units



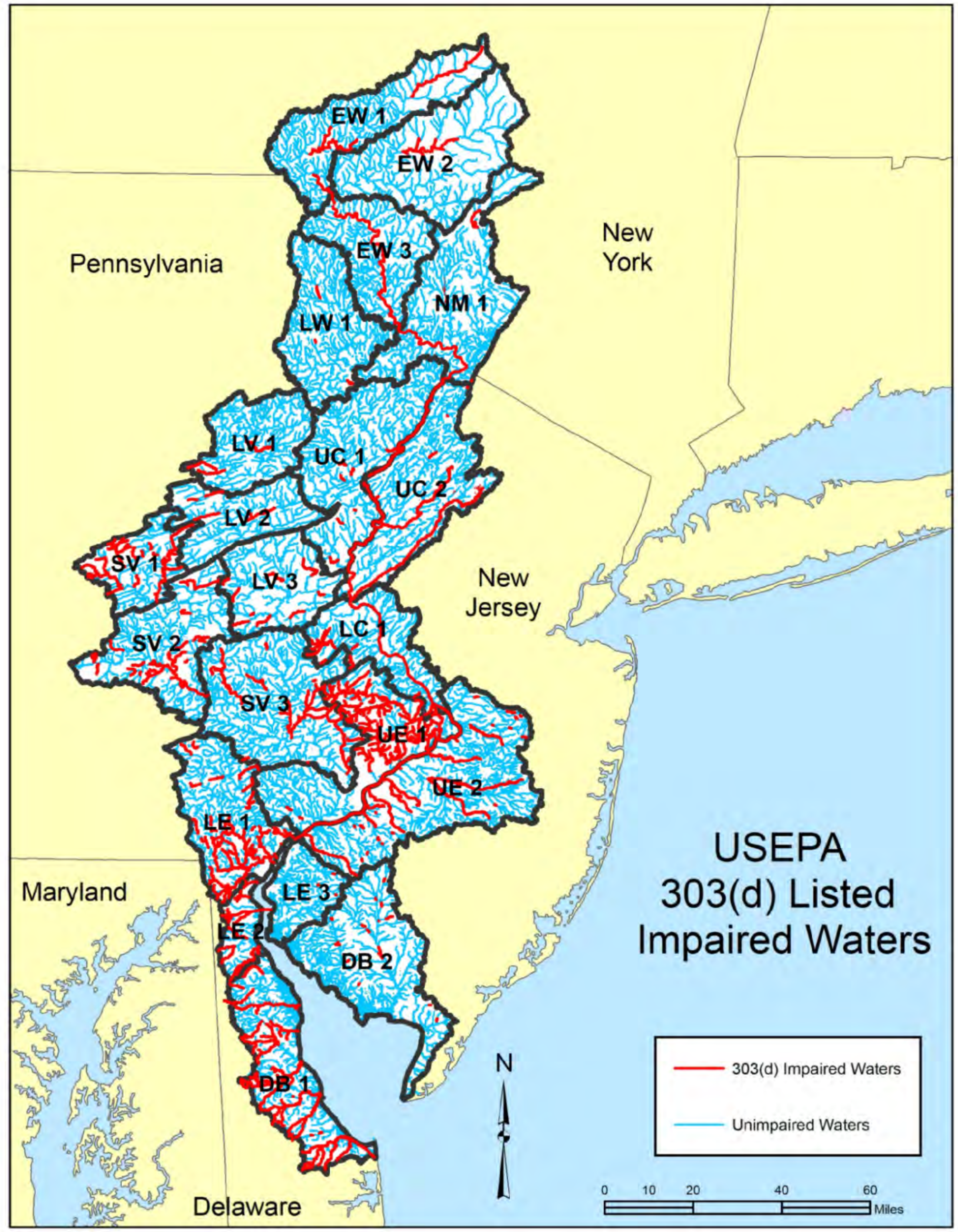
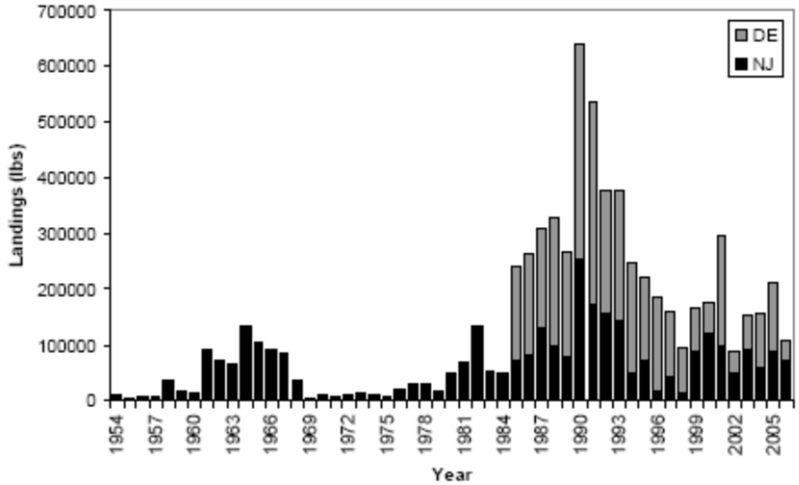
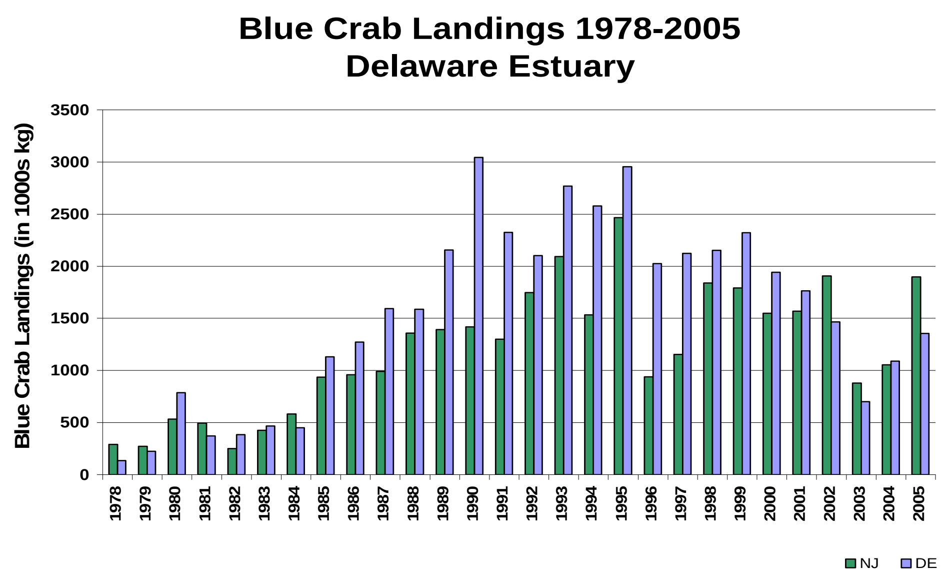
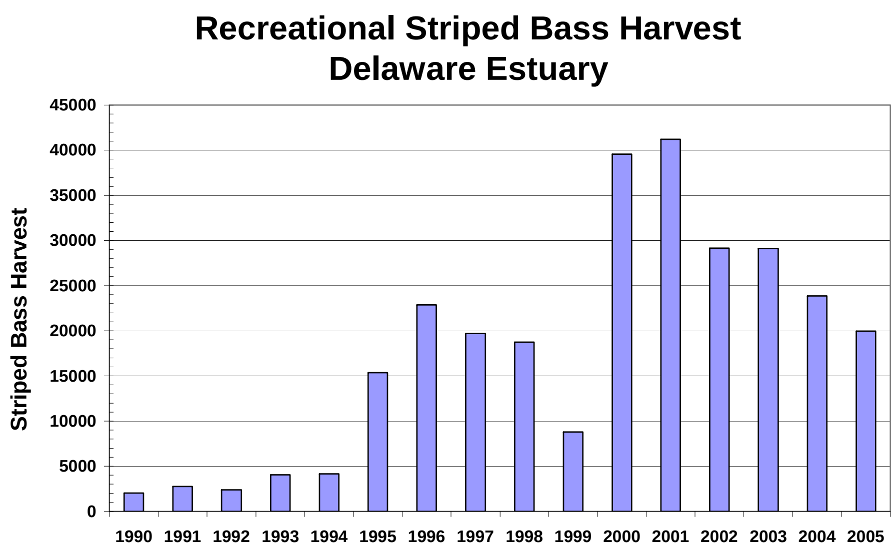
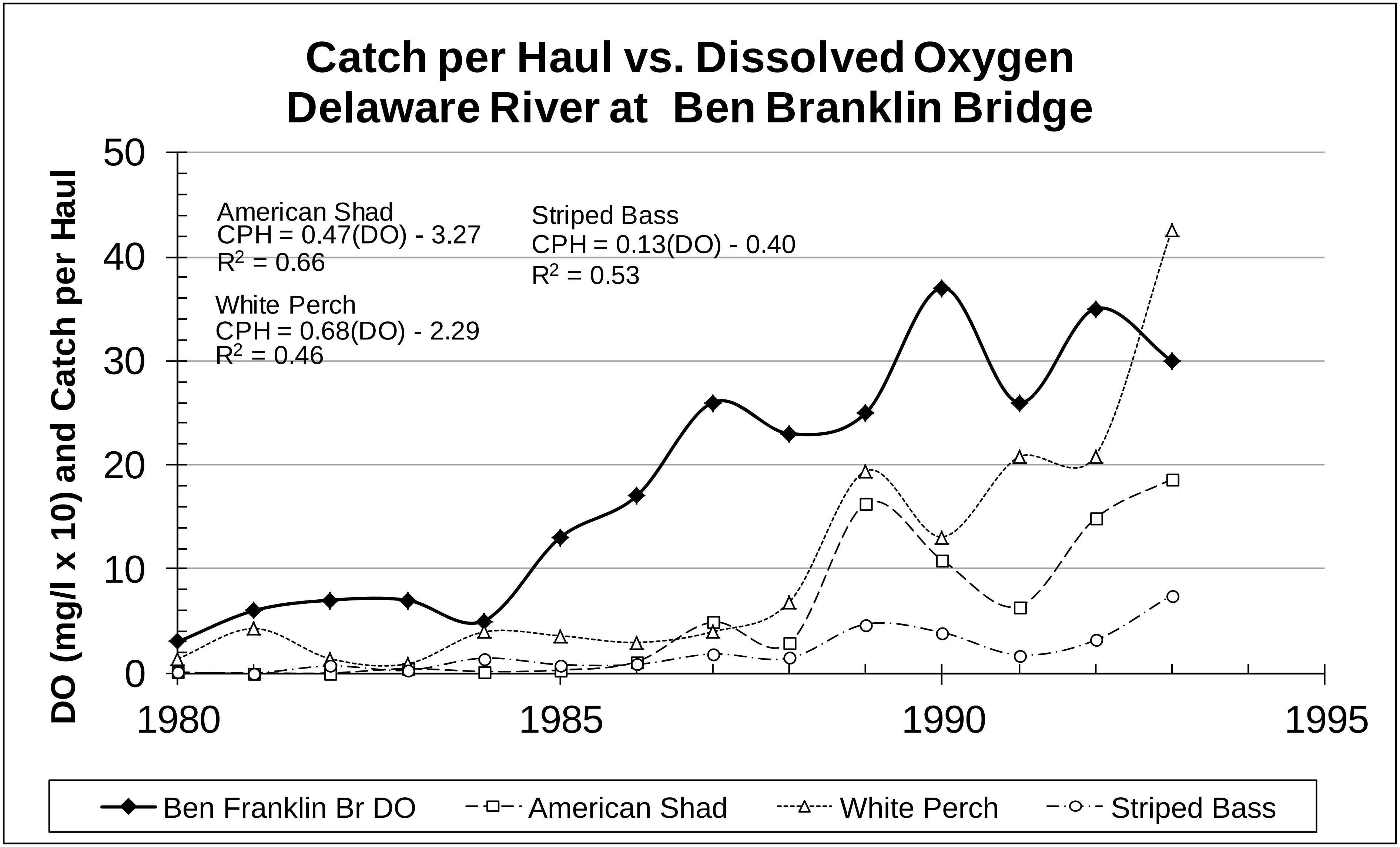


Figure 8. Commercial landings (lbs) of American shad, by state, in the Delaware River Basin, 1954-2006 (Source: ASMFC 2007a, NJ Division of Fish and Wildlife, DE Division of Fish and Wildlife). Landings from the State of Delaware are not available before 1985.

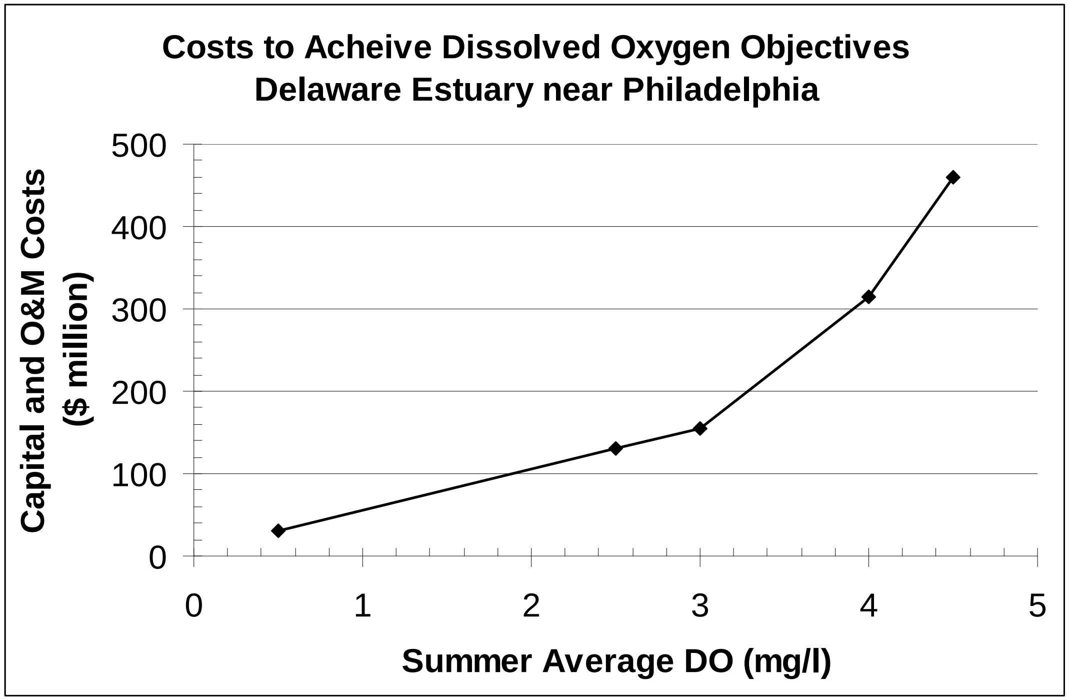




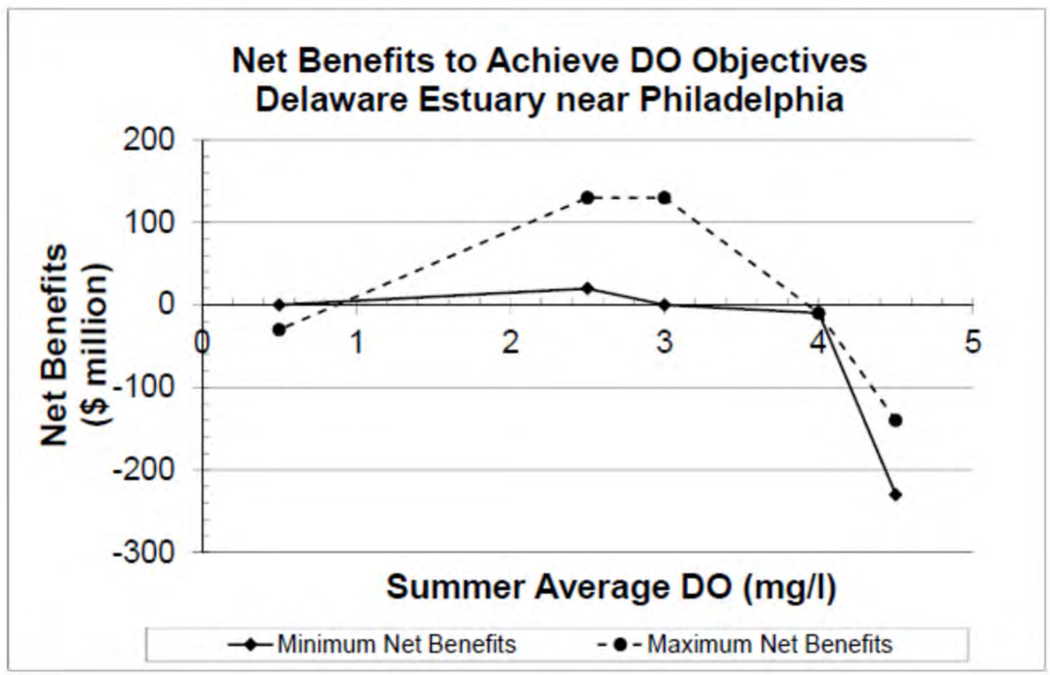




Weisberg et al. 1996 and USGS



First river econ study
FWPCA 1966



The Delaware River Basin in Del., NJ, NY, and Pa. is an economic and ecological system that contributes:

1. **$22 billion** in annual economic value from recreation, water quality, water supply, ecotourism, forest, agriculture, open space, and port benefits.

2. Ecosystem goods and services worth **$21 billion** per year, net present value (NPV) = **$683 billion**.

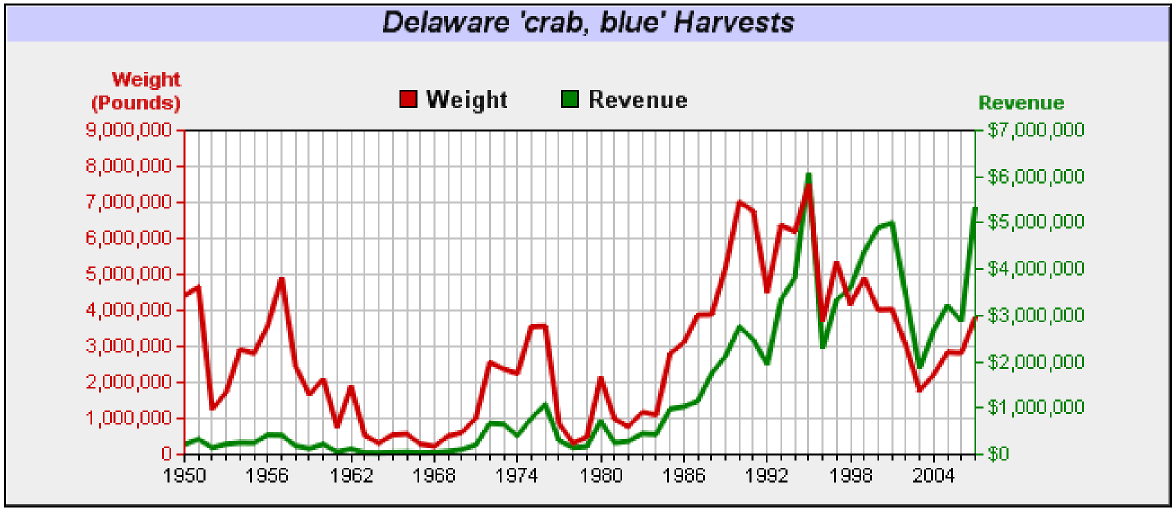
3. Over **600,000 jobs** with **$10 billion** in wages.

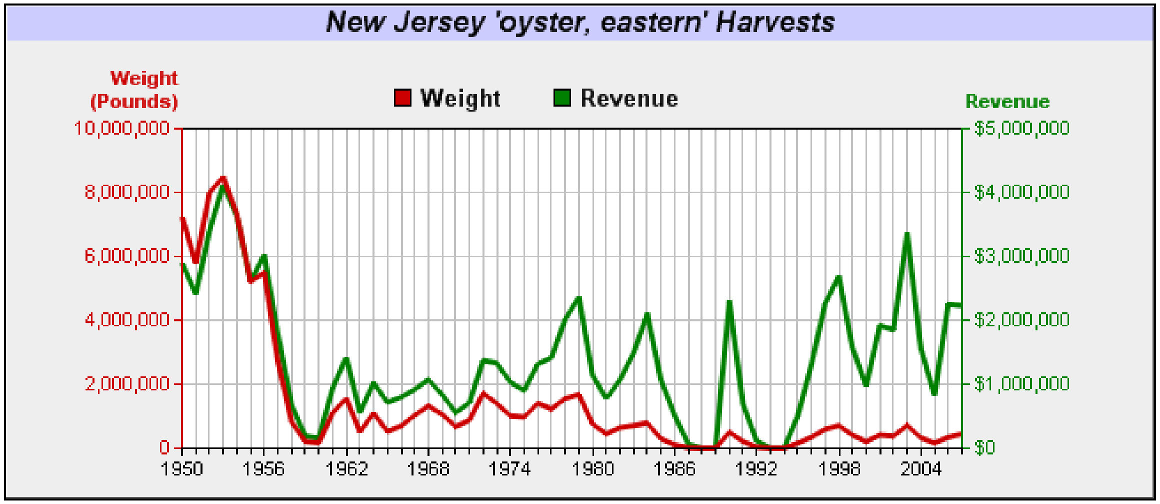
DELAWARE BAY
OYSTER
RESTORATION PROJECT

Commercial Fish Landings

- $34 million
- $0.60/lb
- 58 million lb

source: NMFS





Paddling

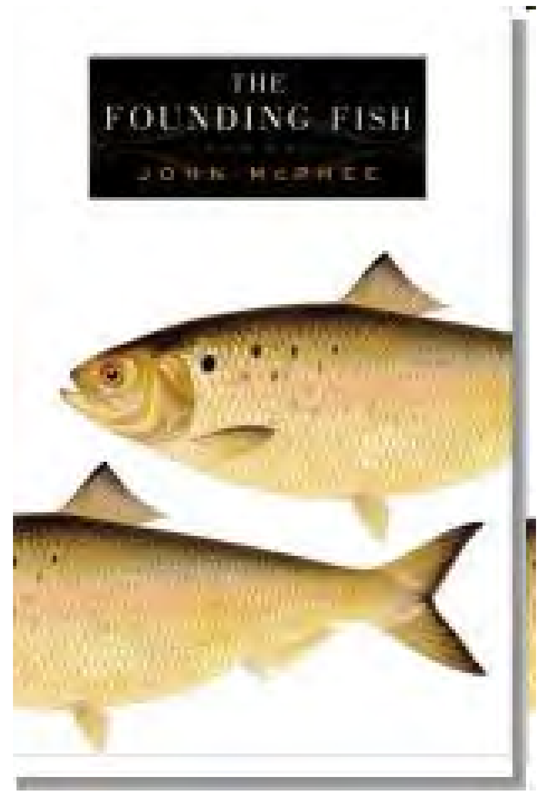
- $362 million
- 4,226 jobs
- Gear: $66 mil
- Trips: $296 mil
- 620,860 paddlers

source: Outdoor Industry Assoc. 2016

Fishing, Hunting, Bird Watching

- Fishing $576 million
  (18 trips/angler, $53/trip)

- Hunting $340 million
  (16 trips/hunter, $50/trip)

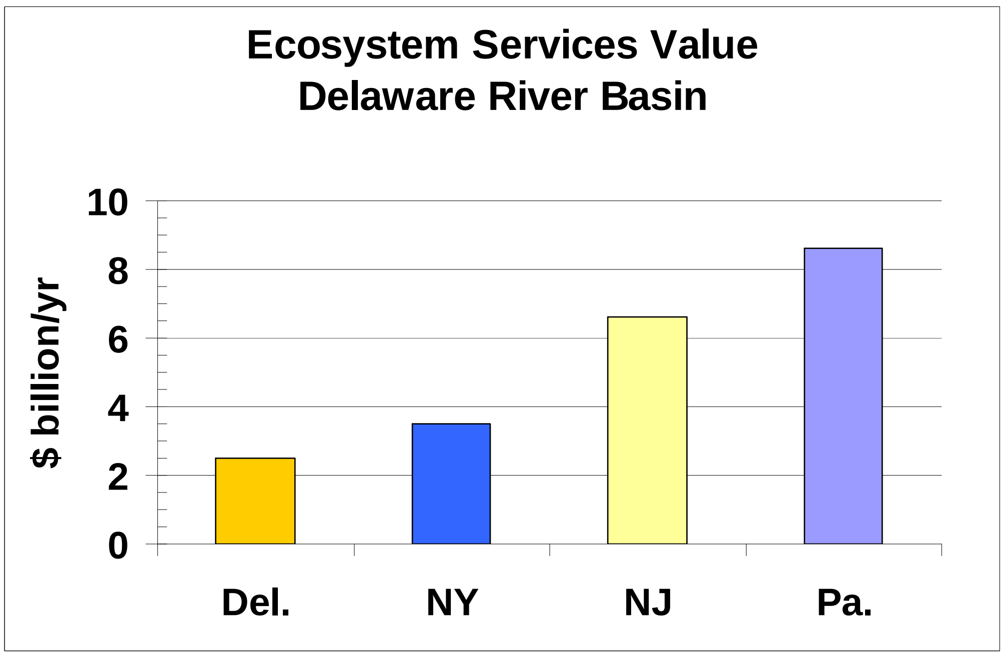


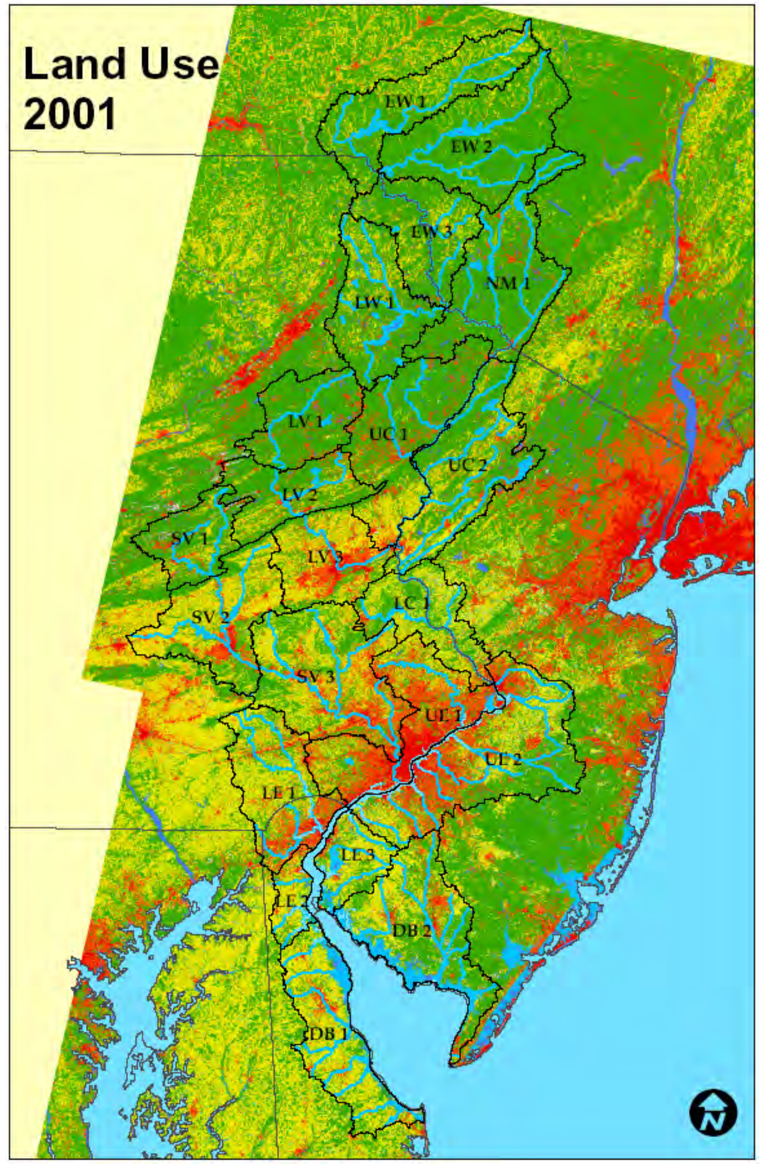
- Bird Watching $561 million
  (13/trips/yr, $27 trip)

Source: USFWS 2011

Ecosystem Goods and Services

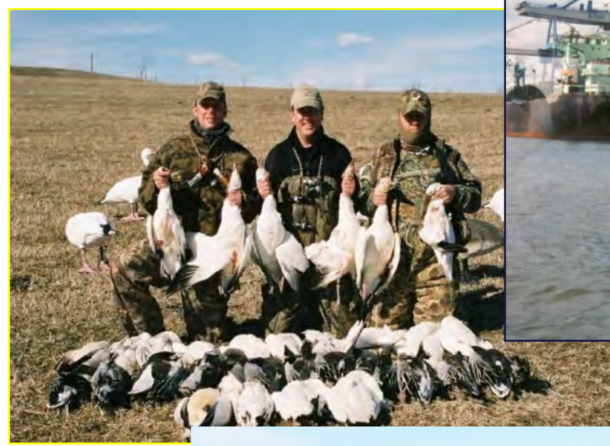
- Wetlands - $6.8 billion
- Farms - $4.8 billion
- Forests – $8.6 billion

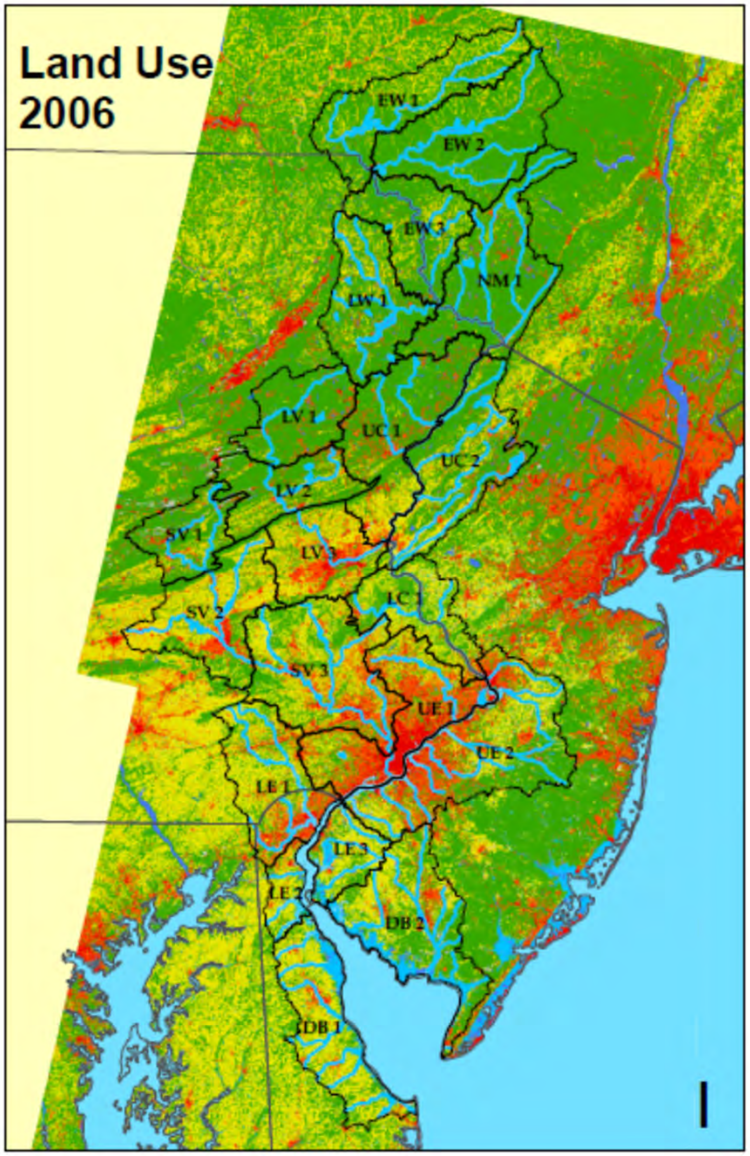


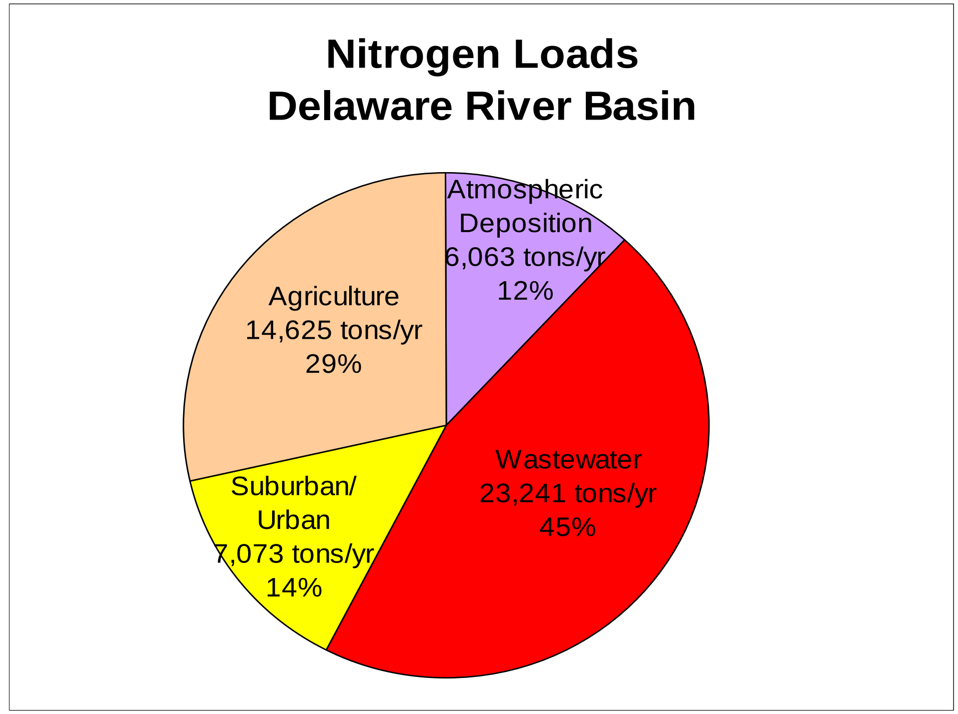


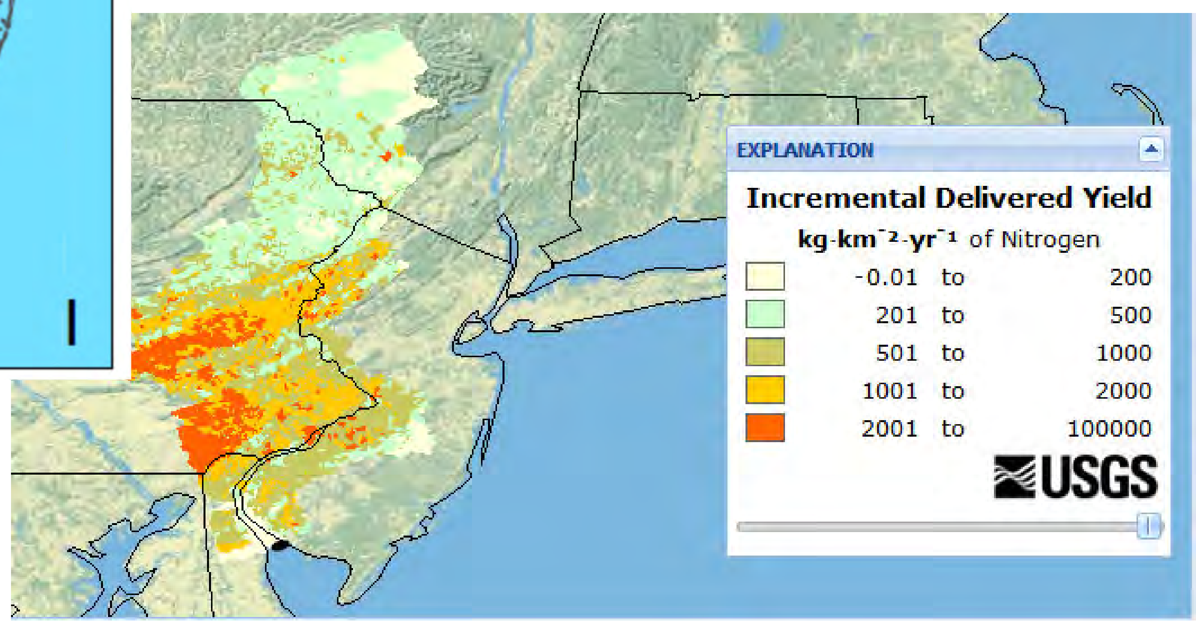
>600,000 jobs ($10 billion in wages)

- Marine & Water-related Construction
- Fishing & Aquaculture
- Ship/Boat Building
- Tourism/Recreation
- Marine Transportation
- Hunting/Fishing/Wildlife Recreation-related
- Farming
- Water/Wastewater Utility
- Ports
- Watershed Protection/Management

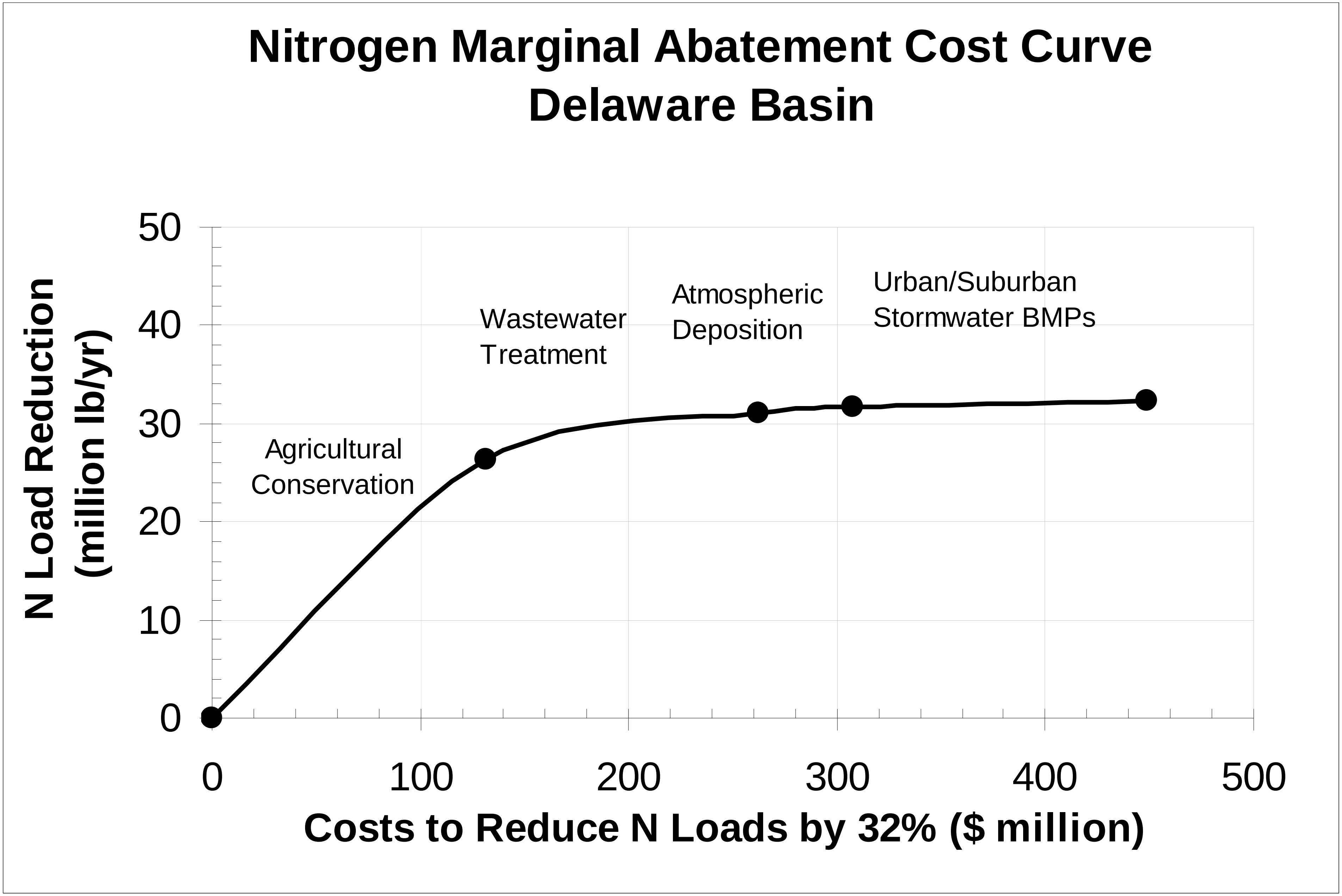





Land Use
2006
EW 1
EW 2
EW 3
NM 1
LW 1
LV 1
UC 1
UC 2
LV 2
SV 1
LV 3
SV 2
LC 1
SV 3
UE 1
UE 2
LE 1
LE 3
LE 2
DB 2
DB 1


Nitrogen Loads
Delaware River Basin
Atmospheric Deposition 6,063 tons/yr 12%
Agriculture 14,625 tons/yr 29%
Wastewater 23,241 tons/yr 45%
Suburban/ Urban 7,073 tons/yr 14%


EXPLANATION
Incremental Delivered Yield
kg·km⁻²·yr⁻¹ of Nitrogen
-0.01 to 200
201 to 500
501 to 1000
1001 to 2000
2001 to 100000
USGS

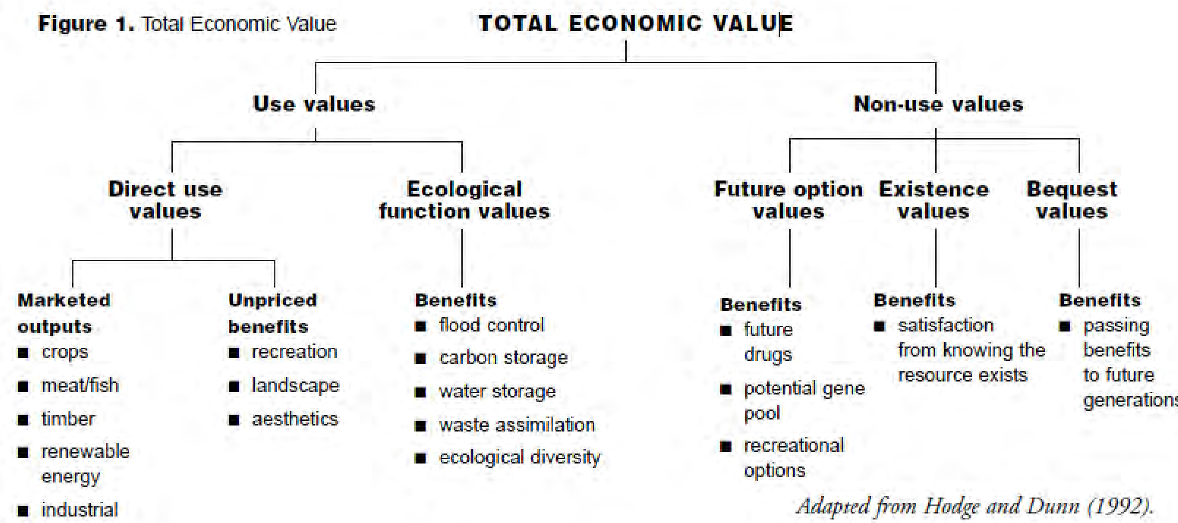
Costs



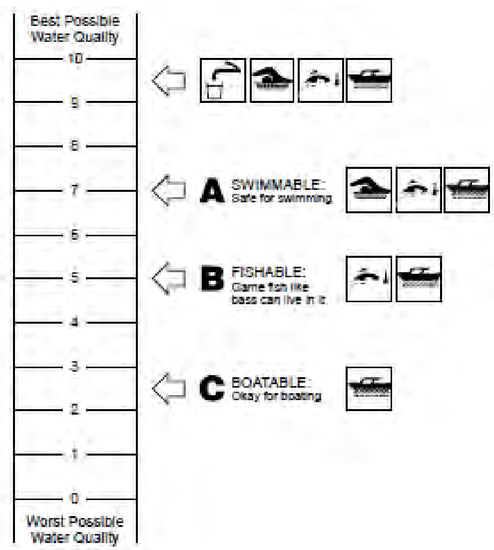
Nitrogen Marginal Abatement Cost Curve
Delaware Basin
N Load Reduction
(million lb/yr)
50
40
30
20
10
0
0
100
200
300
400
500
Costs to Reduce N Loads by 32% ($ million)
Agricultural
Conservation
Wastewater
Treatment
Atmospheric
Deposition
Urban/Suburban
Stormwater BMPs

Benefits

Figure 1. Total Economic Value

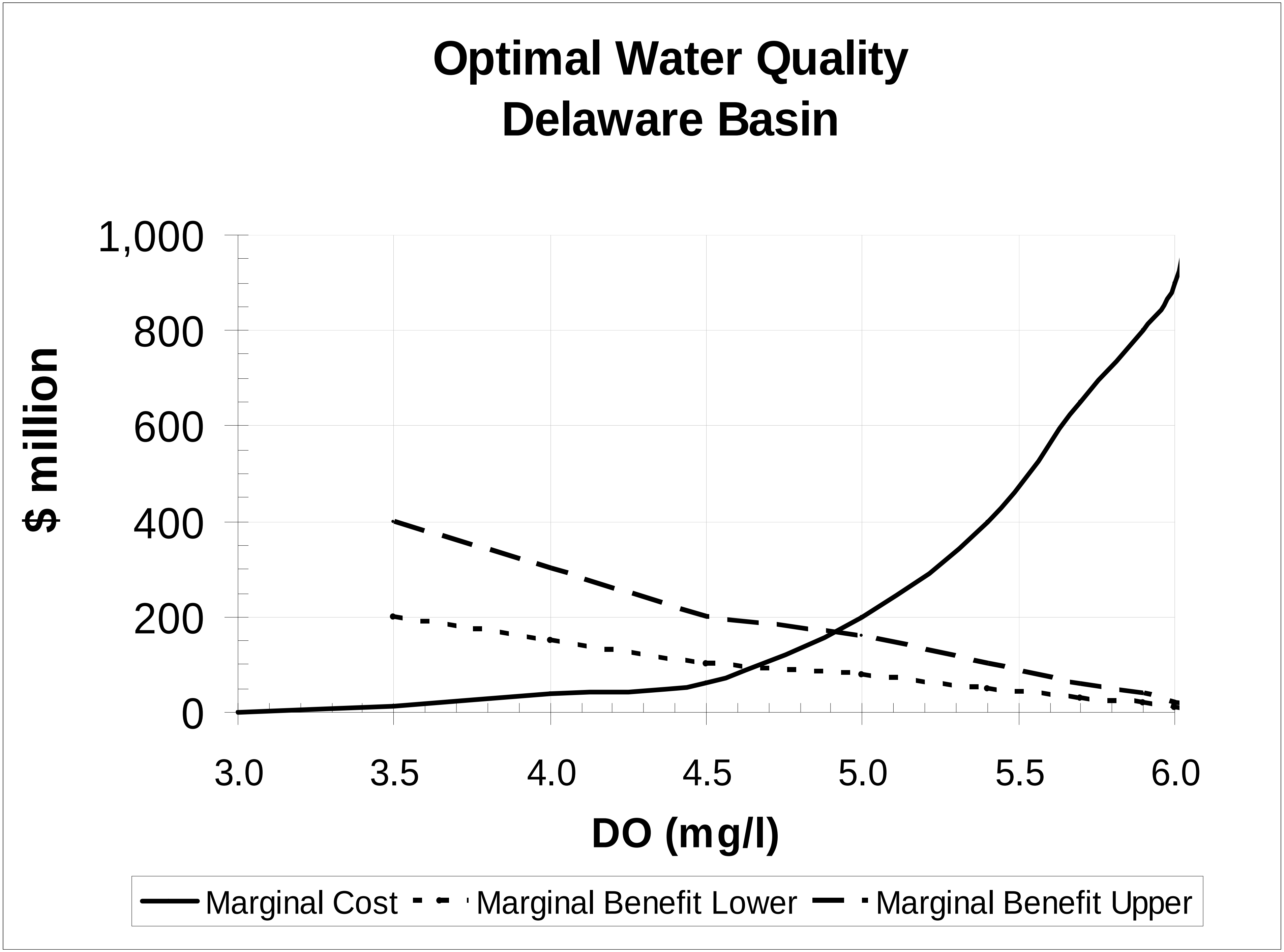


Adapted from Hodge and Dunn (1992).



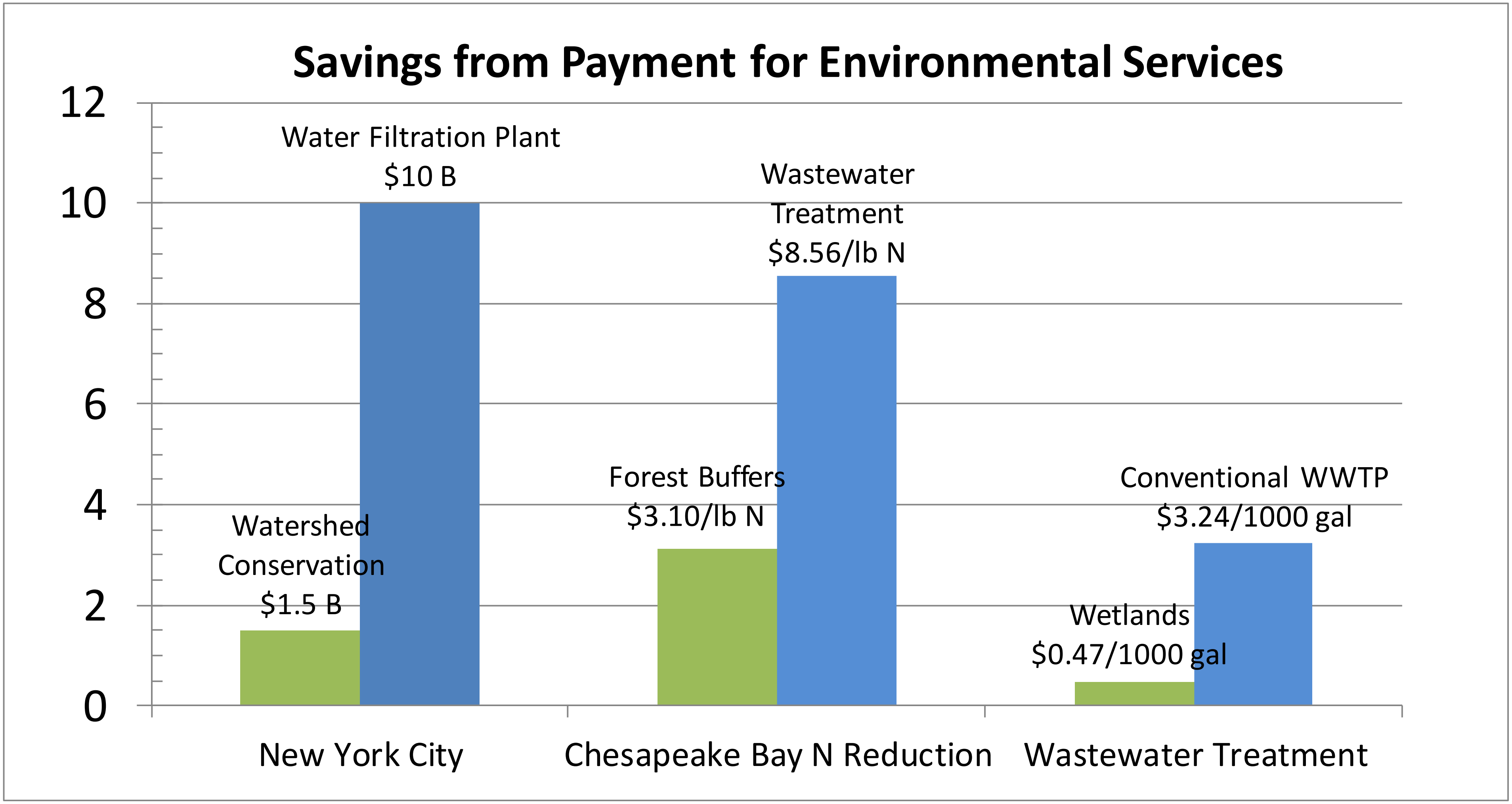
Resources for the Future water quality ladder
(Carson and Mitchell 1993)

Category	Activity	Existing Value (DO 3.5 mg/l) ($ million/yr)		Benefits (DO 5 mg/l) ($ million/yr)	
		Low	High	Low	**High**
Use					
Recreation	Viewing, Boating, Fishing	28	56	11	**22**
	Boating	212	472	61	**350**
	Fishing	286	528	172	**315**
	Shad fishing	0	0	0	**5**
	Bird/Wildlife Watching	430	437	22	**43**
	Waterfowl Hunting	2	22	0.1	**2**
	Swimming	0	0	0	**0**
	Beach Going	9	63	3	**20**
Commercial	Fishing	46	46	0	**26**
Indirect Use	Property Value	762	1,523	61	**122**
Water Supply	Municipal Water Supply	196	196	12	**24**
	Industrial Water Supply	31	31	8	**16**
Nonuse					
Existence/Bequest	WTP Fishable WQ	85	171	65	**131**
	WTP Swimmable WQ			73	**147**
Total		**2,087**	**3,545**	**488**	**1,223**



Optimal Water Quality
Delaware Basin
$ million
1,000
800
600
400
200
0
3.0
3.5
4.0
4.5
5.0
5.5
6.0
DO (mg/l)
Marginal Cost
Marginal Benefit Lower
Marginal Benefit Upper

How to Fix the River? Nature.



Thank you!