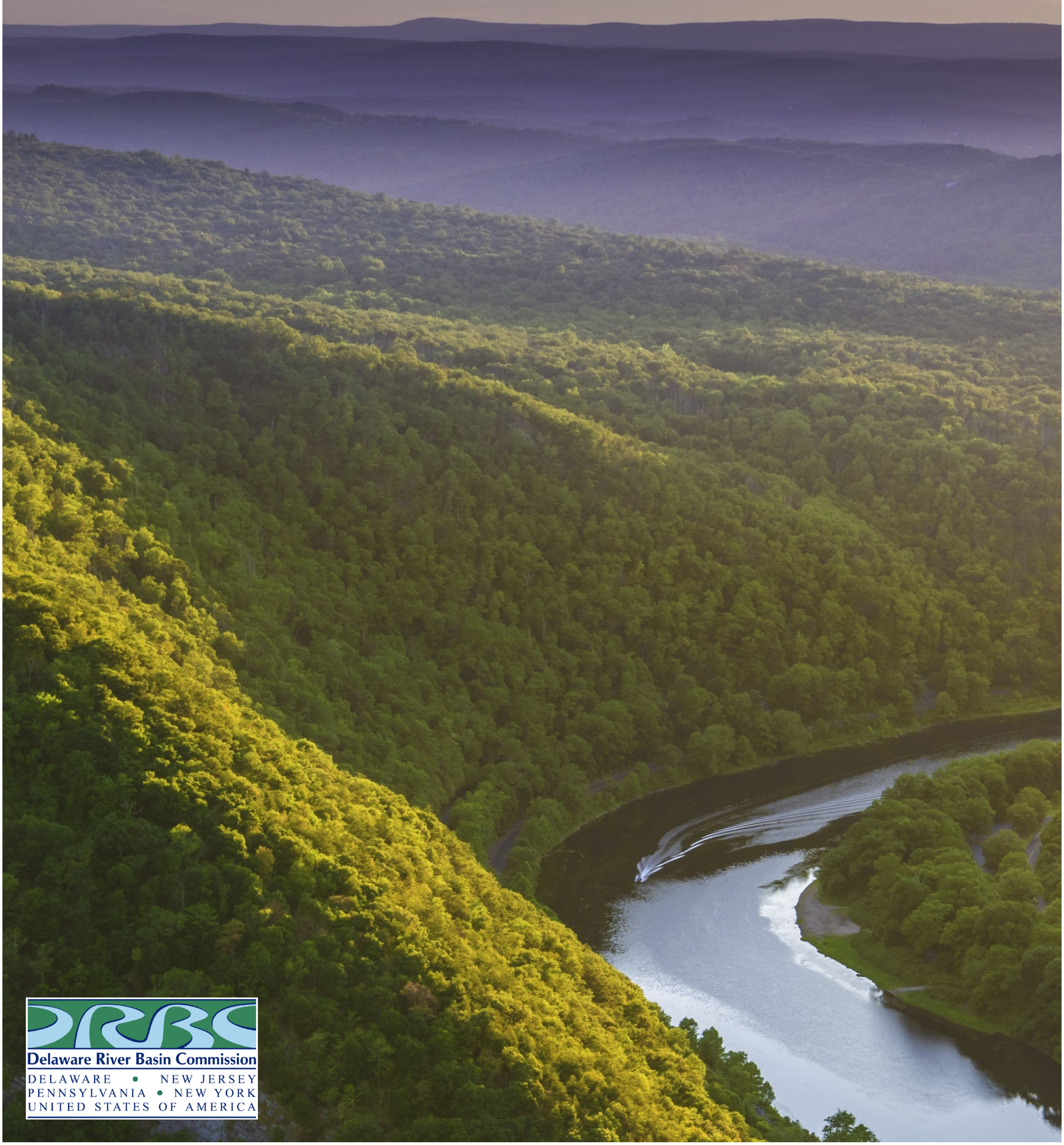
STATE OF THE BASIN 2025



Delaware River Basin Commission
DELAWARE • NEW JERSEY
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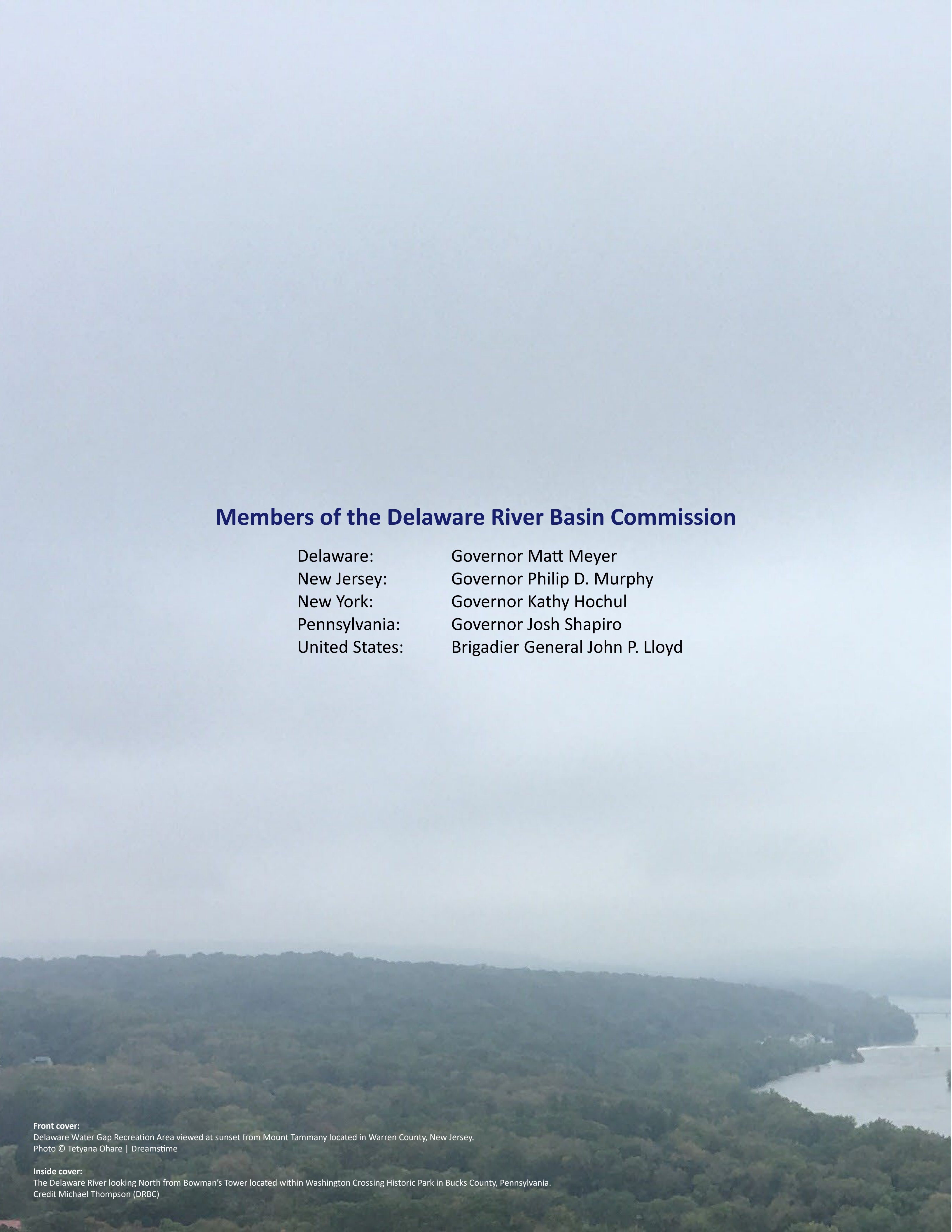
UNITED STATES OF AMERICA



Members of the Delaware River Basin Commission

Delaware:	Governor Matt Meyer
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New York:	Governor Kathy Hochul
Pennsylvania:	Governor Josh Shapiro
United States:	Brigadier General John P. Lloyd

Front cover:
Delaware Water Gap Recreation Area viewed at sunset from Mount Tammany located in Warren County, New Jersey.
Photo © Tetyana Ohare | Dreamstime

Inside cover:
The Delaware River looking North from Bowman's Tower located within Washington Crossing Historic Park in Bucks County, Pennsylvania.
Credit Michael Thompson (DRBC)

Message from the Executive Director

I am pleased to report that the state of the Delaware River Basin is generally good and improving in several areas. The Delaware River Basin Commission's "State of the Basin 2025" – our fourth such publication since 2008 – benchmarks conditions and tracks progress toward achieving key DRBC water resource management goals for maintaining an adequate and sustainable supply of suitable quality water that can be equitably accessed, is resilient in the face of climate change and other emerging challenges, and balances the diverse needs of our region for public water supply, energy, recreation, industry, commerce, agriculture, and aquatic life.

The report provides a detailed evaluation of 36 indicators for watersheds and landscapes, water quantity, climate change, water quality, and living resources. It includes a rating and a directional trend for most indicators, providing a snapshot of the state of our water resources today as well as where we are heading in the future based on current conditions, programs, and policies. Most of the indicators received a "Good" or "Very Good" rating, while trends are predominantly "Neutral." Lower ratings or declining trends for some indicators show us where additional study and stewardship are required.

There are two notable changes from the previous State of the Basin report in 2019. First, climate change was previously included as a single indicator within the chapter on water quantity but has now been incorporated as its own chapter with three specific indicators. Second, a new chapter on Diversity, Equity, Inclusion, Justice and Belonging (DEIJB) has been included. While quantifiable indicators are not included, the chapter highlights milestones in DEIJB related to the Basin's water resources over the last five years, providing information that may inform the development and use of possible indicators in the years to come.

Mark Twain is credited, perhaps apocryphally, with saying, "Whiskey is for drinking; water is for fighting over." What a striking comparison that allows us to recognize water for the vital – and shared – resource it is.

The Delaware River Basin Commission manages, protects, and improves our shared water resources, without the fighting Twain considered inevitable. This arrangement benefits a regional economy that relies upon our water and waterways; diverse habitats for living resources; abundant opportunities for water-based recreation; a high quality of life for residents throughout our region; and over 14.2 million people in Delaware, New Jersey, New York, and Pennsylvania who rely on drinking water from the Delaware River Basin.

Ours is a complex charge that requires the cooperation and commitment of government at all levels, as well as businesses, industries, philanthropic and academic institutions, and all of us who depend on this vital resource. This report not only highlights the work of the Delaware River Basin Commission but also recognizes the important contributions made by agencies and organizations who are working together to achieve our shared goals.

Kristen Bowman Kavanagh, P.E.
Executive Director

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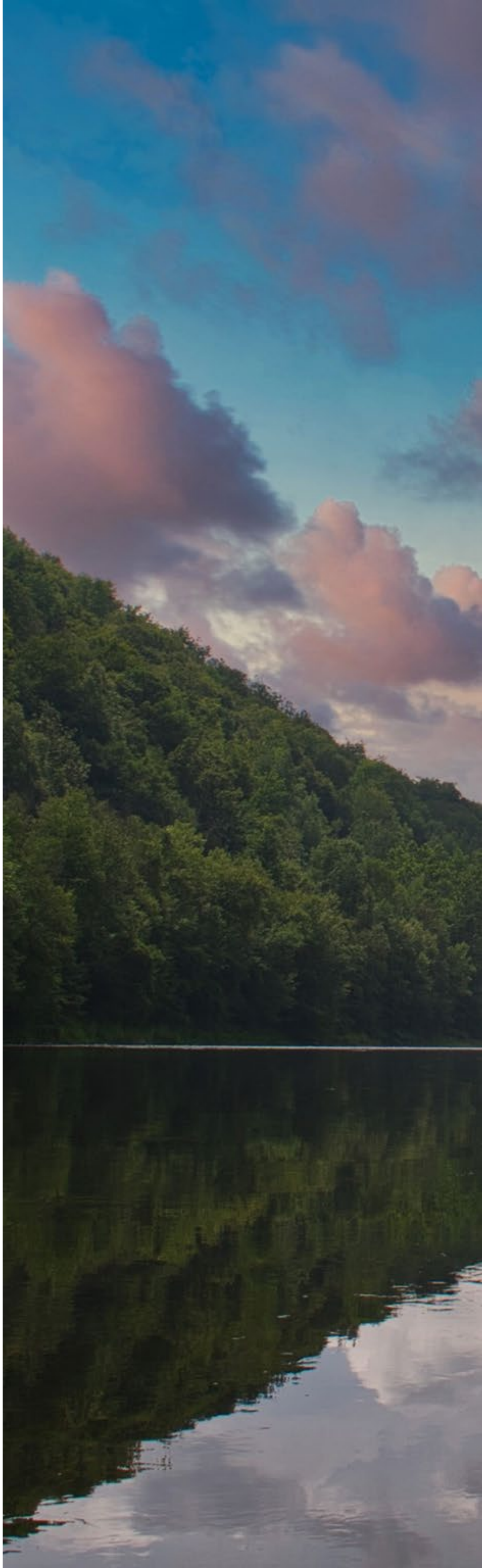

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Sunset reflecting over the Delaware River in New York.
Photo © Marketa Rawn | Dreamstime

Authorization

This work is being conducted in accordance with Article 3 Section 3.6(c) of the Delaware River Basin Compact (PL 87-328, 75 Stat. 688). More specifically, the project is outlined in DRBC Water Resources Program FY2025-2027 (DRBC 2024) under Section 2.2 (Water Resources Management Work Program), sub-section 5 (Education and Outreach for Stewardship (KRA #5)).

Acknowledgements

The Delaware River Basin Commission staff are grateful to the following organizations which assisted in various ways throughout the development of this report.

- Partnership for the Delaware Estuary (PDE)
- Delaware Division of Fish and Wildlife (DDFW)
- NJDEP Fish and Wildlife (NJDEP FW)
- United States Environmental Protection Agency (USEPA)
- United States Fish and Wildlife Service (USFWS)
- United States Geological Survey (USGS)
- Haskin Shellfish Research Laboratory (HSRL)
- Conserve Wildlife Foundation of New Jersey

In addition to data collected by DRBC, other data obtained and used in this report are cited throughout. Where data were obtained and presented from the Delaware Department of Natural Resources and Environmental Control (DNREC) or the Delaware Division of Fish and Wildlife (DDFW), the following statement is applicable: *This work does not represent the opinions of the State of Delaware, Delaware Department of Natural Resources and Environmental Control or Delaware Division of Fish & Wildlife*.

The portion of this report focused on Living Resources (Chapter 5), relies significantly on the *2022 Technical Report for the Delaware Estuary and Basin* prepared by the Partnership for the Delaware Estuary (PDE 2022). Numerous sections were updated with recent data, in many cases obtained from the TREB section authors, referenced throughout the text as appropriate.

In addition to identifying desired environmental end states, the Water Resources Plan for the Delaware River Basin includes goals for the development of partnerships; the exchange of data, information and technology; and the improvement of coordination and cooperation among Basin institutions, agencies and organizations. The *State of the Basin Report 2025* fulfills those goals.

Abbreviations and Units

Organizations

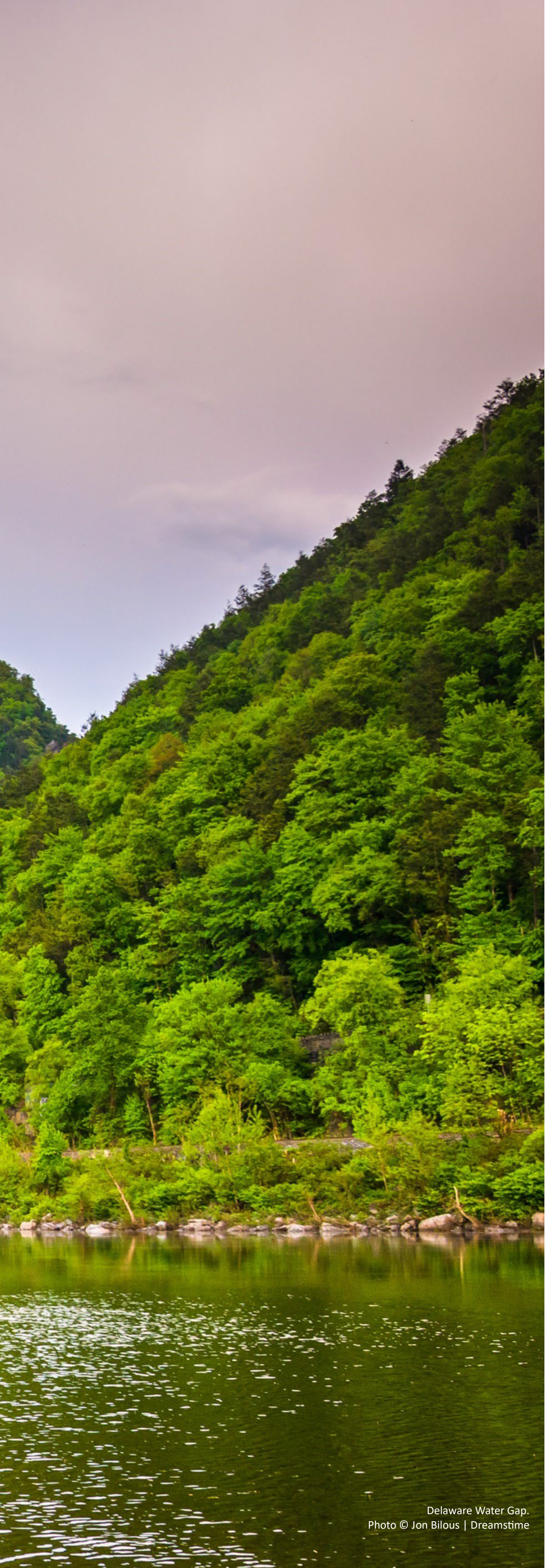
ASMFC..............Atlantic States Marine Fisheries Commission
AWWA..............American Water Works Association
CCMUA.............Camden County Municipal Utilities Authority
CDRW...............Coalition for the Delaware River Watershed
CEQ..................Council on Environmental Quality
CWP.................Center for Watershed Protection
DDFW..............Delaware Division of Fish and Wildlife
DNREC..............Department of Natural Resources and Environmental Control
DRBC................Delaware River Basin Commission
EBTJV................Eastern Brook Trout Joint Venture
HSRL.................Haskin Shellfish Research Laboratory
NFWF................National Fish and Wildlife Foundation
NJDEP...............New Jersey Department of Environmental Protection
NJDEP FW.........NJDEP Fish and Wildlife
NMFS................National Marine Fisheries Service
NOAA................National Oceanic and Atmospheric Administration
NYSDEC.............New York State Department of Environmental Conservation
PADEP...............Pennsylvania Department of Environmental Protection
PDE...................Partnership for the Delaware Estuary
PFBC.................Pennsylvania Fish & Boat Commission
PWD.................Philadelphia Water Department
USEPA...............United States Environmental Protection Agency
USFWS.............United States Fish and Wildlife Service
USGS................United States Geological Survey
UWFP...............Urban Waters Federal Partnership

Units

amsl.................above mean sea level
cfs....................cubic feet per second
CPUE................catch per unit effort
CY.....................calendar year
ft......................foot
m......................meter
mg/L.................milligrams per liter
MGD.................million gallons per day
mm/year...........millimeters per year
ng/L..................nanograms per Liter
RM...................river mile

Miscellaneous

ARM.................Adaptive Resource Management
BOD..................Biochemical Oxygen Demand
BTCZ.................Brook Trout Conservation Zone
C-CAP................Coastal Change Analysis Program
CECs.................Contaminants Emerging Contaminants
CEJST................Climate Change and Environmental Justice Screening Tool
CLCPA...............Climate Leadership and Community Protection Act
CMSA...............Catch Multiple Survey Analysis
DDT..................dichlorodiphenyltrichloroethane
DEIJB................Diversity, Equity, Inclusion, Justice, and Belonging
DO....................Dissolved Oxygen
DRB..................Delaware River Basin
DRWI................Delaware River Watershed Initiative
ECL...................Environmental Conservation Law
EJ......................Environmental Justice
EJMAP..............NJ Environment Justice Mapping, Assessment, and Protection
ELL...................Economic Level of Leakage
EWQ.................Existing Water Quality
FMP..................Fisheries Management Plan
FWAS................Free Water Audit Software
GBIF.................Global Biodiversity Information Facility
GSI...................Green Stormwater Infrastructure
HAB..................Harmful Algal Bloom
HSCs.................Horseshoe crabs
HTF...................High Tide Flooding
HUC..................Hydrologic Unit Code
ILI.....................Infrastructure Leakage Index
IQR...................Inner Quartile Range
MRLC................Multi-Resolution Land Characteristics
MS4..................Municipal Separate Stormwater Sewer System
MSX..................Multinucleated Sphere Unknown
NAS..................Nonindigenous Aquatic Species
NISIC................National Invasive Species Information Center
NJ STAP............New Jersey Science and Technical Advisory Panel
NLCD................National Land Cover Database
PACZM.............Pennsylvania Coastal Zone Management
PBT...................Persistent, Bioaccumulative, Toxic
PCBs.................Polychlorinated biphenyls
PEJAs................Potential Environmental Justice Areas
PFAS.................Per and polyfluoroalkyl substances
PFOS.................Perfluorooctane Sulfonate
PRM.................Potomac-Raritan-Magothy
RCP..................Representative Concentration Pathways
RSLR.................Relative Sea Level Rise
SAV...................Submerged Aquatic Vegetation
SEPA GWPA.......Southeast Pennsylvania Groundwater Protected Area
SFMP................Sustainable Fishery Management Plan
SLR...................Sea Level Rise
SOTB................State Of The Basin
SPW.................Special Protection Waters
SSB...................spawning stock biomass
ssp....................Shared Socioeconomic Pathways
TREB.................Technical Report for the Estuary and Basin
UARL................Unavoidable Annual Real Losses
WQ...................Water Quality
WQAC..............Water Quality Advisory Committee
WWF................Warm Water Fisheries
YOY...................Young-of-Year



Delaware Water Gap.
Photo © Jon Bilous | Dreamstime

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INTRODUCTION

The Delaware River Basin Commission (DRBC) has been playing a unique role since 1961 as the agency charged with managing the Delaware River Basin's water resources. Through the DRBC, the states of Delaware, New Jersey, New York, and Pennsylvania, along with the federal government have built an exceptional record of results to improve water quality and to provide a sustainable water supply.

On September 29, 1999, the Governors of the four Delaware River Basin states signed a resolution challenging the Basin community to develop a unifying vision: a comprehensive Water Resources Plan for the Delaware River Basin. In response to the Governors' challenge, the DRBC convened the Watershed Advisory Council. The council successfully forged a unifying vision for the Basin, which was a goal-based plan to guide policy and action. In 2004, the DRBC published the *Water Resources Plan for the Delaware River Basin* (The Basin Plan).

The Commissioner's resolution (2004-BP) supporting the implementation of the Basin Plan directed staff, in coordination with state and federal agencies, to compile an environmental goals and indicators report every five years to define the state of the Basin and to describe progress towards achieving the desired results of the Basin Plan. This report follows previous iterations (performed in 2008, 2013, and 2019) and satisfies the directive in Resolution No. 2004-BP.

Mount Minsi and the Delaware River seen from a pedestrian bridge in Portland, Pennsylvania Photo

BASIN OVERVIEW

Lying in the densely populated corridor of the northeastern United States, the Delaware River stretches approximately 330 miles from headwaters in New York State to its confluence with the Atlantic Ocean. The Delaware River Basin (Figure 1) encompasses approximately 12,800 square miles of land area, nearly 800 square miles of Bay and over 2,000 tributaries, including many significant rivers such as the Schuylkill and Lehigh. The northernmost tributaries to the Delaware River originate in the forested western slopes of the Catskill Mountains, the highest point being Slide Mountain which peaks around 4,180 feet above mean sea level (amsl). The East and West Branches of the river converge at Hancock, NY (elevation ~800 feet), marking the Delaware River's official start as it begins its descent to the Atlantic Ocean.

***Figure 1**: The Delaware River Basin depicted with the portion of each Basin State as a different color.*

POLITICAL SETTING

The drainage area of the Basin encompasses extensive landscapes in New York, New Jersey, Pennsylvania and Delaware†. All or portions of 42 counties and 838 municipalities within the four Basin states contribute to and benefit from the resources of the Delaware River Basin. Water resources are also exported to cities outside of the Basin boundary in New Jersey and New York. While the states retain autonomy, the Delaware River Basin is unique in governance. The 1961 Compact establishing the DRBC was the first federal-interstate agreement for Basin-scale water resources management. The DRBC pre-dates the first Earth Day (1970), the establishment of the Environmental Protection Agency (1970) and the passage of the Clean Water Act (1972). The national significance of the Delaware River Estuary was acknowledged in 1988 when it became part of the National Estuary Program. This is the only river basin with both an interstate-federal Commission and a national estuary program in place.

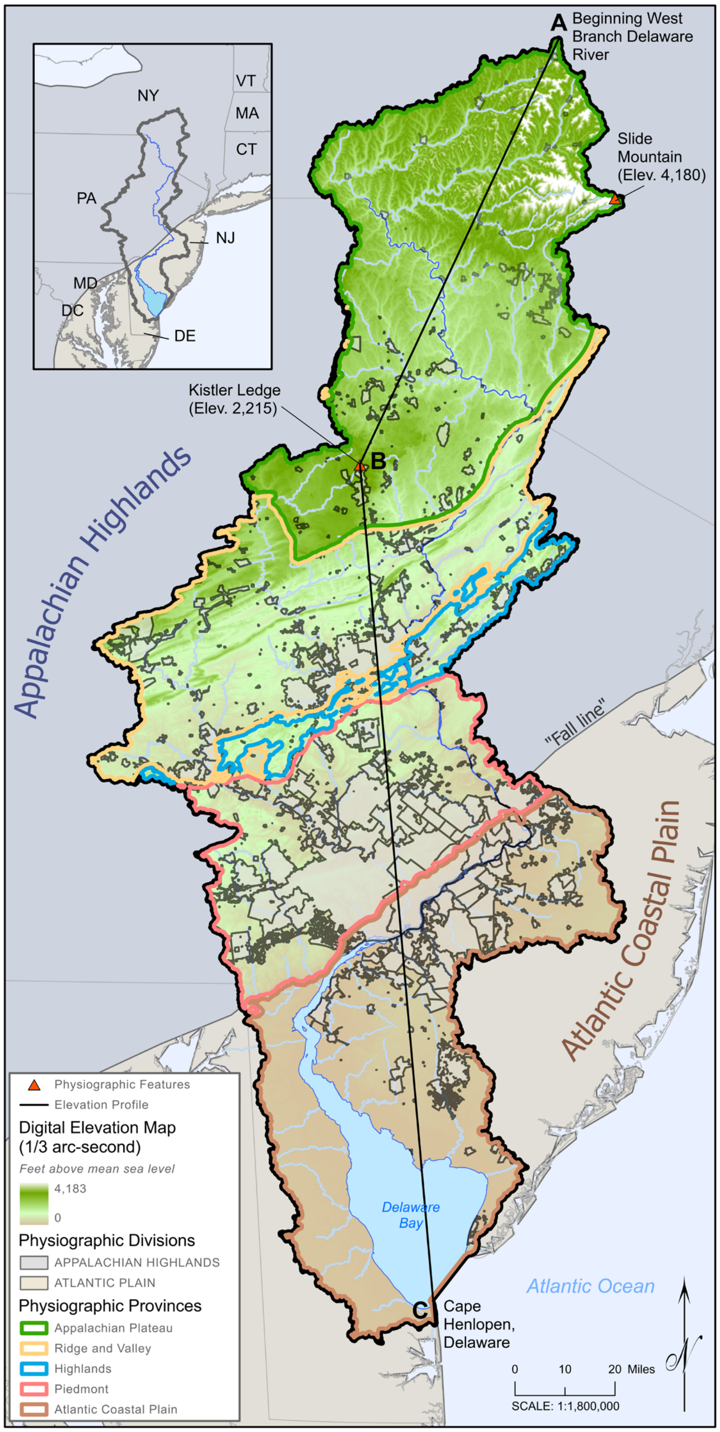
BASIN PERSPECTIVE

The Delaware River Basin is shaped by its tributaries, which are influenced by the underlying geology, topography, microclimates, and land uses of their watersheds. Therefore, this report is largely an assessment of the Delaware River Basin as a whole system of functioning parts. While some analyses are presented as Basin-wide averages, others are or can be broken into smaller regional scales to refine conclusions.

Physiographic Provinces

The Delaware River Basin lies in two significantly different hydrologic regions which correspond with two physiographic divisions: (1) the Appalachian Highlands, and (2) the Atlantic Coastal Plain. These regions are shown on Figure 2A, separated by a natural division called the "fall line".

† *Note that the Delaware River Basin also includes approximately eight square miles in Maryland, which are not typically accounted for in analyses in this report.*



The Appalachian Highlands

This region consists predominantly of consolidated sedimentary rock. This area includes four provinces, each of which has distinctive geology, landforms, and hydrologic characteristics.

I. Appalachian Plateau. This area is largely comprised of the Catskill and Pocono Mountains, where rivers and streams have carved deep and narrow valleys through folded shales and sandstone. The highest point in the Delaware River Basin is also the highest point in the Catskill Mountains, atop Slide Mountain at an elevation of around 4,180 feet amsl; the western slope drains to the headwaters of the Neversink River in a valley around 2,380 feet amsl. The highest point in the Pocono Mountains is also within the Delaware River Basin, Kistler Ledge at an elevation of 2,215 feet amsl.

II. Ridge and Valley. The northern portion contains series of long forested mountain ridges, while the southern portion is a broad lowland with rolling hills called the "Great Valley". A visualization of the aspect ratio between the Ridge and Valley can be seen as Figure 2B, noting that the Appalachian trail tracks along the top of a ridge.

III. Highlands. This is characterized by extensive forested hills and ridges drained by a network of steep, rocky streams.

IV. Piedmont. Widespread branching streams, rolling hills and good agricultural soils cover low yielding sedimentary and crystalline rock.

The Atlantic Coastal Plain

This region is a large wedge of unconsolidated sediments, underlain by bedrock and overlain by a veneer of local surficial soils. The deposits range from about 50 feet thick near the Delaware River to over 6,500 feet thick near the Atlantic Ocean. It is generally characterized by alternating layers of sand, clay and gravel (consequently forming alternating aquifers and confining layers).

B

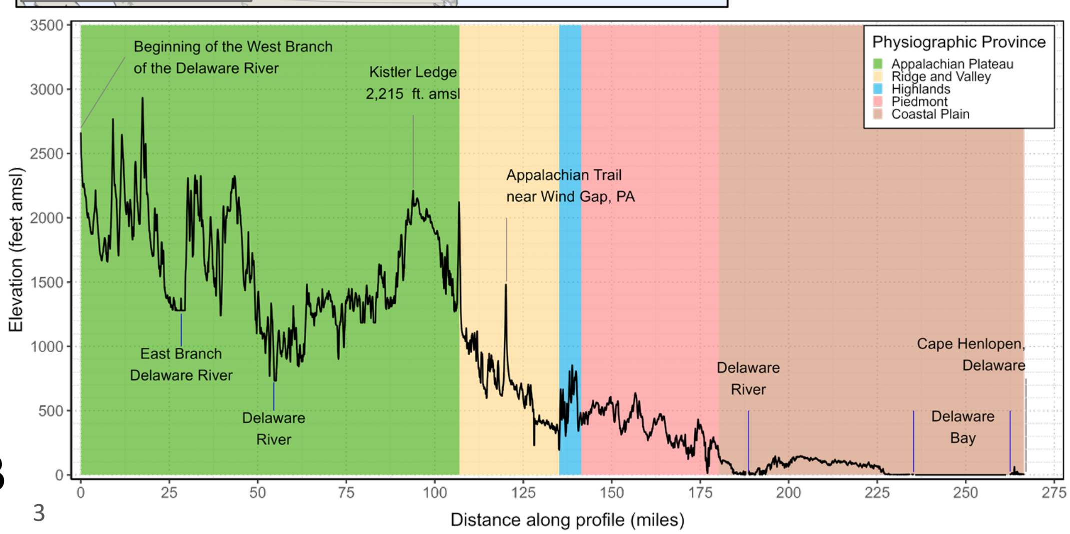


***Figure 2**: (**A**) The Delaware River Basin showing elevation (USGS 1/3 arc-second digital elevation map), physiographic province outlines, and public water supply service areas as semi-transparent grey shapes. (**B**) The elevation profile corresponding to that marked on the map.*

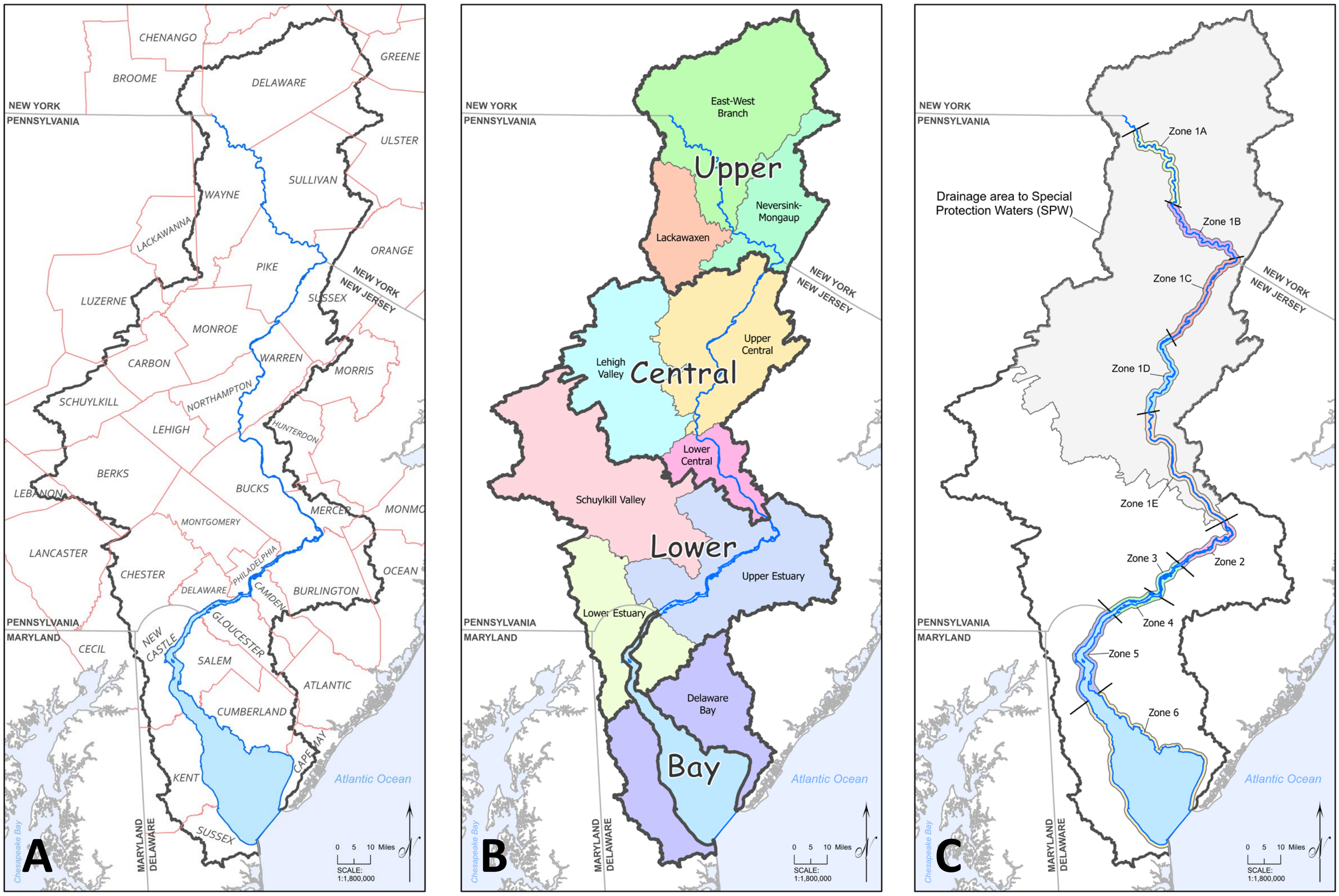


Figure 3: ***(A)*** *An overview of the Delaware River Basin's setting in the United States with the 42 counties overlapping the Basin.* ***(B)*** *The four regions of the Delaware River Basin (Upper, Central, Lower, Bay) and ten sub-regions as originally defined in the 2004 Basin Plan (DRBC 2004).* ***(C)*** *The WQ Zones are specific to the mainstem Delaware River, as well as the drainage area to waters designated as Special Protection Waters (SPW), as defined under 18 C.F.R. Part 410.*

Regional Watersheds

A watershed can be simply described as the area of land draining to a particular stream. As the Delaware River Basin is equal to the sum of its parts, regions and sub-regions are defined by watershed boundaries rather than state or political boundaries. There are four main regions, and ten sub-regions as indicated on Figure 3B. These are created by grouping watersheds together based on the segment of the Delaware River to which they drain.

Water Quality Zones

Much like the Basin itself is divided into smaller regions to help analyze data and trends, the mainstem Delaware River has been divided into portions termed Water Quality Zones. These WQ Zones are defined along the mainstem Delaware River in the non-tidal (WQ Zones 1A, 1B, 1C, 1D, and 1E) and tidal (WQ Zones 2, 3, 4, 5, and 6) portions of the Basin, in accordance with the DRBC Water Code 18 CFR Part 410 and as shown in Figure 3C.

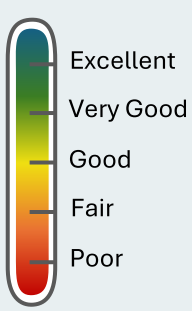
Tidal Regions

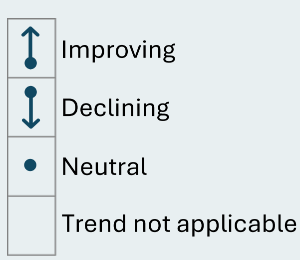
Above the fall line, freshwater riverine conditions exist. Below the fall line, the Delaware River is subject to tidal influences and, with increased proximity to the Delaware Bay, estuarine conditions exist. These factors have created the distinction between the 'Non-Tidal' and 'Tidal' regions of the Delaware River Basin, as indicated on Figure 3C.

- Non-Tidal Region: Upper and Central Regions
- Tidal Region: Lower and Bay Regions. This can also collectively be referred to as the Estuary Region, as it is the same area included in the National Estuary Program.

How to interpret the *State of the Basin*

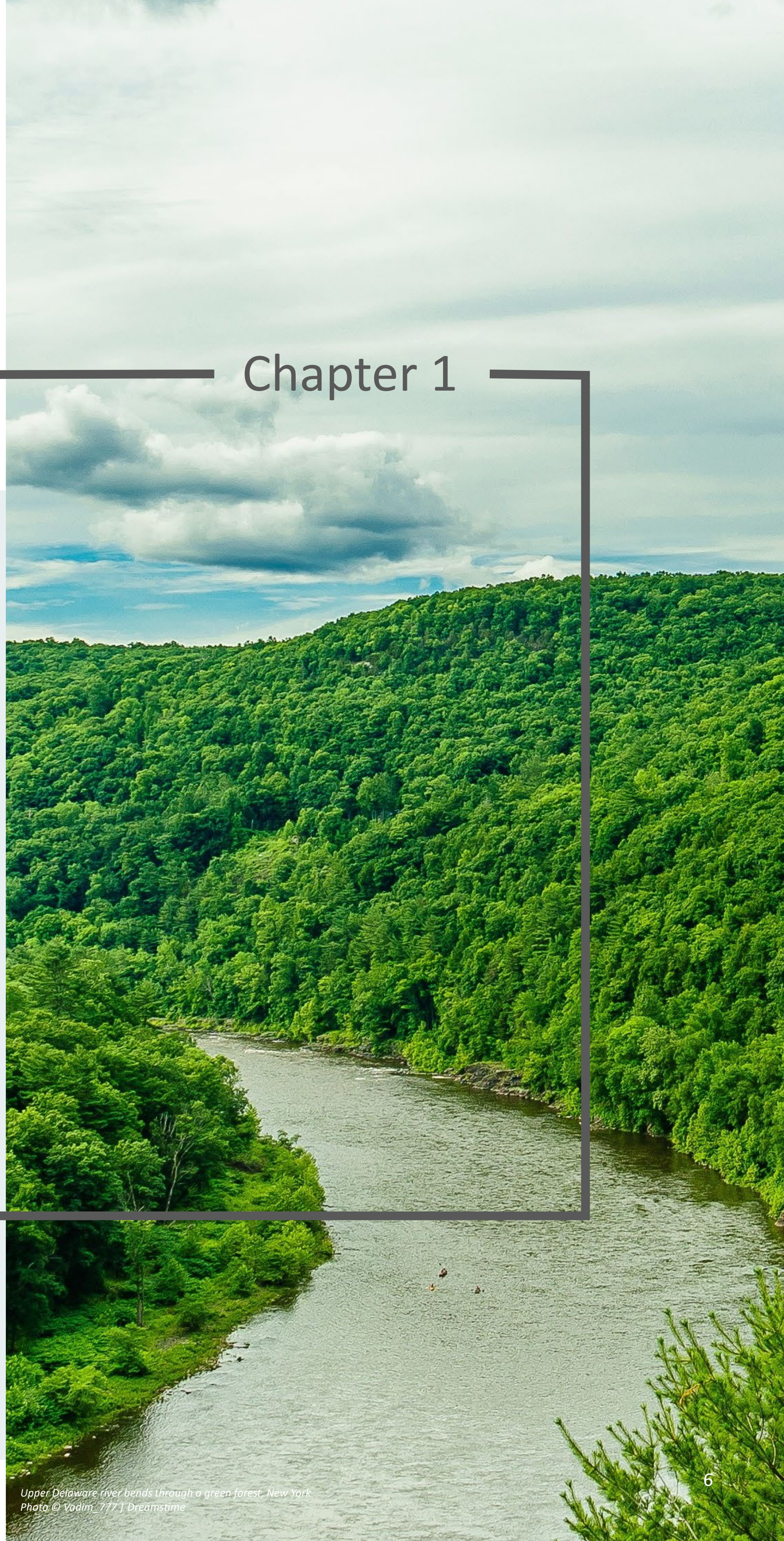
This report uses indicators to help assess the current state of the Delaware River Basin. ***Indicators*** are specific things such as an individual water quality parameter or animal species, where sufficient data is available to perform an analysis on the “status” of the specific indicator. An ***indicator status*** is intended to provide an approximate gauge of the indicator’s current condition or “health” within the Basin. Each indicator status is based on a qualitative scale ranging from Excellent to Poor, which is represented using the depicted thermometer graphic. Referencing one or a combination of indicator statuses can in turn be used to draw conclusions regarding watershed health. An ***indicator status trend*** may be noted as Improving, Declining, or Neutral (where applicable) and is intended to show how the indicator status appears to be changing. For example, the groundwater availability indicator is assessed with a status of “Very Good” and with an “Improving” status trend because data show that Basin-wide groundwater is being used at sustainable rates, and there is increasing awareness and continued implementation of sustainable groundwater management practices. Alternatively, an indicator status and trend may also show where new or updated water resource management programs may be needed in the future. For example, sea level is predicted to continue rising in the future and increase salinity intrusion. While current drought management programs are effective, an indicator status of “Declining” suggests that sea level rise may impact their effectiveness in the future and require new methods or updates to current programs to protect designated uses.





Chapter 1

WATERSHEDS & LANDSCAPES



Upper Delaware river bends through a green forest, New York
Photo © Vadim_777 | Dreamstime

A crowd of people out of focus.
Photo © Stevanovicigor | Dreamstime

POPULATION

No ranking

DESCRIPTION

Human population undoubtedly affects the characteristics of a watershed. In general, higher population density increases stress on the environment which can impact natural resources such as forests, wetlands and water availability. There are two metrics typically referenced when assessing population in the Delaware River Basin: (1) the "in-Basin population" quantifies the number of people living in the Delaware River Basin, whereas (2) the "population served" is an estimate of how many people obtain drinking water from the Delaware River Basin. An accurate estimate of both values is important for understanding water supply needs and associated impacts to water resources.

PRESENT STATUS

Based on census data for 2020, DRBC has estimated that the in-Basin population is 8.629 million people (DRBC 2023b). Data from the U.S. Census Bureau are obtained on a census block and/or block group level, which do not align with hydrologic boundaries such as watersheds. Therefore, where census blocks are split by the Basin boundary, the population value is distributed inside/outside of the Basin proportional to the census block area inside/outside of the Basin.

To estimate the total population served, the populations relying on the two major water exports are added, and the population relying on the largest water import is subtracted from the total. As summarized by Figure 4, the total population served is estimated to be 14.2 million people (approximately 4% of the of the total population of the United States).

TRENDS

Understanding the changes in population over time is essential to plan for future water resource needs. From 1990 to 2020, the population of the Delaware River Basin increased by an estimated 1,307,000 people. Recent county-level projections of population growth in the United States were provided by Hauer 2019 for five growth scenarios (termed shared socioeconomic pathways, "ssp") (Hauer and CEISN 2021). These projections were applied to in-Basin populations by (1) calculating a county-level percent change in population for each ssp, and (2) applying those percent changes to the county population estimated to reside within the Basin. The results of these projections applied to the Delaware River Basin are shown in Figure 5. The most recent data point to compare with projected values (2020) appears to be in line with ssp1 ("Sustainability") or ssp2 ("Middle of the Road") as termed in O'Neill et al. 2014.

The projections provided in Figure 5 are on a relatively large geographical scale. Intuitively, there are many regional dynamics at play which in aggregate account for the Basin-wide trend. For example, projected populations in 2060 under ssp1 suggest that Kent and Sussex counties in Delaware are anticipated to experience the highest percent increases in population relative to 2010 populations (Hauer and CEISN 2021). While the projections are provided at a county level, oftentimes historical trends can be assessed at very small scales such as the census block and lot levels. Additionally, beyond geographical analyses, Homsey 2022 highlights that additional trends can be assessed for population demographics.

ACTIONS/NEEDS

Increasing population can have numerous effects such as increased stresses on the available water resources in the Basin, changes in land cover, and/or increases in impervious cover. Oftentimes, communities need to accommodate population growth with additional infrastructure and development which may come from the conversion of open space, forests, and agricultural land. Understanding where and how populations are changing on a local level can help communities to obtain the necessary funding, resources and political will to sustainably grow with the environment, rather than in spite of it.

SUMMARY

The Delaware River Basin accounts for approximately 0.4% of the United States land area yet provides drinking water to more than 4% of the United States population. Over 8.6 million people live within the Basin's boundary, with most recent data in 2020 appearing to follow moderate growth projections. Maintaining a healthy watershed supports the economic, aesthetic, and ecological value of the Basin for the populations that both live in and rely on it. Understanding population dynamics will help communities plan for and promote equitable access to clean water resources.

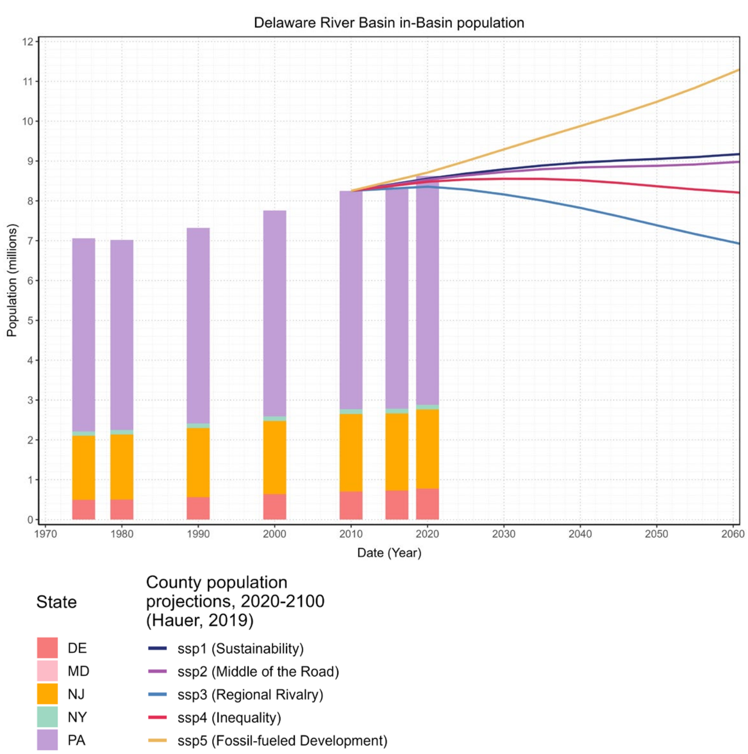


***Figure 5**: Historical estimates of in-Basin population performed by DRBC, along with projections of population growth (county level) applied to areas within the Delaware River Basin (Hauer and CEISN 2021; Hauer 2019; O'Neill et al. 2014).*

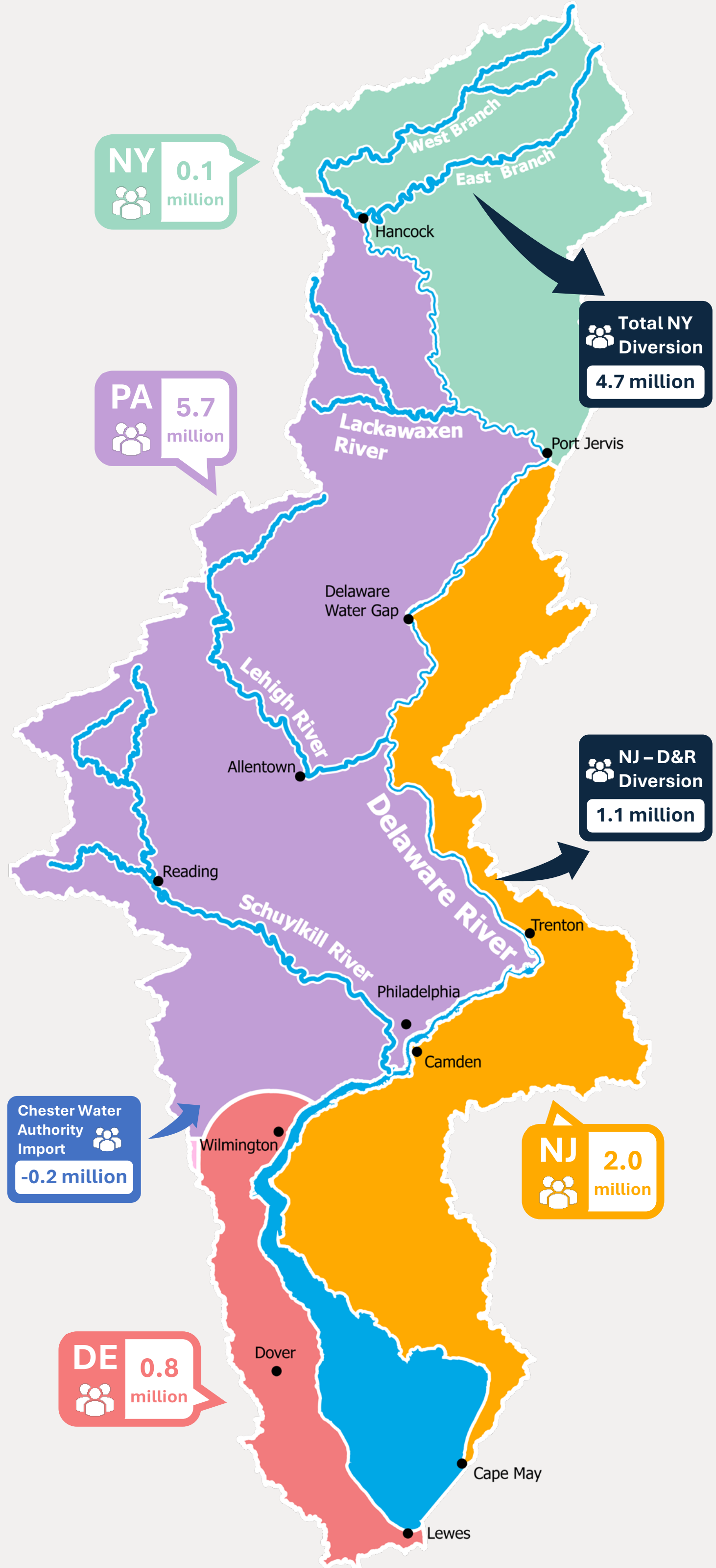


***Figure 4**: A graphical representation for the estimate of "population served" (drinking water) from the waters of the Delaware River Basin based on data from 2020, including the in-Basin population (initially published in the DRBC Water Resources Program FY 2024 – 2026).*

A view of Port Jervis, New York and the Upper Delaware River.
Photo © Mihai Andritoiu | Dreamstime

No ranking

LAND COVER

DESCRIPTION

Land cover is an important indicator of the health of the Basin and its water resources due to its comparability across landscapes (Homsey 2022). Changes in land use and land cover reflect human impacts to natural ecosystems on both a Basin-wide and local scale. Ultimately, alteration of land use and landscapes can directly impact the health of the Basin's watersheds. For example, developed lands have been linked to negative effects on water quality and quantity compared to natural land cover, whereas forests and wetlands provide several ecosystem services (such as water filtration and flood control) in addition to providing natural habitat for animals. As a second example, farmland without conservation practices in place has the potential to adversely impact the health of a watershed.

PRESENT STATUS

Two common datasets regarding land cover include the United States Geological Survey (USGS) National Land Cover Database (NLCD) and the National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP). A benefit to using the NOAA C-CAP data is its inclusion of more refined coastal habitat classifications, such as estuarine wetlands. As the entire Delaware River Basin is captured within the C-CAP dataset, the most recent version of 2016 land cover data are presented in Figure 7, summarizing the 21 categories into six groups.

Land cover is highly variable throughout the Basin and plays a key role in the health of the entire watershed. Natural land covers are understood to preserve the good health of the land and the water related to it by protecting the land's ecological services. The Basin's headwaters are incredible examples of natural watershed integrity which still maintain high percentages of forest cover throughout the Appalachian Plateau (Figure 2A), including portions of the Catskill Mountain region in New York, the Pocono Mountain region in Pennsylvania and the New Jersey Highlands. Moving south into the Lehigh and Schuylkill Valleys, forests and agriculture separate small urban centers in the headwaters, but urban development becomes increasingly dominant in the lower portions of each watershed. And it is here in the Upper/Lower Estuary where the highest density of people live in the Delaware River Basin (intersecting the Northeast megalopolis) resulting in the highest rates of urbanization - a notable exception being the eastern-most part of this region which is a part of the New Jersey Pinelands (still characterized largely by forests and wetlands). Further south in the Delaware Bay region, urban centers are localized with large surroundings of agricultural land use ultimately switching to wetlands before reaching the Delaware Bay boundary.

TRENDS

Monitoring trends in land cover change over time is a critical data resource for communities and planners alike to better understand how humans can continue to grow with the environment. Based on this type of information, it is possible to identify stressors such as areas under development pressure. Land cover in the Basin has generally trended towards urban and suburban development of natural cover (Homsey 2022). Basin-wide percentages of land cover over the past 20 years presented in Figure 7 suggests:

- Around 209 mi^2 were converted to developed land (+10.3%)
- About 106 mi^2 of agricultural land was converted to another use, mostly developed land but some to forest (-3.8%)
- Nearly 94 mi^2 of forested land was lost (-1.5%)
- Around 5.7 mi^2 of fresh and tidal wetlands were lost (-0.5%)

ACTIONS/NEEDS

Land cover is a significant factor contributing to the overall health of the Delaware River Basin, and as noted by Homsey 2022, protecting natural portions of the Basin is a critical need (particularly areas experiencing the highest expected rates of population growth and development). Consequently, there are continued informational needs such as high-resolution land cover data for multiple years – this helps identify changes in land cover over time and is useful in prioritizing areas for protection and restoration of water resources. Conservation efforts by public and private entities to protect and restore lands impacted by development can mitigate some of the harmful effects associated with urbanization.

SUMMARY

As the population within the Basin continues to grow, land use will continue to change, as it has over the last 20 years. Leveraging available data, people and communities should plan to grow with the natural environment, rather than in spite of it. This section of the report presented data at a Basin-scale – finer scale analyses will most certainly highlight regional trends.

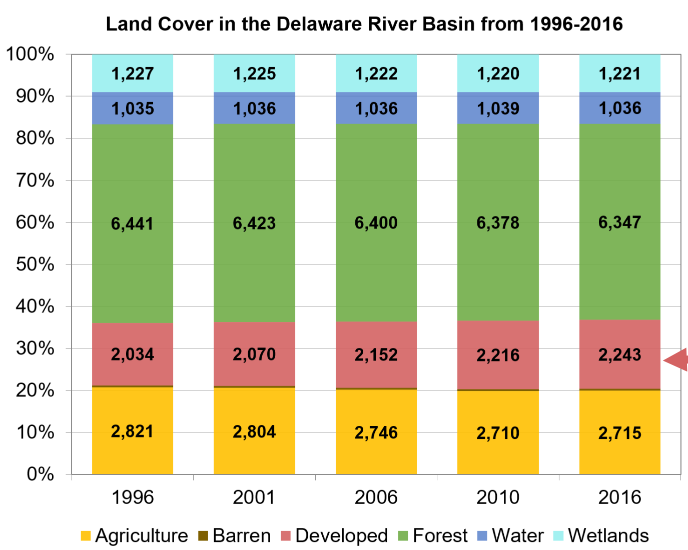


Figure 7*: The summarized land use categories over time based on NOAA C-CAP Coastal United States Regional Land Cover Datasets (available here).*

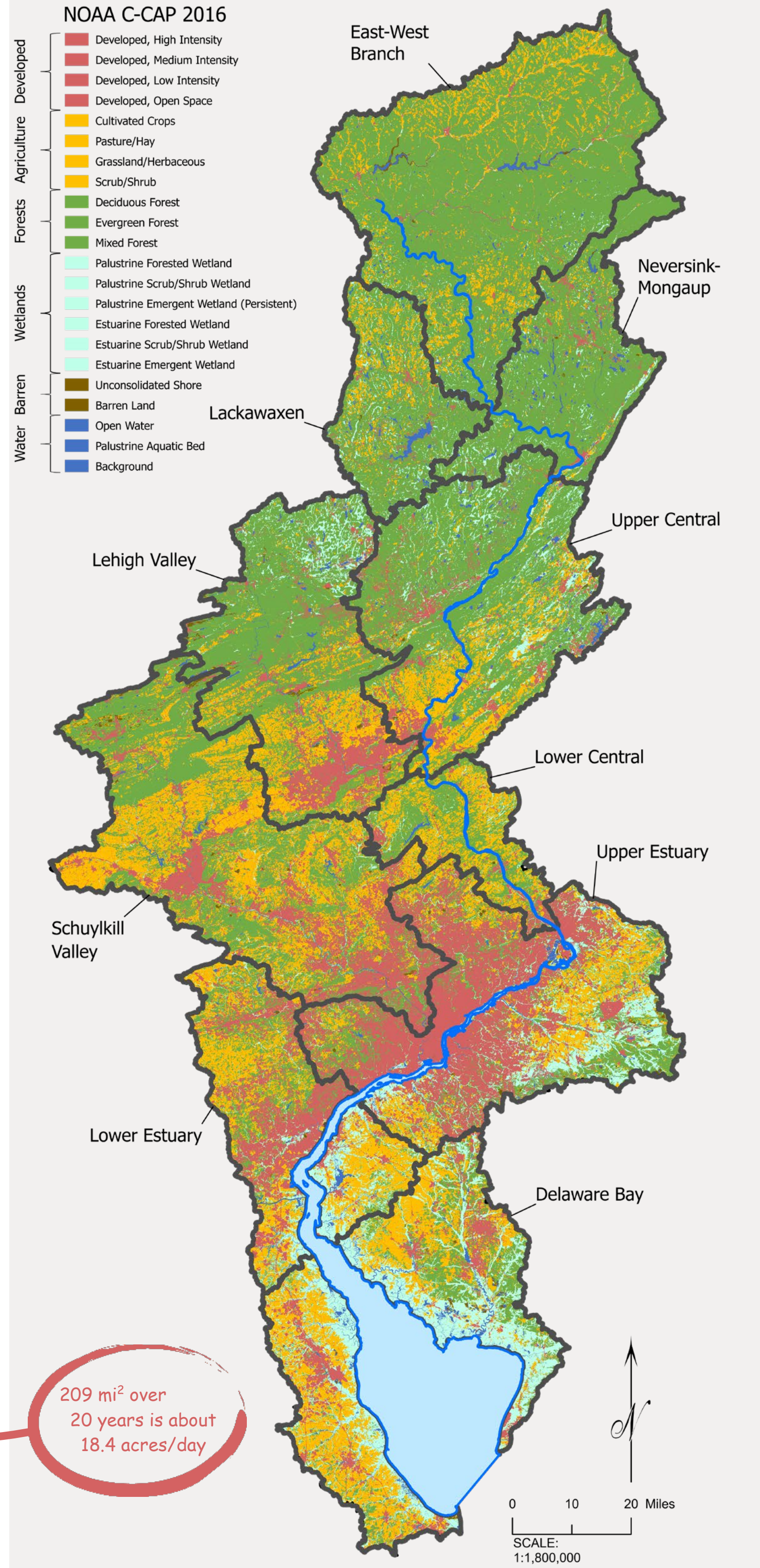


Figure 6*: A map of the Delaware River Basin color coded by land use categories contained in NOAA C-CAP for 2016 (NOAA 2016a). Note that similar land use categories have been grouped into bins of color for simplified analysis, as indicated in the map legend.*

The shadow of a tree on a parking lot.
Photo © Paul Wicks| Flickr | (cropped)

IMPERVIOUS COVER

DESCRIPTION

Impervious surfaces (e.g., roads, parking lots, rooftops) prevent rainfall from infiltrating and recharging groundwater resources. As a result, water runs off impervious areas and potentially contributes to local flooding and/or carries pollutants to streams and rivers. Impervious cover measures the percentage of the land surface that is impervious within a given area. Increased impervious cover is correlated with increased waterbody pollution, increased flooding, and lower streamflow during low flow periods (Homsey 2022). According to an Impervious Cover Model developed by the Center for Watershed Protection (CWP 1998), research suggests that once impervious cover exceeds 10% of a watershed's land area, the associated streams will demonstrate clear signs of declining stream health. Once impervious cover exceeds 25%, streams no longer support their designated uses in terms of hydrology, channel stability, habitat, water quality, or biological diversity (CWP 2003; Schueler et al. 2009).

PRESENT STATUS

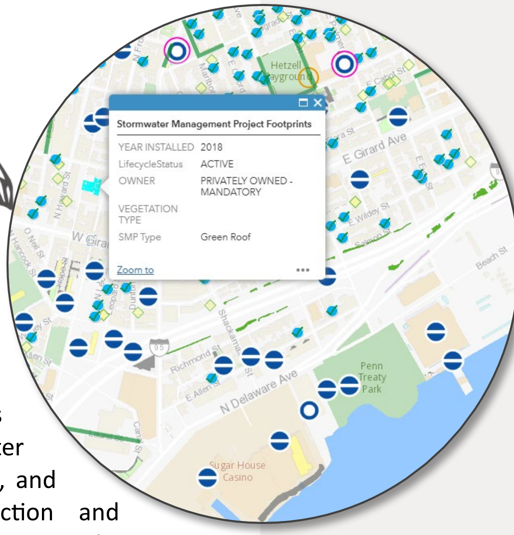
The USGS National Land Cover Database (NLCD) datasets not only provide land cover, but a separate data file where each 30x30m pixel is assigned a value indicating the percentage of that area which is impervious. A map showing the total "percent impervious" for each of 147 sub-watersheds in the Basin is presented in Figure 8. Densely populated urban areas typically have high impervious cover percentage, while the headwaters of the Basin have the least development and impervious cover.

TRENDS

The 147 sub-watersheds nest within the 10 watershed regions; therefore, NLCD data from 2001, 2011 and 2021 are presented for each region in Figure 9. Increases in impervious cover indicate growing development in a region. Impervious cover has increased over time and is predicted to continue increasing, coincident with estimates of population and land use changes. And while no region has reached an average above 25%, data for 2021 suggest that 10 sub-watersheds in the region around Philadelphia are above 25%, indicated on Figure 9 by the darkest red color.

This is not to say that the issue has gone unnoticed, or that no attempts have been made to curb its effects. For example, the Municipal Separate Stormwater Sewer System (MS4) regulatory program began with the USEPA's Water Quality Act of 1987, and regulations were rolled out to large municipalities under Phase I (effective 1990) and to small municipalities under Phase II (effective 1999) (USEPA 2018). Stormwater management has become an industry in/of itself and is too nuanced to capture all related benefits in a report such as this. However, it has greatly strengthened efforts to curb the effects of increased runoff due to impervious surfaces – for example, post-construction minimum control measures such as retention ponds in new developments and redevelopment. Most if not all municipalities within the urban corridor shown on Figure 8 have either individual or general MS4 permits – in fact – you are able to explore green stormwater infrastructure (GSI) projects throughout Philadelphia using an interactive online map.

Explore Philadelphia Water Department's "Big Green Map"



ACTIONS/NEEDS

Stormwater management strategies to reduce impacts from impervious cover vary in states and municipalities throughout the Basin. Integrated stormwater management efforts across federal, state, and local entities are needed for protection and restoration of water resources. Implementation of stormwater best management practices to limit the effects of impervious cover will help maintain healthy streams, provide aquatic habitat, and decrease flooding and groundwater recharge issues. Additional research into the prevalence and impact of existing GSI installed over the last 30 years may help improve future stormwater mitigation efforts.

SUMMARY

Impervious cover is a good indicator of urbanization and consequently stream health in the Delaware River Basin. Identifying small sub-watersheds with increasing impervious cover may help target management efforts to mitigate potential negative impacts on stream health and aquatic life. The current state of impervious cover in the Delaware River Basin is determined to be Good, but with a Declining trend.

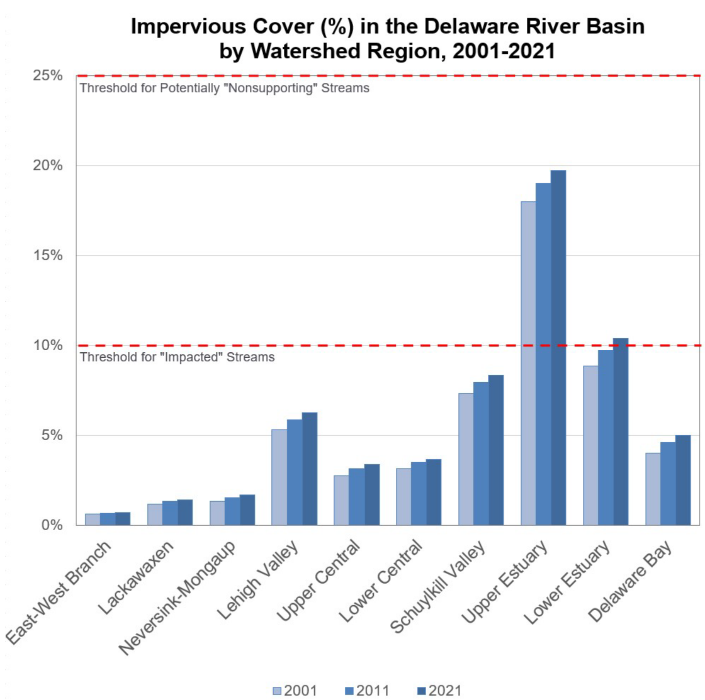


***Figure 9**: Summarized percentages of impervious cover for the 10 watershed regions in the Delaware River Basin, over time. Impervious cover data obtained from the USGS National Land Cover Database (NLCD) datasets (available from the Multi-Resolution Land Characteristics (MRLC) Consortium here).*

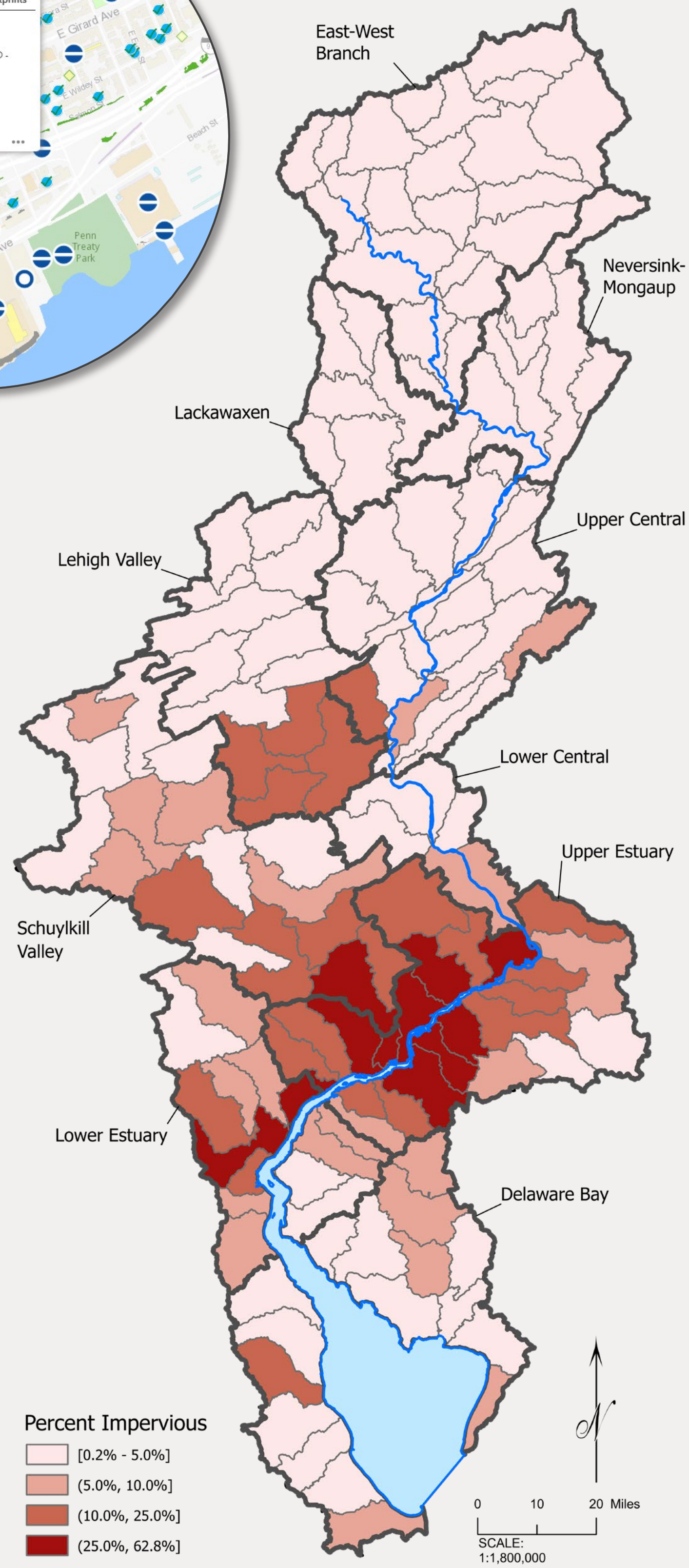
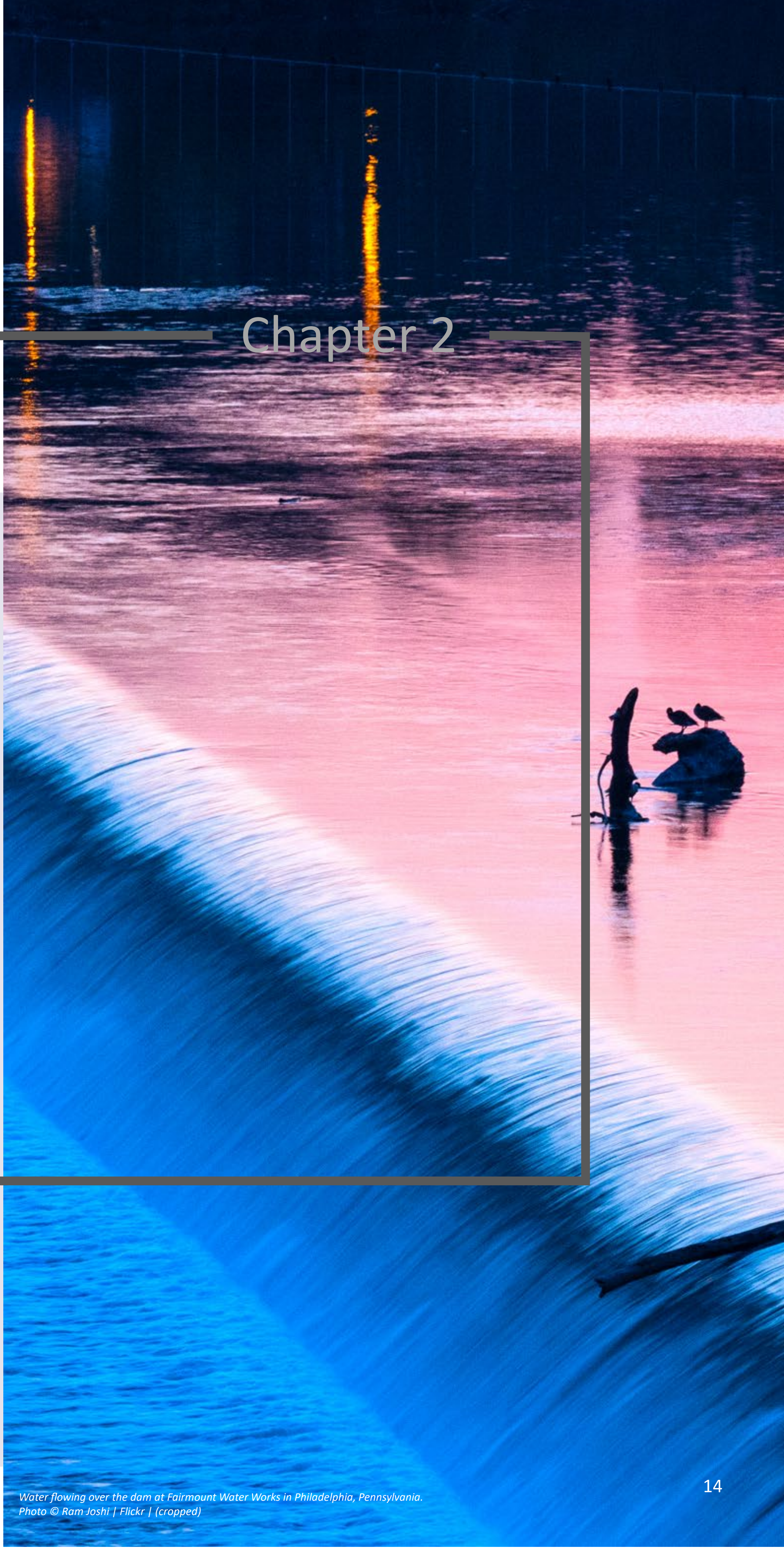


***Figure 8**: A map of the Delaware River Basin color coded by percent impervious cover, as determined from the USGS NLCD 2021 dataset (USGS 2023).*

Chapter 2

WATER QUANTITY



Water flowing over the dam at Fairmount Water Works in Philadelphia, Pennsylvania.
Photo © Ram Joshi | Flickr | (cropped)

Water towers in Pennsauken, New Jersey.
Photo courtesy of Merchantville-Pennsauken Water Company

WATER WITHDRAWALS

DESCRIPTION

Water withdrawals are tracked throughout the Basin to identify key water-using sectors and trends in water use. Accurate and complete data enable proper assessment, planning and management of water resources. The 2022 water withdrawal data were compiled to generate a Basin-wide assessment by water use sector. Most data are based on withdrawals reported to state agencies, while some data may be reported directly to DRBC. Values for some hydroelectric water use are estimated based on net electricity generation data. Values for self-supplied domestic groundwater use are estimated by applying per-capita rates to population totals which reside outside of public water supply service areas.

PRESENT STATUS

Total Delaware River Basin (DRB) water withdrawals are displayed in Figure 10. Based on 2020 data, an estimated 14.2 million people rely on water from the Basin for their daily water needs. Approximately 8.6 million people live within the Basin's boundary, and the volume of water exported to New York City and northeastern New Jersey supplies water to an additional 5.8 million people. In 2022, an estimated 6,096 million gallons per day (MGD) of water was withdrawn from ground and surface water sources. While much of the 6,096 MGD withdrawn is returned to the surface waters of the Basin via discharge, about 14% (~848 MGD) does not and is considered "consumptive use" (discussed more in the next report section). At a high level, four dominant use sectors account for over 95% of total water withdrawals: Thermoelectric power generation (57%), public water supply (including major exports and self-supplied domestic withdrawals) (24%), hydroelectric power generation (9%) and industrial uses (6%).

While approximately 92% of all water used in the Basin is obtained from surface waters, the remaining 8% obtained from groundwater plays a critical role in meeting drinking water demands. Considering all water withdrawals by public water suppliers in 2022 (~819 MGD), groundwater accounts for roughly 31% of the total. Considering all groundwater withdrawals across the Basin, approximately 51% is withdrawn by public water suppliers, while another 20% is attributed to self-supplied domestic uses (such as drinking water). This highlights that a staggering 71% of all groundwater withdrawals support drinking water needs (346 MGD).

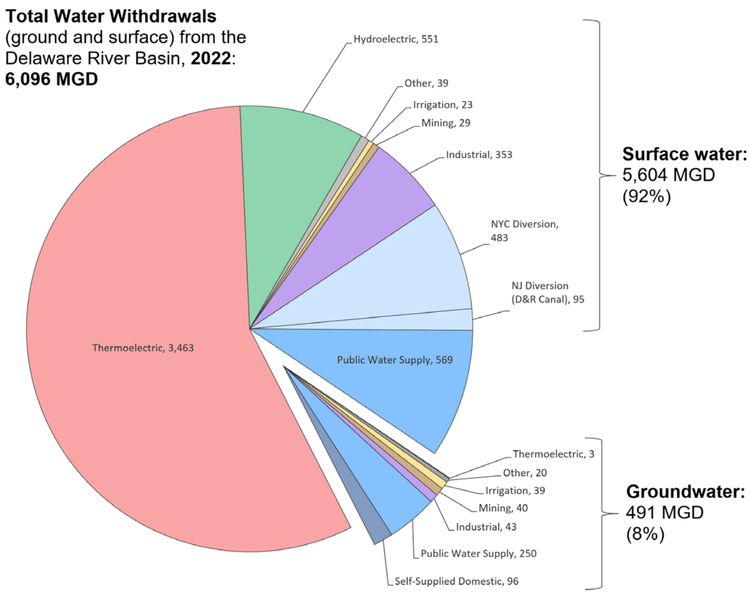


***Figure 10**: Water withdrawal data from the Delaware River Basin for calendar year 2022. Data are separated between source water (groundwater vs. surface water) and color coded by facility sector.*

TRENDS

In 2021, DRBC published a study projecting water withdrawals to estimate future demands (Thompson and Pindar 2021); the historical data from 1990-2017 was published online alongside the report (Link). Since then, DRBC has continued to track and improve water withdrawal data. Timeseries of withdrawal data for three major withdrawal sectors are presented in Figure 11A-C. Withdrawal projections and data prior to 2017 were obtained from Thompson and Pindar 2021, while newer data (2018-2022) have been obtained from DRBC's current water withdrawal database.

Regarding water withdrawals for thermoelectric power generation, the primary use of water is typically for cooling purposes. It was shown in Thompson and Pindar 2021 that the dramatic declines in total withdrawal since the mid-2000s were largely attributable to reduced operation and even closure of coal-fired power plants using once-through cooling technology (Figure 11A). This trend was anticipated to be a limiting factor once all facilities that could transition away from the technology had done so, hence why the projection did not follow the steep decline.

Historical data for industrial withdrawals show a relatively consistent decline from the levels in the early 1990s (Figure 11B). This trend is consistent with information related to the closure of major industrial facilities such as Bethlehem Steel plant in the mid-1990s, which was one of the largest industrial water uses in the Basin. Additionally, specific industry-wide trends can clearly affect water use within the Basin. For example, US production of paper and paperboard peaked around 1999; in the years leading up to and after the peak, multiple paper/paperboard manufacturing facilities within the Basin closed, subsequently reducing overall industrial water use. Considering how the projected water demand compared to reported data, errors were determined to be largely attributed to two facilities with significant changes in operation which greatly reduced water use.

The public water supply sector has reported decreased withdrawals of around 100 MGD over 30 years (Figure 11C) despite continued growth in population (Figure 5). This pattern is primarily attributed to the influence of increased awareness about conservation practices (on both the utility and the customer side) and changes in plumbing codes enacted in the early 1990s. However, it is recognized that the most recent two years of data suggest a slight increase in demand. This is attributed largely to three systems that collectively increased about 30 MGD over the two years; the remaining systems' net change over the same two years was -3 MGD.

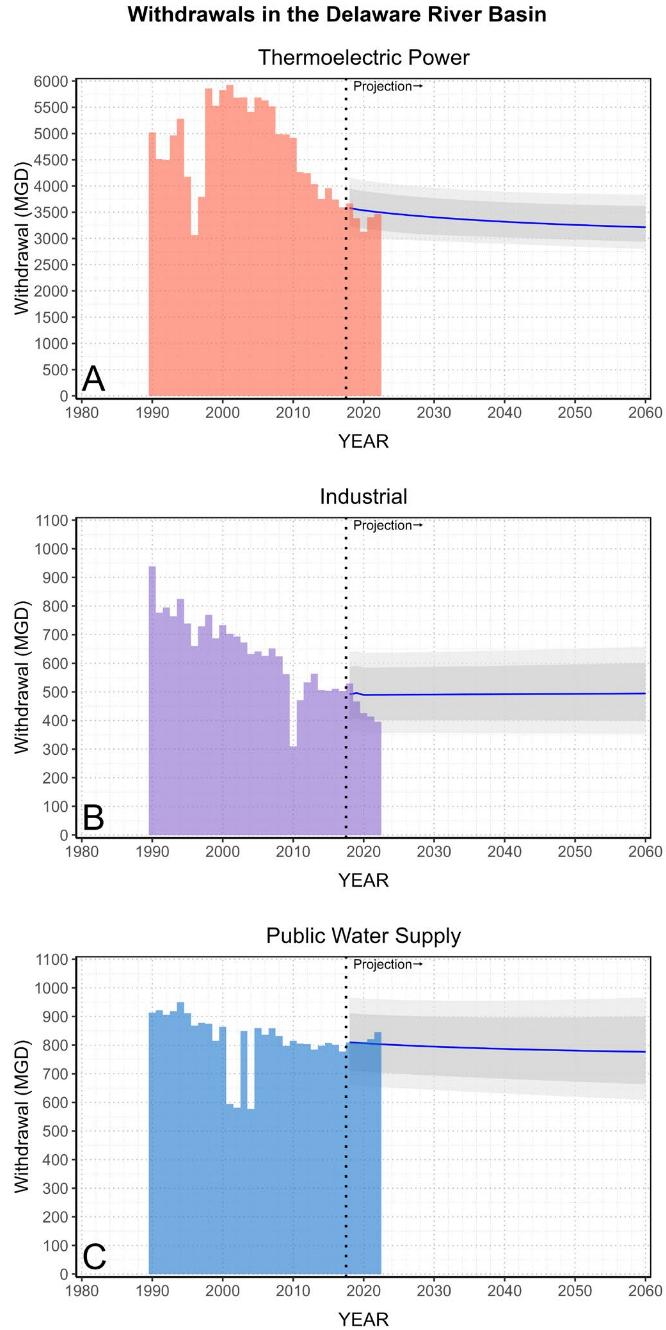


Figure 11*: Trends of water withdrawals in three sectors of the Delaware River Basin, with projections adopted from Thompson and Pindar 2021. Blue lines represent projected values; dark gray and light gray regions represent the 85% and 95% confidence intervals, respectively.*

ACTIONS/NEEDS

Reporting of water withdrawals has improved in recent years due to electronic, web-based reporting; however, state agencies are adopting this approach at different speeds so data improvements are expected to continue. Streamlined methods for compiling and combining data among states should be a priority to ensure consistency between analyses. Developing user-friendly methods of interacting with data may also encourage data review and subsequently improve accuracy.

SUMMARY

Recent efforts to improve the water withdrawal database at DRBC have helped with quality control among various data sources. Trends in water withdrawals remain largely consistent with previous findings, as highlighted by Figure 11A-C. The current state of water withdrawals from the Delaware River Basin is determined to be Good with a Neutral trend.

A natural draft cooling tower visibly shows a portion of withdrawn water not being returned (evaporation).
Photo © Cheryl Fleishman | Dreamstime

CONSUMPTIVE USE

DESCRIPTION

Consumptive use is the portion of water withdrawn from the watershed that is not immediately returned to the watershed. In some ways, it is a more important management consideration than total water withdrawals. Different types of water use can have different rates of consumptive use. For example, irrigation is highly consumptive (an estimate of 90% or greater is often used) as the water is absorbed by the plant or soil or lost to evaporation; withdrawals for the public water supply sector are typically considered to have a low consumptive use (~10%), as only a small portion of water used in homes and cities is not returned to the hydrologic system via sewer or septic systems.

PRESENT STATUS

As shown by Figure 10, total water withdrawals from the Delaware River Basin are in excess of 6,000 million gallons per day (MGD). Of this, approximately 848 MGD are considered to be consumptive use. This total consumptive use includes the major exports of water from the Basin; in CY2022 this was approximately 483 MGD for populations in New York City and 95 MGD for northeastern New Jersey. These two exports account for about 10% of total water withdrawals from the Basin; however, they account for nearly two-thirds of the total consumptive use. The remaining consumptive use is attributed to in-Basin needs (~270 MGD).

The in-Basin consumptive use estimates are calculated using one of two methods: (1) applying a standard percentage to the withdrawal based on facility type (for example, a public water supply system withdrawal volume would be multiplied by 10%), or (2) specific systems report data directly to DRBC, from which facility-specific percentages can be computed and applied to the withdrawal data. Considering the CY2022 estimated 270 MGD of in-Basin consumptive use, 157 MGD is attributed to facilities with site-specific percentages based on reporting – the remainder is calculated using default sector-based percentages.

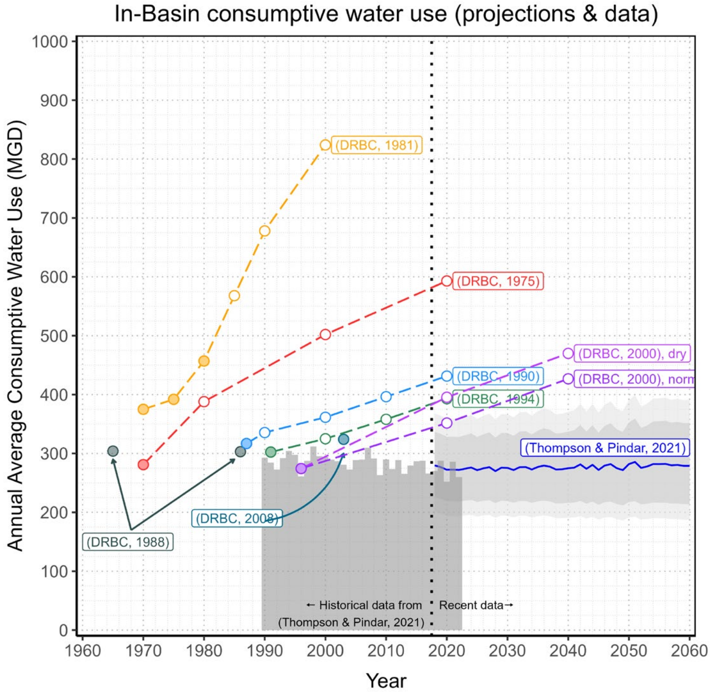


***Figure 12**: Projections of in-Basin consumptive use. Historical estimates of in-Basin consumptive use are represented by filled circles, and projections are represented by hollow circles. Different colors correspond to the respective DRBC studies cited on the figure. The in-Basin consumptive use estimates performed by Thompson and Pindar 2021 are the vertical grey bars, the projection is a blue line, and the predictive intervals are grey bands.*

TRENDS

Total in-Basin consumptive use has been estimated and projected by DRBC on multiple occasions, which speaks to the importance of this data in water resource planning (Figure 12). Most previous estimates of total in-Basin consumptive use were based on a single year or two, with projections at specified intervals. However, the most recent analysis by Thompson and Pindar 2021 leveraged almost 30 years of data and demonstrated good agreement with prior estimates. Additionally, this longer dataset helped justify a less aggressive projection of consumptive use (the blue line) which suggests a continuation of consumptive use at present day levels. Notably, a primary assumption made in the Thompson and Pindar 2021 projection was to only project existing operational trends, and not attempt to predict the construction of new facilities (such as the 1981 study that considered the construction of future power plants in the projections, which were ultimately never built).

Trends of in-Basin consumptive water use for three sectors within the Delaware River Basin are highlighted in Figure 13. Regarding consumptive use by thermoelectric power generation facilities (Figure 13A), it is notable that the trend does not mirror that of the withdrawals previously shown in Figure 11A. This was shown by Thompson and Pindar 2021 to be directly related to changes in cooling technology at many power plants. While many facilities using once-through cooling (large volumes of water with little consumption) closed, other facilities have changed cooling technology to evaporative cooling (small volumes of water with high consumption). Consequently, while the total volume of withdrawal has decreased, the rate of consumptive use has remained relatively unchanged. More recent data have reinforced the projections by Thompson and Pindar 2021.

The industrial sector trend largely mirrors the withdrawal trend, even though the consumptive use for many facilities are calculated using site-specific percentages (Figure 13B). A decrease in recent years is observed similarly to the withdrawal data and assumed to be associated with the same driving factors. For the most part, consumptive use of public water suppliers is calculated by a sector-wide average of 10%; therefore, it is not surprising that the trend in consumptive water use mirrors that of the total withdrawals (Figure 13C) . Additionally, factors which are determined to affect the trend in withdrawals by public water suppliers will therefore proportionally affect this calculated consumptive use.

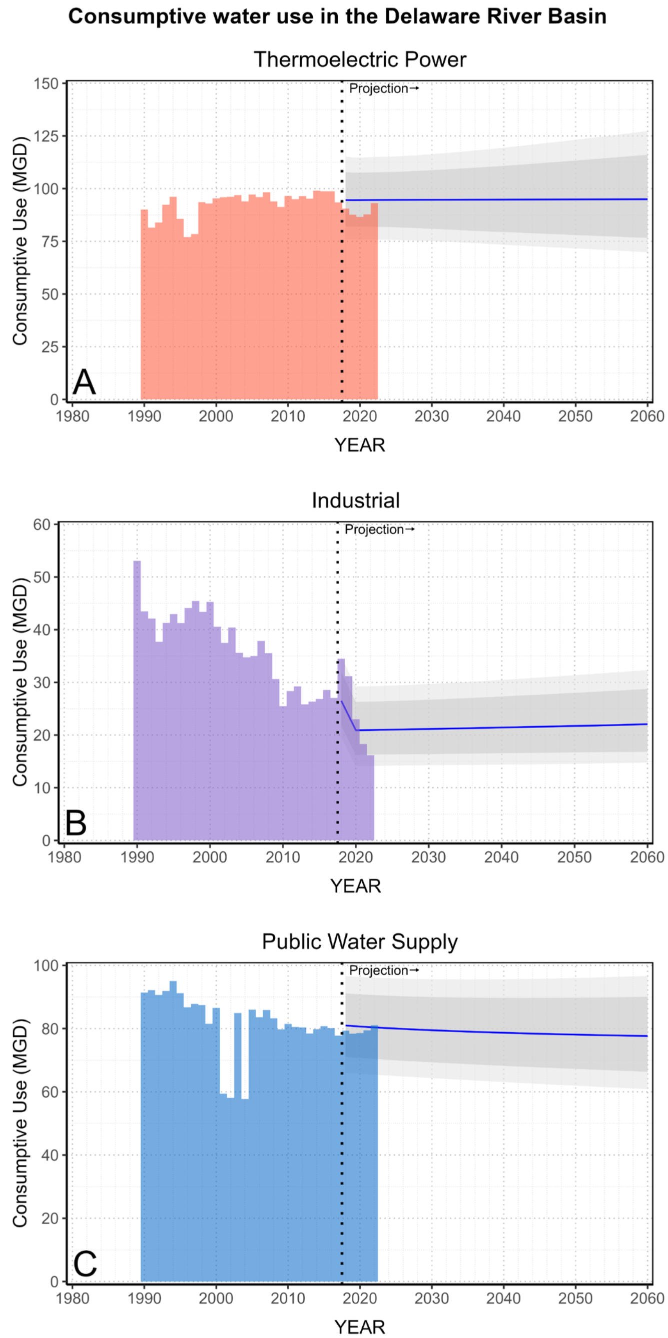


***Figure 13**: Trends of in-Basin consumptive water use in three sectors of the Delaware River Basin: (A) thermoelectric power, (B) industrial, and (C) public water supply.*

ACTIONS/NEEDS

The use of site-specific consumptive use factors is the best estimate available. Perhaps investigation into the composition of individual public water suppliers' customer base could help refine these estimates (e.g., percent residential, presence/absence of major industrial or thermoelectric customers).

SUMMARY

An understanding of consumptive water use provides additional insight into water use patterns and is an important indicator in the management of water resources. Within the Basin, the largest consumptive uses are from the thermoelectric, public water supply and agricultural water use sectors, accounting for approximately 85% of in-Basin consumptive use. Slightly downward consumptive use trends are expected to continue in the public water supply sector, while a stable trend is projected for the thermoelectric sector. The current state of consumptive water use within the Delaware River Basin is determined to be Good with a Neutral trend for the future based on projections of consumptive use volumes.

An old groundwater pump in a field.
Photo © Yaroslaf | Dreamstime

GROUNDWATER AVAILABILITY

DESCRIPTION

Stress on groundwater resources can occur when withdrawals exceed natural recharge. The withdrawal of groundwater by wells is a stress superimposed on a previously balanced groundwater system. The response of an aquifer to pumping stress may result in an increase in recharge to the aquifer, a decrease in the natural discharge to streams, a loss of storage within the aquifer, or a combination of these effects.

Two areas of the Basin are included in special management programs to mitigate historical groundwater supply issues and prevent future stress. DRBC manages the Southeast Pennsylvania Groundwater Protected Area (SEPA GWPA), and New Jersey manages Critical Area 2 in the Potomac-Raritan-Magothy (PRM) aquifer system in southwestern New Jersey (outlined in red on Figure 14A).

The current method DRBC uses for evaluating groundwater availability uses annual data at two scales: (1) 147 sub-watersheds covering the entire Delaware River Basin (Figure 14A), and (2) 76 sub-watersheds which cover the legal boundary of SEPA GWPA (Figure 14B). The method compares two values:

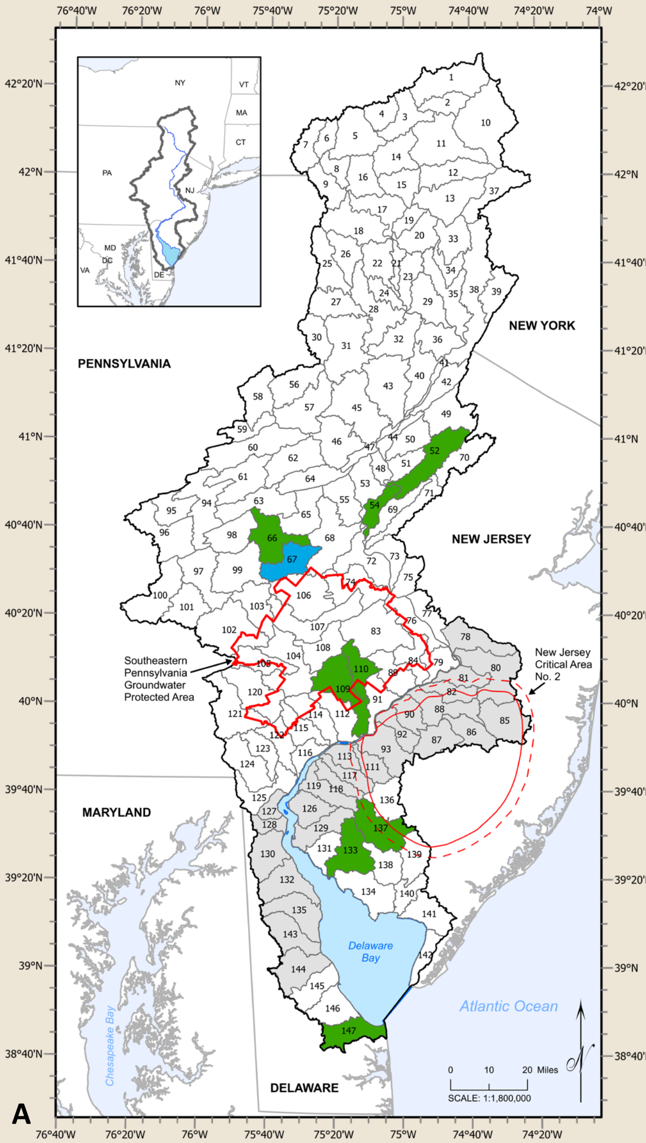
1. **Q_{net}** - The "net" groundwater withdrawal from each sub-watershed (i.e. accounting for the return of water in withdrawal sectors of irrigation, mining, and self-supplied domestic).
2. **RI_{25}** *or* **RI_{50}** - The expected low baseflow to streams within each sub-watershed (which is assumed to be groundwater flow) that is estimated to recur only once in 25 years (RI_{25}) or once in 50 years (RI_{50}).

Calculations of availability are presented as a percentage for each sub-watershed (e.g., Q_{net} / RI_{50}). This method is referred to as a "screening tool" because it includes many assumptions and is performed at coarse resolution (geographically and temporally). Results indicating a high percentage net withdrawal of the calculated RI_{25} or RI_{50} do not in themselves indicate the presence of groundwater impacts – but do identify sub-watersheds where additional investigation of groundwater flow dynamics at a finer resolution may be warranted to guide water resource management. Finally, one last note regarding the methodology comes from Thompson et al. 2022 who determined that the method is not suitable for particular sub-watersheds in the Coastal Plain (greyed out on Figure 14A) as many withdrawals in that region are from confined aquifers.

PRESENT STATUS

Based on an assessment of the data reported for calendar year 2022, the total net groundwater withdrawals from the Basin were about 365 MGD, and it is determined that Basin-wide groundwater resources are being used at sustainable rates (not including analyses of confined aquifers, such as those managed under the New Jersey program for Critical Area 2). Net groundwater withdrawals as a percentage of the RI_{50} for each of the applicable 121 sub-watersheds are presented on Figure 14A. Only one sub-watershed returns a percent use number above 50% (DB-067, the Little Lehigh Creek watershed), which is the same finding as presented in Thompson et al. 2022. Additional review of studies on DB-067 was provided in Thompson et al. 2022.

Considering the same data used in Figure 14A, it is estimated that net withdrawals from SEPA-GWPA were about 45 MGD. DRBC regulations for SEPA-GWPA sub-watersheds are based on the RI_{25} values, and as such, Figure 14B presents net withdrawals as a percentage of the RI_{25} for each sub-watershed. The most notable sub-watershed is SP-29 (Crow Creek in the Schuylkill River watershed). A detailed investigation was performed in Thompson et al. 2022, which noted that net groundwater withdrawals from SP-29 are projected to continue at a relatively constant rate, currently above both RI-25 and RI-50 baseflows. The overwhelming majority of the net groundwater withdrawals from



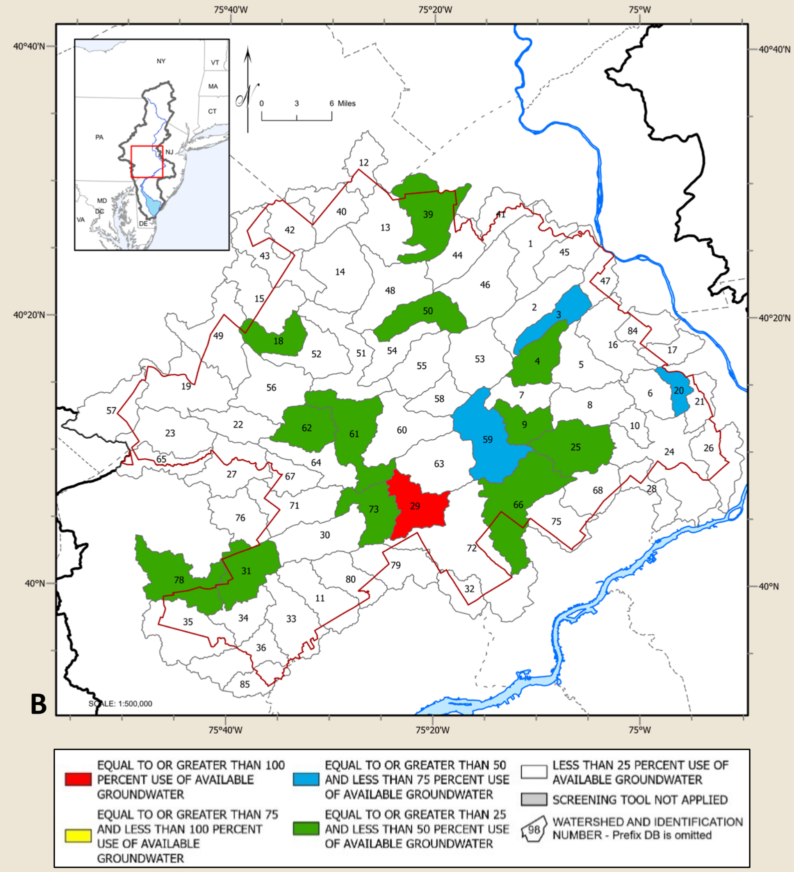


***Figure 14**: (**A**) Comparison of CY2022 net groundwater withdrawals from each sub-watershed in the Delaware River Basin to the 50-year baseflow recurrence interval of the sub-watershed (i.e. groundwater baseflow to streams within the sub-watershed expected to happen once every 50-years). (**B**) Comparison of CY2022 net groundwater withdrawals from each sub-watershed in the SEPA-GWPA, compared to the 25-year baseflow recurrence interval of the sub-watershed.*

SP-29 are for public water supply and to date, the Commission is not aware of any groundwater interference and/or availability issues associated with any groundwater sources, and is not aware of any in-stream impacts attributed to these groundwater withdrawals.

TRENDS

Basin-wide groundwater withdrawals have varied between 340 to 400 MGD for the past 30 years (Thompson and Pindar 2021), with the most recent data for CY2022 suggesting 365 MGD. From 2000 to 2020, cumulative net groundwater withdrawals decreased in the SEPA GWPA. This is likely attributed to improved water conservation and infrastructure changes, such as the diversion of surface water, which helps to offset groundwater use in Bucks and Montogomery counties.

ACTIONS/NEEDS

The screening tool's methodology compares the total net withdrawal throughout the year to estimated annual groundwater recurrence intervals. However, groundwater contributions to streams will vary seasonally, often with significant decreases in available groundwater throughout the late summer and early fall months. DRBC is currently conducting research to develop a new set of Basin-wide estimates for recurrence intervals which are (1) on a smaller geographic scale (i.e. HUC12), and (2) on a monthly timeframe (e.g., 12 values of RI_{25} for a given sub-watershed, one for each month). Model improvements such as these will provide increased screening tool resolution to capture worst-case scenarios that are not currently possible to visualize (such as summer drought). These improvements will help water resource planners make more informed decisions to strive for sustainable and resilient resource utilization. Additional availability analysis in the Coastal Plain is also recommended.

SUMMARY

Study results indicate that groundwater is currently used at sustainable rates in most areas within the Delaware River Basin (not assessing confined aquifers in the Coastal Plain). The current state of groundwater availability within the Delaware River Basin is determined to be Very Good with an Improving trend based on increased awareness and continued implementation of management areas. Current methods utilize annual statistics, and research is ongoing to improve these methods to capture more detailed scenarios (such as low summer flows).

A burst underground water main results in visible leakage (real losses).
Photo © Nigel Spooner | Dreamstime

WATER LOSS & CONSERVATION

DESCRIPTION

The Delaware River Basin provides drinking water for an estimated 14.2 million people (approximately 4% of the of the total population of the United States), while only draining 0.4% of the total continental United States land area. Although the Basin supplies roughly half of the water for the largest city in the United States (New York City), the majority of the population served resides within the Basin boundary – estimated in 2020 to be 8.629 million people. Of that in-Basin population, about 85% (7.366 million people) are served by hundreds of public water supply systems. It is a remarkable feat of engineering that has woven together over 29,000 miles of water mains, which is long enough to circle the globe.

The DRBC has a history of water loss control efforts, notably adopting a resolution which set out an official statement of policy on the conservation of water in 1976. DRBC has since taken many actions which include implementing requirements on source and service metering, requirements on plumbing standards and leak detection practices, promoting and supporting retail water pricing that encourages conservation, and beginning in 2012, requiring regulated water utilities (public and private) to complete the AWWA Free Water Audit Software annually (Delaware River Basin Water Code §2.1.8).

Data collected through the DRBC Water Audit program provide information on how efficiently water is being used by public water suppliers. A key variable in these data is an estimate of water loss (i.e. the difference between the amount of water a facility sends to customers, versus how much water is received by customers). Additionally, water loss can be broken into components termed "apparent losses" (e.g., billing discrepancies or meter errors) and "real losses" (e.g., leaks and breaks). Data on water loss are important in many capacities, including but not limited to: (1) assessing system resilience in terms of demand versus availability, (2) understanding carbon emissions associated with the pumping and treatment of lost water, and (3) assessing equity impacts due to financial costs associated with the pumping and treatment of lost water.

One important caveat to consider when discussing water loss is that all public water supply systems will leak. This has been well understood, but it was not until the late 1990s that a simple yet rational method was developed to estimate a theoretical minimum amount of water loss, termed "unavoidable annual real losses" (UARL). UARL is based on system infrastructure and operation (e.g., length of pipes, number of connections, operating pressure). It was then determined that a system's Infrastructure Leakage Index (ILI) may be quantified as:

$$ILI = \frac{Current\ annual\ real\ losses}{Unavoidable\ annual\ real\ losses}$$

Therefore, an ILI=1 is theoretically the most efficient operation, whereas higher ILI values indicate lower efficiency. While a theoretical minimum amount of water loss may exist (ILI=1), it is often not feasible to reach this value (economically or otherwise). Therefore, it is sometimes noted that a slightly larger "economic level of leakage" (ELL) may exist and be used in goal setting. There are many variables used to assess system performance, but ultimately quantifying how much water gets lost is most useful.

PRESENT STATUS

Data collected for CY2022 are generally consistent with prior data. A water balance encompassing data from all systems audited in the Delaware River Basin has been provided for reference as Figure 15. Audited public water supply systems withdrew an estimated average of 789 million gallons per day (MGD) from their own water supply sources. As many systems are interconnected, cumulative exports (72 MGD) and imports (88 MGD) suggest a net import of about 16 MGD (major Basin exports to New York City and New Jersey under the 1954 Supreme Court Decree are out of the scope of this study).

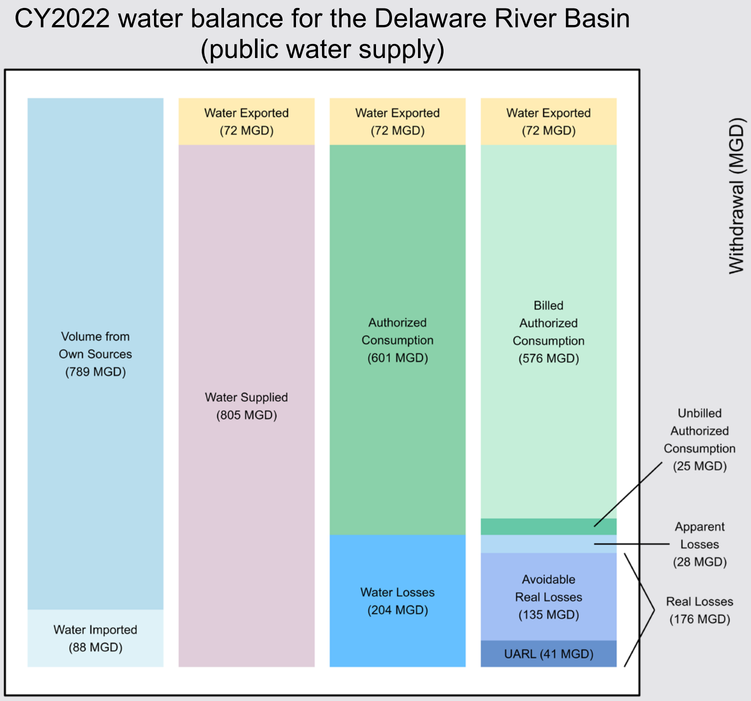


__Figure 15:__ This water balance represents aggregate data for 298 public water supply systems in the Delaware River Basin which were required to submit an AWWA Free Water Audit Software report to DRBC covering the year CY2022.

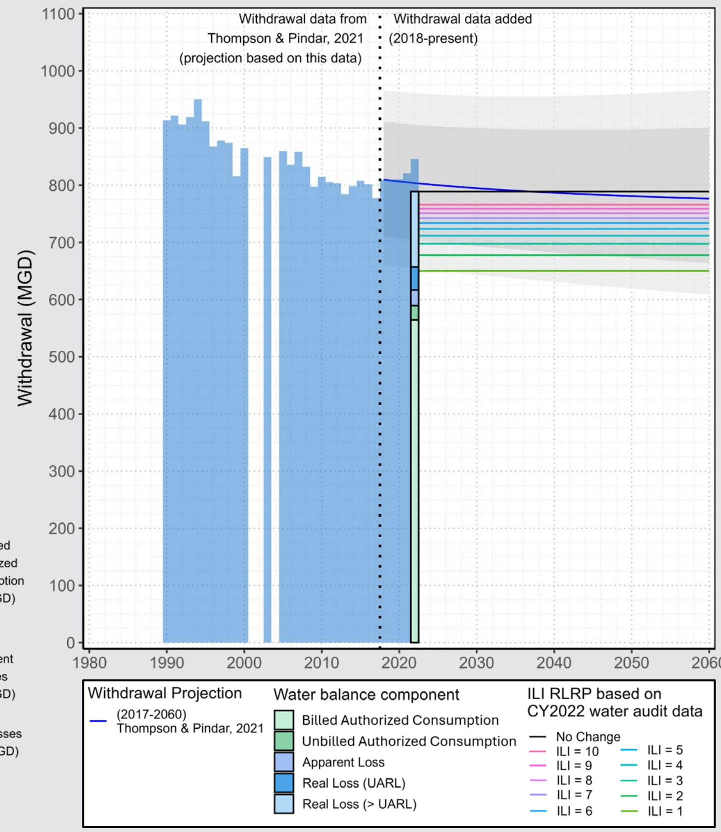


***Figure 16**: Public water supply withdrawal and projection data previously shown as Figure 11C. Water audit data for CY2022 has been superimposed and color coded by water balance component. Horizontal lines represent possible reductions in total water withdrawal should all systems above a particular ILI, reduce water loss to reach the particular ILI.*

Therefore, the total volume of water supplied by these systems is estimated to average 805 MGD. Based on the calculation methods utilized by the AWWA FWAS, it is estimated that these systems register an average of 601 MGD in authorized consumption, and experience 204 MGD in water losses. The total estimated real loss volume is 176 MGD, which can be subdivided into estimated unavoidable annual real losses (41 MGD) and avoidable real losses (135 MGD). The total estimated apparent loss volume is 28 MGD.

Figure 16 presents the trend in withdrawals by public water suppliers (previously shown as Figure 11C), but adds the CY2022 volume from own sources (789 MGD, Figure 15), color coded by water balance component. Assuming that all systems with water losses above a particular level of ILI were to reduce water losses to that level of ILI, it can be shown how withdrawals could reduce under each scenario (i.e. targets of ILI=1 through ILI=10). While water withdrawals have decreased despite a growing in-Basin population, distinguishing between current real losses and theoretically unavoidable real losses highlights that there is still room for improvement.

TRENDS

A recent publication by DRBC assessed ten years of data collected through the DRBC water audit program (Thompson et al. 2023). Per the report, data suggest no significant trends in the volume of water lost from audited systems within the Basin. While DRBC regulations require completion of the water audit, they do not require action or improvement of water loss rates.

ACTIONS/NEEDS

Upon concluding the recent analysis of the DRBC water audit program (Thompson et al. 2023), the research team made numerous recommendations. Among these, two were noted to be (1) improvement of data validity (i.e. accuracy of and confidence in the reported data), and (2) performing ELL analyses where possible to help improve water resource planning efforts. While the report recommends research on the financial and equity impacts of water loss, it should have also captured a need for research on carbon emissions related to treated and pumped water loss.

SUMMARY

The current state of water loss and conservation within the Delaware River Basin is determined to be Good with an Improving trend following continued research and focus. DRBC's water audit program has been in place for just over a decade. While data do not show strong trends at a Basin scale, additional reductions in withdrawals are possible by addressing water loss. Continued program improvements can help effectuate change at the system level.

Pepacton Reservoir in Delaware County, New York.
Photo by Steven Walsh (DRBC)

FLOW

DESCRIPTION

The Delaware River and its tributaries provide water for many different purposes including: drinking and industrial water supply, power generation, water quality maintenance, ecosystem services, fishing, boating, and recreation. Prior to 1927, there were no major reservoirs in the Basin that affected flow on the main stem Delaware River. Since then, flood control, recreation, and water supply reservoirs have been constructed in Basin tributaries. Three of the reservoirs were constructed by New York City (NYC) to divert water from the Delaware River Basin to meet the needs of the growing city. Due to concerns about water in the main stem, the Supreme Court issued a Decree in 1954, resolving the Delaware Diversion Case. One provision of the Decree was the establishment of the Montague Flow Objective, which required NYC to make releases to maintain a flow rate at Montague, NJ, providing water for downstream uses to compensate for water diverted from the Basin.

In 1983, the Commission adopted a drought management program and established the Trenton Flow Objective. The Trenton Flow Objective is intended to assure that enough freshwater flows reach the Delaware River Estuary to “repel” salinity (see SALT FRONT). Releases from larger Basin reservoirs are used to manage freshwater inflows to the Estuary.

The main stem Delaware River is also susceptible to flooding after large rainfall events. After the worst flood on record (1955), the U.S. Army Corps of Engineers constructed five reservoirs, two for flood control and three multi-purpose reservoirs with the additional purposes of recreation and releases to increase flows in the Delaware River during dry and drought conditions. However, pervasive flooding has become an increasing concern for the Basin with much larger storm events occurring since 2000.

PRESENT STATUS

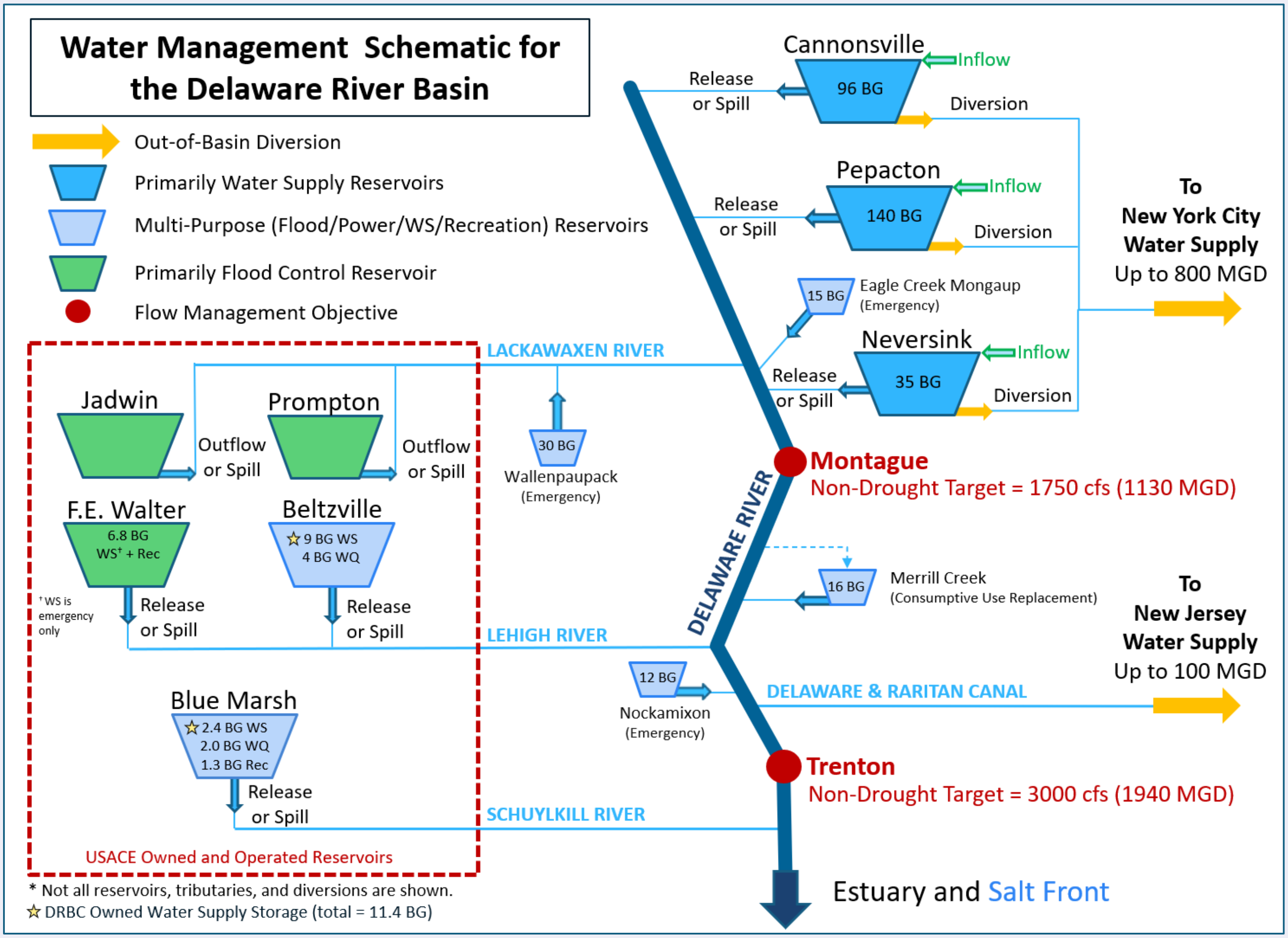
During the 1960s drought of record, the lowest average monthly flow recorded at Trenton was 1,548 cubic feet per second (cfs) in July of 1965. Due to the construction of reservoirs, establishment of the Trenton Flow Objective, the implementation of drought management plans, and reductions in consumptive water use, the main stem River is unlikely to see flows as low as those of the 1960s. The water stored in reservoirs during periods of high flows is later released during periods of low flow, providing some assurance of flow.

With the Trenton Flow Objective, freshwater inflows into the Estuary have been successful at salinity repulsion. The salt front is an indicator of salinity and is the location in the Estuary where the 7-day average concentration of chloride is less than 250 mg/L.

A historic flooding event which occurred on the main stem Delaware River in 1904 was caused by a large rain and snow melt event. The worst flooding experienced along the main stem and in several larger tributaries occurred in 1955 as the result of back-to-back hurricanes (Connie and Diane). However, these flood events were prior to the construction of most flood control reservoirs. After 49 years of relatively minor flooding events, major main stem flooding events occurred in 2004, 2005, 2006 and 2011 (all ranked in the top 10).

TRENDS

The historical records of flow at locations unaffected by anthropogenic influence (human activities) and reservoir releases indicate weak or moderate trends in annual, median, and low flow. Despite efforts to select relatively undisturbed watersheds, urbanization and population growth may account for the more moderate increasing trends in some of the watersheds. It is also important to acknowledge that trends in flow are difficult to evaluate due the length of the historical



record (although a record of 30-years was required), the strong seasonality, and the variation of flow from year to year.

The trend in flows at Trenton, NJ were also evaluated. The frequency of low flows has decreased due to the establishment of the Trenton Flow Objective and reservoir releases to meet it. However, trends in higher flows were not evident because more extreme higher flow events, although increasing, are the result of relatively infrequent, high-intensity and volume rainfall events.

ACTIONS/NEEDS

To better understand potential future issues related to river flows, modeling and other types of analyses are being conducted under the Commission's Water Resources Program and by many others. To improve the Basin's resilience to both drought and floods, these analyses are needed to develop a better understanding of how climate change may affect river flows (hydrology) and how sea level rise may affect salinity. Preliminary results indicate that changes in precipitation and temperature will affect the timing and amount of water reaching the main stem. Shifts in the seasonality of high flows are expected to change along with a slight overall increase in flow. Sea level rise is anticipated to affect the mixing of fresh and salt water in the Estuary. Modeling and analyses will help to determine the adequacy of flow management programs, drought management plans, and water availability to repel the salt front and meet other demands for water in the Basin. In addition to the responsibilities of the Commission for water resources planning and management, flow management for the Basin is also influenced by the 1954 US Supreme Court Decree. Planning for future water needs will be coordinated with the parties and other interested stakeholders, as applicable. More information about climate change and sea level rise is included in CHAPTER 3.

SUMMARY

The Basin has experienced periods when flows persist above or below the long-term average, such as the dry period of the 1960s and the wet periods of the 1970s and mid-2000s. Freshwater inflows impact salinity in the Estuary, which affects the availability of Estuary water for drinking water and industrial uses. The Trenton Flow Objective appears to be managing salinity. However, sea level rise may require new management measures, operations plans and/or additional water to maintain control of salinity. For the purposes of this report, this indicator status is considered Good with a Neutral trend.

Mud flats along the Delaware Bay.
Photo © Llmckinne | Dreamstime

SALT FRONT

DESCRIPTION

The Delaware River Estuary provides drinking water for over one million people. Its suitability as a drinking water source is affected by salinity ("saltiness" of the water). Salt is not easily removed from water, may affect water's taste and odor, and at higher concentrations in drinking water may cause health issues for those sensitive to sodium. The Philadelphia Water Department (Baxter intake) and the New Jersey American Water Company (Delran intake) are located near RM 110 and have the possibility of being adversely affected by high levels of salinity. Higher salinity and chloride concentrations may also increase corrosion to the infrastructure of all surface water users.

The salt front is an indicator used to evaluate the success of the Trenton Flow Objective at salinity repulsion (see FLOW). The salt front is defined as the location in the Estuary where the 7-day average chloride concentration is 250 mg/L (which was based on the U.S. Public Health Service recommended maximum chloride concentration for public water supplies). The location of the salt front is not measured directly but is calculated daily from real-time specific conductivity data. The location fluctuates in the Estuary based on tides and freshwater inflows. The tide pushes salt upstream, while river flows push it downstream or slow its movement upstream.

During the 1960s drought, the maximum location of the salt front reached RM 102, approaching public water supply intakes near RM 110. To reduce the likelihood of salinity intrusion as far upstream of RM 110, DRBC established the Trenton Flow Objective. Additional actions and provisions include water conservation programs, limits on out-of-Basin diversions, reservoir management criteria, storage projects, among others.

PRESENT STATUS

Since the drought of the 1960s, the salt front has remained below RM 91 (Mantua Creek). The ranges of the salt front location by month, for the full period of record (1963-2023), during the drought of record (1963-1967), and after the drought of record (1968-2023), are presented in Figure 17. The comparison of the different periods shows how the range of the salt front has been farther downstream than what occurred during the drought of record. Higher freshwater flows into the Estuary as the result of sufficient rain and the Trenton Flow Objective have prevented the salt front from moving past the Schuylkill River.

TRENDS

The salt front location exhibits seasonal behavior related to the relative mean sea level and tides, flow, and terrestrial salinity contributions. Due to the variability and timing of all these factors, a trend in the salt front location is difficult to determine. However, conditions are becoming more favorable for upstream movement of the salt front. Sea level rise increases the salt being pushed into the Estuary and salinity from land-based sources is increasing (see SALINITY). A significant amount of uncertainty is associated with how climate change may affect the flow regime.

What is salinity?

A measure of dissolved salts in the water (e.g., sodium chloride – NaCl). Consequently, chlorides are primary ions contributing to total salinity. The concentration of dissolved ions in water is often measured by testing the water's ability to carry electrical current (termed "specific conductivity"). This is easier than analyzing water for concentrations of specific chemical compounds; therefore, specific conductivity is frequently used to estimate chloride concentrations and estimate salinity levels.

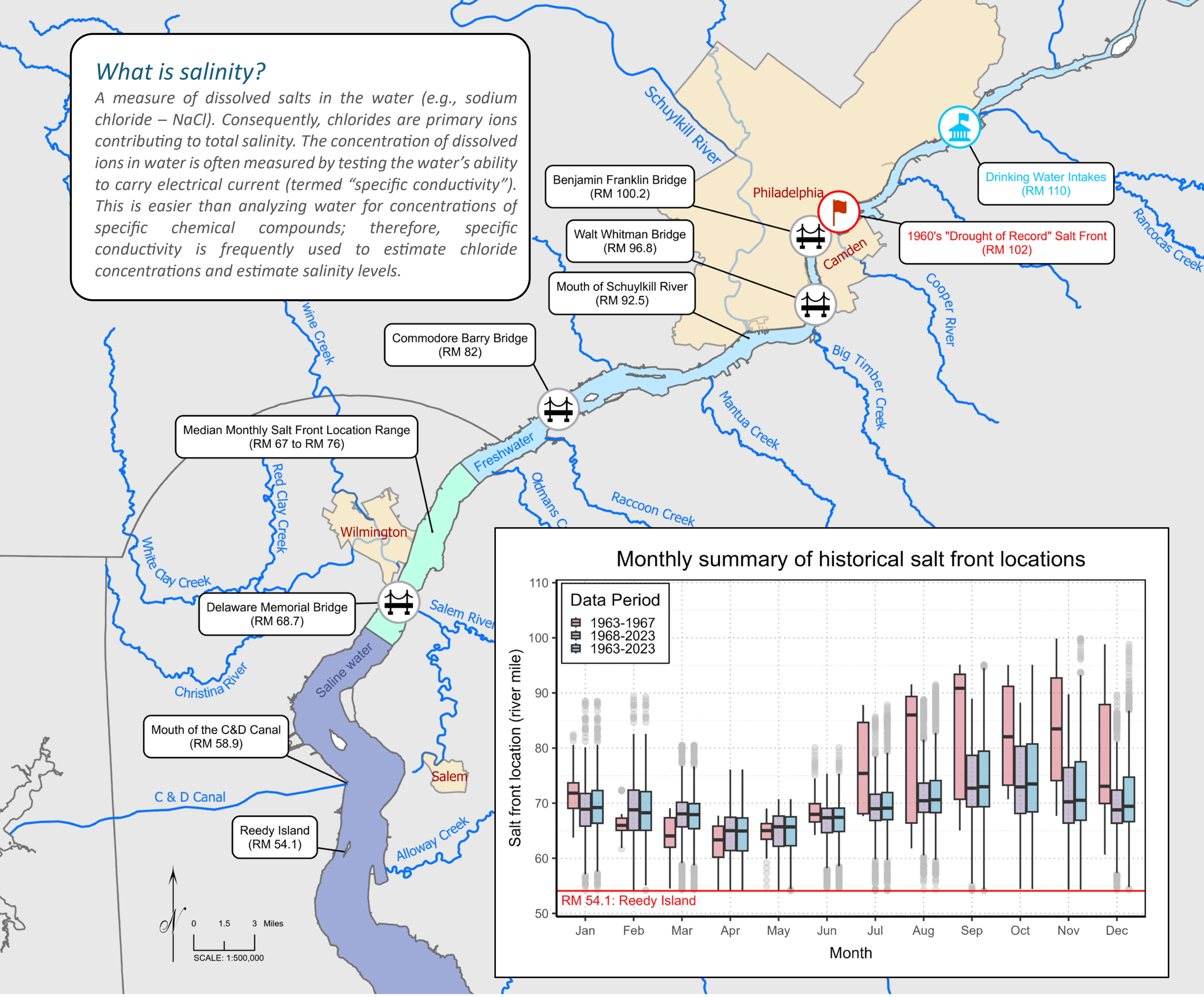


***Figure 17**: (**map**) The upper portion of the Delaware River Estuary highlighting features which are relevant to the salt front. (**boxplot**) The typical monthly range of the salt front (by river mile), calculated as the 7-day average 250 mg/L chloride concentration. Note that DRBC does not calculate the location of the salt front below river mile 54.1 (Reedy Island). Data on the location of the salt front can be obtained from DRBC's website, or viewed on HydroSnap.*

Additionally, changes to water availability may affect the ability to maintain the Trenton Flow Objective.

ACTIONS/NEEDS

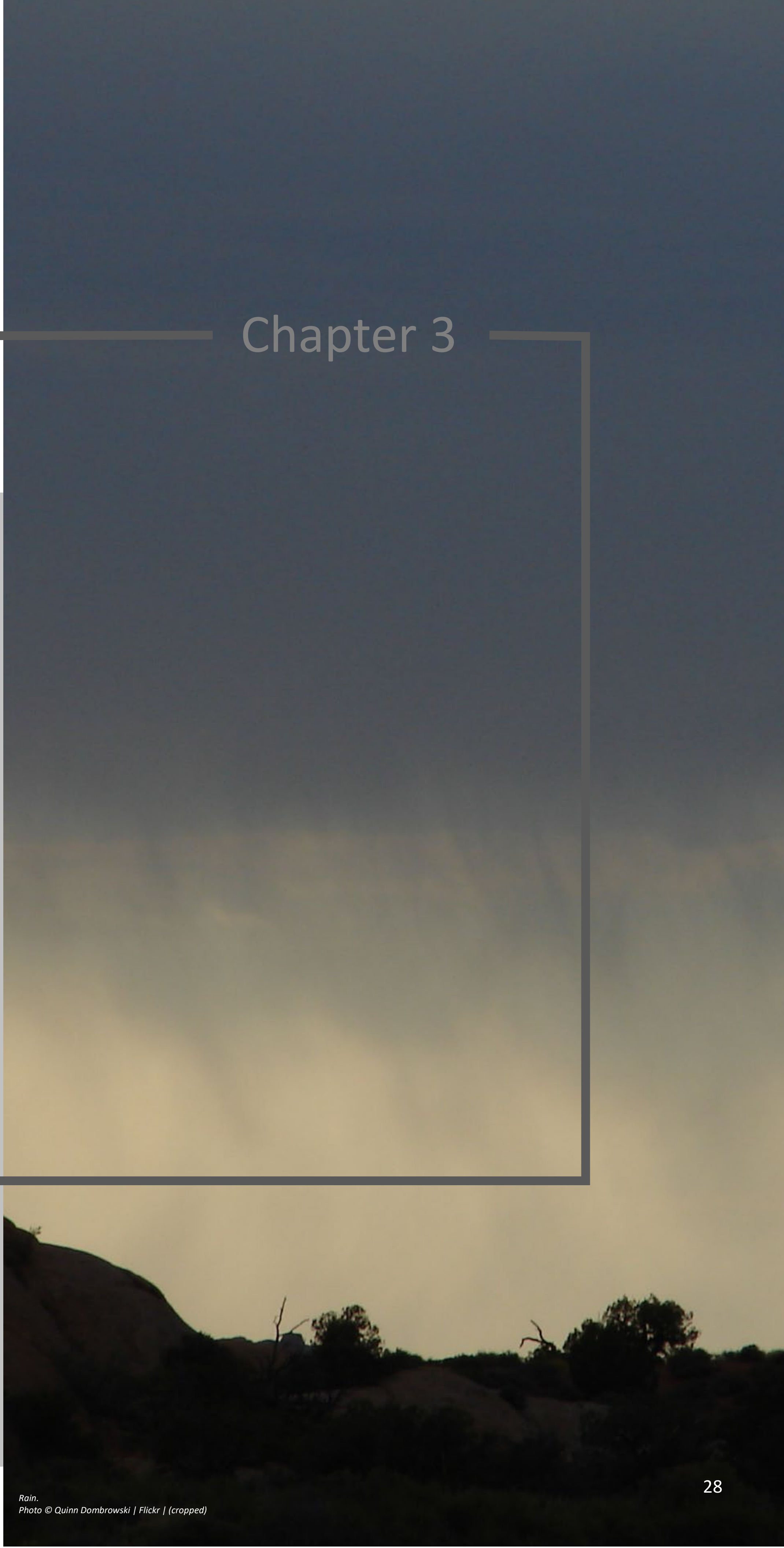
Sophisticated modeling and analyses are needed and underway to establish the relationship between sea level rise and salinity to develop a better understanding of the potential impacts. With models and other tools, different management options for salinity repulsion can be evaluated, including but not limited to, new infrastructure, optimization of infrastructure, and flow management (e.g., different flow objectives and the development of new sources of water). Research regarding the increasing trend of chlorides in freshwater is also necessary to assess the sources of chlorides and develop salinity management options.

SUMMARY

The salt front is an indication of salinity intrusion into the Estuary. Salinity affects the availability of Estuary water for drinking water and industrial uses. The Trenton Flow Objective and associated drought management actions have maintained the salt front below RM 91. However, sea level rise may require additions or modifications to current management measures. Although definitive trends in Estuary salinity have yet to be determined, increased salinity in freshwater flows to the Estuary may contribute to increased salinity levels in the Upper Estuary. For the purposes of this report, this indicator status is considered Good but with a Declining trend.

Chapter 3

CLIMATE CHANGE



Rain.
Photo © Quinn Dombrowski | Flickr | (cropped)

Raindrops on a window.
Photo © Gabriele Diwald | Flickr | (cropped)

PRECIPITATION

DESCRIPTION

Precipitation refers to both rain and snowfall. Precipitation patterns define when and where water is available, sustaining water supplies and habitat throughout the Delaware River Basin. Changes in these patterns can pose both drought and flood risks. Drought conditions may develop when there is below-average precipitation for a sustained period, putting water supplies and aquatic life at risk. When a large amount of precipitation falls in a short time, flooding is possible, posing risk to infrastructure and crops (Payton et al. 2023). Flooding and drought can both impair water quality as well (USEPA 2024a). Heavy rainfall can carry pollutants from land to water, and any pollutants will be less diluted (more concentrated) during times of low flow.

PRESENT STATUS

Across the northeastern United States, including the Delaware River Basin, average annual precipitation has increased by 5–15% in the last 60 years (Marvel et al. 2023). In the Delaware River Basin, long-term, high-quality precipitation data are available at Philadelphia, PA, from 1883–present and at Allentown, PA, from 1951–present (NOAA 2021).

Figure 18A shows long-term annual total precipitation data from Philadelphia and Allentown. The thick solid line shows the 10-year-average precipitation. In Philadelphia, recent average annual precipitation (1993–2022) is 3 inches greater than it was 100 years earlier (1893–1922). Figure 18B is a similar plot showing the number of days with more than 1.5 inches of precipitation over the last 60 years. Compared to 60 years ago, in both Philadelphia and Allentown, two more high-precipitation days occur each year on average.

TRENDS

Total precipitation and extreme precipitation that causes flooding are both projected to continue increasing throughout the Delaware River Basin (Hawkins and Woltemade 2021; Maimone et al. 2023). With less certainty, some studies also project that drought extremes could intensify in the future (Gamelin et al. 2022). Black dashed lines in Figure 18 (A and B) represent the observed trends in total precipitation and high-precipitation days. Total precipitation in Philadelphia is increasing by about 1 inch every 34 years, while total precipitation in Allentown is increasing by about 1 inch every 14 years. Every forty years, both Philadelphia and Allentown are experiencing about one additional high-precipitation day, on average.

ACTIONS/NEEDS

The uncertainty in predicted precipitation changes makes it challenging to design and implement adaptation measures. Planning for known extreme conditions with a margin of safety based on risk tolerance may still be a reasonable approach. The DRBC has released a tool to project extreme precipitation through 2099 (https://drbc-idf.rcc-acis.org/), which can be used to update local flood standards to mitigate flooding damages throughout the Basin. Preparing for drought risks will require a better understanding of how rainfall patterns will change, and especially how persistent future dry periods may be.

SUMMARY

Analyses of historical data indicate that both the amount and number of days with higher rainfall amounts have been increasing in the Basin. For the purposes of this report, this indicator status is considered Good with a Neutral trend.

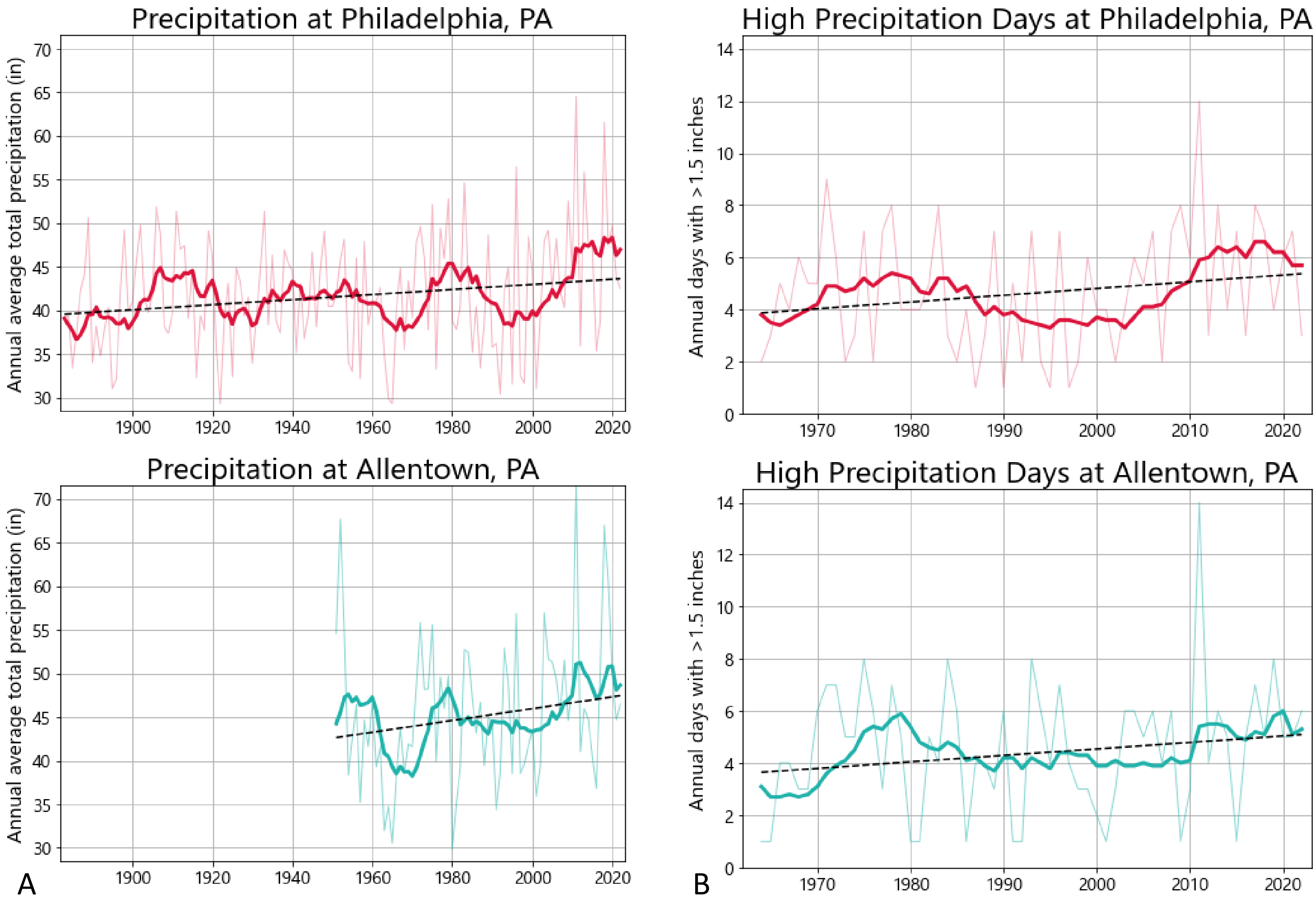


***Figure 18**: **(A)** Long-term precipitation patterns at Philadelphia, PA **(top)**, and Allentown, PA **(bottom)**. Thin lines show annual average annual total precipitation, thick solid lines show the same data averaged over a ten-year period, and dashed black lines show the average trend over the period of record. **(B)** Annual number of days with at least 1.5 inches of precipitation over the past 60 years at Philadelphia, PA **(top)**, and Allentown, PA **(bottom)**. Thin lines show annual number of high-precipitation days, thick solid lines show the same data averaged over a ten-year period, and dashed black lines show the average trend over the past 60 years.*

Snowy trees in Philadelphia, circa 2010.
Photo © Kevin Burkett | Flickr | (cropped)

AIR TEMPERATURE

DESCRIPTION

Air temperature is an important climate indicator that also impacts water resources and habitat. As air temperature rises, plants use more water from the soil, more water evaporates into the air from rivers and other bodies of water, and less water is stored as snowpack in winter (Payton et al. 2023). Higher air temperatures can cause water temperatures to increase, negatively affecting water quality and habitat. In summer, increasing air temperature brings increased human health risks. The "urban heat island" effect describes elevated air temperatures in dense urban areas that magnifies the impact of rising temperatures (Yin et al. 2023).

PRESENT STATUS

Globally, air temperatures have risen by an average of 2°F since 1900. Much of the United States, including the Delaware River Basin, has witnessed air temperatures rising faster than the global average (Marvel et al. 2023). In the Delaware River Basin, long-term, high quality air temperature data are available at Philadelphia, PA, from 1883–present and at Allentown, PA, from 1949–present (NOAA 2021).

Figure 19A shows long-term daily-maximum air temperature data from Philadelphia and Allentown. The thick solid line shows the 10-year-average temperature. In Philadelphia, recent average annual temperature (1993–2022) is 2°F greater than it was 100 years earlier (1893–1922), with daily maximum temperatures increasing faster than daily minimums. Figure 19B is a similar plot showing the number of days with a low temperature below freezing over the last 60 years. Compared to 60 years ago, in Philadelphia, there are currently 23 fewer below-freezing days each year on average and in Allentown there are 16 fewer below-freezing days.

TRENDS

Air temperature is projected to continue increasing throughout the Delaware River Basin (Hawkins and Woltemade 2021). Black dashed lines in Figure 19A and Figure 19B represent the observed trends in air temperature and below-freezing days. In both Philadelphia and Allentown, air temperatures are increasing by about 1°F every 40 years. Every ten years, Philadelphia experiences about 6 fewer below-freezing days while Allentown experiences about 2 fewer below-freezing days.

ACTIONS/NEEDS

Globally, air temperature is expected to continue rising for decades, and the magnitude of warming will depend on future global greenhouse gas emissions (Marvel et al. 2023). On a local scale, steps can be taken to adapt to and protect people from extreme heat. Planting trees, installing green roofs, and using reflective surfaces can mitigate the urban heat island effect. When considering and planning for future water availability, the many impacts of rising air temperatures on the water cycle must be considered.

SUMMARY

Average air temperatures are rising in the Basin and the number of freezing days is decreasing. For the purposes of this report, this indicator status is considered Good but with a Declining trend.

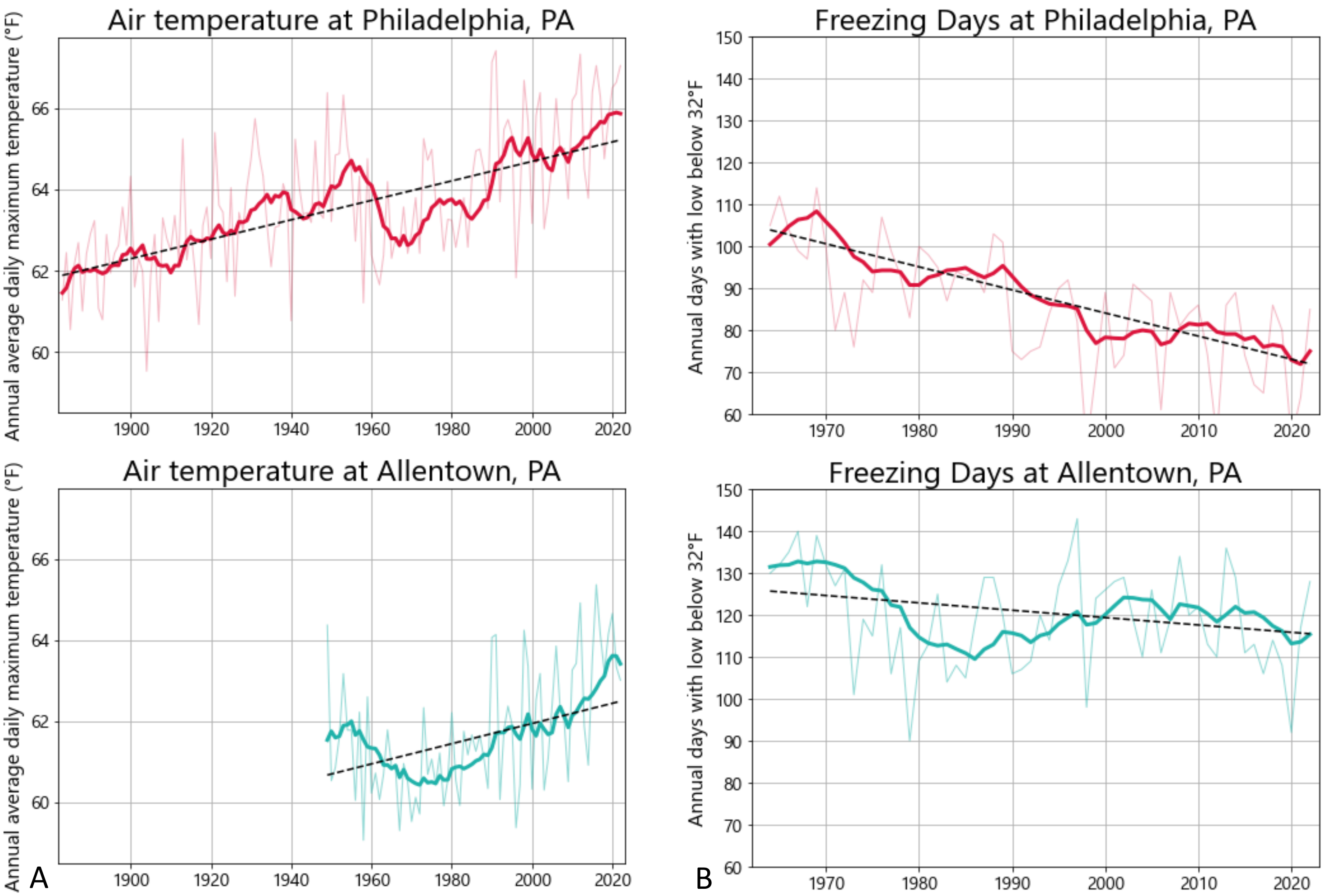


***Figure 19**: **(A)** Long-term temperature patterns at Philadelphia, PA (**top**), and Allentown, PA (**bottom**). Thin lines show annual average daily maximum temperature, thick solid lines show the same data averaged over a ten-year period, and dashed black lines show the average trend over the period of record. **(B)** Annual number of days with temperatures below freezing over the past 60 years at Philadelphia, PA (**top**), and Allentown, PA (**bottom**). Thin lines show annual number of below-freezing days, thick solid lines show the same data averaged over a ten-year period, and dashed black lines show the average trend over the past 60 years.*

Rough waves at Lewes, Delaware.
Photo © Mike Mahaffie | Flickr | (cropped)

SEA LEVEL RISE

DESCRIPTION

Sea level rise (SLR) due to factors such as glacier melt, thermal expansion and vertical land motion is of serious concern to water resource managers and water users in the Delaware River Estuary. The tidal portion of the Estuary extends from Trenton, NJ (RM 133) to the mouth of the Delaware Bay at the Atlantic Ocean between Cape May, NJ and Lewes, DE. In addition to exacerbating tidal flooding, storm surge, and inundation extent, sea level rise also has implications for low flow and drought management.

NOAA has extensively studied the increased potential for storm surge and sunny day high tide flooding (HTF) (Sweet et al. 2022). In the Northeast Atlantic region, the frequency of minor and moderate HTF doubled between 1990 and 2020. Over the next 30 years (2020 to 2050), the frequency of minor HTF is projected to triple, moderate HTF is projected to increase by a factor of 10, and major HTF is projected to increase by a factor of 4. Lewes, DE currently experiences 21 HTF days per year and is projected to experience 60–90 days per year by 2050 (based on *Low* to *Intermediate* emission scenarios). Philadelphia, PA currently experiences 5 HTF days per year and is projected to experience 40–65 HTF days per year by 2050.

Sea level rise in the Estuary can also impact water supplies and water availability. In an estuary, fresh and ocean water mix. In upstream portions of the Estuary, water is relatively fresh (rather than saline) and is heavily utilized for purposes such as drinking water treatment, manufacturing, industrial uses, and cooling for thermoelectric power generation.

Sea level rise will result in salinity intrusion farther upstream in the Estuary and may impact the effectiveness of the current drought management program measures – which exist to protect water users (see FLOW and SALT FRONT). Since the 1960s, the Trenton Flow Objective, drought management program, and other measures have been effective at salinity repulsion and the salt front has not been above RM 91. However, preliminary studies indicate that the Trenton Flow Objective may not be adequate for salinity repulsion with sea level rise; therefore, new management measures and additional freshwater may be needed for salinity management. Although trends in the Estuary salinity are not evident to date, salinity contributions from tributaries and the non-tidal Delaware River (see SALINITY) may exacerbate impact of salinity intrusion in the upper Estuary.

PRESENT STATUS

A change in sea level affects the overall volume of water in the Delaware Bay and Estuary which may also affect the dynamics and persistence of salty water in the upper reaches of the Estuary (see SALT FRONT). Figure 20 presents the mean sea level at Philadelphia, PA (NOAA gage 8545240) over the last century. Since 1900, sea level has risen at an average rate of 3.1 mm/year (1 ft per 100 years), based on monthly mean sea level data. Similarly, Figure 21 presents the mean sea level at Lewes, DE (NOAA gage 8557380), which has risen at an average rate of 3.7 mm/year since 1919. However, these average rates do not

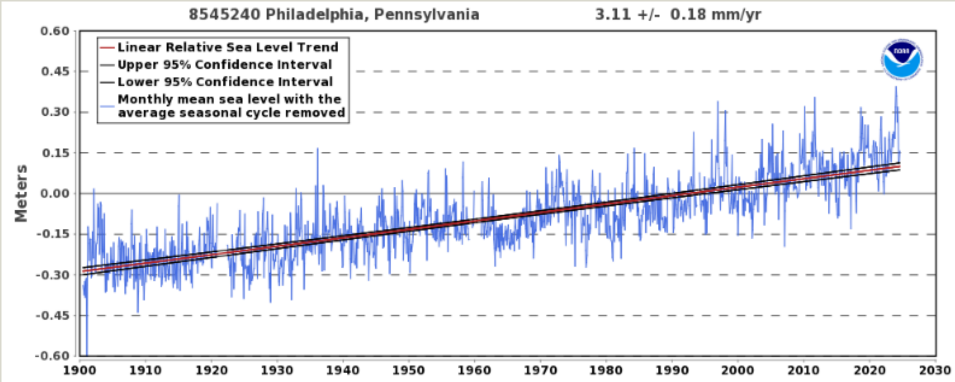


***Figure 20**: The mean sea level trend at Philadelphia, PA. The average, long-term relative sea level trend is 3.11 mm/year with a 95% confidence interval of +/- 0.18 mm/yr. This rate is equivalent to a sea-level increase of 1.02 feet in 100 years.*

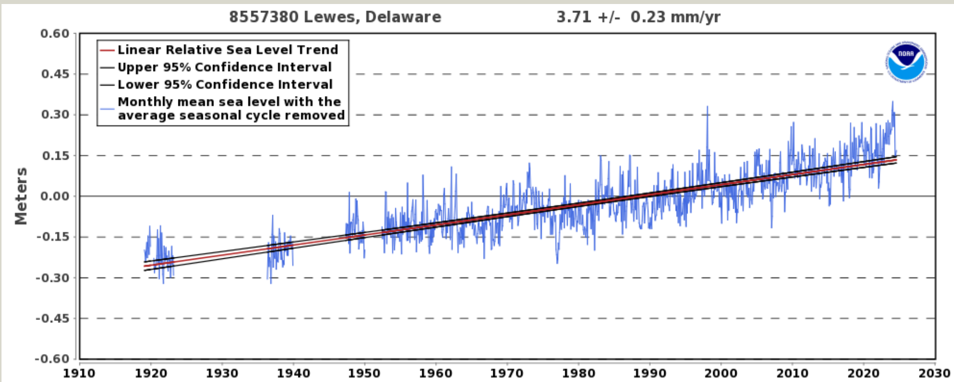


***Figure 21**: The mean sea level trend at Lewes, DE. The average, long-term relative sea level trend is 3.71 mm/year with a 95% confidence interval of +/- 0.23 mm/yr. This rate is equivalent to a sea-level increase of 1.22 feet in 100 years.*

include potential acceleration due to climate change. In Philadelphia, the rate of sea level rise between 2000 and 2023 was 6.7 mm/year, more than double the long-term rate (3.1 mm/year). Similarly, at Lewes, DE the rate of sea level rise between 2000 and 2023 was 8.3 mm/year, much greater than the long-term rate (3.71 mm/year).

TRENDS

Predicted sea level rise in the Delaware Bay from 2020 to 2100 is shown in Figure 22, with a baseline referenced as 2000. The most recent NOAA 2022 Sea Level Rise study results are provided in orange (Sweet et al. 2022), and the geographical extent of land submergence based on each scenario can be seen using the Sea-Level Rise viewer. The relative sea level rise (RSLR) by 2100 is estimated to range between:

- 0.79 m (2.59 ft), NOAA 2022 scenario: *Intermediate-Low*
- 1.61 m (5.28 ft), NOAA 2022 scenario: *Intermediate-High*
- 2.08 m (6.82 ft), NOAA 2022 scenario: *High*

ACTIONS/NEEDS

Modeling and other analyses are underway to further define the risks of salinity intrusion due to climate change, during both dry and wet periods. Once this work has been completed, different mitigation measures will be needed to develop robust plans and resources to address the risks posed by sea level rise.

SUMMARY

Sea level rise may result in salinity intrusion farther upstream impacting the availability of upstream Estuarine water for different purposes. The Trenton Flow Objective, drought management water users, and drought management programs may no longer be adequate for salinity repulsion. Detailed studies and analyses are needed to evaluate the impacts of sea level rise on salinity, and updates or the development of new methods to protect freshwater use in the upper Estuary may be required. For the purposes of this report, this indicator status is considered Good but with a Declining trend.

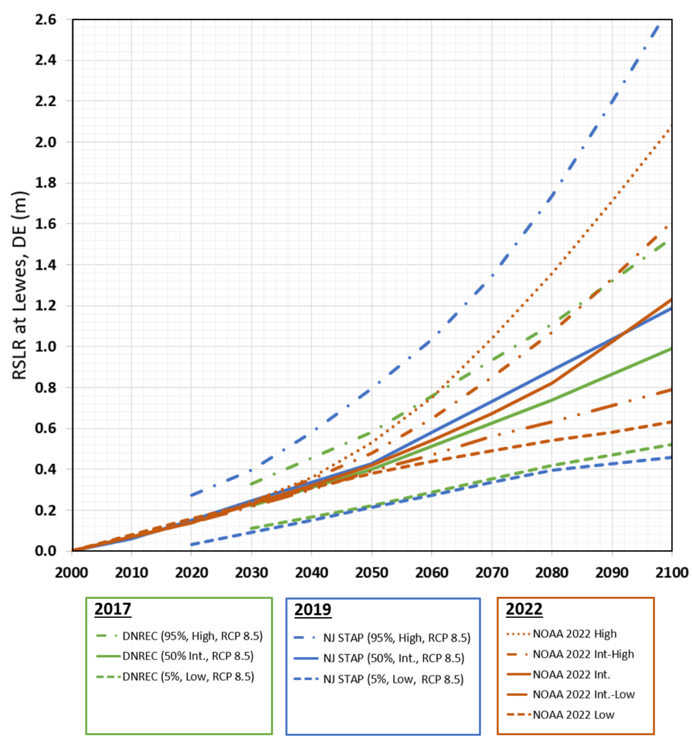
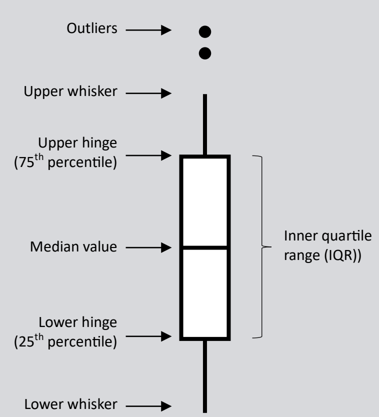


***Figure 22**: Relative sea level rise (RSLR) projections at Lewes, DE. Note that there are uncertainty bounds associated with each projection, but that only the median values of each projection are shown. Representative Concentration Pathways (RCPs) are scenarios with different trajectories of greenhouse gas emission used in climate modelling; RCP 8.5 represents a high-emission scenario.*

How to interpret a boxplot...

Boxplots in this report have been generated using the computational language R, specifically “geom_boxplot” {ggplot2} (Wickham 2016) which follows McGill et al. 1978. Consequently:

- **The lower and upper hinges** correspond to the first and third quartiles (the 25th and 75th percentiles).
- **The upper whisker** extends from the hinge to the largest value no further than 1.5 * IQR from the hinge (where IQR is the inter-quartile range, or distance between the first and third quartiles).
- **The lower whisker** extends from the hinge to the smallest value at most 1.5 * IQR of the hinge.
- **Outlying points** are considered data beyond the end of the whiskers and are plotted individually (if specified).



Chapter 4

WATER QUALITY

6ppd sampling on Sherman Creek.
Photo © Jeremy Conkle (DRBC)

Wastewater treatment plants aerate wastewater to raise dissolved oxygen levels.
Photo © Dedmityay | Dreamstime

DISSOLVED OXYGEN

DESCRIPTION

Dissolved oxygen (DO) refers to the concentration of oxygen gas dissolved in water. Oxygen enters water both by direct exchange from the atmosphere, which can be enhanced by turbulence, and as a by-product of photosynthesis from algae and aquatic plants. DO is an important metric for good water quality because it is essential for growth and reproduction of aerobic aquatic organisms. Oxygen levels in water bodies can be depressed by eutrophication or the discharge of oxygen-depleting materials (often measured in aggregate as biochemical oxygen demand (BOD)), from: wastewater treatment facilities and stormwater runoff; the decomposition of organic matter including algae; the utilization of oxygen by aquatic organisms such as fish, reptiles, macroinvertebrates and bacteria; the oxidation of ammonia and organic carbon; abiotic factors such as temperature; and lastly, the amount of movement and volume of water.

PRESENT STATUS

In the summer, when the temperature is generally high, DO levels are low due to lower solubility of gaseous oxygen in water. DO concentrations during this time are typically characterized by a daily peak in late afternoon and a pre-dawn daily low due to photosynthetic/respiration processes; therefore, continuous monitors are preferable over daytime spot measurements, which miss the daily low concentrations. Tidal influence on DO is also evident in the Delaware River Estuary. For the Estuary, DO is measured routinely by DRBC, and continuously by the USGS with gaging stations at Trenton, Pennypack Woods, Penns Landing, Chester, Delaware Memorial Bridge, Reedy Island and Ship John Shoal. DRBC's current water quality standard for DO in the Estuary is a 24- hour average concentration not less than 5.0 mg/L in WQ Zone 2, 3.5 mg/L in WQ Zones 3, 4, and the upper portion of WQ Zone 5, 4.5 mg/L in the middle portion of WQ Zone 5, and 6 mg/L in the lower portion of WQ Zone 5. In the 2022 Delaware River and Bay Water Quality Assessment (DRBC 2023a), greater than 99.9% of observations met DO criteria in WQ Zones 2 through 4, and greater than 92.9% of observations met criteria in WQ Zones 5 and 6. Figure 23 shows the persisting DO sag in the Estuary centered in the vicinity of river mile 84 during July and August monitoring from 2009 through 2023. DRBC has developed a daily near-real-time assessments of DO comparing the 24-hour mean concentrations at USGS monitors to the DRBC surface water quality standards and the distribution of percent of DO saturation values at each USGS gage, available at: https://drbc.net/Sky/waterq.htm.

TRENDS

Historically, the limited treatment of human and industrial wastes through the mid-1900s caused severe water pollution problems in many areas of the Delaware River Basin. The urbanized portion of the Estuary surrounding Philadelphia was the most notorious of the problem areas. In fact, these water pollution problems were a key motivating factor for forming the DRBC, further leading to the development of the Clean Water Act and other state and federal laws to control water pollution in the 1960s and 1970s. The pollution in the Estuary was so severe that, among many symptoms, there was essentially no DO in the

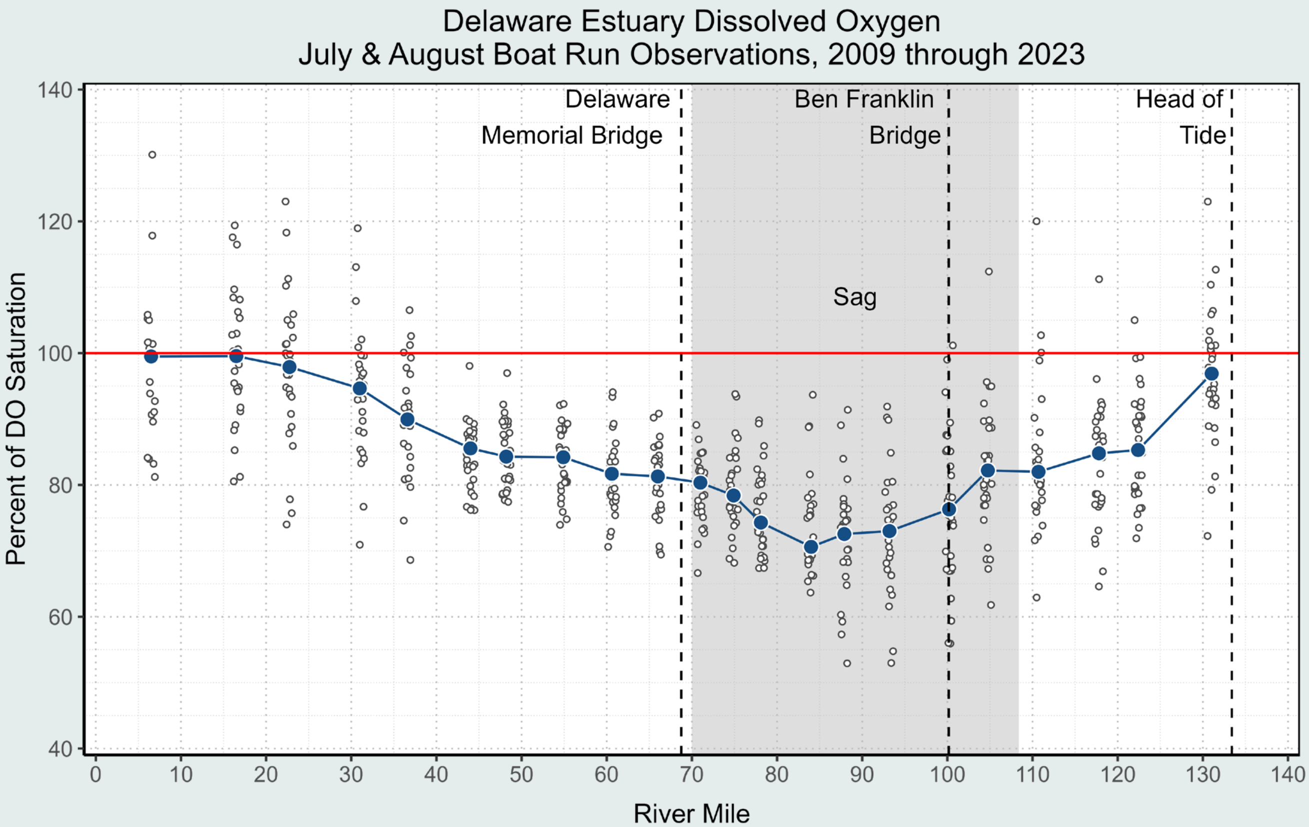


***Figure 23**: July and August percent of dissolved oxygen saturation data by river mile from DRBC's Delaware River Estuary Water Quality Monitoring Program (Boat Run) from 2009 through 2023.*

Delaware River around Philadelphia on a typical day from May through October of every year. This zone of "anoxia" (a lack of DO) and the surrounding zones of "hypoxia" (severe depression of DO) was particularly harmful to fish and other aquatic organisms. For example, adult migratory fishes such as American shad were hindered from completing their runs to the upstream spawning grounds, and juvenile fish which were successfully spawned upriver were hindered from downstream escapement. After the DRBC was created in 1961, the first significant accomplishment was the adoption and implementation of water quality standards in 1967 and the issuance of wasteload allocations for point source dischargers in 1968 for one form of oxygen-consuming pollution known as CBOD (carbonaceous biochemical oxygen demand). As a result of these DRBC regulations, and with the help in subsequent decades from Clean Water Act grants and the diligent work of state and federal agencies, the DO levels in the Estuary steadily improved through the 1970s, 1980s, and into the 1990s (Figure 24). After the 1990s, water quality improved to the point where oxygen levels now meet the targeted goals (such as 3.5 mg/L average DO concentration around the Ben Franklin Bridge) and the fish populations in this region of the Estuary have been partially restored. Overall, DO concentrations are lowest in mid-summer. Figure 24 shows a box and whisker time series of July and August DO distributions at Penns Landing from 1965 through 2023 compared to the current criteria at that location. Figure 24 demonstrates that DO measurements over time improved from mostly below (not meeting) criteria during the 1960s through the mid-1980s to mostly above (meeting) criteria from the mid-1990s forward, but with high variability from year to year.

ACTIONS/NEEDS

Despite treatment plant upgrades throughout the 1970s and 1980s, a DO sag in the Estuary persists. As summarized in the draft document "Linking Aquatic Life Uses with Dissolved Oxygen Conditions in the Delaware River Estuary" published November 2022, current conditions in the Estuary fall below levels protective of propagation for several Estuary fish species including Shortnose Sturgeon (an endangered species), Atlantic Sturgeon (an endangered species), American Shad, Channel Catfish, Largemouth Bass, White Perch, and Stripped Bass (DRBC 2022). Furthermore, the Commission developed a eutrophication model of the Estuary demonstrating the linkage between discharge of effluent ammonia from the largest and oldest wastewater treatment facilities in the urbanized portion of the Estuary and the remaining estuary DO sag (Pathway for Continued Restoration 2024) (Amidon and Beganskas 2024).

As a consequence of USEPA Administrator's Determination in December 2022 (Link), the Commission in September 2023 suspended its actions to develop and promulgate revised aquatic life use water quality standards for the Delaware River Estuary

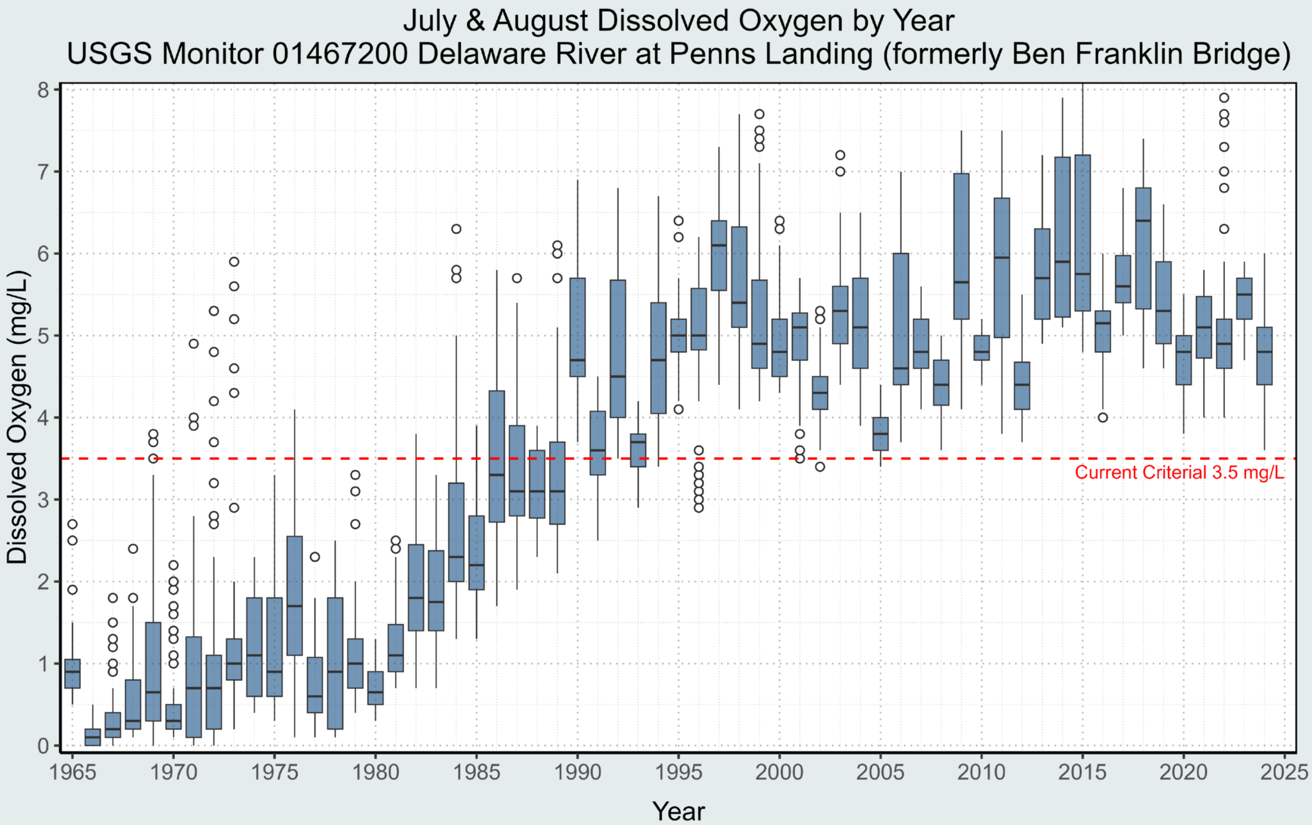


Figure 24*: July and August daily Dissolved Oxygen concentration box and whisker plot from USGS Water Quality meter 01467200 at Penn's Landing (formerly Ben Franklin Bridge) compared to 24-hour surface water quality criteria.*

and announced that it would "continue to provide [the staff's] scientific, technical, and engineering assistance to support USEPA's process for revising aquatic life designated uses and corresponding criteria for WQ Zones 3 and 4 and the upper portion of WQ Zone 5 to attain and maintain propagation of aquatic life, consistent with the staff's best professional judgment and expertise." The Commission further committed to continuing its coordination and collaboration with state and federal co-regulators during the USEPA's rulemaking process. It also promised to "work with the USEPA, co-regulator states, and interested stakeholders through [DRBC's WQAC] to develop plans, analyses, and, if appropriate, related regulations for the implementation of [upgraded] aquatic life uses and criteria in the Delaware River Estuary." On December 13, 2023, USEPA issued a proposed rule to revise the aquatic life designated use and DO water quality criteria applicable to WQ Zone 3, WQ Zone 4, and the upper portion of WQ Zone 5. USEPA proposed this rule to ensure that the aquatic life designated uses and DO criteria are set at levels that protect all life stages of oxygen-sensitive species in those WQ Zones of the Delaware River, including Shortnose and Atlantic Sturgeon which are listed as endangered under the Endangered Species Act.

As of the date of publication of this report, the USEPA proposed rule has not been finalized. The primary action needed to ensure continued recovery of Estuary DO and its dependent species is the finalization of the proposed rule and the development of implementation plans consistent with the rule.

SUMMARY

Available data indicate that DO levels support current designated uses and DO criteria throughout many areas of the Delaware River Watershed but also demonstrate localized areas of low DO within the Delaware River Estuary. The trend for the Delaware River at Trenton suggests that DO is stable at relatively high DO saturation. It is expected that good DO levels in the non-tidal Delaware River will persist under current Special Protection Waters regulations. The long-term trend of DO in the Estuary shows remarkable improvement from near anoxic (DO < 2 mg/L) conditions in the 1960s and 1970s to nearly always above applicable water quality criteria today. A DO sag in the urbanized portion of the Estuary persists, however, and is tied to the discharge of ammonia from the oldest and largest wastewater treatment facilities in that region. To retain and ensure the continued recoveries in fish growth and spawning that have followed improvements in DO since the 1960s, revised DO criteria to reflect the needs of the existing aquatic life community should be adopted and implemented. In multiple studies since the previous State of the Basin Report (2019), it has been indicated that higher DO conditions in the estuary are required to fully support propagation of all aquatic species. Due to that reason, this indicator status has changed from Good to Fair with a Neutral trend.

Aquatic plants grow well in nutrient rich water.
Photo © Charinporn Thayot | Dreamstime

NUTRIENTS

DESCRIPTION

The general category of "nutrients" includes various chemical forms of nitrogen, phosphorous and carbon. Soluble and bioavailable forms of nitrogen and phosphorus stimulate and sustain growth and development of aquatic organisms, such as plants and algae. Of all the forms of nitrogen and phosphorus, two of the best indicators for water quality include the specific chemical substances nitrate (NO_3^-) and orthophosphate (H_3PO_4). These forms are bioavailable, simple and direct to measure, and can be limiting nutrients for aquatic plant and algal growth. High concentrations of nitrate and orthophosphate can stimulate excessive aquatic plant and algal growth, which can lead to dissolved oxygen deficits in a waterbody as the biomass decays. Occasionally, this process (known as eutrophication) can result in the formation of a "Dead Zone" characterized by hypoxia. Sources of nitrate and orthophosphate can include fertilizers, runoff, and effluent from wastewater treatment. The environmental effects from elevated nutrient levels can vary widely from location to location depending on other factors such as light penetration (availability), reaeration rates, flow velocity, and water temperature.

The DRBC Special Protection Waters (SPW) regulations define Existing Water Quality (EWQ) concentrations of several nutrients including total nitrogen, ammonia, nitrate, total Kjeldahl nitrogen, total phosphorus, and orthophosphate at 85 mainstem Delaware River and tributary sampling locations (Atlas of EWQ for SPW). DRBC adopted SPW regulations for Upper and Middle Delaware in 1992, using existing data available at that time to define EWQ, and permanently designated the Lower Delaware as SPW waters in July 2008 (see Figure 3C for map of SPW). The SPW program is designed to prevent degradation of water quality where EWQ is better than the established water quality standards – essentially, "keep the clean water clean". This is achieved through management and control of wastewater discharges and reporting requirements.

The Delaware River Estuary has both high loadings and high concentrations of nutrients relative to other large estuaries such as Narragansett Bay, Chesapeake Bay, and San Francisco Bay. Despite these high loadings and concentrations, the Delaware River Estuary exhibits few symptoms of eutrophication due mainly to light limitation and energetic currents. A recently developed eutrophication model suggests that elevated ammonia loads (rather than nitrate) account for most of the dissolved oxygen sag observed in the Delaware River Estuary. Testing of "what-if" scenarios using the model suggest that while decreasing ammonia loads from wastewater effluent would help mitigate the DO sag, reductions of nitrate would have no benefit with regard to dissolved oxygen (see DISSOLVED OXYGEN).

PRESENT STATUS

Phosphorus

Phosphorus is often a limiting nutrient in freshwater ecosystems. Orthophosphate measurements retrieved from the National Water Quality Portal for 2019 through 2023 suggest lower phosphorus concentrations in the headwaters with greater concentrations observed downstream of more urban areas that

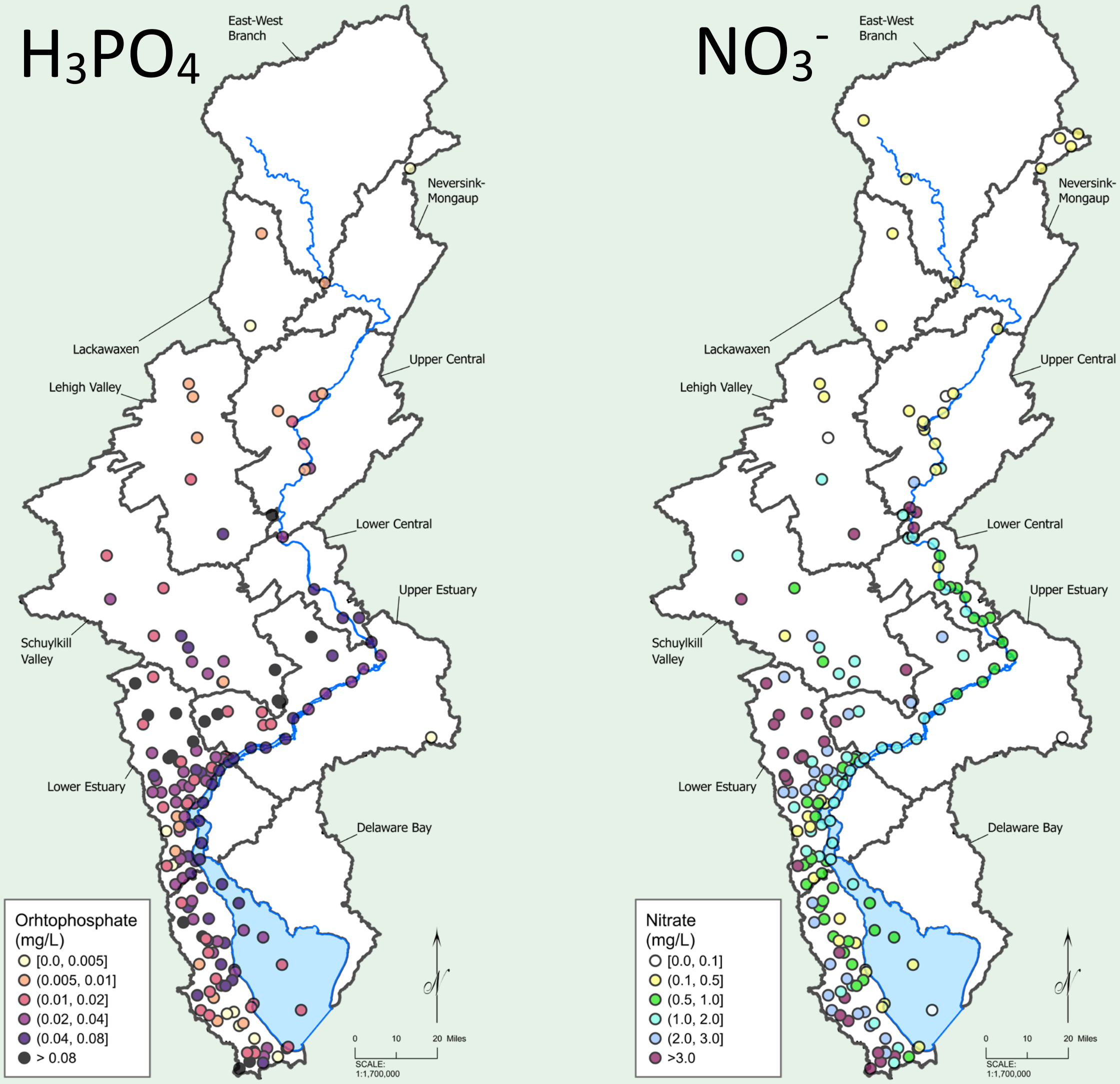


***Figure 25**: Mapped plots of all available surface water orthophosphate (H_3PO_4) and nitrate (NO_3^-) concentration data retrieved from the National Water Quality Data Portal for the period 2019 through 2023. Data were restricted to sample locations with at least n=5 samples within the time period; concentrations represent the average value at each location.*

are more impacted by the discharge of treated wastewater, as shown in Figure 25. Although greater concentrations are observed within the urbanized portion of the Estuary, orthophosphate concentrations during this timeframe are generally below 0.20 mg/L. As orthophosphate concentrations approach the Atlantic Ocean, they decrease toward concentrations similar to those found in the headwaters.

Nitrogen

While nitrogen tends to be a limiting nutrient in estuarine and oceanic environments, the energetic tidal environment in the Estuary results in light being the most important limiting factor. Data compiled from the National Water Quality Portal for 2019 through 2023 suggests lower concentrations of nitrate in the upper portion of the Basin, with greater concentrations seen towards the tidal portion of the Basin (Figure 26). Nitrate concentrations in the Estuary are typically less than 3 mg/L. The greatest concentrations are observed in the urbanized portion of the Estuary in the vicinity of WQ Zones 4 and 5, with somewhat lower concentrations near the head of tide (reflecting lower concentrations in the non-tidal Delaware River) and substantially lower concentrations at the mouth of the Delaware Bay. This pattern is consistent with nitrogen loads originating in the Estuary, particularly in the form of ammonia in the urbanized portion of the Estuary.

Data collected as part of DRBC's eutrophication model development effort have shown that 93% of the ammonia loads to the Estuary come from treated wastewater (Amidon and Beganskas 2024). Once discharged, certain bacteria use ambient dissolved oxygen to oxidize ammonia, turning it into nitrite and ultimately to nitrate. Although nitrate concentrations in the Estuary are elevated, eutrophication symptoms (such as anoxia, fish kills, and harmful algal blooms) are not currently observed within the Estuary. Modeling indicates that enhanced treatment at wastewater treatment facilities to reduce the effluent ammonia concentration would have a positive impact on dissolved oxygen without significantly increasing ambient nitrate concentrations. As ammonia is eventually fully oxidized anyway, enhanced wastewater treatment would merely shift ammonia oxidation from the Estuary to the wastewater treatment plants, conserving the dissolved oxygen in the Estuary's waters.

TRENDS

In 2016, DRBC completed an assessment which demonstrated that the SPW program is effective at "keeping the clean water clean" and has even allowed improvements corresponding to nutrient water quality (report website). Additionally, DRBC compared historical baseline water quality data to the assessment period of 2009 – 2011 at 24 sites located on the

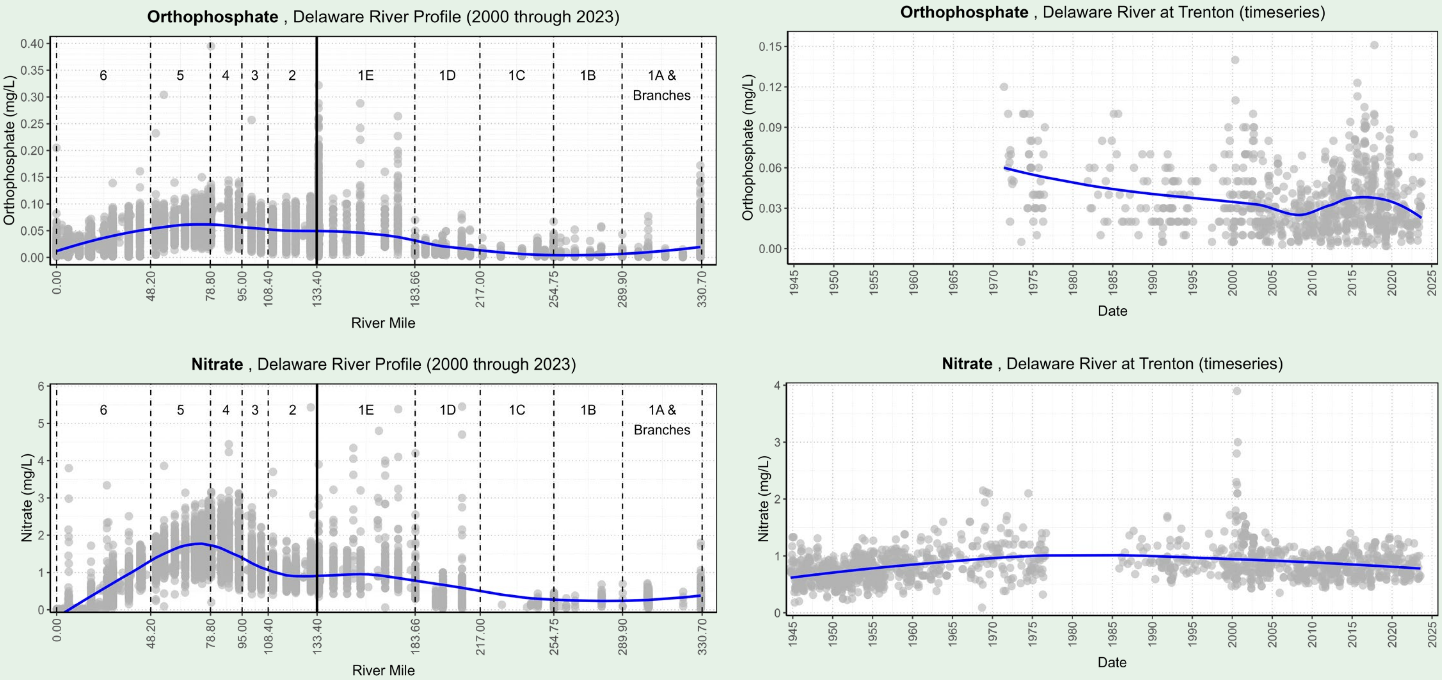


***Figure 26**: Available surface water Phosphate and Nitrate concentration data retrieved from the National Water Quality Data Portal. The blue lines are locally estimated scatterplot smoothing (LOESS) regressions. (**Left**) Main stem Delaware River concentrations by river mile for the period 2000 through 2023. (**Right**) Time series of concentrations measured at USGS 01463500 (Delaware River at Trenton, NJ), approximately RM 134.25.*

Delaware River and tributaries. This analysis demonstrated that several water quality parameters did not show measurable changes to EWQ, and nutrient parameters showed meaningful improvements throughout the SPW area.

Phosphorus

A plot of all available orthophosphate data collected at the Delaware River at Trenton near the Calhoun Street Bridge (Figure 26), shows that concentrations were more elevated in the 1970s and showed a steady decline through the 2000s. There appears to be a temporary increase in concentrations in the 2010s, with further decline in recent years.

Nitrogen

A plot of all available nitrate data collected at the Delaware River at Trenton near the Calhoun Street Bridge (Figure 26), shows concentrations increasing from the 1950s through 1980 but declining from the 1990s through recent years. The data record also shows an approximately 10-year data gap from the late-1970s through the mid-1980s. Additionally, there appears to be a short-term spike in nitrate concentrations in the early 2000s.

ACTIONS/NEEDS

Since publication of the previous State of the Basin report in 2019, our understanding of the impact of elevated nutrients, particularly regarding dissolved oxygen in the Estuary, has improved. Eutrophication modeling demonstrates that reductions in wastewater effluent concentrations of ammonia are needed to improve dissolved oxygen in the Estuary and to reduce the depth, spatial extent, and duration of the current dissolved oxygen sag. While additional reductions of nitrate and orthophosphate concentrations would not appear to provide any additional benefit in terms of dissolved oxygen improvements, future studies may reveal that elevated nutrients cause ecosystem impacts separate from their impact on dissolved oxygen. In September and November of 2019, DRBC's Water Quality Advisory Committee (WQAC) discussed numeric nutrient criteria. The committee reached a general consensus that the negative impacts of elevated nutrients might be masked by the impacts of low dissolved oxygen levels and that these impacts could be better assessed following dissolved oxygen improvements. Thus, further evaluation of nutrient impacts should occur following improvements in dissolved oxygen.

In the non-tidal River, both nitrate and orthophosphate show a trend of decreasing concentrations over time, facilitated as part of the SPW program. The SPW program should continue such that non-tidal nutrient concentrations are maintained at or below EWQ definitions.

SUMMARY

Nutrient concentrations (especially for nitrate and orthophosphate) tend to be lower in the upper portion of the Basin and higher in the Estuary. Over time, concentrations from the non-tidal portion of the Delaware River appear to be stable. Nutrient concentrations in the Delaware River Estuary are elevated. Estuary modeling recently completed in support of development of new dissolved oxygen criteria suggests that the main negative impact to dissolved oxygen is from ammonia (rather than nitrate or orthophosphate). Some members of DRBC's WQAC, however, have suggested that elevated estuary nutrient concentrations could be exerting a negative impact on aquatic life that is currently masked by the impact of the current dissolved oxygen sag. They have further recommended that DRBC reassess the impact of elevated nutrients after additional dissolved oxygen recovery. For the purposes of this report, this indicator status has changed from Very Good to Good with a Neutral trend.

Spreading road salt in anticipation of wintery conditions.
Photo © Luboslav Ivanko | Dreamstime

SALINITY

DESCRIPTION

Salinity is a key water quality indicator that reflects the concentration of dissolved salts and minerals in river systems. In the Delaware River's non-tidal portion, salinity levels are primarily influenced by natural factors such as geology, precipitation, and evaporation. However, human activities such as agricultural runoff, de-icing salt applications, wastewater discharge, and mining processes also contribute to increasing salinity levels, leading to freshwater salinization (Cañedo-Argüelles et al. 2018). Specific conductance (which measures the ionic content of water) is commonly used as a proxy indicator of salinity in freshwater systems. Chloride (a major component of common salts) is of particular concern because it affects biological health and water corrosivity. Increasing salinity concentrations are a concern due to potential impacts on human and ecosystem health, including drinking water quality, biodiversity, and mobilization of heavy metals (Kaushal et al. 2021)

CURRENT STATUS

The DRBC's Special Protection Waters (SPW) program is designed to prevent degradation of water quality in the non-tidal Delaware River, maintaining what is known as Existing Water Quality (EWQ) at 85 monitoring locations. This program sets strict wastewater discharge limits and includes regular monitoring to track water quality over time. In a 2016 assessment of data from 2009–2011, most water quality parameters met EWQ definitions, with some even improving (Atlas of EWQ for SPW). However, specific conductance and chloride showed upward trends, indicating signs of degradation, consistent with regional and global trends; for example, as observed at the Delaware River monitoring site at Trenton, NJ, which captures the freshwater inflows from the SPW drainage (Figure 27). More recent monitoring (2021–2023) found that chloride and specific conductance levels exceeded baseline EWQ conditions, reinforcing concerns about ongoing freshwater salinization in the Basin (Figure 28).

TRENDS

The trend toward increasing chloride and specific conductance in the Delaware River's non-tidal portions has been noted over the past decade. Non-point sources such as de-icing salts and agricultural runoff are thought to be the primary contributors to the issue. These sources are more challenging to regulate than point sources due to their diffuse nature. Additionally, dissolved salts can accumulate in groundwater and slowly release into surface waters, compounding the problem over time.

Though chloride concentrations in the Delaware River are not, on average, near the acute or chronic toxicity thresholds recommended by the USEPA for drinking water (maximum 250 mg/L) or aquatic life (230 mg/L chronic and 860 mg/L acute), the overall trend toward increased salinity is concerning. The ongoing salinization of the non-tidal river, as seen in both chloride and specific conductance data, could continue to worsen unless more effective mitigation strategies are implemented.

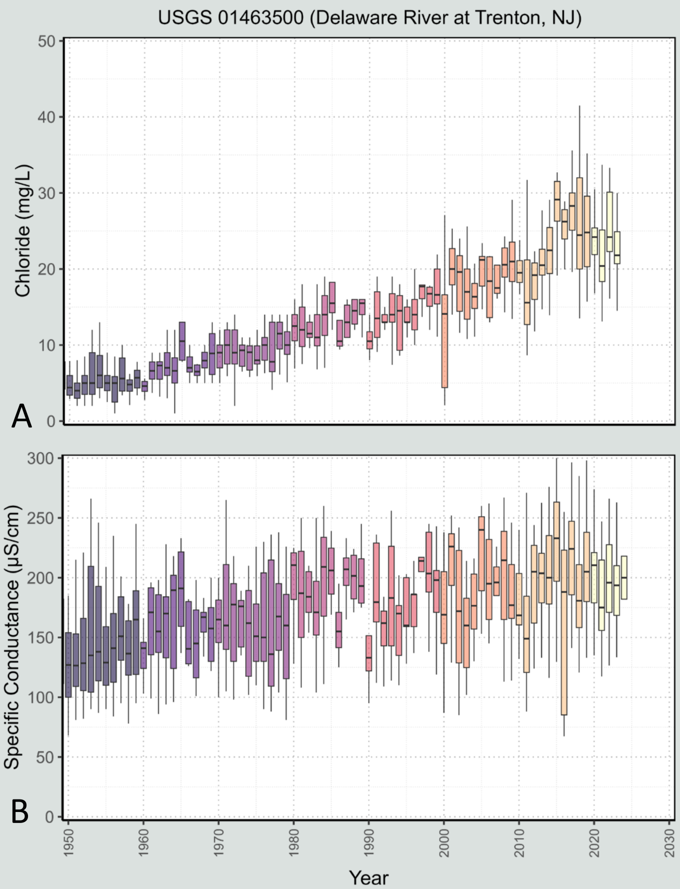


***Figure 27**: Water quality data obtained from the National Water Quality Monitoring Council's Water Quality Portal for USGS Gage 01463500 (Delaware River at Trenton, NJ). (**A**) Timeseries of chloride concentrations. (**B**) Timeseries of specific conductance values.*

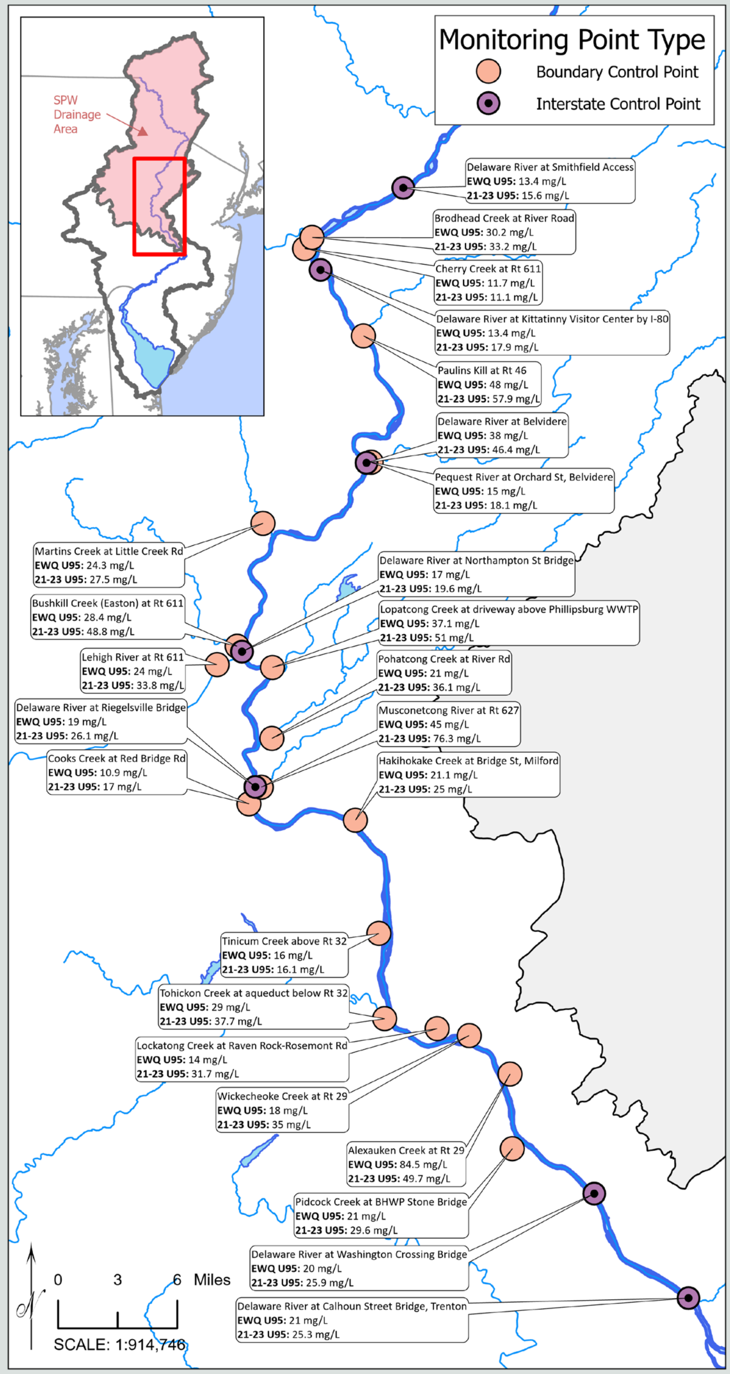


***Figure 28**: Chloride sampling results from 2021-2023 (95% upper confidence limit (U95) in mg/L) for 25 of the 85 SPW monitoring locations, as compared to baseline Existing Water Quality data (link to EWQ Atlas). Note that DRBC hosts an interactive data explorer for the SPW monitoring program (data explorer).*

ACTIONS/NEEDS

To address rising salinity and chloride levels in the non-tidal Delaware River, a combination of strategies is needed. An improved understanding of source apportionment of chloride would help identify target areas, including loads from background/natural sources, dischargers, groundwater, de-icing salt, agricultural runoff, water softener waste, and others. Prioritizing efforts to reduce salted runoff, optimize de-icing salt application, and explore alternative deicing methods can help mitigate the issue. Educating the public and stakeholders about the importance of salt management is essential to foster cultural shifts regarding salt use and expectations of winter road maintenance. Public safety concerns complicate addressing salt as a pollutant as it also acts as a measure to decrease road accidents during winter storms. DRBC will continue to monitor salinity through the SPW monitoring program and work with partner agencies and stakeholders to address this issue.

SUMMARY

Salinity levels in the non-tidal Delaware River are driven by both natural processes and human activities, such as de-icing salt applications, and have shown a steady increase over time. The DRBC's SPW program aims to preserve water quality in the non-tidal Delaware River, but data show an increasing trend in chloride and specific conductance (which are effective proxies for salinity), indicating potential degradation. While these concentrations are not yet at levels of acute concern, the ongoing rise in salinity levels poses a potential long-term threat to both ecological and human health. For the purposes of this report, this indicator status is Fair with a Declining trend.

Ice pancakes on the Delaware River near Yardley, Pennsylvania.
Photo © Michael Thompson (DRBC)

TEMPERATURE

DESCRIPTION

Water temperature is an important factor for the health and survival of fish and aquatic communities. Temperature can affect embryonic development, juvenile growth, adult migration, competition with non-native species, and the relative risk and severity of disease. Temperature assessment in the non-tidal Delaware River is confounded by artificially lowered temperatures from reservoir releases in the headwaters of the Delaware River. Temperature criteria in the Delaware River Estuary are expressed in DRBC regulations by day of year.

PRESENT STATUS

Summer temperatures (June-Sept) in the non-tidal Delaware River are depicted on Figure 29 at multiple USGS monitors, based on the median daily values (2019-2023). This plot helps visualize the shift from colder temperatures in the reservoir-influenced headwaters (18.5°C median at Lordville, NY), to warmer temperatures downstream (23.9°C median at Trenton, NJ).

In the tidal Delaware River, maximum daily water temperatures (2019-2023) recorded at USGS continuous monitors at Penn's Landing (formerly Ben Franklin Bridge) and Chester were compared to DRBC's zone specific day-of-year temperature criteria (Figure 30). Water temperatures rarely exceed zone-specific temperature criteria, as indicated by the fraction of total days in exceedance by month (over the five-year period) on Figure 30. It is apparent that in both zones, February-April account for most issues.

TRENDS

While Pennsylvania criteria for warm water fisheries are not applicable to the Delaware River at Trenton, comparing temperature data to those criteria demonstrates a typical compliance rate of around 80% of days in a year (Figure 31). No discernable trend in the number of "exceedances" per year is evident from the data. The water temperature at Trenton appears to be stable over the monitoring period of record and is expected to remain stable for the foreseeable future.

ACTIONS/NEEDS

The development of temperature criteria in the non-tidal portion of the Delaware River could help protect aquatic communities and allow meaningful interpretation of presently collected data. Consequently, additional research to improve understanding of drivers on non-tidal water temperatures is necessary (e.g., impacts from reservoirs and other human activities).

SUMMARY

Water temperatures in the non-tidal portion of the Basin are complicated by numerous factors, such as reservoir releases. Where temperature criteria exist (e.g., WQ Zones 3 and 4), the maximum daily temperature is within compliance around 96% of the time, with almost all exceedances occurring between February-April. For the purposes of this report, this indicator status is Good with a Neutral trend.

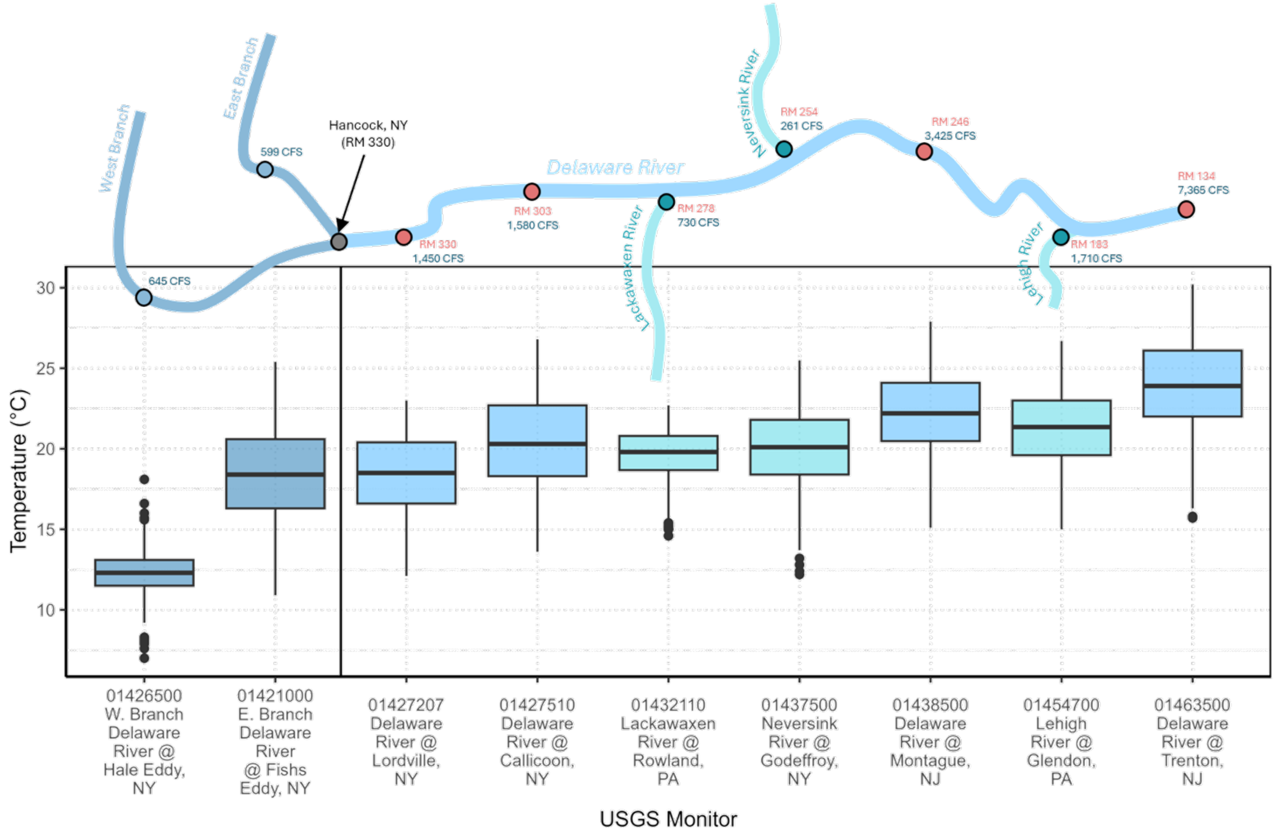


***Figure 29**: Summer water temperature (2019-2023) at various non-tidal USGS gages. The approximate river mile is indicated above the boxplot – for tributaries, this represents the point of confluence with the mainstem Delaware River. For additional context, the median summer flow (CFS) is provided over the same period for each gaging station.*

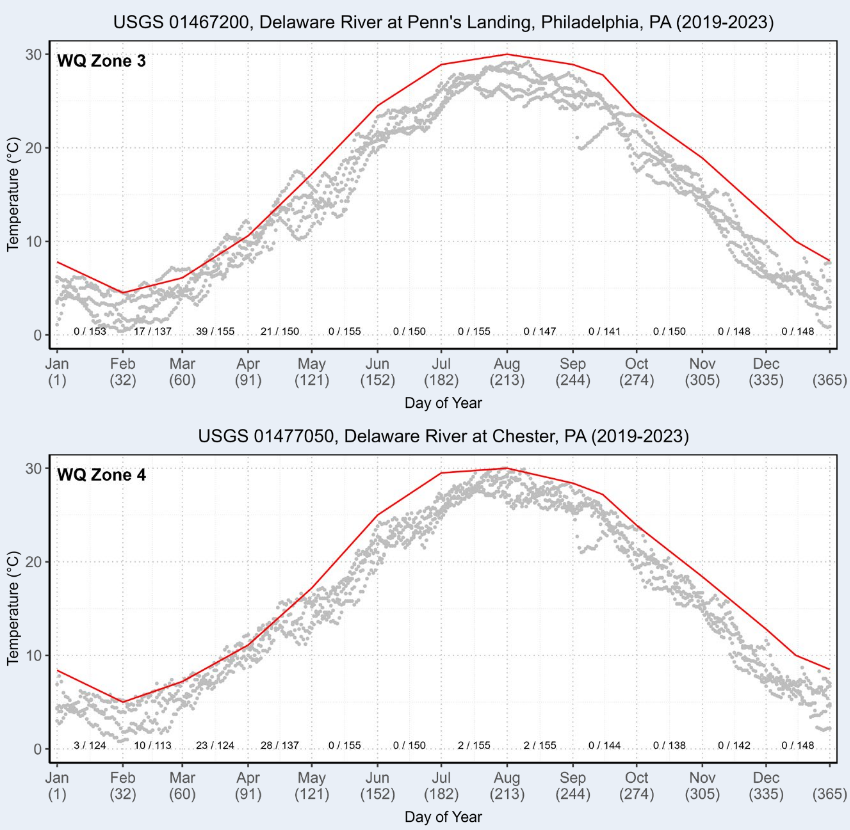


***Figure 30**: Daily values (maximum) temperature data for two USGS monitors in the Delaware River Estuary, as compared to the applicable DRBC's zone specific day-of-year temperature criteria (DRBC WQ Regs §4.30.6.C). The fraction of days within each month (over the five-year period) which exceed the respective temperature criteria are indicated.*

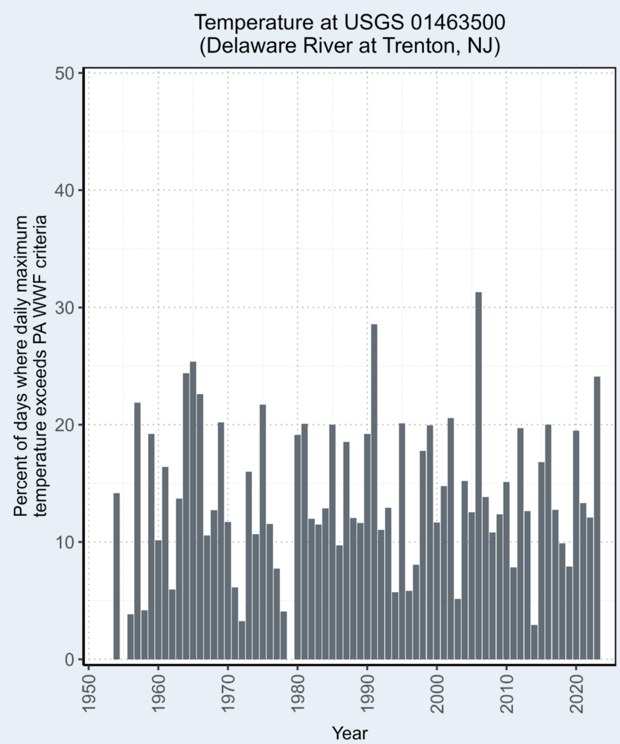


***Figure 31**: Assuming that the maximum daily temperature recorded at USGS 01463500 (Delaware River at Trenton, NJ) were to be compared to the Pennsylvania criteria for Warm Water Fisheries (WWF), this plot shows the percentage of days in a year which would "exceed" the WWF criteria. However, it should be noted that PA WWF criteria do not apply to the mainstem Delaware River, and that this analysis is a hypothetical scenario for illustrative purposes.*

Laboratory glassware.
Photo © Madamlead | Dreamstime

pH

DESCRIPTION

pH is the mathematical notation for the negative log of the hydrogen ion concentration (-log[H^+]) and indicates that conditions are either acidic (pH < 7), neutral (pH = 7), or basic (pH > 7). The pH of surface waters can be an important indicator of ecological function and productivity, and pH impacts the bioavailability and toxicity of pollutants such as metals and ammonia. Currently, DRBC criteria for the Delaware River and Estuary requires pH to be between 6.5 and 8.5.

PRESENT STATUS

- **In the Estuary**, monitoring of water quality parameters such as pH is recorded at multiple USGS continuous monitoring stations on the Delaware River. Box plots of discrete pH values measured at such stations from 2017 through 2023 are presented in Figure 32, compared to the minimum and maximum pH criteria in DRBC water quality standards. While the distributions differ by location, all values are within the DRBC criteria.
- **In non-tidal Basin waters**, data are restricted to summer months as aquatic plants undergoing active photosynthesis can absorb carbon dioxide out of the water which results in an increase of pH. Box plots of summer pH measurements from 2017 through 2023 are presented in Figure 32. It is notable that the different locations show different distributions in pH, but also that all locations exceed criteria on at least one occasion. Exceedances of the criteria are permissible when due to natural conditions, but more work is needed to evaluate what proportion of exceedances this accounts for.

TRENDS

Long-term trends of pH can be assessed for the non-tidal mainstem Delaware River using data from 1968-present (Delaware River at Trenton, USGS 01463500) and for the Estuary with data from 1967-present (Delaware River at Penn's Landing, USGS 01467200). No clear trend in pH has been determined at the Delaware River at Trenton in recent years. In the Estuary, data continue to demonstrate an increase in pH over the period of record at Penn's Landing, to the current levels shown in Figure 32. This phenomenon is likely linked to the gross pollution historically found in the urban corridor of the Estuary and the remarkable progress at eliminating some of this pollution over the past 40 years. In addition, this same period has seen the cessation of highly acidic industrial waste inputs to the Estuary, which may have also contributed to these trends.

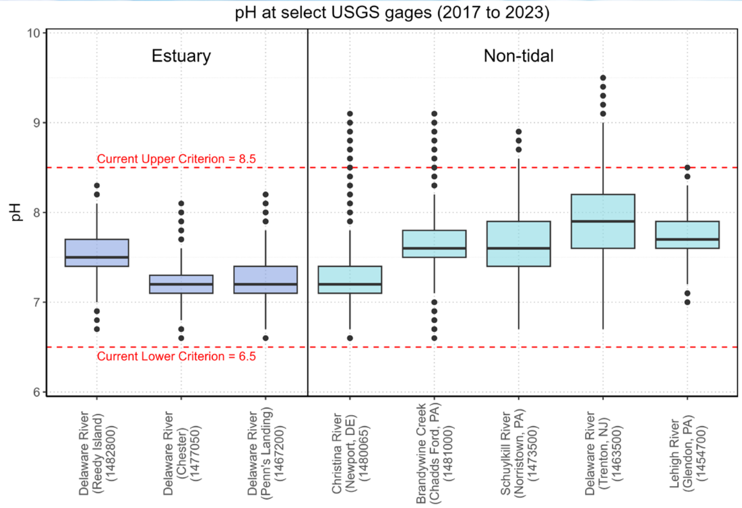


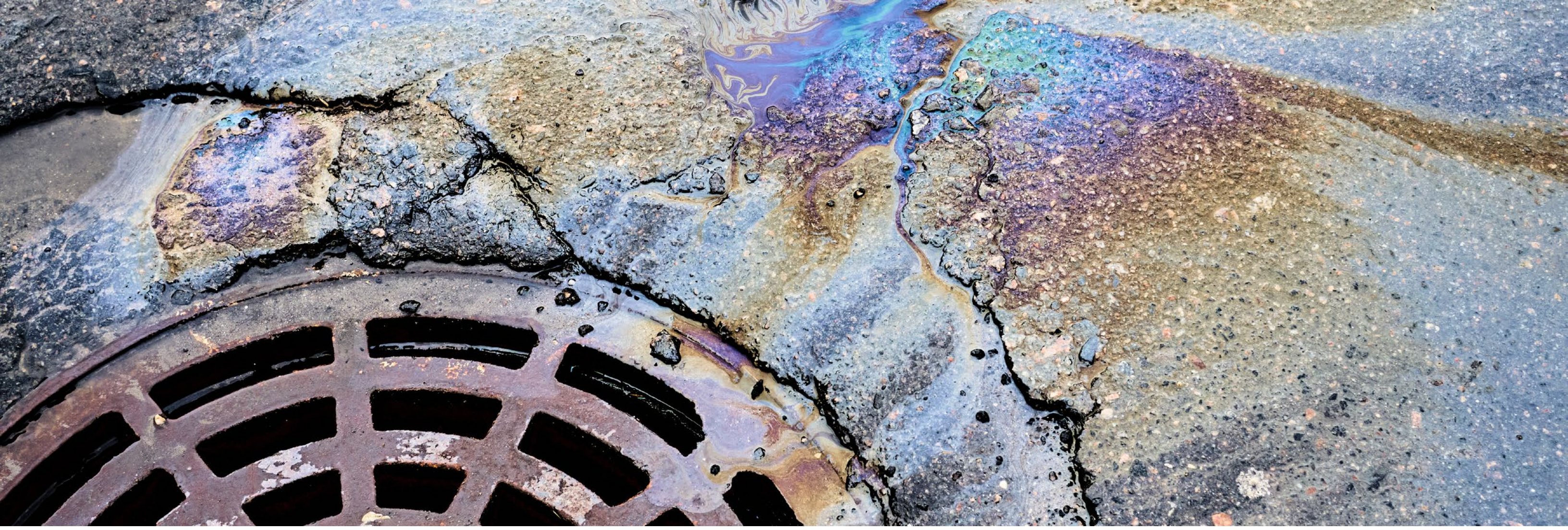
***Figure 32**: pH data for select USGS monitoring stations throughout the Delaware River Basin.*

ACTIONS/NEEDS

A better understanding of the Delaware River Estuary carbon cycle and its impact on pH is needed. While nutrients may play a role, pH excursions above 8.5 have been observed in the upper portion of the Delaware River, where nutrient concentrations are substantially lower and water quality generally reflects more pristine conditions. Further improvements to waste treatment in the urbanized portion of the Estuary could lead to further improvements in pH for those freshwater zones of the Estuary.

SUMMARY

The pH of surface waters has long been recognized as both a natural and human-induced constraint to the aquatic life of fresh and saltwater bodies, both through direct effects of pH and through indirect effects on the solubility, concentration, and ionic state of other important chemicals. For the purposes of this report, this indicator status is Good with a Neutral trend.



An example of pollution pathways of entry into the environment.
Photo © Aliaksandr Filimonau | Dreamstime

POLLUTANTS

DESCRIPTION

"Pollutants" are substances in the environment above background or natural concentrations that produce a negative, undesirable, and/or toxic effect. A pollutant's effect varies based on its properties in relation to various environmental parameters (temperature, pH, salinity, etc.) and the organism or ecosystem exposed. Water quality monitoring data from multiple organizations (DRBC, DNREC, NYSDEC, NJDEP, PADEP and USGS) are compared to stream quality objectives and a narrative standard to evaluate water quality impairments from pollutants. The narrative standard applicable to waters of the Basin requires that: "the waters shall be substantially free from… substances in concentrations or combinations which are toxic or harmful to human, animal, plant, or aquatic life."

PRESENT STATUS

The "2022 Delaware River and Bay Water Quality Assessment" offers insight into the extent to which the Delaware River and Bay are attaining designated uses (Report Link). This biennial report demonstrates instances where aluminum, copper, lead and zinc had exceedances of Aquatic Life Objectives (Report Table C2) in freshwater WQ Zone 1 of the Delaware River, while copper had the only exceedance in marine waters (WQ Zone 6). Regarding Human Health Objectives for systemic toxicants due to fish consumption, only methylmercury produced an exceedance in WQ Zone 1 (freshwater) and mercury in WQ Zone 6 (Delaware Bay, brackish to marine). Therefore, there is a need for further evaluation of these substances in the Delaware River.

TRENDS

Among the pollutants with water quality criteria in the Delaware River Basin, there are occasional exceedances for a few substances but no clear trend. However, there are consistent exceedances for aluminum and copper. Aluminum exceeded the chronic toxicity threshold (87 $\mu g\ L^{-1}$) in freshwater WQ Zones 1A, 1B, 1D, and 1E for nearly each instance reported in each Water Quality Assessment from 2012-2022. The chronic threshold was also consistently exceeded in estuarine WQ Zones 2, 3, 4 and 5, particularly from 2018-2022. However, previous reporting periods (2012, 2014, and 2016) did not always have data to assess aluminum exceedances, so the trend could extend further into the past. There were also many occurrences where aluminum exceeded the acute toxicity threshold (750 $\mu g\ L^{-1}$). Regular exceedance of the acute threshold occurred in WQ Zones 1E, 4 and 5 for 2018, 2020, and 2022 Water Quality Assessments. For copper, there were consistent exceedances in the 2016-2020 Water Quality Assessments in WQ Zones 1A, 1B, 1D, 1E and 5. However, copper exceedances were less common in the 2022 Assessment, indicating a possible improvement in copper concentrations that the next assessment may better evaluate.

ACTIONS/NEEDS

DRBC has water quality criteria for many substances. However, as can be seen in DRBC's biennial Water Quality Assessment, many are not consistently monitored in all WQ Zones of the Delaware River to make a broad assessment of their status related to water quality criteria. For those monitored frequently, there were only a few exceedances (other than aluminum and copper). This generally indicates that most water quality criteria parameters are below toxicity thresholds. In the future, DRBC will assess pollutants that are not regularly monitored to establish a rotational sampling plan to ensure they are better accounted for in the biennial Water Quality Assessments. For copper and aluminum, their source is unknown and could be from anthropogenic or natural sources. DRBC will investigate their presence and attempt to identify sources of these metals so that, if possible, they can be better managed.

SUMMARY

DRBC regularly monitors pollutants in the Delaware River, and exceedances of water quality are the exception rather than the norm. However, not all parameters are consistently monitored. The exceedances that did occur are typically related to metals in WQ Zone 1 (non-tidal waters), where there is less human influence on water quality. The source of metal exceedances in WQ Zone 1 is unknown. DRBC is developing a plan to monitor water pollutants on a rotational basis in the mainstem Delaware River. For the purposes of this report, this indicator status is Fair with a Neutral trend.

Pipette and test tubes.
Photo © Oleg Dudko | Dreamstime

EMERGING CONTAMINANTS

DESCRIPTION

Contaminants of emerging concern (CECs) are a broad term for chemicals in a gray area between a contaminant and a pollutant. These are overwhelmingly human-made chemicals detected in the environment and therefore meet the threshold to be called a contaminant (above natural background concentrations) but have not yet been studied enough to know if they would meet the threshold of a pollutant (above natural background concentrations and has a known harm). CEC trends ebb and flow as new compounds and materials are discovered in the environment. CECs which have received a lot of attention in the past include polybrominated diphenyl ethers (PBDEs), as well as pharmaceuticals and personal care products; these compounds have all been heavily studied and the scenarios where they may cause harm are more well-known than in the past. The current CEC focus in the Delaware River Basin is on microplastics, PFAS (Per and polyfluoroalkyl substances), and 6-PPDq (N-(1,3-Dimethylbutyl)-N′-phenyl-p-phenylenediamine quinone). Microplastics are discussed in the next report section (MICROPLASTICS). PFAS are a broad group of chemicals (>15,000) with properties ideal for use in countless consumer and industrial products. Their broad application, ubiquitous environmental presence, and PBT properties (persistent, bioaccumulative, toxic) make them particularly problematic for organismal, ecosystem, and human health. 6-PPDq was a relatively unknown chemical until a groundbreaking study in 2021 that directly tied the chemical to acute deaths of coho salmon during rainfall-runoff events in the Pacific Northwest. It has since been found to be toxic to other salmonids, including several trout species.

PRESENT STATUS

DRBC and other state and federal agencies are actively monitoring PFAS in water, sediment and fish of the Delaware River Basin. There are ~20 years of publicly available data that DRBC is working through to assess long-term trends in their environmental presence and accumulation in aquatic species. Various PFAS compounds (out of the >15,000) have been quantified in the Basin's water, sediment, and fish. Water concentrations generally increase as water moves from upstream (more pristine) through population-dense and industrialized areas to the Delaware Bay (Figure 33). Sediment concentrations vary across sites DRBC has sampled, with no trend observed as water moves downstream. This may be due to the physicochemical properties of compounds found in sediment and each site’s proximity to a source. Fish concentrations also vary across sites and species. There is also a “Do Not Eat” fish consumption advisory in the Neshaminy Creek due to a specific PFAS, Perfluorooctane Sulfonate (PFOS), found above safe human consumption levels.

For 6-PPDq, DRBC is conducting baseline studies of the chemical in suitable trout habitat streams and the mainstem Delaware River. Final data were not available at the time of this report. Still, preliminary analysis found the chemical in several trout streams and the mainstem Delaware River during normal flow conditions at concentrations from non-detect to ~3 ng L^{-1}. In a single rain event, concentrations at one stream spiked to ~150 ng L^{-1}. When quantified, the concentrations are at levels considered toxic to coho salmon which do not live in the Basin (40 - 95 ng L^{-1}) but are below acute toxicity thresholds for brook trout (510 ng L^{-1}) and rainbow trout (650 – 2260 ng L^{-1}). However, there are sparse data on chronic or sub-lethal effects of 6-PPDq on trout behavior, feeding, predation, and reproduction. Impacts on species outside of the salmonid family are unknown. Therefore, more research is needed to determine the potential influence of this chemical on aquatic species of the Delaware River Basin.

TRENDS

Assessing trends in Emerging Contaminants is difficult, as our collective focus often moves from one set of compounds to the next. However, PFAS are a group of chemicals woven into industrial processes and consumer products. They have been and will be in use for decades, and their long-term persistence and environmental impact will be a concern indefinitely. After a decade-plus of growing interest, the global PFAS research infrastructure is maturing. This will enable the types of complex, systematic studies needed to fully quantify the presence and negative impacts of this diverse group of chemicals in the environment and on human health. DRBC is leading these efforts in the Delaware River Basin and is assessing PFAS trends using our 20 years of data.

For 6-PPDq, the scientific community is only beginning to quantify its effects on aquatic and ecosystem health. Field studies are examining environmental concentrations, while toxicologists are beginning to tease out the lethal and sub-lethal effects on organisms. At the regulatory level, multiple states have made efforts to force manufacturers to find suitable alternatives for the use of 6-PPD (which reacts with oxygen or ozone to become 6-PPDq). These efforts could take years but are a positive first step at such an early stage in our understanding of this chemical, and they speak to the harm caused by 6-PPDq in aquatic ecosystems.

ACTIONS/NEEDS

For PFAS, DRBC is developing a PFAS roadmap that will guide our efforts to protect water quality and quantity in the Delaware River Basin. This will involve analyzing the past ~20 years of data we have collected and other publicly available data from the Basin to assess PFAS presence, trends, and hot spots. The synthesis of these data will inform our future research and monitoring actions as we help to protect water resources.

For 6-PPDq, DRBC will continue its ongoing baseline studies and use them to focus any future efforts on this chemical. The results of these efforts will be shared with communities in the Basin as they work to preserve and protect their delicate trout habitat.

SUMMARY

DRBC proactively monitors emerging contaminants in the Basin, often long before any water quality criteria are developed. Current efforts are focusing on 6-PPDq and PFAS. Preliminary work shows that 6-PPDq is in the Basin, but given current knowledge about its effects, concentrations observed are below known acute toxicity thresholds for the Basin's trout species. For PFAS, DRBC has documented its presence in the Basin for ~20 years and is synthesizing this information to determine trends and to reduce PFAS presence and impacts throughout the Delaware River Basin. For the purposes of this report, this indicator status is Fair, but does not indicate a trend, as is the nature of a field of emerging science.

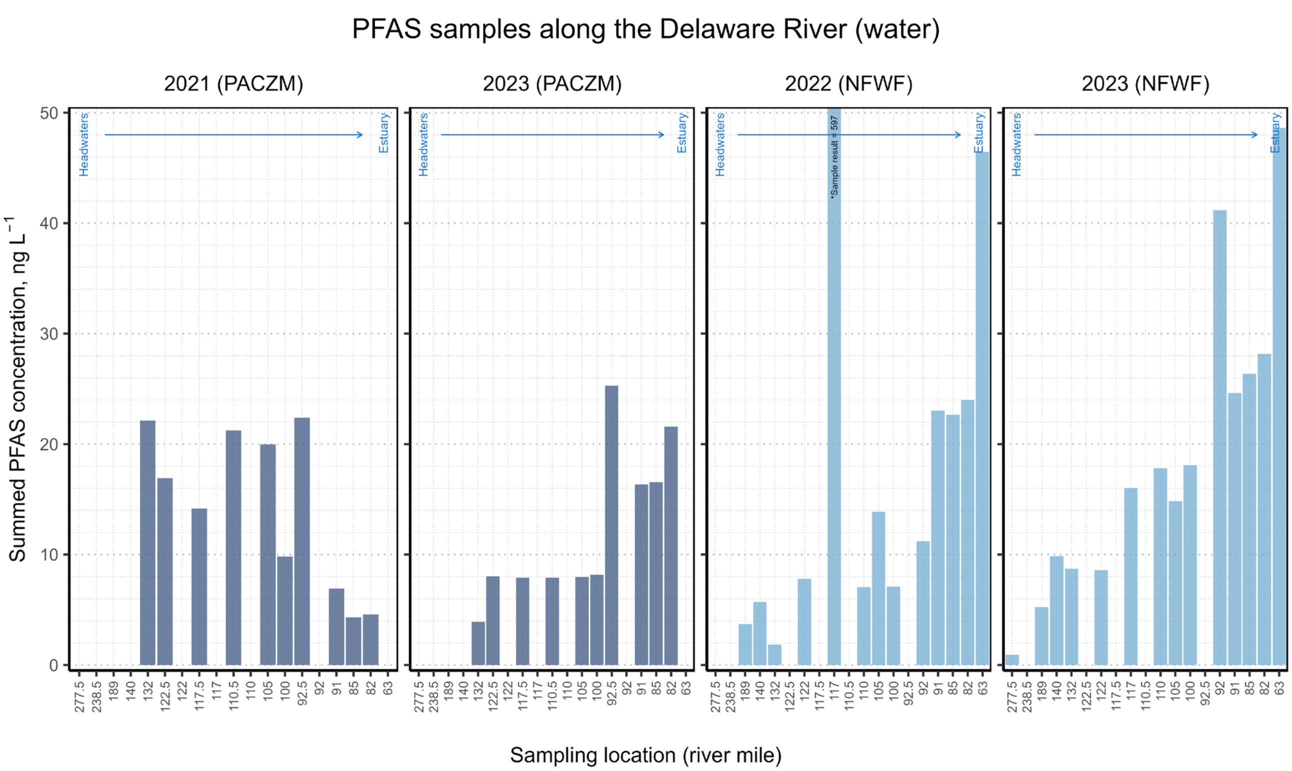


Figure 33*: Summed concentrations of PFAS (USEPA Method 1633, targeting 40 PFAS compounds) detected in mainstem Delaware River water samples collected during 4 studies from 2021-2023. NFWF = National Fish and Wildlife Foundation; PACZM = PA Coastal Zone Management.*

Large plastic debris can degrade into microplastics.
Photo © Panadda Phromngoi | Dreamstime

MICROPLASTICS

DESCRIPTION

Plastic is perhaps the most prevalent type of debris found in our oceans, rivers, and large lakes (NOAA 2016). Plastic debris comes in all shapes and sizes, but those that are less than 5 mm in length (or about the size of a sesame seed) are called microplastics. These tiny particles easily pass through water filtration systems and end up in receiving waters, with the potential to negatively impact the health of humans and animals. Over time, larger plastics degrade into microplastics, but microplastics also include man-made products such as the following:

1. Microbeads, found in cosmetics and personal care products
2. Industrial scrubbers used for abrasive blast cleaning
3. Resin pellets used in the plastic manufacturing process
4. Microfibers, generated from washing synthetic clothing

PRESENT STATUS

Data on microplastics and their effects on fish and wildlife in the Delaware River Basin are sparse. Several research groups have initiated studies on microplastics in recent years. The University of Delaware has examined microplastics in the Delaware Bay (Cohen et al. 2019) and the USGS has explored microplastics in the non-tidal Delaware (Baldwin et al. 2021). In 2018, DRBC received a grant to collect baseline information on microplastics concentrations in the upper Estuary (Figure 34). This reach of the Delaware River is largely urbanized and is likely a major contributor to microplastic loading in the Estuary. This study, along with others, found microplastics to be widespread in surface waters of the Basin.

TRENDS

As a contaminant of emerging concern, it is difficult to determine trends in microplastic concentrations. Most studies have been initiated and completed in the past five years; therefore, continued monitoring will be essential to assess long-term trends in microplastic pollution. Theoretically, actions that have taken place like single-use plastic bans should help reduce microplastics in the Basin, but additional monitoring will need to occur to determine the success of these actions.

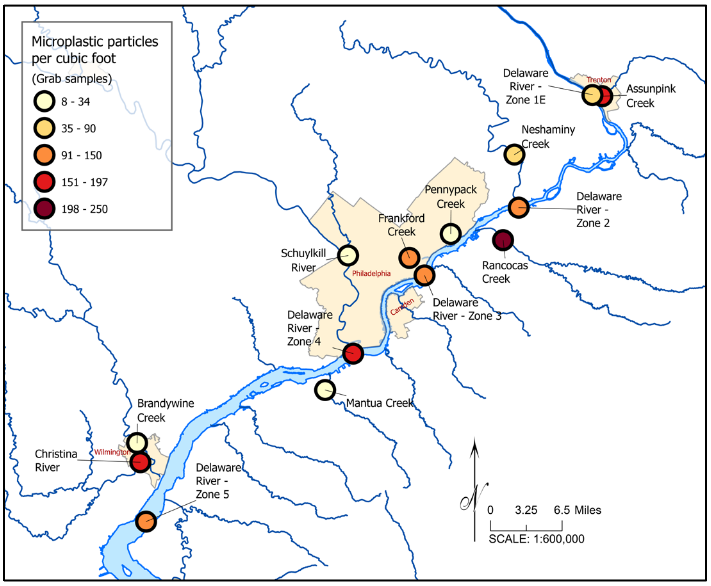


***Figure 34**: To investigate microplastics in the upper Delaware River Estuary, DRBC collected grab samples at nine tributary locations and five mainstem locations in August 2019 (Bransky and Chen 2022).*

ACTIONS/NEEDS

Understanding microplastic loading into the Delaware River Basin is a vital first step towards understanding the potential problems posed by this contaminant of emerging concern. Additional work is necessary to synthesize results between various studies that have been completed in the Basin and to begin tracking microplastics back to their source. Microplastic studies can also help concentrate plastic cleanup efforts. DRBC used its study results to select locations in the Estuary where it has held trash pick-up events to remove plastic pollution from the shorelines before it re-enters the Delaware River and degrades into microplastics.

SUMMARY

Plastics in the aquatic environment are of increasing concern because of their persistence and potential effect on the environment, wildlife, and human health. Even with several studies focused on microplastics completed within the Delaware River Basin, the effects of these microplastics are still understudied. This report proposes an initial status of Poor, and a Neutral trend (based on the need for additional research).

An example harmful algal bloom.
Photo © Andrii Shablovskyi | Dreamstime

HABs (Harmful Algal Blooms)

DESCRIPTION

Algae are simple, plant-like organisms in aquatic ecosystems that produce food through photosynthesis, forming the base of food webs. However, harmful algal blooms (HABs) occur when colonies of toxin-producing algae rapidly grow due to high nutrient levels, often from agricultural runoff or wastewater, warmer temperatures, and other factors (USEPA 2024b). These blooms can release toxins (including skin, nerve, and liver toxins) that can cause public health concerns by contaminating drinking water sources (Bukaveckas et al. 2018), or by becoming airborne leading to respiratory concerns (Lim et al. 2023). In freshwater, cyanobacteria (photosynthetic bacteria) are usually responsible for HABs, while in marine environments, dinoflagellates and diatoms are the main culprits (USEPA 2024b).

PRESENT STATUS

State agencies, the USEPA, and other organizations monitor, identify, and issue advisories for water bodies impacted by HABs. Lakes, ponds, beaches, and reservoirs within the Delaware River Basin are regularly monitored, and advisories are posted when HABs are identified. These toxic algal blooms typically occur in still or slow-moving waters; however, research in flowing waters, such as rivers, is less common (Bukaveckas et al. 2018). Some examples of current monitoring/control efforts include:

- **Pennsylvania** formed a PA HABs Task Force, which includes representatives from seven state agencies. Additionally, an interactive dashboard has been developed with HAB-related water sampling data from 2018 to present (Link).
- **New Jersey** implemented a Cyanobacterial HAB Freshwater Recreational Response Strategy in 2017 to provide a unified statewide approach for HABs response. Observations of HABs can be reported to NJDEP online (Link), and current HAB sampling status viewed via online map (Link).
- **Delaware** DNREC monitors for and has a list of posted water bodies affected by HABs (Link); additional monitoring primarily along the Atlantic Coast is performed by the University of Delaware's Citizen Monitoring Program (Link).
- **New York** DEC has routinely monitored for HABS since 2012, has created numerous specific HAB action plans (Link) and maintains an updated interactive web map which shows that even the Basin's headwaters are not immune to HABs (Link).

In 2023, the DRBC completed a two-year study to passively sample cyanobacterial toxins in the Delaware River and Estuary (Link to data), with results indicating the presence of microcystin, a cyanobacterial toxin commonly found in freshwater systems (Graham et al. 2020). These monitoring efforts are vital for early detection and management of HABs to protect public health, aquatic ecosystems, and local economies.

TRENDS

The frequency and severity of HABs are increasing globally, driven by factors such as rising temperatures due to climate change and increased nutrient runoff from urban and agricultural areas (Larsen et al. 2020; Anderson et al. 2021; Griffith and Gobler 2020). The only Basin-relevant quantitative analysis on HAB trends is from NJDEP, indicating that as of 2022, the number of water bodies in New Jersey with confirmed HAB occurrences has increased about 38% since 2017 (Poretti et al. 2023).

ACTIONS/NEEDS

Further research is needed to understand the mechanisms driving HAB formation, toxin transport, and bioaccumulation in the food web (Graham et al. 2020). For the Basin, advancing these efforts is essential for safeguarding public health and the environment, enabling effective management and timely advisories within the Basin.

SUMMARY

While many forms of algae are harmless and play crucial roles in the environment, some specific species are toxin-producing with the ability to grow unchecked, forming harmful algal blooms. All Basin-states have monitoring programs in place, although it is clear that additional research is needed. This report proposes an initial status of Fair, and a Neutral trend (largely based on the current prevalence, but strong need for additional research).

Chapter 5

LIVING RESOURCES

A beaver swimming in Quakertown, Pennsylvania.
Photo by A. McCarty | iNaturalist

Atlantic sturgeon swimming underwater.
Photo by Ryan Hagerty (U. S. Fish and Wildlife Service)

ATLANTIC STURGEON

DESCRIPTION

Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*, may live to 60 years, reach lengths of 14 feet, and weigh over 800 pounds. Mature Atlantic sturgeon are anadromous, returning to spawn in fresh water rivers. Juveniles will remain in natal estuaries for several years before migrating to the ocean. They are distributed along the Atlantic Coast from Canada to Florida, and historically ranged into Europe before extirpation (Elvira et al. 2015). There are five distinct population segments (DPS) in U.S. waters, including the "New York Bight", which includes Atlantic sturgeon living and spawning within the Delaware River and Estuary. A coastwide moratorium on the harvest of Atlantic sturgeon was put in place in 1998 (ASMFC 1998a). In 2012, all population segments were listed as endangered or threatened under the Endangered Species Act (Link). In 2017, Critical Habitat was designated within the Delaware River Basin (50 CFR Part 226).

PRESENT STATUS

Historically, the Delaware River supported the largest Atlantic sturgeon population in the United States. Factors such as commercial fishing, degraded water quality and ship strikes have all contributed to a declining population. According to Kahn and Park 2022, two data indices assess the health of the population:

1. **Primary data index**: the DNREC Division of Fish and Wildlife (DDFW) performs a sturgeon-specific gill net survey which is intended to monitor the annual production of young sturgeon in the Delaware River (Figure 35A). The data indicate the number of fish caught per hour per square meter of gill net. It is highlighted in Kahn and Park 2022 that the survey has been conducted with similar effort since 2014, and that higher abundance was observed in 2014 and 2018. Additionally, that the U. S. Army Corps of Engineers performed a sturgeon relocation project in 2016 which likely affected the survey results.
2. **Secondary data index**: the DDFW performs an Adult Groundfish Research Trawl, which for sturgeon, serves as a relative abundance index of larger juvenile and some adult sturgeon (Figure 35B). Recent data have shown a consistent increasing trend in sub-adults. While it is possible that some sturgeon are from other spawning stocks (as sturgeon are known to travel the Atlantic Coast entering various estuaries), the increased sub-adult catch in 2021 is noted to have correlated with the higher 2018 primary index value, as many sub-adult sturgeon caught in 2021 were estimated to be around three years old.

Beyond the two indices, other notable highlights include:

- DDFW implements a tagging program using acoustic sensors to track sturgeon using a hydrophone or using a passive network of receivers. A tag-recapture study in 2014 estimated total abundance of juvenile sturgeon of ages 0-1 years to be 3,656 (95% CI: 1,935-33,041) juvenile Atlantic sturgeon within the Delaware River (Hale et al. 2016); abundance in 2018 was estimated to be 5,846 (95 CI = 2,394-14,446) (Park 2020).
- White et al. 2023 analyzed the genetics of juvenile sturgeon captured by DDFW to determine the number of adults needed to produce each cohort of offspring. The estimated

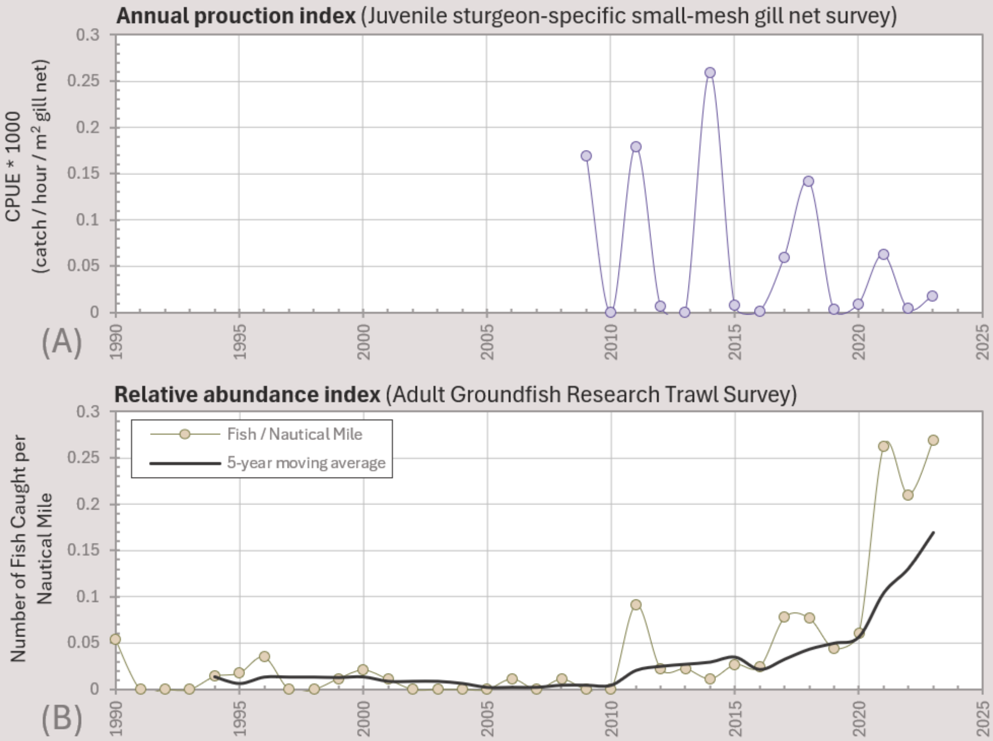


***Figure 35**: **(A)** Relative abundance trend of age 0 Atlantic sturgeon in the Delaware River, based on the DDFW sturgeon-specific gill net survey. The indices are the catch per unit effort in small mesh gill-nets set in the tidal Delaware River. **(B)** Relative abundance trend of older juvenile and adult Atlantic sturgeon based on results of the Adult Groundfish Research Trawl. The black line indicates a 5-year moving average of the annual data.*

Fishing for science

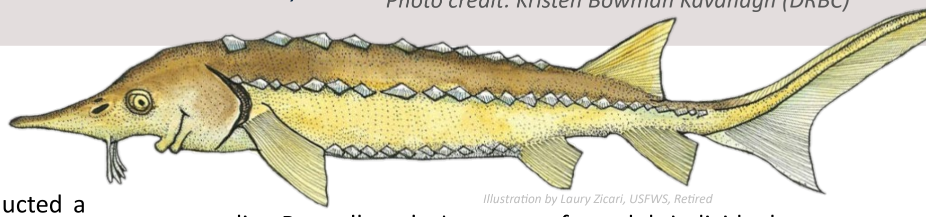
DRBC's Jake Bransky with an Atlantic sturgeon collected during DNREC's juvenile Atlantic sturgeon survey. The survey is conducted using small mesh gill nets, targeting fish hatched within the past two years; the number of fish caught are used to estimate population sizes for the young year classes. This activity was conducted under a NOAA National Marine Fisheries Service ESA Permit No. 19255-01, issued to Ian Park, Fisheries Biologist, DNREC Division of Fish and Wildlife. Photo credit: Kristen Bowman Kavanagh (DRBC)

number of successfully spawning adults each year ranged from 125 to 250 between 2009 and 2019.

- The National Marine Fisheries Service (NMFS) conducted a five-year review for the New York Bight DPS of Atlantic sturgeon. The review recommended no change to the current "endangered" status (NMFS 2022).

TRENDS

- The Atlantic States Marine Fisheries Commission (ASMFC) 2024 stock assessment update used nine surveys to develop indices of abundance. Most individual indices had no trend or were slightly increasing; the combined coastwide index suggest steady increases since 2013 (ASMFC 2024c).
- The NMFS 2022 five-year review stated, "The status of the DPS has likely neither improved nor declined from what it was when the DPS was listed in 2012."
- White et al. 2023 estimated higher numbers of adult sturgeon spawned in the Delaware River from 2015 to 2019 than from 2009-2014.
- Despite challenges in data availability for trend analysis, DDFW has documented successful sturgeon reproduction in recent years which could result in stock growth in the Delaware River.
- There has been a recent increase in reported sturgeon carcasses attributed to vessel strikes; however, it is unclear if this is a result of increased reporting awareness, or increased mortality. Regardless, losing even a few adult individuals per year can have impacts on population recovery.



- Dissolved oxygen levels in nursery areas of the Delaware River and Estuary can play a critical role in the survival rate and/or growth rate of young sturgeon. This concept is complex and has many implications, some of which are discussed in Kahn and Park 2022. Additional information on recent developments related to dissolved oxygen in the Delaware River and Estuary is presented in DISSOLVED OXYGEN.

ACTIONS/NEEDS

Some recommended actions include (1) continue monitoring abundance to support model development, (2) continue telemetry studies to better understand behavior and habitat use, and (3) expand study of ship strikes and collaboration with the shipping industry to minimize population impacts.

SUMMARY

The Delaware River spawning stock, once the largest population on the Atlantic coast, was declared endangered in 2012. Mortality from shipping traffic strikes, impaired habitat and water quality all threaten current populations. While recent Basin-specific surveys have indicated recent spawning success, additional research is needed for future predictions on species recovery. The status remains at Poor but Improving.

A typical white perch found on tidal creeks and rivers in the New Jersey, Delaware Bay region.
Photo © Matt Broderick

WHITE PERCH

DESCRIPTION

White perch, *Morone americana*, are one of the most abundant and likely widespread fish in the Delaware River Estuary, making them an important ecological indicator. The species is tolerant of a wide range of water temperatures and salinities, thriving from inland freshwater lakes to brackish tidal waters. In spring, white perch in the Estuary move to tidal tributaries to spawn and then overwinter in the deeper waters of the Estuary. White perch support local recreational and commercial fisheries and have routinely been among the top five finfish species landed commercially in Delaware. White perch were among the top ten fish species harvested recreationally in Delaware annually since 2000; however, there are several consumption advisories for white perch in the Estuary (DNREC 2018; NJDEP 2021).

PRESENT STATUS

White perch are not managed by the Atlantic States Marine Fisheries Commission, and therefore research on population sustainability is slightly more limited than some other fish indicators in this report. To assess the status of white perch, a few sources of data may be referenced:

1. The NJDEP Fish and Wildlife (NJDEP FW) recruitment survey collects data which can be used to estimate an index for the young-of-year (YOY), which is assumed to correlate with the number of recruits into the fishery several years later; data provided as Figure 36A. The most recent YOY estimates (2022/2023) have fallen below the timeseries mean, although the 5-year average is almost equal to the timeseries mean.
2. The DNREC Division of Fish and Wildlife (DDFW) perform an Adult Groundfish Research Trawl Survey, using a 30-foot otter trawl net at nine fixed locations in the Delaware Bay, which can be used to gain an understanding of relative abundance; data provided as Figure 36B. Recent data share a similar trend as observed in the YOY index, where recent years are below the long-term mean, although the 5-year average is almost equal to the timeseries mean.
3. Commercial white perch landings data collected by DDFW provide good insight into the commercial fishery's ability to capitalize on the relative abundance (Figure 37A). From personal communication with DDFW, statewide commercial landings of white perch are largely attributed to harvests from the Delaware Bay and River – adding to the importance of this dataset for assessments of Delaware River Basin populations. Additionally, the total landings can be normalized by the corresponding total number of fishing vessel trips to calculate an index of "commercial harvest effort" (Figure 37B).

TRENDS

From the indices in Figure 36, populations of white perch appear to be maintaining themselves within the Estuary. There is the possibility that a slight declining trend exists for both indices in Figure 36; however, a more prominent downward trend may exist for the total abundance index since 2010. Notably, white perch typically spawn in areas of the Delaware River and in the upper reaches of the Estuary tidal tributaries which have experienced intense development in the past 60 years (Clark 2022), although this has not been proven as a factor driving trends in white perch indices.

A sharp decline in commercial landings of white perch is observable since a peak around 2010 (Figure 37A), possibly coinciding with the downward trend in the relative abundance index. Hypotheses on whether this decline is due to a lack of fishing effort or market conditions appear to be ruled out by a similar decline in the commercial effort index, suggesting that the total landings decline is more likely related to poor fishing conditions (or changes in gear being used, as that is not accounted for in the calculation of pounds/trip).

ACTIONS/NEEDS

Delaware established an 8-inch minimum size limit for white perch in 1995, which has been effective in allowing white perch to spawn at least once before being recruited into the fishery. Neither Pennsylvania nor New Jersey have size limits for white perch in the Estuary and Bay, and it has been suggested that a consistent 8-inch minimum size limit across the Estuary and Bay would be beneficial to the population resilience (Clark 2022). Additional research focused on estimating total abundance within the Estuary and Bay would help support management decisions.

SUMMARY

White perch are tolerant of a variety of environmental conditions and are widespread throughout the Delaware River Basin. White perch have been historically abundant and the population within the Estuary seems to be maintaining itself, although it is possible that slight declining trends in YOY and total abundance exist. Basic management practices may help ensure the population continues to thrive. Based on the data available presented in this report, this indicator retains a status of Very Good, but changes the trend from the prior report to be Declining.

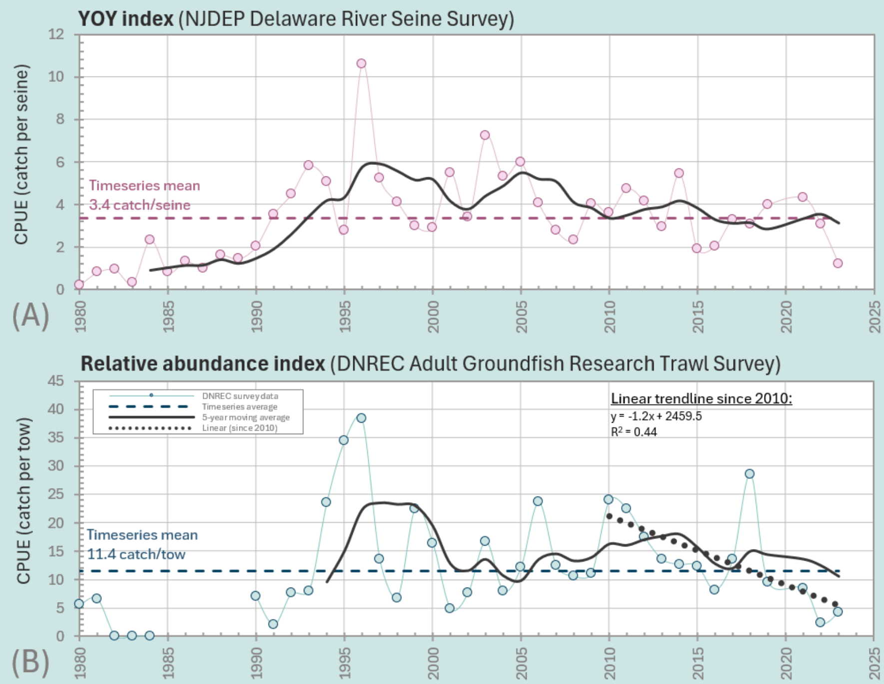


***Figure 36**: **(A)** A young-of-year index for white perch, calculated from the NJDEP recruitment survey which uses seine haul sampling techniques (currently at 32 fixed beaches in the Delaware River / Estuary). **(B)** An index of relative abundance calculated from DDFW's Adult Groundfish Research Trawl Survey results.*

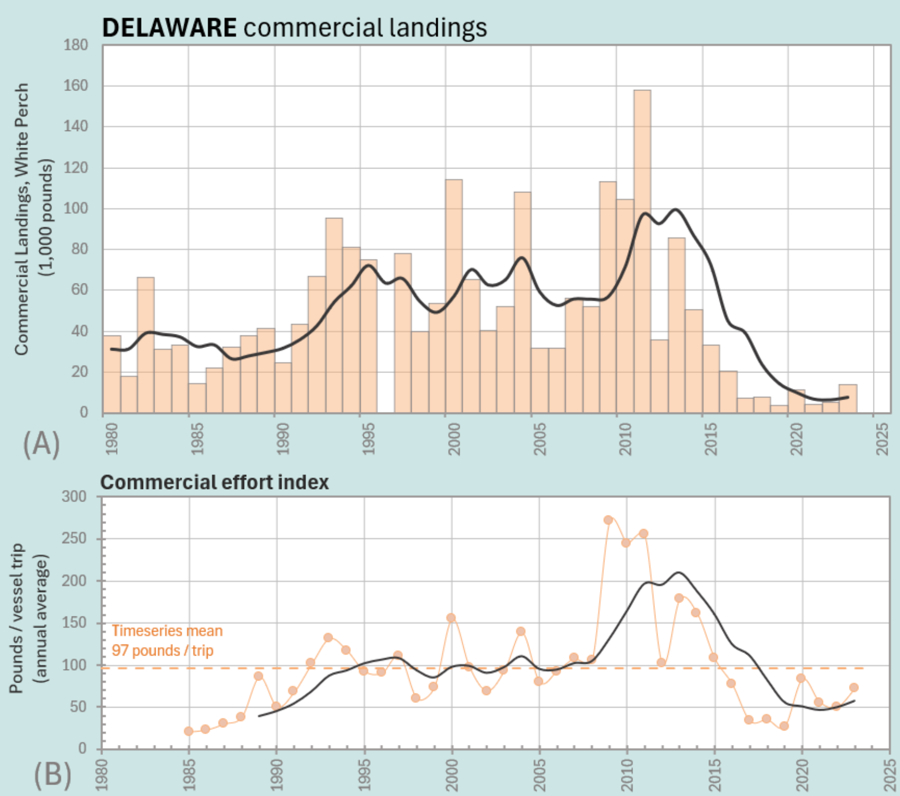


***Figure 37**: **(A)** Total commercial landings of white perch reported to DDFW; note that most commercial landings are from the Delaware Bay and Delaware River. **(B)** The same commercial data normalized by the number of commercial fishing "vessel trips" per year, to create a sort of "commercial fishing index".*

Striped bass swimming underwater
Photo by Ryan Hagerty (U. S. Fish and Wildlife Service)

STRIPED BASS

DESCRIPTION

Striped bass, *Morone saxatilis*, are large, predatory fish with dark horizontal stripes extending along their flanks. Depending upon age and the time of year, striped bass will inhabit a wide variety of environments including tidal creeks, rivers, jetties, reefs and relatively open water in the Delaware Bay and River. Mature females spawn in the tidal freshwater portion of the Delaware River prior to migrating up the Atlantic Coast annually, while many males remain in the Estuary or nearby ocean waters year-round. Young bass feed primarily on small invertebrates (e.g., insects, worms). As they mature, they will eventually feed on small pelagic fish (e.g., anchovies, river herring) and larger invertebrates (e.g., blue crab). The stiped bass fishery is largely recreational which accounted for approximately 90% of removals in 2022 (across the Atlantic Coast); a commercial fishery exists in Delaware but is prohibited in New Jersey.

PRESENT STATUS

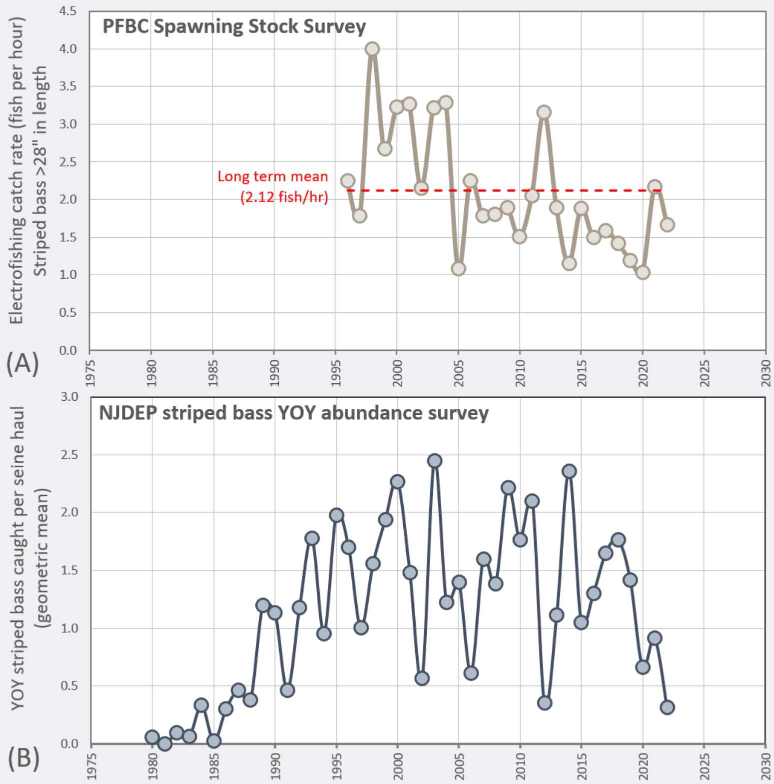
The striped bass population within the Delaware River was at one point thought to be extirpated by some biologists, prior to improvements of dissolved oxygen in the 1980s (see DISSOLVED OXYGEN). Today, the Delaware River population is one of the major spawning stocks on the Atlantic Coast, along with the Hudson River and Chesapeake Bay stocks. In fact, a recent study by the University of New Hampshire estimated that the Chesapeake Bay and Delaware River spawning stocks contribute an estimated 80-88% of striped bass to the Atlantic fishery (Kovach et al. 2024).

Pertaining to ASMFC action: Management of the Atlantic striped bass fishery has an extensive history, dating back to the initial interstate fisheries management plan (FMP) of 1981 (ASMFC 2023c). More recently in 2019, ASMFC published the 2018 stock assessment which found that the 2017 striped bass population had been overfished since 2013, and were still experiencing overfishing (ASMFC 2019b). This resulted in:

1. (2019) ASMFC Addendum VI to FMP Amendment 6 reduced all state commercial quotas by 18%, required circle hooks for recreational bait fishing, and enhanced ocean recreational harvest restrictions (1 fish bag limit, 28”-35” slot limit).
2. (2022) ASMFC adopted FMP Amendment 7 adjusted the management program in order to rebuild the spawning stock biomass (SSB) to target levels by 2029 (ASMFC 2022b).

The 2022 stock assessment concluded that in 2021, the fishery was still overfished but no longer experiencing overfishing, and modelled the probability of rebuilding SSB by 2029 (SSB-2029) at a 97% chance (ASMFC 2023a). However, ASMFC models were updated in 2023 to include harvest data from 2022 which consequently updated the SSB-2029 probability to only 15% (ASMFC 2024b). This led to ASMFC adopting:

1. (2023) Temporary Emergency Action requiring all states to implement a 31” maximum recreational size limit.
2. (2024) Adoption of FMP Amendment 7 Addendum II implementing additional management measures, but also allowing for ASMFC to change management actions via board action rather than FMP addendum, if the modelled SSB-2029 is below 50% (ASMFC 2024b).



Catching new data

Pennsylvania Fish & Boat Commission (PFBC) staff hold two large striped bass from the Delaware Estuary. The PFBC uses electrofishing techniques to conduct adult striped bass sampling at 21 index sites between the mouth of Rancocas Creek, NJ (RM 109) and the mouth of Raccoon Creek, NJ (RM 80). In addition to helping assess population metrics, many fish are tagged as part of a multi-state, coastwide effort. Between 1995 and 2020 the PFBC tagged 5,670 striped bass in the Delaware River Estuary. As of 2021, approximately 16% of those had been reported as caught—primarily in New Jersey, Pennsylvania, Delaware and Maryland, but also as far north as Maine and as far south as North Carolina. Photo credit: (Grabowski and Porta 2022)

***Figure 38**: **(A)** The Pennsylvania Fish and Boat Commission adult striped bass spawning stock survey data show catch rates for Striped Bass over 28" in length which are typically mature females and comprise most of the spawning stock biomass (Grabowski and Porta 2022). **(B)** The NJDEP Bureau of Marine Fisheries annually performs the Delaware River Striped Bass Recruitment Seine Survey to estimate the abundance of juvenile striped bass (currently at 32 fixed beaches). Juvenile striped bass remain in the Estuary for several years before returning to the ocean to join the coastal population; estimating YOY abundance helps understand adult abundance in future years.*

In the Delaware River Basin, each Basin state has made their own responses to ASMFC management actions and creel limit information can be found online. Additionally, two surveys help measure the relative health of the striped bass population:

1. Pennsylvania Fish and Boat Commission (PFBC) performs an annual spawning stock survey of striped bass in the Delaware River Estuary via electrofishing to estimate the spawning population (Grabowski and Porta 2022). Figure 38A shows a generally declining catch rate of striped bass larger than 28 inches (which are typically mature females that comprise the SSB). Although 2021/2022 catch rates are below the long-term average, they do seemingly reverse a steep downward trend.
2. NJDEP Fish and Wildlife (NJDEP FW) performs a recruitment survey using a seine haul to measure the annual average reproductive output of the stock. A large young-of-year (YOY) abundance often results in a greater number of recruits into the fishery several years later (Figure 38B). There has been a seemingly declining trend since about 2015, consistent with findings from PFBC's surveying.

TRENDS

Low dissolved oxygen in the Estuary downstream of Philadelphia greatly impacted the Delaware River spawning stock in the mid-twentieth century. Improvements to water quality following the creation of the DRBC, the Clean Water Act and a conservative fishery management regime improved the habitat. As a result, the population increased through the 1980s and the Delaware River stock was considered 'recovered' in 1998. Despite the Delaware spawning stock survey index results falling below the running average in recent years, the long-term recovery since the 1980s is still evident from the NJ Recruitment Survey (Figure 38B). Considering the entire Atlantic Coast population, there have been many management actions by ASMFC since the first FMP was approved in 1981. While the 2018 stock assessment determined the stock to be "overfished and experiencing overfishing" in 2017, the 2022 assessment determined the stock was no longer experiencing overfishing in 2021. Management actions continue to reduce striped bass mortality, with a goal of rebuilding the stock by 2029.

ACTIONS/NEEDS

Continued monitoring of long-term trends in biomass and recruitment, responding when necessary with management action.

SUMMARY

The population within the Basin has responded favorably to decades of management, improved habitat availability and water quality improvements to become one of the major striped bass populations on the Atlantic Coast. However, recent declines in SSB have prompted continued and enhanced management efforts by ASMFC with a goal of rebuilding the SSB by 2029. Given the updated data and findings since the prior State of the Basin report, this indicator retains Declining trend but has been changed to a status of Good.

A weakfish caught from the Delaware Bay.
Photo © Aaron Maffei

WEAKFISH

DESCRIPTION

Weakfish, *Cynoscion regalis*, is a marine fish in the family *Sciaenidae*. While commonly referred to as the "grey trout" or "sea trout", they have no relation to actual trout which are classified in the family *Salmonidae*. Weakfish occur along the Atlantic Coast but are most common from New York to North Carolina. At the beginning of spring, adult weakfish begin an inshore spawning migration to the Delaware Bay and other estuaries. Spawning in the Delaware River Estuary occurs in the shallows and on shoals of the Bay. Larger weakfish leave the Bay for New England after spring spawning, while younger adult weakfish tend to stay in the Bay all summer. Younger fish feed on crustaceans and mollusks including shrimp species, while larger weakfish feed primarily on smaller fish. Weakfish are one of the 27 species of shellfish, fish and marine mammals managed by the Atlantic States Marine Fisheries Commission (ASMFC).

PRESENT STATUS

The initial Fisheries Management Plan (FMP) for weakfish was adopted in 1985 and has been amended and reviewed over time. The most recent stock assessment was performed in 2016 (ASMFC 2016) and was updated in 2019 (ASMFC 2019c). Notably, the 2016 stock assessment determined that the coastwide stock would be considered "depleted" when the spawning stock biomass (SSB; the total weight of fish in a stock which are old enough to spawn) falls below 30% of the estimated average SSB over the period 1982-2014. The 2016 stock assessment concluded that the coastwide stock is and has been considered depleted since 2003; the additional data incorporated into the 2019 assessment update did not change those findings.

Specific to the Delaware River Basin, the following surveys are performed by DDFW which provide information about weakfish productivity in the Delaware River Estuary:

1. A Juvenile Finfish Research Trawl Survey to measure relative young-of-year abundance, using a 16-foot trawl to sample 39 stations in the Delaware Bay and River; the index is calculated from the 33 non-river stations (Figure 39C).
2. An Adult Groundfish Research Trawl Survey, using a 30-foot otter trawl net at nine fixed locations in the Delaware Bay (Figure 39D).

TRENDS

Within the Delaware Bay, weakfish were only moderately abundant prior to 1970; however, increasing fish size and population made the Delaware Bay famous for trophy-sized weakfish during the spring spawning run by the late 1970s. By the late-1980s, the coastal fishery started to decline in terms of total landings quantity (Figure 39A and B). The ASMFC imposed coastwide restrictions throughout the early-1990s, coinciding with a slight rebound in abundance and landings through the late-1990s. However, subsequent declines were observed in parallel to modelled increases in natural mortality during the late 1990s and early 2000s, although the underlying cause or causes remains unknown (ASMFC 2016). In 2010, the ASMFC required states to implement revised commercial limits and a one fish recreational creel limit. While still considered depleted, the ASMFC 2019c stock assessment indicated some positive signs in the weakfish stock showing that SSB and recruitment have been relatively stable compared to the declines of the late 1990s and early 2000s.

However, despite both indices in Figure 39 being relatively close to historical averages for the Delaware River Estuary, it appears that there has been a slight observable downward trend since the mid-1990s. Notably, the age distribution of weakfish caught in the 30-foot trawl remains truncated (similar to findings in the 1990s) with around 80% of survey catch being less than age two (Greco 2022).

ACTIONS/NEEDS

While some factors have been identified as contributing to recent weakfish decline, more investigation is warranted into possible causes of high natural mortality rates (e.g., research concerning predator and prey interactions, weakfish diets and food availability, habitat characteristics such as water temperature) and other mortality rates (e.g., bycatch rates, discard rates associated with commercial gear) (ASMFC 2019c).

SUMMARY

Delaware Bay weakfish abundance indices are near the historical averages; however, survivorship has declined to a point where catches of legal-size weakfish are uncommon in the Delaware Bay (Greco 2022). A recent coastwide stock assessment indicated a small increase in abundance; however, the current stock remains well below the recommended threshold and still faces threats due to natural mortality. For this report, this indicator retains a status of Poor but with a Neutral trend.

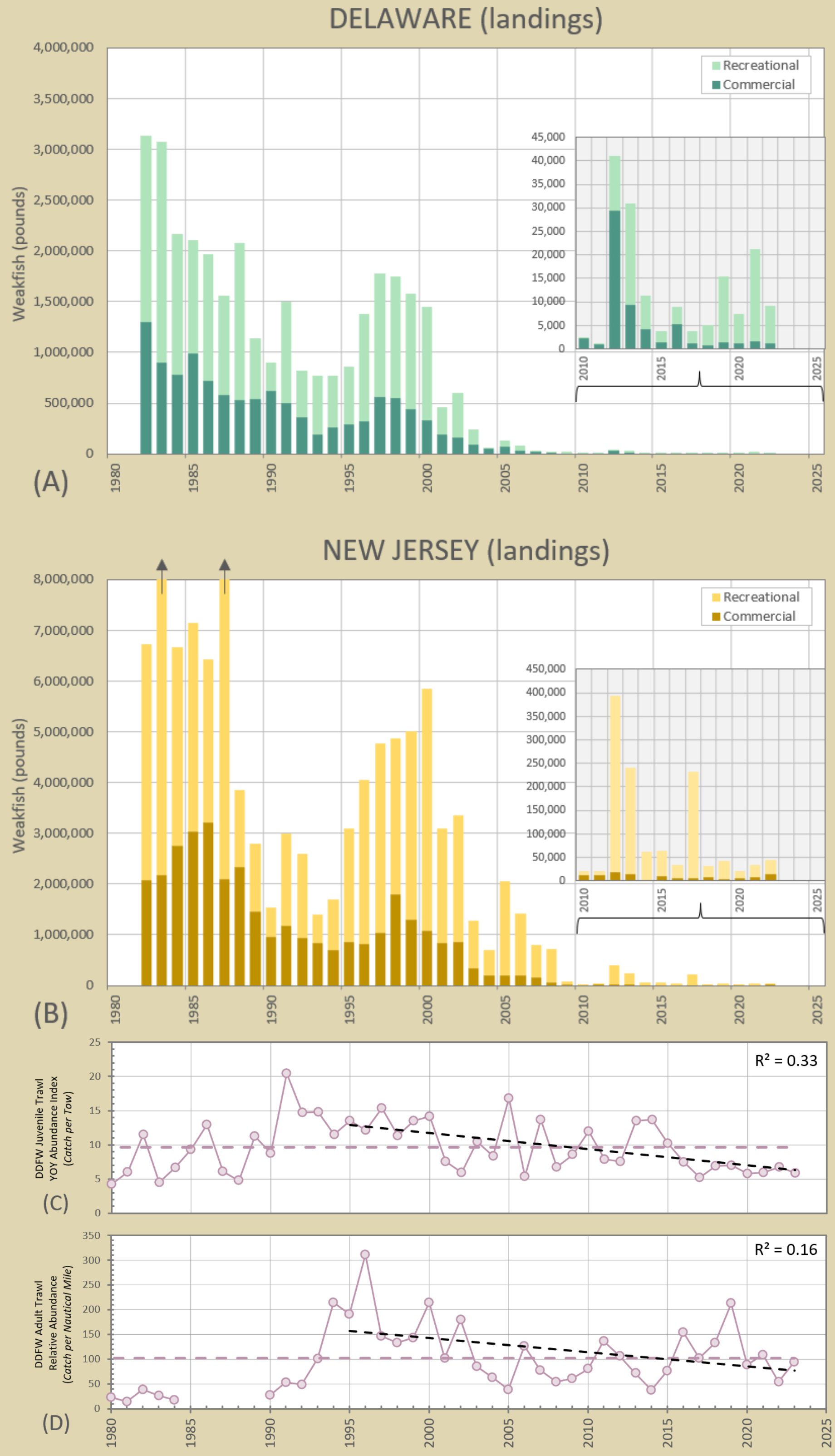
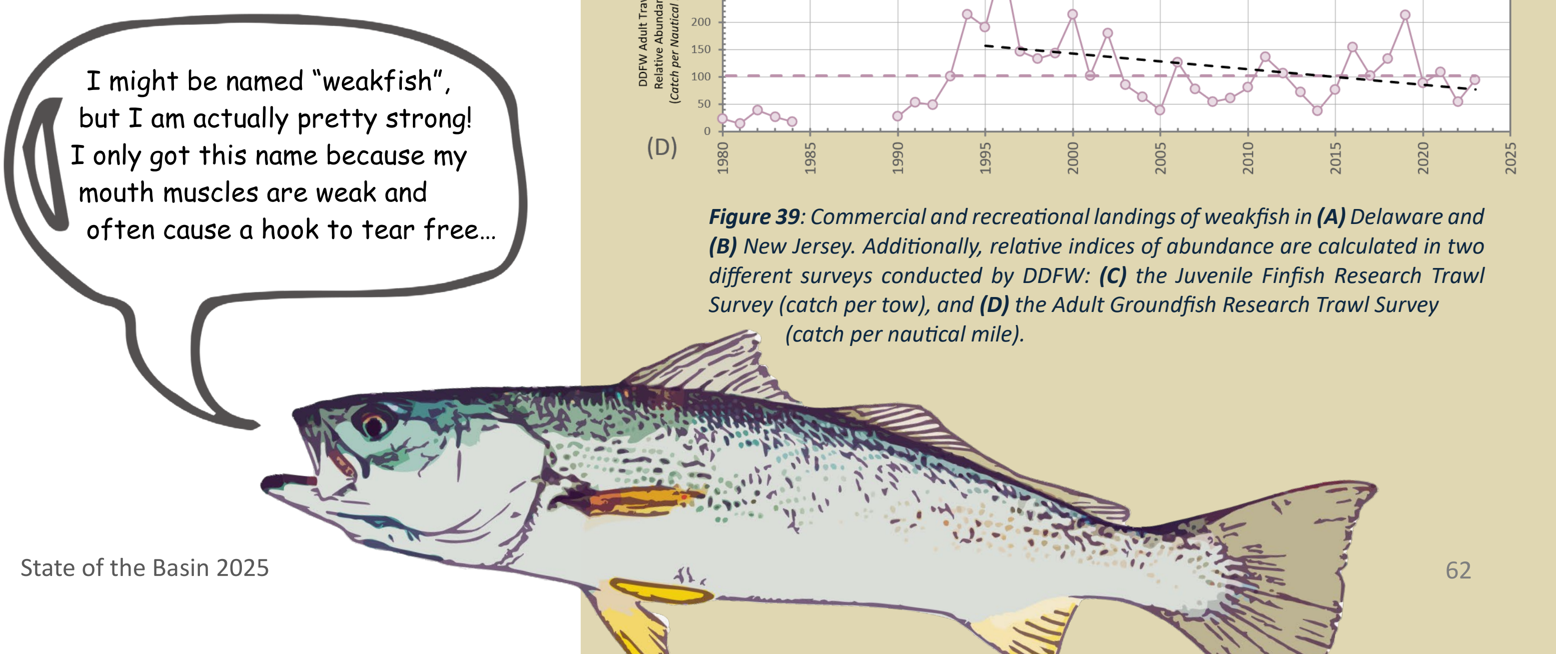


Figure 39: Commercial and recreational landings of weakfish in ***(A)*** *Delaware and* ***(B)*** *New Jersey. Additionally, relative indices of abundance are calculated in two different surveys conducted by DDFW:* ***(C)*** *the Juvenile Finfish Research Trawl Survey (catch per tow), and* ***(D)*** *the Adult Groundfish Research Trawl Survey (catch per nautical mile).*



Viewed from a migration window, several American shad swim together.
Photo by Bill Byrne (MassWildlife)

AMERICAN SHAD

DESCRIPTION

American shad, *Alosa sapidissima*, are the largest North American member of the herring family. They are an anadromous fish, spending the majority of their life at sea and only returning to freshwater tributaries to spawn. Beyond filling an important role in the food chain as both predator and prey, shad are a popular sport fish and have historically supported valuable commercial fisheries along the entire Atlantic Coast. In the late 1890s, the Delaware River had the largest annual commercial shad harvest of any river on the Atlantic Coast. However, factors such as overfishing, dammed spawning tributaries and degraded water quality (e.g., low dissolved oxygen) all contributed to population decline. Despite legislative action and artificial propagation, their numbers fell so low by 1920 that the shad industry collapsed. Based on historical shad abundance and the nature of factors attributed to the population's decline, trends in shad populations are a good indicator of restorative efforts within the Delaware River Basin.

A late 1700s representation of "Shad Fishing on the Delaware", using a haul seine method.
By Cornelius Tiebout (American, c. 1773 or 1777–1832); retrieved from philamuseum.org

PRESENT STATUS

Current shad population numbers reflect a rebound from historical lows but still experience year-to-year variation. The shad fishery is collaboratively managed by the Atlantic States Marine Fisheries Commission (ASMFC) and the Delaware River Basin Fish and Wildlife Management Cooperative (Co-op), resulting in a Sustainable Fishery Management Plan (SFMP) specific to the Delaware River Basin, most recently updated in 2022. The Co-op uses six benchmarks to define American shad sustainability, which are reassessed every five years corresponding with SFMP revision. Failing to meet these benchmarks can result in management actions to protect the fish population. The benchmarks are based on a series of relative indices, as follows:

1. Female Total Mortality
2. Non-tidal juvenile abundance index
3. Tidal juvenile abundance index
4. Smithfield Beach CPUE of adult female shad spawning run
5. Commercial harvest to Smithfield Beach relative ratio
6. Mixed stock landings

Notably, the ASMFC 2020 stock assessment found that the index of female total mortality was unsustainable in the Delaware Basin (ASMFC 2020). In response, the 2022 SFMP required state action to reduce both commercial landings and recreational harvest by 33%, beginning in the 2023 season—this means that the daily recreational creel limit was reduced to 2 fish on the Delaware River (beginning in 2023), and the Lehigh and Schuylkill Rivers remained catch-and-release only (ASMFC 2022c). However, it is

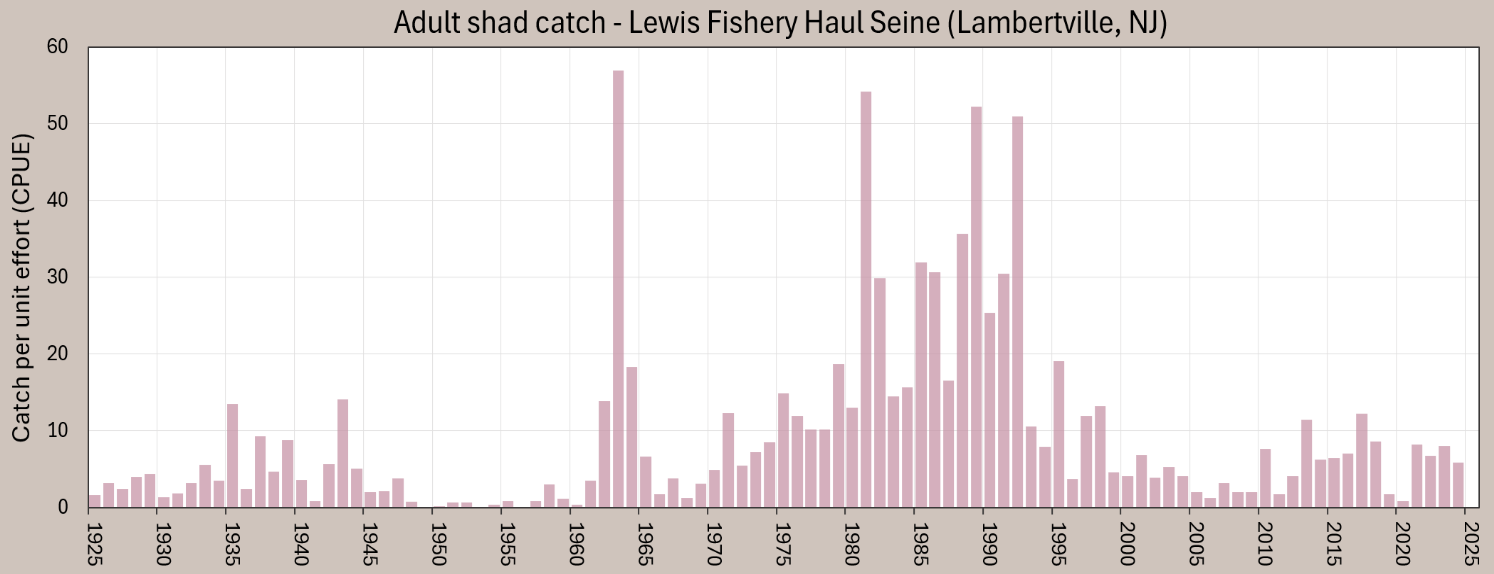


***Figure 40**: Historical catch of adult American shad at the Lewis Fishery in Lambertville, NJ. The fishery was established in 1888 by William Lewis and is currently managed by his great-grandson Steve Meserve.*

also worth highlighting that while the ASMFC 2020 stock assessment concluded the *coastwide* abundance to be "depleted", it could not definitively make conclusions about Delaware River shad abundance due to conflicting indices trends. However, some factors known to influence abundance include:

- **Increasing fish passage** via the removal of dams has been noted as a priority by organizations such as The Nature Conservancy (DeSalvo et al. 2022). A great example is the Musconetcong Watershed Association's initiative which removed three obsolete dams on the lower Musconetcong River between 2011-2016. The most upstream Hughesville Dam was removed in 2016 (see picture), and in 2017, shad were documented above the former site of the upstream-most dam (NJDEP 2017).
- **Invasive species** such as the Northern snakehead (*Channa argus*), flathead catfish (*Pylodictis olivaris*), and blue catfish (*Ictalurus furcatus*) are larger predatory fish documented to potentially prey on adult and juvenile shad.
- **Ocean overfishing and bycatch** have been theorized to have affected river stocks, although it is not clear which stock a shad comes from when caught at sea (e.g., Delaware River stock). Directed commercial harvest for shad in ocean waters has been banned by U.S. Atlantic coastal states since 2005.

TRENDS

An invaluable source of data on American shad in the Delaware River Basin is the Lewis Fishery; the last commercial shad fishery in the non-tidal Delaware River, located in Lambertville, NJ (Figure 40). The Lewis Fishery uses a haul seine method, such as that depicted on the previous page, and the data therefore represents a CPUE. The long-term trends in Figure 40 reflect a population that has rebounded from lows in the early-mid 1900s, largely attributed to efforts in restoring water quality (e.g., dissolved oxygen levels in the Delaware River).

What did the fish say when it swam into a wall?

Removing dams allows for fish migration to occur and opens up previously restricted habitats. This example shows the most upstream of three dams which were removed on the Musconetcong River. Photo credit: Princeton Hydro.

Additionally, the Pennsylvania Fish & Boat Commission Biologist Report for Area 5 provides updated data on the six SFMP benchmarks (Pierce 2022). The trend observed in data for index #4 (adult female shad spawning run measured at Smithfield Beach in East Stroudsburg, PA) indicates that adult abundance has been declining since about 2011.

ACTIONS/NEEDS

- Continue to restore blocked habitat through dam removal and fish passage devices.
- Maintain and monitor habitat conditions in spawning reaches.
- Reintroduce shad into newly opened bodies of water for spawning.
- Establish sustainable harvest limitations after restoration.

SUMMARY

The ASMFC 2020 stock assessment found elevated levels of adult female shad mortality triggering management actions, and recent data for SFMP index #4 (adult female shad spawning run CPUE) has suggested a declining trend. Continued management, monitoring and research efforts play a key role in determining the causes behind trends of this indicator and identifying strategies to keep the Basin healthy. This indicator retains a status of Good but with a Declining trend.

A brook trout caught in the Delaware River Basin (Jean's Run, Carbon County, PA).
Photo by Jake Bransky (DRBC)

BROOK TROUT

DESCRIPTION

Brook trout (*Salvelinus fontinalis*) are widely recognized for their recreational and cultural importance, as well as being indicators of good water quality and watershed health. They are the only trout species native to the Delaware River Basin, inhabiting high-quality freshwater streams with characteristics such as riffles, various stream beds, a vegetative canopy, and other forms of in-stream cover (PADCNR 2016). Brook trout are sensitive to environmental factors, especially water temperature. The maximum thermal tolerance of brook trout has been reported between 22–24°C (Albertson et al. 2018). The optimal water temperature for brook trout has been reported as spanning between 16–18°C for adults and 14–15°C for the young of the year, ideally with a high dissolved oxygen concentration near saturation (Ouellet and Daniels 2021). Notably, water temperature depends on land cover; research has shown that stream water temperature remains below maximum thermal thresholds of cold-water fish species, such as the brook trout, if 80% or more of the stream bank is covered by forests larger than 30 meters in width (Albertson et al. 2018).

PRESENT STATUS

Within the mid-Atlantic region, including the Delaware River Basin, brook trout populations are primarily located in headwater streams originating in mountains, foothills, and spring-fed limestone creeks (EBTJV 2008). Based on a 2015 publication by the Eastern Brook Trout Joint Venture (EBTJV) (Coombs and Nislow 2015), data on the presence or absence of trout species within catchments were used to classify "patches" of trout populations (Figure 41). Additional data related to brook trout can be accessed online at the Trout Unlimited Brook Trout Atlas.

- In 2018 New Jersey established a "Brook Trout Conservation Zone" (BTCZ) in the northern portion of the state, where all brook trout caught within the BTCZ must be immediately released unharmed (N.J.A.C. 7:25-6.6); the BTCZ is portrayed on Figure 41. All brook trout within the BTCZ are wild trout.
- Updated in 2023, the National Fish & Wildlife Foundation's Delaware River Watershed Business Plan aims to improve brook trout habitat in several focus areas (as indicated on Figure 41). This includes actions such as restoring connectivity in streams which support brook trout, as well as addressing impairments through restoration and best management practices (BMPs). Progress intends to be tracked via metrics such as the relative abundance of brook trout within streams.

TRENDS

Brook trout population trends typically depend on water quality and hydrological connectivity (stream habitat fragmentation) (NFWF 2023). In the Delaware River Basin, brook trout populations have historically declined; however, due to the implementation of pollution control measures in the past few decades, brook trout populations have shown the potential to rebound in the Basin (EBTJV 2023; NFWF 2023). Habitat loss due to development still remains a threat.

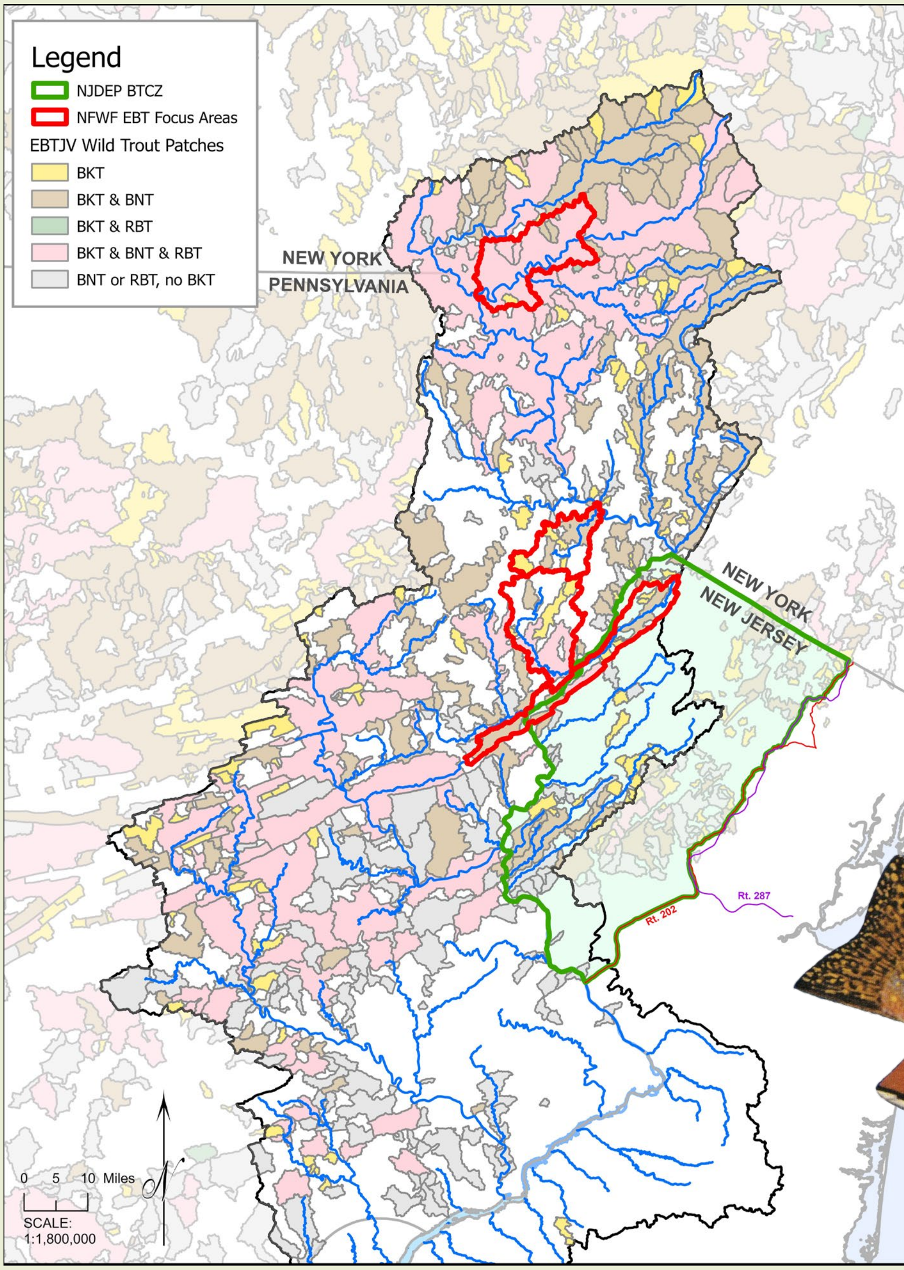
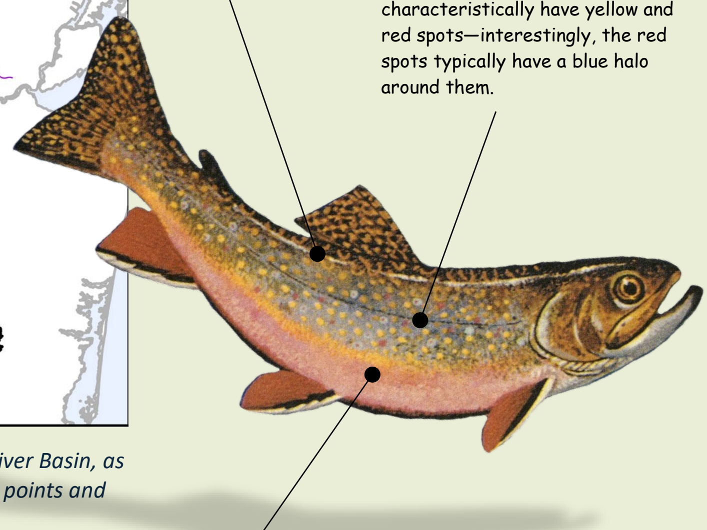


Figure 41: *Distribution of brook trout catchment habitats across the Delaware River Basin, as determined by a 2015 analysis based on inputs such as salmonid species sample points and anthropogenic barriers. Data retrieved from Coombs and Nislow 2015.*
BKT = brook trout; BNT = brown trout; RBT = rainbow trout



ACTIONS/NEEDS

The restoration of suitable and unfragmented habitat (e.g., land cover which impacts water quality and temperature) as well as restoration of river connectivity (e.g., dam removal) can help support current brook trout populations and provide a better environment for population numbers to successfully rebound. Continued monitoring of the populations should be performed to assess the impacts of habitat improvement.

SUMMARY

Brook trout are native to the Delaware River Basin, and widely seen as indicators of high-quality water and good watershed health. While research has shown that native populations have been reduced over time, a recent push for conservation and management is seeking to restore populations to historic native levels. Without quantitative data estimating populations it is difficult to change the indicator status. As such, the indicator status remains at Fair, but with a Neutral trend.

An American eel swimming among submerged aquatic vegetation.
Photo © Rick Koval | iNaturalist

AMERICAN EEL

DESCRIPTION

American eels (*Anguilla rostrata*) are catadromous, meaning they are born in the ocean, migrate into freshwater and the estuary where they spend most of their lives (up to 20 years), and return to the ocean to spawn once before dying (Figure 42). Commercially, the primary value of American eel is as bait for certain recreational fishing (such as striped bass) with some secondary value in particular food markets. Ecologically, certain freshwater mussels (such as Eastern Elliptio) are known to be highly dependent on eels for the transport of larvae, which helps sustain freshwater mussel populations integral to water quality (Lellis et al. 2013).

PRESENT STATUS

The most recent coastwide stock assessment of American eels by the Atlantic States Marine Fisheries Commission (ASMFC) performed in 2023 concluded that the stock is “depleted”, meaning it is at or near historically low levels (ASMFC 2023b). However, as stated in the Technical Report for the Estuary and Basin (TREB), “All indications from anecdotal accounts from fishermen and biologists are that eel abundance is currently very high” (Zimmerman 2022). Specific to the Basin, data from two long-running surveys are useful because a “catch per unit effort” (CPUE) of American eels can be calculated and viewed as an indicator of eel abundance:

- **Delaware**: The DNREC Division of Fish and Wildlife (DDFW) Juvenile Finfish Trawl Survey includes data collected from 23 fixed sites in the Delaware Bay and 17 fixed sites in the Delaware River. A 17-foot trawl net is pulled against the current by a 60-foot research vessel for 10 minutes (ASMFC 2023b). Eels caught per unit effort as shown in Figure 43A.
- **New Jersey**: NJDEP Fish and Wildlife (NJDEP FW) performs a Delaware River seine survey, which uses a 100-foot long, 6-foot-deep seine net with ¼-inch mesh (NJDEP 2023). Eels caught per unit effort as shown in Figure 43B.

TRENDS

Commercial landings. Both Delaware and New Jersey have historically had a significant commercial fishery for yellow eels; the total annual landings per year are shown in Figure 44. In 2000 the ASMFC adopted an Interstate Fishery Management Plan (FMP) for the American Eel, requiring states/jurisdictions to maintain existing or more conservative American eel commercial fishery regulations. FMP Addendum IV (2014) established a coastwide harvest cap of 907,671 pounds of yellow eel. The cap was slightly increased to 916,473 pounds by Addendum V (2018). Using a new methodology, Addendum VII (2024) has reduced the coastwide harvest cap to 518,281 pounds.

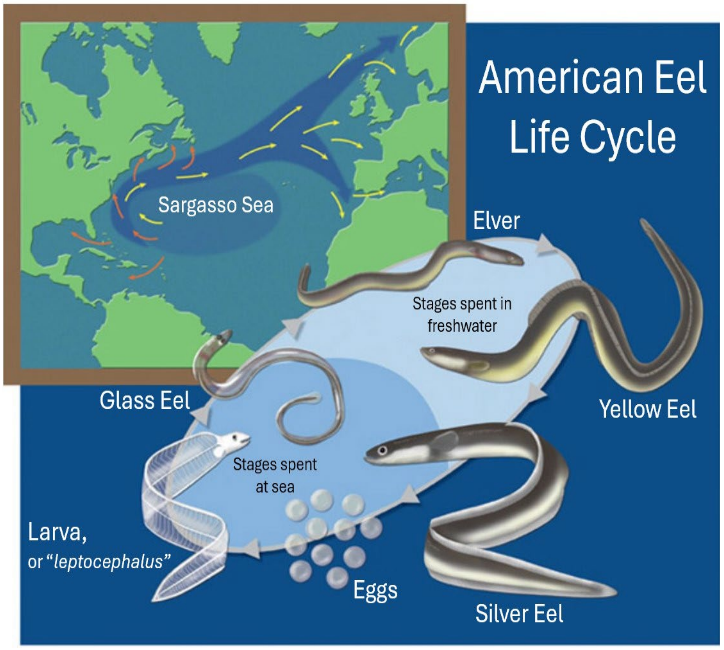


***Figure 42**: The lifecycle of an American Eel.*
Graphic ©2009 Melisa Beveridge (Adapted from www.naturalhistoryillustration.com)

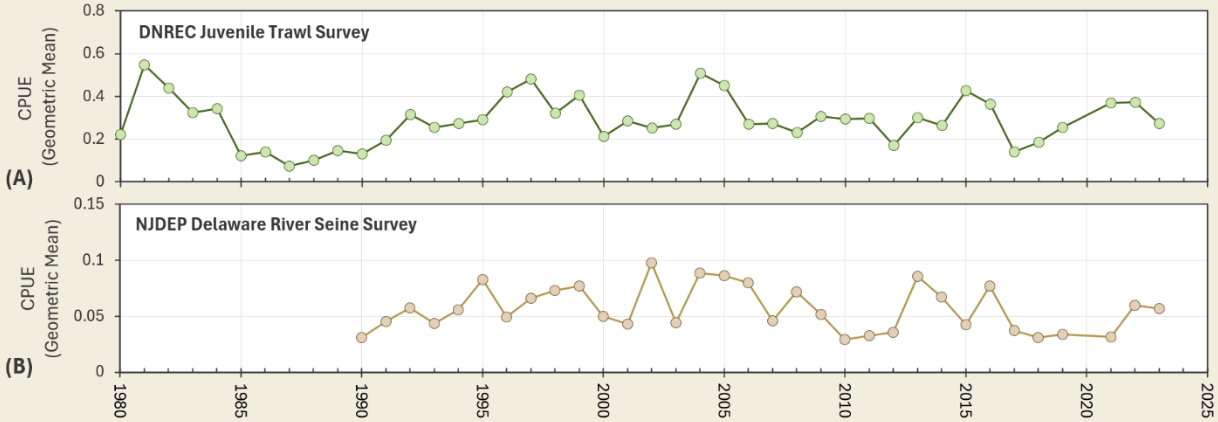


***Figure 43**: The catch of American eels per unit effort (per trawl, or per seine) in two different state surveys. **(A)** Only DDFW trawl data from the 23 fixed sites in the Delaware Bay and 17 fixed sites in the Delaware River are included. **(B)** All data from the NJDEP survey are from within the Basin.*

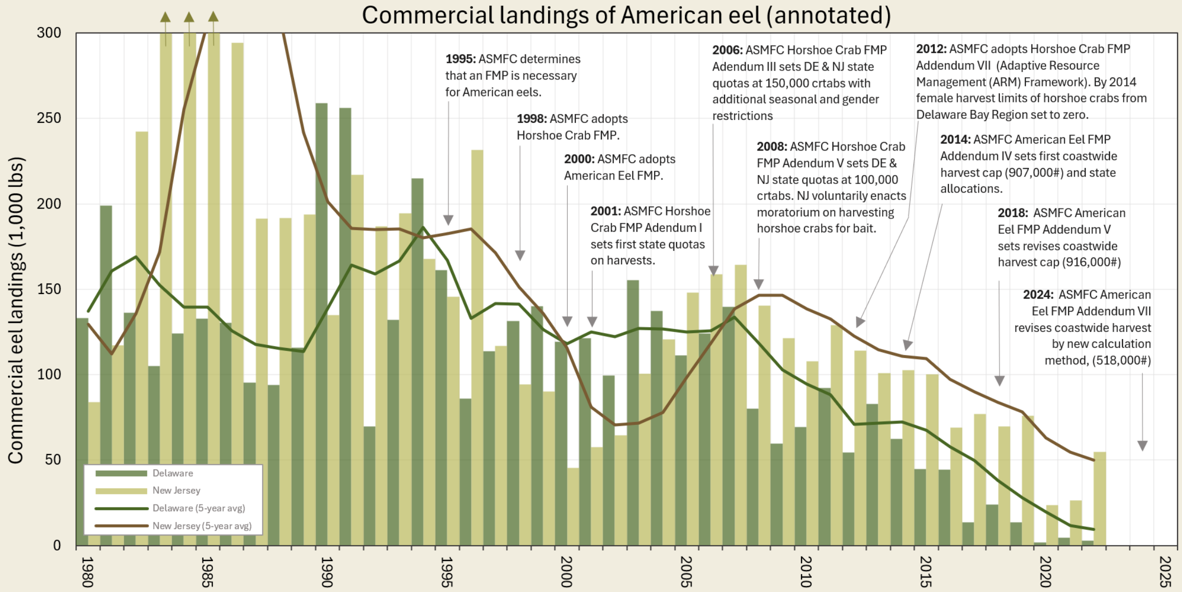


***Figure 44**: Commercial landings of American eels in the states of Delaware and New Jersey (data obtained primarily from NOAA Fisheries). Annotations of regulatory conservation efforts are noted for American eels and horseshoe crabs, based on the fact that horseshoe crab is a primary bait for catching American eels.*

Commercial landings have also been affected by the availability of bait, which has primarily been adult horshoe crabs (next report section). The ASMFC FMP for horseshoe crab set state harvest quotas in 2001 (Addendum I), lowered quotas in 2006 (Addendum III), again in 2008 (Addendum V), and in 2014 placed a moratorium on the harvest of females of Delaware Bay origin (Addendum VII). New Jersey voluntarily enacted a moratorium on harvesting horseshoe crabs in 2008, with an exemption for biomedical use.

Population. While commercial landings of American eel have declined dramatically in Delaware and New Jersey (Figure 44), coastwide harvest levels remained relatively constant over 1998–2018. The 2023 ASMFC stock assessment created a coastwide relative abundance index of American eel based on 25 YOY, 10 elver, and 14 yellow eel surveys (Link). The index trend suggests large declines in abundance of yellow eels during the 1980s, a primarily neutral trend from the mid-1990s through 2010, followed by futher declines (ASMFC 2023b).

While the ASMFC uses data from the two surveys referenced in this report to calculate indices of abundance, it is perhaps helpful to simply view the survey data directly. A geometric mean of the number of eels caught per trawl (DDFW) and per seine (NJDEP FW) is presented in Figure 43. In both surveys, it appears that the number of eels caught per unit effort has remained relatively constant over the time series.

ACTIONS/NEEDS

Dams along tributaries of the Delaware River impact suitable habitat for American eels, while decreases in riparian forested buffer along streams can increase non-point source pollution, sediment runoff and sun exposure to American eel habitat. Fish passage and riparian buffer restoration would help improve habitat for American eels by increasing connectivity and improving in-stream habitat. Continued and improved monitoring of species abundance in the non-tidal reaches of the Delaware River Basin and continued monitoring in the Delaware River Estuary will support future predictions.

SUMMARY

Coastwide trends and calculated population abundance indices reported by ASMFC in 2023 led to further reductions in coastwide harvest limits and a stock status label of “depleted”. However, while coastwide commercial landings have remained relatively constant over 1998–2018, commercial landings have dramatically decreased in both Delaware and New Jersey. Calculated CPUE of American eels in DDFW’s trawl survey and NJDEP FW’s seine survey suggest trends which are not decreasing, and perhaps indicate that progress is being made for local eel populations. For this reason, the indicator status retains a status of Good, and the trend changes to Neutral. Additional time and data will show how the American eel population responds to recent management efforts.

Horseshoe crabs on the Delaware Bay beach, one with a tracking tag attached.
Photo © Susan Allen (@what.sue.seas)

HORSESHOE CRAB

DESCRIPTION

Horseshoe crabs (*Limulus polyphemus*) are benthic arthropods that inhabit both estuarine and continental shelf habitats stretching from the Yucatan Peninsula to Maine; however, the largest spawning population in the world is supported by the Delaware Bay. Horseshoe crabs (HSCs) may live up to 27 years, initially near intertidal breeding beaches before moving into deeper water up to a few miles offshore (ASMFC 2019a). In the Delaware Bay Region, spawning primarily occurs from mid-May to mid-June, usually coincides with the full and new moon high tides and is usually more prevalent at night (Smith et al. 2010). An adult female may deposit up to an estimated 90,000 eggs annually on intertidal beaches (in various egg clusters). Eggs which become uncovered (e.g., wave action, bioturbation caused by high spawning densities) are an essential source of food for migratory birds, such as the red knot, which stop at the Delaware Bay on northward migrations. Commercially, HSCs have two niches (1) as bait for the American eel and conch fisheries, and (2) their unique blue blood is used by the biomedical industry to produce Limulus Amoebocyte Lysate, which is used to test medical products for contamination (ASMFC website).

PRESENT STATUS

Atlantic Coast HSCs are managed under the Atlantic States Marine Fisheries Commission (ASMFC) Fishery Management Plan for Horseshoe Crab (ASMFC 1998b) and its subsequent addenda (Addenda I-VIII). The ASMFC divides the Atlantic Coast into four regions, of which the Delaware Bay Region extends from Virginia to New Jersey as indicated in Figure 45. Specific to the Delaware Bay Region, there are two highlights to consider:

1. The Adaptive Resource Management (ARM) Framework

The ARM method was adopted in Addendum VII (ASMFC 2012) to set cumulative bait harvest limits on HSCs originating from the Delaware Bay Region. Based on an annual assessment of the population of (1) horseshoe crabs and (2) red knots, the ARM model determines a cumulative limit for the region, which then gets portioned among the four states. Notably, Addendum VIII (ASMFC 2022a) adopted a proposed 2021 modification the ARM Framework such that:

- The Catch Multiple Survey Analysis (CMSA) estimates HSC abundance. The CMSA includes data from scientific surveys, such as the Virginia Tech Horseshoe Crab Trawl Survey.
- Separate harvest limits for female and male HSCs are determined annually based on a continuous scale, ranging from a full moratorium to maximum gender-specific limits.
- The maximum harvest limits of each gender are unchanged from Addendum VII (500,000 males and 210,000 females), as well as state proportions.

The 2024 season harvest recommendation based on the ARM Framework was 500,000 male and 175,000 female HSCs; the ASMFC Horseshoe Crab Management Board approved limits of 500,000 male and zero female HSCs (ASMFC 2023d, 2023e). In New Jersey, a moratorium on the harvest of HSCs has been in place since 2008, with an exception for biomedical research. In

Delaware, annual harvest limits are based on ASMFC Addendum VIII – the ARM Framework.

2. Coastwide and regional stock assessments

The ASMFC performs stock assessments on both the coastal and regional basis, most recently in 2019, updated in 2024. Overall, the assessment evaluates data from six survey programs in the Delaware Bay Region, as highlighted on Figure 45. However, based on statistical rigor, only five indices from three of the surveys are used to develop a "stock status" for the region. Trends for the five indices are assessed using a moving average model, and the last year of the model is compared against the corresponding 1998 value. In 2024, ASMFC determined that 5/5 survey indices were above their 1998 reference point, and the stock is considered "Good" (ASMFC 2024a).

TRENDS

In the 1990s, horseshoe crab populations experienced high harvesting levels, resulting in significant and rapid population decline in the Delaware Bay. Since then, adaptive management plans have been set in place to recover their populations. Other conservation actions have targeted protection of spawning habitat from loss due to beach erosion, beach transgression, and armoring in the bay (Botton et al. 2022). Two trends worth highlighting are:

- The ASMFC has performed stock assessments in 2009, 2013, 2019 and 2024 – although only the 2019 and 2024 used comparable methods. The stock status changed from "Neutral" (2019) to "Good" (2024).
- The CMSA model, while not used in the stock assessment, is used in the ARM Framework and provides population estimates. This model estimates that there are approximately 40 million mature male and 16 million mature female HSCs in the Delaware Bay region in 2022 and suggests that mature female HSC populations have been steadily increasing in the Delaware Bay Region since implementation of the initial ARM Framework in 2012 (Figure 46).

ACTIONS/NEEDS

Consistent funding and support for monitoring programs which collect essential data are imperative; these data help run models such as the CMSA, which now help drive the ARM Framework to make critical management decisions. Additionally, the ASMFC includes numerous research recommendations in recent publications which should be an industry focus (e.g., tagging efforts, natural mortality estimates, HSC ecology and movement).

SUMMARY

Horseshoe crabs have historically supported a commercially important fishery, aided advancements in the biomedical industry, and are an essential element of not only the Delaware River Basin ecosystem, but a broader food web including endangered migratory birds. Management efforts by both the ASMFC and individual states (e.g., NJ bait harvest moratorium) appear to have aided in the Delaware Bay Region HSC population rebound. The indicator status for this report remains at Good with an Improving trend.

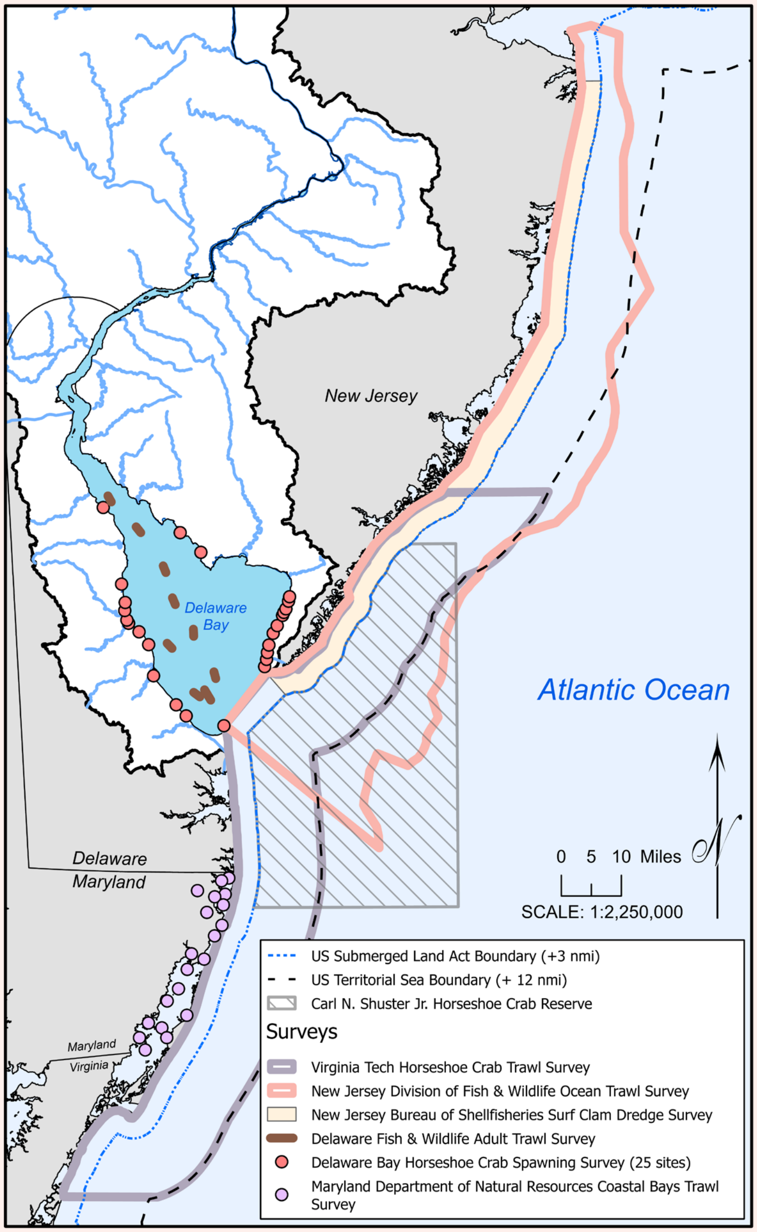


Figure 45*: A map showing the approximate extent of the Delaware Bay Region surveys as related to the ASMFC stock assessment analyses for horseshoe crabs.*

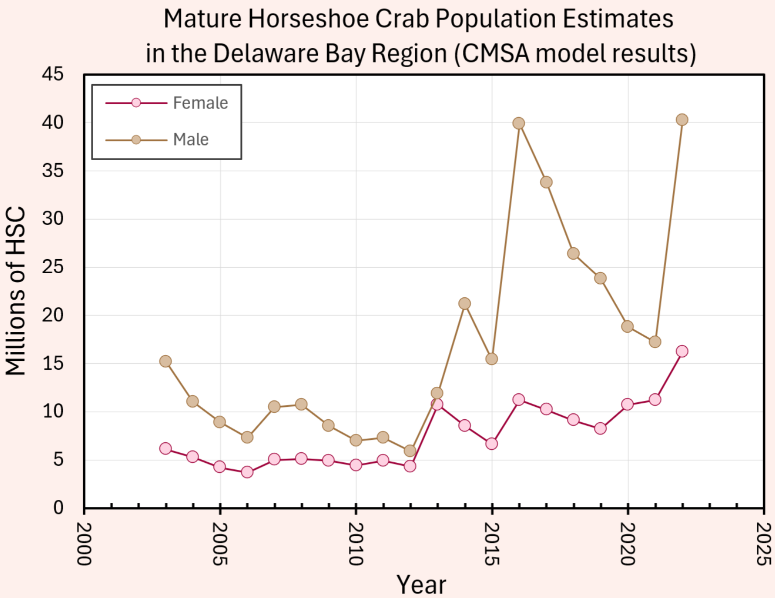


Figure 46*: Estimates of the total mature horseshoe crab population in the Delaware Bay Region based on the CMSA model. Data obtained from ASMFC 2024.*

An Eastern Elliptio mussel, the most common the Delaware River Basin, showing siphons used for filter feeding. Photo by Ryan Haggerty (U. S. Fish and Wildlife Service)

FRESHWATER MUSSELS

DESCRIPTION

Freshwater mussels (*Mollusca*: *Bivalvia*: *Unionida*) are filter feeding bivalve mollusks that live in lakes, rivers, and streams. They provide valuable ecosystem services such as increasing water clarity, filtering particulate contaminants, enriching habitats, stabilizing bed erosion and even providing long-term storage of several kilograms of nutrients such as carbon, nitrogen, and phosphorus. An excellent reference which summarizes freshwater mussel contributions to the environment can be found in Atkinson et al. 2023, Table 1. Typically, freshwater mussel species grow slower yet live longer than their marine counterparts, in some cases up to 50 years or longer. They also have complicated reproduction strategies – freshwater mussel larvae are nonpathogenic (harmless) parasites and require specific species of host fish to live until they develop anatomical structures, at which point they drop off into hopefully suitable habitat – a mechanism which also helps transport mussels throughout a watershed (Grabarkiewicz and Davis 2008). Due to their long and complex lifecycle, freshwater mussels are recognized as sensitive long-term indicator of water quality, biodiversity, and habitat conditions.

PRESENT STATUS

Freshwater mussels (order *Unionida*) are one of the world's most diverse taxonomic orders within the taxonomic class *Bivalvia*, having an estimated 900 different species (Huber 2010). It has recently been recognized that 298 of these species occur within the United States and Canada (Williams et al. 2017); however, freshwater mussels are also recognized as being among the most at risk of all groups of aquatic animals in North America (Nobles and Zhang 2011). There are only about a dozen species of freshwater mussel which are native to the Delaware River Basin. The conservation status of each species as defined by NatureServe is provided in Table 1 as an update from the previous State of the Basin report (Byun et al. 2019). Federal and state regulatory or special protection statuses are also provided for each species, as applicable.

TRENDS

Historically, freshwater mussels were abundant in the Delaware River Basin, but populations have drastically declined over time due to water pollution, overharvesting, habitat loss, dams, and concurrent declines in fish populations that act as hosts for larval mussels. For example, the most common freshwater mussel in the Delaware River Basin (Eastern Elliptio) relies on five species of fish to act as host, of which BROOK TROUT and AMERICAN EEL are two, and the American eel was determined to be the most effective (Lellis et al. 2013). Notably, populations of both these host fish have been discussed in this report in the context of restorative management efforts.

The Partnership for the Delaware Estuary (PDE) has played a large role in advancing the importance of mussel status and implementing restoration efforts throughout the Basin. For example, PDE recently updated a comparison between historical freshwater mussel surveys (1919-1996) and more recent surveys (1996-2016) in the Lower and Bay Regions (Figure 3B). The results show that while species diversity appears to have been maintained on the mainstem Delaware River, overall range, abundance and diversity in many tributaries have dramatically decreased (Kreeger and Chen 2022). Changes in conservation status on Table 1 from the prior State of the Basin (2019) have been summarized on Table 2, and largely reflect worse assessments.

However, these findings are not intended to diminish or cast aside the efforts which have been put forth to help restore freshwater mussels – rather it serves as additional motivation that work must continue. Some examples of increased freshwater mussel management effort include:

- In 2007, PDE launched the Freshwater Mussel Recovery Program with the main goal of conserving and restoring native freshwater mussels within the Delaware River Estuary. Many studies done by PDE in the Lower and Bay Regions include surveys of mussel presence, conservation, assessments on stream stability suitability for restorative habitat, and reintroduction of the species into the ecosystem.
- The nation's first city-owned mussel hatchery is in Philadelphia at the Fairmount Water Works which began in 2018 with the goal of propagating new mussels to improve the current populations in the Delaware River (Heffernan 2024). PDE is also partnering with Bartram's Gardens in Philadelphia to construct a commercial-scale freshwater mussel hatchery, capable of producing up to 500,000 mussels each year (info).
- Habitat reclamation has played a major role in improving the populations of freshwater mussels in the Basin, such as increasing fish passage via dam removals. A recent and ongoing project worth highlighting has taken place on Bushkill Creek in Northampton County, Pennsylvania. Three obsolete low-head dams were removed (2023-2024), and approximately 2,600 freshwater mussels (Alewife Floater and Eastern Pondmussel) which were hatchery propagated by PDE were stocked at two locations in 2024. Continued monitoring and study of the stocked mussels is being performed by Lafayette College.

ACTIONS/NEEDS

As noted in PDE's 2022 Technical Report for the Estuary and Basin, the future prospects of freshwater mussels are likely to hinge on careful watershed management practices and deliberate conservation efforts (Kreeger and Chen 2022). Some actions/needs include:

- Increased proactive monitoring for species presence and population health, as well as improved data sharing.
- Improving host fish populations and increasing fish passage will help promote natural propagation.
- Increasing hatchery capacity to supply mussels for regional restoration, enhancement, bioassessment, research and engagement programing the Delaware River Basin.

SUMMARY

Freshwater mussels are an invaluable asset to a watershed's ecosystem. However, watershed development and climate change pose continued threats. Given the current state, it is unlikely that existing populations have the ability to recover independently, driving a push for planning/management efforts to assist in population rebound (e.g., hatcheries and stocking) while also focusing on creating an environment suitable for natural propagation. There appears to be good positive momentum in the Basin which can hopefully result in an ability to quantify improvement. For these reasons, the indicator retains a status of Poor with a Neutral trend.

Table 1: *Summary of conservation status for freshwater mussel species found in the Delaware River Basin.*

Common Name	Species	Global		United States		Delaware		New Jersey		New York		Pennsylvania	
		G-Rank[1]	Last Rev.	N-Rank[1]	Reg.[2]	S-Rank[1]	Reg.[3,4]	S-Rank[1]	Reg.[5]	S-Rank[1]	Reg.[6]	S-Rank[1]	Reg.[7]
Alewife Floater	*Anodonta implicata*	G5	2017-08-01	N5	--	S1	SC	S4	--	S1	--	S3	--
Brook Floater	*Alasmidonta varicosa*	G3	2024-06-28	N3	--	SX	E	S1	E	S1	T	S1S2	--
Creeper	*Strophitus undulatus*	G5	2017-08-01	N5	--	S1	SC	S3	SC	S4	--	S5	--
Dwarf Wedgemussel	*Alasmidonta heterodon*	G2	2024-05-29	N1N2	E	SH	E	S1	E	S1	E	S1	E
Eastern Elliptio	*Elliptio complanata*	G5	2017-08-01	N5	--	SNR	SC	S4	--	S4	--	S4	--
Eastern Floater	*Pyganodon cataracta*	G5	2017-08-01	N5	--	S4	SC	S4	--	S4	--	S4	--
Eastern Lampmussel	*Lampsilis radiata*	G5	2016-02-11	N5	--	S1	E	S2	T	S4S5	--	S1	--
Eastern Pearlshell	*Margaritifera margaritifera*	G4	2024-06-24	N4	--	Not in DE		SX	--	S2S3	--	S1	E
Eastern Pondmussel	*Ligumia nasuta*	G3	2024-06-27	N3	--	S1	E	S2	T	Not in NY-DRB		S2S3	--
Green Floater	*Lasmigona subviridis*	G2G3	2024-01-03	N2N3	--	Not in DE-DRB		S1	E	S2	T	S2S3	--
Northern Lance	*Elliptio fisheriana*	G4	2007-10-30	N4	--	S2	SC	Not in NJ		Not in NY		Not in PA-DRB	
Rayed Bean	*Villosa fabalis*	G2	2020-10-20	N2	E	Not in DE		Not in NJ		Not in NY-DRB		S1S2	E
Tidewater Mucket	*Leptodea ochracea*	G3G4	2024-06-21	N3N4	--	S1	E	S2	T	Not in NY-DRB		S1	--
Triangle Floater	*Alasmidonta undulata*	G4	2024-05-30	N4	--	SH	E	S2	T	S3	--	S3	--
Yellow Lampmussel	*Lampsilis cariosa*	G3G4	2024-06-25	N3N4	--	SH	E	S2	T	S2S3	--	S4	--

Table 2: *Status changes from the 2019 State of the Basin.*

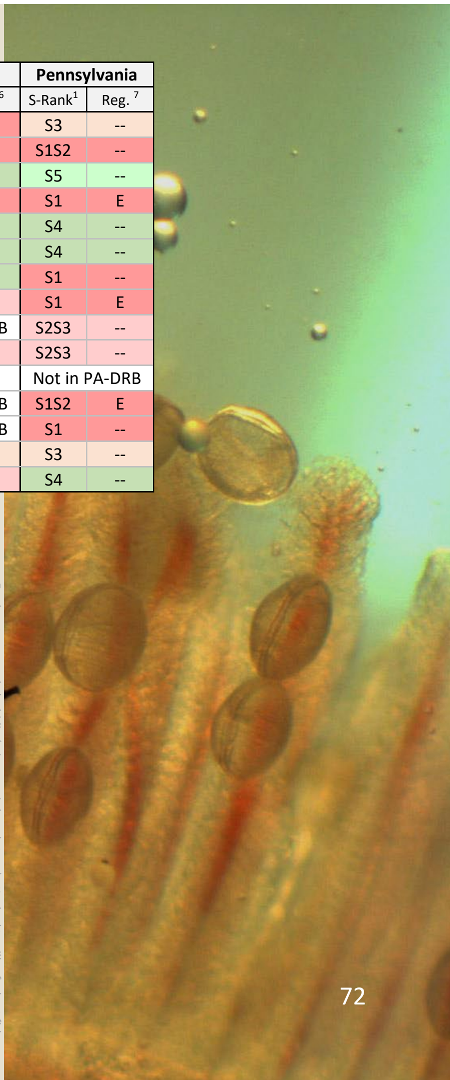
Species	State	Status Type	SOTB, 2019	SOTB, 2025
Alewife Floater	NY	NatureServe	S1S2	S1
Eastern Elliptio	DE	NatureServe	S5	SNR
Eastern Elliptio	NY	NatureServe	S5	S4
Eastern Pearlshell	NY	NatureServe	S2	S2S3
Eastern Pondmussel	Global	NatureServe	G4	G3
Eastern Pondmussel	USA	NatureServe	N4	N3
Green Floater	Global	NatureServe	G3	G2G3
Green Floater	USA	NatureServe	N3	N2N3
Green Floater	NY	NatureServe	S1S2	S2
Rayed Bean	PA	Regulatory	Threatened	Endangered
Triangle Floater	NY	NatureServe	S4	S3
Yellow Lampmussel	NY	NatureServe	S3	S2S3

Subnational Status Rank
SX: Presumed Extirpated
SH: Possibly Extirpated
S1: Critically Imperiled
S2: Imperiled
S3: Vulnerable
S4: Apparently Secure
S5: Secure
SU: Unrankable
SNR: Not Yet Ranked

Regulatory Status
E: Endangered
T: Threatened
SC: Special Concern

Notes:

[1] Global (G-Rank), National (N-Rank) and Subnational (S-Rank) from NatureServe Explorer (accessed: 09/11/2024). (Link)
[2] US Federal Regulatory Status as indicated under the Endangered Species Act of 1973 (accessed: 09/11/2024). (Link)
[3] Delaware regulatory status as indicated in 7 Del. C. § 3900.16.2.3 (Last updated May 2024). (Link)
[4] All freshwater mussel species in Delaware are considered "Species of Special Concern" per 7 Del. C. § 3900.17.0
[5] New Jersey regulatory status as indicated in N.J.A.C. 7:25-4 (Last amended October, 2023). (Link)
[6] New York regulatory status as indicated in 6 CRR-NY Part 182.5 (Current through October 15, 2021). (Link)
[7] Pennsylvania regulatory status as indicated in 58 Pa. Code § 75.2 (Last amended March 1, 2024). (Link)



Freshwater mussel glochidia (microscopic larval stage) attached to gills of a host fish.
Photo by Rachel Mair (U.S. Fish and Wildlife Service)

An underwater photograph of a Stenacron mayfly nymph on a rock.
Photo © Dustin Lynch | iNaturalist | (cropped)

MACROINVERTEBRATES

DESCRIPTION

Benthic macroinvertebrates refer to a group fauna which live at the bottom of a waterbody such as the stream bed sediment, stones or debris ('benthic'), can be seen without magnification ('macro') and do not have backbones ('invertebrates'). While this group largely consists of insects, other examples are snails, clams, aquatic worms, and crayfish. It is widely acknowledged that macroinvertebrates are an essential biological indicator in freshwater ecosystems, for numerous reasons:

- **Localized results:** Most macroinvertebrates have limited movement and inhabit a short segment of stream; therefore, they generally reflect the local habitat conditions.
- **Current picture**: Benthic macroinvertebrates typically have a short lifespan, so their presence is generally indicative of present and recent conditions.
- **Habitat sensitivity**: The term "macroinvertebrates" encompasses a diverse group of organisms with different niches, and varying degrees of tolerance to changes in water quality and watershed characteristics. This means that the presence or absence of a notable species can help indicate stream health.
- **Study feasibility**: Macroinvertebrates are relatively abundant, easy to sample for, and easy to analyze. A program of study usually entails sampling, identifying the organisms, applying a bioassessment metric (e.g., scoring system), and calculation of a single index of biological integrity (IBI).

PRESENT STATUS

Data for assessing macroinvertebrates within the Delaware River Basin are primarily derived from the four states, the Delaware River Watershed Initiative (DRWI), and the DRBC; however, there are many additional groups which perform essential monitoring throughout the Basin. While differences in bioassessment protocols and analytical methods complicate the comparison of IBI scores between organizations, it is possible to qualitatively compare the condition of macroinvertebrate communities. A generalized "biological condition" is presented for each of the Delaware River Basin's 548 HUC12s watersheds in Figure 47, based on data from monitoring programs in DE, NJ, NY, PA and the DRWI. While each agency has slightly different methods and grading scale, all classify the biological assessments into four qualitative categories that describe the biological condition of the stream. To create a generalized biological condition, each agency's data were mapped to the following categories: Excellent, Good, Fair, and Poor. A biological condition was then calculated at the HUC12 sub-watershed scale by assigning values to the qualitative scores (Excellent=4, Good=3, etc.) and averaging the scores (Kroll et al. 2022).

To help visualize the data regionally, Figure 47 also summarizes the land area within each of the Basin's 10 sub-regions (Figure 3B) by the percentage assigned to each biological condition. Generally speaking, the condition of benthic macroinvertebrate communities is better in the upper portions of the Delaware River Basin and worse in the urbanized portions of the Basin. It's worth noting that the data presented in this report may not represent a random selection of sites, as would be required for a formal Basin-wide assessment of ambient conditions. Additionally, differences in each state's qualitative categorizations may result in some bias in visual interpretation of Figure 47.

TRENDS

Although highly important, quantitative monitoring of trends is challenging due to short or inconsistent datasets. Sampling frequencies may vary based on the size of a watershed, and ecoregional differences may warrant the application of one index inappropriate (e.g., New Jersey currently uses three different macroinvertebrate indexes for the Pinelands, Coastal Plains, and High Gradient zones). Scientific studies have suggested that general watershed characteristics correlate with macroinvertebrate conditions negatively (e.g., increased urban development, population and impervious surfaces) and positively (e.g., watershed with greater areas of forest and wetland, cobble substrates and consistent baseflows).

DRBC performs biomonitoring at twenty-five fixed stations along the mainstem Delaware River. The samples are collected via a standardized kick-net method, and an IBI is calculated on a scale ranging 0–100 based on the number macroinvertebrates and specific species collected. The DRBC has established a threshold such that when a sample location scores an IBI≥75.6, it suggests that "biological integrity" has been attained at that location. Sample locations were grouped by WQ Zone, and the percentage of locations within each WQ Zone scoring at or above the threshold is summarized in Figure 48. Historically, all sample locations within WQ Zone 1A have returned values above the threshold. Typically, the percentage of sites meeting thresholds decreases when moving downstream.

ACTIONS/NEEDS

Bioassessment of macroinvertebrates has become a core element of the regulatory system for protecting water quality in the United States and is a well-established practice in state environmental agencies. Nonetheless, there are some needs which include but are not limited to:

- Encourage refinement of growing datasets as organizations gain experience with the interpretation of data.
- Foster development of methods for more meaningful interstate comparisons.
- Consistent monitoring stations from year to year or on a designated sampling frequency

SUMMARY

Benthic macroinvertebrates are a diverse and important resource within the ecosystem. While they are well known to those involved with water quality and watershed health, their importance is often unrecognized, or they are not considered for targeted management. It is expected that macroinvertebrates thrive best when water pollution is reduced and their natural aquatic habitats are protected and restored. The status of this indicator remains Very Good with a Neutral trend.

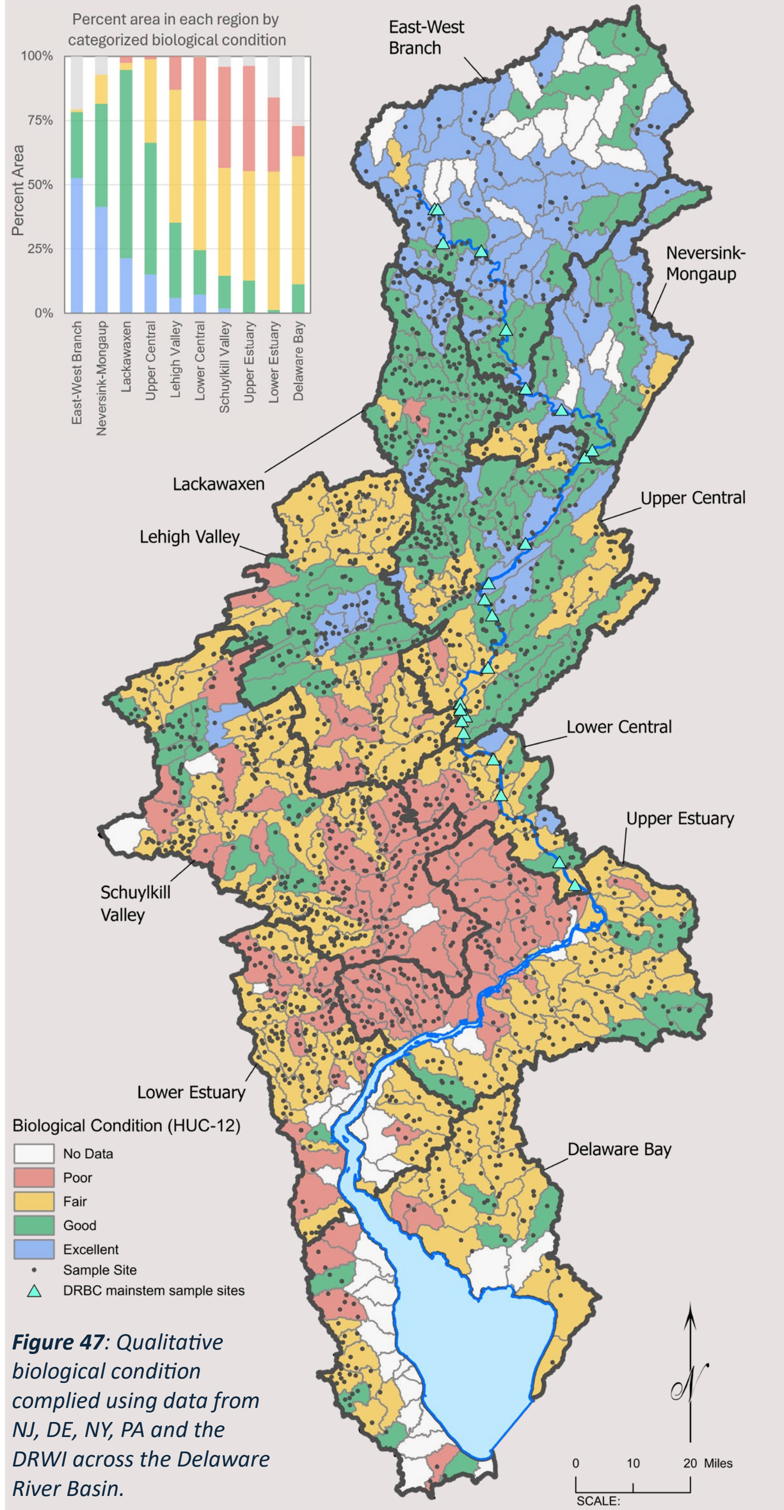


Figure 47: *Qualitative biological condition complied using data from NJ, DE, NY, PA and the DRWI across the Delaware River Basin.*

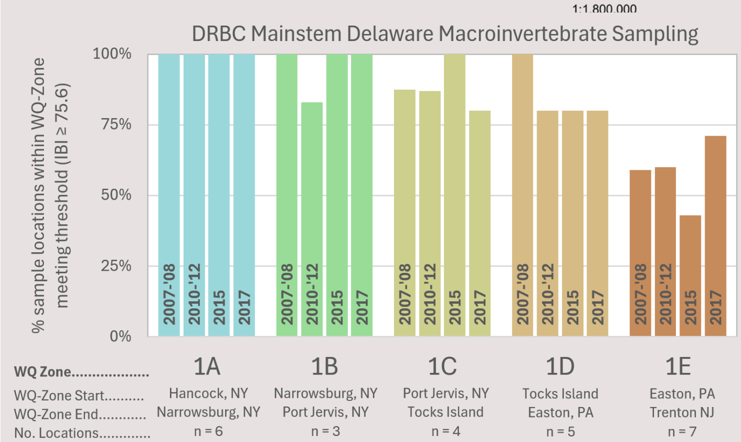


Figure 48: *Biomonitoring data collected by the DRBC along the mainstem Delaware River, aggregated into WQ Zones and presented by year.*

Eastern oysters fuse together as they grow to build essential natural habitats.
Photo © Andrea Benville | iNaturalist | (cropped)

EASTERN OYSTER

DESCRIPTION

The eastern oyster (*Crassostrea virginica*) is a keystone species in the Delaware Bay. Oysters build reefs in the benthic layer and create structural complexity in an environment otherwise dominated by sand and mud. Initially spawning as a free-swimming larva, they will attach to a hard substrate within a few weeks and grow over 3–6 years to reach a marketable size. They stabilize sediments and create habitats for other species by forming oyster beds (reefs). In addition to providing habitat for many species, oysters filter large quantities of water which enhances nutrient cycling within a system. Like other bivalve mollusks, oysters are sensitive to degraded water conditions and are recognized as a bioindicator of environmental conditions. The vast majority of oyster populations exists on reefs and beds in the upper portion of the Bay. About 90% of the oysters in this region occur on the New Jersey side of the Bay (Morson et al. 2022).

PRESENT STATUS

Oysters are great indicators of water quality and overall ecosystem health. The Rutgers Haskin Shellfish Research laboratory (HSRL) annually monitors 23 oyster beds in the Delaware Bay off the New Jersey coast, grouped into six management regions based on natural mortality rates, following the Bay's salinity gradient (Figure 49). Each oyster bed is subdivided into a ~25-acre grid where each grid cell is assigned a "strata designation" of high quality, medium quality or low quality (which loosely correlates to oyster population density). Each year HSRL uses a uses a standard 1.27m commercial oyster dredge to sample various medium- and high-quality grid cells in each oyster bed in order to estimate population abundance. As reported in the 2024 Stock Assessment Workshop Report, 244 grids were sampled in 2023 leading to conclusions that the overall population abundance increased from 2022 (still remaining below target reference points), and the natural mortality decreased (Bushek et al. 2024).

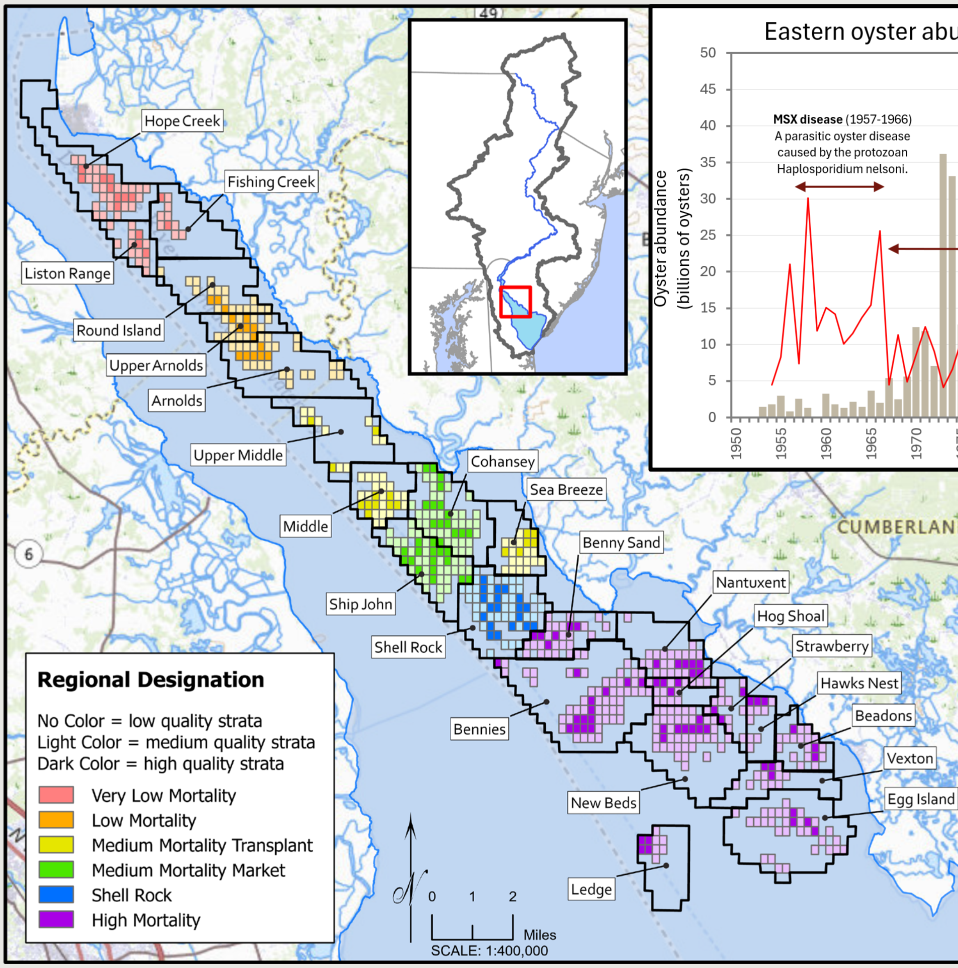
TRENDS

Population. Surveys of commercial oyster beds on the New Jersey side of the Delaware Bay have been conducted since 1953 (Fegley et al. 2003), as is shown in Figure 50. Two diseases lethal to oysters but which are not harmful to humans have greatly affected historical oyster populations in the Delaware Bay:

a. "MSX" (Multinucleated Sphere Unknown) disease first appeared in the Delaware Bay in 1957 and caused increased mortality through the mid-1960s. However, oysters in the Delaware Bay have developed a high level of resistance to MSX through natural selection (Ford and Bushek 2012).

b. "Dermo" is a disease caused by the protozoan *Perkinsus marinus*, and was typically infrequent among oyster beds in the Delaware Bay prior to 1990. However, in 1990 an epizootic of Dermo began and has been attributed to a regional warming trend that allowed for the northern spread of *P. marinus* from warmer southern waters (Ford and Tripp 1996; Cook et al. 1998; Bushek et al. 2012). The two most influential environmental factors on Dermo prevalence are temperature and salinity. Regarding temperature, *P. marinus* proliferates within, spreads between and kills oysters most rapidly at temperatures above 25°C (Ford and Tripp 1996). Regarding salinity, Bushek et al. 2012 noted a that Dermo prevalence and mortality shared a direct relationship with increased salinity, and an inverse relationship with mean annual freshwater inflow to the bay from the Delaware River.

As noted in HSRL's Oyster Seedbed Monitoring Program 2023 Status Report, the current picture of oyster populations in the Delaware Bay continues to be one of improvement, but remains highly dependent on environmental conditions in any given year, such as water temperature, salinity and Delaware River discharge (Bushek et al. 2012).



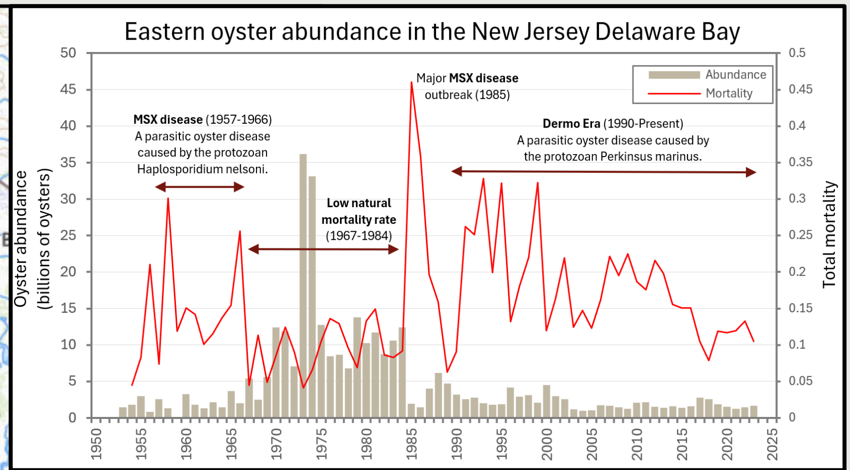


Figure 50*: A time series of total oyster abundance in the New Jersey portion of the Delaware Bay (left axes) compared to natural mortality rate (right axis). Note that the very low mortality region is not included in this data as it was not surveyed until 2007.*

Figure 49*: A map of oyster bed strata designation in the Delaware Bay (New Jersey portion), based on 2024 data provided by Rutgers University Haskin Shellfish Research Laboratory (HSRL). Each of the 23 oyster beds are labelled and outlined in black. Oyster beds are classified into one of six regional designations based on long-term disease mortality patterns and management categories (indicated by color in the legend). The color intensity indicates what quality the strata is within each grid cell.*

Commercial harvesting. Historically, fishing has been only a small fraction of total mortality as compared to natural mortality (Bushek et al. 2024). Market-sized oysters can be directly harvested from oyster beds in the lower three regions (Figure 49), and oysters of all sizes can be "transplanted" from the upper three "Transplant Regions" to enhance the abundance and harvest quotas of the lower three "Direct Market Regions". This direct market fishery program is regulated under N.J. Admin. Code § 7:25A-2, which also stipulates the setting of annual quotas. In 2023, the post-transplant quota was ~94,200 bushels (with a long-term average of about 270 oysters/bushel); the total market harvest in 2023 was 95,661 bushels. Upon review of the oyster stock abundance, the harvest time series, and management practices from 1996 to present, the 2024 Stock Assessment Review Committee recommended continued acceptance of the following statement:

> *The New Jersey Delaware Bay oyster fishery is sustainable under current fishery management strategies and prescribed exploitation rates.*

Shellplanting. Oysters create their own habitat; therefore, available shell, whether as natural reef or "planted", is critical to oyster population resiliency and growth. Shellplanting is the addition of clean, recycled shell to the bay bottom to provide attachment surfaces for oysters, and has been recognized as a critical component to sustainable management (Burt et al. 2023). Over time, shellplanting in the Delaware Bay has occurred with varying regularity and intensity, typically tied to available funding. One current effort is an agreement between PDE, the Philadelphia Water Department, and local restaurants to run an oyster shell recycling program.

ACTIONS/NEEDS

- Continue annual survey of the oyster population and oyster disease in the Delaware Bay.
- Improve and enhance habitats through shellplanting.
- Continue monitoring temperature and salinity in the Delaware Bay.

SUMMARY

The eastern oyster is an important living resource within the Delaware River Basin that helps sustain a diverse ecosystem by creating habitat, contributing to water quality improvement, and providing socioeconomic benefits to the Basin community. Historical population abundance has largely been controlled by natural mortality rates and distinct periods of disease. Recently, populations have been relatively stable (although below management target reference points); however, continued changes to the environment such as sea level rise and climate change pose future threats. The status of this indicator remains at Fair with an Improving trend.

A blue crab walking along soft substrate.
Photo © Joshua Rapp Learn | iNaturalist

BLUE CRAB

DESCRIPTION

The blue crab (*Callinectes sapidus*) can be literally translated from its Latin name as the beautiful (*calli*) swimmer (*nectes*) that is savory (*sapidus*). Blue crabs live in estuarine habitats throughout the western Atlantic Ocean. They spawn primarily in the summer months in the mid to lower Delaware Bay. The larvae from crabs are transported from the Delaware River Estuary to the coastal ocean during zoeal development and return to the Delaware Bay via wind-driven flows. **Ecologically**, blue crabs are an important link in the food web because they are opportunistic benthic omnivores, meaning they feed on things such as bivalves, fish, crustaceans, plant material and detritus (Guillory et al. 2001). Consequently, blue crabs have been shown to affect the broader infaunal community (aquatic animals living in substrate, such as soft sediment) through the predation of bivalves, but also disturbance of the sedimentary habitats while foraging (Virnstein 1977). Additionally, there are more than 60 known fish species that prey on blue crabs. **Economically**, blue crabs are by far the most valuable commercial fishery species in the State of Delaware, and while the State of New Jersey has a much larger commercial fishery, blue crabs are consistently among the top five most valuable species.

PRESENT STATUS

The State of Delaware has monitored blue crab populations since 1978. Notably, a three-fold increase in commercial landings over 1985–1995 reaching a peak of 12.7 million pounds (1995) raised concerns of overfishing and stock sustainability (Figure 51C). In 1998, the State of Delaware passed legislation directing the DNREC Division of Fish and Wildlife (DDFW) to prepare a fishery management plan and perform stock assessments (Wong 2022). As such, DDFW collects biological information and references year-round landings reports to assess the size and status of blue crab stock to make informed management decisions for both recreational and commercial fishing industries.

Stock assessments of the Delaware Bay blue crab are performed annually by DDFW, in collaboration with the State of New Jersey, funded by the NOAA Atlantic Coastal Act grant – most recently published in 2024 covering the year 2023 (Wong and Wasserman 2024). Notable highlights from the assessment include:

- A catch-survey population model is used by DDFW to estimate the absolute abundance of blue crabs in the Delaware Bay (as well as fishing mortality rates and exploitation rates) based on methods outlined in Collie and Sissenwine 1983. Estimates of total abundance had been above the long-term median for seven years (2015-2021), but dropped below in 2022 and declined again in 2023 as shown in Figure 51B. The 2023 estimate of Delaware Bay juvenile and adult blue crabs is 70 and 23 million crabs respectively, which are below respective long-term medians of 95 and 27 million crabs.
- A fishery-independent trawl survey is run by DDFW, operating monthly from April through October, to collect unbiased measures of abundance and size distribution.

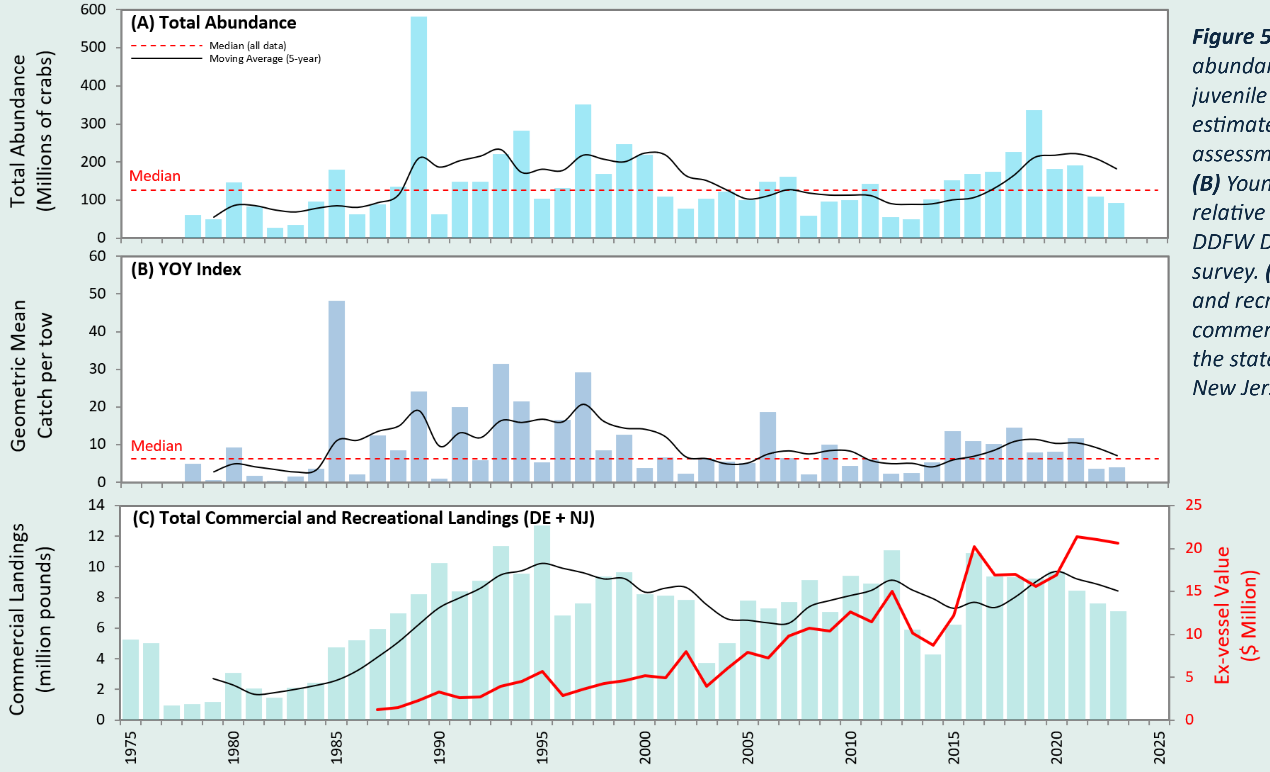


***Figure 51**: **(A)** Absolute abundance (on Sep 1) of both juvenile and adult blue crabs estimated from a population assessment model. **(B)** Young-of-year blue crab relative abundance from the DDFW Delaware Bay trawl survey. **(C)** Total commercial and recreational harvest and commercial ex-vessel value in the states of Delaware and New Jersey.*

These data are used to calculated seven "indices of relative abundance", such as young-of-year (YOY) recruitment which gives an idea of the prior seasons' spawning success. The YOY-index was above average for seven years (2015-2021); however, it dropped below the long-term median in 2022. The index increased slightly in 2023, but remains below the long-term median (Wong and Wasserman 2024).

- Combined commercial landings for Delaware and New Jersey declined below the median levels in 2023; however, the ex-vessel value remained at a time-series high level of about $20.6 million.

SUMMARY

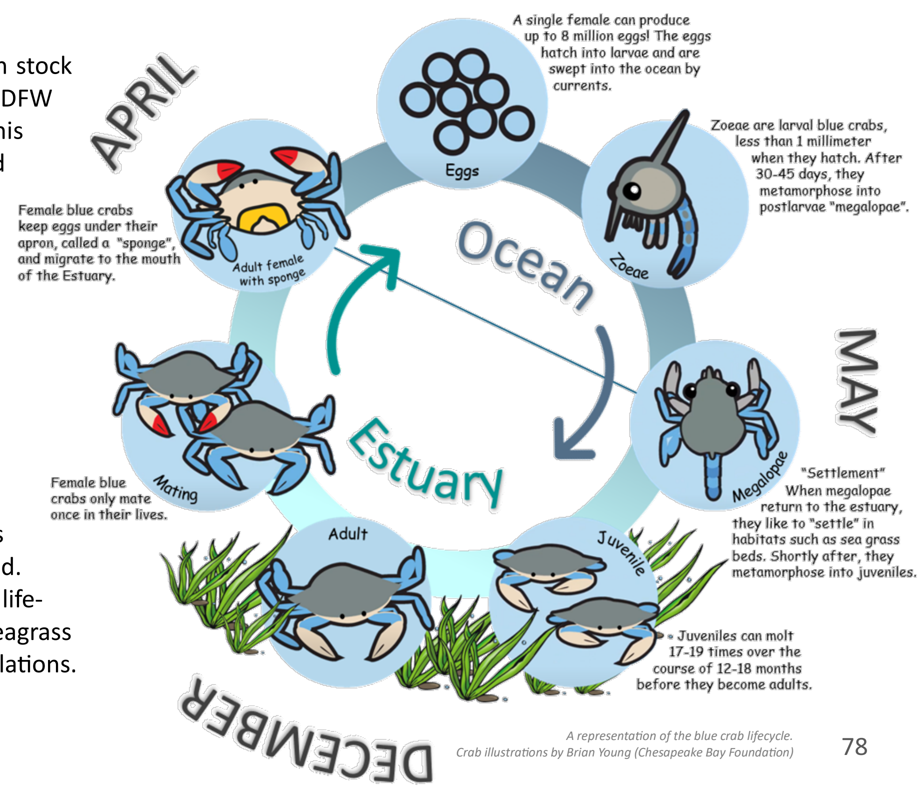
Recent levels of blue crab exploitation rates have been high; however, juvenile recruitment has rebounded and has increased adult stock abundance. Currently, the blue crab stock in the Delaware Bay is at healthy levels of abundance and fishing mortality rates have been estimated to be below management thresholds. Based on the reviewed metrics for blue crabs in this report, the indicator status remains Good, but the trend is reversed to a Declining trend.

TRENDS

Within the Delaware Bay, there was a period of high stock productivity for about 15 years (1985-1999) where DDFW indices were generally at or above median levels; this was followed by a period of lower recruitment and total abundance, also spanning approximately 15 years (2000-2014) (Wong 2022). Recent data since 2014 suggest a return to a high stock productivity regime, characterized by higher recruitment and abundance.

ACTIONS/NEEDS

To protect the high abundance of blue crab populations and maintain low levels of fishing mortality, continued fishery-independent monitoring of stock abundance through trawl surveys and accurate reporting of fishery landings are required. Habitat preservation and restoration for critical life-history stages, particularly in nursery grounds in seagrass beds, is crucial to continue to protect blue crab populations.



A representation of the blue crab lifecycle.
Crab illustrations by Brian Young (Chesapeake Bay Foundation)

Osprey observed in the Fortescue Fish and Wildlife Management Area in New Jersey.
Photo © Stephen John Davies | iNaturalist

OSPREY

DESCRIPTION

Osprey (*Pandion haliaetus*) are a large bird of prey with an average wingspan of five to six feet. They occur near rivers, lakes and the coast (e.g., estuaries and salt marshes) as their diet is almost exclusively fish. Consequently, they are also a migratory species, spending warmer months in habitats such as the Delaware Bay and travelling south during colder months when water freezes and cold temperatures move fish into deeper waters (HM 2024). They arrive in the Delaware Bay in early March, and typically begin nesting near large bodies of water by mid-March. They are known to use a variety of nesting sites, including live or dead trees, man-made platforms, utility poles or even channel markers. Osprey are good indicators of the health in an aquatic ecosystem because they are widely distributed and at the top of the food web, exposing them to accumulated concentrations of contaminants.

PRESENT STATUS

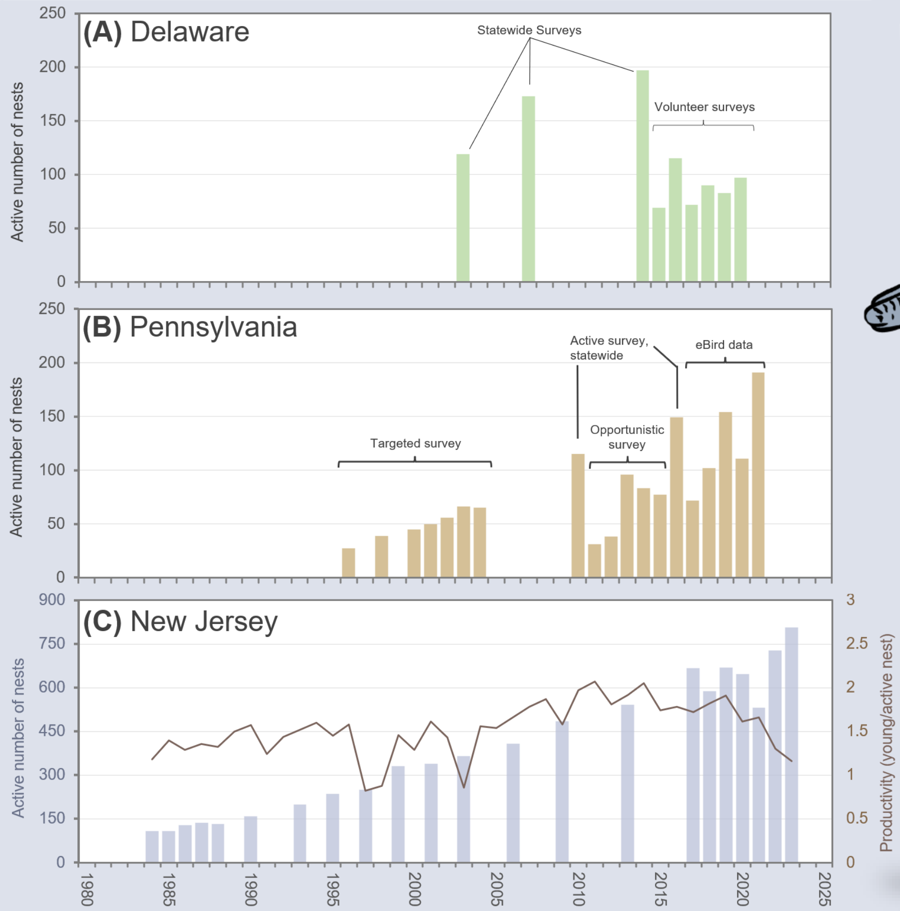
The most recent survey of active osprey nests in Delaware, Pennsylvania and New Jersey are provided in Figure 52. Notably, the datasets in Delaware and Pennsylvania may be heavily influenced by the method of survey conducted and have consequently been annotated to some extent.

The Cornell Lab of Ornithology manages the eBird website (Link), which houses data documenting bird distribution, abundance, habitat use and trends; specifically, there are data related to the osprey (Link) (Fink et al. 2023). Notably, the eBird Observational Dataset is uploaded annually to the Global Biodiversity Information Facility (GBIF) – whereby observations of osprey throughout the Delaware River Basin can be queried. And while an observation of an osprey has quite a different meaning than an active nesting pair, observations recorded in 2023 clipped to the Delaware River Basin totaled almost 25,000 (DE: 8,186; NJ: 7,516; NY: 161; PA: 9,073) (GBIF 2024).

TRENDS

Osprey populations declined drastically as a result of exposure to the chemical dichlorodiphenyltrichloroethane (DDT) during the 1950s through the 1970s. While the osprey was never listed under the Endangered Species Act of 1973, as a migratory bird, the osprey is still federally protected under the U.S. Migratory Bird Treaty Act (50 CFR Part 10.13). Similarly, individual states have implemented different management efforts, including the establishment of conservation designations:

- **In New Jersey**, osprey populations declined to about 50 nesting pairs in the early 1970s, and osprey were listed as a state endangered species in 1974. By 1984 there were 108 nests observed, and the designation was changed to "threatened" in 1985 (Clark and Jenkins 1993). Annual monitoring reports from NJDEP and the Conserve Wildlife Foundation of New Jersey are available online (Link) – nesting data are summarized on Figure 52C. The most recent 2023 report documented 808 occupied nests across the state, the highest in the program's history; however, it also documented one of the worst breeding seasons in years (low nest productivity rates), attributed to severe weather which limited the availability of prey during the nesting period (Wurst and Clark 2024). In January 2025, NJDEP adopted regulatory changes to delist the osprey (Link).
- **In Pennsylvania**, the osprey was declared extirpated from the state in 1982; following reintroduction efforts the osprey was added to the state's endangered species list in 1985. The nesting population expanded widely in the 1990s, and by 1999 the Pennsylvania Game Commission upgraded the osprey to threatened status (Master et al. 2015). In 2017, osprey populations in Pennsylvania met the objectives of the Management Plan for osprey in Pennsylvania (2015-2025). Consequently, osprey were removed from the threatened species list, but remain a protected species (47 Pa.B. 1467).



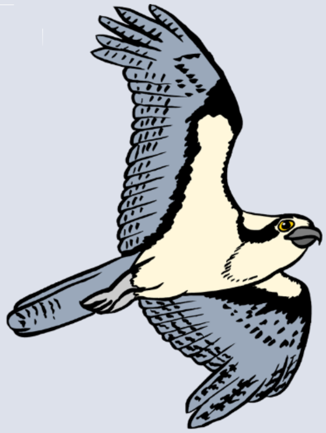


***Figure 52**: Survey data for osprey nests from respective states. **(A)** In Delaware, statewide surveys are more comprehensive than those performed by volunteers (Delaware Citizen Osprey Monitoring Program). **(B)** Pennsylvania data are collected from Pennsylvania Game Commission Wildlife Management Annual Reports (Link) and reflect different levels of effort as indicated. "Targeted surveys" reflect data obtained from specific cooperating organizations which monitor osprey populations on a localized basis. "Opportunistic surveys" are data reported online via volunteers and cooperating organizations. **(C)** New Jersey data as reflected in the 2023 New Jersey Osprey Project Report (Wurst and Clark 2024).*

- **In Delaware**, under Title 7 Regulation 3900 of Delaware's Administrative Code, the initial list of state endangered species was adopted in 2000 (3 DE Reg. 1738), and the initial list of Species of Special Concern was adopted in 2002 (6 DE Reg. 536). The osprey was not listed as a state endangered species, but as it is a raptor (bird of prey) it is considered a Species of Special Concern. While data are limited, the available statewide survey results suggest similar trends as observed in the other two states (Figure 52).
- **In New York**, the osprey was listed as a state endangered species in 1976, downgraded to threatened in 1983, and downgraded once again to "Special Concern" in 1999 (NYSDEC 2024). However, the majority of osprey in New York do not reside within the Delaware River Basin as they are located near the coast (e.g., Long Island).

In general, osprey populations have rebounded due to the reduction of contaminants in the environment as well as other conservation actions. Osprey nesting has increased in both the Delaware Bay and the Delaware River, as evidenced by the trends discussed on a state-by-state basis. However, as noted by the NJDEP 2023 Osprey Report, the 2022/2023 seasons were some of the least productive for osprey in recent history – attributed to difficulty finding and catching prey due to severe weather (such as storms increasing wave action and turbidity). It's possible that inland osprey (such as those residing along the Delaware Bay and River) could be insulated from such coastal effects making them an important part of population resiliency.

ACTIONS/NEEDS

Osprey populations have continued to increase over time, but active protection efforts are required to maintain productivity and growth of the population. Efforts include continued installation and maintenance of nesting platforms as well as efforts to minimize legacy contaminants such as PCBs and DDT metabolites to reduce the risk of biomagnification for osprey. It is apparent that food availability can have drastic effects on productivity rates which are essential to maintain healthy osprey populations. Understanding the effects of fishery management, climate change, and severe weather patterns during breeding seasons is important.

SUMMARY

As a bird of prey high on the food chain, osprey continue to serve as an important indicator of ecosystem health. Populations were drastically reduced by the 1970s (attributed to widespread use of the pesticide DDT) but have since rebounded as a result of conservation and management efforts. The success of osprey conservation is reflective of both sound environmental management practices and volunteer support. The current state of osprey populations in the Delaware River Basin appears to be at healthy levels, resulting in many conservation statuses being lifted. The indicator status for this report remains at Very Good, but based on possible emerging trends in productivity, the trend has been changed to Neutral.

American eelgrass in flowing water.
Photo © lauzude | iNaturalist | (cropped)

SAV (Submerged Aquatic Vegetation)

DESCRIPTION

Submerged aquatic vegetation (SAV) is an important component of a healthy aquatic ecosystem. Juvenile fish use SAV as nursery habitat during this critical developmental period and freshwater mussels are often found co-occurring with SAV beds. Additionally, SAV beds provide physical services such as shoreline stabilization, carbon sequestration, nutrient filtration, sediment entrapment and wave energy dissipation. Like its terrestrial counterpart, aquatic vegetation requires specific conditions to thrive, including clear water that allows light penetration, suitable substrates, and an appropriate nutrient balance.

PRESENT STATUS

SAV is present throughout the mainstem Delaware River and Estuary from the headwaters down to the salt line. It is common in the non-tidal Delaware River, where shallow, clear waters allow sunlight to penetrate to the bottom, nourishing beds of SAV. In the Delaware River Estuary, SAV beds occur in habitats where water is deep enough to be inundated at low tide, but shallow enough to allow light penetration at high tide.

Notably, recent USEPA surveys in 2017, 2018 and 2019 have documented healthy SAV beds in the upper Estuary from the head of tide (Trenton, NJ) downstream to the Delaware Memorial Bridge. While plant identification was not a focus, studies did note species such as American eelgrass (*Vallisneria americana*), hornwort (*Ceratophyllum demersum*), southern waternymph (*Najas guadalupensis)*, horned pondweed (*Potamogeton cornutus*)*,* and invasive species like hydrilla (*Hydrilla verticillate*). Surveys found no SAV downstream of the Delaware Memorial Bridge in saline habitats (Somers and Mansolino 2022). A full interactive map of the SAV survey results can be accessed online (Link).

The most recent 2019 survey used a single beam echosounder to detect and quantify the presence of SAV (Figure 53). Signal data from the echosounder were correlated to "percent vegetative cover" values (individual underwater points were evaluated and classified by the USEPA Scientific Dive Unit (Figure 54) to build a calibration curve for all signal data). Navigating a research vessel throughout the survey boundary like a lawnmower helped to create a broad picture of data to be used by interpretive models (Figure 55 – callout). As evident in Figure 55, the survey boundary was largely restricted to depths around 3m or less (e.g., according to the USDA, eelgrass typically grows at depths 3m or less on the east coast (Murphy et al. 2012)). Figure 55 presents the interpolated results for only a small section of the entire study.

TRENDS

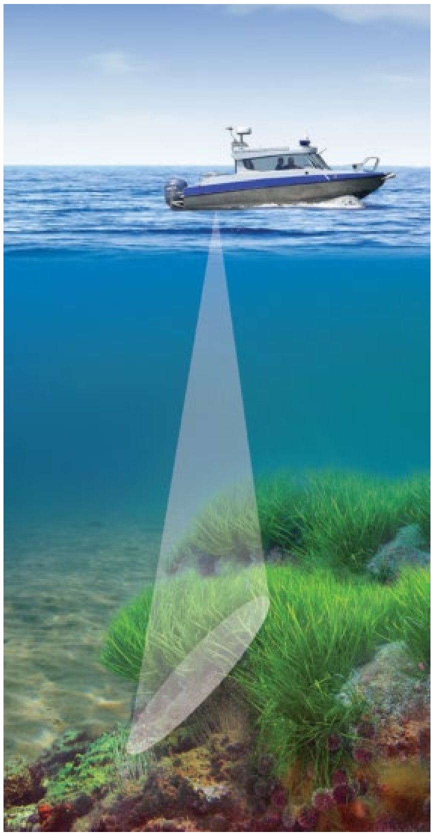
No long-term datasets of SAV exist in the Basin, so it is not feasible to present findings related to trends over time.

ACTIONS/NEEDS

- Continue monitoring SAV in the Estuary to develop a long-term dataset for trend analysis.
- Initiate monitoring of SAV in the non-tidal Delaware River to track changes in SAV beds.

SUMMARY

The Technical Report for the Estuary and Basin (TREB) included SAV as a pilot indicator; likewise, this is the first time SAV has been included in the State of the Basin Report. As a critical component of the Basin ecosystem, it will likely prove to be a useful indicator as long as research continues. The indicator status for this report is set at Good with a Neutral trend.



Scanning the substrate

***Figure 53**: Example of a single beam echosounder sending pings down the water column (image from BioSonics). This scientific equipment was used by USEPA during the 2019 SAV survey to detect the presence of SAV based on the return signal from the echosounder. The boat is used like a lawnmower within the study area to obtain a broad coverage of data (call-out in Figure 55).*

Diving into model calibration

***Figure 54**: Each survey point returns a signal, which is correlated to a percentage of plant cover via calibration using square grids corresponding to sample points. Staff from the USEPA Scientific Dive Unit perform the visual inspections underwater.*

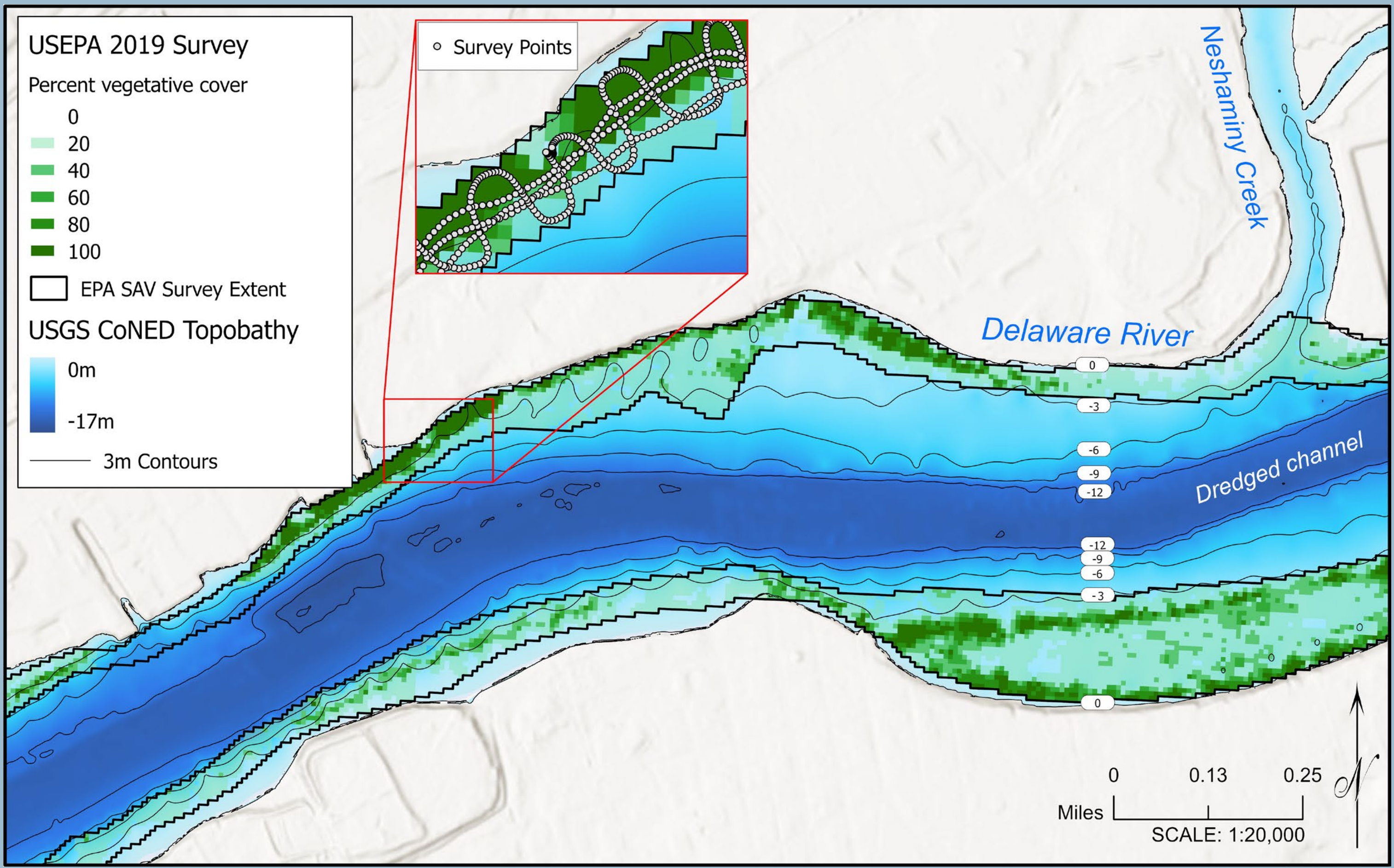


***Figure 55**: The USEPA performed a study on the tidal Delaware River to quantify SAV using a single beam echosounder; the results shown in this figure are from the 2019 survey. The approximate survey boundary is shown as the black outline, typically following the approximate 3m depth contour. Discrete data points (echosounder signals) are collected and calibrated to a percentage of vegetative cover.*

Common carp observed in Darby Creek, Pennsylvania.
Photo © Eric Vitols | iNaturalist | (cropped)

INVASIVE SPECIES

DESCRIPTION

Invasive species are animals, plants or other organisms introduced (intentionally or accidently) into habitats outside their natural environment. Their introduction into new habitats is currently one of the greatest impacts to biodiversity and species extirpation, particularly for ecosystems that have been weakened by pollution, climate change and habitat fragmentation. Invasive species often have the advantage of outcompeting or predating on native species that have naturally evolved to fill a particular habitat which has specific amounts of sunlight, water, and minerals. Their occupancy generally results in detrimental ecological, socioeconomical and in more severe situations, human health impacts.

Presently, horticulture is one of the most common reasons for the introduction of a new species. Other species are generally introduced through means of farming, hunting, fishing or even as new exotic pets. Transportation of invasive species is not always intentional, for example, some species have been introduced merely by accident such as boaters inadvertently transporting them through bait buckets, live wells or in ballast water. In addition, climate change will enable some invasive species to continue to expand their non-native range as a result of increased average temperatures and changes to precipitation patterns. Taking advantage of drought-weakened plants, insect infestations could be more severe. Several plants species increase their chances of survival by secreting harmful chemicals into soils as a defense mechanism, which can limit the growth of other plant species. Warmer oceans, rivers and lakes will reduce cold-water fisheries and increase the range of more tolerant species, such as carp and catfish, or non-native species may begin hybridizing with native species.

PRESENT STATUS

The Delaware River Basin offers a diverse number of habitats for invasive species to occupy. Table 3 shows only some of the many invasive species of concern currently found in the Basin, some of which may become introduced to the Delaware River in the coming years. Presently, many stewardship, restoration and management plans have been initiated throughout each state to: increase awareness of the risks posed by invasive species, identify new invasive species soon after their arrival, control established invasive species, and eliminate invasive species from key areas to prevent their spread.

TRENDS

It is likely that as climate change continues, invasive species may increasingly thrive and new invasive species may be introduced. However, government and non-profit organizations have begun working together to drive management and action plans. Presently, all Delaware River Basin states have their own invasive species councils, cooperate in rapid response initiatives, and utilize volunteers and the public to help identify and stop the spread of these species.

ACTIONS/NEEDS

- Implement management and eradication of exotic invasive plants and replace them with species native to Delaware, New Jersey, Pennsylvania, and New York.
- Increase the density and diversity of native plants in riparian zones, forests and other areas.
- Construct new wetlands, and restore and expand existing wetlands.
- Inform citizens of invasive species found within the Delaware River Basin and how to properly handle the spread of such species after recreation. If individuals find what they think is an invasive species in the Delaware River Basin, they should contact respective State Agencies (documenting with pictures and coordinates).

Invasive Species Contact Information

Delaware DNREC Division of Fish and Wildlife's website

NYSDEC, Division of Lands and Forests, Bureau of Invasive Species and Ecosystem Health

NJDEP Invasive Species Resources

Pennsylvania Governor's Invasive Species Council

National Invasive Species Information Center (NISIC)

Nonindigenous Aquatic Species (NAS) Information Resource

Mud snails crawling on aquatic vegetation. Photo © Alex Bairstow | iNaturalist | (cropped)
A spotted lanternfly on a tree. Photo © Mila Barreto | iNaturalist | (cropped)
A northern snakehead guards its young. Photo © drennack | iNaturalist (cropped)

***Table 3**: Commonly found invasive species and species of concern throughout the Delaware River Basin.*

COMMON NAME	SCIENTIFIC NAME
AQUATIC VEGETATION	
Creeping Primrose	*Ludwigia peploides*
Brazilian Waterweed	*Egeria densa*
Didymo (Rock Snot)	*Didymosphenia geminata*
Eurasian Watermilfoil	*Myriophyllum spicatum*
Hydrilla	*Hydrilla verticillata*
Parrot-Feather	*Myriophyllum aquaticum*
Water Chestnut	*Trapa natans*
Water Hyacinth	*Eichhornia crassipes*
RIPARIAN AND UPLAND VEGETATION	
Autumn Olive	*Elaeagnus umbellata*
Common Reed	*Phragmites australis*
Garlic Mustard	*Alliaria petiolata*
Honeysuckle Spp	*Lonicera spp*
Japanese Barberry	*Berberis thunbergii*
Japanese Stiltgrass	*Mycrostegium vimineum*
Knotweed	*Polygonum spp*
Multiflora Rose	*Rosa multiflora*
Norway Maple	*Acer platanoides*
Oriental Bittersweet	*Celastrus orbiculatus*
Poison Hemlock	*Conium maculatum*
Purple Loosestrife	*Lythrum salicaria*
Tree of Heaven	*Ailanthus altissima*
Wineberry	*Robus phoenicolasius*
Yellow Flag Iris	*Iris pseudacorus*
INVERTEBRATES	
Asian Clam	*Corbicula fluminea*
Asian Longhorn Beetle	*Anoplophora glabripennis*
Asian Shore Crab	*Hemigrapsus sanguineus*
Asian Tiger Mosquito	*Aedes albopictus*
Chinese Mitten Crab	*Eriocheir sinensis*
Chinese Pond Mussel*	*Sinanodonta woodiana*
European Periwinkle	*Littorina Littorea*
Green Crab	*Carcinus maenas*
Gypsy Moth	*Lymantria dispar dispar*
Hemlock Woolly Adelgid	*Adelges tsugae*
New Zealand Mud Snail	*Potamopyrgus antipodarum*
Red Swamp Crayfish	*Procambarus clarkii*
Rusty Crayfish	*Orconectes rusticus*
Spotted Laternfly	*Lycorma delicatula*
Virile Crayfish	*Orconectes virilis*
Zebra and Quagga Mussels	*Dreissena spp.*
FISH	
Asian Swamp Eel*	*Monopterus albus*
Common Carp	*Cyprinus carpio*
Bighead and Silver Carp*	*Hypophthalmichthys spp.*
Blue Catfish	*Ictalurus furcatus*
Flathead Catfish	*Pylodictis olivaris*
Freshwater Drum	*Aplodinotus grunniens*
Grass Carp (Triploid)	*Ctenopharyngodon idella*
Northern Snakehead	*Channa argus*
Oriental Weatherfish	*Misgurnus anguillicaudatus*
Round Goby*	*Neogobius melanostomus*
REPTILES	
Red-Eared Slider	*Trachemys scripta elegans*
Yellow-Bellied Slider	*Trachemys scripta scripta*
TERRESTRIAL ANIMALS	
European Starling	*Sturnus vulgaris*
Feral Swine	*Sus scrofa*
Mute Swan	*Cygnus olor*
Nutria	*Myocastor coypus*

**Reported in the Basin, but not yet reported in the Delaware River.*

For the first time since publications began in 2008, the 2025 State of the Basin includes a section on Diversity, Equity, Inclusion, Justice, and Belonging (DEIJB). In future reports, DRBC will assess progress on DEIJB in relation to Basin water resources. Though they are connected, DEIJB and Environmental Justice (EJ) are two distinct concepts. In this chapter, "DEIJB" will be used to refer to broad, foundational considerations of justice and equity work; environmental justice, by contrast, is the goal aimed at addressing systemic and disproportionate environmental impacts on certain communities. The chapter provides a non-exhaustive snapshot of milestones in these areas from the last five years.

Chapter 6

DIVERSITY, EQUITY, INCLUSION, JUSTICE, AND BELONGING

Rowing on the Schuylkill River.
Photo © Michael Stokes

Women's rowing team, focus on the foremost oar.
Photo © Geoffrey Kuchera | Dreamstime

DEIJB

DESCRIPTION

Since the last State of the Basin report, each of the Commission's member states and the federal government developed, advanced and in certain cases, rescinded, a tool or tools to assess environmental justice and socioeconomic burdens, according to their distinct chosen indicators. DRBC has not yet adopted or created a methodology for identifying disadvantaged communities on a Basin scale.

The federal Climate Change and Environmental Justice Screening tool (CEJST), in use from Nov. 2022 to Jan. 2025, used high-level data to classify communities as disadvantaged. A census tract was classified as disadvantaged if it is "(1) at or above the threshold for one or more environmental, climate, or other burdens, and (2) at or above the threshold for an associated socioeconomic burden."[1]

The Basin states have their own tools to visualize and characterize environmental justice and/or DEIJB considerations. The tools use region-specific indicators to identify the presence of disadvantaged tracts, considering, generally, a nexus between socioeconomic and environmental variables. The tools are as follows:

- New Jersey EJMAP
- Delaware - EJ Area Viewer
- Pennsylvania: PennEnviroScreen
- New York: PEJAs

PRESENT STATUS

Each Commission member advanced significant DEIJB and EJ policy initiatives between 2019 and 2024. State and federal agencies worked to address DEIJB and environmental justice with a whole-of-government approach, with these issues considered within a broader context of agency and programmatic goals, with federal policy shifts beginning in 2025. The inventory below provides insight into key advancements and major milestones from our members.

Federal Milestones

2021 – Executive Order 14008 established the Justice40 Initiative, instructing the Council on Environmental Quality to allocate "40 percent of the overall benefits of certain Federal climate, clean energy, affordable and sustainable housing, and other investments flow to disadvantaged communities that are marginalized by underinvestment and overburdened by pollution."[2]

2021 – Bipartisan Infrastructure Law makes investments in clean drinking water, legacy pollution, public transit, clean school buses, modern and clean infrastructure, and resilience. Central to these initiatives is the advancement of environmental justice and support for the economy.

2023 – Executive Order 14096 **"**Revitalizing Our Nation's Commitment to Environmental Justice for All," notes the Federal Government's duty to uphold health and set significant targets holding environmental justice at the center of this work.

2025 – Executive Order 14148 "Initial Rescissions of Harmful Executive Orders and Actions" rescinds policies including Executive Orders 14008 and 14096.

New York Milestones

2019 – The Climate Leadership and Community Protection Act (CLCPA) passes and requires state agencies to direct between 35 to 40 percent of clean energy and efficiency program, project, or investment benefits to disadvantaged communities in areas including pollution reduction.[3]

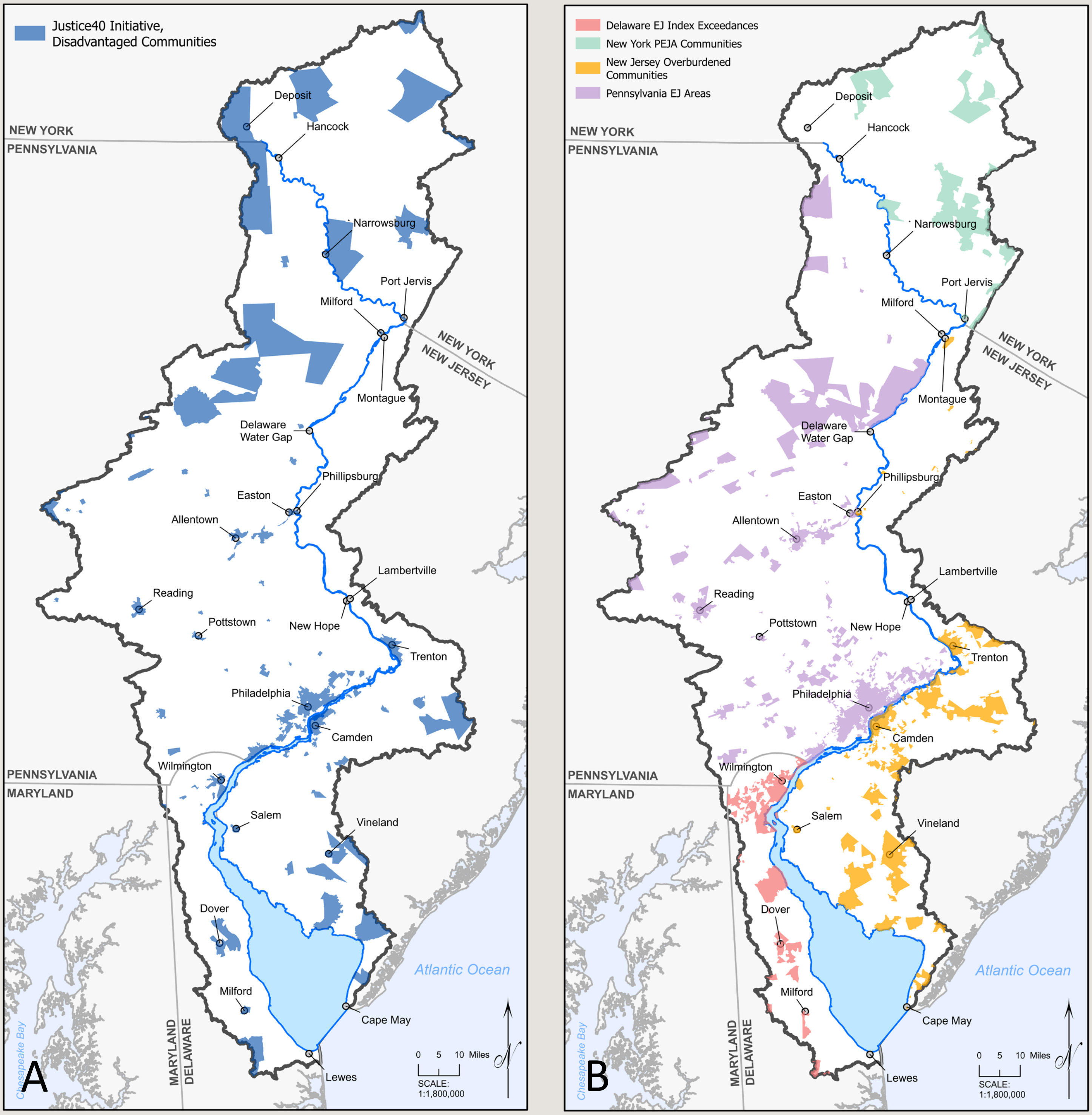


***Figure 56**: **(A)** From 2022-2025, disadvantaged census tracts could be tracked using data from the Climate and Economic Justice Screening Tool (CEJST) developed by the federal Council on Environmental Quality (CEQ). Here, the data are projected over a basin-wide scale. **(B)** The maps show each DRBC state's tool constrained to the portion of the state within the Delaware River Basin. For the purposes of this report, one color is used to represent all qualifying zones, rather than a multi-color gradient.*

2023 – Under amendments to the Environmental Conservation Law (ECL) (Sec. 70-0118), the Department of Environmental Conservation (DEC) may not permit projects that "cause or contribute more than a *de minimis* amount of pollution to a disproportionate pollution burden on the disadvantaged community."[4]

New Jersey Milestones

2020 – The Environmental Justice Law requires DEP to "evaluate environmental and public health impacts of certain facilities on overburdened communities (OBCs) when reviewing certain applications."[5] This law makes NJ the first state to "issue denials for new facilities that cannot avoid disproportionate impacts on OBCs or serve compelling public interest."[6]

2023 – Final regulations implementing New Jersey's landmark EJ Law following a public input process, with a goal of equitable access to "live, work, learn, and recreate in a clean and healthy environment."[7]

Pennsylvania Milestones

2021 – In Executive Order 2021-07, Governor Wolf sets broad targets such as publishing an Environmental Justice strategic plan every 5 years and maintaining an online repository of EJ information and data.

2023 – PADEP adopts its interim final Environmental Justice Policy, which enhances the former Environmental Justice Policy and Environmental Justice Public Participation Policy, both from 2004.

Delaware Milestones

2021 – The Delaware Climate Action Plan, in addition to developing a framework for the state's climate initiatives, calls for equitable climate action through partnerships and community-building.

2021 – Clean Water for Delaware Act applies goals for improving the state's water and wastewater systems to make special consideration for the goal of "increased accessibility to low-income and traditionally underserved communities."[8] Delaware targets low-income communities in this description.[9]

Stakeholder Milestones

Throughout the Delaware River Basin, partner organizations, coalitions, and businesses have played a central role in advancing DEIJB actions. Since the last State of the Basin report in 2019, partners have expanded DEIJB and environmental justice-focused programming and established targeted workgroups that meet regularly to advance these efforts. The following highlight non-exhaustive, noteworthy advancements:

2019 – The Partnership for the Delaware Estuary (PDE) hosts the Urban Waters Federal Partnership (UWFP), focused on four cities within the Delaware River Basin facing disproportionate climate and economic impacts – Camden, NJ, Wilmington, DE, and Philadelphia and Chester, PA. Milestones include a 2024 Environmental Justice Gathering.

2022 – The Camden County Municipal Utilities Authority (CCMUA) begins using odor sensors to detect and address emission hotspots from its wastewater treatment processes. Advancements in this technology were aimed at improving the quality of life for residents who live in close proximity to industrial sites and experience the burdens of environmental and economic stressors.

2024 – The Coalition for the Delaware River Watershed (CDRW) hosts a DEIJ Day of Learning shaped by its DEIJ Work Group and an outgrowth of its DEIJ Screening Tool.

Ongoing – Since 2019, new and expanded outreach and engagement events have been held in overburdened communities throughout the Delaware River Basin. DRBC spotlights many of these events through its outreach, communications, and social media. Partners have noted an increase in multilingual programs and resources, along with internal training, increased staffing and staff reflecting the communities they serve, and policies to promote DEIJB in their own organizations.

DRBC Milestones

In partnership with its members, the Delaware River Basin's regulated community, and partners, the DRBC has advanced efforts to build DEIJB considerations into its work.

2022 – DRBC approves an updated *Vision, Mission, and Values* statement to express the Commission's commitment to DEIJB principles, adding under its values section: "Diversity and inclusion: promoted both as an employer and as a public agency."

2022 – In September 2022, DRBC issued its draft report, Social and Economic Factors Affecting the Attainment of Aquatic Life Uses in the Delaware River Estuary. The report includes residential indicators such as household affordability.

2024 – DRBC's DEIJB Strategic Plan is released, demonstrating the DRBC's commitment to a safe, respectful, and inclusive workplace; environmental justice in regulatory programs; equitable access to the Basin's shared water resources; and meaningful engagement with diverse stakeholders. The Plan sets strategic recommended actions for integrating DEIJB with water resources management, working with the regulated community, and increasing public and stakeholder participation, as well as advancements within DRBC's own workplace.

FUTURE ACTIONS

This State of the Basin report is the first to include a survey of DEIJB status across the basin. As noted above, DRBC's own DEIJB strategic plan was released in 2024.

Future DRBC actions under the plan may include developing metrics to benchmark progress towards meeting the Commission's DEIJB strategic goals. Going forward, reports on progress toward the Commission's DEIJB goals may be included in DRBC's Annual Report, and future actions may be outlined in the annual Water Resources Program.

Additionally, DRBC is evaluating ways of defining baseline conditions and measuring collective progress on DEIJB—the cumulative result of actions by all contributors—in relation to water resources basinwide. Specific indicators may be introduced and assessed in future State of the Basin reports.

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[1] Climate & Economic Justice Screening Tool (Unofficial archive, official site last active Feb. 2025.)
[2] Justice40 Initiative | Environmental Justice | The White House
[3] Investments Benefits Reporting Guidance - New York's Climate Leadership & Community Protection Act (ny.gov)
[4] NYS Open Legislation | NYSenate.gov
[5] NJDEP| Environmental Justice | Environmental Justice Law
[6] NJDEP| Environmental Justice | Environmental Justice Law
[7] Governor Murphy Announces Nation's First Environmental Justice Rules to Reduce Pollution in Vulnerable Communities (nj.gov)
[8] Delaware Code Online
[9] Delaware Clean Water Initiative - DNREC

Bombay Hook National Wildlife Refuge, Delaware.
Photo © Wirestock | Dreamstime

INDICATOR SUMMARY

Sunset over the Delaware Bay, observed from Lewes, Delaware.
Photo © Chad Pindar (DRBC)

1. WATERSHEDS AND LANDSCAPES	2019	2025
POPULATION	No rating	No rating
LAND COVER	No rating	No rating
IMPERVIOUS COVER	Good ↓	Good ↓
2. WATER QUANTITY		
WATER WITHDRAWALS	Good ↔	Good ↔
CONSUMPTIVE USE	Good ↔	Good ↔
GROUNDWATER AVAILABILITY	Very Good ↑	Very Good ↑
WATER LOSS & CONSERVATION	Not in report	Good ↑
FLOW	Good ↔	Good ↔
SALT FRONT	Good ↓	Good ↓
3. CLIMATE CHANGE		
PRECIPITATION	No rating ↓	Good ↔
AIR TEMPERATURE		Good ↓
SEA LEVEL RISE		Good ↓
4. WATER QUALITY		
DISSOLVED OXYGEN	Good ↑	Fair ↔
NUTRIENTS	Very Good ↑	Good ↔
SALINITY *	Not in report	Fair ↓
TEMPERATURE	Good ↔	Good ↔
pH	No rating ↔	Good ↔
POLLUTANTS **	Fair ↑	Fair ↔
EMERGING CONTAMINANTS	Fair ↑	Fair
MICROPLASTICS	Not in report	Poor ↔
HABs (Harmful Algal Blooms)	Not in report	Fair ↔
5. LIVING RESOURCES		
ATLANTIC STURGEON	Poor ↑	Poor ↑
WHITE PERCH	Very Good ↔	Very Good ↓
STRIPED BASS	Very Good ↓	Good ↓
WEAKFISH	Poor ↑	Poor ↔
AMERICAN SHAD	Good ↑	Good ↓
BROOK TROUT	Fair ↑	Fair ↔
AMERICAN EEL	Good ↓	Good ↔
HORSESHOE CRAB	Good ↑	Good ↑
FRESHWATER MUSSELS	Poor ↔	Poor ↔
MACROINVERTEBRATES	Very Good ↔	Very Good ↔
EASTERN OYSTER	Fair ↑	Fair ↑
BLUE CRAB	Good ↑	Good ↓
OSPREY	Very Good ↑	Very Good ↔
SAV (Submerged Aquatic Vegetation)	Not included	Good ↔
INVASIVE SPECIES	Fair ↓	Fair ↓

* In the SOTB 2019 report, the section titled “Salinity” was primarily focused on the salt front; therefore, the assigned grade has been captured in this table under “Salt Front”. In this SOTB 2025 report, the section titled “Salinity” is primarily focused on non-tidal salinity.

** In the SOTB 2019 report, the “Pollutants” section was named “Contaminants” but is considered the same indicator.

The Upper Delaware River and Hawk`s Nest scenic road near Port Jervis, New York
Photo © Mihai Andritoiu | Dreamstime

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Bushkill Falls in Lehman Township, Pennsylvania in the Pocono Mountains.
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