Technical Report for the Delaware Estuary and Basin

2022

Partnership for the DELAWARE ESTUARY

A publication of the Partnership for the Delaware Estuary and the Delaware Estuary Program

Technical Report for the Delaware Estuary and Basin

2022

Partnership for the DELAWARE ESTUARY

The Partnership for the Delaware Estuary, host of the Delaware Estuary Program, leads collaborative, science–based efforts to improve the Delaware River and Bay, which covers portions of Delaware, New Jersey, and Pennsylvania.

Acknowledgments

Funding for development of the Technical Report for the Delaware Estuary and Basin was provided by the Environmental Protection Agency to the Partnership for the Delaware Estuary (PDE), under National Estuary Program Grant Section 320 Grant Funding.

This report was prepared by dozens of individual experts, representing diverse organizations including state and federal agencies, academic institutions, companies, and non-profit entities, who are listed as authors or contributors. Additional thanks go to Angela Padeletti and Elizabeth Horsey, who graciously volunteered to review the entirety of this report before its finalization. We are also grateful to the Delaware Estuary Program's Science and Technical Advisory Committee and Estuary Implementation Committee for marshaling the necessary staff and resources to provide peer review.

Graphics

Cover photographs for this report were taken by Gavin Brown (Chapter 1), LeeAnn Haaf (Chapters 2, 3, 5, and 6), Bill Matulewicz (Chapter 4), and Kate Layton (Chapters 7 and 8).

Aerial photography for maps are courtesy of National Agriculture Imagery Program (NAIP), unless otherwise noted.

Suggested Citation

Partnership for the Delaware Estuary. 2022. Technical Report for the Delaware Estuary and Basin. L. Haaf, L. Morgan, and D. Kreeger (eds). PDE Report No. 22-05. 445 pages.

Abstract

The Technical Report for the Delaware Estuary and Basin (TREB) analyzes the most accessible, comprehensive and recent data on the status and trends of more than 50 environmental indicators, including a diverse suite of indicators that are relevant for water, habitat, and living resources. Taken together, the condition of these indicators reflects the overall environmental health of the Delaware River and Bay, and the watershed that drains into it. This report is produced every five years by the Partnership for the Delaware Estuary, which coordinates the Delaware Estuary Program, a part of the National Estuary Program. The TREB serves as the technical foundation for "State of the Estuary" reports for the public. There are eight key indicator categories: watersheds and landscapes, climate change, water quantity, water quality, sediments, habitats, living resources, and restoration progress. Scientists and managers examined historic, recent, and predicted future changes in each indicator's status to develop an understanding of trends. Finally, this report describes future actions and needs that can strengthen indicator reporting and potentially improve environmental conditions. The results from this assessment suggest that the current health of the Delaware Estuary and River Basin in 2022 is "fair," reflecting a mix of positive and negative trends. The overall assessment of "fair" health is unchanged from TREB 2017, TREB 2012, and the smaller State of the Estuary Report published in 2008.

The land and waterways that we discuss here are part of the traditional territory of the Lenni-Lenape, called

Lenapehoking

The Lenape People lived in harmony with one another upon this territory for thousands of years. During the colonial era and early federal period, many were removed west and north, but some also remain among the continuing historical tribal communities of the region: the Nanticoke Lenni-Lenape Tribal Nation; the Ramapough Lenape Nation; and the Powhatan Renape Nation, the Nanticoke of Millsboro Delaware, and the Lenape of Cheswold Delaware. We acknowledge the Lenni-Lenape as the original people of this land and their continuing relationship with their territory. In our acknowledgment of the continued presence of Lenape people in their homeland, we affirm the aspiration of the great Lenape Chief Tamanend, that there be harmony between the indigenous people of this land and the descendants of the immigrants to this land,

"as long as the rivers and creeks flow, and the sun, moon, and stars shine."

Photo by Hillel Brandes.

Table of Contents

Executive Summary

The purpose of the 2022 Technical Report for the Delaware Estuary and Basin (TREB) is to assess the overall environmental condition of the watershed by examining the status and trends of key indicators that reflect the health of its natural systems. Meeting this goal is challenging because the Delaware River Basin is a large and complex watershed, encompassing more than 35,000 square kilometers (>13,500 square miles) and extending from headwater streams and mountains in New York State to the coastal plain and ocean near Cape May, NJ, and Cape Henlopen, DE. The Delaware Estuary forms the lower 52% of the overall basin. The watershed spans four ecoregions, is home to 8.6 million people, and supplies drinking water to another 5 million in New York City and northern New Jersey living outside the basin. Hundreds of plant and animal species live in balance with people in diverse habitats, including many ecological treasures. The region also has a storied history, starting with rich Native American peoples and extending through the birth of the United States and the Industrial Revolution, up to the present day where it continues to function as a nationally important economic center and strategic port.

Environmental indicators are aspects of the environment which can be quantified and are representative of prevailing local conditions. The approach used in this report was to gather, analyze and interpret the most extensive and recent data for a broad suite of more than 50 indicators that represent different facets of the natural ecosystem, such as water quality, living resources, habitats, land cover, and climate. The last section of the report includes indicators that reflect our progress in preserving and restoring natural systems. When considered together, this indicator-based report provides a comprehensive picture of the status and trends in environmental health of the Delaware Estuary and Basin.

The eight chapters of TREB are organized topically into the following sections: watershed and landscapes, climate change, water quantity, water quality, sediments, habitats, living resources, and restoration. Each section includes a number of different indicators, written by a different set of authors with expertise relevant to the topic. For each indicator, authors present and interpret the most recent available data and summarize any actions and needs that could strengthen future indicator reporting or lead to improved environmental conditions.

On balance, the results from this assessment suggest that the current health of the Delaware Estuary and Basin in 2022 is "fair," reflecting a mix of positive and negative trends. The status of many indicators is good, and others are not so good. Trends for some indicators appear to be improving, while others appear to be worsening. The overall assessment of "fair" health is unchanged from TREB 2017, TREB 2012 and the smaller State of the Estuary Report in 2008.

Although the "fair" overall health assessment is unchanged since 2008, it reflects substantial improvement compared to earlier decades for many key indicators. For example, advances in wastewater treatment and implementation of the Clean Water Act led to dramatic improvement in dissolved oxygen in the river's urban corridor over the past 40+ years. These improvements in many facets of water quality have supported healthier living resources, demonstrated by the propagation of signature species such as sturgeon and increasing public interest in river recreation. Unfortunately, the continued loss and degradation of important habitats and emerging threats associated with climate change could or may undermine the recent recovery. Meanwhile, the human population in the watershed continues to increase, resulting in expanding human activities are likely to increasingly tax our natural resources and require management diligence, especially with regard to water withdrawals, forest cutting, wetland loss, and development. These challenges will be exacerbated by a shifting climate, especially increasing temperature, precipitation, sea level, and salinity. Of particular note, future predictions for many of the key climate indicators in the 2022 TREB reflect a much higher

level of certainty compared to the 2017 TREB, largely because of more robust datasets and stronger recent trends.

Where possible, the future status and trends of indicators are also discussed in the context of the expected increase in human activities and climate change. As one example, warming water (from climate change) holds less dissolved oxygen, which is vital for aquatic animals such as fish. Oxygen deficits can also be exacerbated by excess nutrients from runoff, which in turn fuel microbial respiration. With increased water temperature and potentially greater nutrient runoff from more people, it is plausible to expect the trajectory of past improvements in dissolved oxygen conditions to reverse course. Therefore, even more effort to manage dissolved oxygen will be needed as compared to the past. This report includes many other similar examples of past successes and emerging threats.

The cumulative impacts to natural resources from both anthropogenic alterations and shifting climate conditions are difficult to predict. Hence, continued careful monitoring of the indicators reported in this report will be critical so that environmental managers can make adaptive decisions to maintain crucial life-sustaining ecosystem services, which are worth billions of dollars per year. Specifically, to address future environmental challenges while preserving prosperity in the region, agencies, scientists, and others must work together to:

- Sustain and strengthen the effectiveness of monitoring, protection and restoration efforts by focusing on a set of shared, strategic priorities
- Set science-based goals that plan for change as part of the natural landscape
- Adopt realistic environmental targets that focus on preserving and enhancing key life-sustaining features
- Apply an ecosystem-based approach to management that considers cumulative impacts and ecological linkages
- Facilitate collaboration among states, federal agencies and other sectors to implement the Delaware Esturary Comprehensive Conservation and Management Plan (CCMP), which was updated in 2019. The CCMP is a guiding document developed by partners involved with the Delaware Estuary Program, which is the congressionally designated National Estuary Program for the Delaware River and Bay.

The information, perspectives, and future needs stated in this report reflect the best current scientific consensus of the authors that drafted individual sections and do not necessarily represent the official views of the Partnership for the Delaware Estuary, other members of the Delaware Estuary Program, or any other participating entity or specific author. This report is a collective, peer reviewed effort which attempted to coordinate a consistent style and content among sections; however, the written presentations and depth of analysis will reflect (or vary in accordance with) the availability of data, methods of presentation, and analytical rigor that are appropriate for different fields and different writing styles of various authors. Examples of key findings in this report are summarized in the table below which shows both improving and declining environmental conditions (Table 0.1). The list is not prioritized, and many similar examples can be found in various report sections. Scattered throughout the TREB are additional features that showcase recent case studies or hot topics.

Table 0.1 Top positive (A) and negative (B) findings from the 2022 Technical Report for the Delaware Estuary and Basin. Impact scores are qualitative and based on relative overall impact to estuary and basin wide health, and immediacy of action need. Impact scores of 1 for positives are very good, whereas a score of 6 for a negative is detrimental. Averaging all impact scores yields a total score of 3.5, or an overall "fair" rating for the reporting period's Estuary and Basin health.

A.

Chapter	Positives		
	Indicator	Condition	Impact
Watersheds	Protected lands	Estuary and Basin has >2,900 sq mi of protected lands, with a increase by 1.3% in the last decade	2
Water Quantity	Water Withdrawals	Peak water withdrawals occurred in 2006-2007 and have subsequently declined	2
Water Quality	Dissolved Oxygen	Concentrations increased dramatically 1960s to present	1
Sediments	Total Suspended Sediment	Declined from 2005-2010 to 2017-2021, especially in the Lower Estuary (but this could also have negative effects to tidal wetlands in the Bayshore)	3
Habitats	Fish Passage	Between 2017-2021, 29 dams have been removed in the Delaware River Basin	1
Living Resources	Population Increases	Osprey, blue crab, American eel, and sturgeon populations have increased	1
Climate	Temperature	Not yet a significant increase in hot temperature extremes, despite average warming trends	3
Restoration	Habitat Type	Increase in restored acres in 2017-2022, compared to 2006-2011 and 2012-2016	2

B.

Chapter	Negatives		
	Indicator	Condition	Impact
Watersheds	Land Cover	Development increased by ~17.5 acres per day from 1996-2016	6
Water Quantity	-	No negatives observed	-
Water Quality	Temperature	Water temperatures are possibly increasing, but more monitoring and analysis will be required	4
	Contaminants	Many fish consumption advisories remain; ecotoxins in pharmaceuticals and personal care products remain a concern	6
Sediments	Contaminants	Sediment contaminant concentrations highest in areas of the Estuary near Environmental Justice communities	6
Habitats	Tidal Wetlands	From 1996-2016, 340 hectares of tidal wetland were lost; percentage losses were >15% for tidal freshwater wetlands	5
Living Resources	Population Decreases	Striped Bass, Weakfish, White Perch, and freshwater mussel populations show signs of decline	5
Climate Change	Sea Level Rise	Sea levels rose between ~4-6 cm per decade from 1992-2021 in the Estuary	5
Restoration	Regulatory Climate	The time and complexity of permits required to do restoration may be increasing	4

Introduction

The 2022 Technical Report for the Delaware Estuary and Basin (TREB) reviews the status and trends in extent or health of more than 50 environmental indicators as a way to take a holistic and scientific look at the current health of the Delaware Estuary and Basin. Environmental indicators are specific, measurable markers that are used to assess the condition of the environment and indicate whether conditions are improving or worsening over time.[1]

Additionally, indicators help raise awareness about important environmental issues, serve as tools for evaluating the effectiveness of management actions, and can function as early warning signals for detecting adverse changes in environmental quality[1]. Indicators were chosen based on data availability and an indicator's ability to tell something important about the status of the natural resources, water quality, and climate conditions of the Delaware Estuary and its watershed. This report provides the best possible current synthesis of status and trends for the important environmental indicators that could be examined.

This assessment report was led by the Delaware Estuary Program's Science and Technical Advisory Committee (STAC) in collaboration with many other contributing scientists and managers. Indicators were selected by the STAC and approved by core members of the Delaware Estuary Program: Delaware River Basin Commission, Delaware Department of Natural Resources and Environmental Control, New Jersey Department of Environmental Protection, Pennsylvania Department of Environmental Protection, Philadelphia Water Department, and Partnership for the Delaware Estuary. Other authors, contributors, and reviewers represented dozens of academic, non-profit, and business organizations.

The purpose of this report is to compile a scientific synthesis of the most recent status and trends data into a technical report, which can serve as the basis for translation products such as State of the Estuary Reports (PDE) and State of the Basin Reports (DRBC) that are written for the public. The 50+ indicators were chosen to reflect a broad suite of physical, chemical, biological, and watershed features of the ecosystem that have sufficient spatial and temporal datasets with consistent methodologies over time. The 2022 TREB includes a new "trial" indicator, but some 2012 or 2017 indicators were omitted due to insufficient recent data or other issues. As before, most indicators reflect monitoring data for "things" such as numbers of fish or concentrations of pollutants. To enrich future indicator reporting, we anticipate that indicators will be developed that reflect ecological processes, such as rates of primary production, carbon sequestration or biofiltration. Although some analyses were not able to be completed for some important resource conditions in this TREB, the balance of indicator data covered in this report reflects the best possible regional perspective on overall environmental conditions and trends in the Delaware Estuary and Basin.

TREB results are also vital for measuring the progress made toward implementing the Comprehensive Conservation and Management Plan (CCMP) for the Delaware Estuary. By tracking indicators and assessing their status and trends every 5 years, periodic revisions and updates to CCMP strategies can be responsive to changing conditions. To assist with such CCMP updates and guide environmental managers and scientists, this report includes future "Actions and Needs" for each indicator. In many cases, these actions and needs call for improved coordination and/or monitoring. Where data are currently incomplete or unavailable, PDE will continue to work with partners to sustain and improve monitoring to address data gaps and facilitate data sharing and management.

1. U.S. EPA. 2015. Indicator Development for Estuaries. Available at: https://www.epa.gov/sites/default/files/2015-09/documents/indicators_manual.pdf

Organization of the TREB

The sample framework for TREB is the entire Delaware River Basin, although the focus for some indicators is particular sub-watershed areas such as the Delaware Estuary study area which forms the lower half of the Basin. Indicators are grouped into eight chapters, beginning with watershed traits and land use in Chapter 1. The watershed regions considered in this report extend from headwater streams in New York to the mouth of Delaware Bay between Cape May, NJ and Cape Henlopen, DE. The nomenclature and coverage of various watershed regions and sub-regions in TREB are described in the series of maps in Figure 2. Note that these maps highlight the land areas of the watershed (~12,900 square miles), but when the open waters of Delaware Bay are included, the total watershed area is 13,539 square miles.

Climate change is the subject of Chapter 2, which was moved forward in the order of TREB 2022 chapters because of the pivotal importance of changing conditions that serve as drivers for everything that follows. Water resource indicators are discussed next in Chapters 3 and 4, followed by sediment indicators in Chapter 5. Habitat and living resource indicators are examined in Chapters 6 and 7, respectively. Indicators reported in Chapters 1-7 focus on status and trends in environmental conditions; in Chapter 8, we focus on measures of progress for improving conditions through protection and restoration efforts.

Using the TREB

No single indicator or chapter is diagnostic for overall environmental conditions in the Delaware Estuary and Basin. Thus, the information in this report should be interpreted carefully. Changes in some indicators may also not necessarily reflect declining or improving conditions per se, but instead reflect natural variability. For example, it is possible that some species or conditions are actually improving at the expense of others, due to complex ecological inter-relationships. Since monitoring programs typically count or measure "things" rather than "processes," the indicators primarily reflect structural elements of the system rather than ecological functions or ecosystem services. In some cases, this reporting effort was hampered because certain components of the ecosystem that could serve as strong indicators were not able to be included due to insufficient data. The development of this report therefore allows us to assess not only the state of the environment, but also the state of our knowledge and understanding. Furthermore, the restoration chapter is a recent attempt to begin using available data to assess our management progress in preserving, enhancing and restoring environmental conditions, in addition to assessing intrinsic environmental conditions (which is the focus of most of the rest of this report).

For information on the status and trends of any specific indicator (e.g., American Eels), refer to the appropriate section. To obtain an overall status summary for the Delaware Estuary and Basin, one can refer to the Executive Summary although we recommend reviewing the entire report for several reasons. Many indicators interact through complex physical, chemical, and biological relationships, and a complete review facilitates a fuller understanding of the status of functional interrelationships (how the system is working) in addition to any single parameter (what is present). For example, the population abundance of some fish species may depend on others through predation or competition relationships (striped bass versus weakfish, both are never abundant at the same time). Suspended sediment in the water can both represent a pollutant (e.g., in non-tidal tributaries) as well as an essential limiting resource (e.g., for tidal wetlands).

The Delaware Estuary and Basin also has many unique features, such as having one of the world's largest tidal freshwater ecosystems. This is why salinity rise (with climate change and other factors) is more of a threat in this watershed compared to many other estuaries. The natural high turbidity in part of the Estuary is thought to help to stem eutrophication problems by light shading of phytoplankton blooms, despite high nutrient loadings. This runs counter to the stereotypical understanding of estuarine eutrophication processes and is an example of why ecosystem models need to be tailor-designed for the Delaware Estuary. By cross-comparing results among chapters and reading the collective authors' narratives, one can obtain a better understanding of such unique features and complex interactions.

It is difficult to assign a single grade ("good", "fair" or "poor") to the overall Delaware Estuary and Basin given the different trends observed. Taken together, however, an integrated analysis of all chapters provides the best possible basis for judging the holistic environmental condition of the Delaware Estuary and Basin.

Regional Divisions of the Delaware Estuary and Basin

To simplify status and trend analyses, the Delaware Estuary and Basin are divided into four different "watersheds" or "regions". Additional geospatial resolution (e.g. sub-watersheds) varies among indicators, depending on the coarseness of datasets and scientific intent. Geospatial resolution of sub-regions therefore varies from coarse (e.g., nontidal versus tidal; see page 6) to moderate (e.g., ten sub-watersheds; see pages 7 and 8) to fine (e.g., twenty-one sub-regions similar to HUC12s; see page 9).

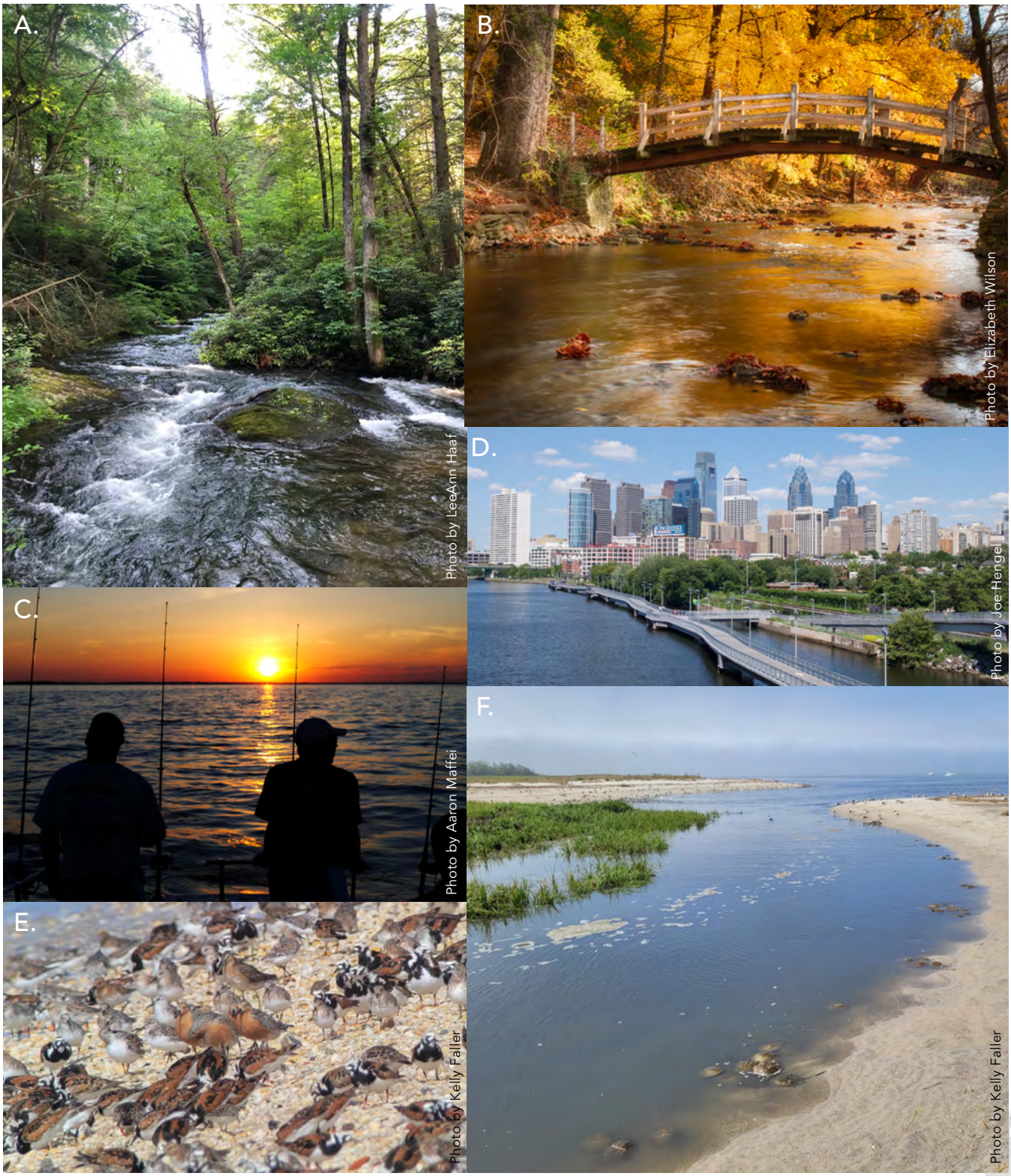


Figure 1 Examples of the sub-regions (see map on page 7) of the Delaware Estuary and Basin: Wild Creek, Albrightsville, PA (A, Central); Valley Creek, Valley Forge, PA (B, Lower); a view of Philadelphia, PA (D, Lower); Fortescue, NJ (C, Bay); shorebirds (E) and horseshoe crabs (F) in NJ (Bay).

Delaware Estuary and Basin

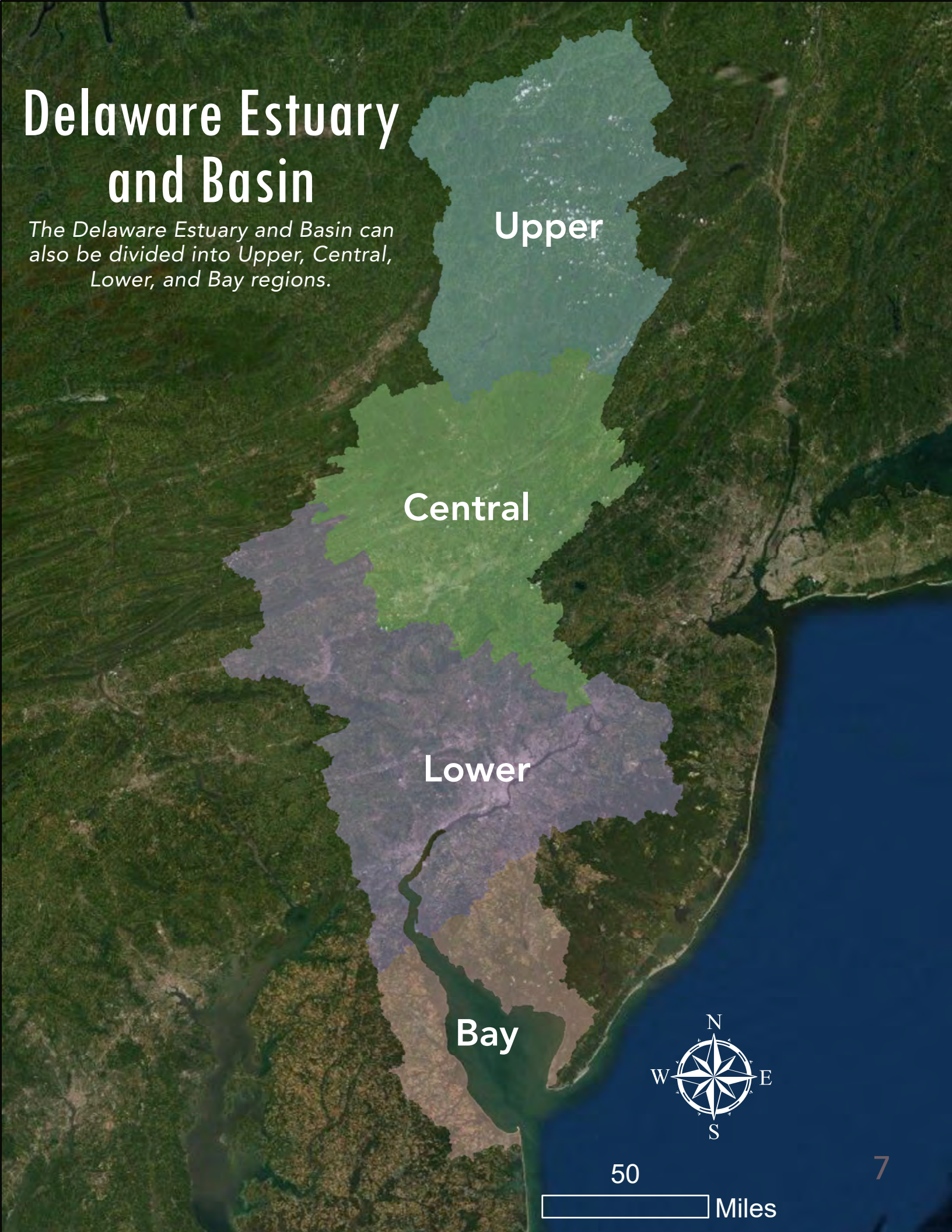
The Delaware Estuary and Basin watershed spans New York, Pennsylvania, New Jersey, and Delaware, with a small portion in Maryland.

Delaware Estuary and Basin

The watershed consists of two macroregions: the upper Basin, which contains headwaters of the Delaware River, and the lower Estuary, which encompasses watersheds of the Schuylkill Valley, as well as the tidal Delaware River and Delaware Bay.

Delaware Estuary and Basin

The Delaware Estuary and Basin can also be divided into Upper, Central, Lower, and Bay regions.



Delaware Estuary and Basin

The Delaware Estuary and Basin watershed is composed of 10 watershed regions.

Delaware Estuary and Basin

The ten watershed regions of Delaware Estuary and Basin are further divided into 21 separate subregions for this report.