Improving Dissolved Oxygen and Aquatic Life Uses in the Delaware River Estuary

Steven J. Tambini, P.E.
Executive Director
Delaware River Basin Commission

Partnership for the Delaware Estuary Science and Environmental Summit

January 30, 2023

Photo: Paul Michael Bergeron

Photo: Delaware River Waterfront Corporation

Photo: Partnership for the Delaware Estuary

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

Improving Dissolved Oxygen and Aquatic Life Uses in the Delaware River Estuary

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

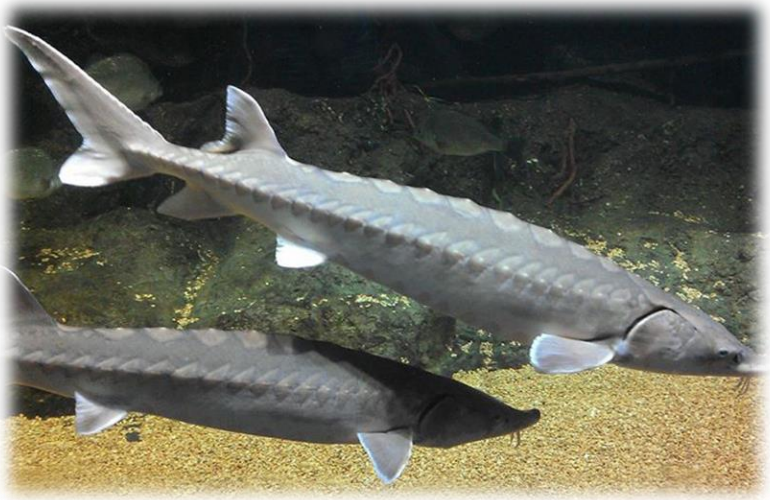
Topic	Presenter
Why are we here?	**Steve Tambini**
How did DRBC address low dissolved oxygen in the Delaware Estuary - then and now?	Namsoo Suk
Where do ammonia and other nutrients in the Delaware Estuary originate, and how do we know?	John Yagecic
What is this estuary-wide eutrophication model and why do we need it?	Li Zheng
What matters and what doesn't with regard to low dissolved oxygen events in the Delaware Estuary?	Fanghui Chen
What combination of wastewater improvements will achieve the best dissolved oxygen outcome in the Delaware Estuary?	Sarah Beganskas
What is the highest attainable dissolved oxygen condition in the Delaware Estuary, and what will it mean for aquatic life uses?	Thomas Amidon
Q&A Panel: Enhancing support for aquatic life uses in the Delaware Estuary	**All**

Shared Goals
Clean Water Act (1972)

"…fishable, swimmable waters…"

"for the protection and propagation of fish, shellfish, and wildlife, and to provide for recreation in and on the water."

Photo: Lane Fike



fisheries.noaa.gov

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

Shared Goals
DRBC Water Quality Regulations

Uses to be Protected:

1. agricultural, industrial, and public water supplies after reasonable treatment, except where natural salinity precludes such uses;

2. **wildlife, fish and other aquatic life;**

3. recreation;

4. navigation;

5. controlled and regulated waste assimilation to the extent that such use is compatible with other uses;

6. such other uses as may be provided by the Comprehensive Plan.

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

Objective: Reduce Pollutant Loads

WQ Assessment:

- Monitoring
- Measurement
- Compliance w/ WQS and CWA

Analysis:

- Apply science and engineering to understand problems and develop solutions.

Coordination with:

- Co-regulators
- Advisory committees
- Stakeholder community

Public:

- Outreach
- Input
- Education

New or Revised Policy:

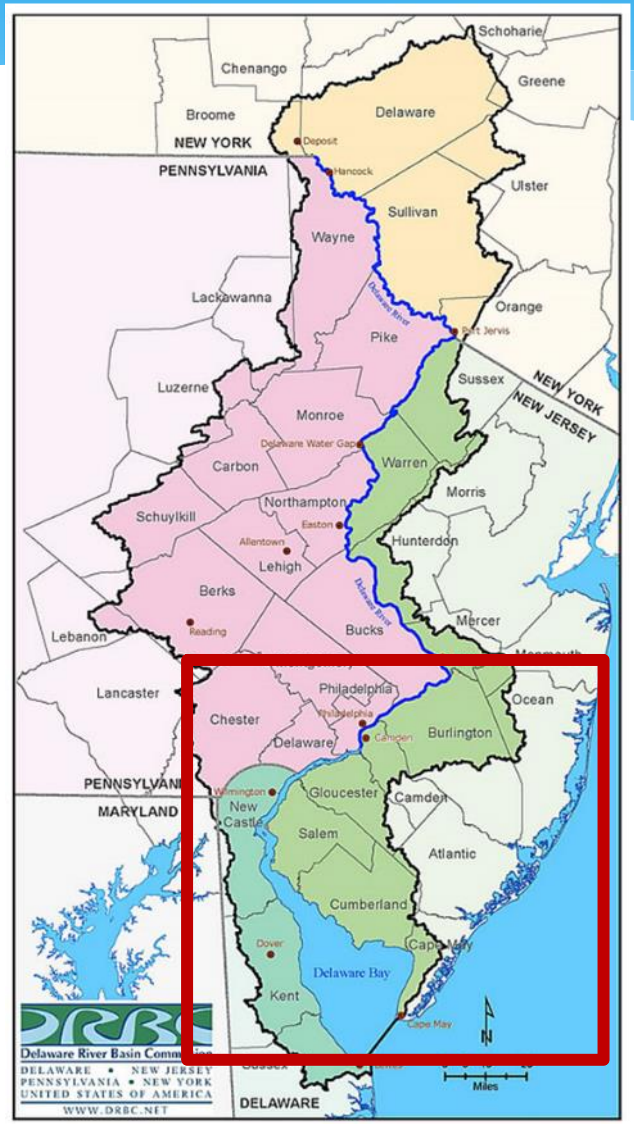
- Regulation
- Enforcement

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

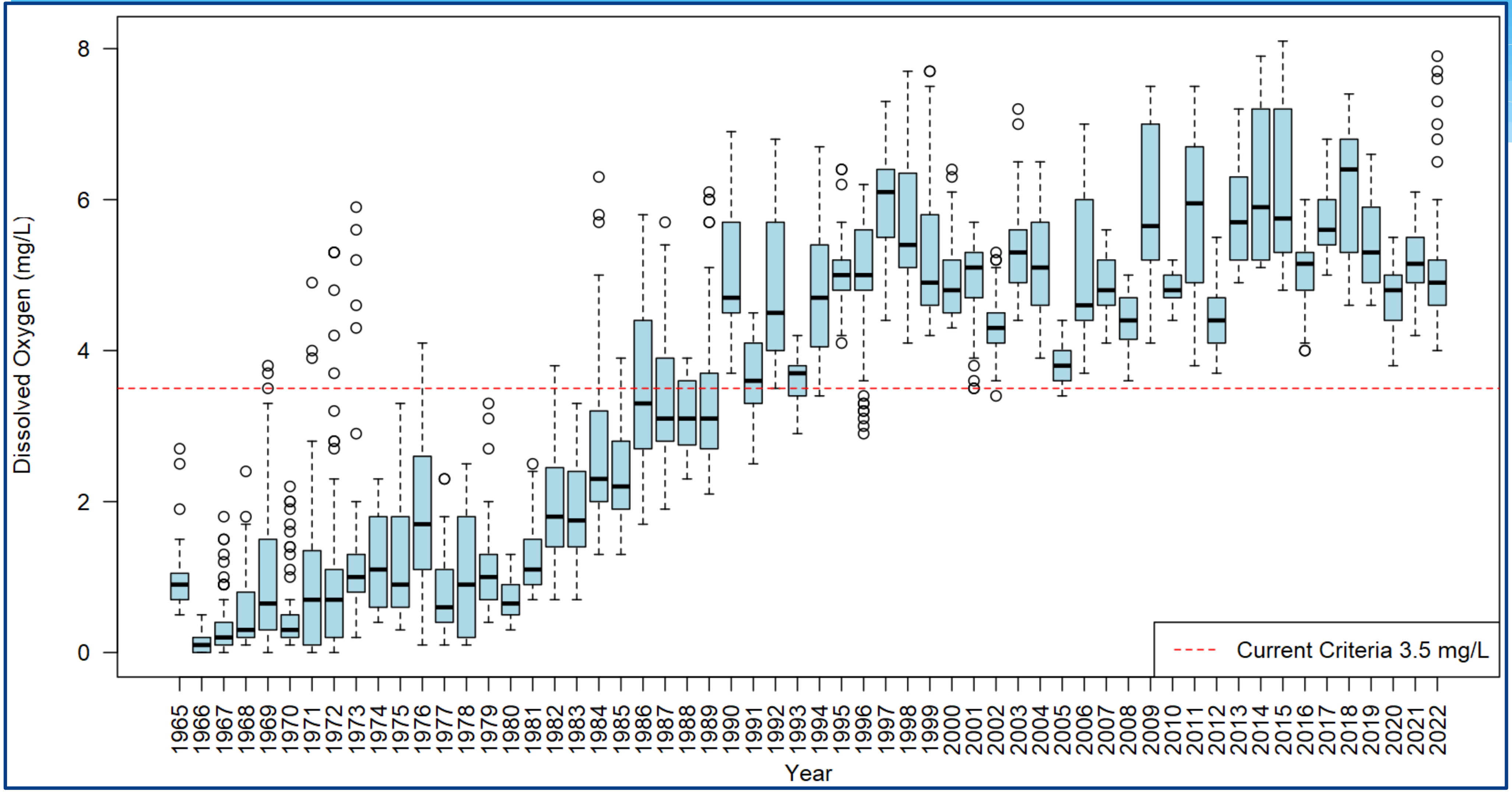
Continuous Water Quality Improvement Process

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

Focus on the Delaware River Estuary



Since the mid-1990s, DO in the urban estuary consistently meet water quality criteria

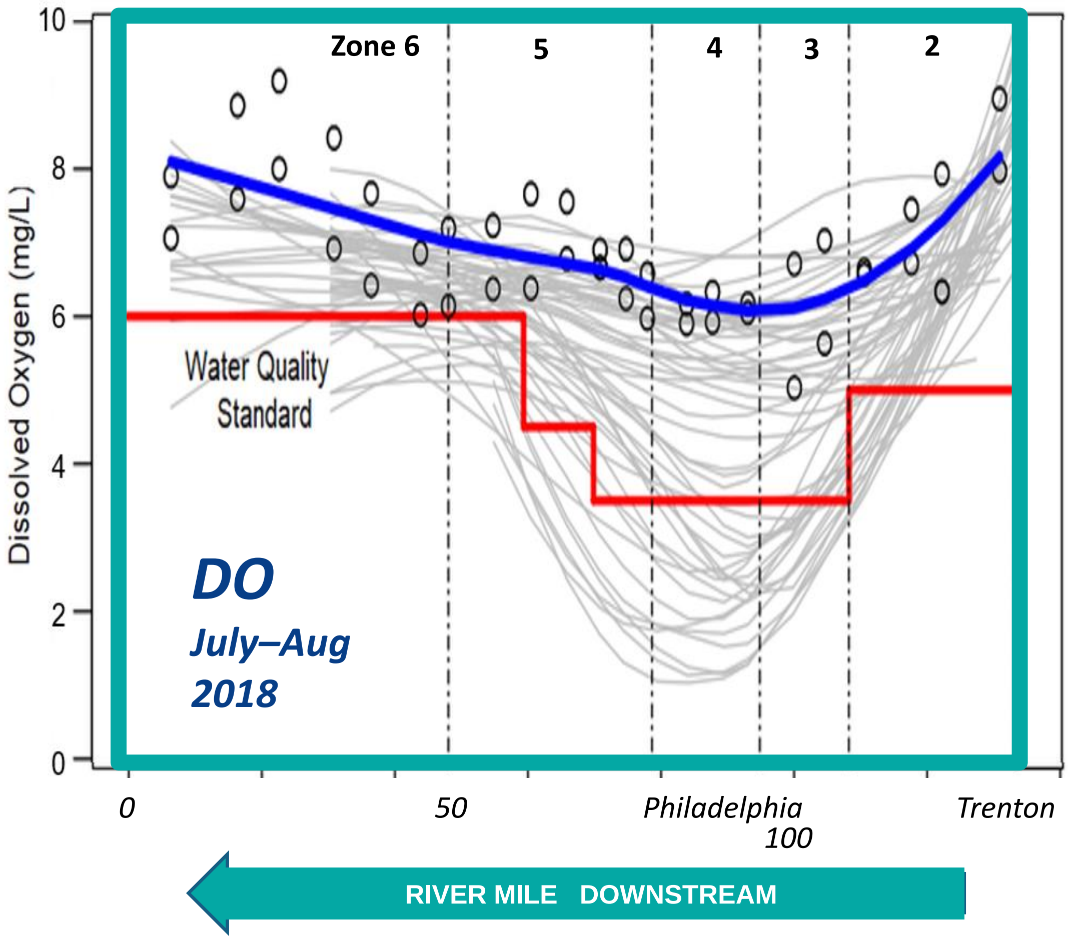


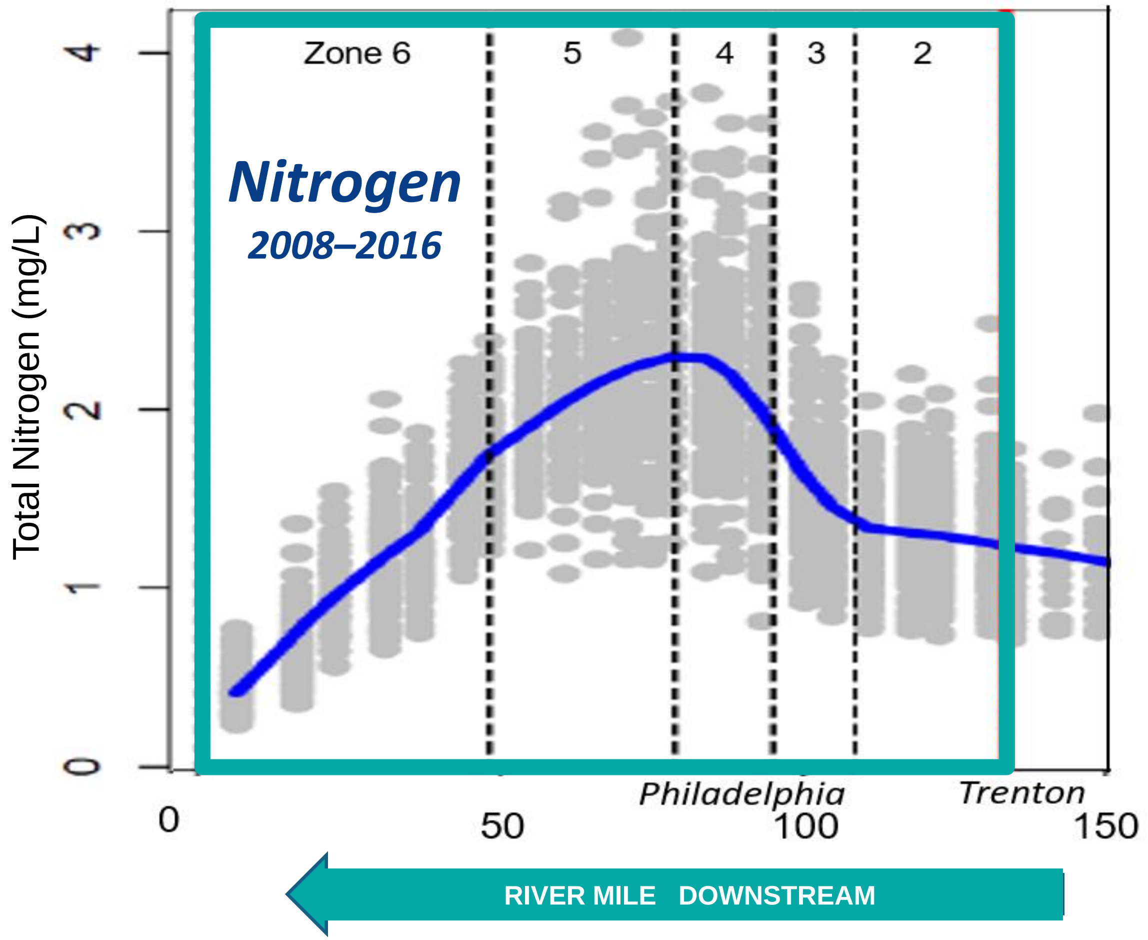
USGS gage, Delaware River at Ben Franklin Bridge (River Mile 100)

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

Nitrogen levels are highest in the urban estuary where DO levels are lowest

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





Delaware Estuary Fisheries

Map Credit: DRBC, Fish Images: PFBC

- **The health of fish communities is an indicator of water quality**
- The Delaware River Basin supports a diverse array of fisheries
- Location in the basin determines what species of fish will be present
- The Delaware Estuary is an important habitat for several anadromous species
  - ✓ Atlantic sturgeon
  - ✓ Striped bass
  - ✓ American shad
- Iconic species of the Delaware Estuary

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

Objective: Reduce Pollutant Loads to Improve WQ

Continuous Water Quality Improvement Process

WQ Assessment:

- Monitoring
- Measurement
- Compliance w/ WQS and CWA

Analysis:

- Apply science and engineering to understand problems and develop solutions.

Coordination with:

- Co-regulators
- Advisory committees
- Stakeholder community

Public:

- Outreach
- Input
- Education

New or Revised Policy:

- Regulation
- Enforcement

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

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

DRBC Resolution 2017-4

Review of Aquatic Life Designated Uses
Studies required before Rulemaking

Fish/DO Studies

- 6(a). Input on the **dissolved oxygen requirements of aquatic species**
- 6(b). Field studies of the occurrence, spatial and temporal distribution of the life stages of Estuary fish species
- 6(c). Input from consultations pursuant to the **Endangered Species Act** ("ESA")

Modeling Studies

- 6(d). Development and calibration of a **eutrophication model** for the Delaware River Estuary and Bay;
- 6(e). Determination of the nutrient **loadings from point and non-point sources** necessary to support key aquatic species;

Cost/Feasibility Studies

- 6(f). Evaluation of the **capital and operating costs for treatment** capable of achieving higher levels of dissolved oxygen;
- 6(g). Evaluation of the physical, chemical, biological, **social and economic factors affecting the attainment of uses**,

6. "Analysis of Attainability"

6(h).

Preparation of a **draft report and final report** containing findings and conclusions.

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

Water Security for over 13 million people

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

- Water Quality
- Water Equity
- Water Availability
- Water Resiliency

Improving Dissolved Oxygen and Aquatic Life Uses in the Delaware River Estuary

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

Topic	Presenter
Why are we here?	Steve Tambini
How did DRBC address low dissolved oxygen in the Delaware Estuary - then and now?	**Namsoo Suk**
Where do ammonia and other nutrients in the Delaware Estuary originate, and how do we know?	John Yagecic
What is this estuary-wide eutrophication model and why do we need it?	Li Zheng
What matters and what doesn't with regard to low dissolved oxygen events in the Delaware Estuary?	Fanghui Chen
What combination of wastewater improvements will achieve the best dissolved oxygen outcome in the Delaware Estuary?	Sarah Beganskas
What is the highest attainable dissolved oxygen condition in the Delaware Estuary, and what will it mean for aquatic life uses?	Thomas Amidon
Q&A Panel: Enhancing support for aquatic life uses in the Delaware Estuary	**All**

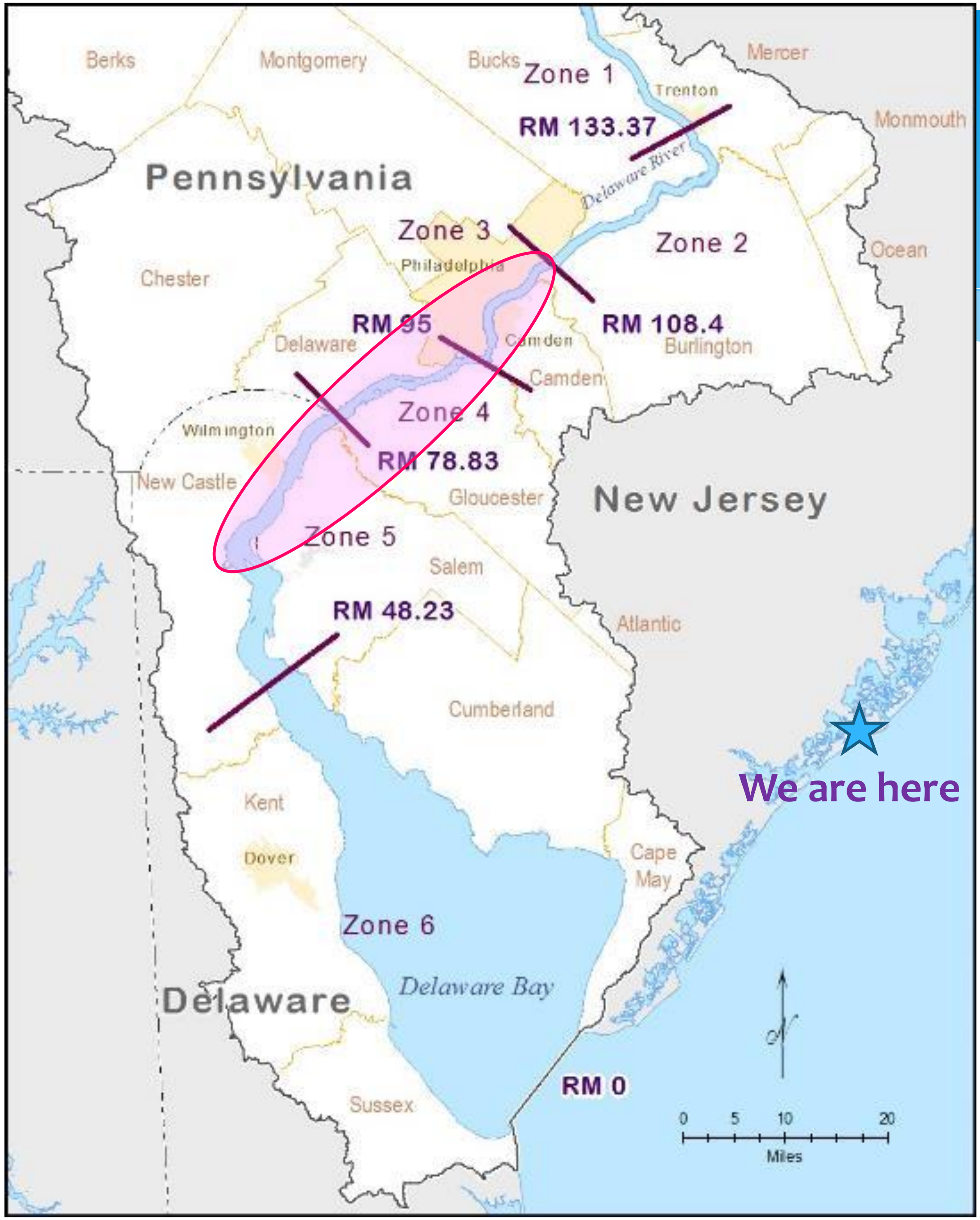
How did DRBC address low dissolved oxygen in the Delaware Estuary - then and now?

Namsoo Suk, Ph.D.
Director, Science and Water Quality Mgmt.
Delaware River Basin Commission

Partnership for the Delaware Estuary Science and Environmental Summit

January 30, 2023

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



Delaware River Estuary

<u>**Water Quality Assessment Units:**</u>

Zone 1: Non-tidal (Upstream from Trenton)

Estuary:

Zone 2 - 5: Tidal Delaware River

Zone 6: Delaware Bay

<u>**River Miles:**</u>

RM 0.0 = Atlantic Ocean

RM 70 = City of Wilmington

RM 100 = Ben Franklin Bridge, Philadelphia / Camden

RM 133 = “Head of Tide”, Trenton, NJ

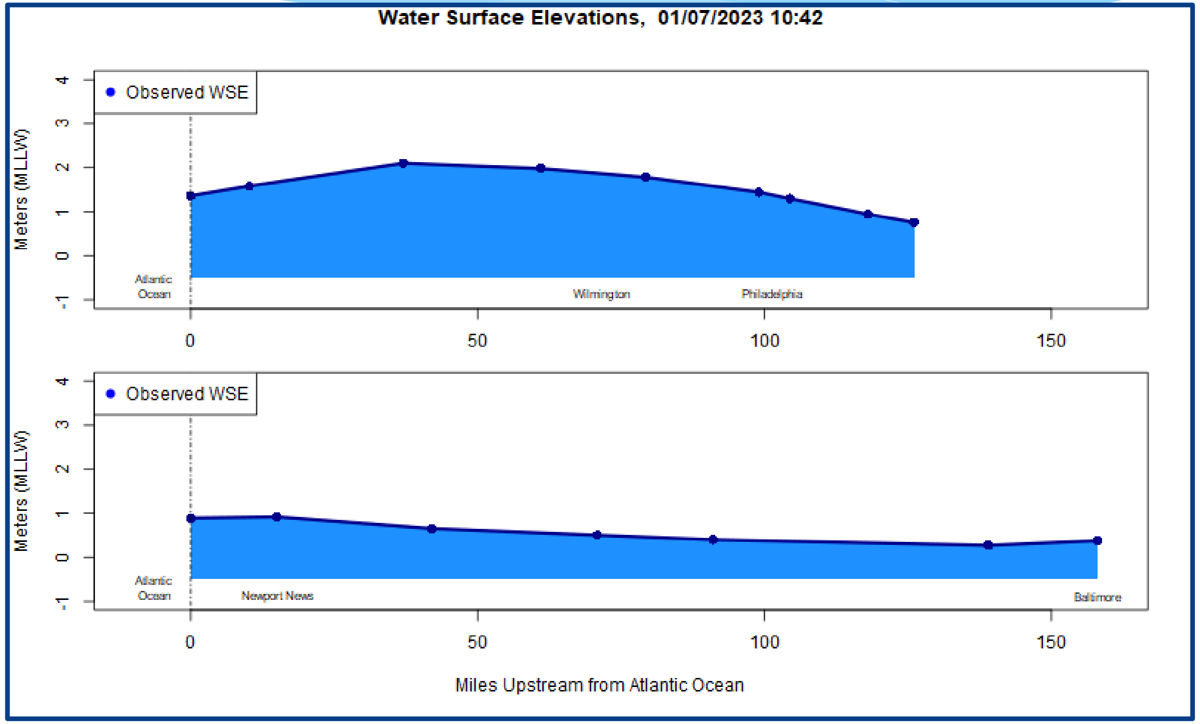
Delaware Estuary Characteristics

Tidal System

- Semi-diurnal tidal estuary
  - flow direction reversed twice a day
  - Tidal flow excursion ~13 miles/ tide
- Tidal amplitude increases upstream due to physical shape of the estuary (like a bellows)
  - Mean tidal range of ~4 feet at the mouth of bay and ~8 feet near the head of tide at Trenton, NJ
  - Delaware Estuary is highly energetic system
  - Stratified in bay but relatively well mixed in tidal river

Freshwater Inflows

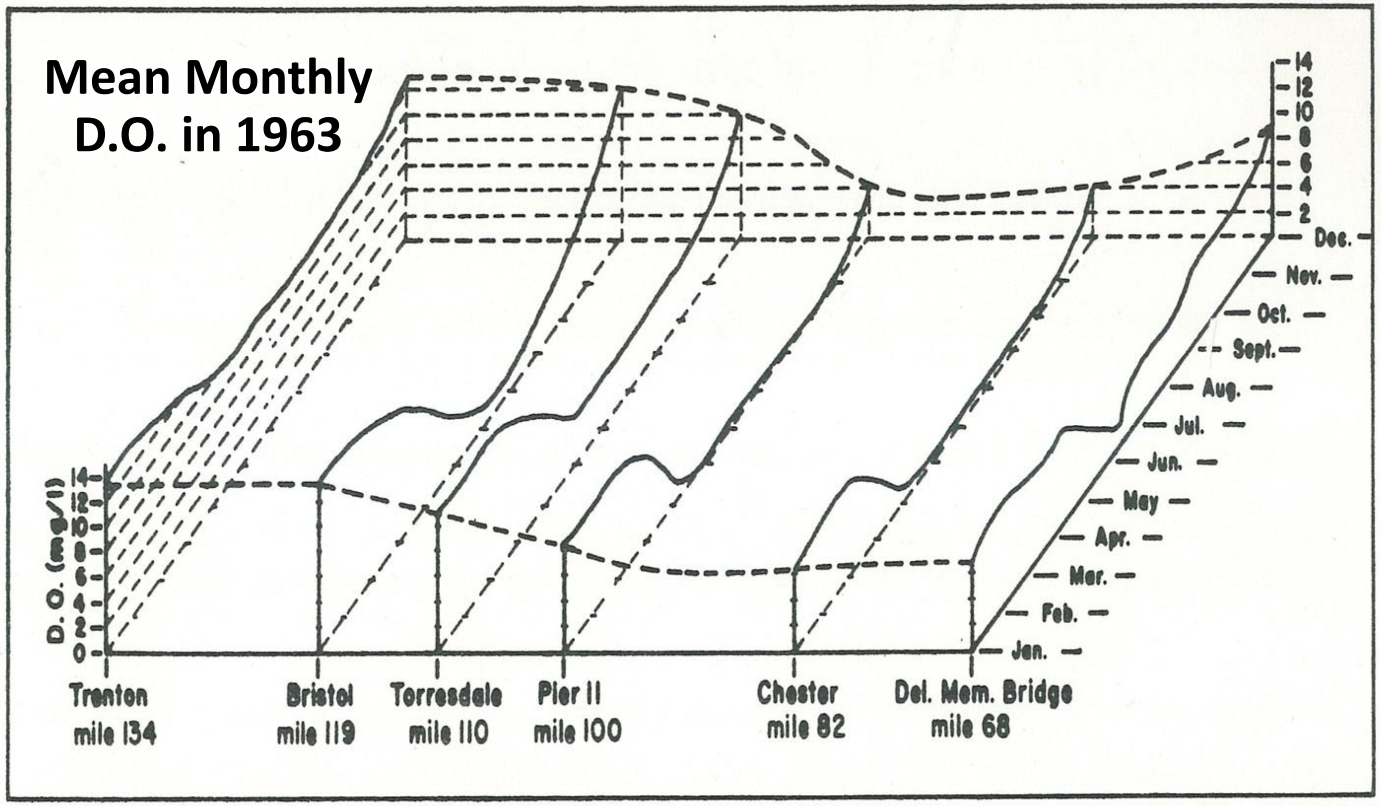
- ~66% of freshwater flows from Delaware River at Trenton (51%) and Schuylkill River (15%)
- During the persistent low freshwater inflow condition, up to 30% of flow in the urban estuary is from treated wastewater



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

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

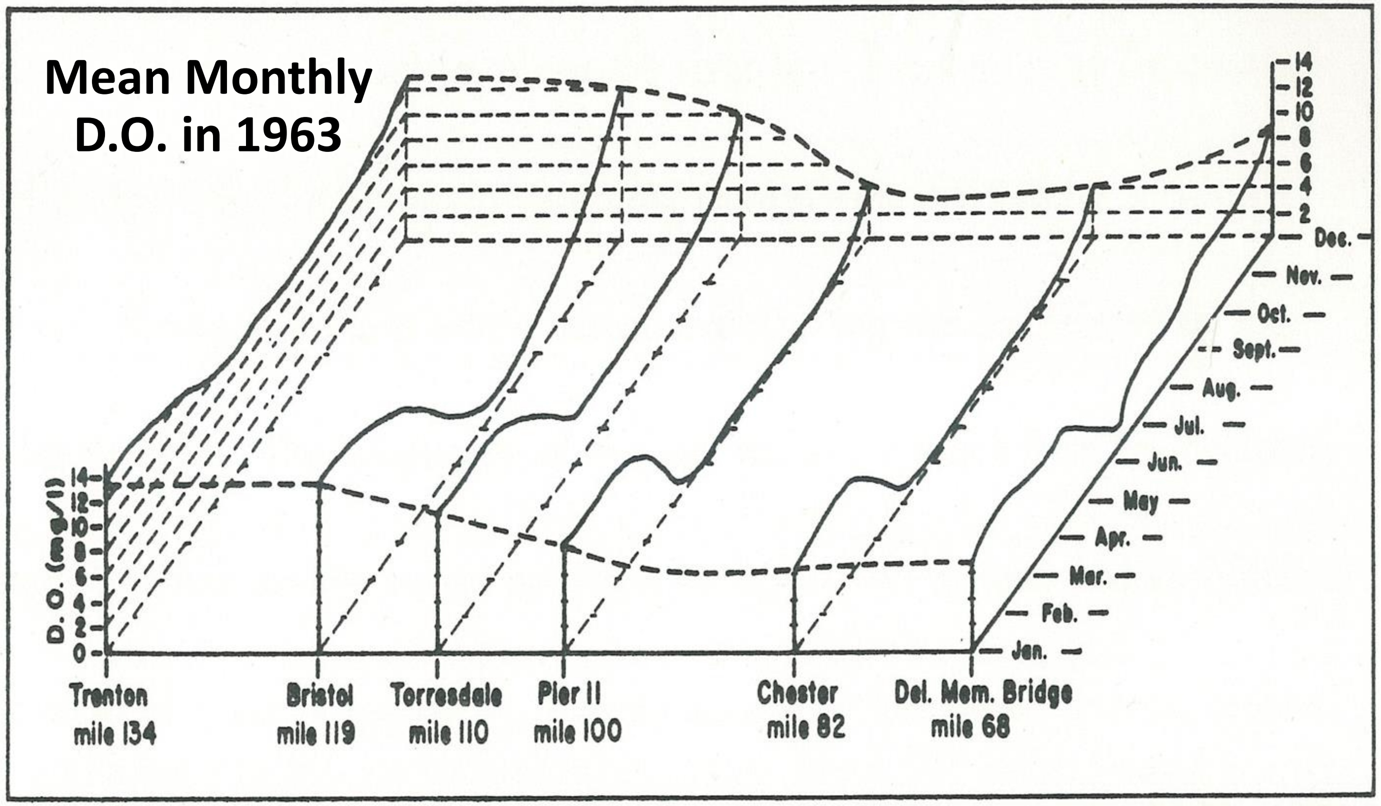
Water Quality in mid-1900s in Delaware Estuary



Upstream **Downstream**

Slaughterhouses discharging in 1928
(PWD Historic Collection)

Water Quality in mid-1900s in Delaware Estuary



Upstream Downstream

- Historically, summer dissolved oxygen (DO) levels near urban portions of estuary were too low to support aquatic life
- Caused by human and industrial wastes:
  - Carbonaceous Biochemical Oxygen Demand (CBOD): Oxidation of organic materials
  - Nitrogenous Biochemical Oxygen Demand (NBOD): Oxidation of ammonium (NH_4) to nitrate (NO_3)
- DRBC adopted water quality standards in 1967
- DRBC established CBOD wasteload allocations for facilities in Zones 2-5 in 1968
  - Required 86.0 – 89.25 % treatment of CBOD

Aquatic Life Designated Uses in Current DRBC Regulations since 1967

	Zone	River Mile	Aquatic Life Use	Migratory Fishes	24-hour average D.O. Criteria
	2	108.4 – 133.4	**maintenance** and **propagation** of resident fish and other aquatic life	**passage** of anadromous fish	5.0 mg/l
Urbanized portion of Delaware Estuary or Fish maintenance area (FMA)	3	95 – 108.4	**maintenance** of resident fish and other aquatic life	**passage** of anadromous fish	3.5 mg/l
	4	78.8 – 95	**maintenance** of resident fish and other aquatic life	**passage** of anadromous fish	3.5 mg/l
	5	70 – 78.8	**maintenance** of resident fish and other aquatic life	**passage** of anadromous fish	3.5 mg/l
		48.2 – 70	**maintenance** and **propagation** of resident fish and other aquatic life	**passage** of anadromous fish	4.5 – 6.0 mg/l
The Delaware Bay	6	0 – 48.2	**maintenance** and **propagation** of resident fish and other aquatic life **maintenance** and **propagation** of shellfish	**passage** of anadromous fish	6.0 mg/l

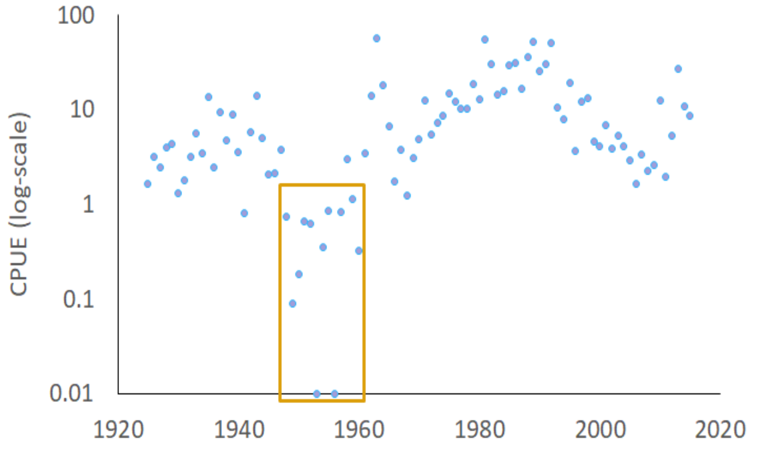
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Dissolved Oxygen (DO) and Fisheries in Urbanized Delaware River Estuary

- Water quality goals established in 1967 have been met since 90s
  - Upgraded wastewater treatment
  - CWA funding
- Fisheries enhanced due to increased dissolved oxygen
- American Shad (example)
  - American shad are the largest member of the herring family
  - Historically American shad were abundant throughout the basin from the upper river to the Estuary

American shad migration. Photo Credit: DRBC

- Populations in the Delaware
  - Crashed in the 1950's

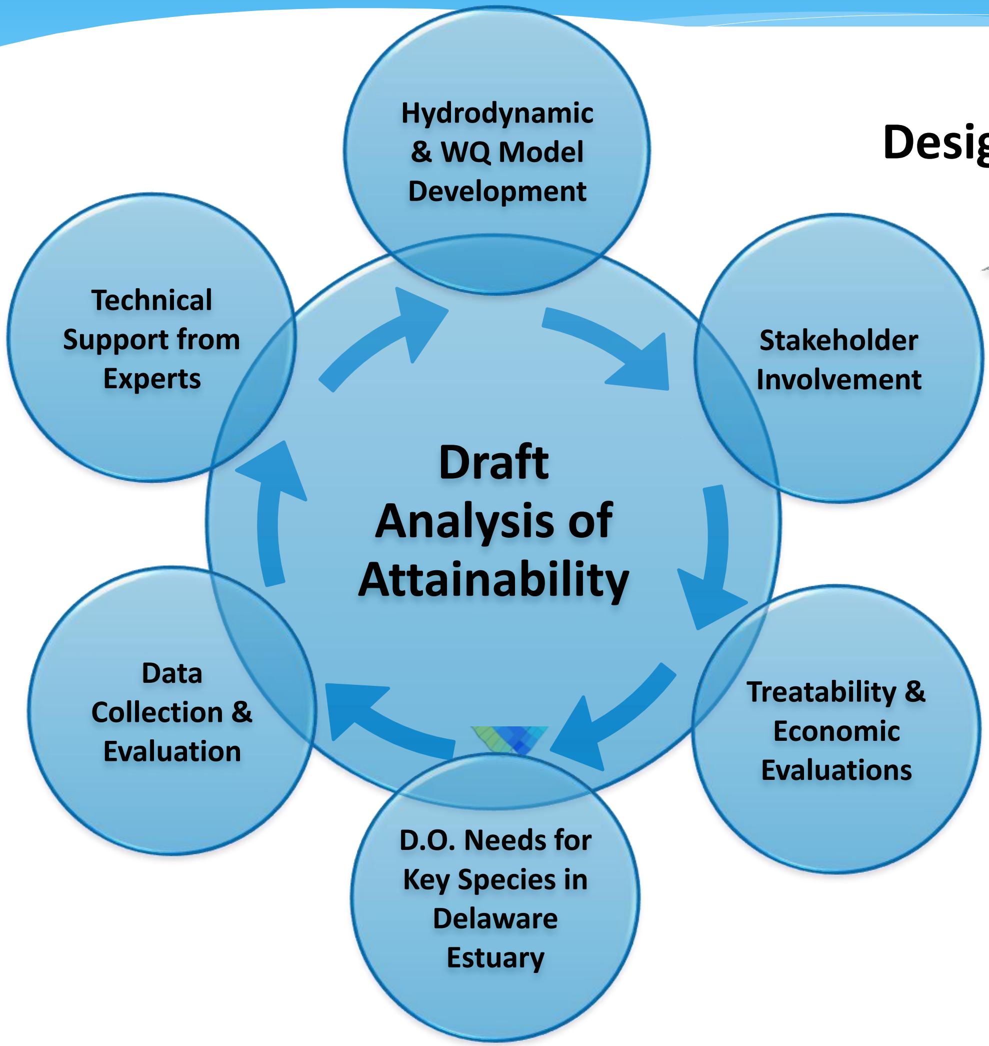


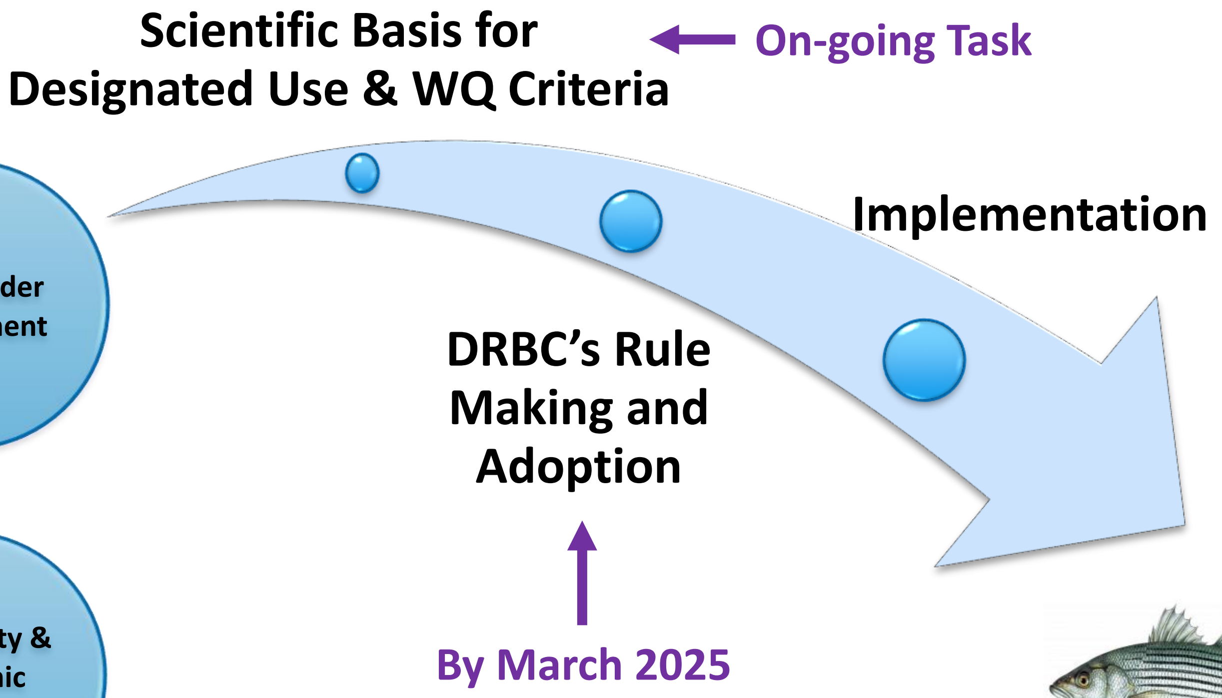
American Shad CPUE from the Lewis Haul Seine Fishery in Lambertville, NJ (1925-2015)

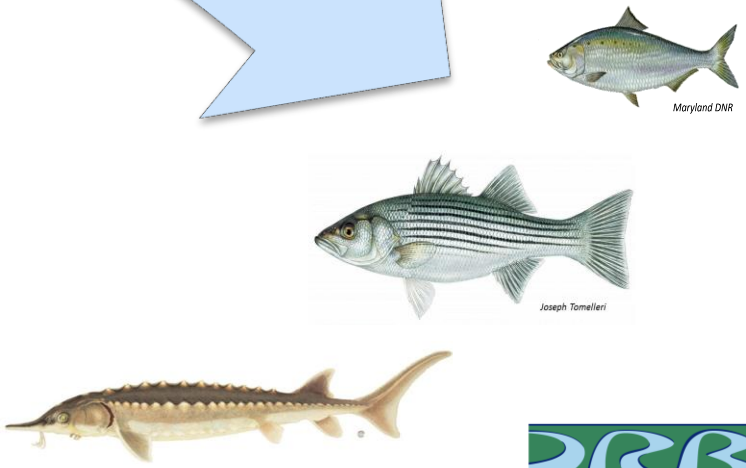
  - Rebounded in the 1980's
- Still room for further improvement

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

Adopt new designated use and DO criteria to support fish propagation (DRBC Resolution No. 2017-4)







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

How did DRBC address low dissolved oxygen in the Delaware Estuary - then and now

- Significant water quality (DO) improvements have been achieved through CBOD control
- Aquatic life use is directly related to Dissolved Oxygen levels
- DRBC front-loaded scientific and technical studies prior to rule making
- Transparent processes for stakeholders through DRBC's Water Quality Advisory Committee
- The draft 'Analysis of Attainability' was completed in 2022 and Linkages developed for
  - DO levels and fisheries response;
  - Levels of ammonia (and other nutrients) reductions and achievable DO levels (models);
  - Ammonia reduction technologies for WWTPs, cost and affordability
- Development of water quality standards (aquatic life designated use and criteria) are underway.

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

Improving Dissolved Oxygen and Aquatic Life Uses in the Delaware River Estuary

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

Topic	Presenter
Why are we here?	Steve Tambini
How did DRBC address low dissolved oxygen in the Delaware Estuary - then and now?	Namsoo Suk
Where do ammonia and other nutrients in the Delaware Estuary originate, and how do we know?	**John Yagecic**
What is this estuary-wide eutrophication model and why do we need it?	Li Zheng
What matters and what doesn't with regard to low dissolved oxygen events in the Delaware Estuary?	Fanghui Chen
What combination of wastewater improvements will achieve the best dissolved oxygen outcome in the Delaware Estuary?	Sarah Beganskas
What is the highest attainable dissolved oxygen condition in the Delaware Estuary, and what will it mean for aquatic life uses?	Thomas Amidon
Q&A Panel: Enhancing support for aquatic life uses in the Delaware Estuary	**All**

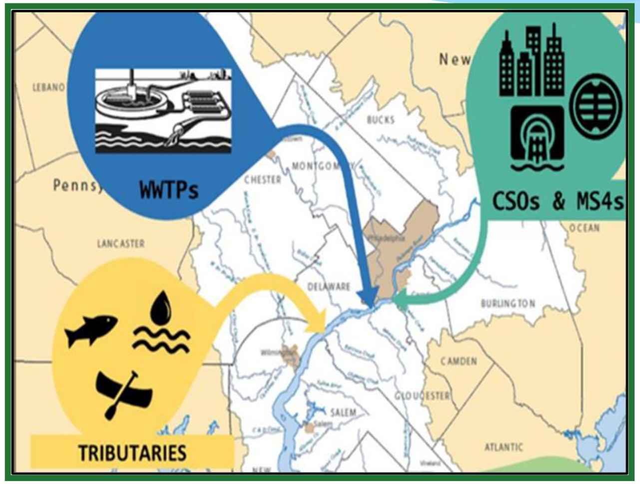
Where do ammonia and other nutrients in the Delaware Estuary originate, and how do we know?

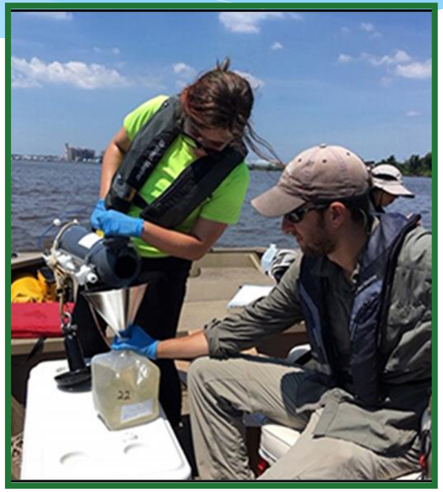
John Yagecic
Manager, Water Quality Assessment

and

Elaine Panuccio
Water Resource Scientist

Delaware River Basin Commission





Partnership for the Delaware Estuary Science and Environmental Summit

January 30, 2023

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

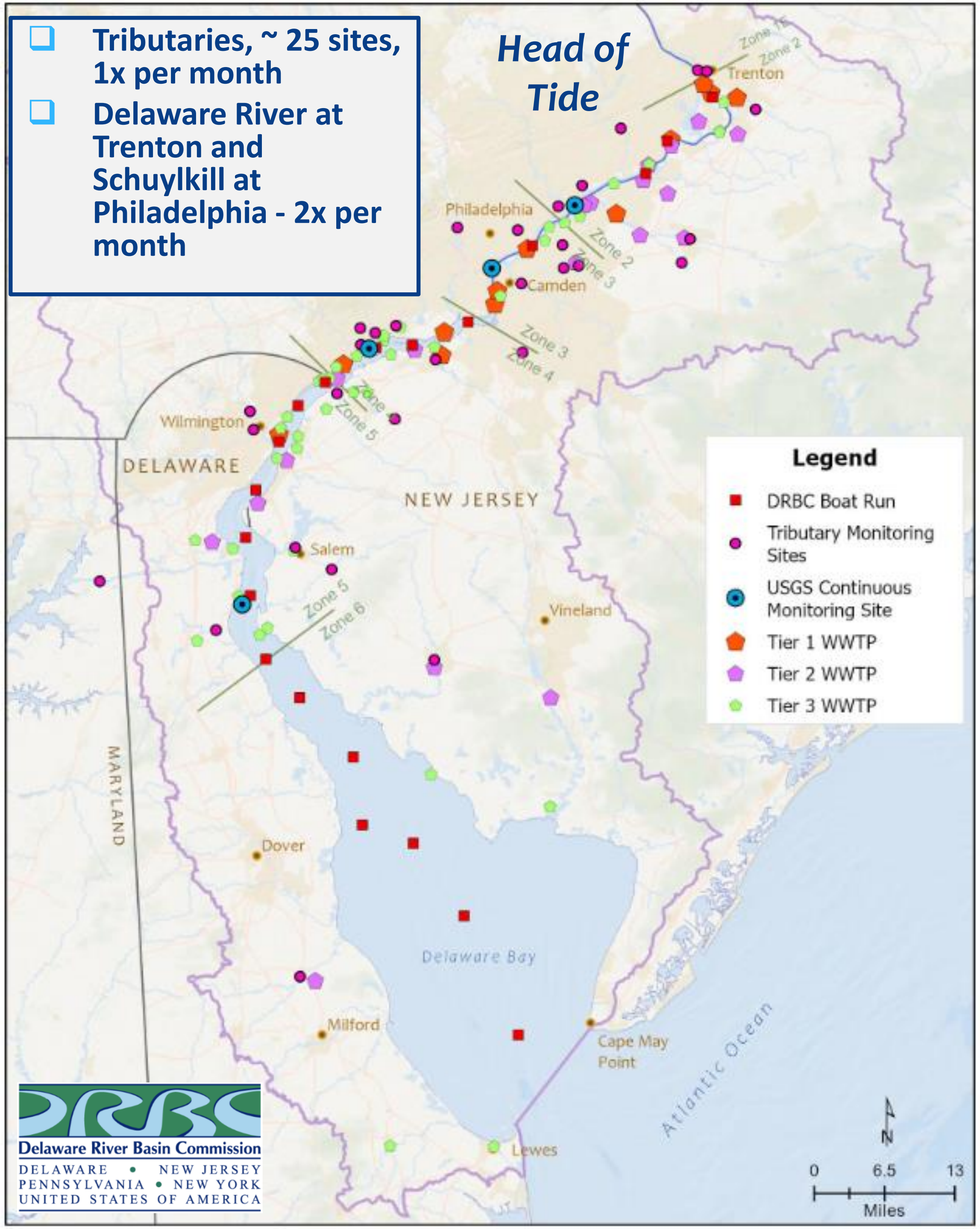
Monitoring in Support of Aquatic Life Uses

- Point discharge nutrient monitoring (1st round) (2011 – 2015)
- Ferry Monitoring Flux Study (2013)
- Primary productivity studies (2014 & 2018, 2019)
- Winter Ammonia Study (2016)
- Expanded tributary nutrient monitoring (2016-2020)
- Expanded ambient nutrient monitoring (2017-2020)
- Addition of salinity monitors to tidal boundaries (Lewes, DE and C&D Canal) (2017-Present)
- Continuous real-time nitrate spectral analyzers (2017-Present)
- Ichthyoplankton Survey Augmentation (2018)
- Light attenuation & CDOM studies (2018-2019)
- Point discharge nutrient monitoring (model calibration period) (2018-2019)
- Algal speciation studies (2018-2019)

Focus on Ammonia

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

DRBC initiated <u>extensive monitoring</u> during the 2018-2019 eutrophication model calibration period

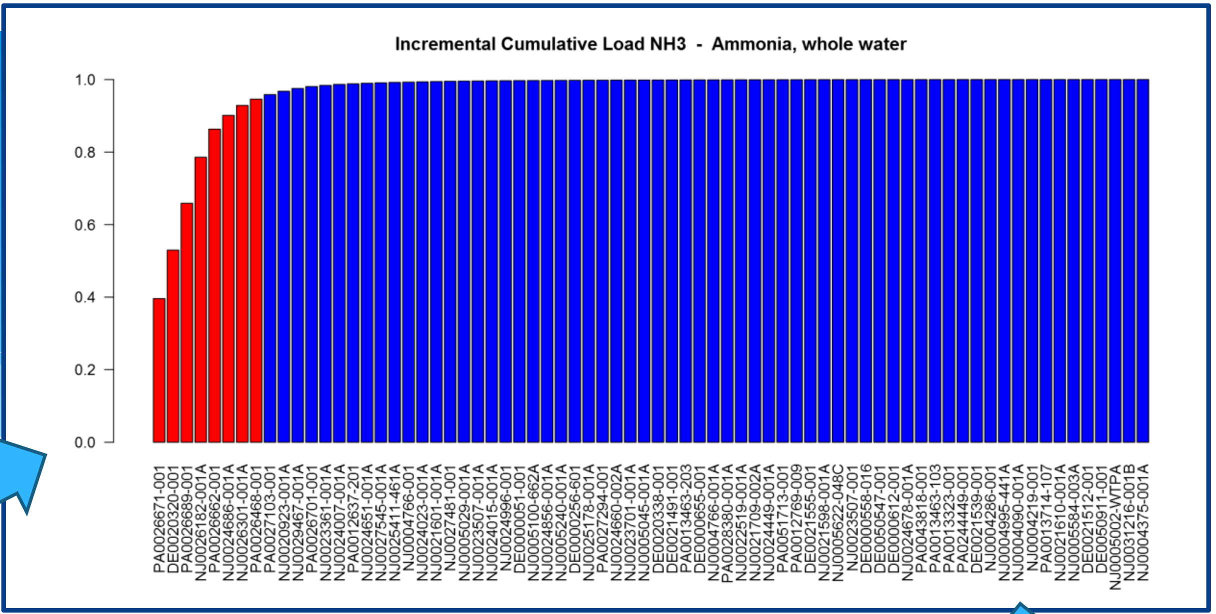


Analytical Parameter	Units	Filtration	Sample Type
Total Phosphorus (TP)	mg/L as P	Unfiltered	24-hour composite
Total Kjeldahl Nitrogen (TKN)	mg/L as N	Unfiltered	24-hour composite
Nitrate Nitrogen (NO3-N)	mg/L as N	Unfiltered	24-hour composite
Nitrite Nitrogen (NO2-N)	mg/L as N	Unfiltered	24-hour composite
20-day Biochemical Oxygen Demand (BOD_{20})	mg/L	Unfiltered	24-hour composite
5-day Carbonaceous Biochemical Oxygen Demand ($CBOD_5$)*	mg/L	Unfiltered	24-hour composite
Chemical Oxygen Demand (COD)	mg/L	Unfiltered	24-hour composite
Total Organic Carbon (TOC)	mg/L	Unfiltered	24-hour composite
Dissolved Organic Carbon (DOC)*	mg/L	0.45 µm filter	24-hour composite
Total Suspended Solids (TSS)	mg/L	Unfiltered	24-hour composite
Soluble Reactive Phosphorus (SRP)	mg/L as P	0.45 µm filter	24-hour composite
Ammonia Nitrogen (NH3-N)	mg/L as N	0.45 µm filter	24-hour composite
Discharge Flow	MGD	N/A	daily average
Water Temperature	°C	N/A	24-hour mean
Dissolved Oxygen	mg/L	N/A	24-hour mean
pH	1-14 S.U.	N/A	24-hour mean
Specific Conductance or TDS	µS/cm or mg/L	N/A	24-hour mean

Two Rounds of Point Discharge Nutrient Monitoring

First Round (2011-2015)

- Facilities < 1 MGD: quarterly for 2 years (28 facilities)
- Facilities > 1 MGD: monthly for 2 years (55 facilities) for:
  - BOD5, CBOD5, BOD20
  - Ammonia, Nitrite, Nitrate, TKN, SKN
  - TP, SRP
  - Discharge flow (Q), temperature, DO, Conductivity, pH
  - Ultimate BOD (UBOD) by the 21 discharges with largest BOD loads twice (1 summer, 1 winter)

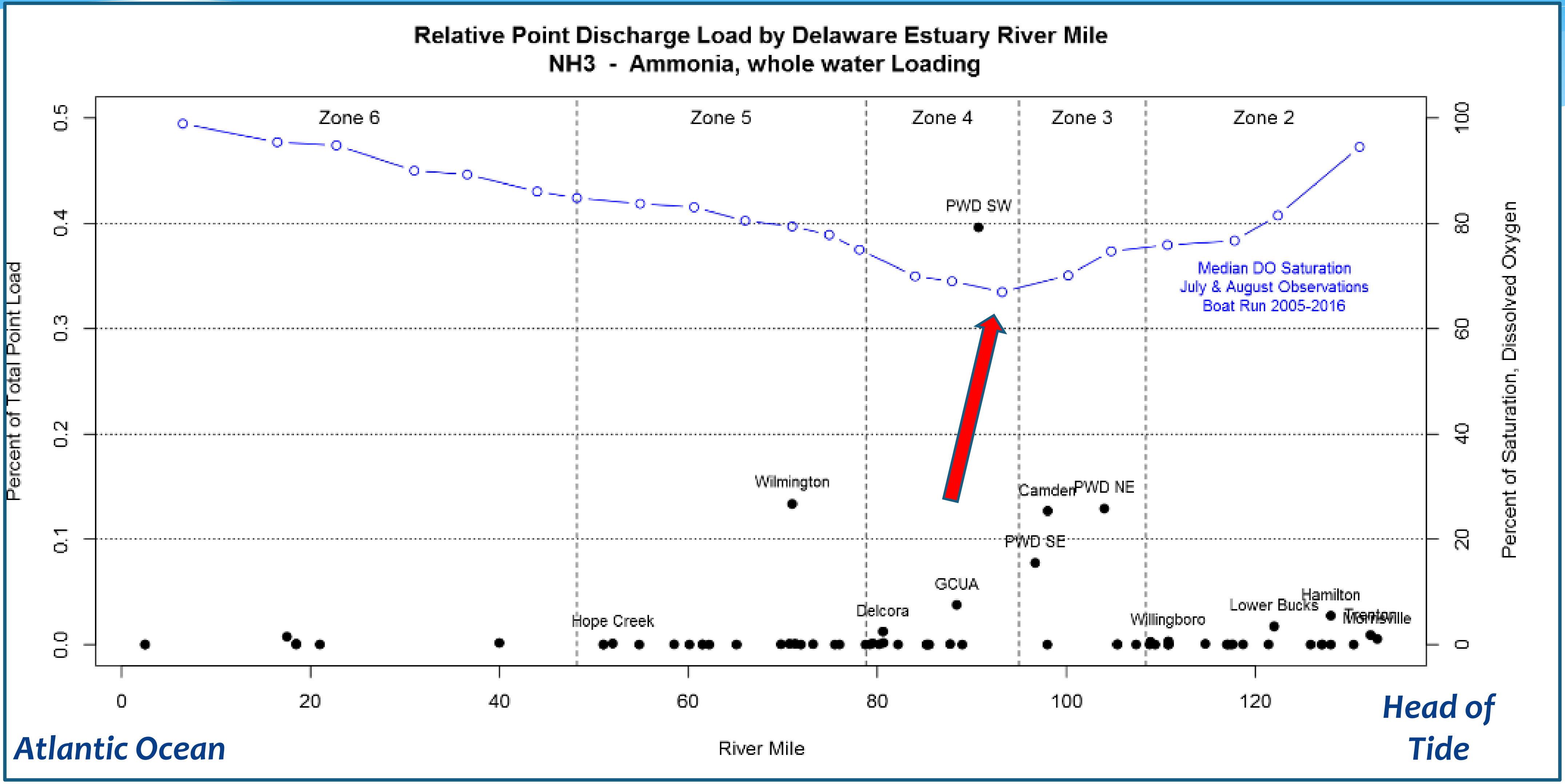


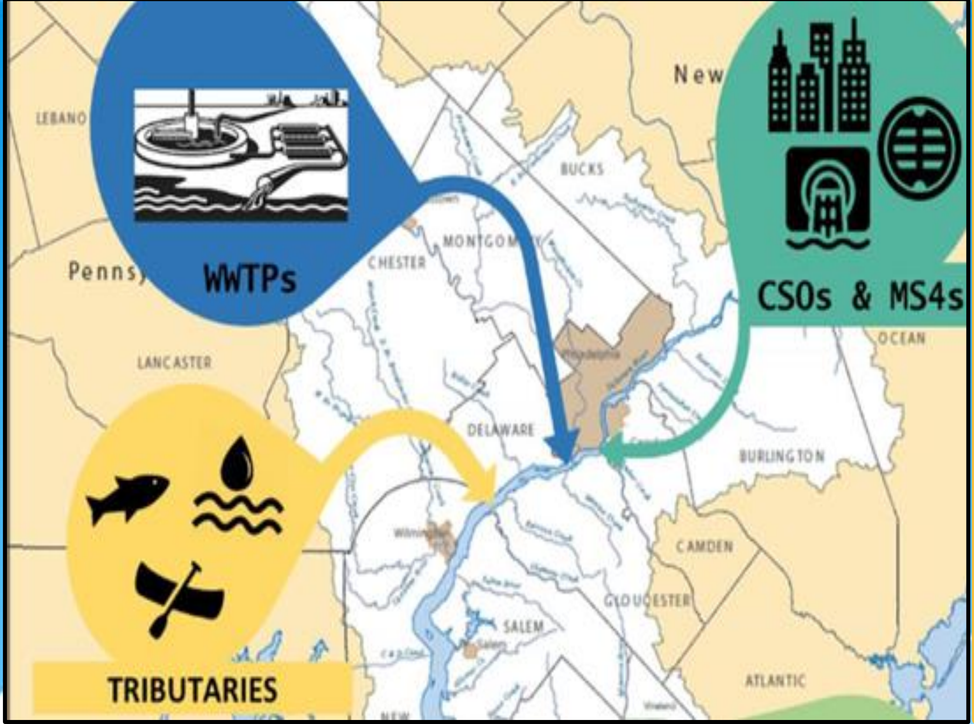
Model Calibration Period

- Weekly for Tier 1 (Top 12)
- Monthly for Tier 2 (Next 20)
  - COD, TOC, DOC, CBOD5
  - Ammonia, Nitrite, Nitrate, TKN, SKN
  - TP, SRP
  - TSS, TDS or conductivity
  - In-situ DO, pH, and temperature
- Daily discharge

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

DO Sag Co-Located with Highest Ammonia Point Discharge Loads





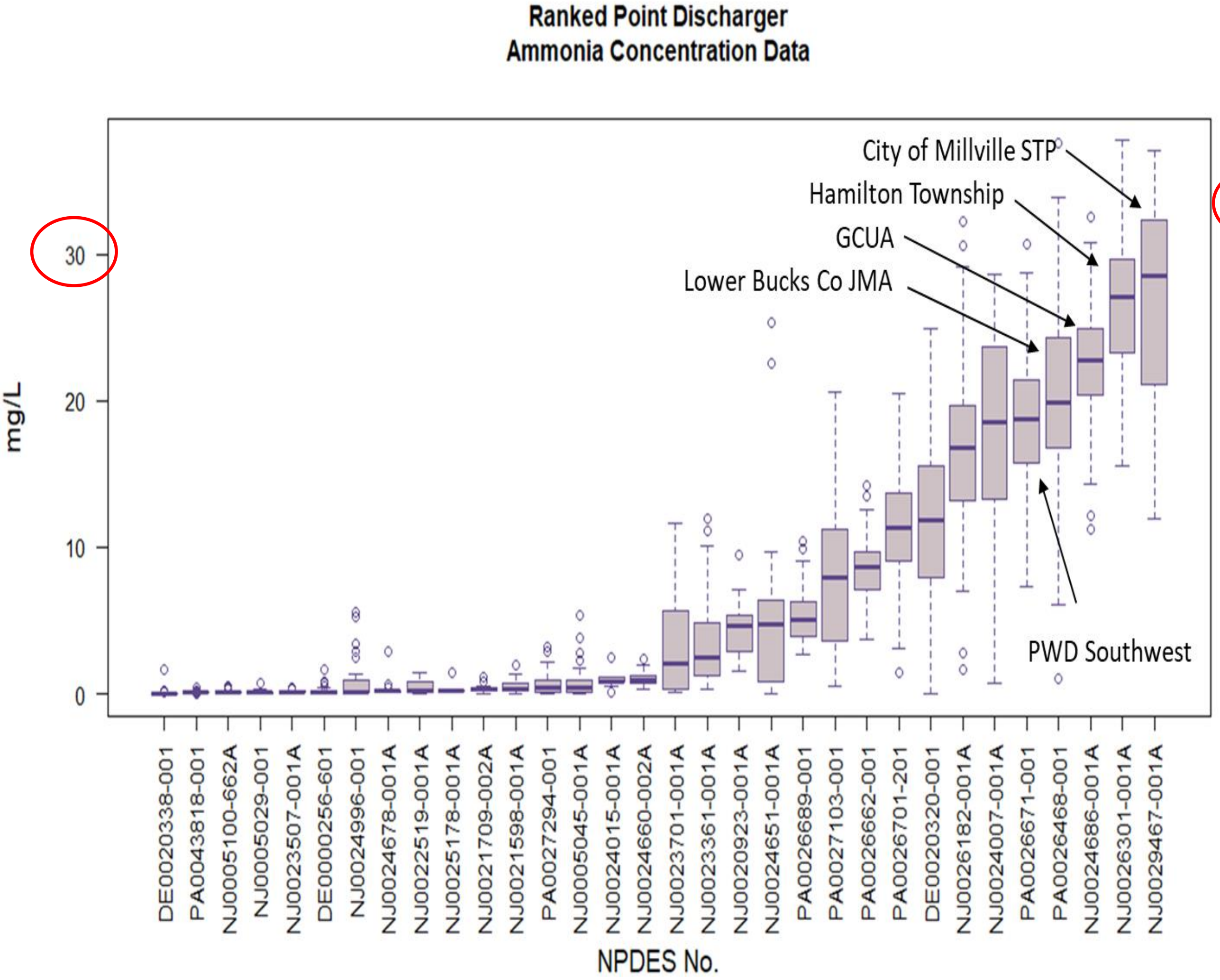
Where do ammonia and other nutrients originate in the Delaware Estuary?

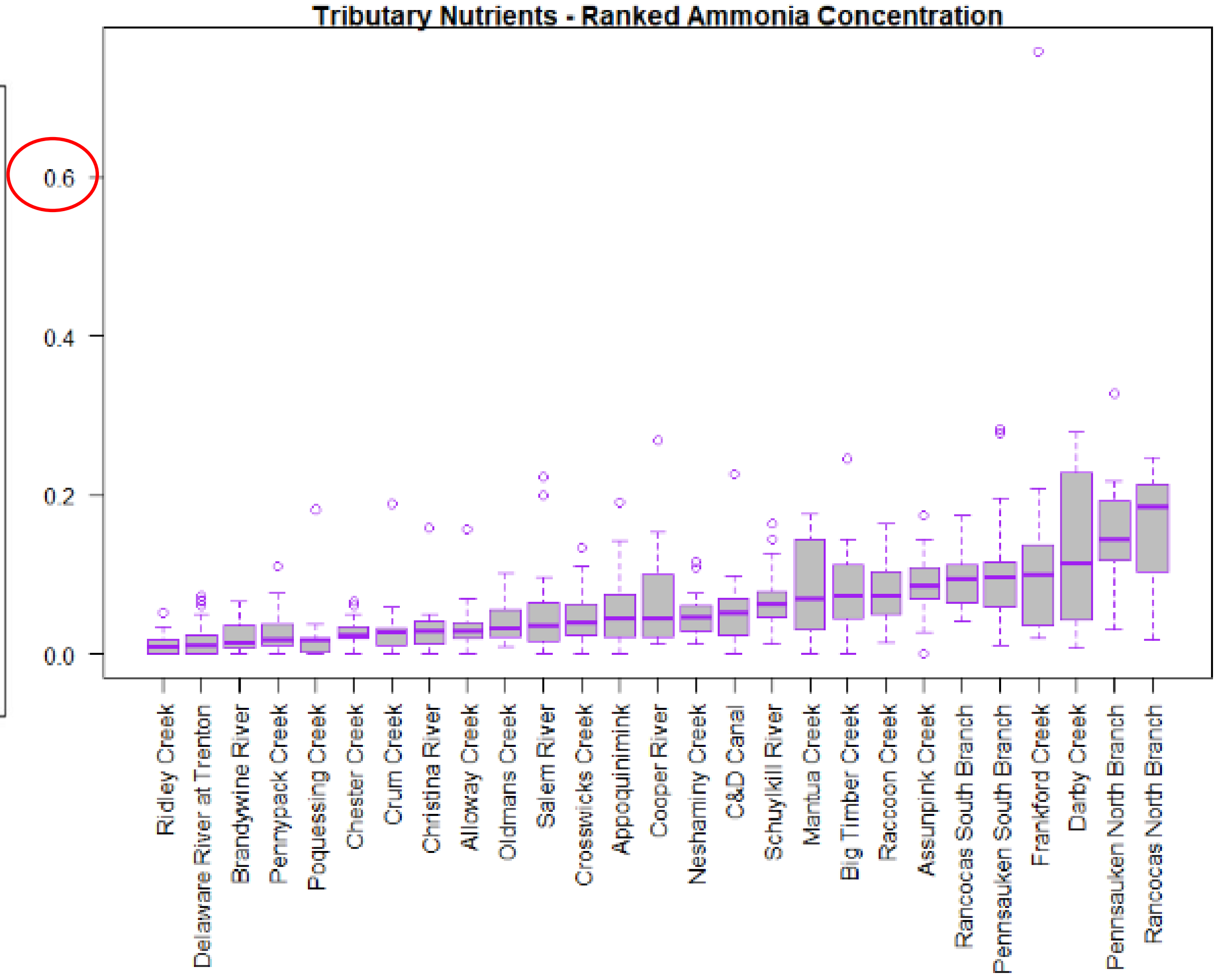
How do we know?

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

Ammonia concentrations: point-discharges and tributaries

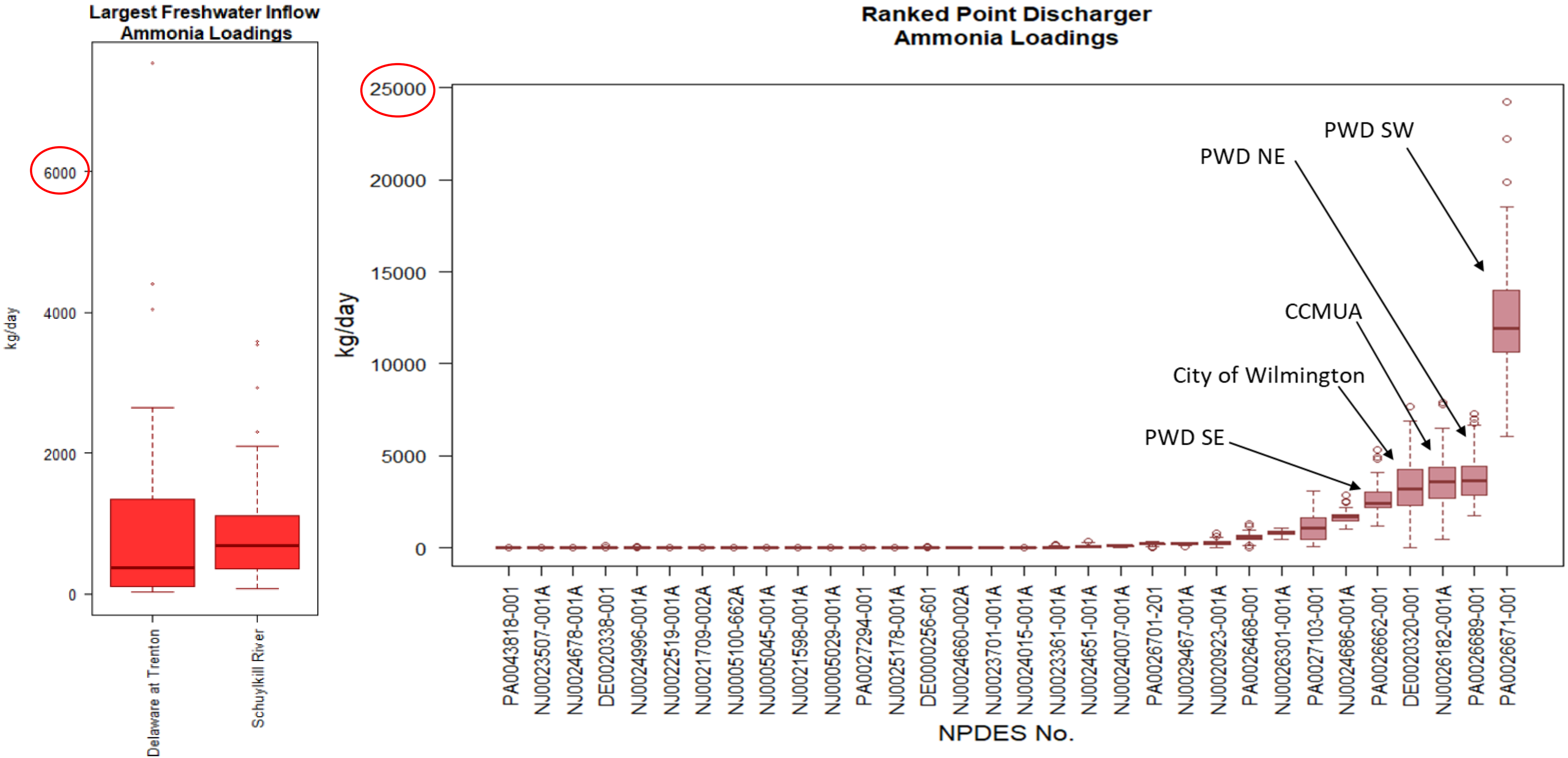
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA



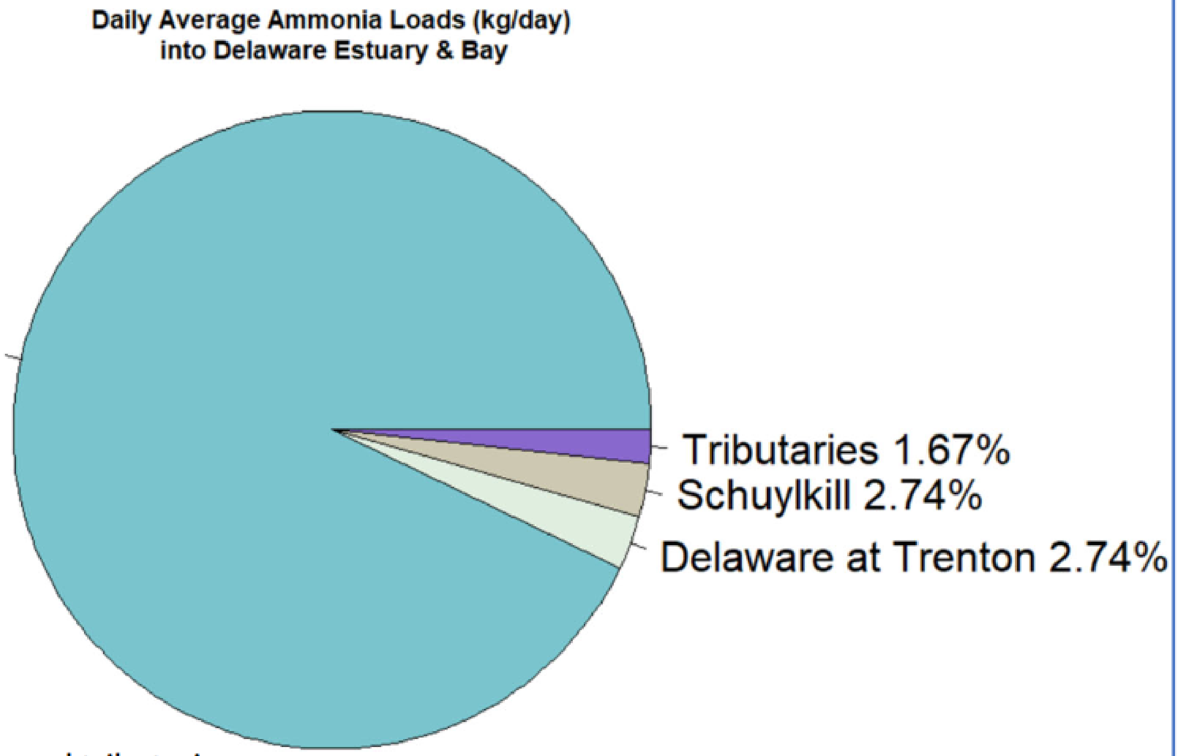


Loading of ammonia from point-discharges compared to the largest freshwater inflows of the Delaware Estuary

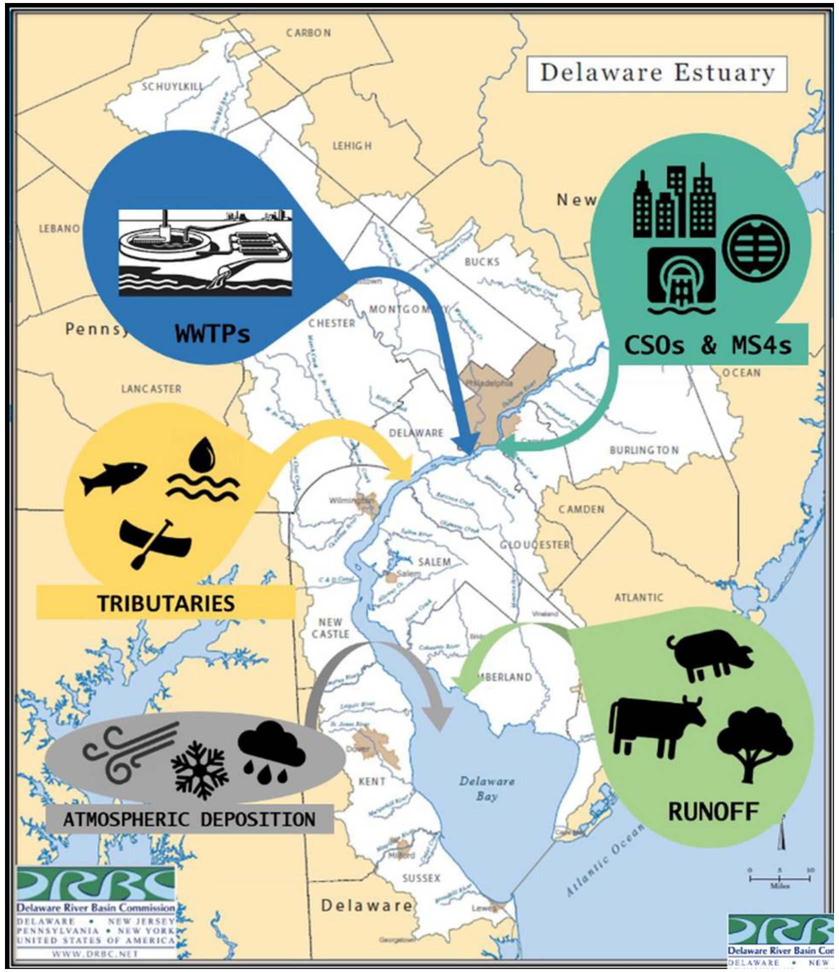
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

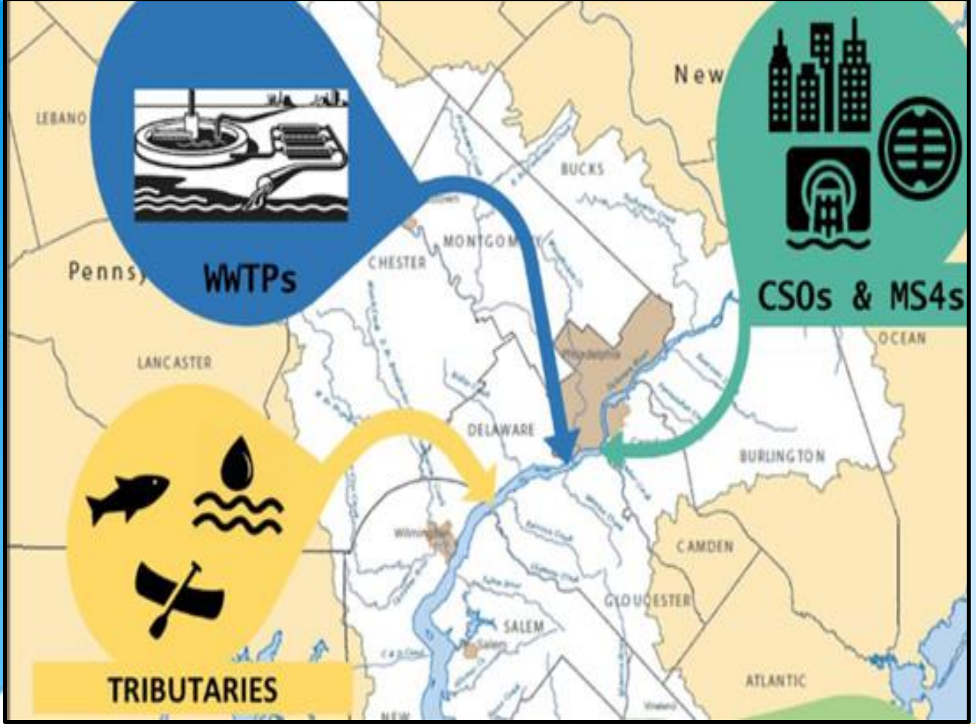


Load characterization:
Most Ammonia from Point Discharges (>90%)



Note:
includes only loads
from monitored treatment plants and tributaries

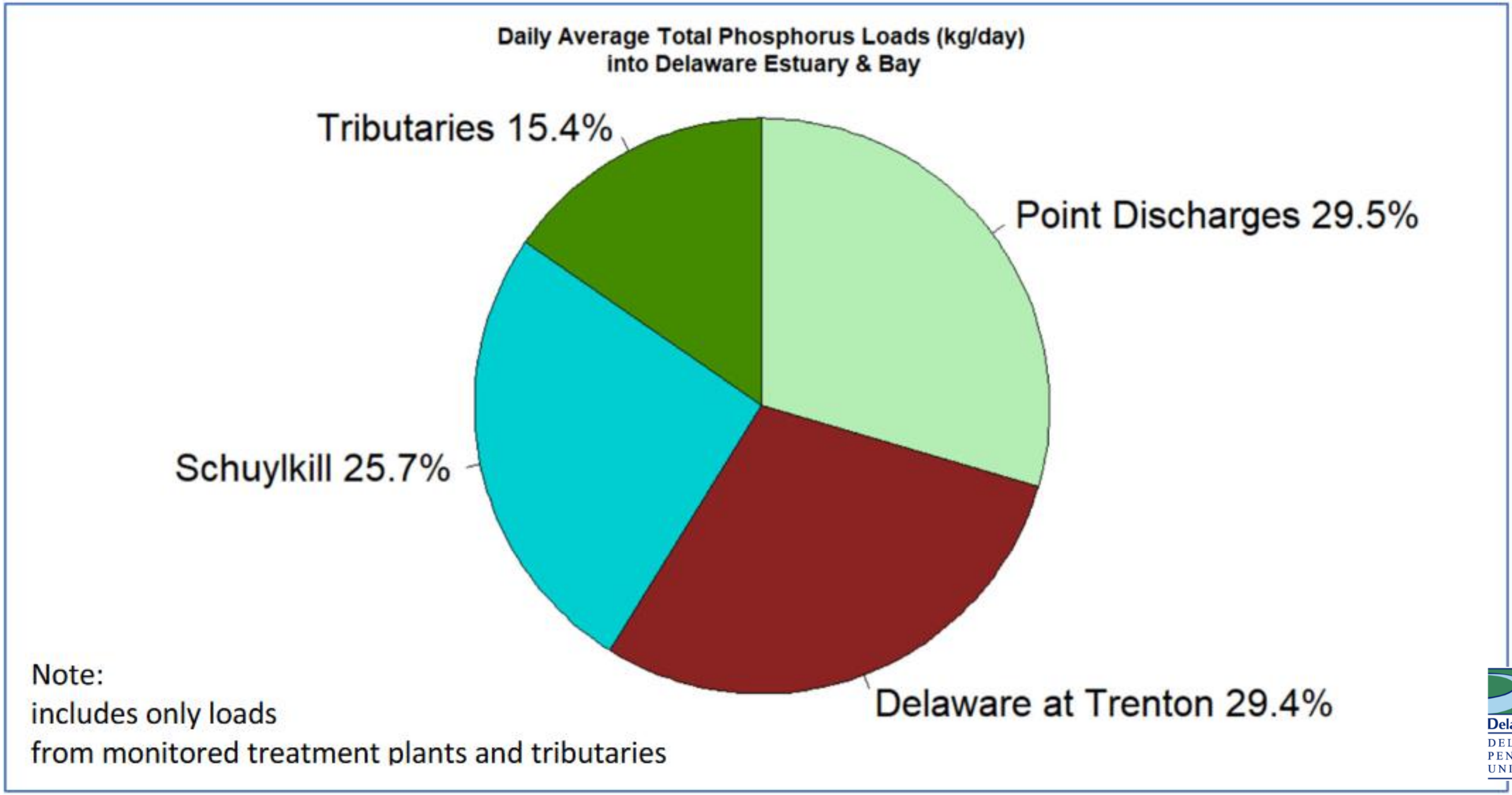




Wastewater treatment facilities account for **more than 90%** of ammonia inputs to the Delaware Estuary

DRBC characterized loads based on **actual measurements** of **32 point-discharge facilities** and **27 tributaries** during the 2018-2019 eutrophication model calibration period

Total phosphorus loads to the Delaware Estuary are not as drastically split between point-discharges and tributaries



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

Improving Dissolved Oxygen and Aquatic Life Uses in the Delaware River Estuary

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

Topic	Presenter
Why are we here?	Steve Tambini
How did DRBC address low dissolved oxygen in the Delaware Estuary - then and now?	Namsoo Suk
Where do ammonia and other nutrients in the Delaware Estuary originate, and how do we know?	John Yagecic
What is this estuary-wide eutrophication model and why do we need it?	**Li Zheng**
What matters and what doesn't with regard to low dissolved oxygen events in the Delaware Estuary?	Fanghui Chen
What combination of wastewater improvements will achieve the best dissolved oxygen outcome in the Delaware Estuary?	Sarah Beganskas
What is the highest attainable dissolved oxygen condition in the Delaware Estuary, and what will it mean for aquatic life uses?	Thomas Amidon
Q&A Panel: Enhancing support for aquatic life uses in the Delaware Estuary	**All**

What is this estuary-wide eutrophication model and why do we need it?

Li Zheng, Ph.D.
Senior Water Resource Modeler
Delaware River Basin Commission

Partnership for the Delaware Estuary Science and Environmental Summit

January 30, 2023

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

Model Development Team

DRBC Personnel

Name	Title
Kristen B. Kavanagh	Deputy Executive Director
Thomas Amidon	Manager, Water Resource Modeling
Sarah Beganskas	Water Resource Scientist
Jacob Bransky	Aquatic Biologist
Fanghui Chen	Senior Water Resource Engineer
Vince DePaul	Hydrologist (USGS)
Elaine Panuccio	Water Resource Scientist
Namsoo Suk	Director, Science and WQ Management
John Yagecic	Manager, Water Quality Assessment
Li Zheng	Senior Water Resource Modeler

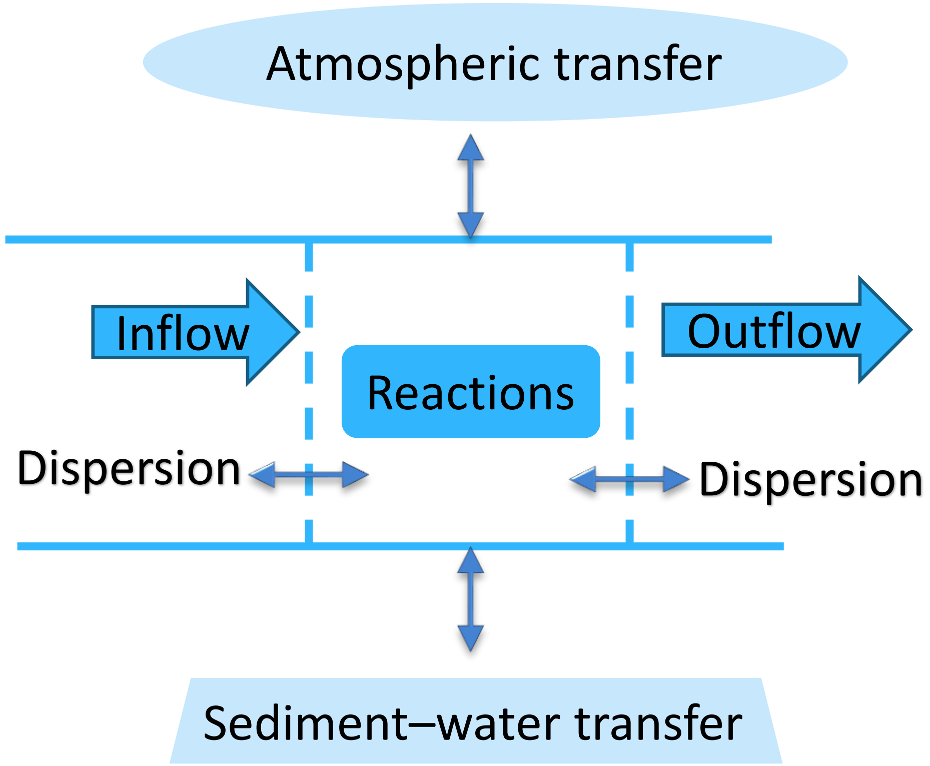
Expert Panel Members & Consultants

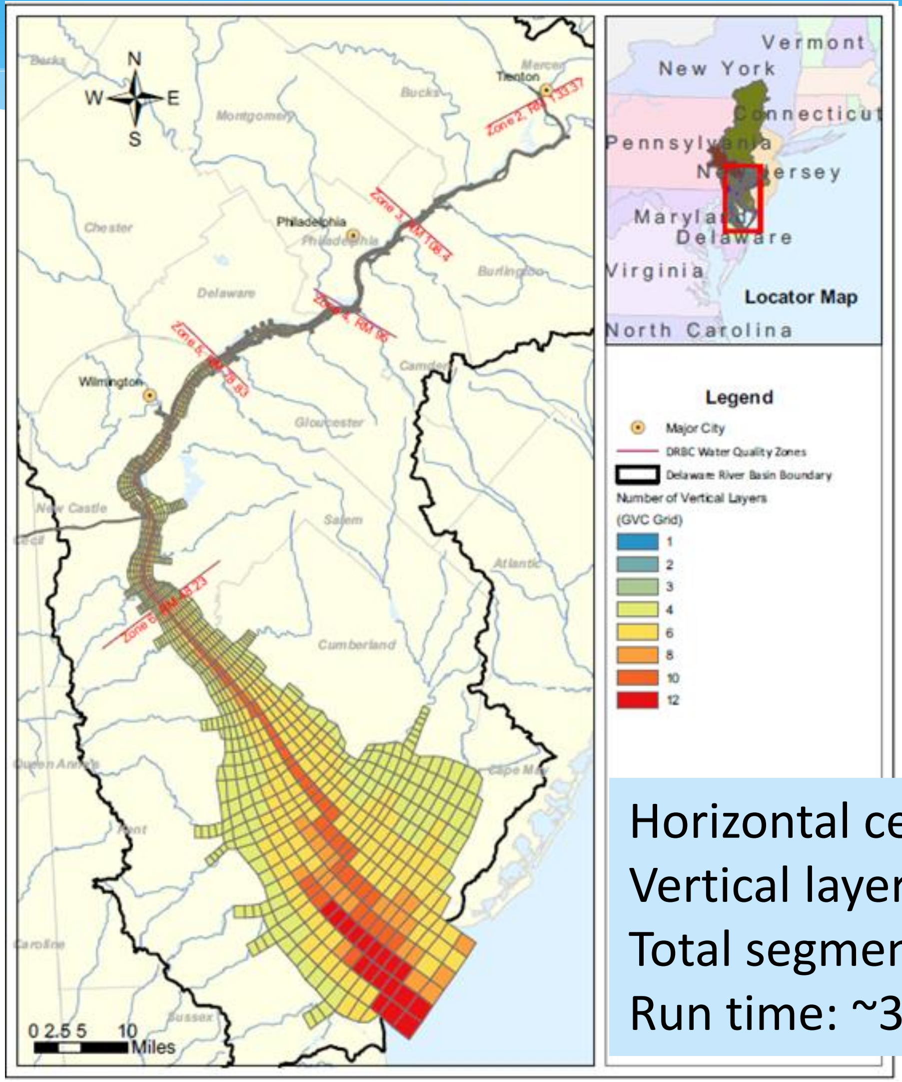
Name	Organization	Service
Carl Cerco	U.S. Army Corps of Engineers (Retired)	Panel Members
Bob Chant	Rutgers University	
Steve Chapra	Tuffs University	
Tim Wool	U.S. EPA Region 4 (Retired)	
Vic Bierman	LimnoTech	Consultant to DRBC
Scott Hinz	LimnoTech	

Hydrodynamic and Eutrophication Models

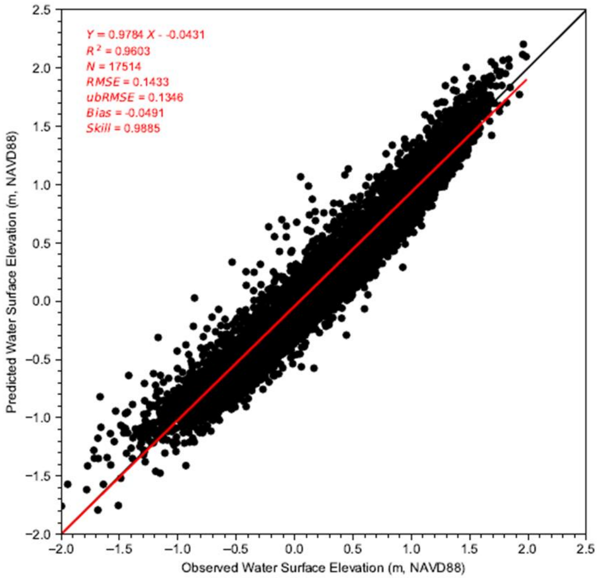
Purpose:

To determine ambient dissolved oxygen levels that would result from various pollutant reduction scenarios





Model–data comparison of water surface elevation at NOAA Philadelphia



Horizontal cell: 1876

Vertical layer: 10 in nav. Channel

Total segments: 11,490

Run time: ~32-hr in 3D

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

State Variables and Processes Applied to Delaware Estuary Model

Dissolved Constituents

Gases

- **DISOX: dissolved oxygen**

Inorganic Nutrients

- NH-34: ammonia nitrogen
- NO3O2: nitrate nitrogen
- D-DIP: inorganic phosphate
- IN-SI: inorganic silica

Organic nutrients

- CBODU1: ultimate CBOD from stream
- CBODU2: ultimate CBOD from PS
- CBODU3: refractory CBOD
- ORG-N: dissolved organic nitrogen
- ORG-P: dissolved organic phosphorus
- ORG-SI: dissolved organic silica

Particulate Constituents

Phytoplankton Biomass

- PHYTO1: spring marine diatom community
- PHYTO2: summer freshwater diatom community
- PHYTO3: summer marine diatom community

Detritus

- DET-C: detrital carbon
- DET-N: detrital nitrogen
- DET-P: detrital phosphorus
- DET-SI: detrital silica

Other Solids

- TOTDE: particulate detrital organic material (dw)
- SOLID: inorganic solid

Major Processes Simulated

Chemical Processes

- **Oxidation of CBOD**
- **Nitrification of ammonia to nitrate**
- Dissolution and Mineralization
- **Sediment oxygen demand**

Physical Processes

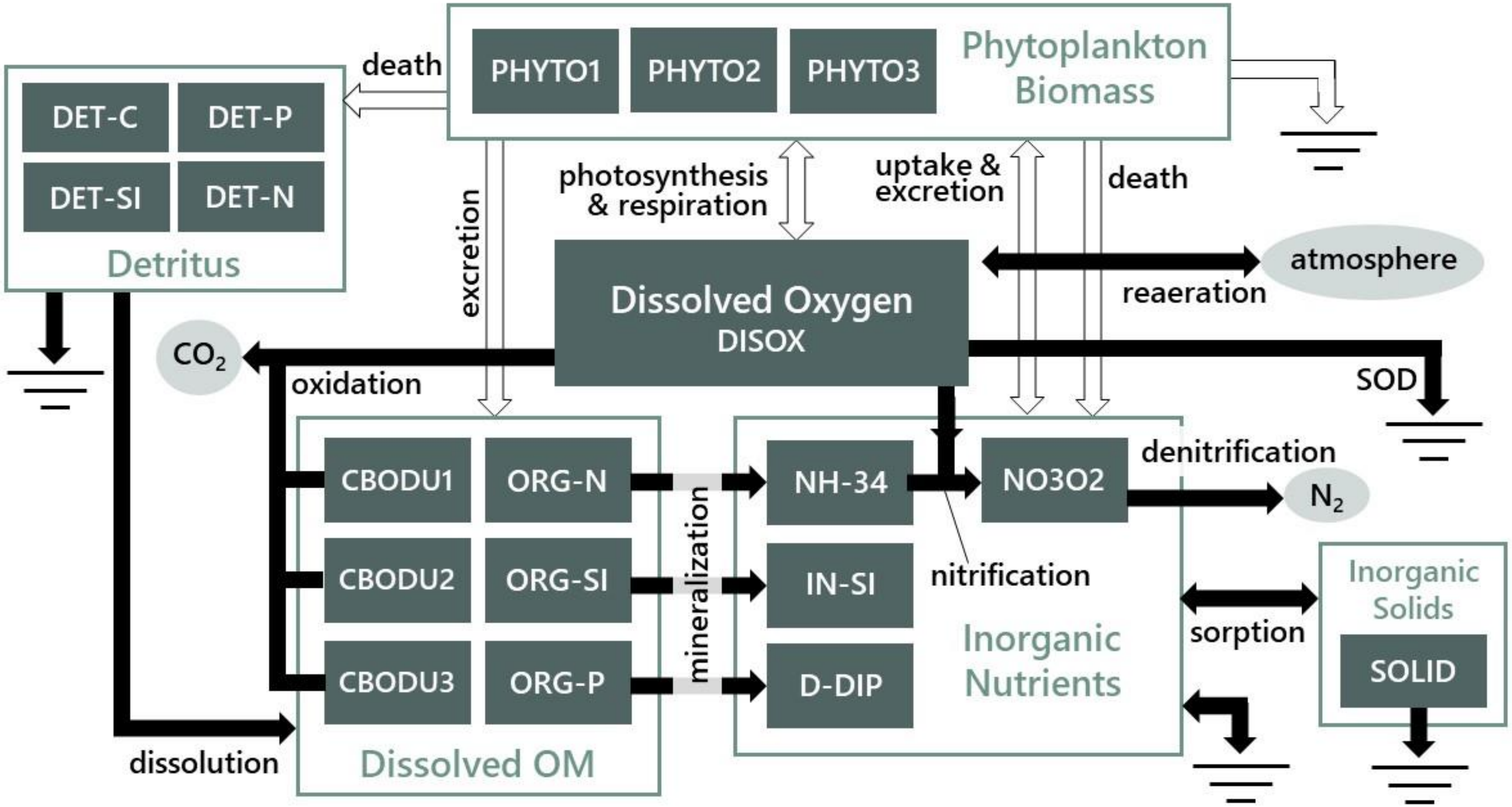
- Settling
- **Reaeration (influx and efflux)**
- Sorption

Biological Processes

- **Photosynthesis**
- **Respiration**
- Phytoplankton growth and death
- Uptake

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

Delaware Estuary Eutrophication Model Kinetics



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

Advancements to State-of-the-Art

Model Improvements

- Integration of hydrodynamic (EFDC) and eutrophication (WASP) models
  - Code modification
  - Model correction
- **Light extinction**
- **Reaeration**

Implementation

- Statistical sub-models for boundary assignments
  - Flows
  - Concentrations
- Input and output processing tools

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

Light Extinction Simulation

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

- Light extinction (Ke) refers to how quickly light is attenuated in the water column
  - Ke for salinity fitted using data downstream of ETM Zone
  - Ke for chl-a, and DOC fitted using data outside ETM Zone
- Used expression of intercept as f(RM) to calculate intercepts along the entire estuary

$$Ke = Ke_{Int} + (0.014 \times Chla) + (0.345 \times DOC) - (0.097 \times Salinity)$$

Where:

$$Ke_{Int}\ as\ f(RM) = 3.5944 \times e^{(-0.016*RM)} + Max\left[0, \left(1.7549 - 0.069 \times ABS(54.9 - RM)\right)\right]$$

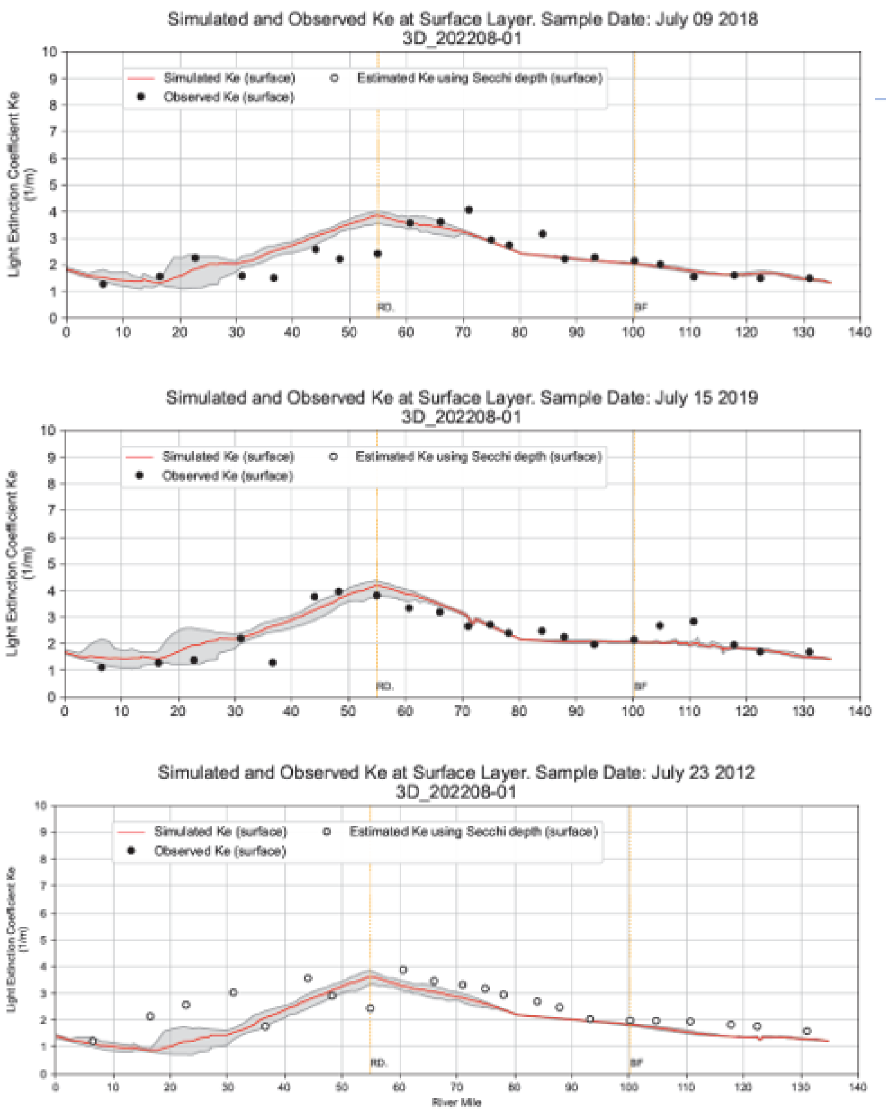
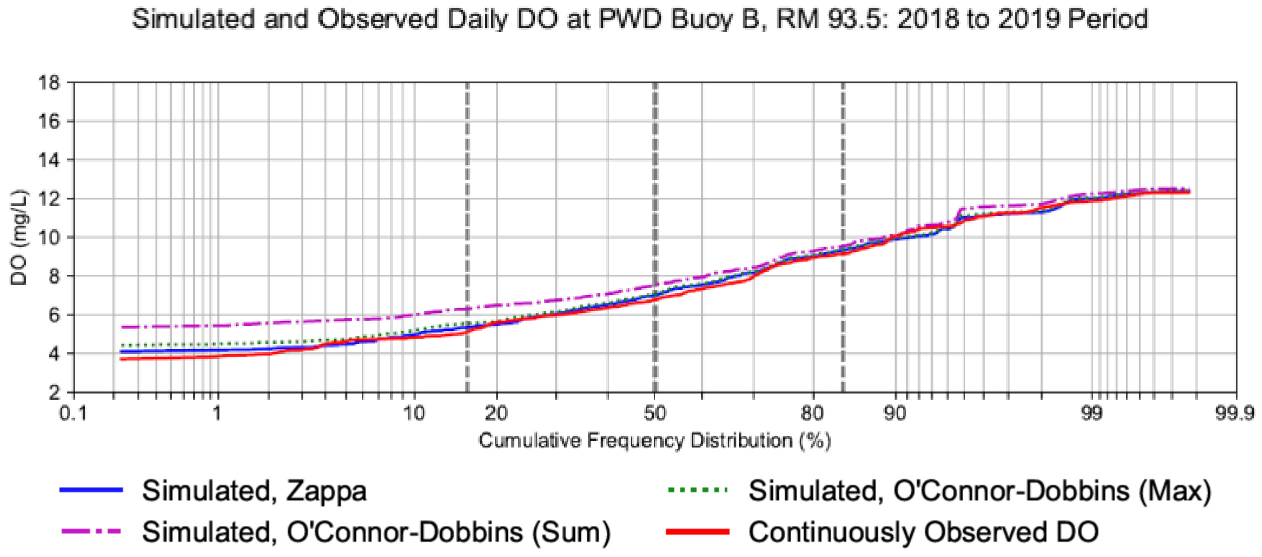


Figure 3-32: Light extinction – July 2018, 2019, and 2012

Reaeration Simulation Enhancements

- Reaeration: rate of DO transfer at the air-water interface
- Mass Transfer Coefficient
  - Existing WASP model options
    - Hydraulic-driven reaeration for river & stream
    - Wind-driven reaeration for lake or bay
  - Utilize turbulent energy dissipation rate at air-water interface (Zappa et al. 2007)
    - Include the effects of both hydraulic and wind-induced

Figure 3-1c: Model–Data Comparisons of Daily DO during 2018–2019 at PWD Buoy B



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

Calibration Strategy

- Calibration period: 2018 and 2019
- Corroboration period: 2012
- Principal data used for comparison with model predictions
  - DRBC monthly boat-run survey with grab samples
  - USGS & PWD continuous measurement
- Approach
  - Spatial plots, time series plots, 1-1 plots, cumulative frequency distributions, target diagrams, and statistical metrics used to compare predicted and observed
  - Phytoplankton output compared based on growth seasons of three communities

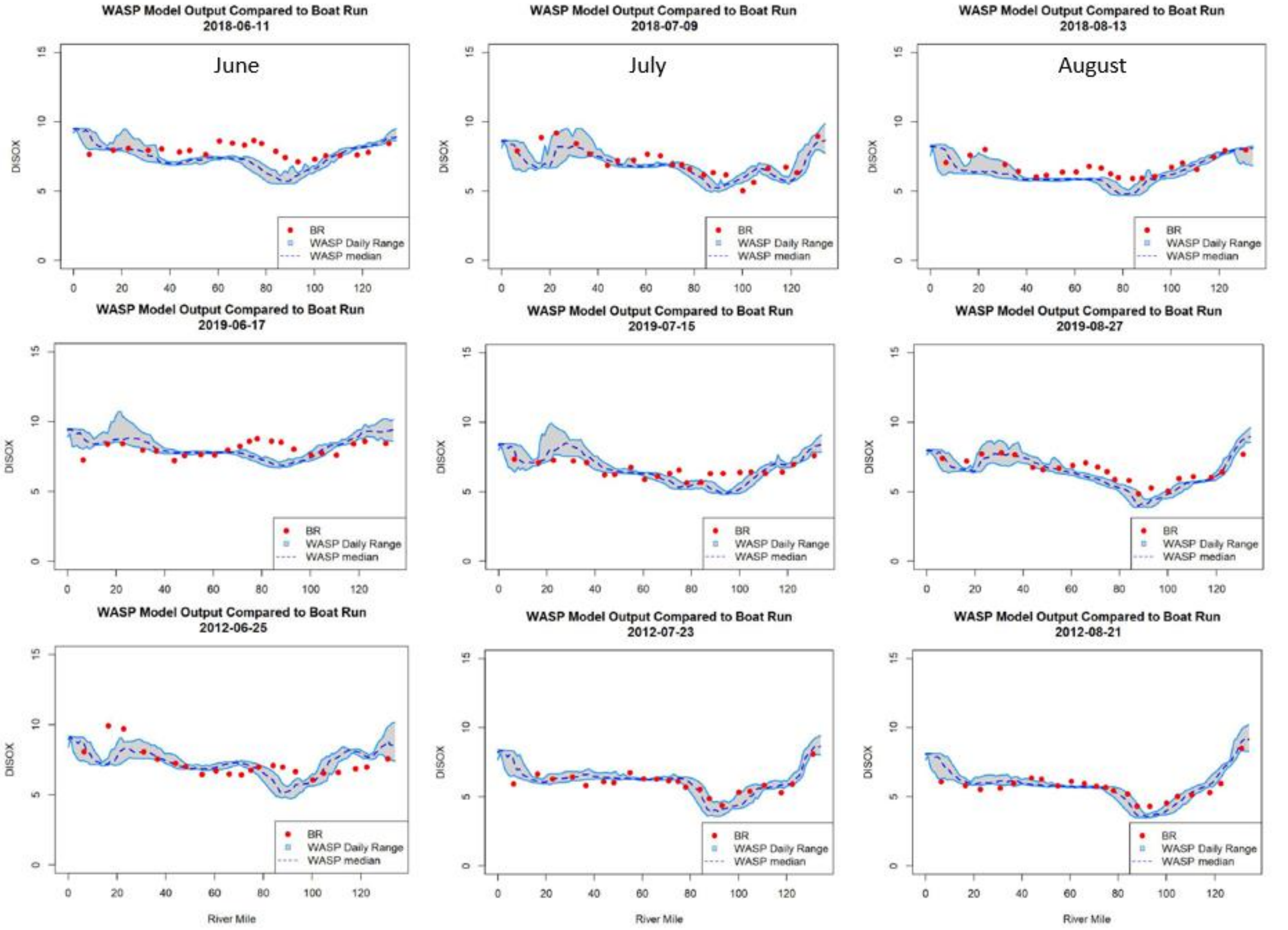
Calibration data locations

Model – Boat Run Data Comparison: DO during Summer

calibration 2018

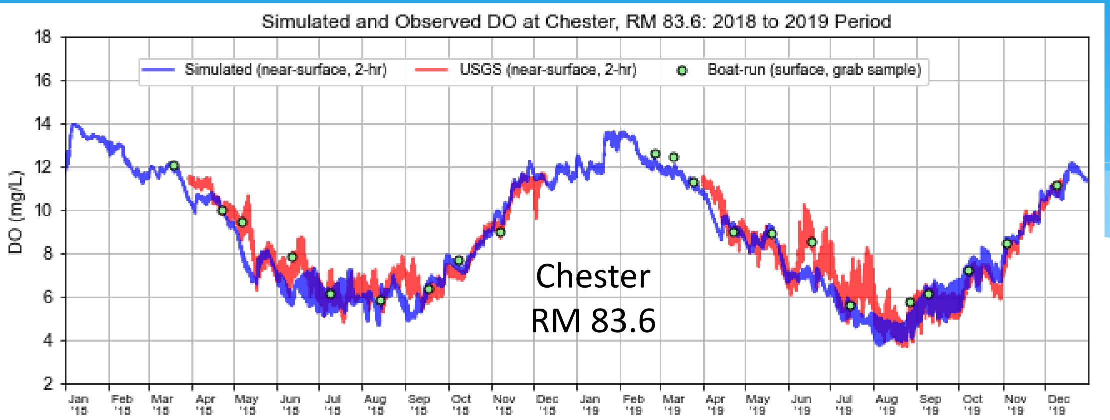
calibration 2019

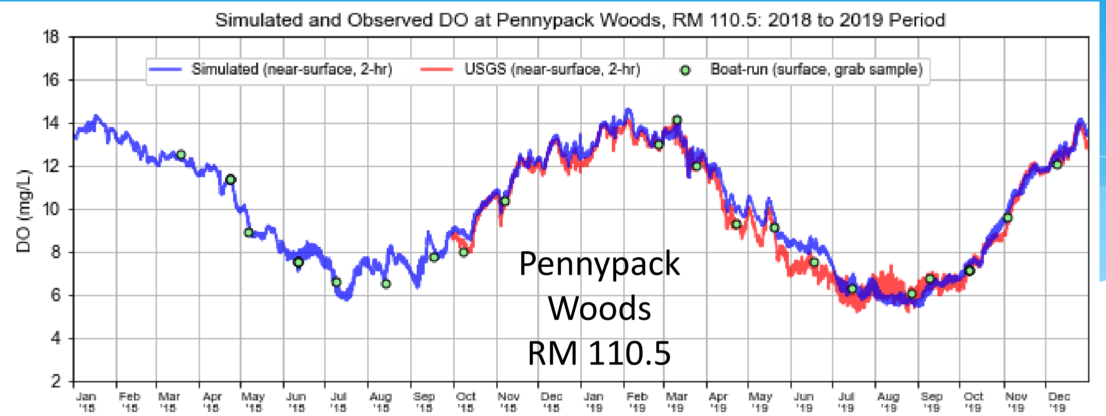
Corroboration 2012

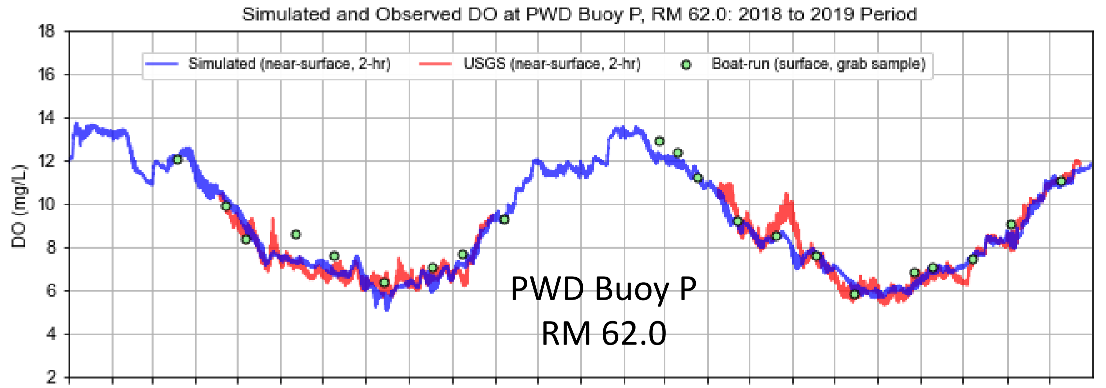


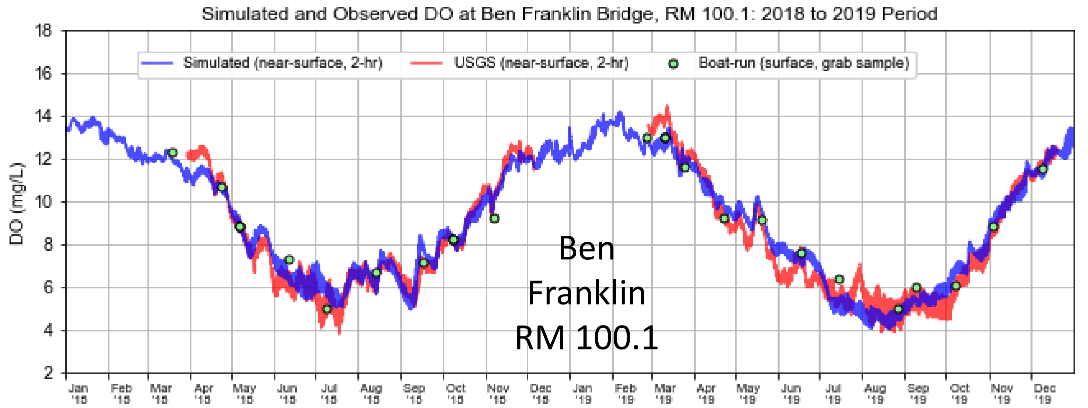
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

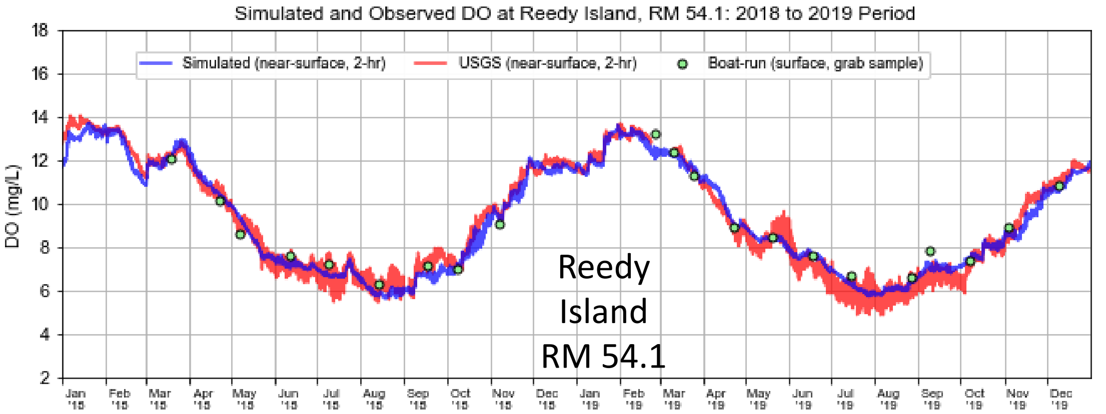
In-Situ Continuous DO: 2018 – 2019

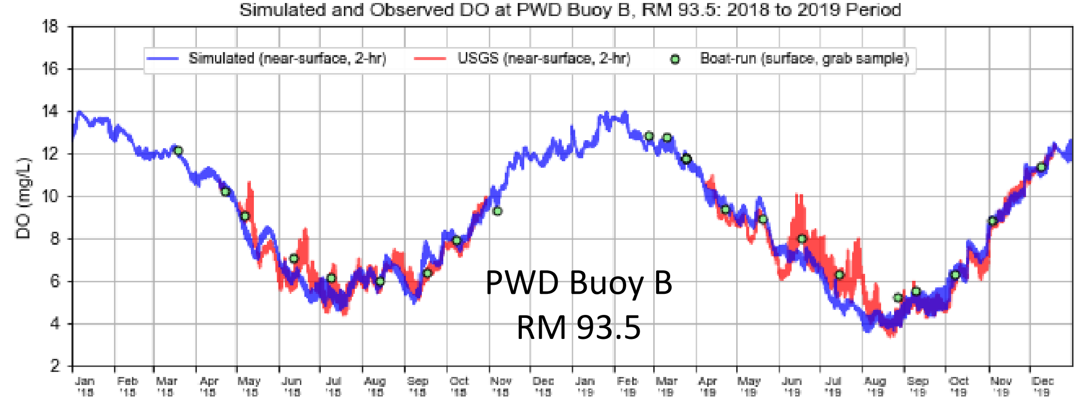








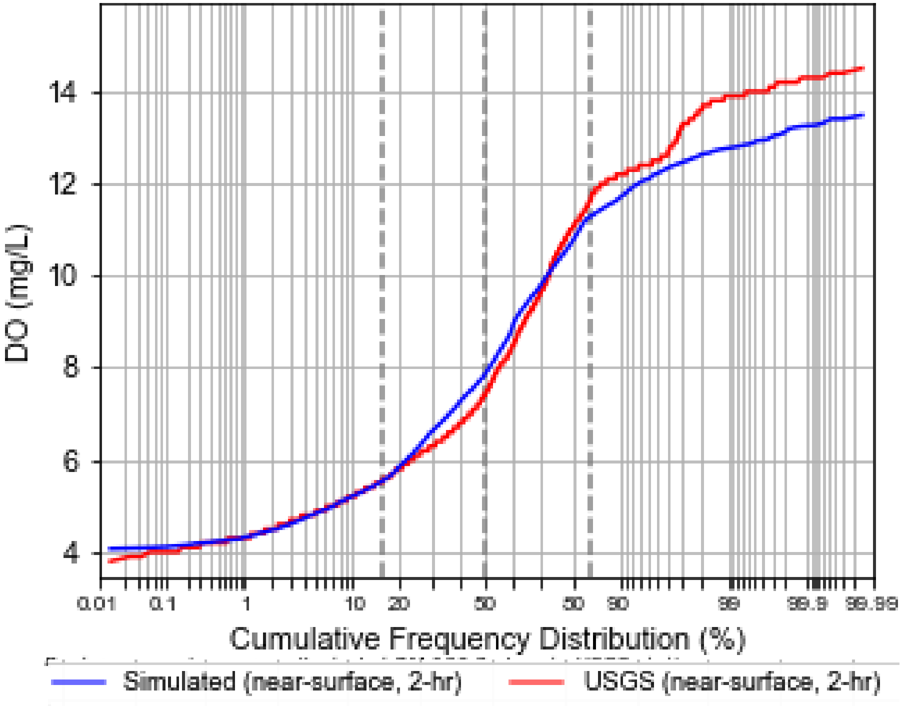


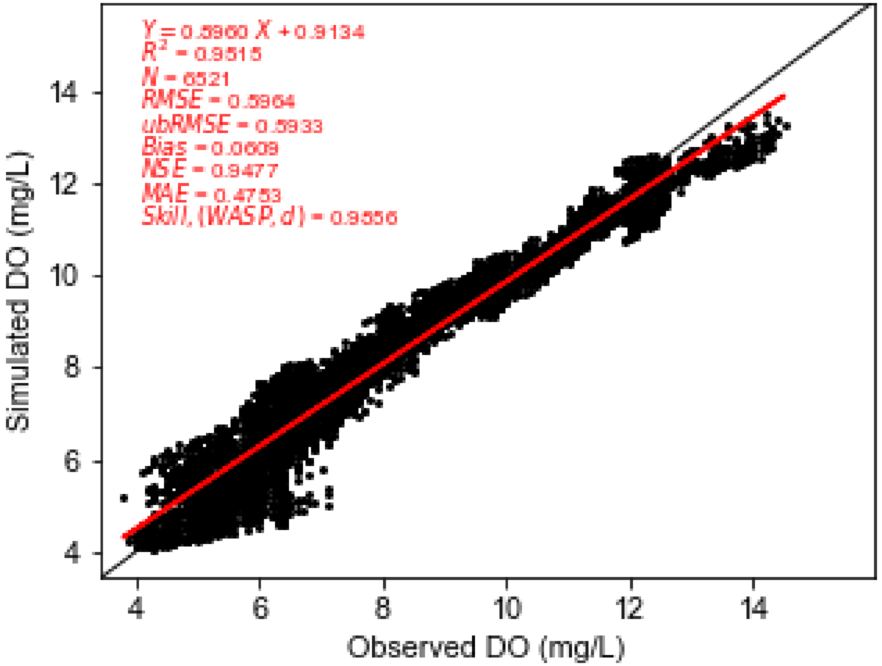


Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

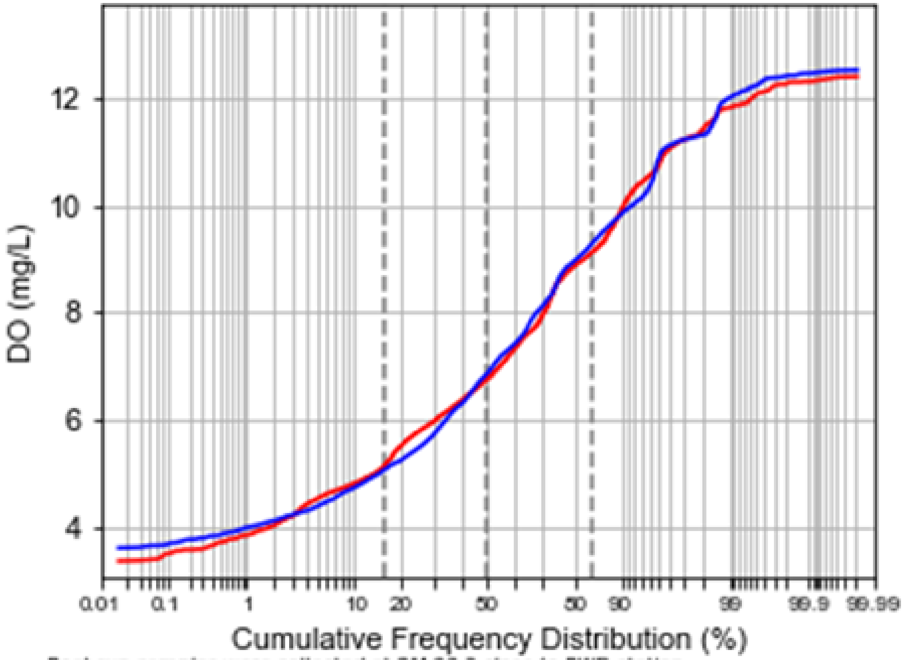
In-Situ Continuous DO: 2018 – 2019

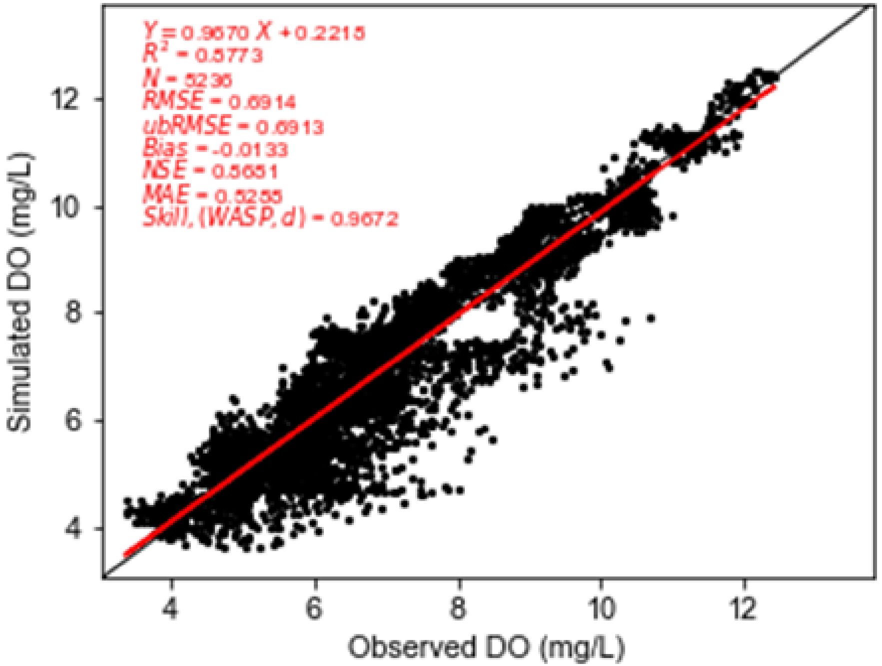
Ben Franklin Bridge, RM 100.1





Buoy B, RM 93.5

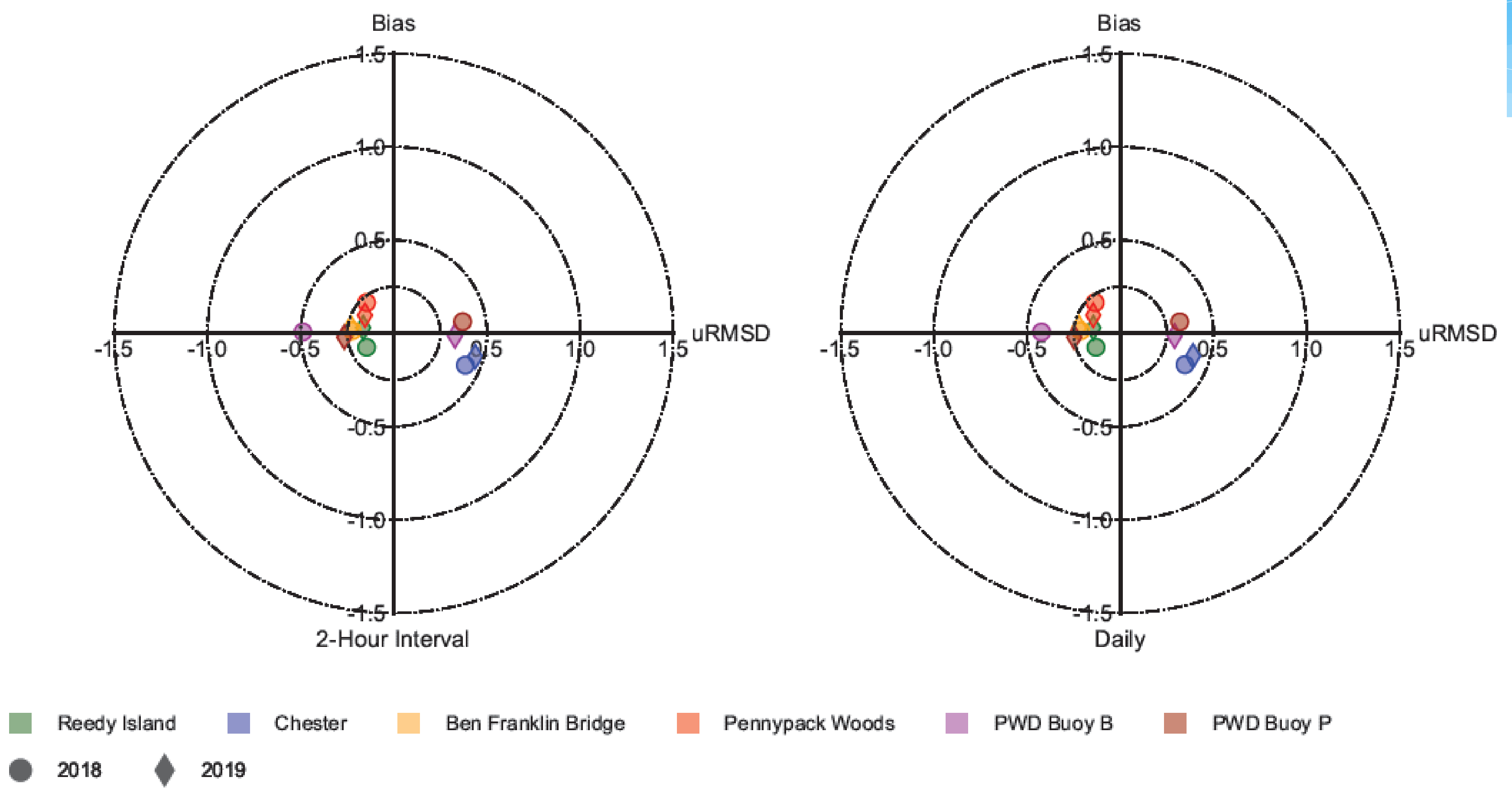




Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

In-Situ Continuous DO: 2018 – 2019

Target Diagram for Predicted Dissolved Oxygen



Normalized Bias and Unbiased RMSD (ubRMSD) are shown.
Nomalization was based on the standard deviation of the data

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

Conclusions

DRBC technical staff and Expert Panel Members

1. Model is scientifically defensible over a wide range of environmental conditions in the Delaware Estuary

2. Model is appropriate for its intended use
   - To determine the improvement in dissolved oxygen condition that would result from specific reductions to point and nonpoint source loadings

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

Improving Dissolved Oxygen and Aquatic Life Uses in the Delaware River Estuary

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

Topic	Presenter
Why are we here?	Steve Tambini
How did DRBC address low dissolved oxygen in the Delaware Estuary - then and now?	Namsoo Suk
Where do ammonia and other nutrients in the Delaware Estuary originate, and how do we know?	John Yagecic
What is this estuary-wide eutrophication model and why do we need it?	Li Zheng
What matters and what doesn't with regard to low dissolved oxygen events in the Delaware Estuary?	**Fanghui Chen**
What combination of wastewater improvements will achieve the best dissolved oxygen outcome in the Delaware Estuary?	Sarah Beganskas
What is the highest attainable dissolved oxygen condition in the Delaware Estuary, and what will it mean for aquatic life uses?	Thomas Amidon
Q&A Panel: Enhancing support for aquatic life uses in the Delaware Estuary	**All**

What matters and what doesn't regarding low dissolved oxygen events in the Delaware Estuary?

Fanghui Chen, Ph.D., P.E.
Senior Water Resources Engineer
Delaware River Basin Commission

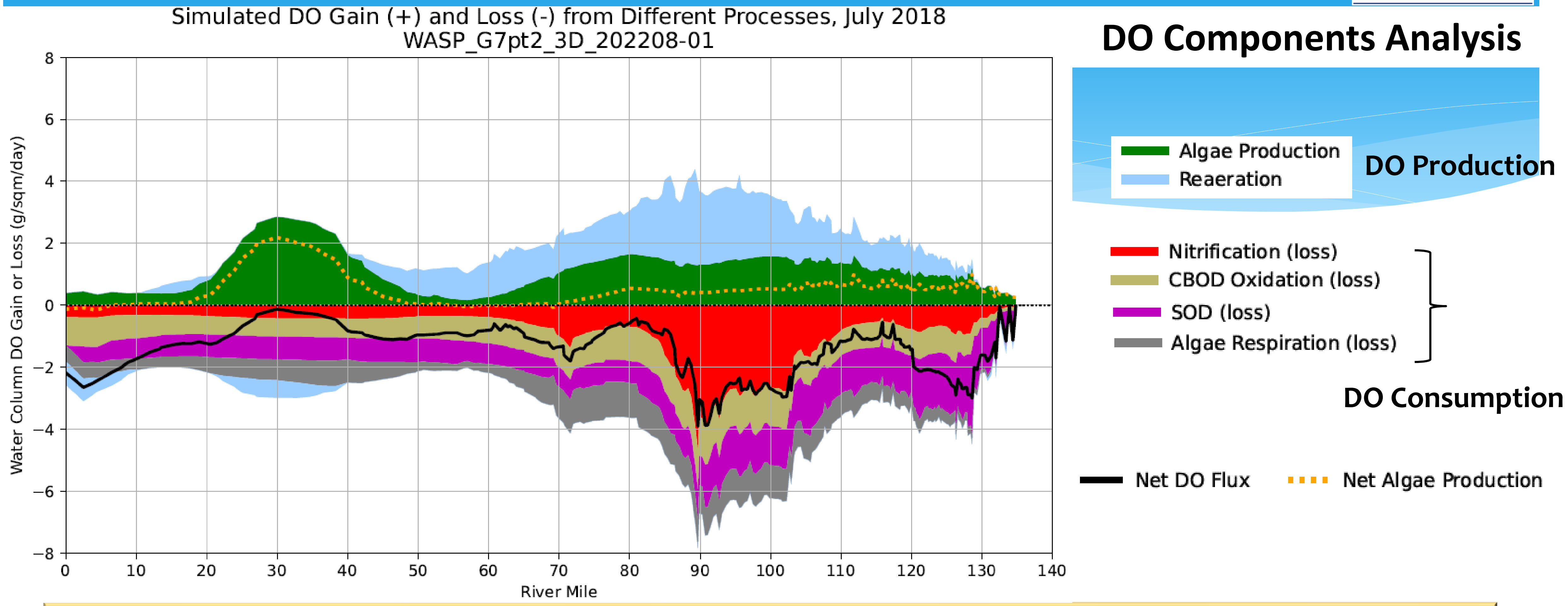
Partnership for the Delaware Estuary Science and Environmental Summit

January 30, 2023

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

Understanding dissolved oxygen processes

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



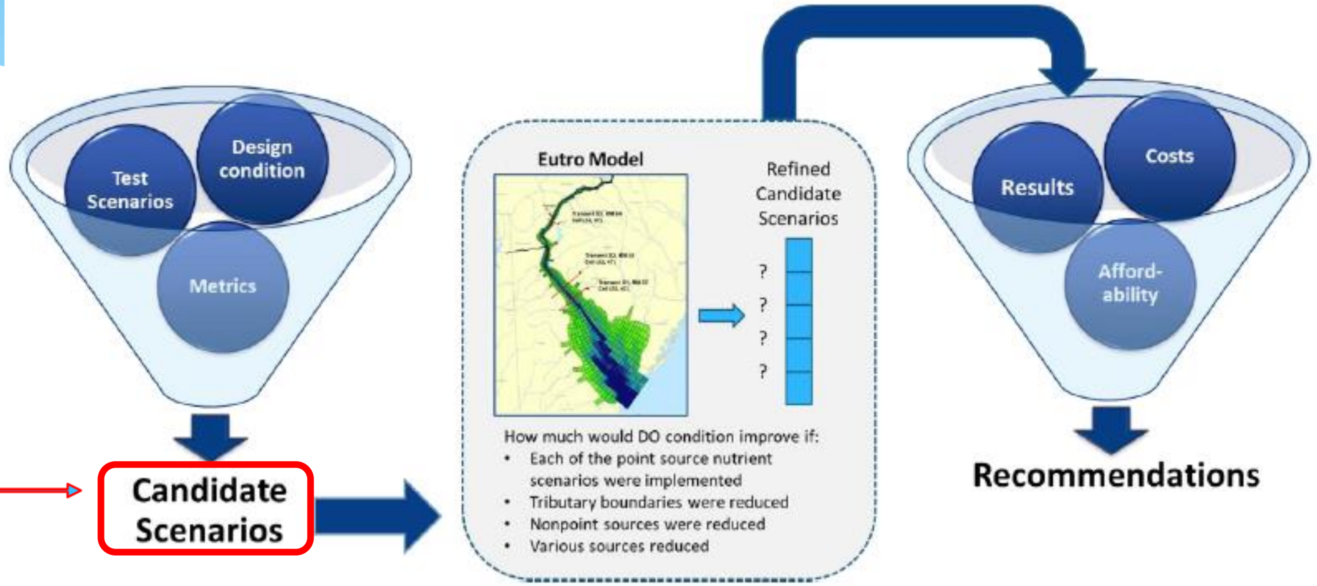
- *Processes that control DO production: reaeration, photosynthesis.*
- *Processes that affect DO consumption: nitrification, followed by SOD, CBOD oxidation, and respiration*
- *DO gain from net algal production << DO loss caused by nitrification in the urban portion of the tidal river*
- *Reaeration impacts can offset both sinks and sources*

Analysis of Attainability (AA)

- Design Condition, Source Sensitivity, Metrics

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

- ❑ Design Condition (baseline)
- ❑ Test Scenarios
  - ➢ Pollutant source sensitivity scenarios
  - ➢ Pollutant load reduction scenarios
- ❑ Metrics



Elements of analysis of attainability

Characterize the distribution, magnitude, frequency, and/or duration

"**Critical propagation season**": **from May 1 to October 15**

- Longitudinal Plots: DO Percentiles and "Percent-Above"
- DO Relative Stress Index
- Tabular Maps

This "summer" season reflects the temporal overlap between historically low DO events and important stages in juvenile development in which fish may be particularly vulnerable to low DO concentrations

AA: Design Condition

- **Hydrologic conditions** from 2012
  - tributary and watershed inflows and concentrations
  - tidal inputs at the mouth of the Bay and the C&D Canal
  - weather inputs
- **Permitted flow** rates for all point source (wastewater treatment plant) discharges
- Seasonal median **effluent concentrations** for wastewater discharges (current treatment levels)
- Post-channel deepening **bathymetry**

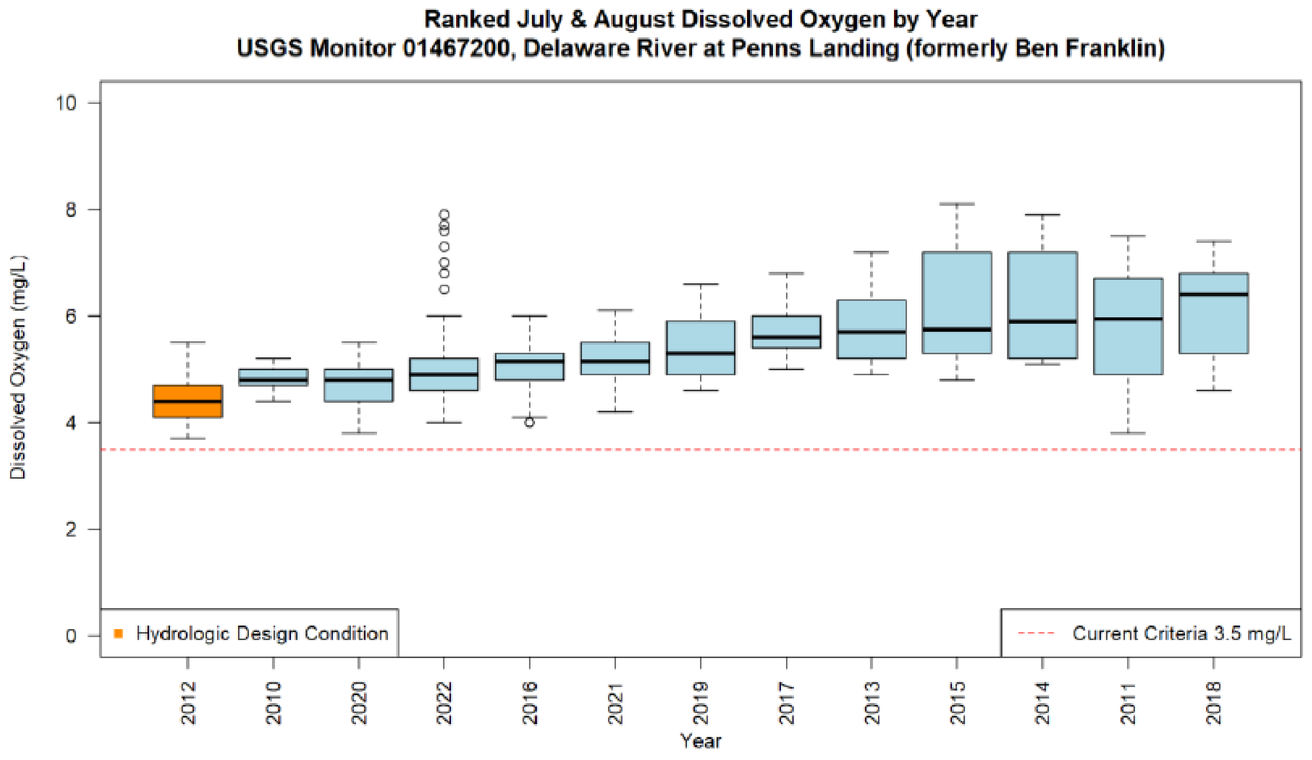


Figure 2-5: Dissolved oxygen at Penn's Landing during July and August from 2010–2022

DO in the Delaware River Estuary usually reaches its annual minimum in July and August period. 2012 showed lowest DO during 2010-2022 period. Low flow with dry-weather conditions brought lower DO in the summer of 2012.

Notes: The permitted flow rates established by individual NPDES permits.
"summer" (May–October) and "winter" (November–April) median values calculated based on model-interpolated concentrations assigned based on intensive data collection during the 2018–2019 calibration period.

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

AA: Source Category Sensitivity Tests

Which pollutant sources to the Estuary may substantially impact DO improvement in the FMA?

- Wastewater Treatment Plants
- CSOs
- Non–point sources (NPS)
- Municipal separate storm sewer systems (MS4)
- Tributaries

Source constituents

NH34, TN, P, CBOD, DO, etc.

FMA: the fish maintenance area, which covers Zone 3, 4, and upper Zone 5, roughly from RM 70 to near RM 108

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

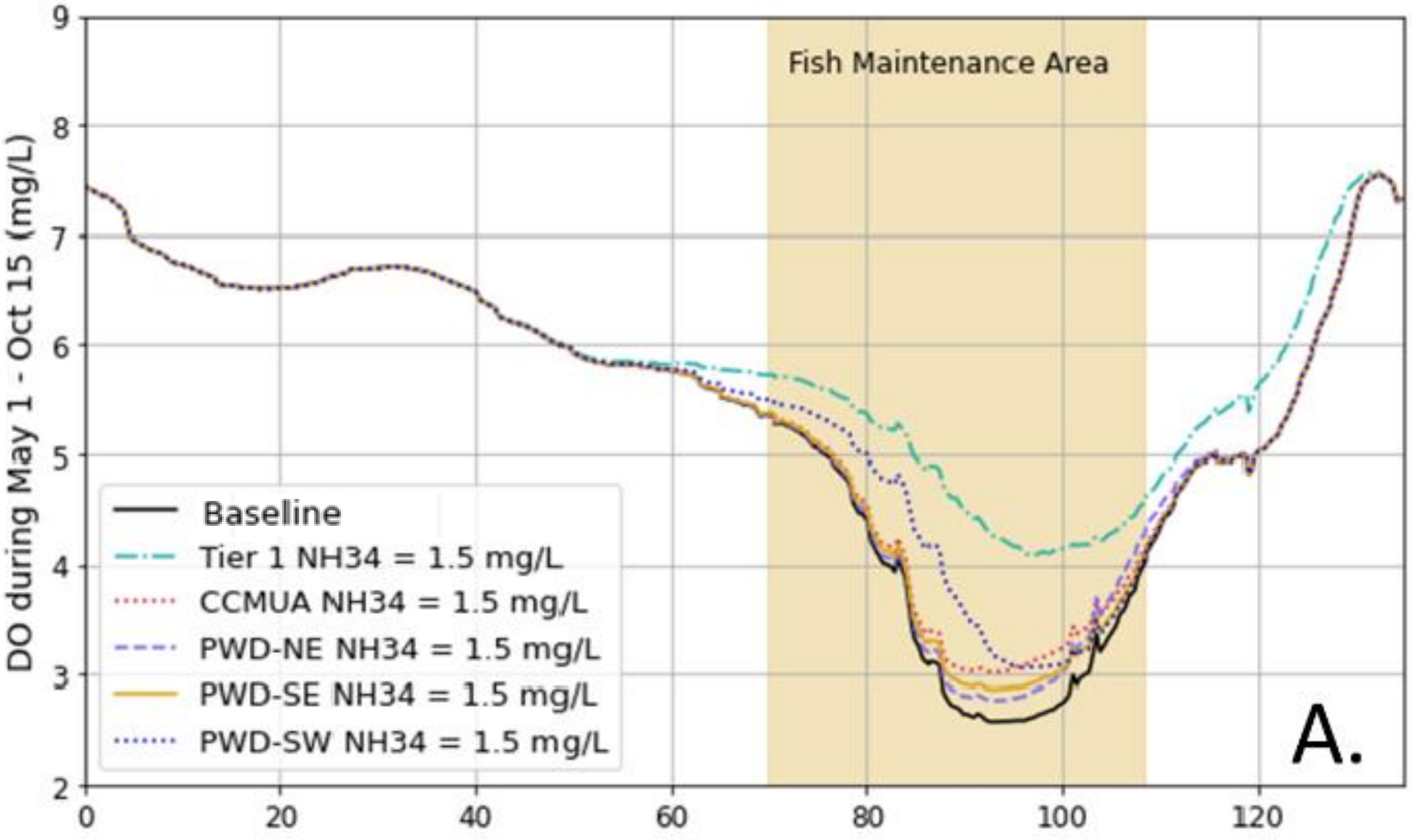
Source category sensitivity tests

Results from sensitivity tests are compared to the Baseline scenario

Individual wastewater discharge NH34 reduced to 1.5 mg/L

1st Percentile DO

Reducing effluent ammonia loads from these discharges resulted in substantial DO improvement in the FMA

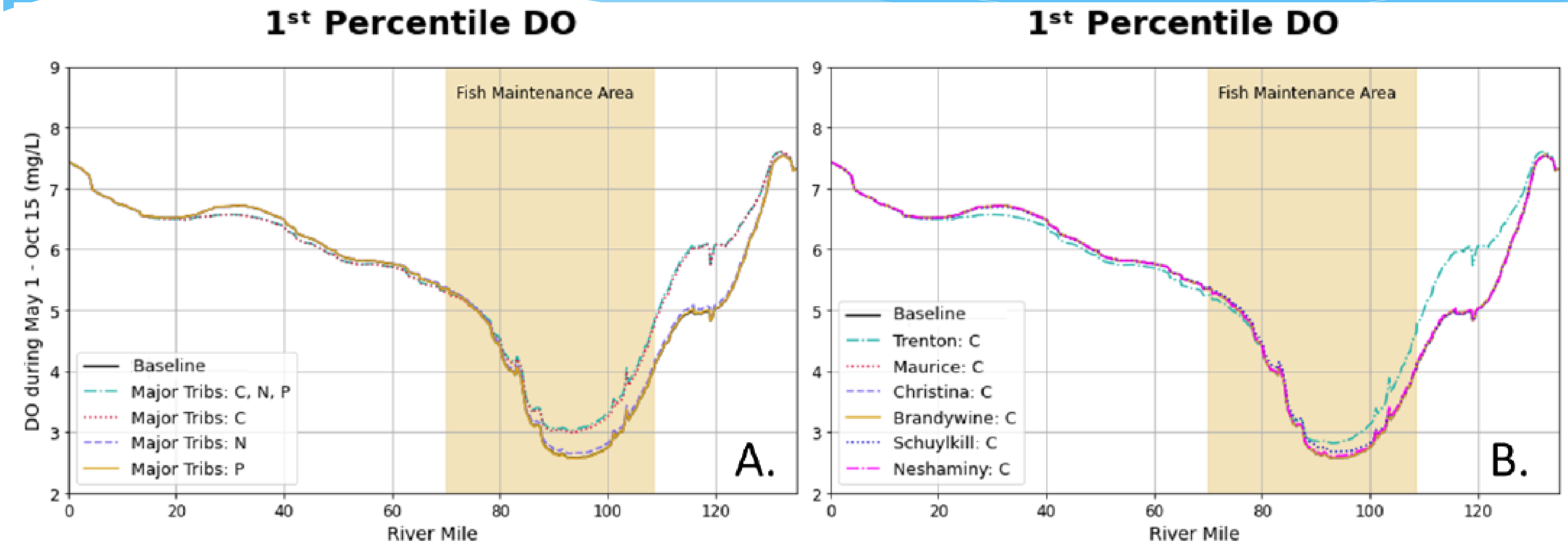


River Mile

Note: Tier 1 discharges were identified based on two years of effluent loading data collected during the 2010s; the Tier 1 discharges together constitute 95% of total point source nutrient load

Tributary Sensitivity Tests

C, N, and P set to minimal concentrations in 6 major tributaries:
(Maurice, Christina, Brandywine, Schuylkill, Neshaminy, Delaware @Trenton)



A. Four test scenarios where C, N, and/or P from six major tributaries (Delaware River at Trenton, Schuylkill River, Maurice River, Christina River, Brandywine Creek, and Neshaminy Creek) were set to minimal values. **B**. Six test scenarios where C was reduced from each major tributary individually.

Factors That Can Improve Dissolved Oxygen In Fish Maintenance Area

Factors that can most improve DO in the FMA	Factors that can slightly improve DO in the FMA	Factors that cannot measurably improve DO in the FMA
▪ **Summer (May–Oct) ammonia loads from specific point-source discharges** ▪ Carbon loads from Delaware River at Trenton (high % of total flow)	▪ Combined sewer overflows (CSOs) ▪ DO concentration in treated effluent from the largest point-source discharges ▪ Carbon loads from Schuylkill River	▪ Nutrient (C, N, P) loads from tributaries, except C loads from Delaware River at Trenton and Schuylkill River ▪ Winter (Nov–Apr) ammonia, CBOD, and TN from all point-source discharges ▪ Summer (May–Oct) ammonia loads from many point-source discharges ▪ Direct stormwater runoff into the Delaware Estuary

Improving Dissolved Oxygen and Aquatic Life Uses in the Delaware River Estuary

Topic	Presenter
Why are we here?	Steve Tambini
How did DRBC address low dissolved oxygen in the Delaware Estuary - then and now?	Namsoo Suk
Where do ammonia and other nutrients in the Delaware Estuary originate, and how do we know?	John Yagecic
What is this estuary-wide eutrophication model and why do we need it?	Li Zheng
What matters and what doesn't with regard to low dissolved oxygen events in the Delaware Estuary?	Fanghui Chen
What combination of wastewater improvements will achieve the best dissolved oxygen outcome in the Delaware Estuary?	**Sarah Beganskas**
What is the highest attainable dissolved oxygen condition in the Delaware Estuary, and what will it mean for aquatic life uses?	Thomas Amidon
Q&A Panel: Enhancing support for aquatic life uses in the Delaware Estuary	**All**

What wastewater improvements will achieve the best dissolved oxygen outcome in the Delaware Estuary?

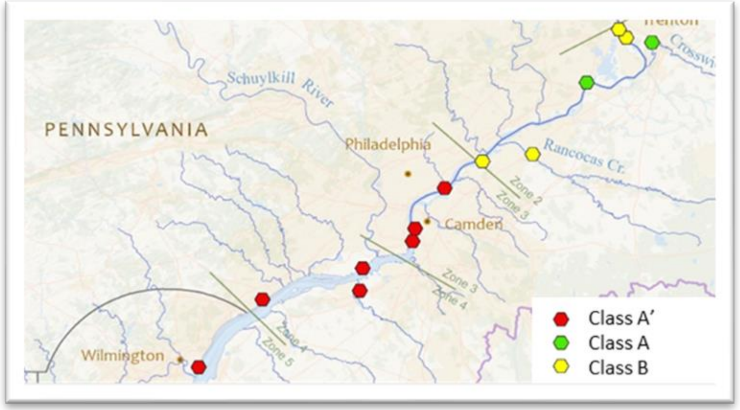
Sarah Beganskas, PhD

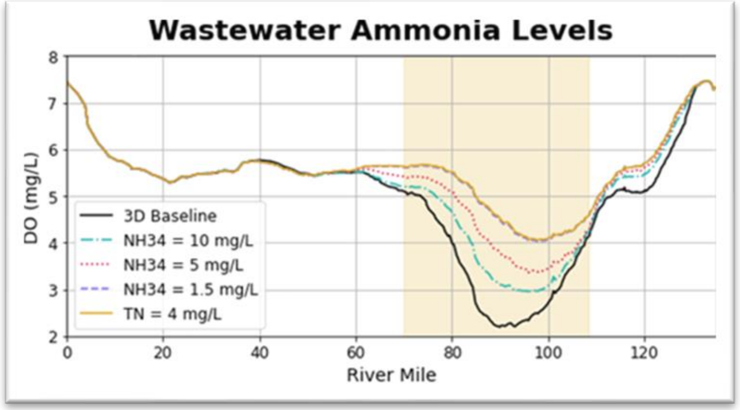
Water Resource Scientist

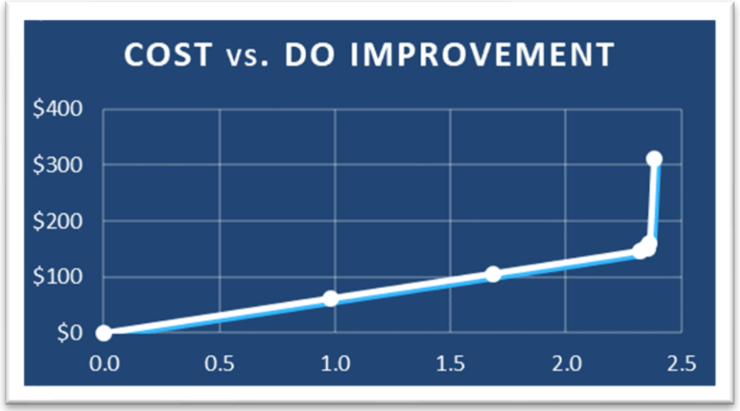
Delaware River Basin Commission

Partnership for the Delaware Estuary Science and Environmental Summit

January 30, 2023

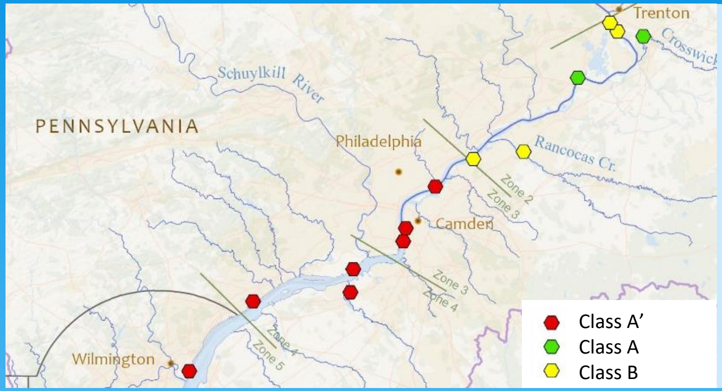




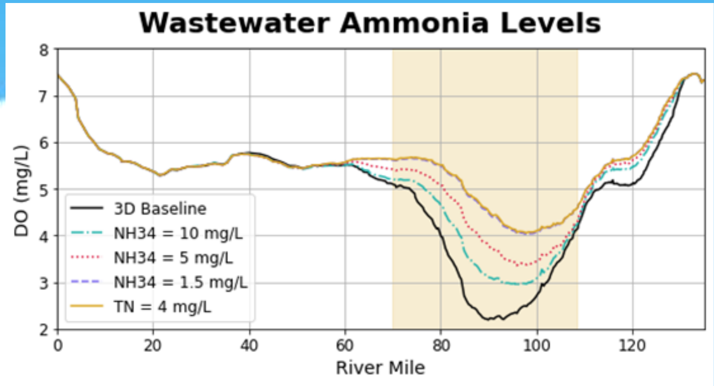


Delaware River Basin Commission

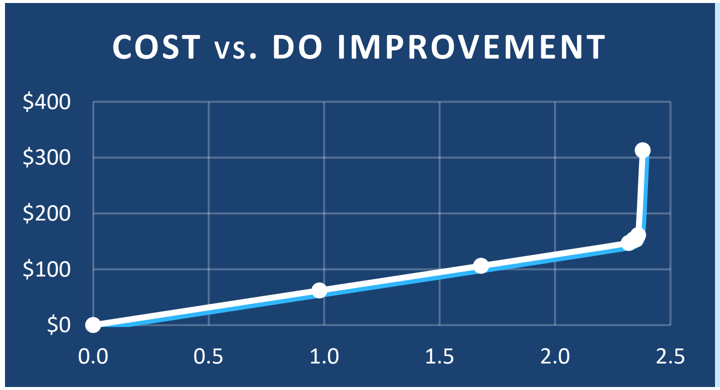
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA



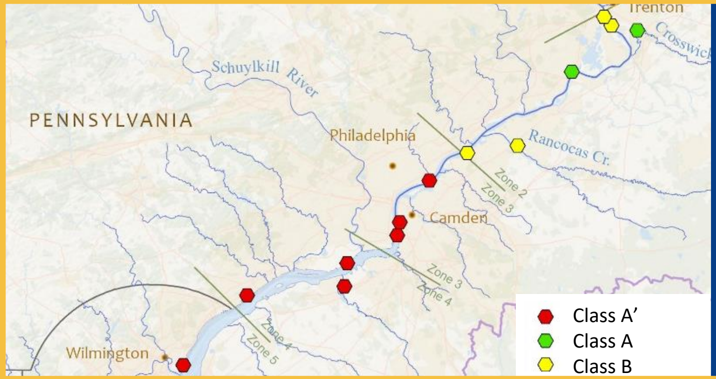
Which wastewater discharges are most important for DO?



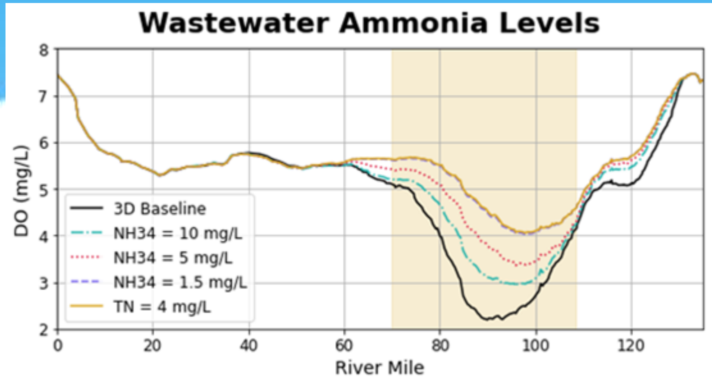
How much ammonia reduction is needed to maximize DO improvement?



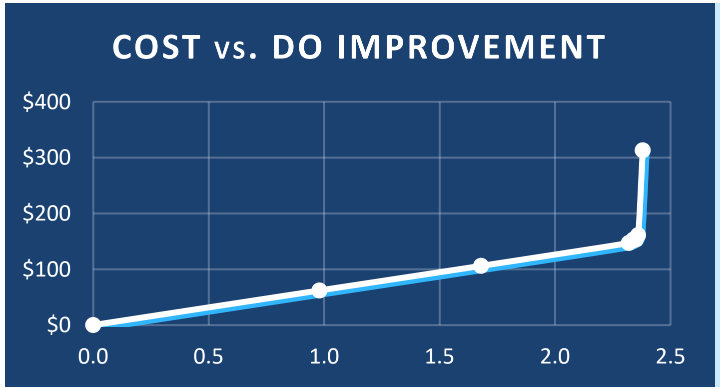
What are the associated costs?



Which wastewater discharges are most important for DO?

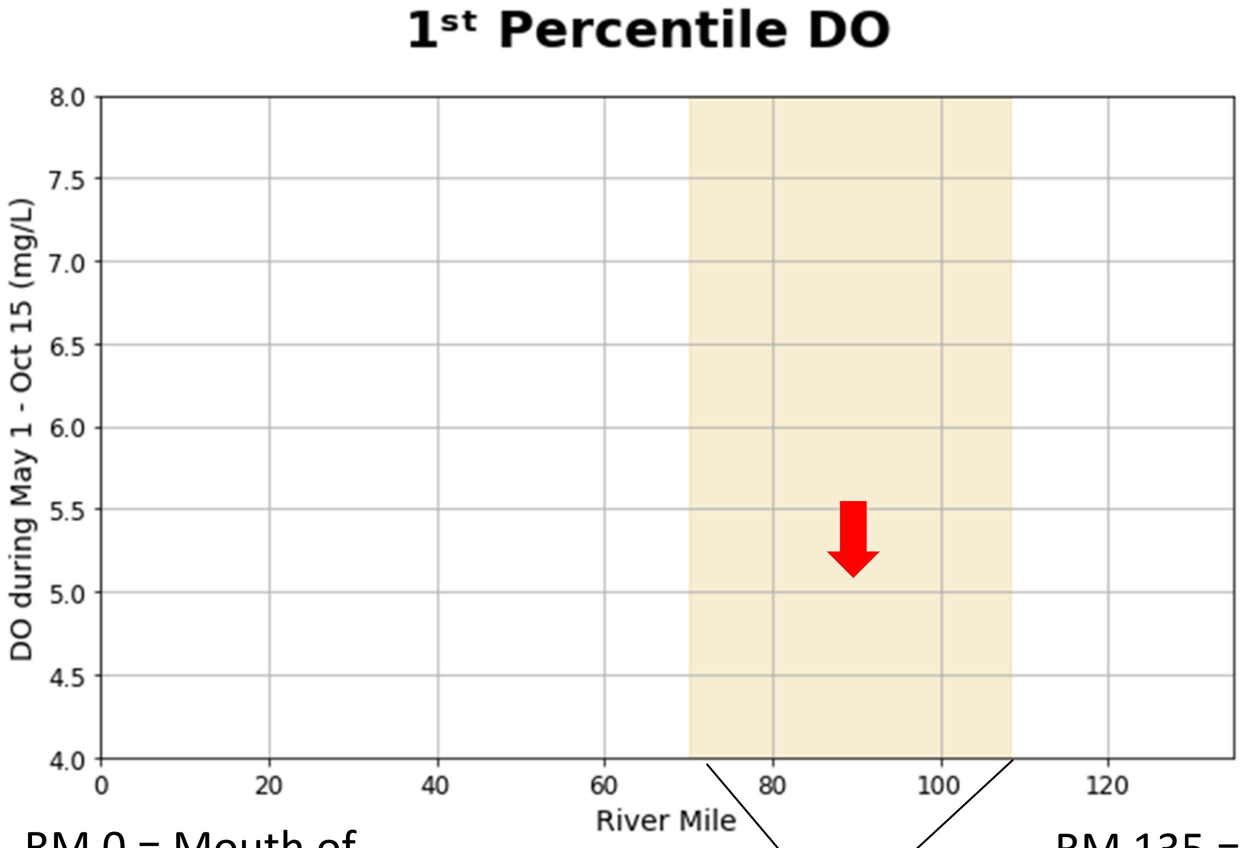


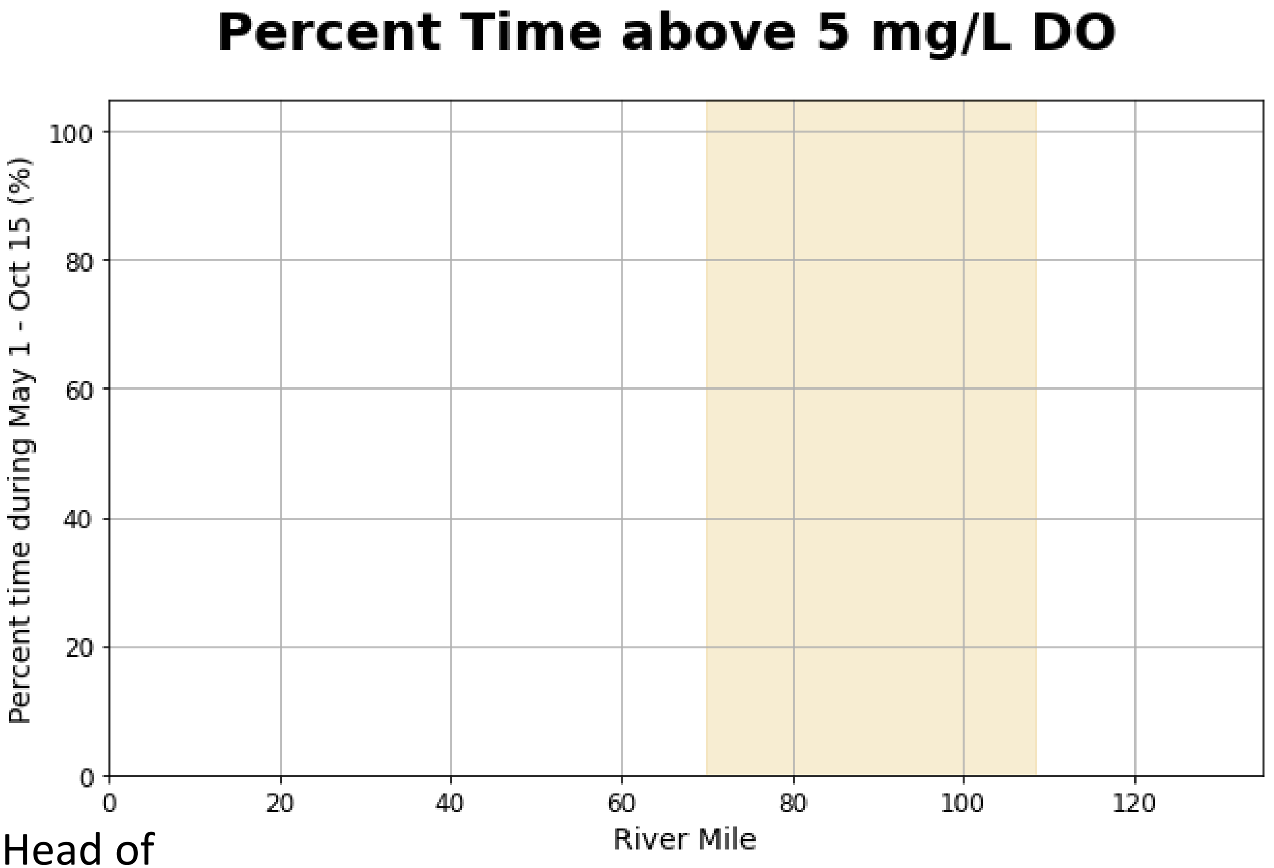
How much ammonia reduction is needed to maximize DO improvement?



What are the associated costs?

How does **ammonia reduction from an individual discharge** impact low DO in the FMA?





RM 0 = Mouth of Delaware Bay

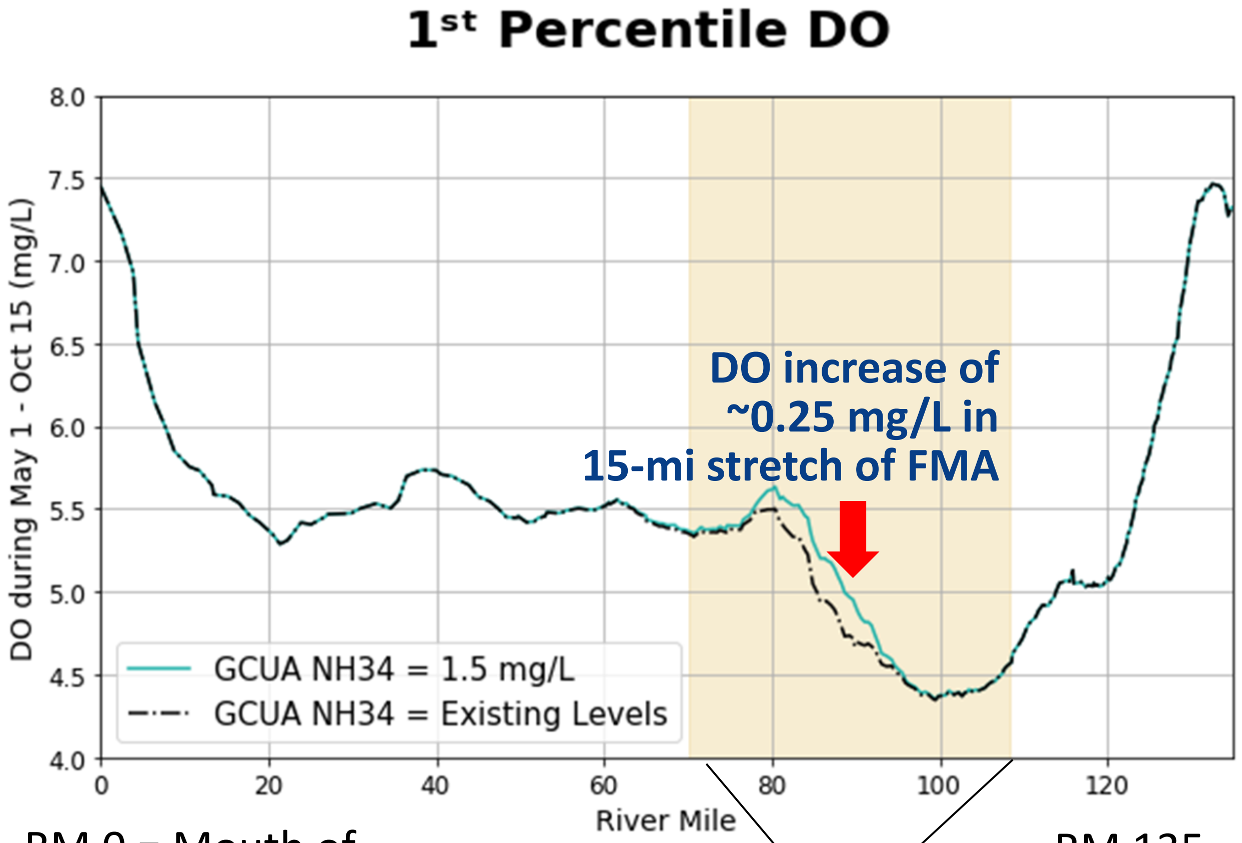
Fish Maintenance Area: RM 70–108.4

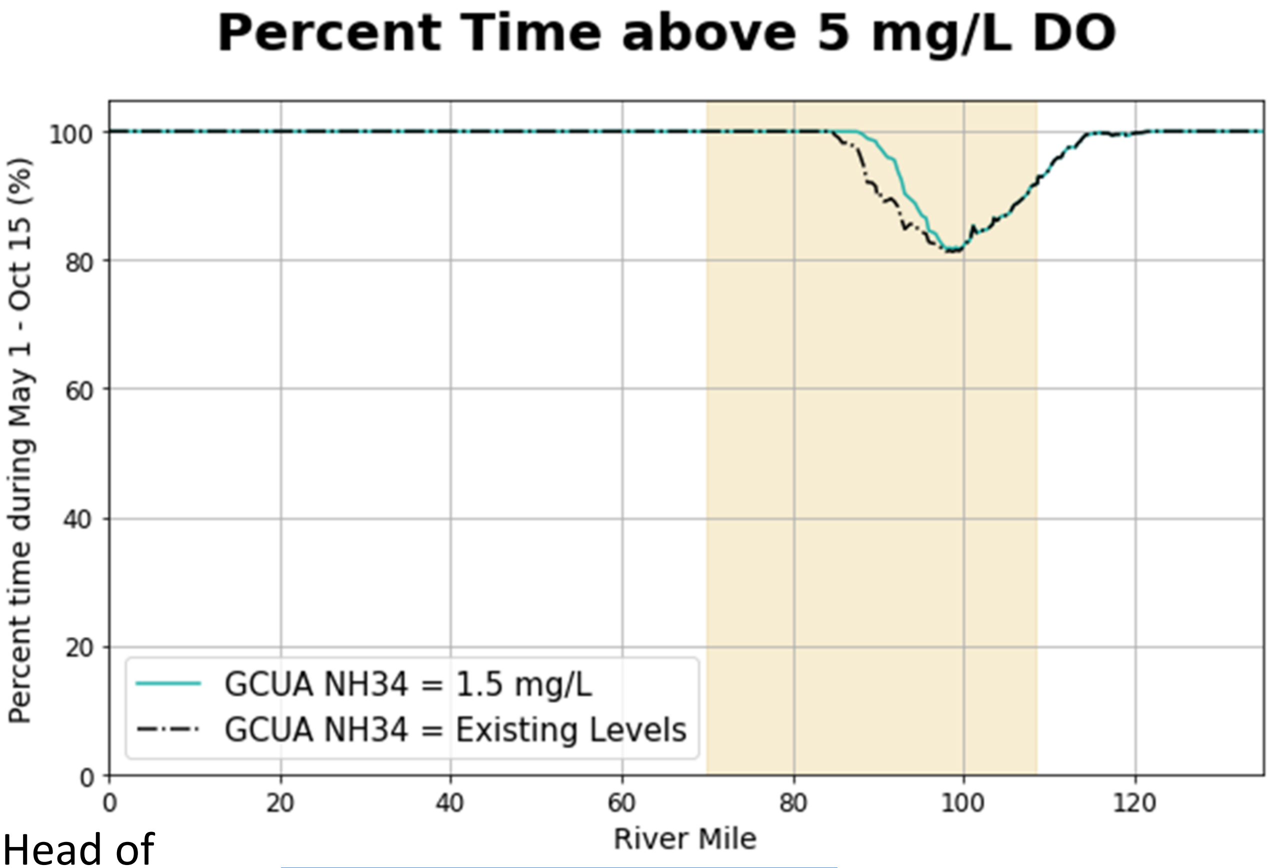
RM 135 = Head of tide at Trenton, NJ

For both metrics: Higher is better!

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

Class A' discharges have a **major impact** on low DO in the FMA





RM 0 = Mouth of Delaware Bay

Fish Maintenance Area: RM 70–108.4

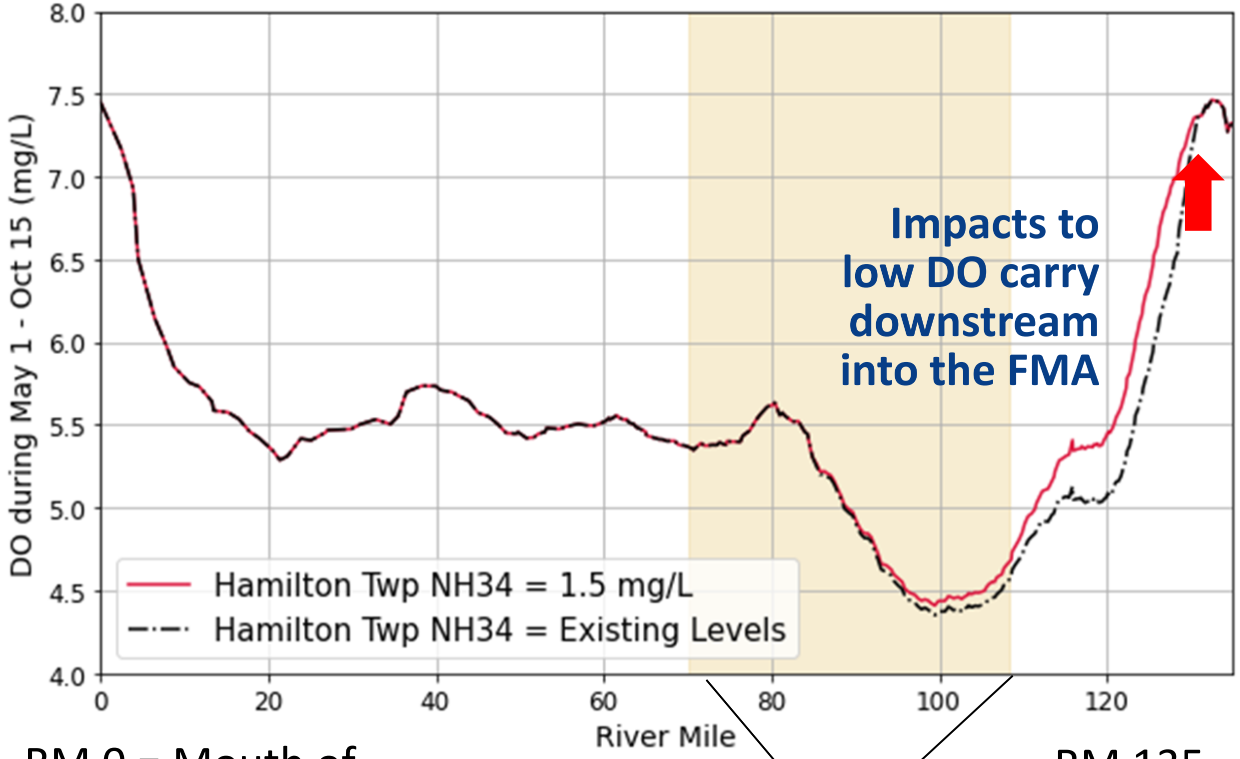
RM 135 = Head of tide at Trenton, NJ

For both metrics: Higher is better!

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

Class A discharges have a **marginal impact** on low DO in the FMA

1st Percentile DO

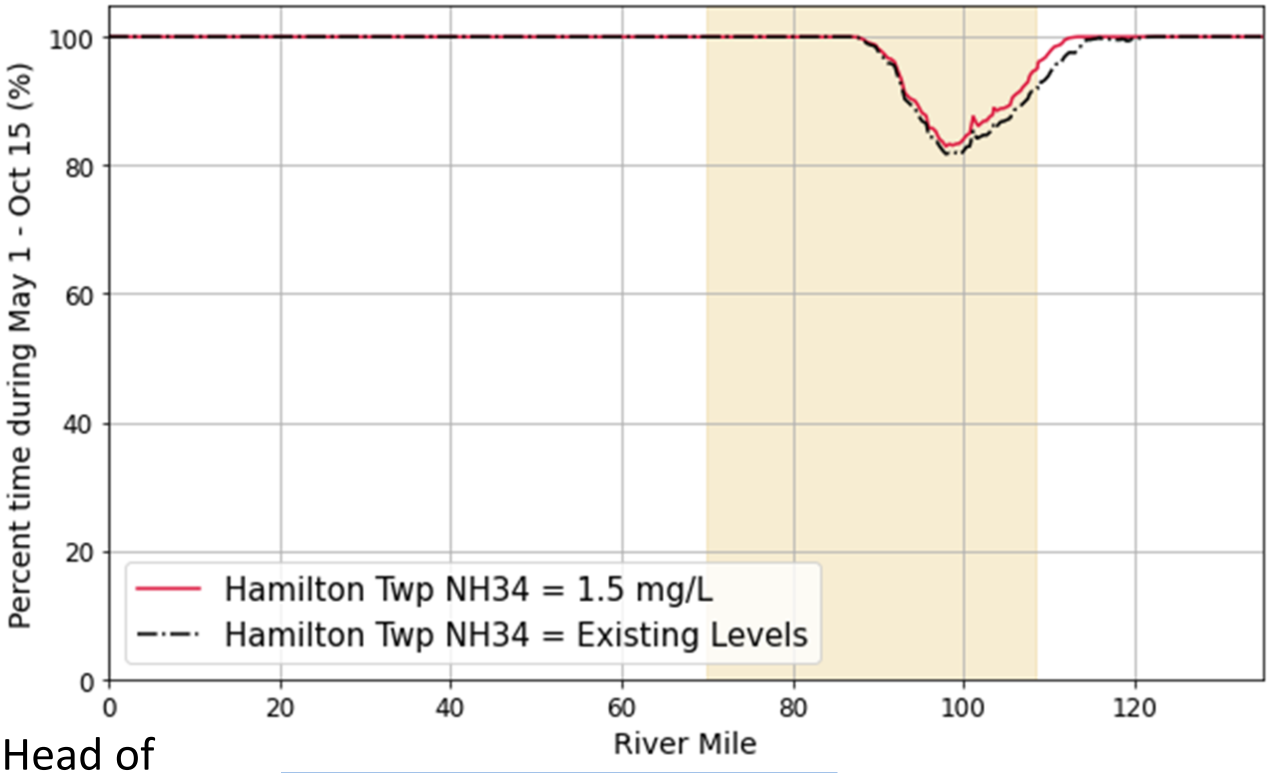


RM 0 = Mouth of Delaware Bay

Fish Maintenance Area: RM 70–108.4

RM 135 = Head of tide at Trenton, NJ

Percent Time above 5 mg/L DO

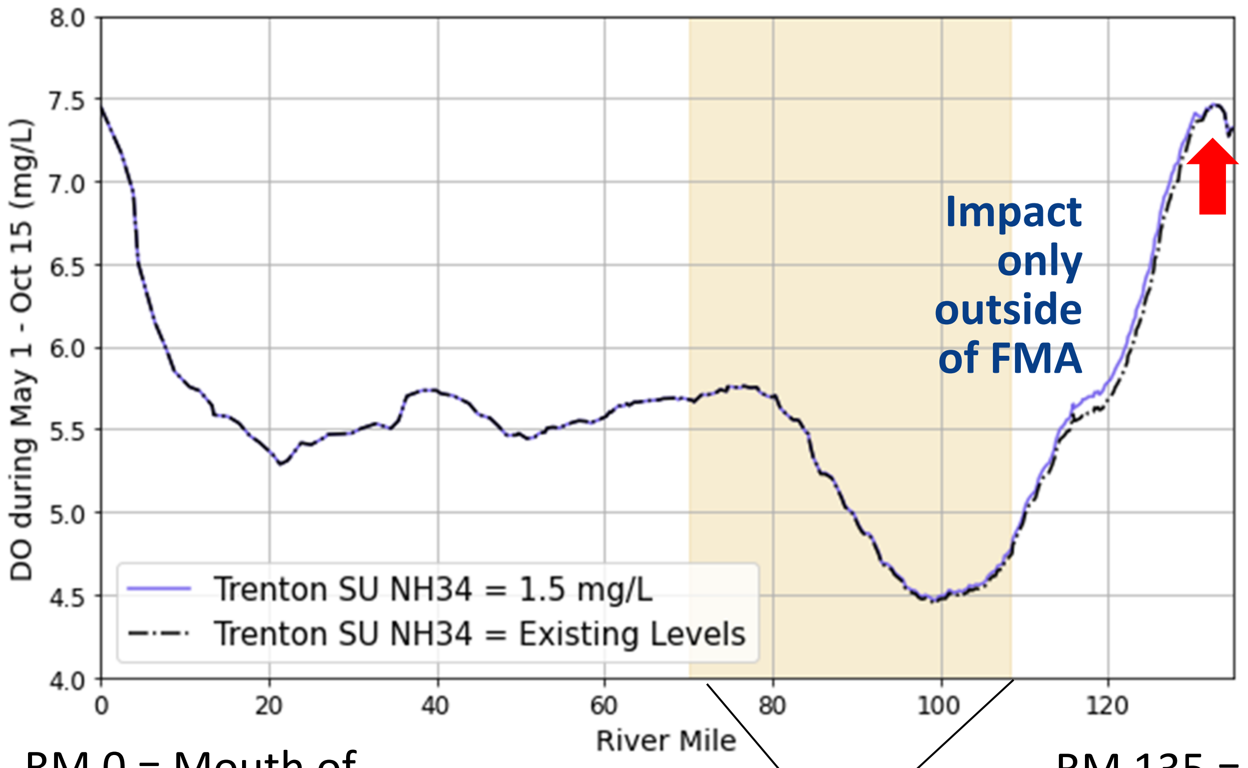


For both metrics: Higher is better!

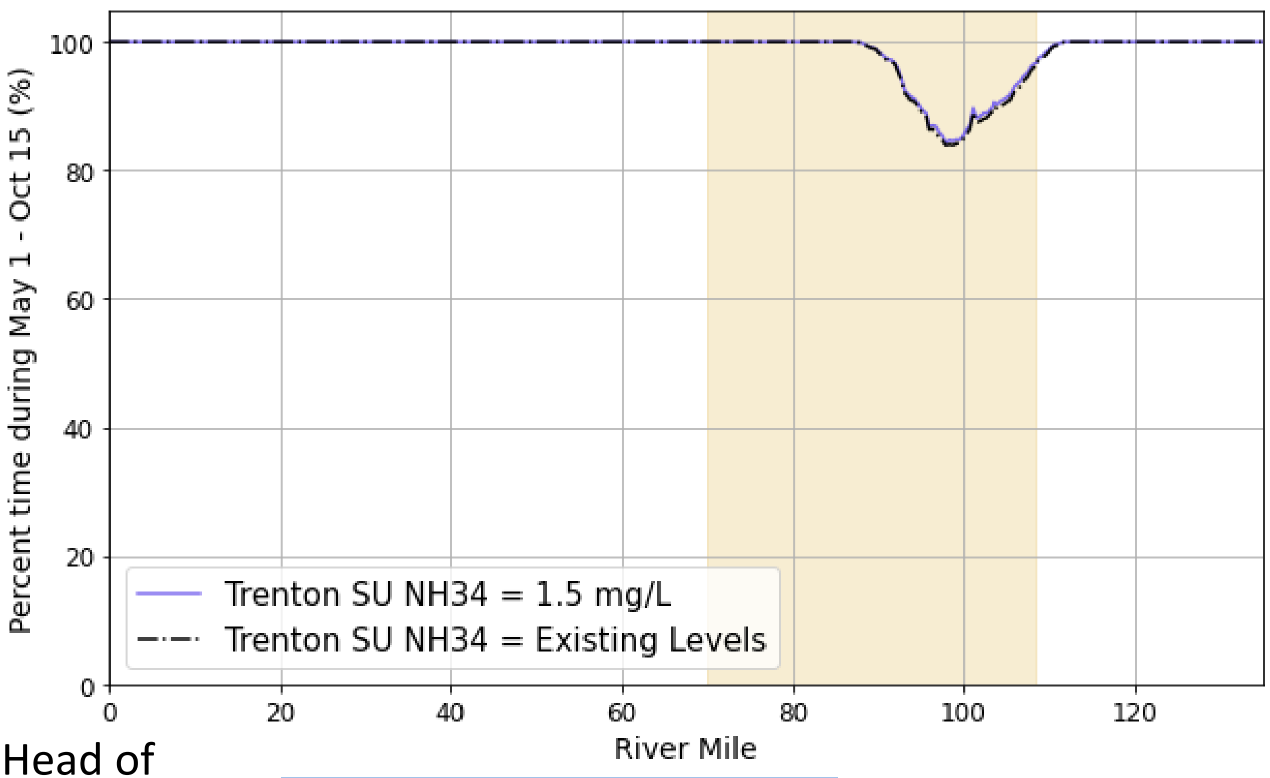
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Class B discharges have **no measurable impact** on low DO in the FMA

1st Percentile DO



Percent Time above 5 mg/L DO



RM 0 = Mouth of Delaware Bay

Fish Maintenance Area: RM 70–108.4

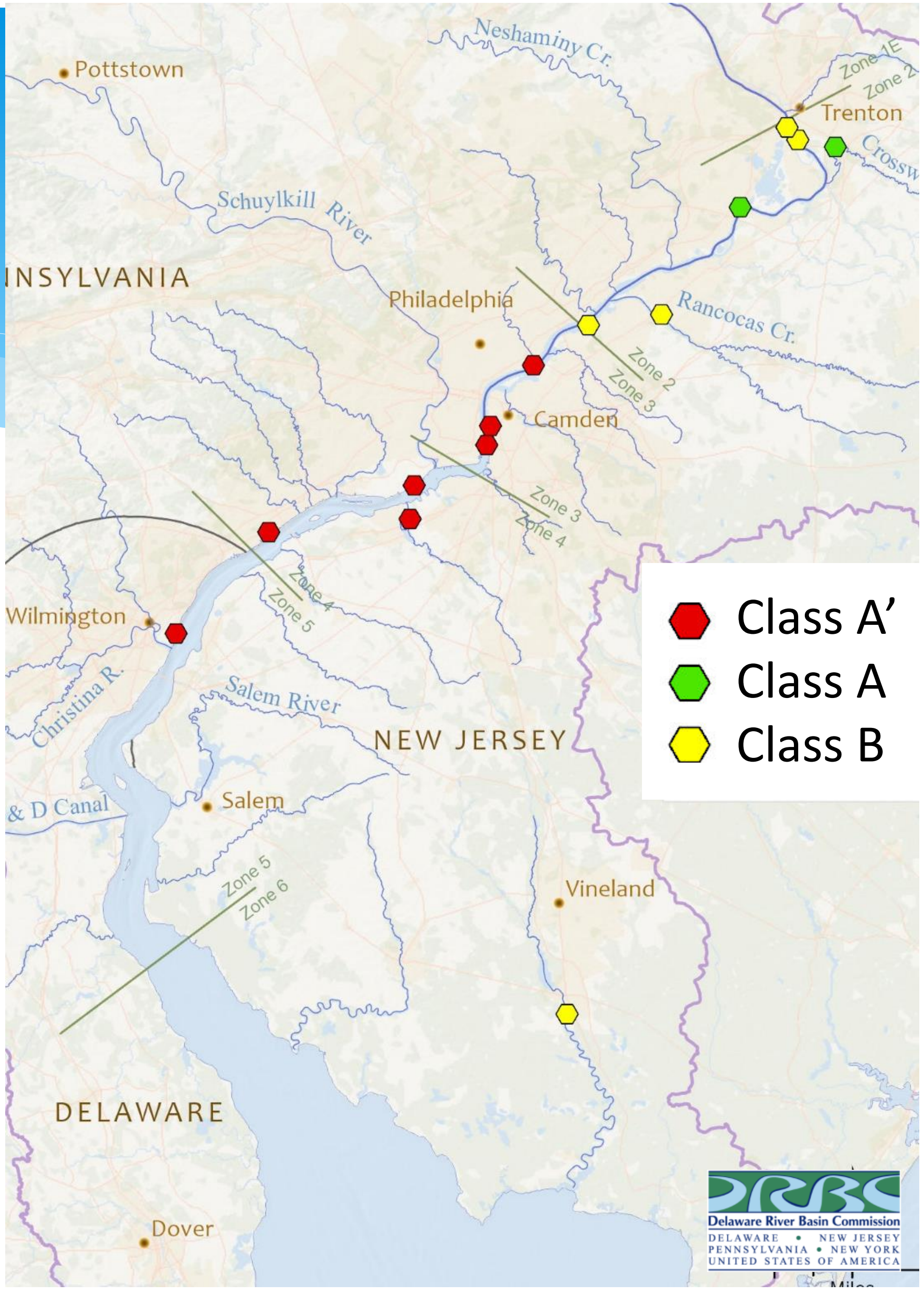
RM 135 = Head of tide at Trenton, NJ

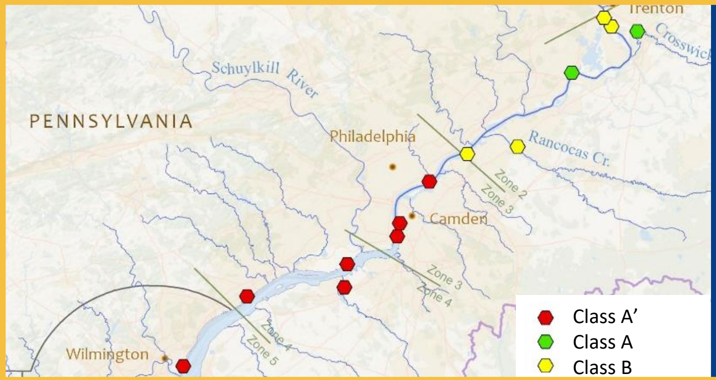
For both metrics: Higher is better!

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

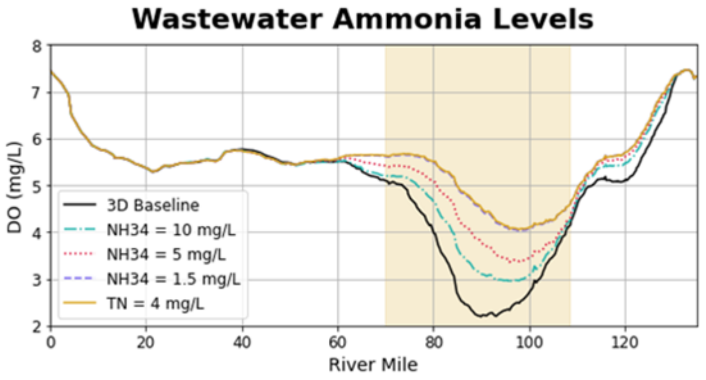
Discharges by Class

Class	Discharge Name	Zone	River Mile	Permitted Flow (MGD)	Effluent Ammonia (mg/L)
A' (7)	PWD Northeast	3	103.9	210	4.4
	Camden County MUA	3	97.9	80	17.3
	PWD Southeast	3	96.7	112	8.6
	PWD Southwest	4	90.7	200	19.0
	Gloucester County UA	4	89.9	27	23.9
	DELCORA	4	80.4	70	3.8
	City of Wilmington	5	71.6	134	9.5
A (2)	Hamilton TWP WPCF	2	128.4	16	27.0
	Lower Bucks JMA	2	121.9	10	19.7
B (58)	Morrisville BMA	2	132.5	7	9.7
	Trenton SU	2	131.8	20	5.4
	Willingboro WPCP	2	111.4	5	1.4
	Cinnaminson SA	2	108.7	2	16.0
	…	…	…	…	…

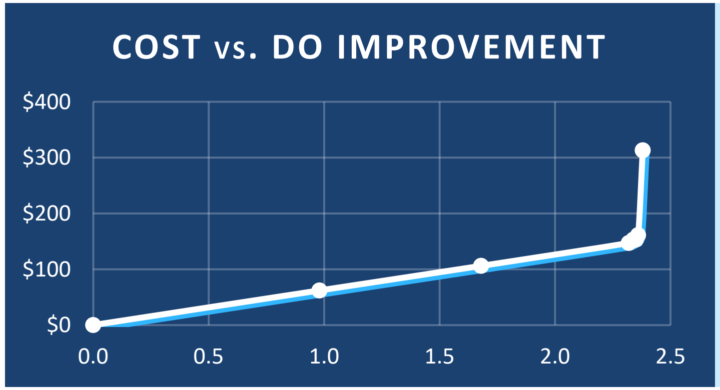




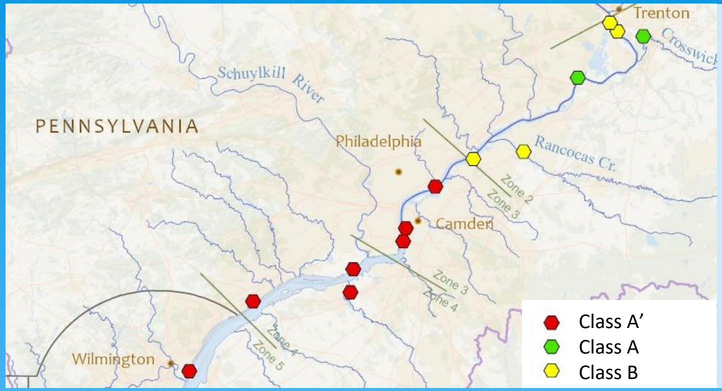
Nine wastewater discharges have great potential to **improve DO in the FMA**



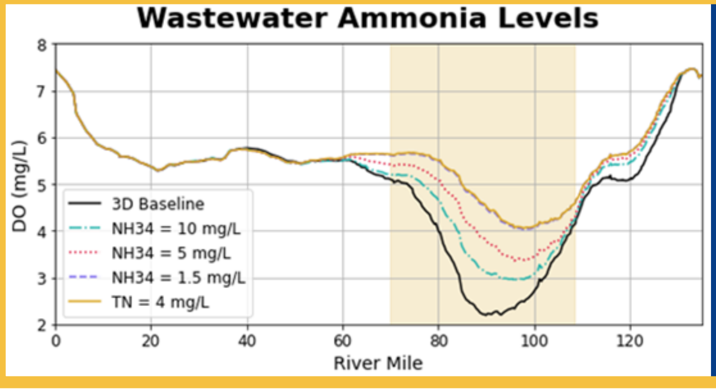
How much ammonia reduction is needed to maximize DO improvement?



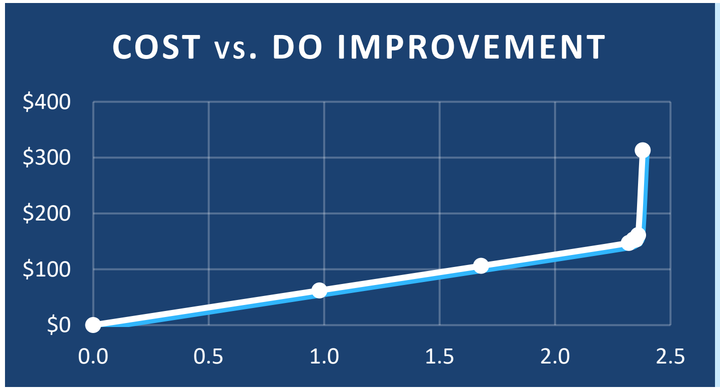
What are the associated costs?



Nine wastewater discharges have great potential to **improve DO in the FMA**



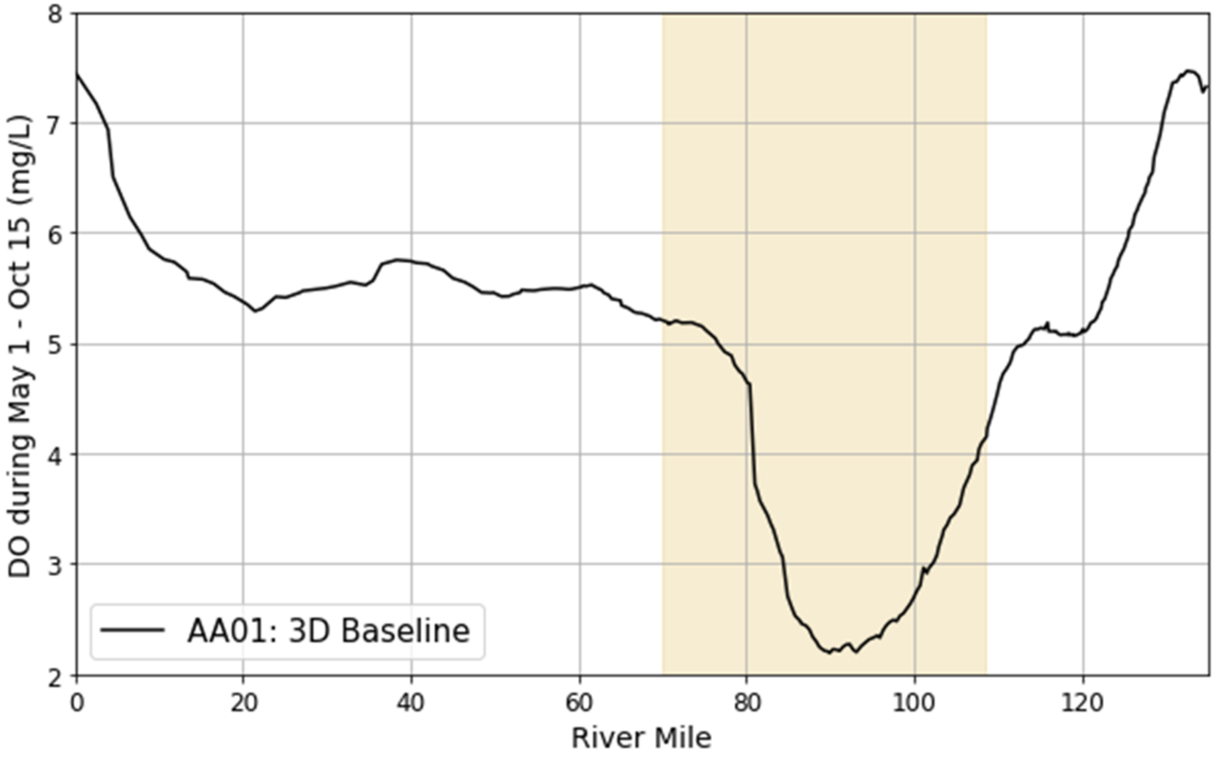
How much ammonia reduction is needed to maximize DO improvement?



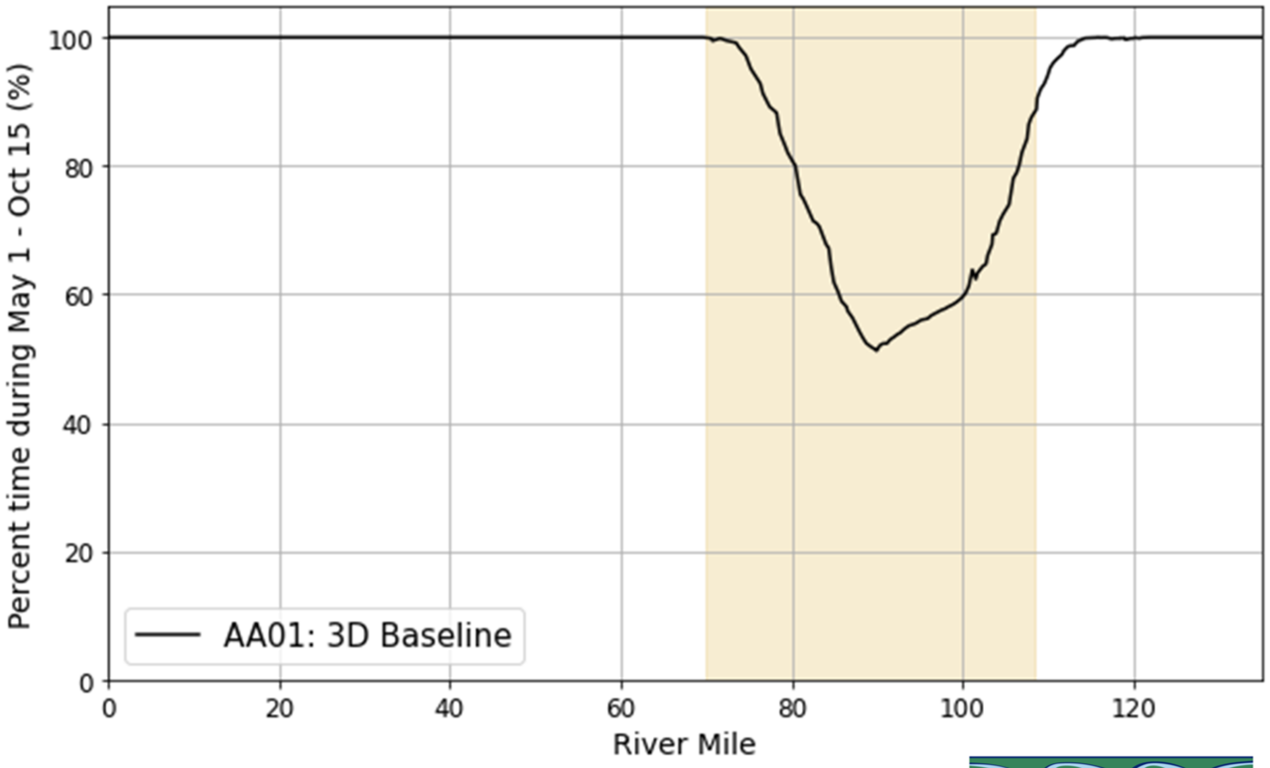
What are the associated costs?

Baseline design condition represents **protection of existing water quality and uses**

1st Percentile DO

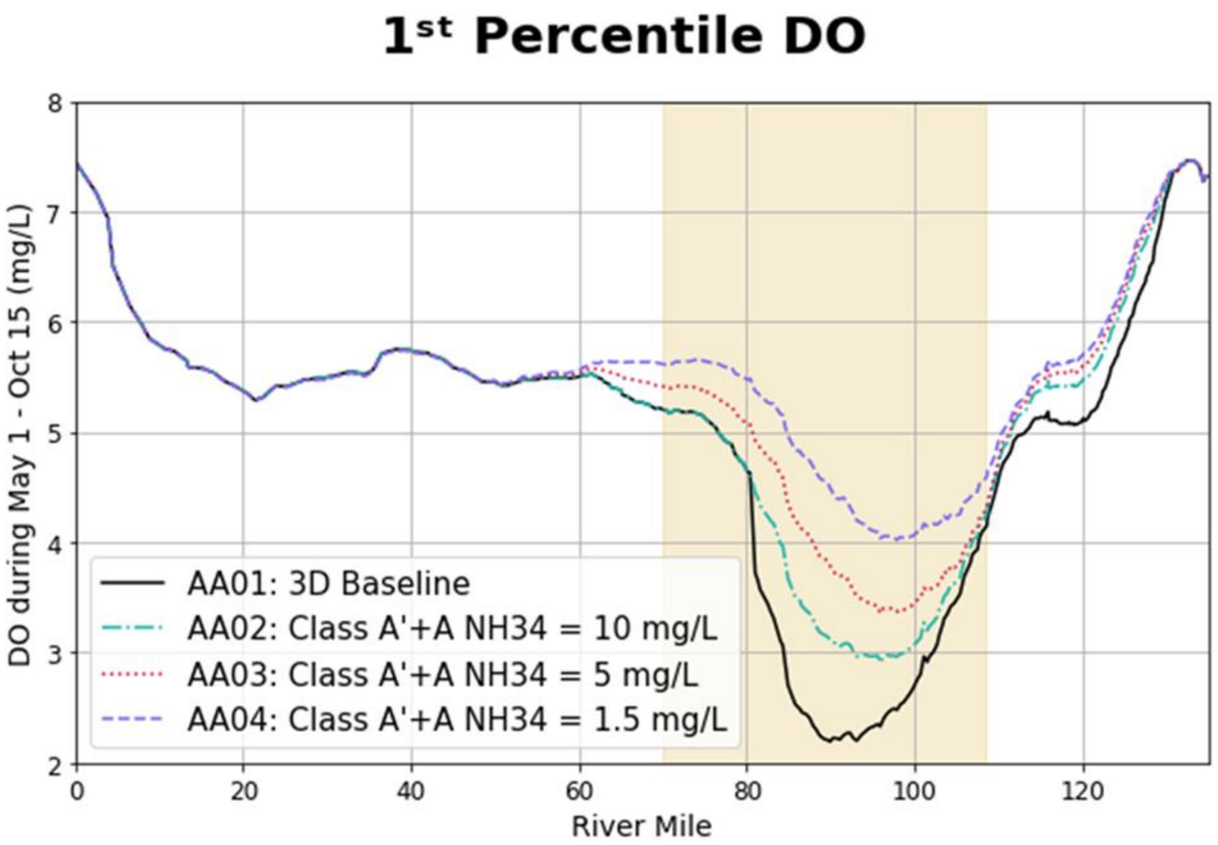


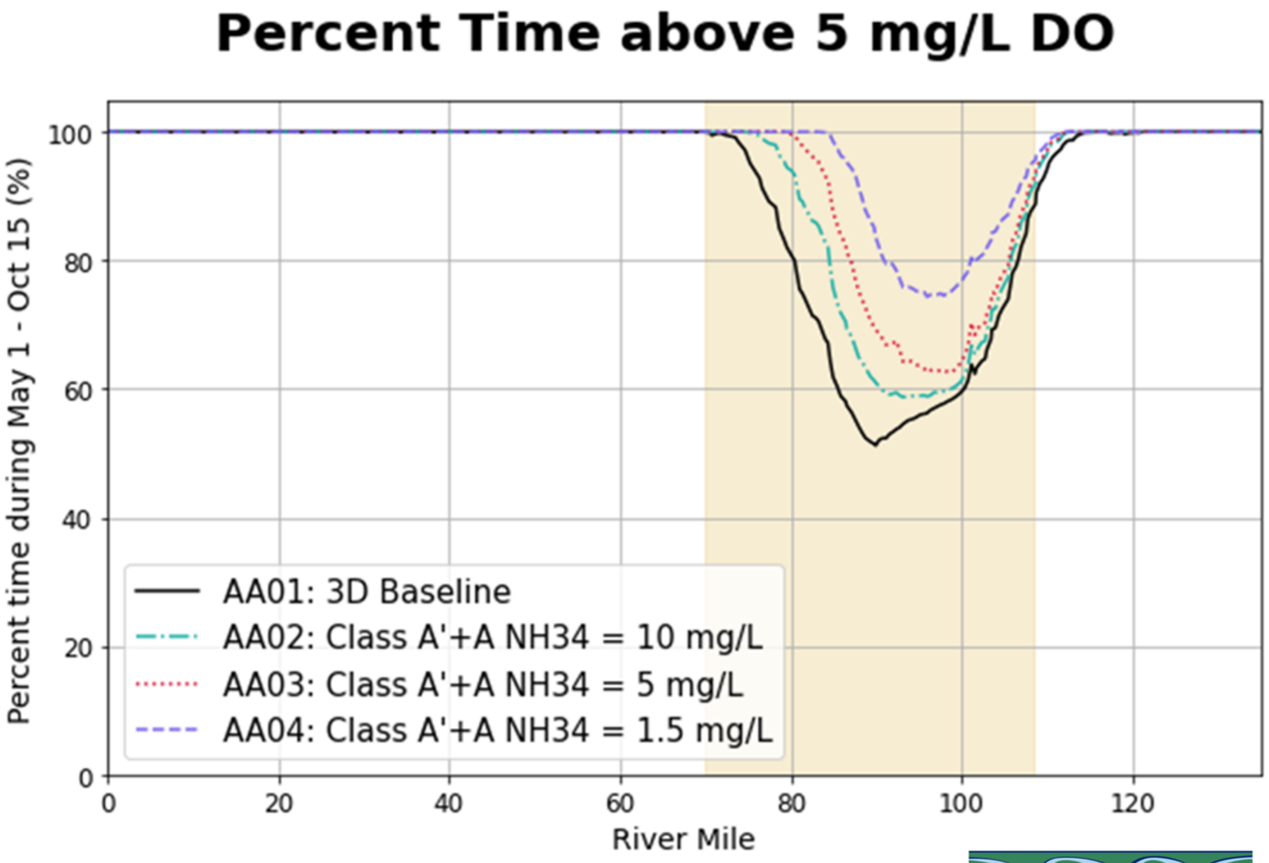
Percent Time above 5 mg/L DO



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

Bringing minimum DO above 4 mg/L requires **reducing effluent ammonia to 1.5 mg/L**

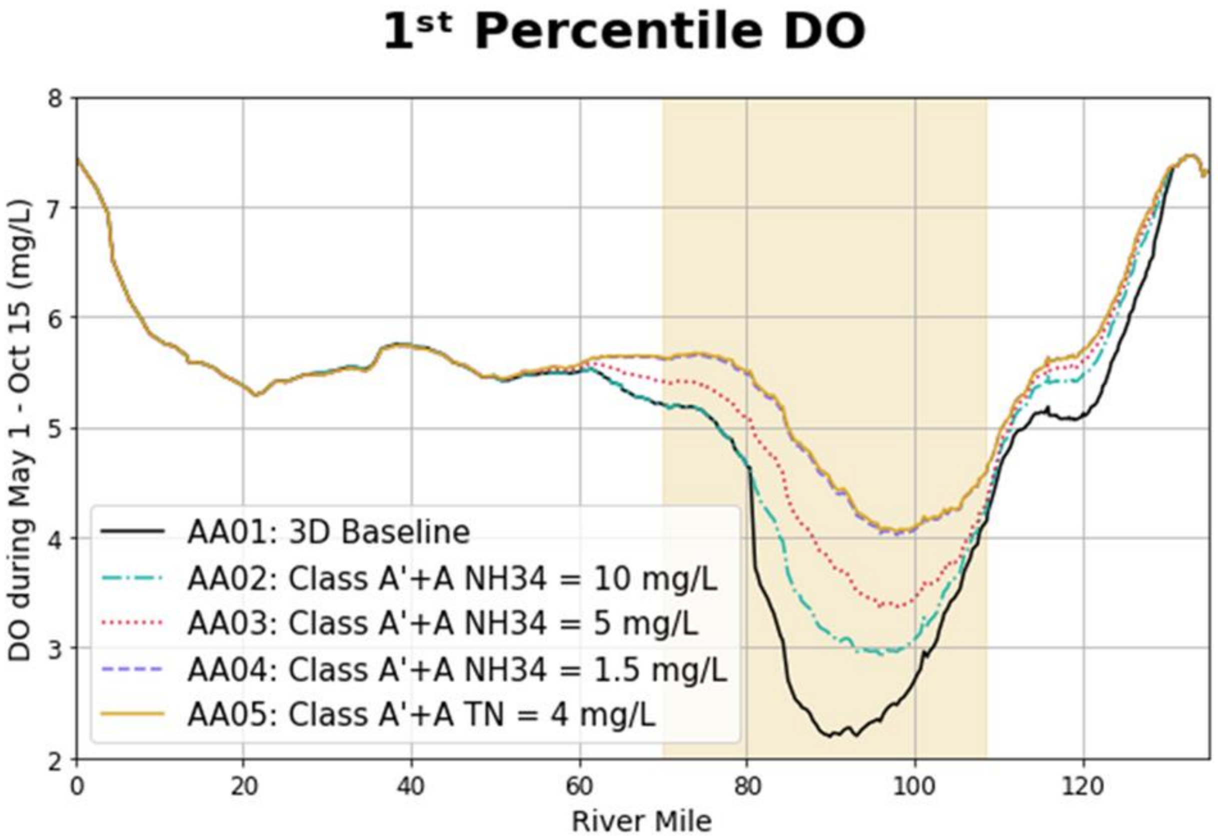


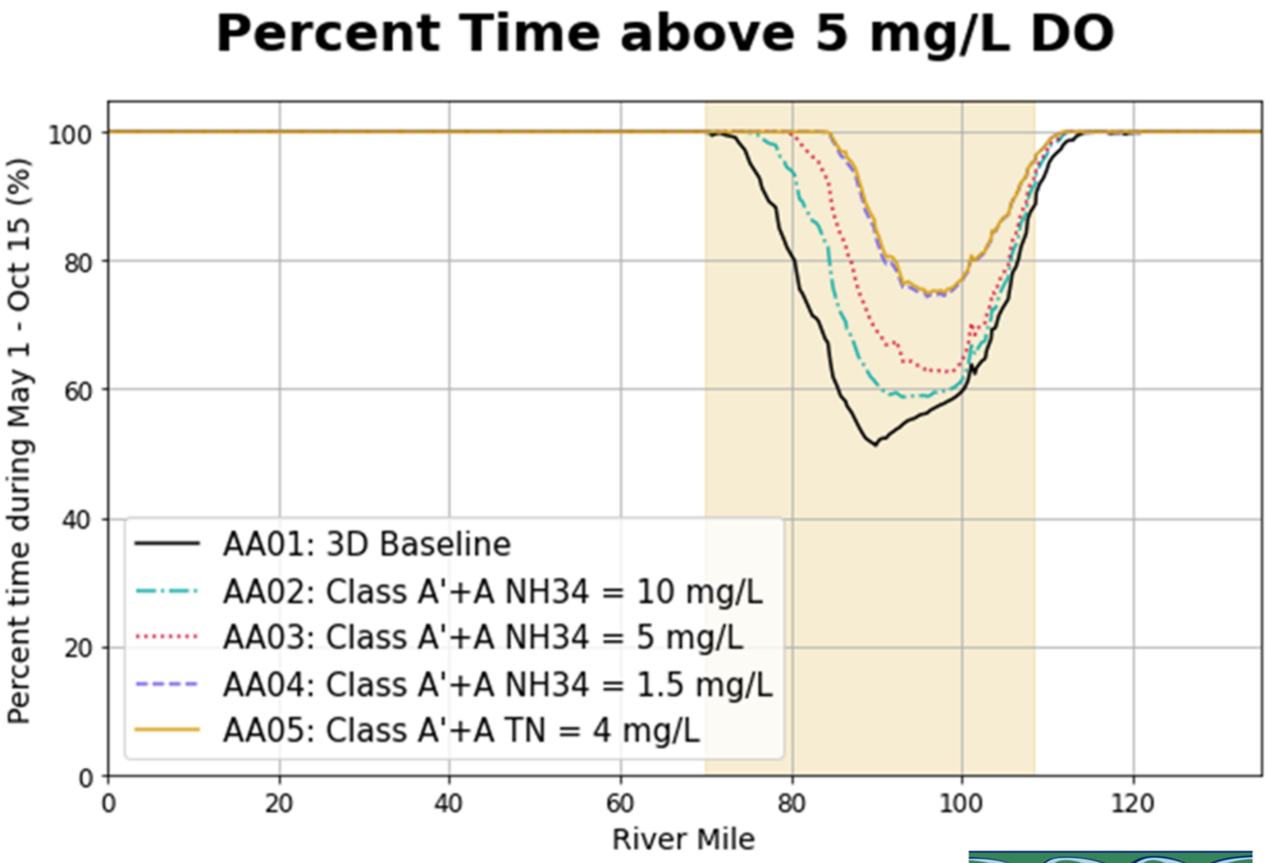


"Summer" (May through October) effluent NH4-N, CBOD, NO3-N, and DO were adjusted

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

Reducing total nitrogen (TN) **brings no additional benefit to low DO**





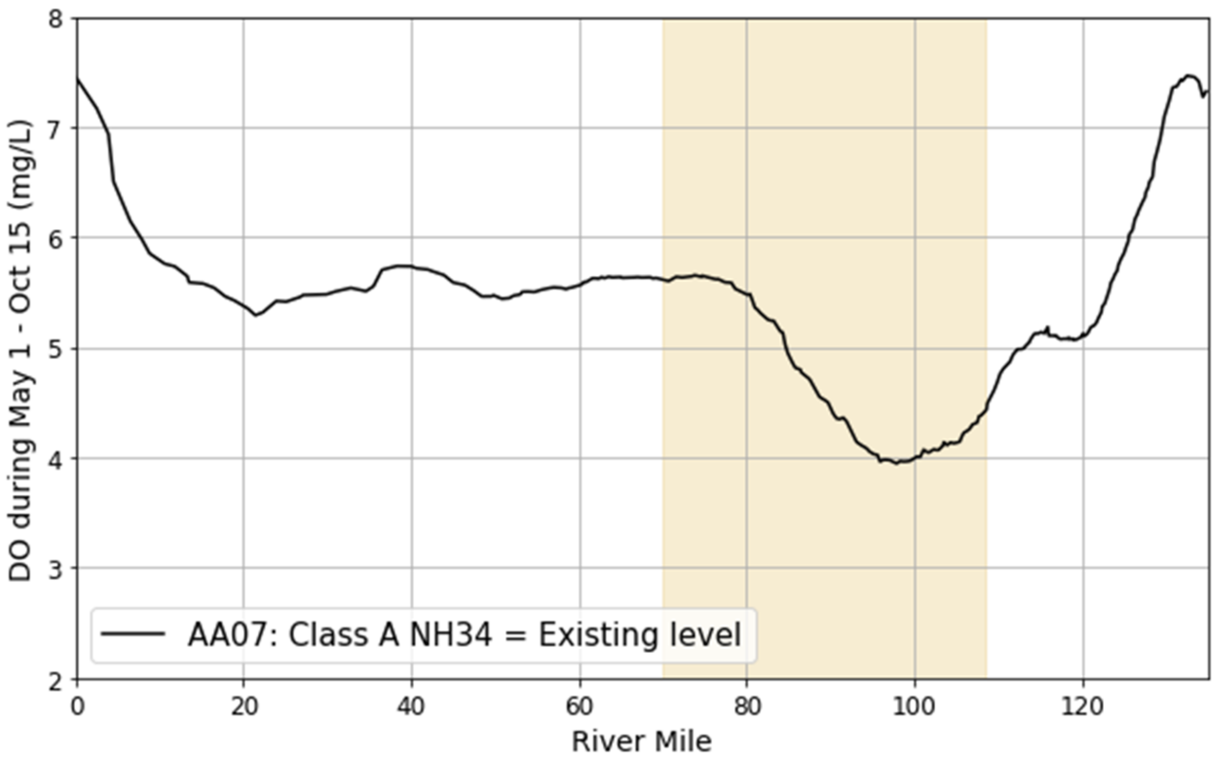
“Summer” (May through October) effluent NH4-N, CBOD, NO3-N, and DO were adjusted

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

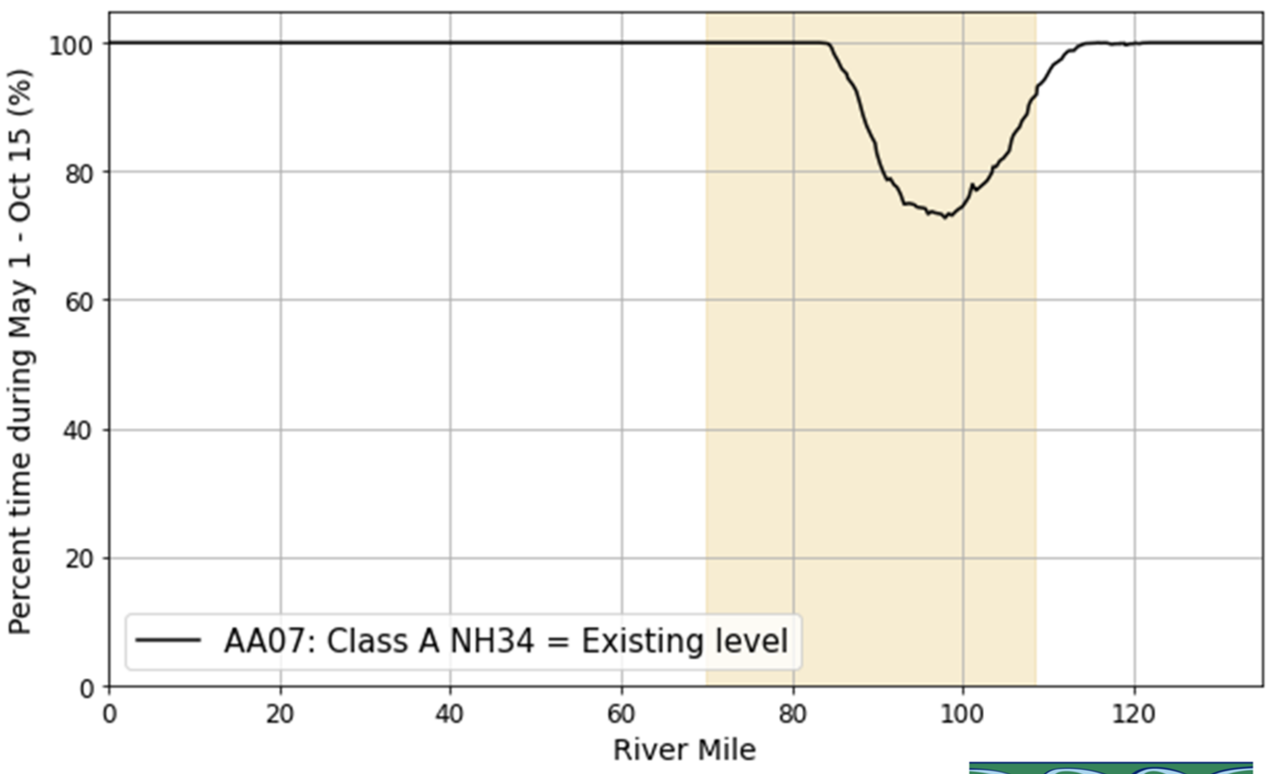
How sensitive is low DO to **Class A ammonia levels**?

(with Class A' ammonia = 1.5 mg/L)

1st Percentile DO



Percent Time above 5 mg/L DO

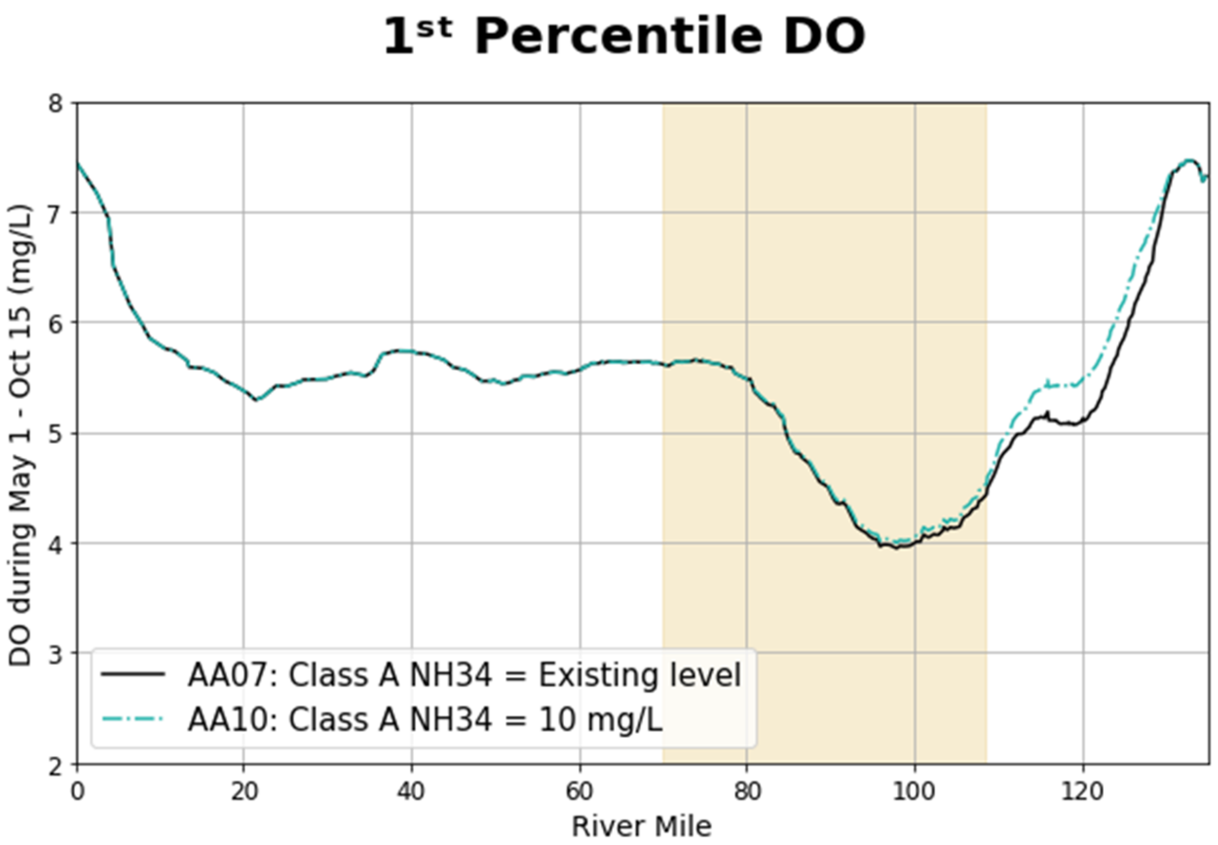


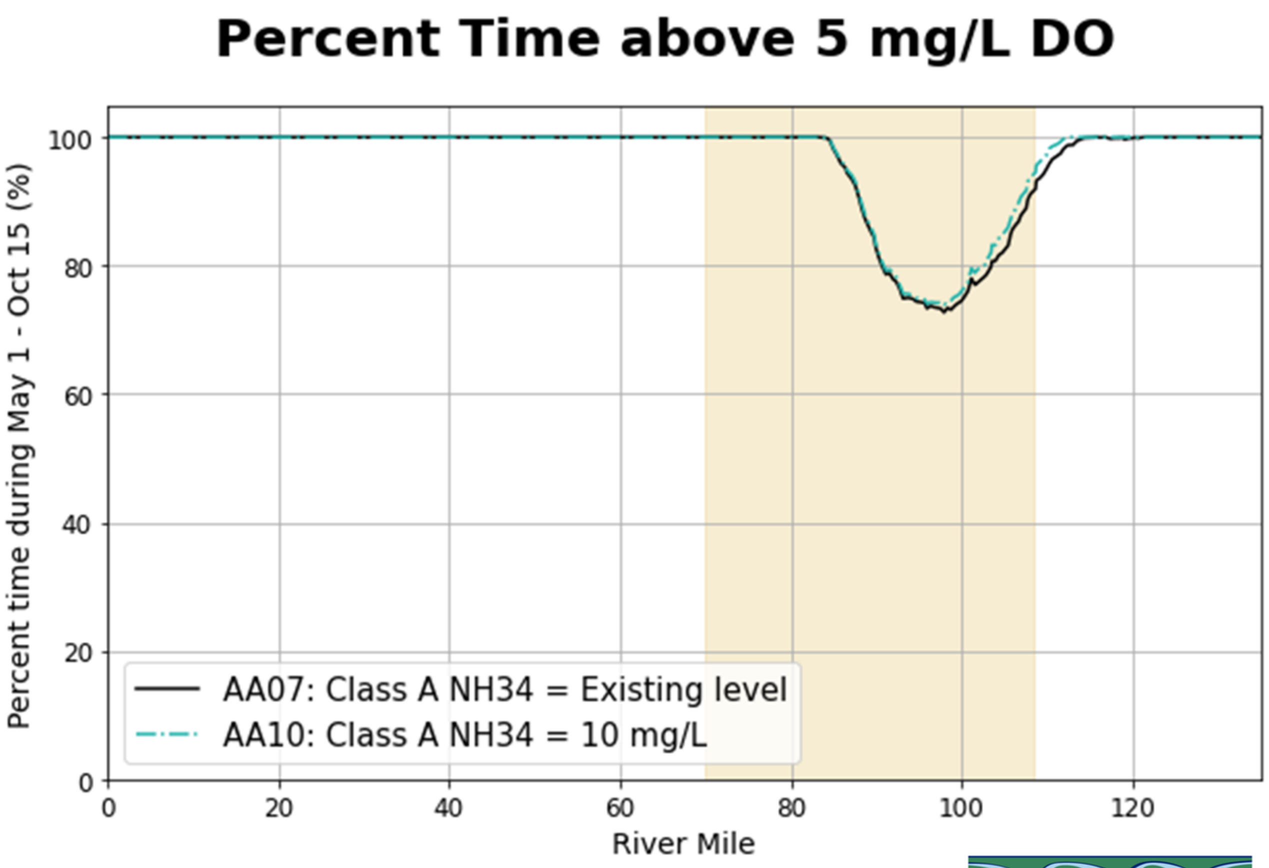
"Summer" (May through October) effluent NH4-N, CBOD, NO3-N, and DO were adjusted

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

How sensitive is low DO to **Class A ammonia levels**?

(with Class A’ ammonia = 1.5 mg/L)



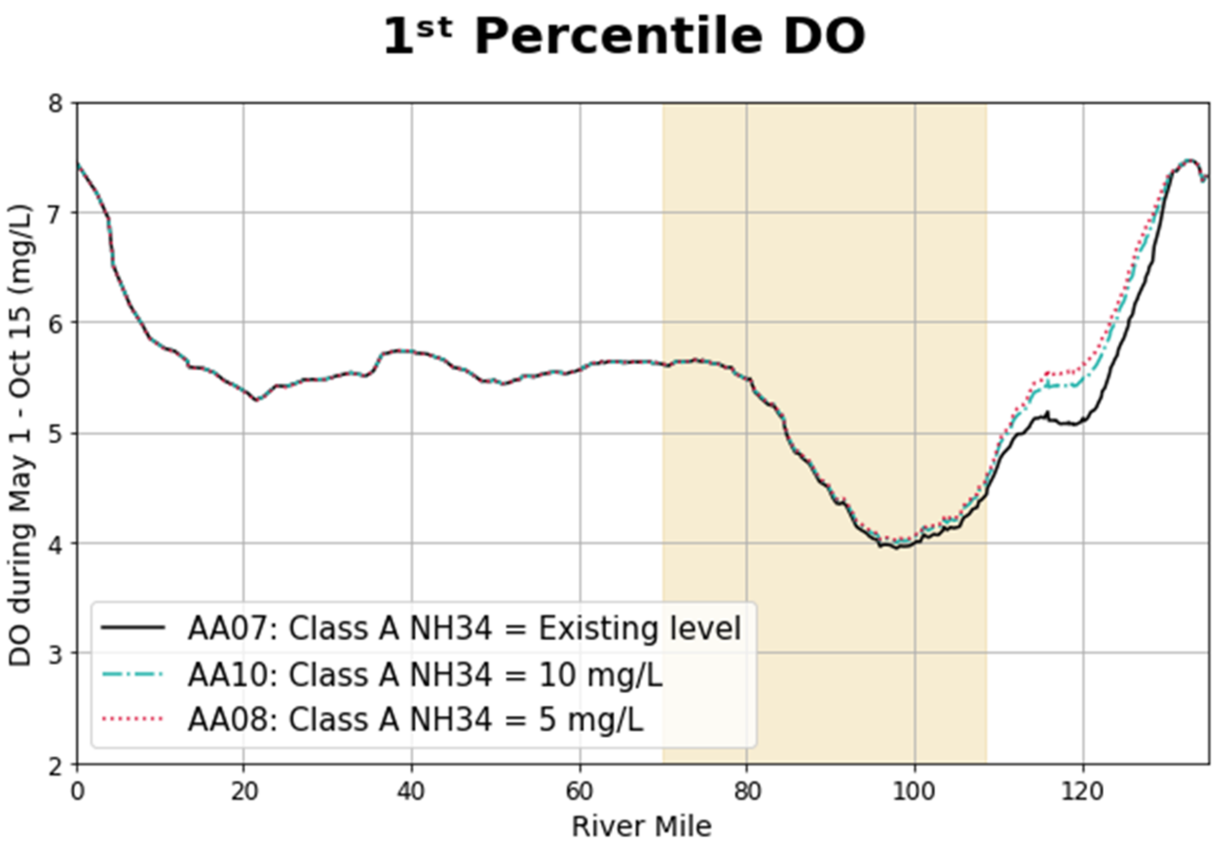


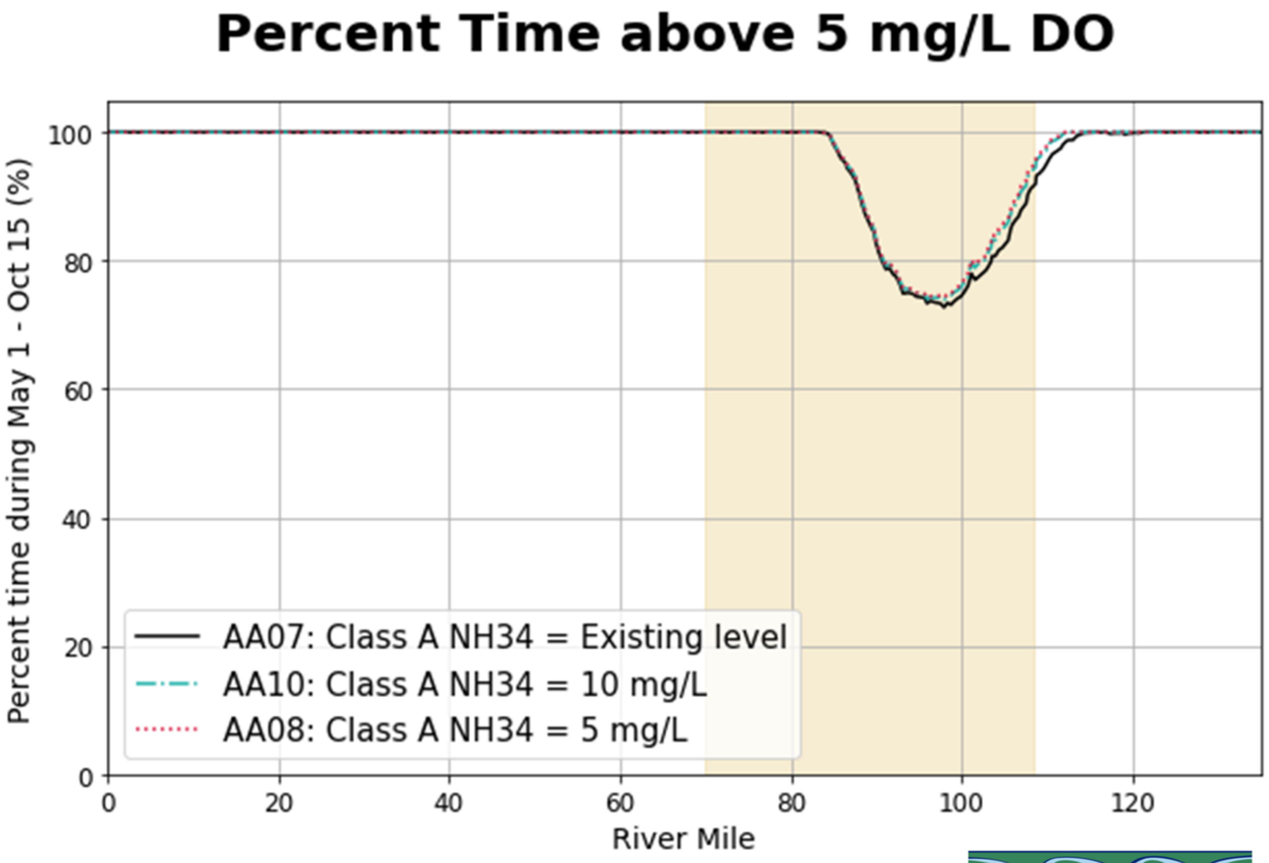
“Summer” (May through October) effluent NH4-N, CBOD, NO3-N, and DO were adjusted

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

How sensitive is low DO to **Class A ammonia levels**?

(with Class A' ammonia = 1.5 mg/L)

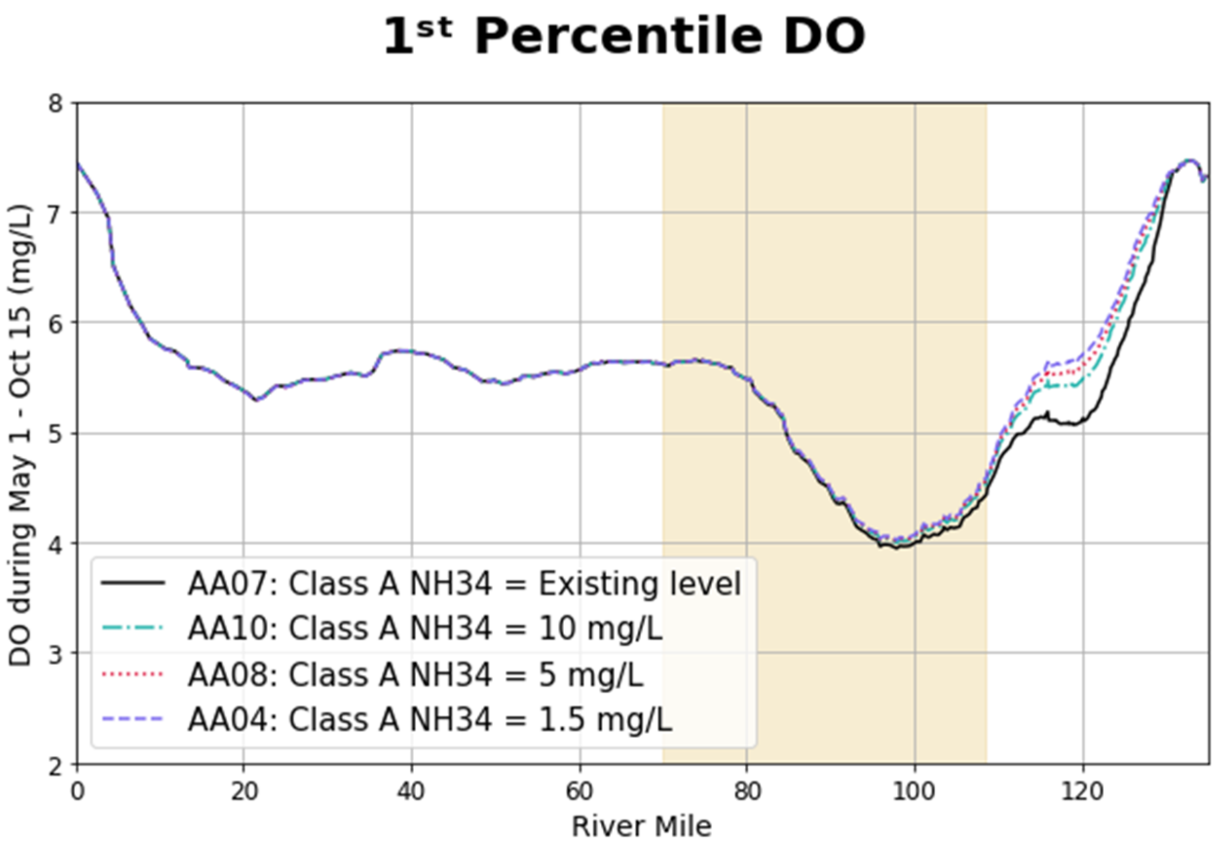


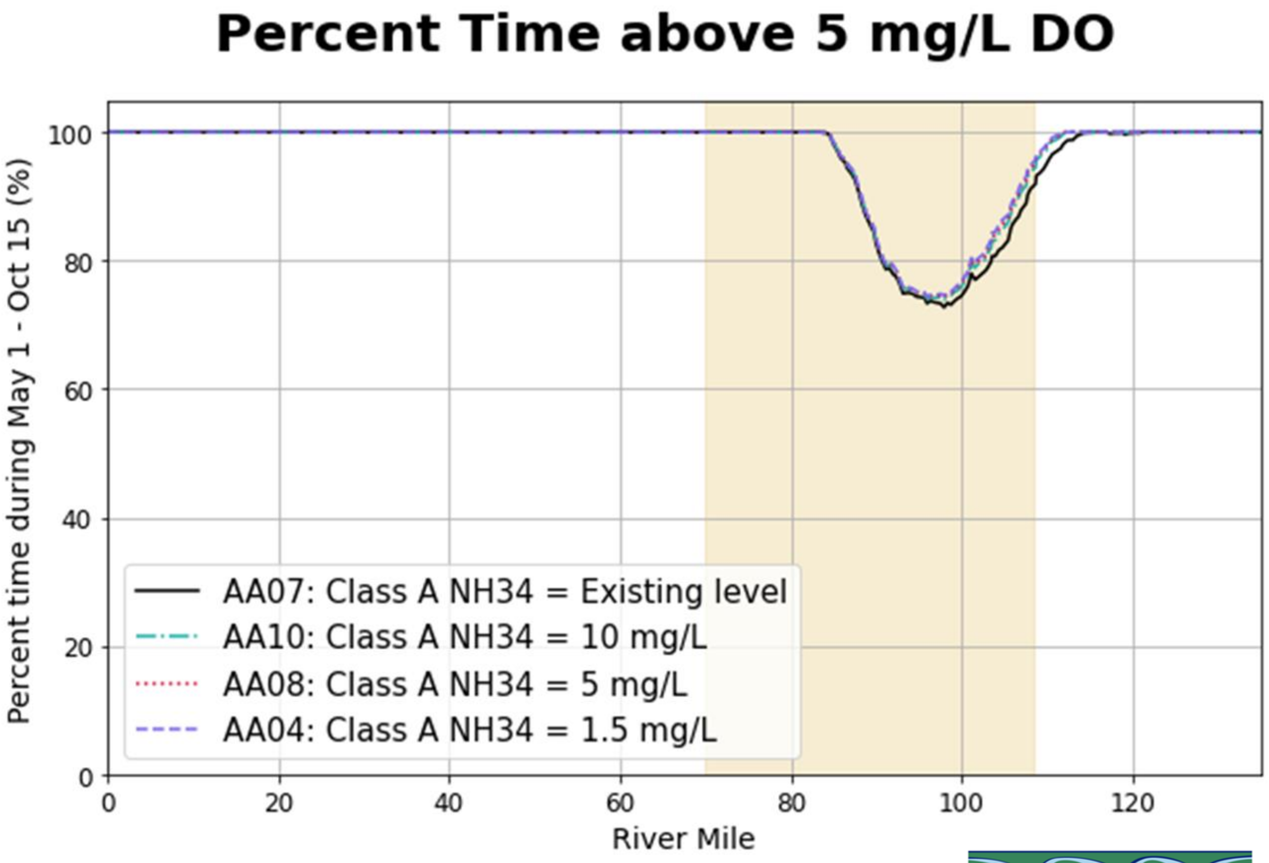


"Summer" (May through October) effluent NH4-N, CBOD, NO3-N, and DO were adjusted

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

DO is less sensitive to Class A ammonia levels, **but ammonia reduction does have an impact**

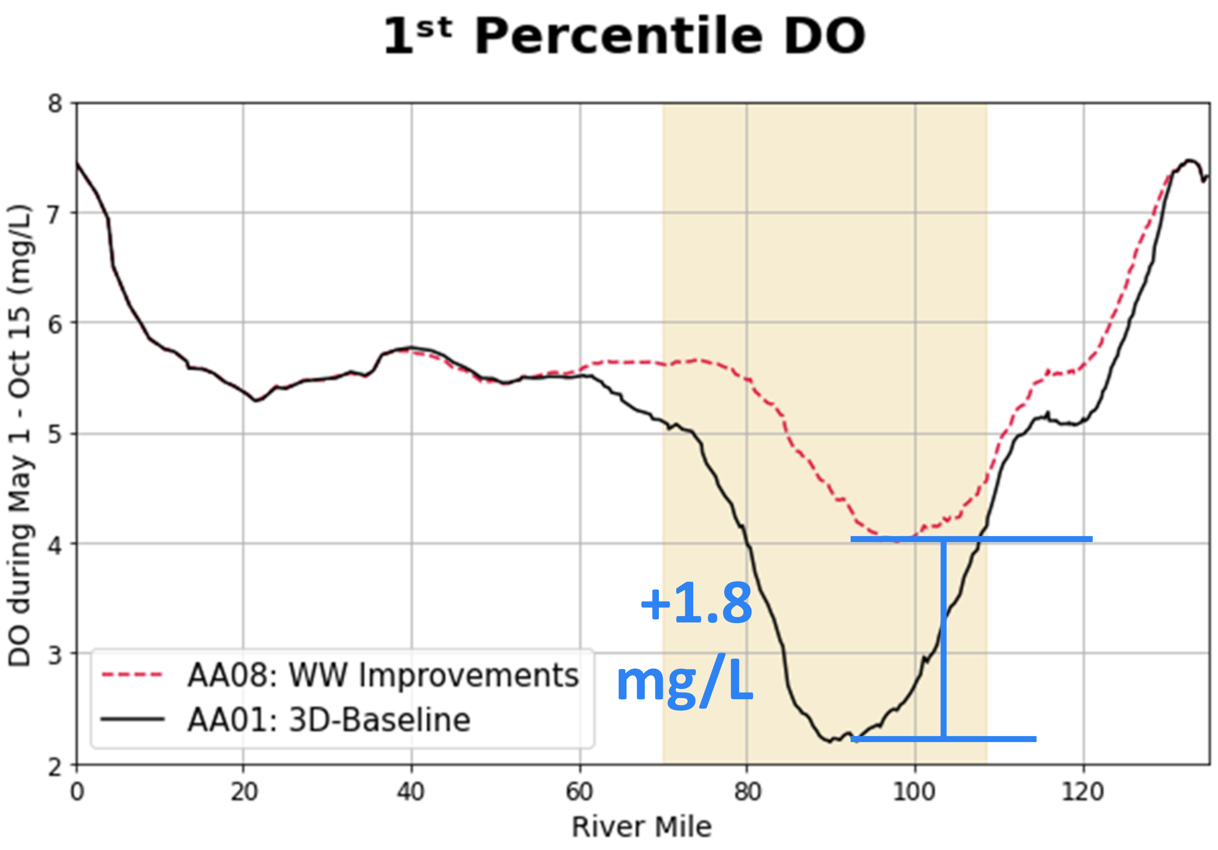




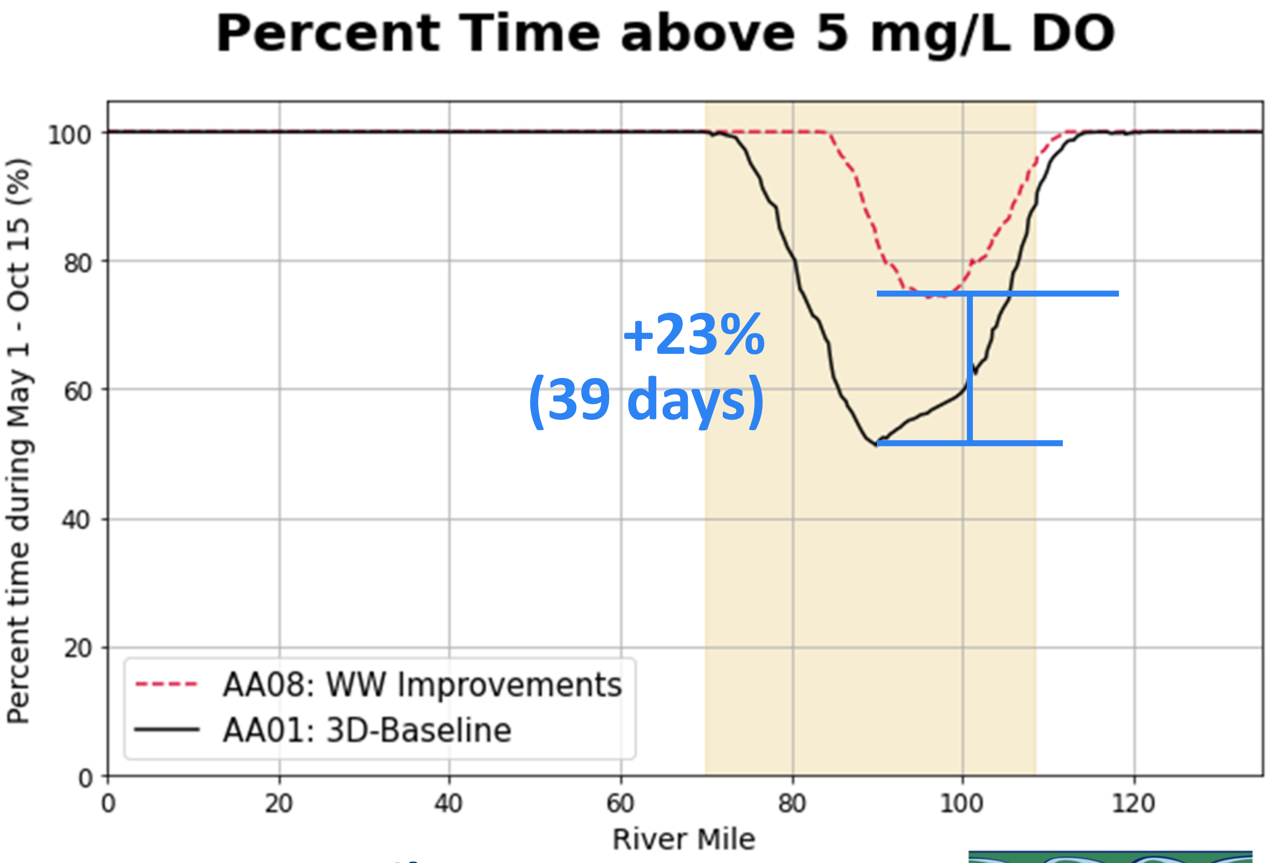
"Summer" (May through October) effluent NH4-N, CBOD, NO3-N, and DO were adjusted

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

Implementing these improvements **substantially benefits habitat**

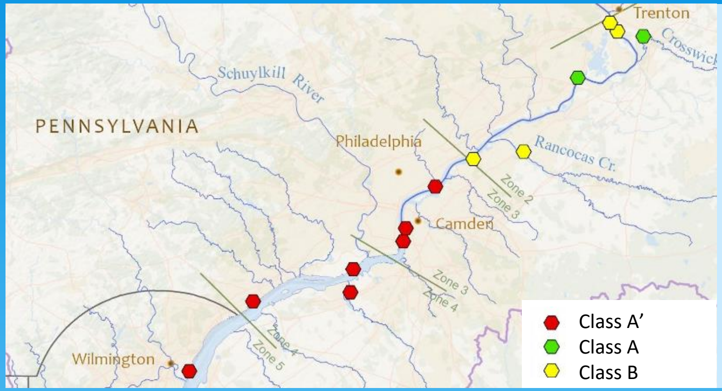


The lowest DO value in the Estuary **increases** and **moves upstream**

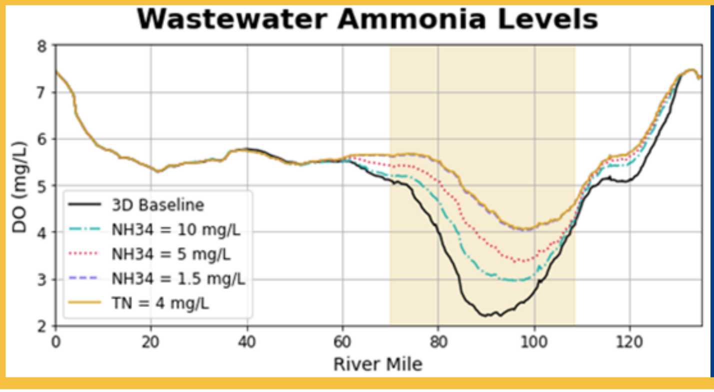


~~**50**~~ **28 miles** experience DO less than 5 mg/L

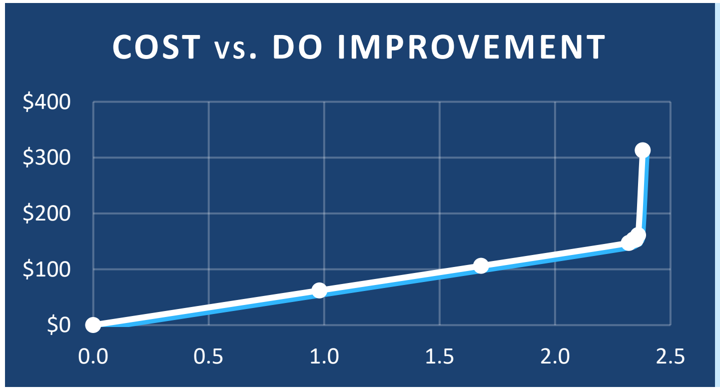
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA



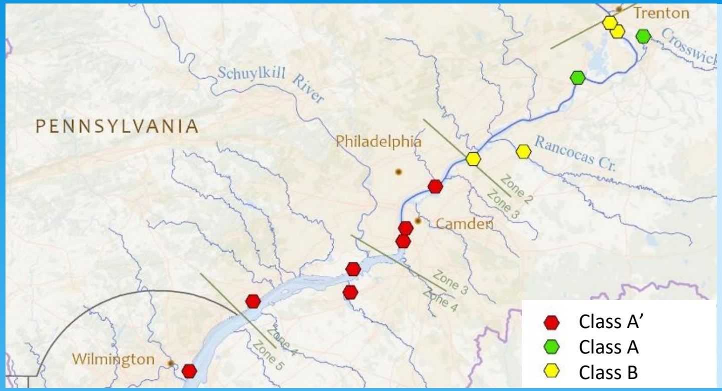
Nine wastewater discharges have great potential to **improve DO in the FMA**



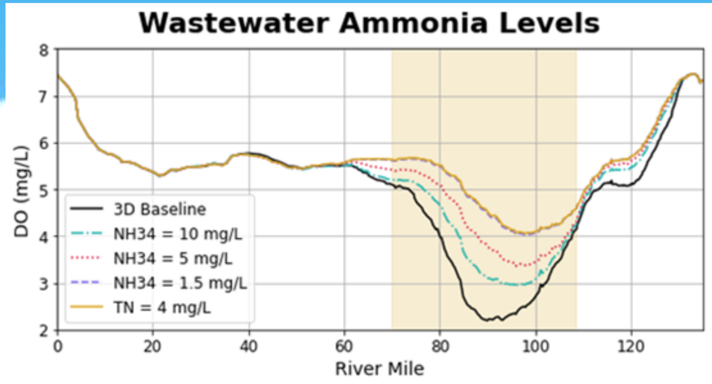
Reducing effluent ammonia to **1.5** mg/L (Class A') and **5** mg/L (Class A) **improves habitat** in the urban estuary



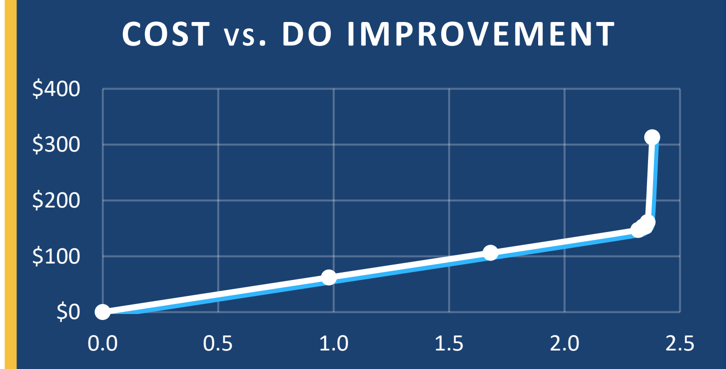
What are the associated costs?



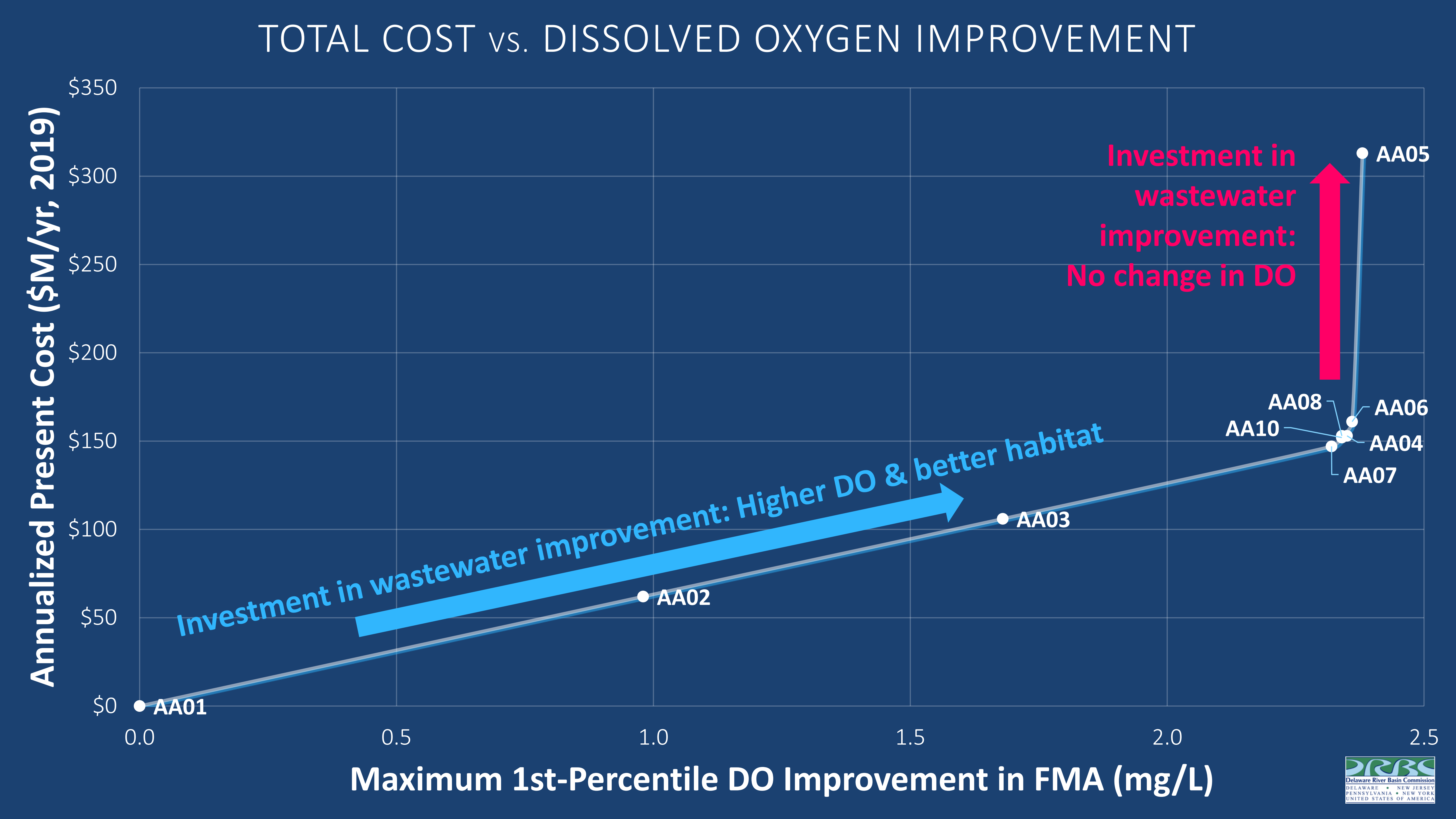
Nine wastewater discharges have great potential to **improve DO in the FMA**



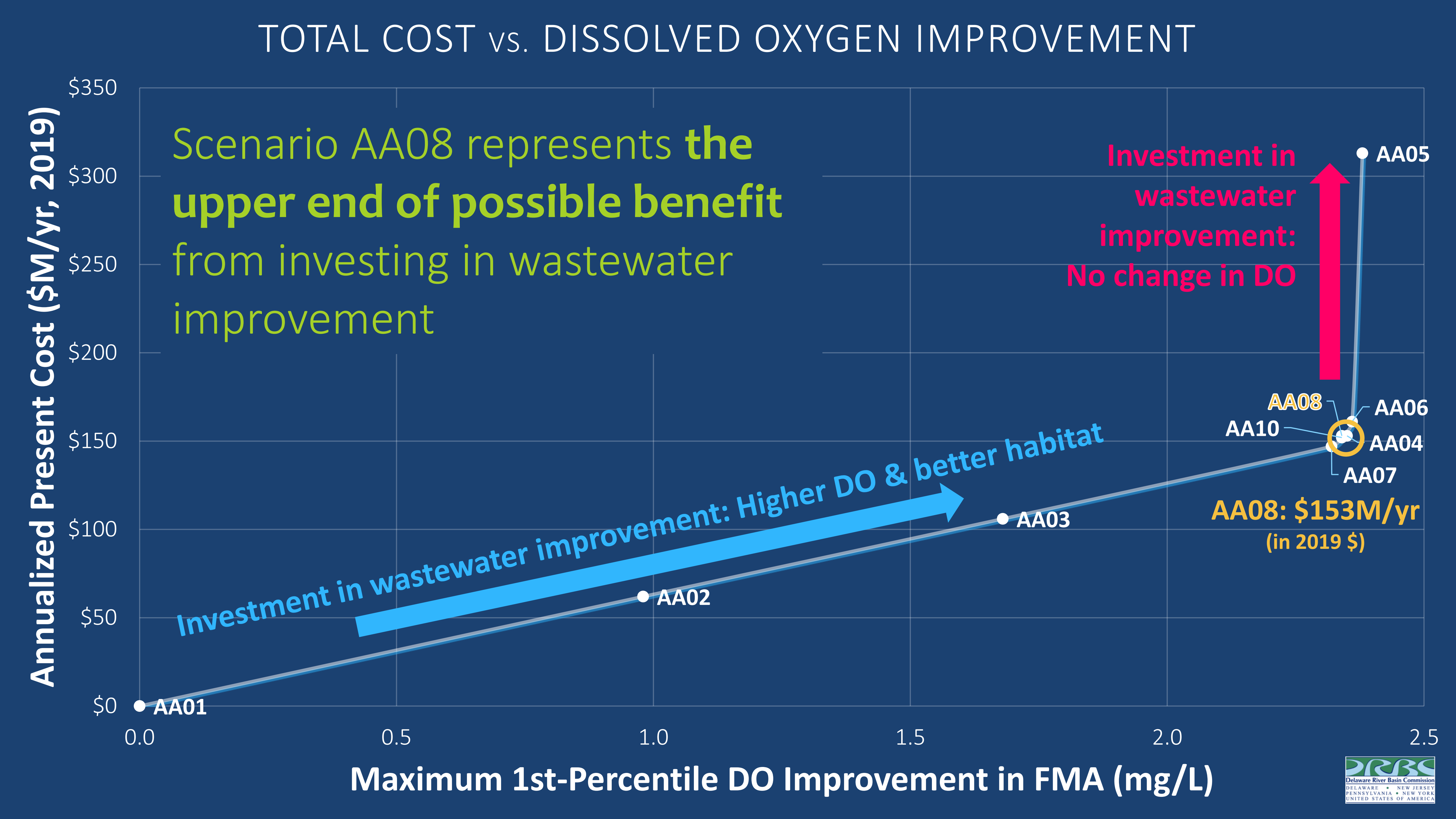
Reducing effluent ammonia to **1.5** mg/L (Class A’) and **5** mg/L (Class A) **improves habitat** in the urban estuary

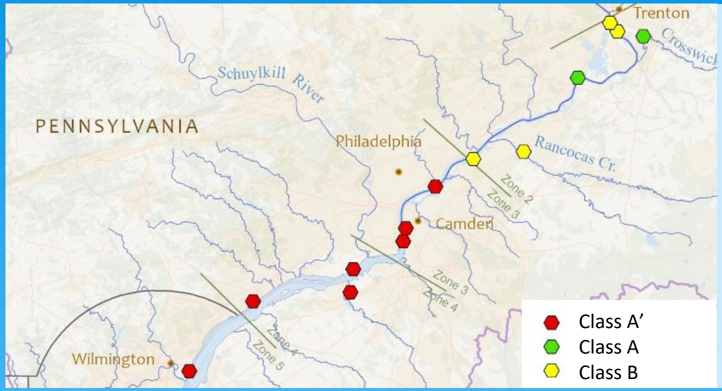


What are the associated costs?

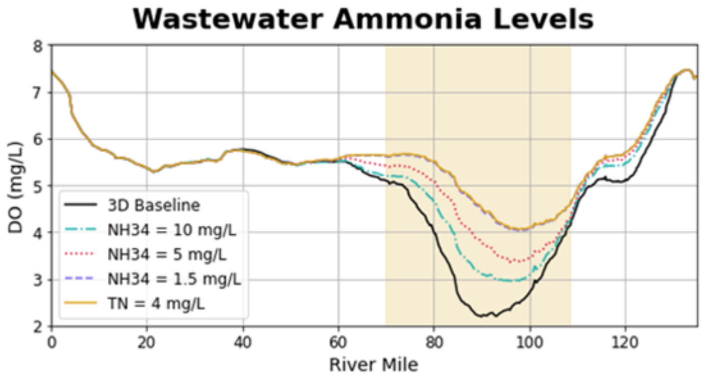


TOTAL COST vs. DISSOLVED OXYGEN IMPROVEMENT
Annualized Present Cost ($M/yr, 2019)
$350
$300
$250
$200
$150
$100
$50
$0
0.0
0.5
1.0
1.5
2.0
2.5
Maximum 1st-Percentile DO Improvement in FMA (mg/L)
Investment in wastewater improvement: No change in DO
Investment in wastewater improvement: Higher DO & better habitat
AA01
AA02
AA03
AA04
AA05
AA06
AA07
AA08
AA10
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

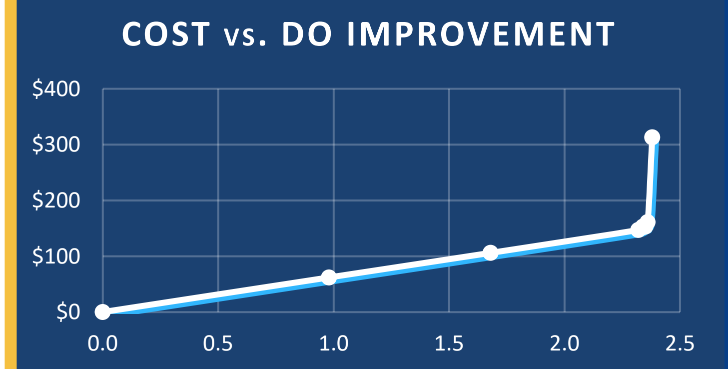

TOTAL COST vs. DISSOLVED OXYGEN IMPROVEMENT
Scenario AA08 represents the upper end of possible benefit from investing in wastewater improvement
Investment in wastewater improvement: No change in DO
Investment in wastewater improvement: Higher DO & better habitat
AA01
AA02
AA03
AA04
AA05
AA06
AA07
AA08
AA10
AA08: $153M/yr
(in 2019 $)
Annualized Present Cost ($M/yr, 2019)
$0
$50
$100
$150
$200
$250
$300
$350
0.0
0.5
1.0
1.5
2.0
2.5
Maximum 1st-Percentile DO Improvement in FMA (mg/L)
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA



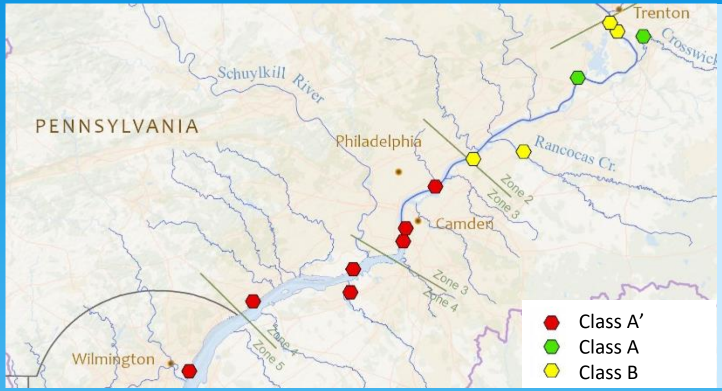
Nine wastewater discharges have great potential to **improve DO in the FMA**



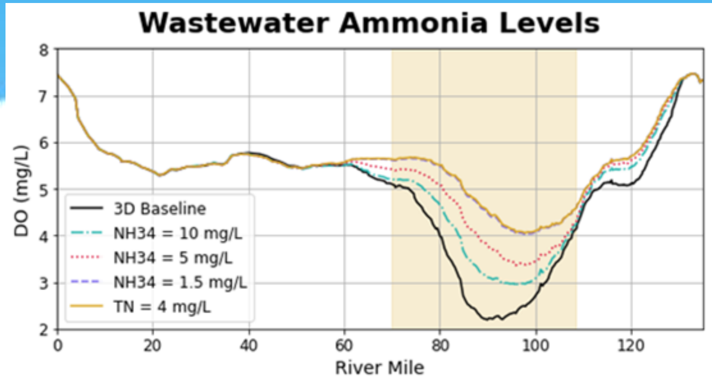
Reducing effluent ammonia to **1.5** mg/L (Class A’) and **5** mg/L (Class A) **improves habitat** in the urban estuary



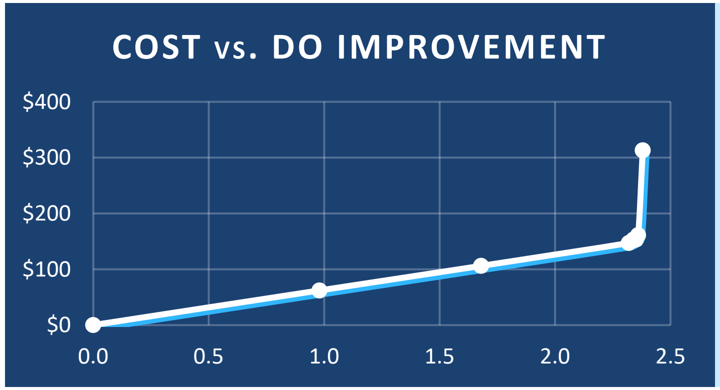
Cost (**$153M/yr** in 2019) was considered, but selected scenario **driven by maximum achievable DO improvement**



Nine wastewater discharges have great potential to **improve DO in the FMA**



Reducing effluent ammonia to **1.5** mg/L (Class A’) and **5** mg/L (Class A) **improves habitat** in the urban estuary



Cost (**$153M/yr** in 2019) was considered, but selected scenario **driven by maximum achievable DO improvement**

Improving Dissolved Oxygen and Aquatic Life Uses in the Delaware River Estuary

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

Topic	Presenter
Why are we here?	Steve Tambini
How did DRBC address low dissolved oxygen in the Delaware Estuary - then and now?	Namsoo Suk
Where do ammonia and other nutrients in the Delaware Estuary originate, and how do we know?	John Yagecic
What is this estuary-wide eutrophication model and why do we need it?	Li Zheng
What matters and what doesn't with regard to low dissolved oxygen events in the Delaware Estuary?	Fanghui Chen
What combination of wastewater improvements will achieve the best dissolved oxygen outcome in the Delaware Estuary?	Sarah Beganskas
What is the highest attainable dissolved oxygen condition in the Delaware Estuary, and what will it mean for aquatic life uses?	**Thomas Amidon**
Q&A Panel: Enhancing support for aquatic life uses in the Delaware Estuary	**All**

What is the highest attainable dissolved oxygen condition in the Delaware Estuary, and what will it mean for aquatic life uses?

Thomas Amidon, BCES
Manager, Water Resources Modeling

and

Jake Bransky
Aquatic Biologist

Delaware River Basin Commission

Partnership for the Delaware Estuary
Science and Environmental Summit

January 30, 2023

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

Question #2:

What will enhancing dissolved oxygen mean for aquatic life uses in the Delaware Estuary?

Question #1:

What is the highest attainable dissolved oxygen condition in the Delaware Estuary?

Sarah & Fanghui addressed this question:

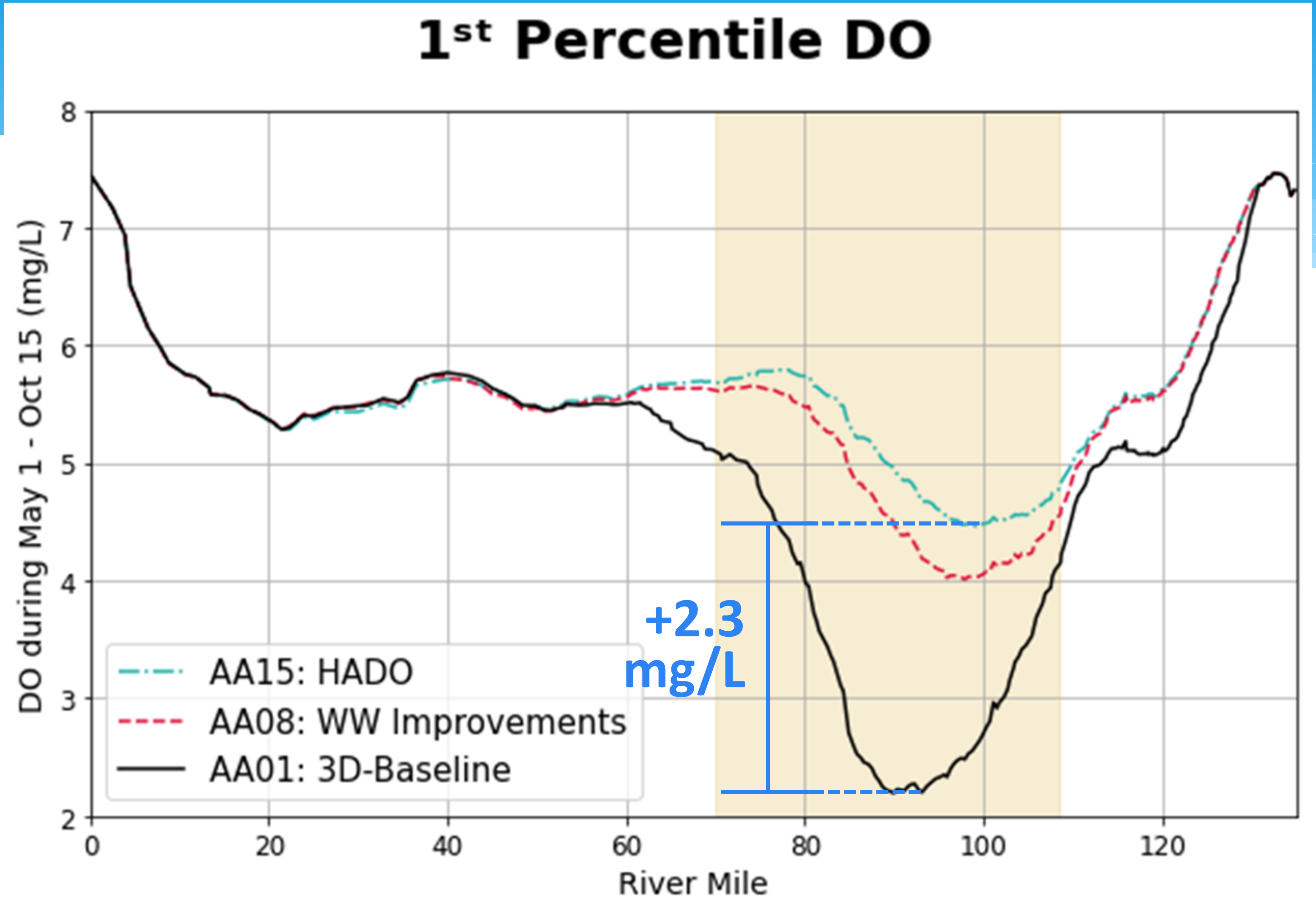
What pollutant reductions will achieve the best dissolved oxygen outcome in the Delaware Estuary?

What is the highest attainable dissolved oxygen condition in the Delaware Estuary?

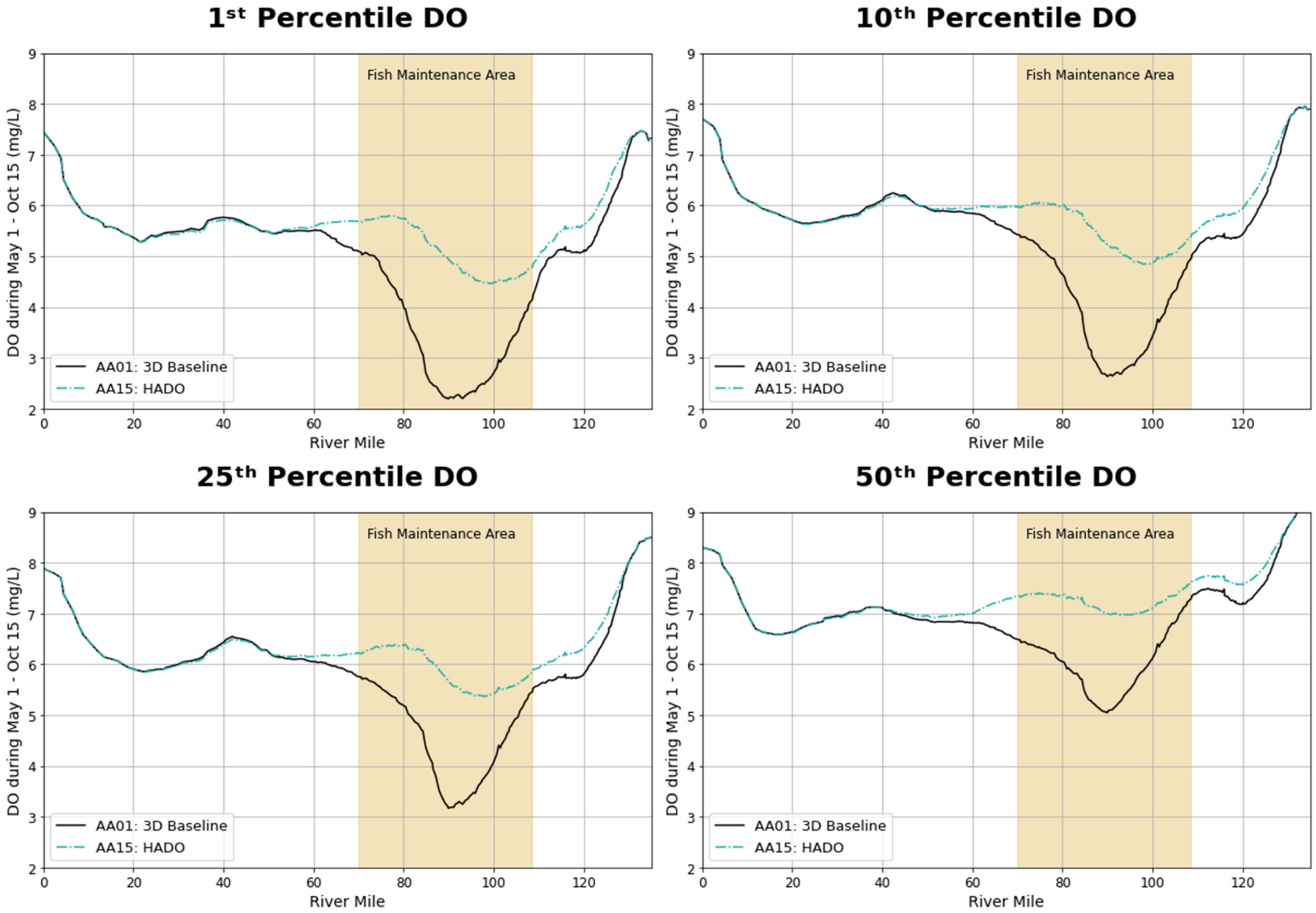
- Recall: pollutant reductions that can achieve the best dissolved oxygen outcome
  - 7 Class A' at ammonia = 1.5 mg/L
  - 2 Class A at ammonia = 5 mg/L
- Additional factors considered:
  - CSO reductions (based on LTCPs)
  - Effluent DO
  - Seasonally variable nitrification
  - 10% Reserve Capacity

CSO Reductions to reflect LTCP	
CSO System	**Post-LTCP (% reduction)**
PWD	55%
CCMUA	59%
Delcora	51%
Wilmington	0%

What is the highest attainable dissolved oxygen condition in the Delaware Estuary?



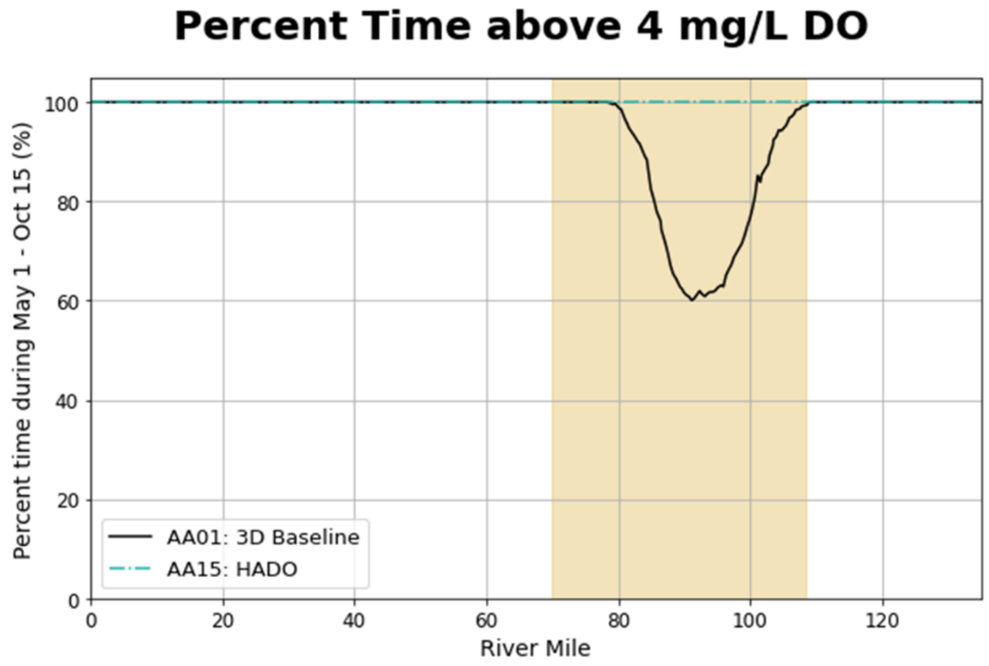
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

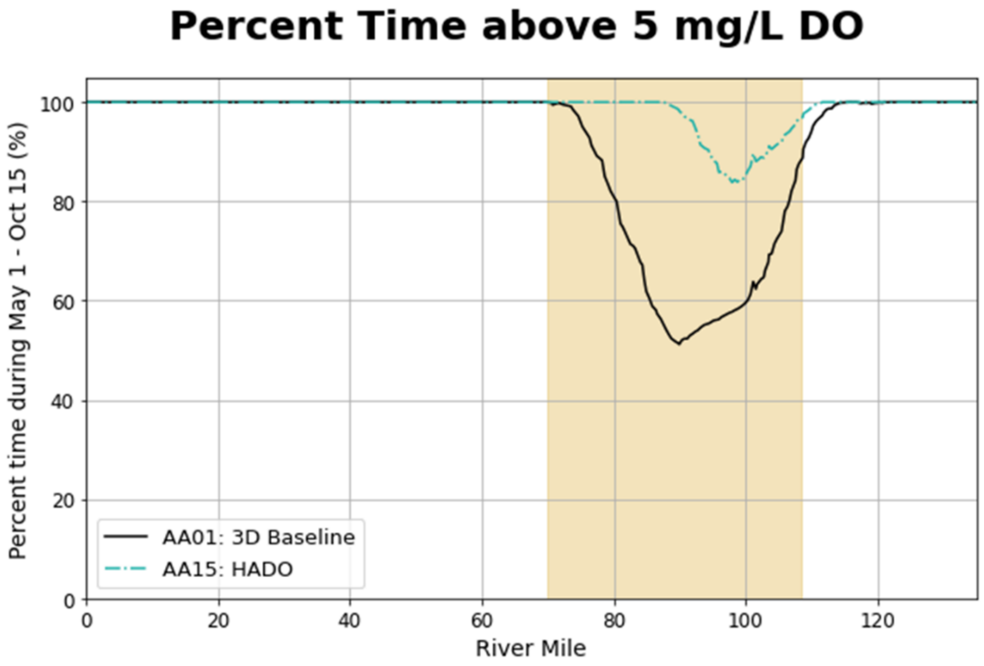


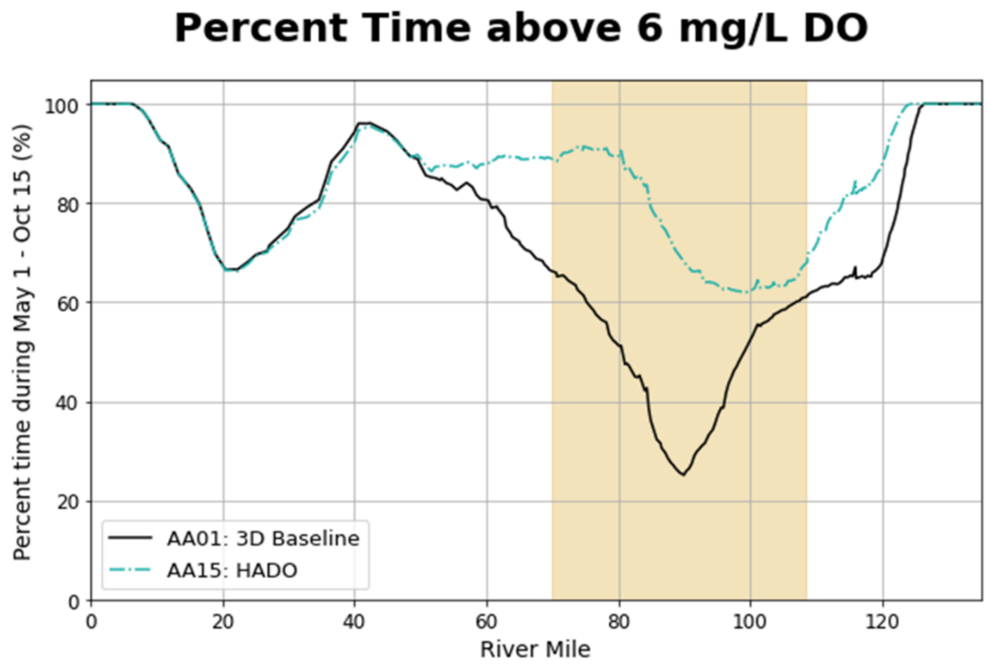
What is the highest attainable dissolved oxygen condition in the Delaware Estuary?

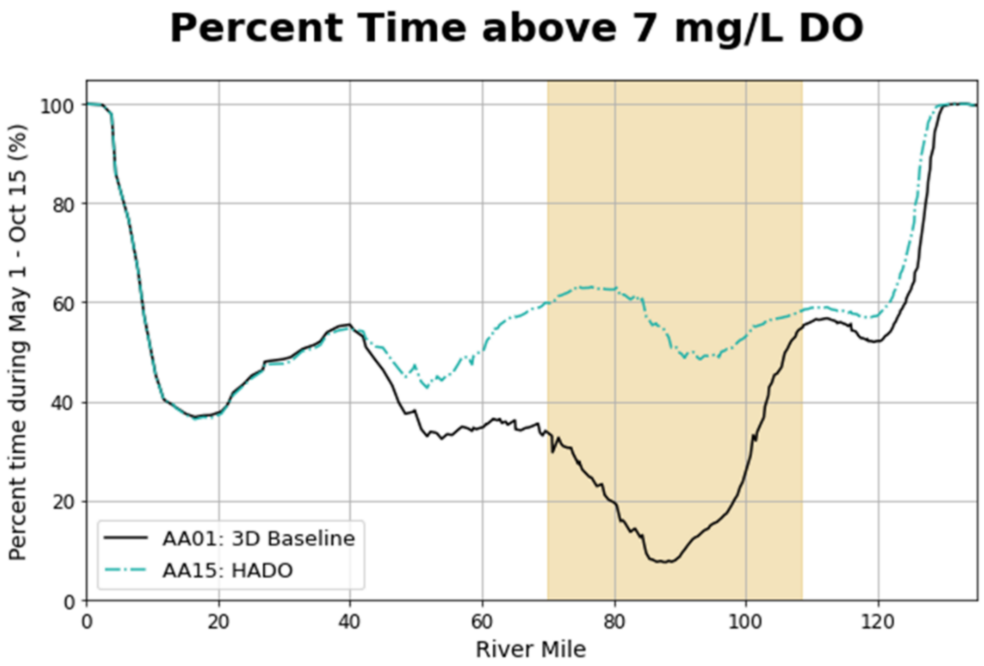
Percentile	Min value in FMA AA01	Min value in FMA AA15
1	2.2 mg/L	4.5 mg/L
10	2.6 mg/L	4.8 mg/L
25	3.2 mg/L	5.4 mg/L
50	5.0 mg/L	7.0 mg/L

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









What is the highest attainable dissolved oxygen condition in the Delaware Estuary?

% Time Above	Min value in FMA	
	AA01	AA15
4.0	60%	100%
5.0	51%	84%
6.0	25%	62%
7.0	7.5%	49%

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

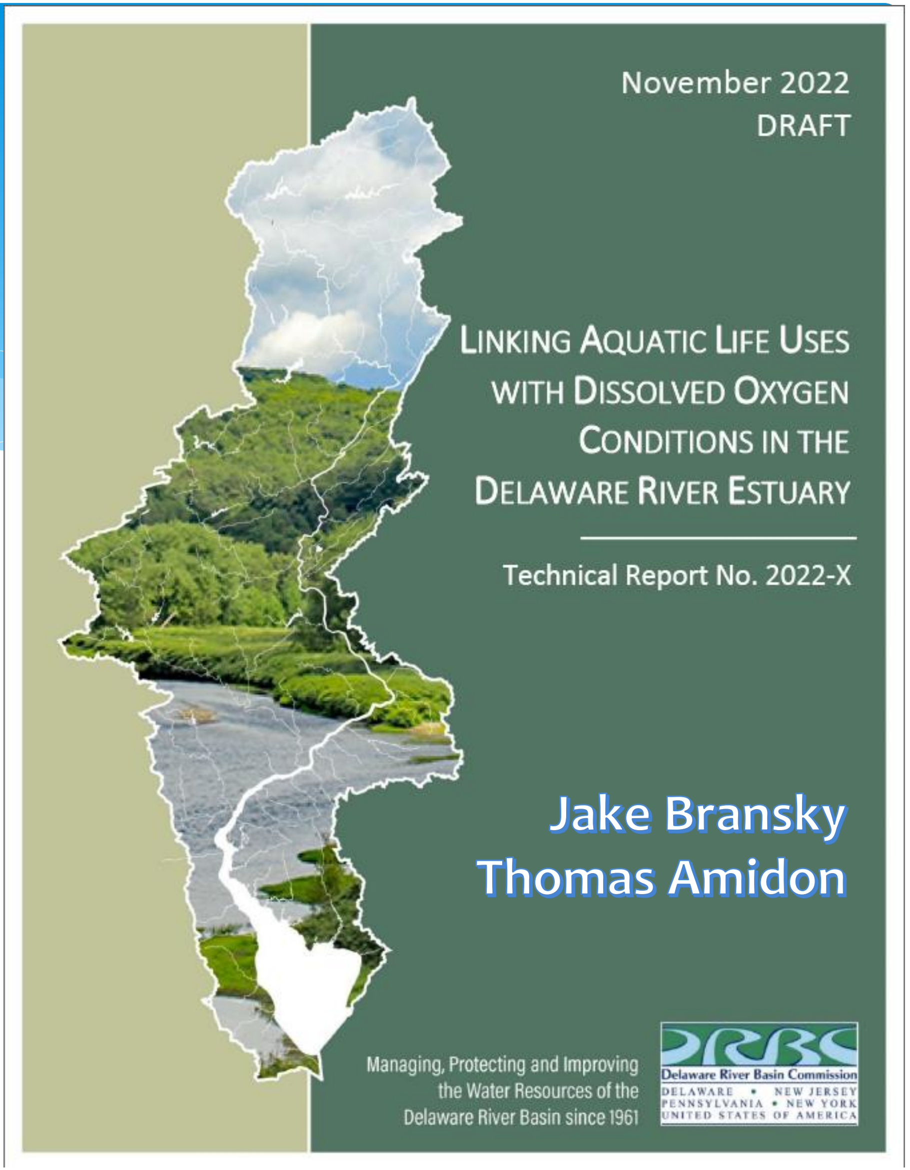
Why is this important?
How does it relate to aquatic life?

Delaware River Basin Commission

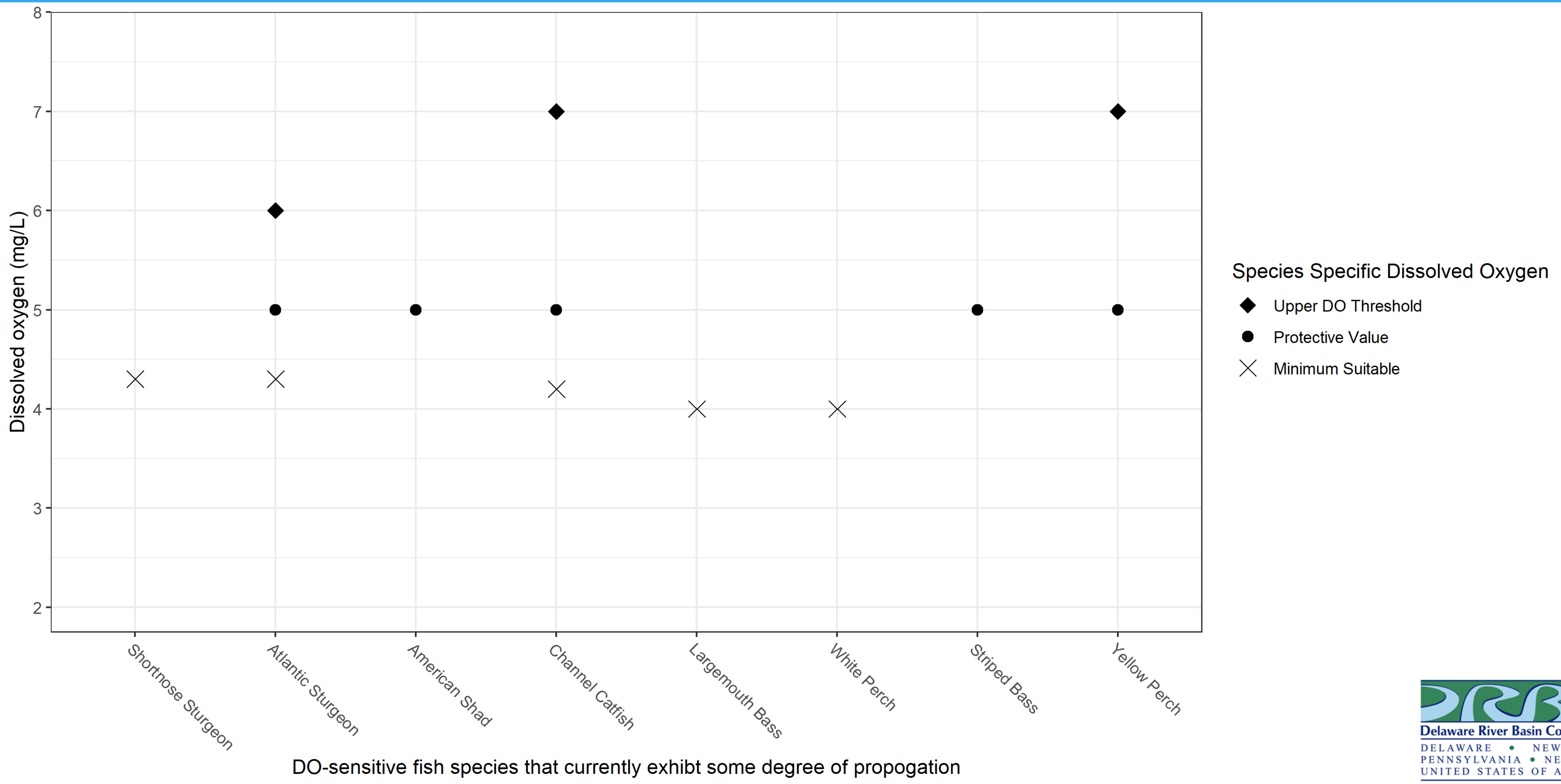
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Linking aquatic life uses with dissolved oxygen conditions

- Aquatic life uses are strongly dependent upon DO levels in the water column
- Identified eight DO-sensitive species in the estuary
- Characterized occurrence and distribution of the life stages of DO-sensitive fish species
- Identified relevant research on the oxygen requirements of each at different life stages
- Determine the ranges of DO values that support propagation of DO-sensitive species

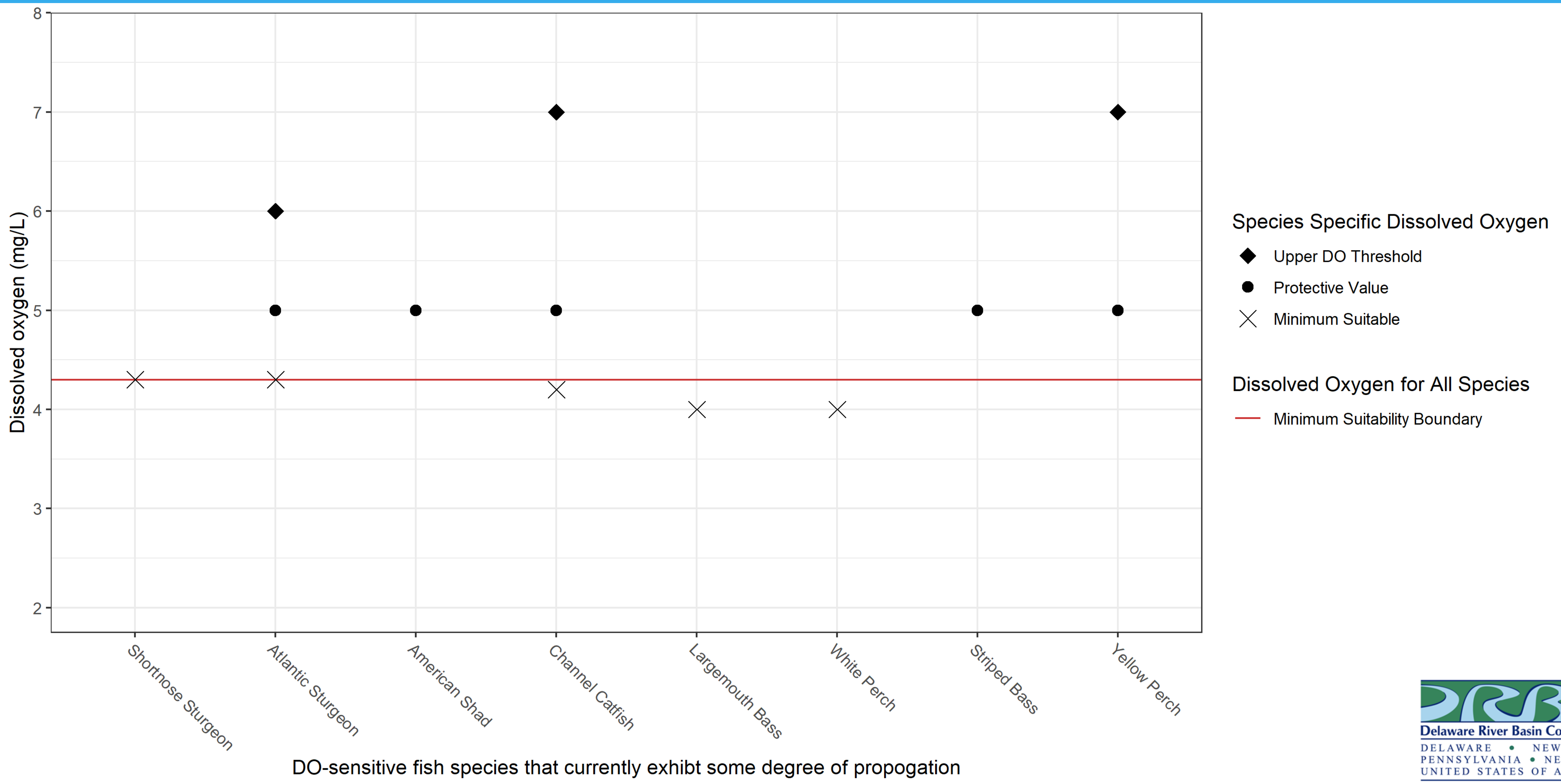


Eight DO-Sensitive Fish Species Identified in Tidal River Estuary (Zones 2–5)



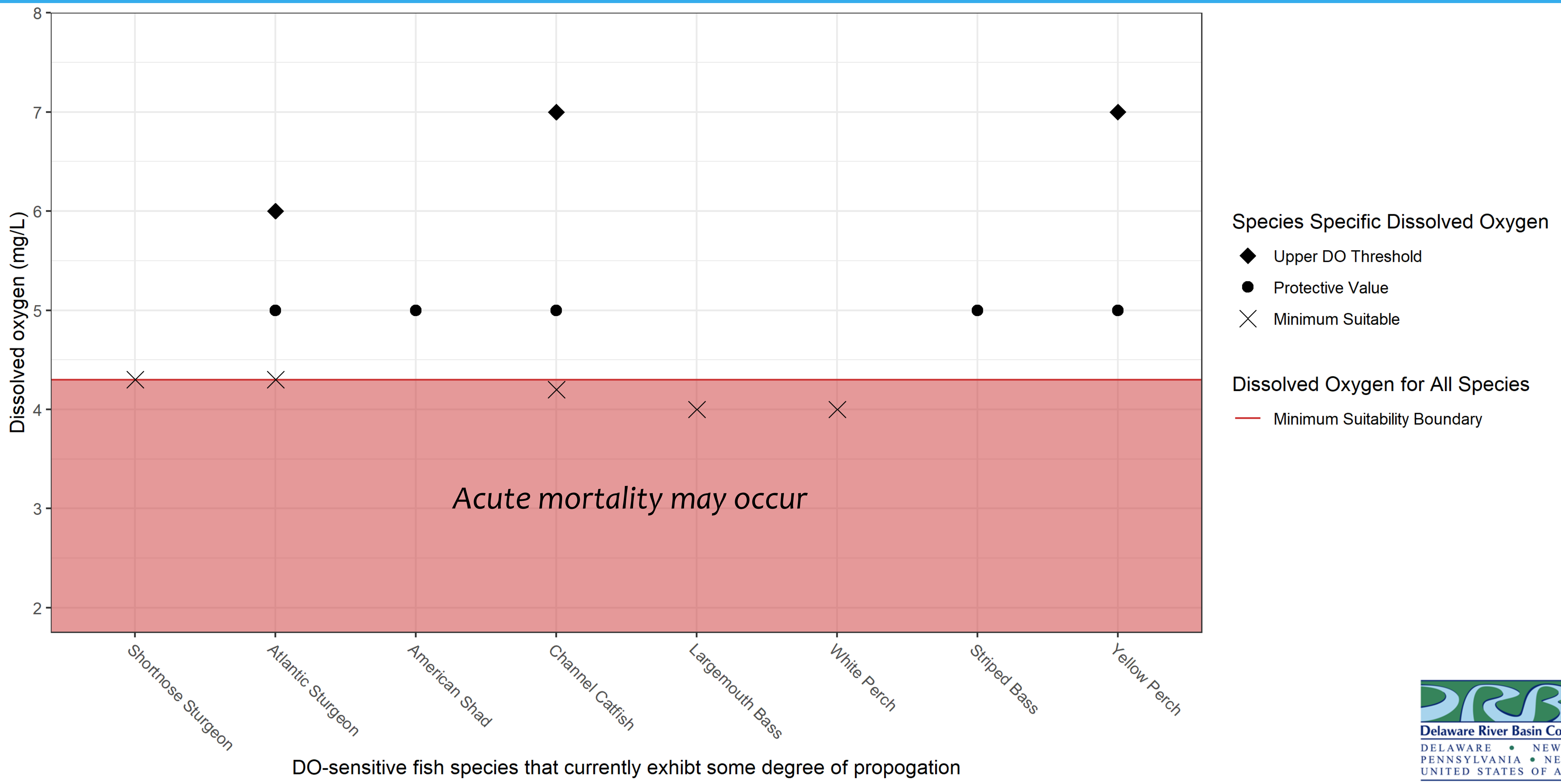
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Eight DO-Sensitive Fish Species Identified in Tidal River Estuary (Zones 2–5)



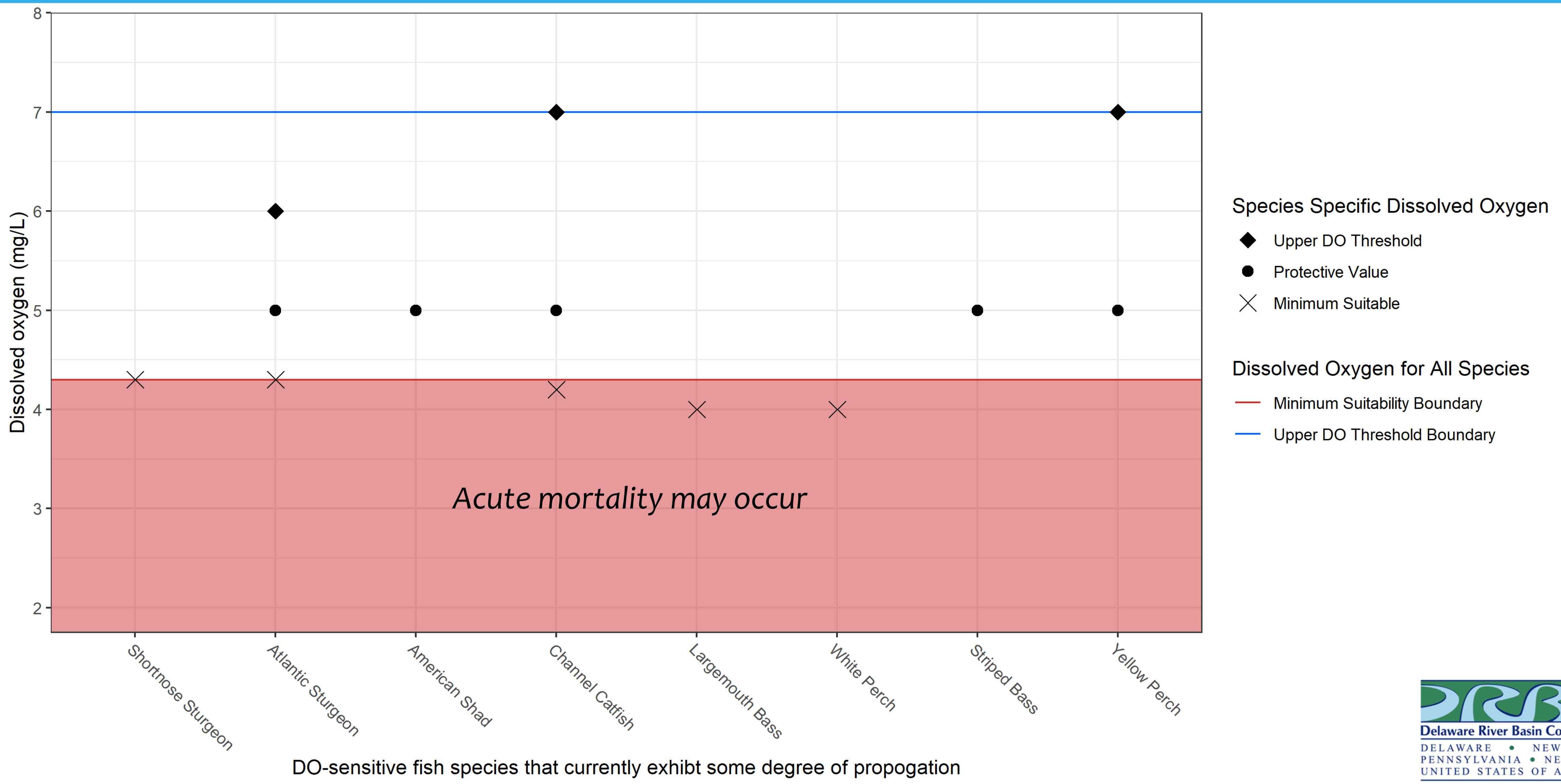
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Eight DO-Sensitive Fish Species Identified in Tidal River Estuary (Zones 2–5)



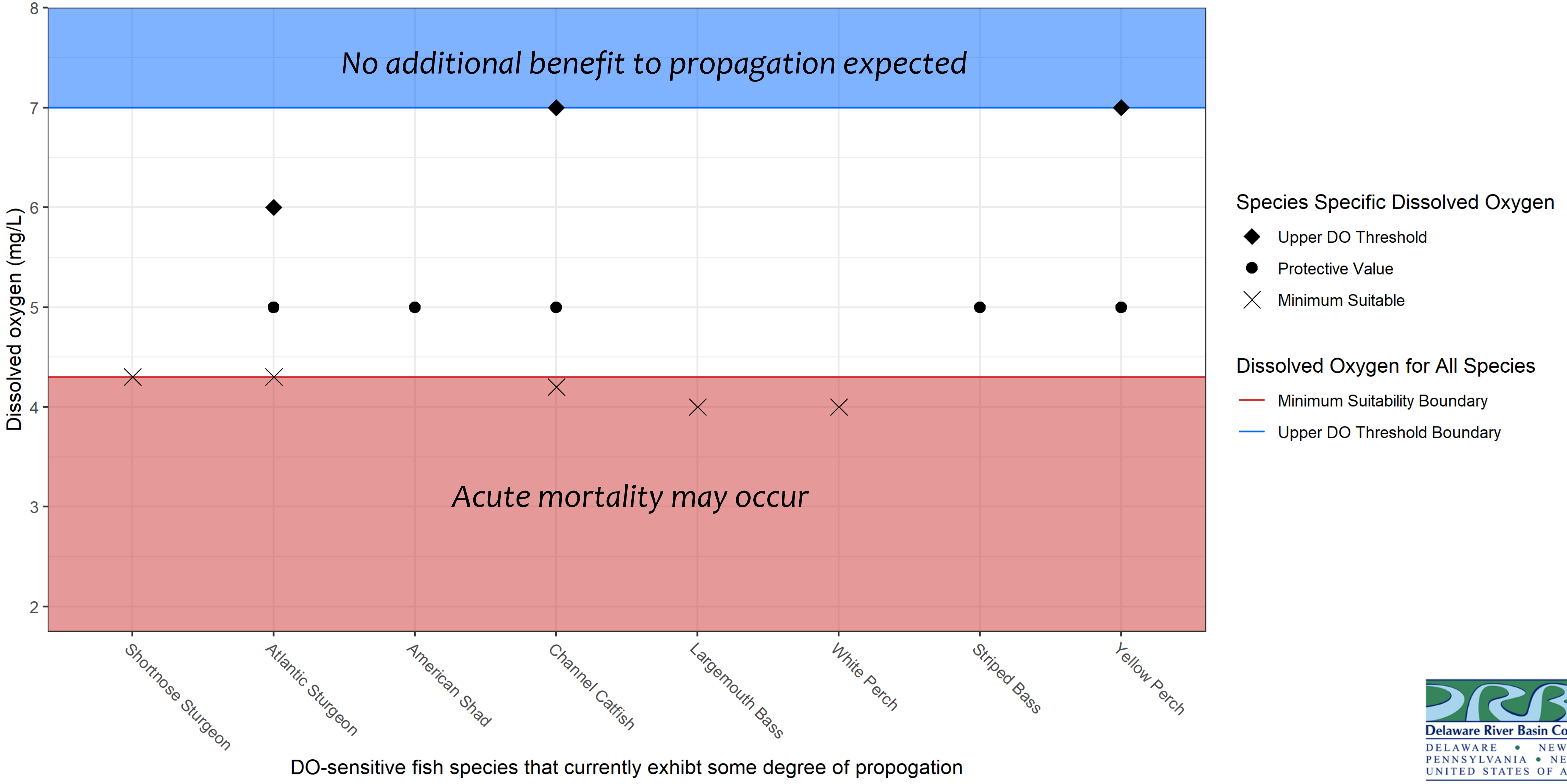
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Eight DO-Sensitive Fish Species Identified in Tidal River Estuary (Zones 2–5)



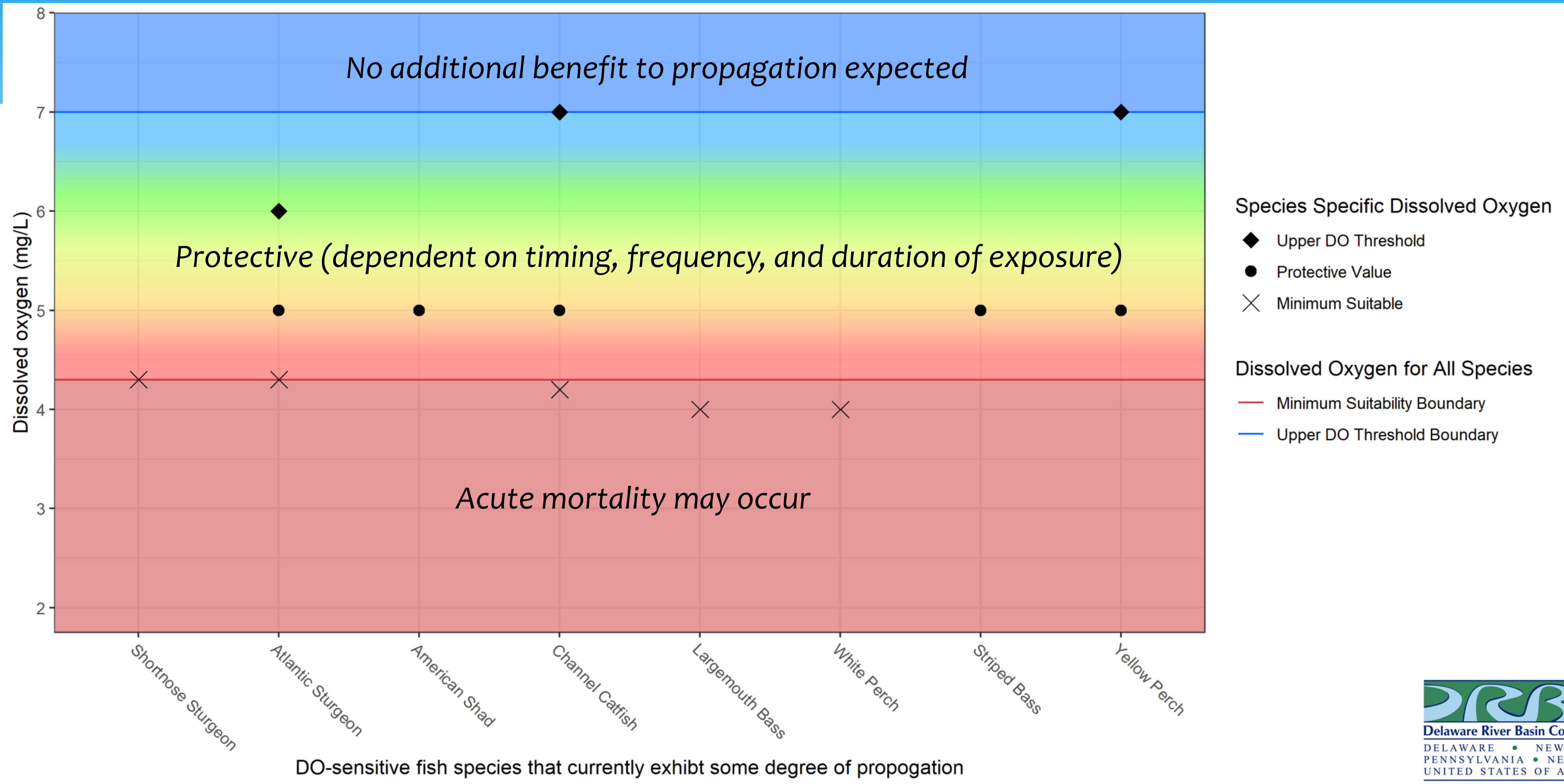
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Eight DO-Sensitive Fish Species Identified in Tidal River Estuary (Zones 2–5)



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

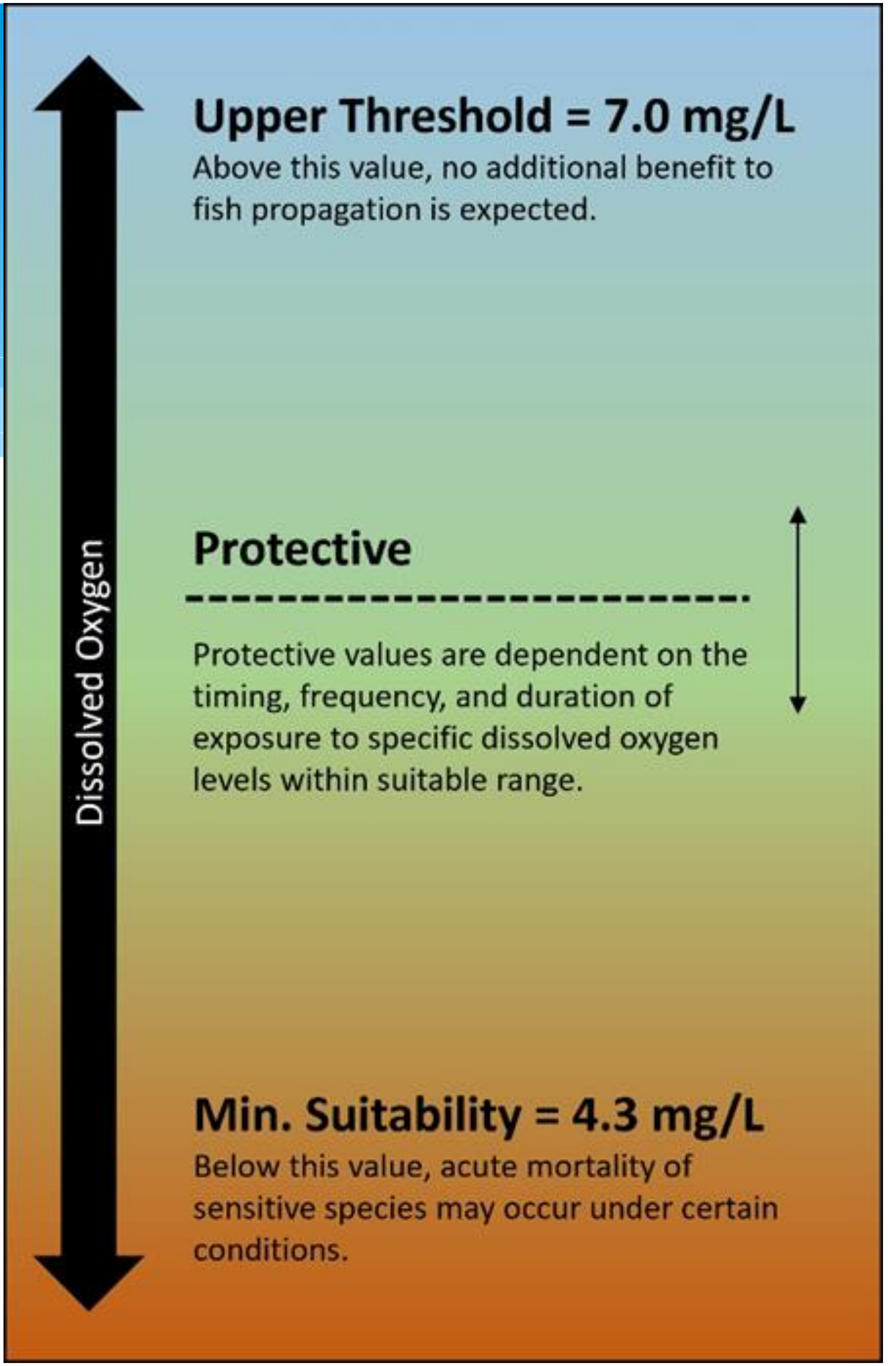
Eight DO-Sensitive Fish Species Identified in Tidal River Estuary (Zones 2–5)



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

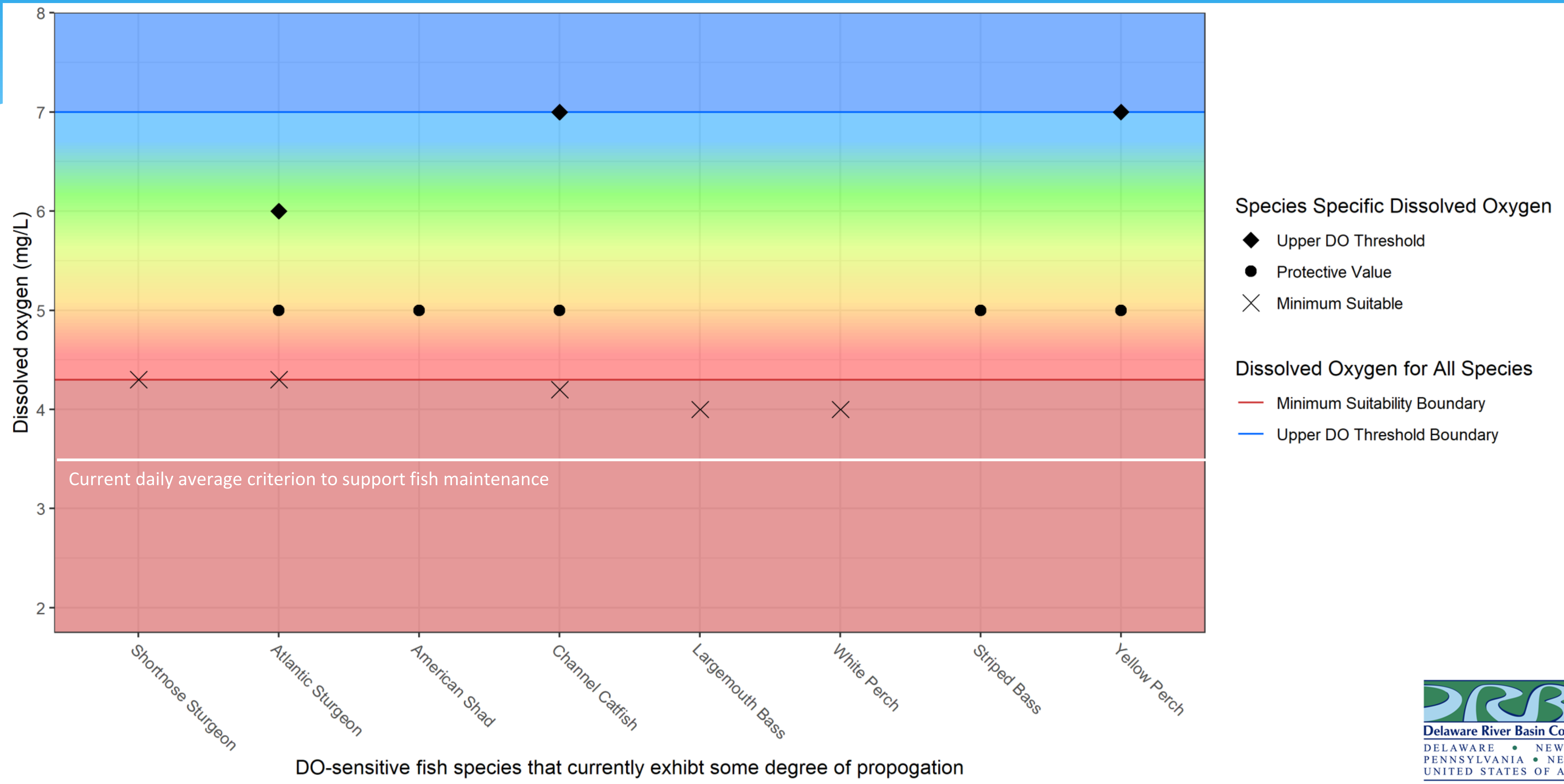
Suitability Gradient

- Minimum suitability threshold of 4.3 mg/L
  - EPA, 2003/2017
  - NOAA, 2017
  - Minimum DO to protect both endangered sturgeon species at stressful temperatures
    - ≥26°C for Atlantic Sturgeon
    - ≥29°C for Shortnose Sturgeon
- Minimum suitability threshold of 5.0 mg/L for spawning
  - American Shad (Stier and Crance, 1985)
  - Striped Bass (Turner and Farley, 1971)
- Upper DO threshold of 7.0 mg/L
  - Yellow Perch (Thorpe, 1977)
  - Channel Catfish (McMahon and Terrell, 1982)



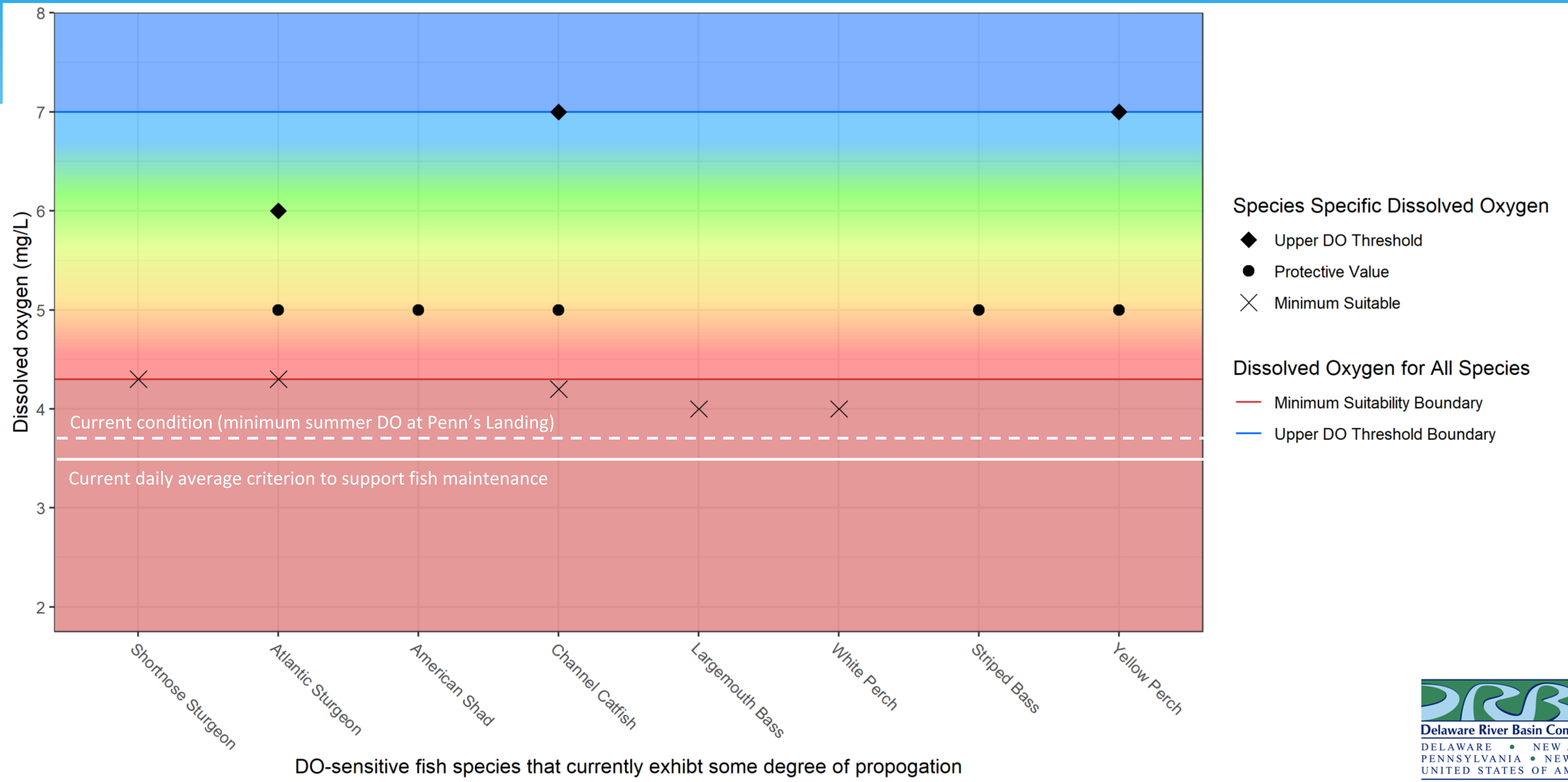
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

What will enhancing dissolved oxygen mean for aquatic life uses in the Delaware Estuary?



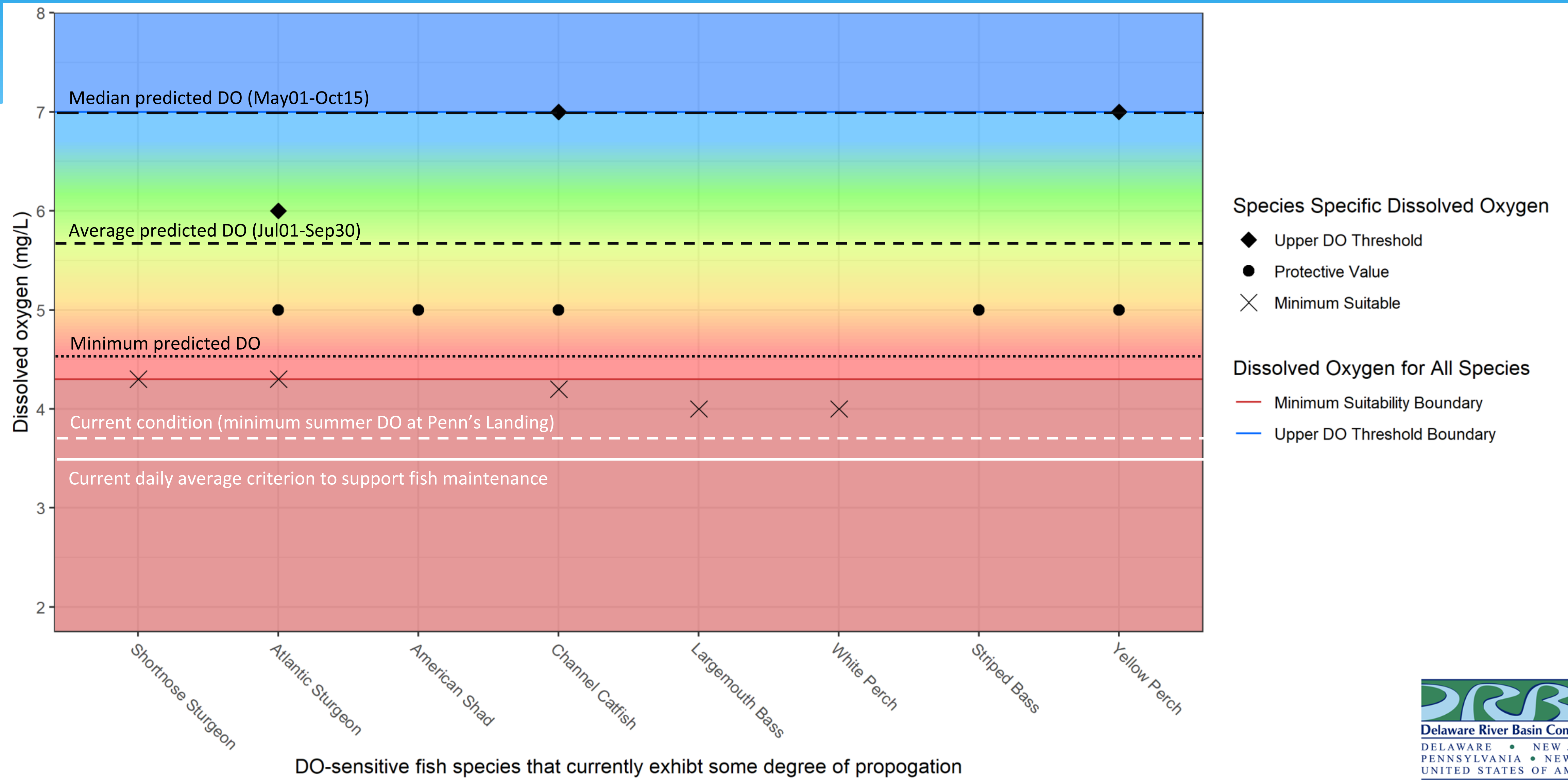
Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

What will enhancing dissolved oxygen mean for aquatic life uses in the Delaware Estuary?



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

What will enhancing dissolved oxygen mean for aquatic life uses in the Delaware Estuary?



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

DRBC concluded, and USEPA affirmed, that:

1) propagation is attainable throughout the estuary must therefore be reflected in designated uses; and
2) DO criteria must be enhanced to protect an upgraded designated use

Designated uses in freshwater tidal river estuary (Zones 2–5)

Portion of Freshwater Estuary	Current Use for resident fish and other aquatic life	Upgraded Aquatic Life Use (draft)
Zone 2 (RM 108–133)	Maintenance and Propagation	Maintenance, migration, and propagation of resident fish, diadromous fish, shellfish, and other aquatic life inhabiting the freshwater Delaware River Estuary
Zones 3, 4, and upper 5 (RM 70–108)	Maintenance	
Rest of Zone 5 (RM 48–70)	Maintenance and Propagation	

Ongoing Work:
Revise Water Quality Standards and Establish Wasteload Allocations

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

Aquatic Life Use Co-Regulator Workgroup:

- DRBC working together with USEPA in collaboration with estuary States
- Develop Estuary-specific WQS
  - Upgrade Aquatic Life Use to include propagation
  - Develop DO criteria to support propagation of DO-sensitive fish in FMA
- Deliverable by 11/30/2023
  - Basis and background document(s)
  - Rule proposals to be developed concurrently by DRBC and EPA)

Next Steps:

- Administrative process
  - Notices of proposed rulemaking – by Jan 2024
    - Federal and States
  - Public process – est. by May 2024
    - Public meetings / hearings (at least each State)
    - Written comments
  - CRD and Adoption – no later than March 2025
- Implementation
  - Establish wasteload allocations to meet criteria
  - Through State NPDES permits or DRBC dockets

Enhance water quality to fully support maintenance, migration, and propagation of resident and diadromous fish inhabiting the freshwater Delaware River Estuary

Striped Bass, NOAA Fisheries

White Perch, Maine DIFW

Largemouth Bass, Maine DIFW

Yellow Perch, NC Wildlife

American Shad, NC Wildlife

Channel Catfish, NC Wildlife

Atlantic Sturgeon, NOAA Fisheries

Shortnose Sturgeon, NOAA Fisheries

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

Improving Dissolved Oxygen and Aquatic Life Uses in the Delaware River Estuary

Topic	Presenter
Why are we here?	Steve Tambini
How did DRBC address low dissolved oxygen in the Delaware Estuary - then and now?	Namsoo Suk
Where do ammonia and other nutrients in the Delaware Estuary originate, and how do we know?	John Yagecic
What is this estuary-wide eutrophication model and why do we need it?	Li Zheng
What matters and what doesn't with regard to low dissolved oxygen events in the Delaware Estuary?	Fanghui Chen
What combination of wastewater improvements will achieve the best dissolved oxygen outcome in the Delaware Estuary?	Sarah Beganskas
What is the highest attainable dissolved oxygen condition in the Delaware Estuary, and what will it mean for aquatic life uses?	Thomas Amidon
Q&A Panel: Enhancing support for aquatic life uses in the Delaware Estuary	All