PENNSYLVANIA FISH AND BOAT COMMISSION
CLIMATE ACTION PLAN:

Strategies for Enhancing Climate Adaptation and Resiliency to Protect, Conserve, and Enhance Pennsylvania's Aquatic Resources and Support Anglers and Boaters

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LEXICON

Abbreviations

AIS	Aquatic Invasive Species
CCVI	Climate Change Vulnerability Index
cHABs	Cyanobacteria Harmful Algal Blooms
CNU	Cooperative Nursery Unit
CSO	Combined Sewer Overflow
GISC	Governor's Invasive Species Council
HABs	Harmful Algal Blooms
NAACC	North Atlantic Aquatic Connectivity Collaborative
NECASC	Northeast Climate Adaptation Science Center
NFWPCAS	National Fish, Wildlife, Plants Climate Adaptation Strategy
NIACS	Northern Institute of Applied Climate Science
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NPS	National Park Service
PABS	Pennsylvania Biological Survey
PACFWRU	Pennsylvania Cooperative Fish and Wildlife Research Unit
PADA	Pennsylvania Department of Agriculture
PADCNR	Pennsylvania Department of Conservation and Natural Resources
PADEP	Pennsylvania Department of Environmental Protection
PADLI	Pennsylvania Department of Labor and Industry
PDH	Pennsylvania Department of Health
PAWAP	Pennsylvania Wildlife Action Plan
PEMA	Pennsylvania Emergency Management Agency
PennDOT	Pennsylvania Department of Transportation
PFBC	Pennsylvania Fish and Boat Commission
PGC	Pennsylvania Game Commission
PNHP	Pennsylvania Natural Heritage Program
PSU	Pennsylvania State University
RISCC	Regional Invasive Species and Climate Change (Network)
SGCN	Species of Greatest Conservation Need
USACE	U.S. Army Corps of Engineers
USDA-NRCS	U.S. Department of Agriculture-Natural Resources Conservation Service
USDA-FS	U.S. Department of Agriculture-Forest Service
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

Common Terms

The topic of climate change can bring new terms which, without definition, can complicate understanding of the science and management actions. Here, we provide a few common words relevant to this document. It is beyond the scope of this document to list all terms as more complete lists have been developed (Adhikari et al., 2011; USEPA, 2017; USGCRP, n.d.).

Adaptation	Initiatives and measures to reduce the vulnerability of natural and human systems to actual or expected climate change effects (Adhikari et al., 2011).
Bioturbation	The stirring or mixing of sediment or soil by organisms, especially by burrowing or boring (American Heritage Dictionary of the English Language, 2016).
Climate Change	Statistically significant variability in the mean state of the climate or variations, persisting for an extended period (typically decades or longer) (Adhikari et al., 2011). Used here, it refers to human-caused changes.
Extirpation	The loss or disappearance of a species from part of its range (Adhikari et al., 2011).
Extreme Weather Event	Meteorological conditions that are rare for a particular place or time, such as an intense storm or heat wave (Adhikari et al., 2011).
Life-history	Sequence of events for an organism related to survival and reproduction (Britannica, n.d.).
Mitigation	Strategies and policies that reduce the concentration of greenhouse gases in the atmosphere by either reducing their emissions or increasing their capture (Adhikari et al., 2011).
Phenology	The timing of natural seasonal events such as insect emergences or migration (USEPA, 2017).
Resilience	A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage (USEPA, 2017).
Stochastic	Involving chance or probability (Merriam-Webster, n.d.).
Weather	The behavior of the atmosphere on a daily basis in a relatively local area (Adhikari et al., 2011).

EXECUTIVE SUMMARY

The Pennsylvania Fish and Boat Commission's (PFBC) 2020-2023 Strategic Plan, through Goal 8, established the goal of addressing climate change effects on the Commonwealth's aquatic species and aquatic-based recreational activities. Based on current scientific sources, statewide climate change impacts include warmer air and water temperatures; increased precipitation; and intermittency of precipitation events contributing to increased drought frequency. In southeast Pennsylvania, rising sea levels in the Delaware River Estuary are anticipated.

These changes are expected to have notable and long-term consequences for PFBC trust species (i.e., fish, amphibians, reptiles, freshwater mussels, crayfishes, other aquatic invertebrates) and their habitats, recreational angling and boating opportunities, as well as PFBC infrastructure and management. This plan highlights anticipated climate change impacts and provides a framework for the PFBC to adapt and build resiliency for the natural resources entrusted to its care.

2020-2023 PFBC Strategic Plan Goal 8

By June 30, 2021, identify and begin to implement strategies that addresses climate change impacts on habitat, fish species and angler behavior.

In 2020, PFBC issued a staff survey asking for anticipated effects of climate change on PFBC's jurisdictional species and infrastructure, and potential solutions to these issues. These survey results were used to formulate the Goals, Strategies, and Actions outlined in this plan, along with four guiding principles: 1) science-based evidence, actions, and decision making; 2) building and expanding partnerships; 3) enhancing habitat resiliency; and 4) communicating with staff and the public.

In this plan, eight PFBC climate change *Goals* (**Figure 1, Table 1**) provide overarching themes which include *Strategies* (i.e., approaches to achieving each goal); each with *Actions*, or measurable steps to achieve each strategy. These goals, strategies, and actions encompass the broad array of the PFBC's trust species, habitats, recreational opportunities, facilities, and functions.

PFBC's Climate Action Plan aligns closely with the scientific literature and climate plans developed by other state and federal partners. The PFBC fully anticipates collaborating with these agency partners, as well as non-governmental organizations, anglers, boaters, and other stakeholders to address the climate change threat. As this plan is implemented, PFBC will strive to employ effective communication, track implementation, increase staff capacity, and develop updates for consistency with current scientific information.

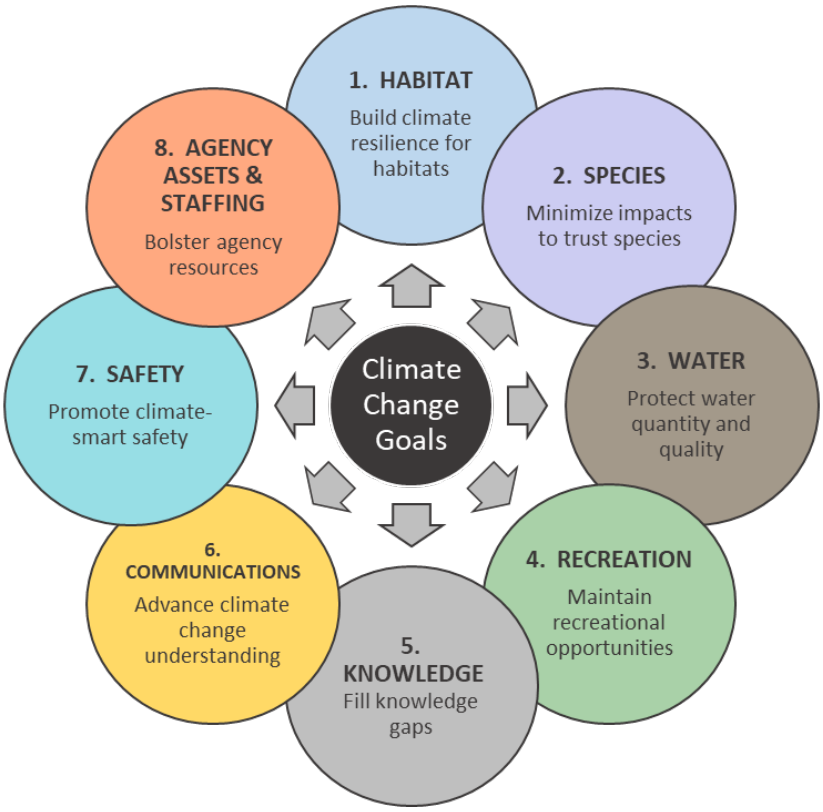

Figure 1. Eight climate change goals in this PFBC Climate Action Plan.

Table 1. Pennsylvania Fish and Boat Commission Climate Action Plan goals and descriptions.

GOAL	GOAL DESCRIPTION
1. HABITAT	*Build climate resilience for habitats used by PFBC trust species*.
2. SPECIES	*Minimize impacts to PFBC trust species through protection and adaptation measures in response to a changing climate*.
3. WATER	*Protect water quantity and quality for ecological integrity and recreational opportunities*.
4. RECREATION	*Adapt and implement actions to maintain PFBC support of recreational opportunities for anglers and boaters*.
5. KNOWLEDGE	*Fill knowledge gaps to understand species' response, enhance habitat resilience, and guide resource planning and management*.
6. COMMUNICATIONS	*Through a broad array of media, advance understanding of climate change impacts and conservation actions for ecological integrity and human well-being*.
7. SAFETY	*Adapt and promote climate-smart safety measures for PFBC staff and the public*.
8. AGENCY ASSETS AND STAFFING	*Bolster staff capacity and agency resources to proactively meet anticipated climate change needs*.

INTRODUCTION

In 2020, the PFBC Board of Commissioners approved the 2020-2023 PFBC Strategic Plan, a comprehensive document encompassing more than 100 goals. For the first time in the PFBC's 156-year history, this Strategic Plan identified a goal specifically addressing climate change. Through this goal (Goal 8), the PFBC will, *By June 30, 2021, identify and begin to implement strategies that address climate change impacts on habitat, fish species, and angler behavior*.

At a Glance

- *PFBC's Strategic Plan identifies a goal of addressing climate change.*
- *This Climate Action Plan highlights the anticipated ways climate change will impact PFBC trust species, habitats, anglers, and boaters.*

This PFBC Climate Action Plan (hereafter Climate Action Plan) identifies climate change issues anticipated to impact PFBC's trust species (i.e., fish, amphibians, reptiles, freshwater mussels, crayfishes, other aquatic invertebrates), their habitats, the angling and boating public, and other assets. From these issues, we provide goals, strategies, and actions to build resilience and support adaptative actions. In the development process, the PFBC Climate Action Plan Team broadly considered "fish" as all PFBC's trust species (see Legal Authority below). Thus, goals, strategies, and action items are made in this context.

This document references relevant climate science, offers highlights of key environmental factors projected to impact Pennsylvania ecosystems and, where available, impacts specifically affecting PFBC trust species and habitats. With prospects of climate impacts encompassing the coming decades, we envision this document as the first iteration of many plans which will be needed to accommodate evolving climate science. Thus, we include recommendations for maintaining and updating this document to provide ongoing relevance on this issue.

The PFBC Climate Action Plan is an initial assessment of the primary anticipated climate change threats to PFBC trust species, their habitats, and angling and boating activities. Beyond the original goal (Goal 8), this plan offers insights into climate change issues and potential impacts for PFBC assets (e.g., facilities), staff safety, and communications, though because they were not the primary purpose, these topics may require additional discussion and revision. The PFBC Climate Action Plan focuses specifically on issues pertaining to the agency, its mission, trust species and their habitats, angling and boating. This plan complements other state agencies' climate change documents. For example, the Pennsylvania Department of Environmental Protection (PADEP) *Pennsylvania Climate Action Plan* (PADEP, 2019) broadly outlines statewide climate change consequences for human health, agriculture, recreation, energy consumption and production, ecosystems, waste management, and water resources. The Pennsylvania Department of Conservation and Natural Resource (PADCNR) *Climate Change Adaptation and Mitigation Plan* (DCNR, 2018) is specific to the PADCNR mission and lands. Though these plans have different areas of focus, they overlap on numerous conservation goals and natural resources

management activities, offering collaborative opportunities to advance Pennsylvania's climate adaptation and resiliency.

Climate change is global in scope, yet local actions taken by an agency, groups of agencies, or individuals can have cumulative and tangible benefits for Pennsylvania's natural resources. With this document, the PFBC is actively engaging to address this threat to its trust species, habitats, anglers and boaters.

LEGAL AUTHORITY

As an independent administrative agency of the Commonwealth of Pennsylvania, the PFBC receives legal authority through Title 30 (Fish), which includes jurisdiction over aquatic organisms [*Any plant or animal that grows or lives in or upon water*], amphibians, and reptiles. More specifically, through Title 58, Chapter 75, the Commission's authority extends to Pennsylvania Endangered §75.1, Threatened §75.2, and Candidate species §75.3.

Pennsylvania Constitution

Article 1, § 27

The people have a right to clean air, pure water and to the preservation of the natural, scenic, historic and esthetic values of the environment...

Providing further legal support for developing this plan, Article 1, §27 of the Pennsylvania Constitution states, *The people have a right to clean air, pure water and to the preservation of the natural, scenic, historic and esthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people*. May 18,1971, P.L. 769, J.R. 3. Actions in this plan will help the PFBC advance the principles in this Article.

Through these authorities, and its mission *to protect, conserve, and enhance the Commonwealth's aquatic resources and provide fishing and boating opportunities*, the PFBC is effectively positioned to develop and implement this Climate Action Plan.

THE CASE FOR TAKING ACTION

Climate change poses a fundamental threat to nearly all aspects of natural systems and human society and, globally, enhances the risk of species extinction (Jay et al., 2018; IPBES, 2019; Urban, 2015; Weiskopf et al., 2020). Freshwater habitats are imperiled, and freshwater fishes have the highest extinction rates of vertebrates in the 20th century (Burkhead, 2012; Krabbenhoft et al., 2020). Increasing severity of extreme temperatures and weather events as a result of climate change have already been observed globally and are predicted to worsen in the coming decades, depending on trends in greenhouse gas emissions (IPCC, 2014).

At a Glance

- *Mean air and water temperatures have increased over the past decades and continue to rise.*
- *Average precipitation is expected to increase, but time between precipitation events is expected to become more intermittent thereby increasing drought frequency.*
- *Sea level rise is likely to impact southeastern parts of the Commonwealth.*

The call for action is global and, for aquatic ecosystems, a consortium of 110 world aquatic societies endorsed a statement for urgent action to address climate change by reducing greenhouse gas emissions (American Fisheries Society et al., 2020). The northeastern United States and Pennsylvania are no exception and are predicted to witness changes in biodiversity as well as ecosystem function, stability, and resilience as a result of a changing climate (PADEP, 2021; Shortle et al., 2015; Talbot et al., 2018). Understanding the specific climate factors affecting biological systems, as well as their predicted rate of change, is critical for predicting how PFBC trust species will respond, and what actions the PFBC can implement to minimize effects on Pennsylvania's resources. Here we highlight several key factors which current science and modeling predict to substantially change in this century, and which are most likely to have consequences for PFBC trust species and agency assets.

Temperature

Air temperature in Pennsylvania has increased by 1.8°F since the early 20th century and corresponding changes in stream and lake temperatures have also been observed (Frankson et al., 2016; Kaushal et al., 2010; Shortle et al., 2015; Staudinger et al., 2015). In a study of long-term temperature trends at 40 sites across the U.S., the Delaware River at the Ben Franklin Bridge in Philadelphia was observed to have the fastest rate of thermal (0.14°F/year) increase across all sites (Kaushal et al., 2010). PFBC-managed habitats and species are expected to be especially influenced by changing thermal regimes, either directly from changing water temperature or indirectly caused by loss of riparian habitat contributing to stream warming. Modified thermal regimes can alter biodiversity, increase extinction risk, change ecosystem productivity, reduce habitat availability, and influence phenology and distribution of aquatic species (Weiskopf et al., 2020).

Current projections show a 5.9°F increase in average annual air temperature across Pennsylvania by mid-century (2041-2070) (Frankson et al., 2016; PADEP, 2021) and, even with this progressive increase in temperature, high annual variability along with extreme cold events are anticipated (**Figure 2**). Increased temperatures are expected to be reflected in the number and intensity of extreme events (**Table 2**).

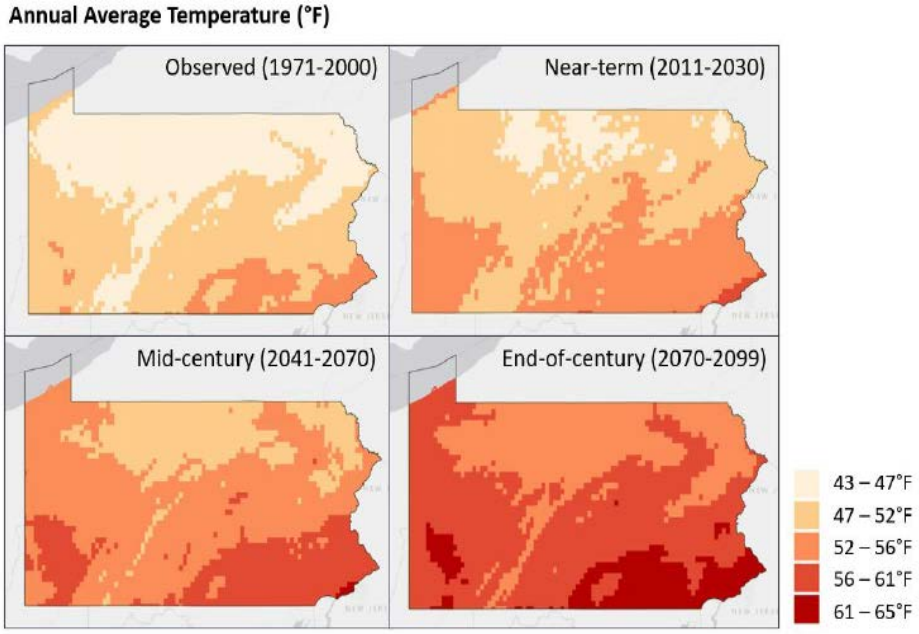

Figure 2. Observed and projected annual average temperatures in Pennsylvania. *Source: Figure 6 in PADEP (2021).* Based on 50th percentile of 32-model ensemble of Localized Constructed Analogs downscaled data, RCP 8.5 (Pierce et al., 2014).

Table 2. Projected changes in select climate change parameters in Pennsylvania. *Source: Adapted from Table 3, 4* (PADEP, 2021).

Parameter	1971-2000 Baseline	2041-2070	Trend
Air Temperature (Average)	48.3 °F	54.1 °F	Increasing
Days ≥ 90°F	5.1 days	31.9 days	Increasing
Cooling Degree Days [a]	483	1,185	Increasing (+150%)
Heating Degree Days [b]	6,600	5,165	Decreasing (-22%)
Annual Precipitation (inches)	43.5	47.1	Increasing (+8.4%)
Annual Maximum Consecutive Dry Days[c]	12.5	13.4	Increasing (+7.2%)
Days with precipitation above baseline ("very heavy")	12.4	15.4	Increasing (+24.5%)

[a]Cumulative degree difference between observed average daily temperature and 65°F when average daily temperatures are > 65°F; reflection of energy use required for cooling buildings; [b] Cumulative degree difference between observed average daily temperature and 65°F when average daily temperatures are < 65°F; reflection of energy use required for heating buildings; [c]Number of consecutive days when precipitations is 0 mm.

The Pennsylvania Department of Environmental Protection (PADEP) ranks increasing average temperature and heat waves as the highest risk factor for the Commonwealth by 2050 (PADEP, 2021). Water temperatures are also rising in the U.S., especially in urban areas, and higher ambient air temperatures are anticipated to be a continuing influential factor on water temperatures (Kaushal et al., 2010; Lynch et al., 2016; Rice & Jastram, 2015). In Pennsylvania such increases in water temperature are expected especially where groundwater influences and riparian buffers are insufficient to moderate the effects of elevated ambient temperatures (Merriam et al., 2019) and increases in water temperatures in the northern part of the Chesapeake Bay region have been shown to occur even under increasing stream flows (Rice & Jastram, 2015).

Precipitation

Pennsylvania is getting wetter! With average annual precipitation data for 1971-2000 as baseline, in the subsequent period of 2000-2020 the average annual precipitation increased by 4.6 inches with the greatest increases in May, June, and October (NOAA, 2021; PADEP, 2021) **(Figure 3)**. As with temperature, the timing and magnitude of precipitation events are likely to substantially impact PFBC's trust resources (Foden et al., 2008; PADEP, 2021) with the number of "very heavy" precipitation events projected to increase (PADEP, 2021) **(Figure 4**). Many species have life history requirements that have evolved around the predictability of precipitation events, the use of spring floodplain habitat, and sufficient groundwater recharge. Flashy flows from intense precipitation are predicted to increase runoff and degrade water quality, alter ecosystem productivity, directly displace animals, interrupt critical behavioral, and reproductive processes (e.g., migration, nest building), and alter habitats through increased scour, erosion, and sediment deposition (Poff et al., 2002; Shortle et al., 2015; Walls et al., 2013).

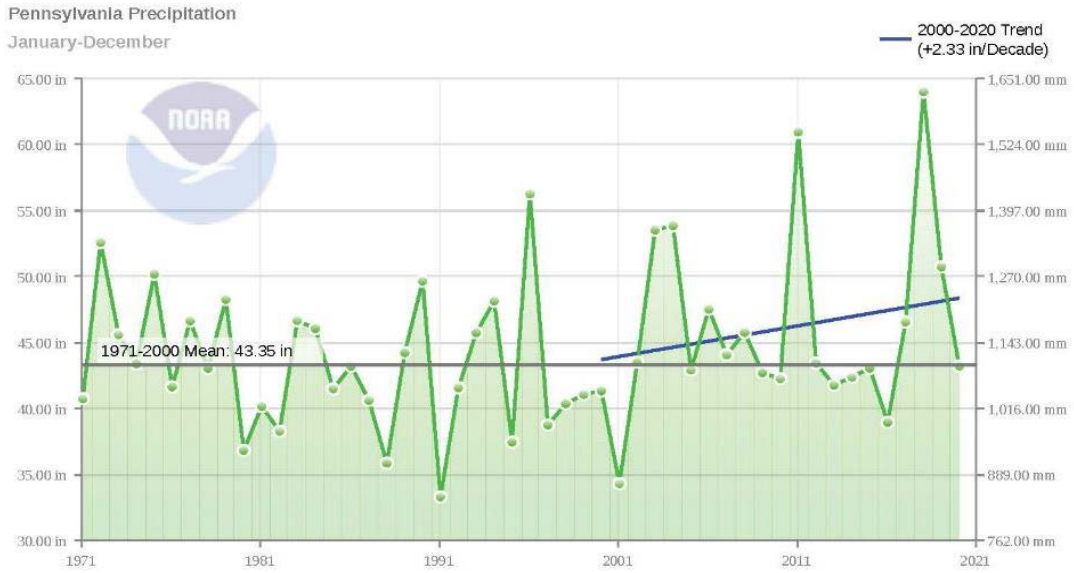

Figure 3. Average annual precipitation in Pennsylvania from 1971-2020 (green) and trending in average annual precipitation from 2000-2020 (blue). *Source: NOAA National Centers for Environmental information, Climate at a Glance: Statewide Time Series, published June 2021, retrieved on June 8, 2021 at* https://www.ncdc.noaa.gov/cag/.

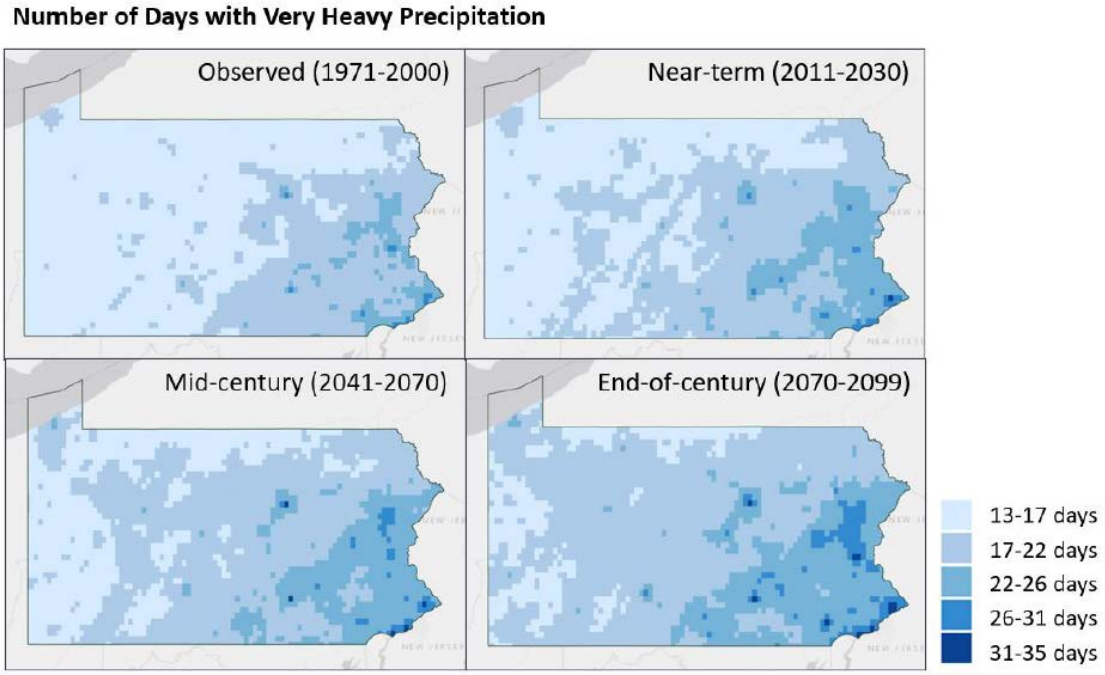

Figure 4. Observed and projected annual days with "very heavy" precipitation. *Source: Figure 16 (PADEP, 2021)*. A "very heavy" rainfall event occurs less than 5% of the time.

Beyond intensity, the timing of precipitation events is expected to change as warming temperatures alter the timing of snowmelt and seasonal high flow regimes. Similarly, the prolonged intermittency of precipitation events will result in more severe droughts, desiccating habitats, making them unsuitable due to insufficient water quantity or quality, and thereby impacting critical life-history stages (Poff et al., 2002; Walls et al., 2013). Extremes in precipitation may also degrade terrestrial and riparian habitats that support PFBC trust species and provide shade, nutrient and organic matter sources, and bank stability for aquatic ecosystems (Capon et al., 2013). Therefore, climate change is likely to directly and indirectly affect the distribution, phenology, and abundance of many PFBC trust species and the species on which they depend (Parmesan, 2006; Poff et al., 2002; Shortle et al., 2015). Key points about precipitation noted by PADEP (2021):

- extreme rain events are anticipated to increase in magnitude, frequency, and intensity;
- an increasing number of consecutive dry days are projected;
- the greatest increases in precipitation are projected to occur in winter and spring.

The outcome of these projections is more total rainfall, but in irregularly timed heavy precipitation events (PADEP, 2021).

Sea Level Rise

Pennsylvania is also expected to experience the effects of sea level rise in the Delaware Estuary, a diverse, tidal ecosystem. Global sea level has risen approximately eight inches over the last two centuries and is projected to rise another one to four feet by 2100 (DRBC, 2019; Frankson et al., 2016) (**Figure 5**). Climate change will degrade estuarine water quality, primarily dissolved oxygen levels which are closely tied to water temperature, and increase salinity due to saltwater intrusion from sea-level rise and reductions in streamflow (Poff et al., 2002; Shortle et al., 2015). Reduction in dissolved oxygen and increased salinity may result in population declines and extirpations, and shifts in aquatic species composition of both riverine and estuarine species as well as those inhabiting surrounding sensitive wetland areas (Fanghui, 2021; Shallcross, 2018; Shortle et al., 2015).

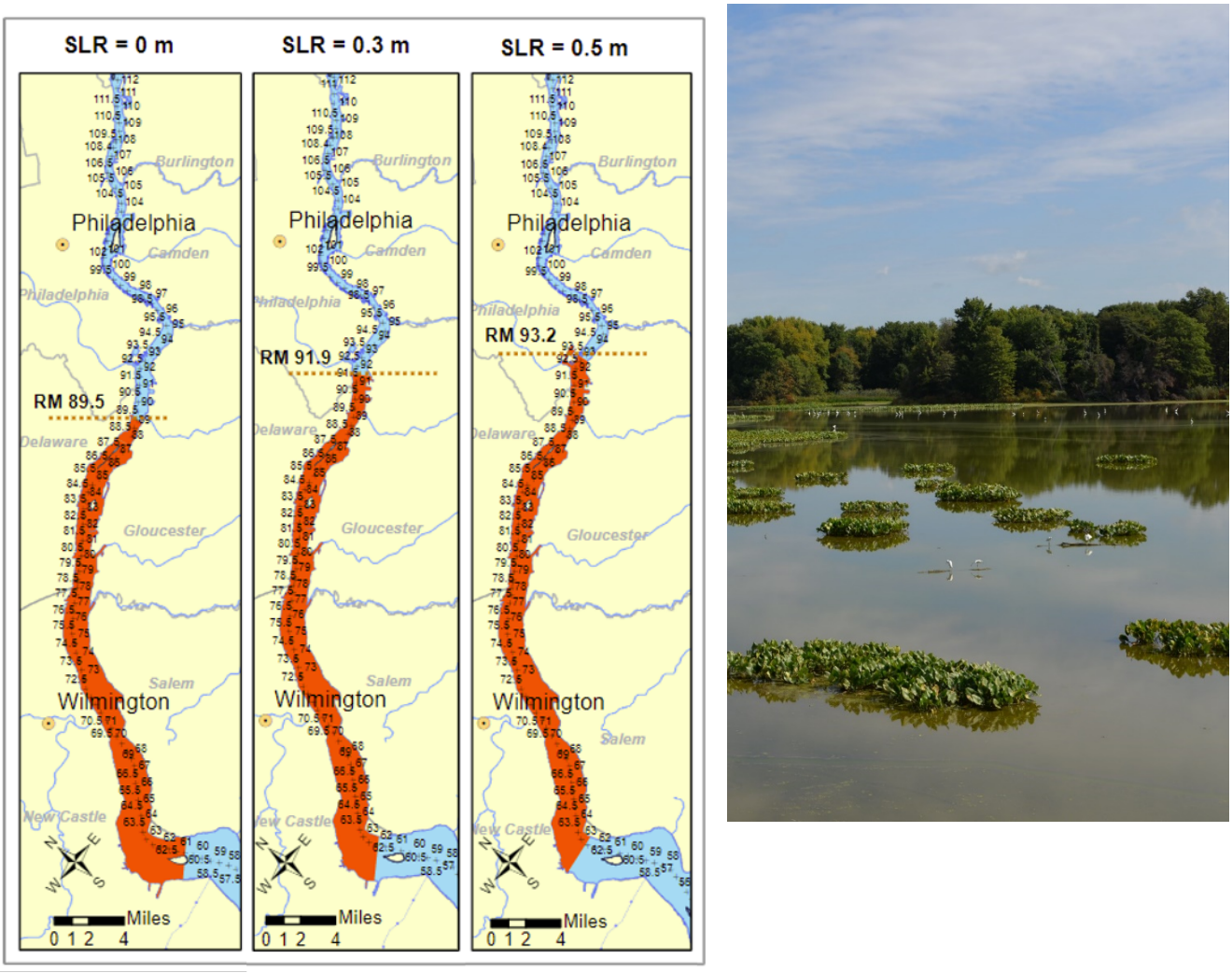

Figure 5. Simulated salt front location in the Delaware River estuary under sea level rise scenarios of 0 m (in 2000), 0.3 m (predicted to occur as early as 2030), and 0.5 m (predicted to occur as early as 2050). *Source: Delaware River Basin Commission, Water Resource Operations Science and Water Quality Assessment.* | *Background image: Heinz National Fish and Wildlife Refuge, Philadelphia, PA, Credit: Spring Gearhart, PFBC.*

CLIMATE CHANGE RELEVANCE TO PFBC

At a Glance

- *Climate change will impact numerous PFBC trust species and critical habitats.*
- *Recreational angling and boating opportunities will be influenced by increased precipitation, warmer temperatures, and decreased ice cover.*
- *PFBC infrastructure and management will need to be updated to ensure climate resilience.*

Climate change is of special concern for species exhibiting certain characteristics including those with specialized or vulnerable habitat requirements (e.g., vernal pools, wetlands), narrow environmental tolerances, dependance on environmental cues (e.g., spawning, migration, feeding), dependence on interspecific interactions, and those with a poor ability to disperse and colonize new areas (Foden et al., 2008). Based on this information, climate change is anticipated to broadly affect the Commonwealth's species and resources (DCNR, 2018; PADEP, 2019, 2021; PNHP, 2019) by eliminating critical habitat, shifting species' distributions across the state, altering phenology, and contributing to population declines, local extirpations, and extinctions (Foden et al., 2008; Parmesan, 2006; Shortle et al., 2015). In this section we provide a snapshot of climate change relevance to the PFBC including select trust species and critical habitats, as well as recreational anglers and boaters. More fully understanding climate change effects on Pennsylvania's aquatic resources and enhancing models for more accurate predictions will rely on expanding survey, monitoring, research and analytical initiatives.

Select Species Impacts

Species of Greatest Conservation Need

Pennsylvania has 664 Species of Greatest Conservation Need (SGCN) of which PFBC's jurisdiction includes: fish (65), amphibians (18), reptiles (22), freshwater mussels (50), and non-mussel invertebrates (162) that spend at least a portion of their life-cycle in an aquatic environment (PGC-PFBC, 2015). Of PFBC's 317 jurisdictional SGCN, 46 are listed as state endangered and nine as state threatened (**Table 3**). While individual species vary in their susceptibility to climate change, rare species with small or isolated populations, or those on the edges of their range (which includes many SGCN), are more likely to be extirpated by stochastic events.

NatureServe's Climate Change Vulnerability Index (CCVI) (NatureServe, 2022; Young et al., 2012), provides a standardized assessment using a species' climate change exposure and sensitivity, along with documented or modeled climate change responses. The result is a climate change vulnerability index score. Several of Pennsylvania's SGCN have specific habitat requirements or biological traits that make them extremely or highly vulnerable to climate change. Yet, substantial knowledge gaps need to be filled for many species before their climate change vulnerability can be assessed. Of PFBC's SGCN, only 14 (28.5%) have associated Climate Change Vulnerability Index (CCVI) scores and no fish species have CCVI assessments (**Table 3**). Of the 85 species that do have assigned CCVIs, the largest proportion of

those assessed (47%) are plants. The at-risk nature of the state's SGCN makes filling data gaps and prioritizing conservation actions for these species a top priority.

Table 3. Species of Greatest Conservation Need (SGCN) delineated by taxonomic grouping for Pennsylvania (PFBC trust species highlighted in grey), including total number of SGCN, total number of Pennsylvania threatened or endangered species, those with federal listing status (i.e., T-threatened or E-endangered), and total number of SGCN with an assigned Climate Change Vulnerability Index (CCVI) score. *Source:* *Furedi et al. (2011); PGC-PFBC (2015); PGC-PFBC (2021).*

Taxonomic Group	Total SGCN	PA Endangered	PA Threatened	Federal T or E	# with CCVI
Amphibians	18	5	2	0	4
Birds	90	17	3	2	8
Fish	65	29	5	2	0
Invertebrates					
Freshwater mussels	50	7	1	11	6
Aquatic, non-mussel	162	0	0	0	5
Non-aquatic	238	0	0	1	10
Mammals	19	6	3	2	
Reptiles	22	5	1	2	4
TOTAL	664	69	15	20	37

PFBC candidate species: (4) fish; (2) reptiles;

Wild Brook Trout

Wild Brook Trout *Salvelinus fontinalis* populations may be particularly vulnerable to climate change as their cold-water habitat becomes reduced from warming (**Figure 6**). However, predicting long-term trends in wild Brook Trout (and other aquatic organism) populations is challenging given the interacting factors that regulate these populations (Bassar et al., 2016). Changes to instream thermal and flow regimes are predicted to have direct consequences for wild Brook Trout populations. For example, in the Chesapeake Bay Watershed, ambient temperatures and altered precipitation are predicted to effect habitat including, by 2062, a projected loss of functional wild Brook Trout fishery habitat value in at least 3,000 km (9% of current value) (Merriam et al., 2019). As defined, functional fishery

Terry Malloy

Figure 6. Brook Trout *Salvelinus fontinalis.*

value (of habitat) is the stream segment length multiplied by the probability of Brook Trout predicted occupancy (Merriam et al., 2019).

Other climate change effects could influence habitat connectivity, with potential implications for wild Brook Trout distribution and abundance. In cold water streams, resident trout could become increasingly isolated when temperatures in connecting coolwater streams become increasingly uninhabitable, putting fish at risk of genetic bottlenecks and extirpation due to stochastic events (Argent & Kimmel, 2013). The severity and extent of these issues however, depends on variation in groundwater connectivity and riparian cover that may help to buffer some of these effects at the local scale (Argent & Kimmel, 2013; Snyder et al., 2015).

Species interactions are also expected to change with increasing temperatures, especially among wild Brook Trout, other wild trout species, and hatchery-reared trout. Wild Brook Trout are more thermally sensitive than their Brown Trout *Salmo trutta* and Rainbow Trout *Oncorhynchus mykiss* counterparts and may be the first to experience range reductions under climate change (Eaton et al., 1995). Compared to Brook Trout, under warmer temperatures, Brown Trout are superior competitors for both food and flow refugia; the consequences of which could lead to decreased growth rates of wild Brook Trout in some areas, or instances of Brown Trout displacing Brook Trout (Carlson et al., 2007; Hitt et al., 2017; Taniguchi et al., 1998).

Beyond interspecific competition, introgression between hatchery-reared Brook Trout and wild Brook Trout may result in offspring with reduced survivorship and reproductive capacity and increased susceptibility to disease, further exacerbating potential effects of climate-change on trout populations (Harbicht et al., 2014).

Freshwater Mussels

Freshwater mussels are benthic invertebrates often found in streams and rivers around the world. Of their ecological benefits, mussels filter sediment, toxins, and other particulate matter from the water column; provide habitat to unique assemblages of aquatic communities; increase substrate stability; and oxygenate the sediment through bioturbation (Spooner & Vaughn, 2006; Vaughn, 2010). Pennsylvania supports 67 freshwater mussel species, including 11 federally or Pennsylvania threatened and endangered species (**Figure 7; Table 3**). Thirteen species are considered extirpated.

Western Pennsylvania Conservancy

Mary Walsh

Figure 7. Freshwater mussel quantitative sampling is important for documenting changes in populations as well as occurrence.
Inset: Yellow Lampmussel *Lampsilis cariosa*.

Primarily sedentary, mussels are often unable to escape habitat disturbance, and therefore are highly susceptible to climate change effects.

Freshwater mussels vary in their thermal tolerance, with some more sensitive to thermal extremes than others (Galbraith et al., 2012; Galbraith et al., 2020; Spooner & Vaughn, 2008). Mussels rely heavily on natural thermal cues for feeding and reproduction and disruptions to these cues can result in decreased fecundity, brood abortion, increased loads of parasites, or asynchronous timing of larval release with the presence of their obligate host fish (Aldridge & McIvor, 2003; Galbraith & Vaughn, 2009, 2011). In addition to thermal sensitivity, mussels can be extremely susceptible to drought conditions, rapid fluctuations in water levels, and declining water quality, all of which are expected to increase with climate change (Galbraith et al., 2015; Galbraith et al., 2010; Watters, 2000). Of the six Pennsylvania freshwater mussel species assessed for climate change vulnerability, five species (Dwarf Wedgemussel *Alasmidonta heterodon,* Clubshell *Pleuobema clava,* Rayed Bean *Villosa fabalis,* Northern Riffleshell *Epioblasma torulosa rangiana*, and Yellow Lampmussel *Lampsilis cariosa*) were ranked as "Highly Vulnerable" and one coldwater mussel species (Eastern Pearlshell *Margaritifera margaritifera*) was ranked as "Extremely Vulnerable" (Furedi et al., 2011). Mussels rely on the presence of a suitable host fish for their successful reproduction, thus mussel populations are also likely to be impacted by changes in fish community composition and loss of host fish populations (Galbraith et al., 2018; Vaughn & Taylor, 1999).

PFBC Archives

Figure 8. Eastern Hellbender *Cryptobranchus alleganiensis alleganiensis.*

Hellbenders

Pennsylvania's state amphibian, the Eastern Hellbender *Cryptobranchus alleganiensis alleganiensis* (**Figure 8**) has experienced dramatic declines across its range in the past decades. A species sensitive to changes in hydrology, sediments, and water temperature (Gates et al., 1985; Nickerson et al., 2017; Quinn et al., 2013; Wheeler et al., 2003), projected increases in severe precipitation events under climate change would be expected to accelerate stream erosion and runoff, further degrading Hellbender habitat and contributing to contraction in distribution. These influences are reflected in the CCVI assessment (Furedi et al., 2011) where the species was found "Extremely Vulnerable" to climate change. Sediment is considered a major factor in Hellbender population extirpation (Quinn et al., 2013). Thus, in streams influenced by increasing ambient temperatures and diminished riparian cover, water quality for Hellbenders would be further expected to degrade.

Hellbenders and other amphibians are also susceptible to a variety of diseases that have resulted in rapid population decline. How these host-pathogen interactions might change under climate change is

difficult to predict. Larvae and young amphibians have a rapidly developing immune system and increased stress due to unpredictable temperature and precipitation regimes could make this life stage even more susceptible to debilitating pathogens such as chytrid fungus (Rollins-Smith, 2017).

Reptiles

Globally, reptiles are among the most endangered taxonomies, in large part due to habitat modification and other human-caused factors, and growing impacts of climate change (Mothes et al., 2020). Only four of Pennsylvania's 22 reptile SGCN have an assigned CCVI (**Table 3**), with Bog Turtle *Glyptemys muhlenbergii* considered "Highly Vulnerable" and Spotted Turtle *Clemmys guttata* ranked as "Moderately Vulnerable" (Furedi et al., 2011). The diverse, and often specific, habitat requirements of turtles and snakes may make them particularly vulnerable to changing conditions in future climate scenarios. For example, the Bog Turtle (**Figure 9**) is a habitat specialist needing open-canopy fens or wet meadows (Erb, 2019). The Eastern Massasauga is likewise a habitat specialist requiring a mix of swamps and bottomland wetlands (for overwintering), along with upland meadows, old field or grassland habitats (Shiels, 2007). Among the threats brought about by climate change are projected increases in precipitation which could raise water levels in wetlands reducing habitat suitability for critical life stages (Erb, 2019; Pomara et al., 2014).

Tom Diez

Figure 9. Bog Turtle *Glyptemys muhlenbergii.*

Karl Lutz

Figure 10. Timber Rattlesnake *Crotalus horridus.*

Other reptile species are expected to be generally affected by "habitat loss," but the degree to which climate change will directly contribute to this loss is often unclear and complicates assigning CCVI to certain species. For example, the Wood Turtle *Glyptemys insculpta* in the northeast United States is predicted to lose 29-52% suitable habitat and 62-82% of optimal habitat by 2070 (Mothes et al., 2020). Models indicate Wood Turtle habitats are strongly influenced by increasing temperatures with greatest losses of suitable habitat predicted in the southern portion of

their range (south of New York state (Furedi et al., 2011; Mothes et al., 2020). Similarly, forests are the primary habitat for the Timber Rattlesnake *Crotalus horridus* (**Figure 10**) with open canopies essential for denning and basking areas. In the southeast United States, models for this species suggest that climate change may not pose as much of a threat as incompatible land use (Costanza et al., 2020). However, not well-understood are Timber Rattlesnake population and range responses to potential effects of changing forest composition under climate change (Butler-Leopold et al., 2018). Because of these confounding factors, both species have CCVIs of "Presumed Stable" (Furedi et al., 2011). As additional research becomes available and further climate change vulnerability assessments are conducted, the status of these SGCN may change.

Invasive Species

Invasive species are a major threat to native biodiversity and, in Pennsylvania, climate change and degraded water quality can provide more suitable conditions for invasiveness (DCNR, 2018; Rahel & Olden, 2008). The interaction between climate change and aquatic invasive species is complex, and in some cases could be synergistic (Dukes et al., 2009; Rahel & Olden, 2008). Altered habitat conditions (e.g., temperature, ice cover, flow regimes, salinity) could change pathways of species introductions (e.g., increased dispersal through flooding and changing river networks), influence whether non-native species can establish and spread, and change the backdrop for how native and non-native species interact and compete for resources (Rahel & Olden, 2008).

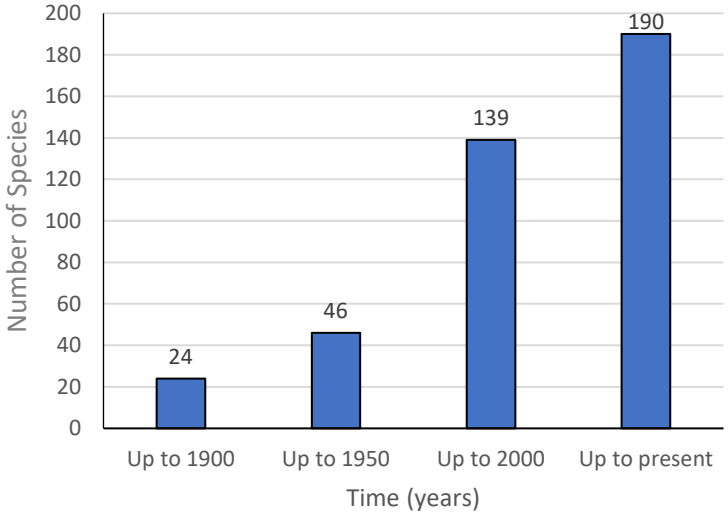

Figure 11. Cumulative number of invasive species reported in Pennsylvania through time. *Source: USGS (2021).*

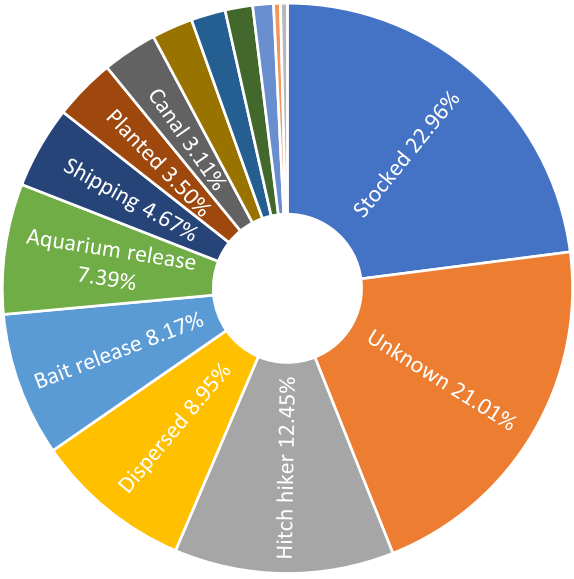

Figure 12. Major pathways of introduction for invasive species in Pennsylvania. Unlabeled pie sections include: released, pet release, aquaculture, escaped captivity, other, and hybridized, respectively. *Source: USGS (2021).*

Pennsylvania is at the intersection of major ecological regions (e.g., Ohio River, Lake Erie, Chesapeake Bay, Delaware River) and each of these regions offers pathways for inter-regional species movement (Day et al., 2016). The Commonwealth supports over 190 documented aquatic invasive

species, of which over 50% are fish species (USGS, 2021) (**Figure 11**). Pathways for spread and dispersal vary but include species that have been intentionally stocked, hitchhiker species (e.g., attached to boats and clothing), and bait and aquarium releases (USGS, 2021) (**Figure 12**). Additionally, opportunities for movement may occur through ships in the ports of Erie and Philadelphia, barges on the Ohio River, inadvertent distribution by anglers, recreational boaters, and other mechanisms which can relocate non-native aquatic species in or among drainages in Pennsylvania where they may not be native. Thus, there are many opportunities for invasive species to be transported and become established. For some species, climate change can act as a potential enhancement for colonization (Hellman et al., 2008).

Select Habitat Impacts

Streams and rivers

The more than 85,000 miles of Pennsylvania's rivers and streams are distributed among the Ohio, Genesee, Susquehanna, Delaware, Erie, and Potomac watersheds. Ranging in size from headwater streams and creeks to tidal large rivers (**Table 4**), the majority of Pennsylvania's flowing waters are classified as headwater streams and creeks (86.2%), with much lower proportions of small rivers (7.1%), medium and large rivers (2.9 and 2.4%, respectively), and a small portion of streams and rivers consisting of tidal streams of varying sizes (0.2%). Of these stream types, *High Gradient, Cold, Headwaters and Creeks* (26.6%), *Moderate Gradient, Cool, Headwaters and Creeks* (22.3%), and *High Gradient, Cool, Headwaters and Creeks* (14.8%), comprise over 60% of Pennsylvania's streams miles (PGC-PFBC, 2015) **(Table 4)**.

As with other diverse freshwater aquatic assemblages across North America affected by climate change (Lynch et al., 2016), Pennsylvania's riverine resources are currently experiencing impacts (PADEP, 2021). Among the factors, increasing water temperatures, flashier stream flows due to extreme precipitation events, increased erosion, runoff, sedimentation, and more extreme drought periods are expected to have substantial effects on stream ecosystems and aquatic organisms (PADEP, 2021). Streams may be further degraded by current and future land use changes, barriers to movement among suitable habitats, as well as pollution from various sources (e.g., municipal and industrial pollution, excess nutrients) and other causes (PADEP, 2021). Yet, degradation of streams may be ameliorated by intrinsic characteristics.

In their assessment, Anderson et al. (2013) determined that under climate change conditions, streams vary in their resiliency. They evaluated physical factors (e.g., length of connected network, classes of stream gradient, temperature classes) and stream condition characteristics (e.g., natural land cover in floodplain, watershed intactness). Resilient streams are characterized as those supporting a full array of species biodiversity as well as maintaining functional integrity under changing hydrologic conditions, but with perhaps changes in species composition (Anderson et al., 2013, PGC-PFBC, 2015) (**Figure 13**).

Climate change impacts are of particular concern for stream-dwelling organisms which have evolved under largely predictable patterns of temperature and flow and rely on these patterns for cuing feeding, reproduction, emergence, and migration (Bunn & Arthington, 2002; Lynch et al., 2016; Poff et al., 1997).

Table 4. Pennsylvania stream and river habitat types and associated river miles (mi), kilometers (km), and percentage (%). *Source: Modified from 2015-2025 Pennsylvania Wildlife Action Plan (PAWAP; PGC-PFBC, 2015).*

Major Categories (Macrogroups)	Habitat	PA (mi)[a]	PA (km)	%
Headwaters and Creeks	High Gradient, Cold, Headwaters and Creeks	14,272.3	22,969.0	26.6
	High Gradient, Cool, Headwaters and Creeks	7,940.0	12,778.2	14.8
	High Gradient, Warm, Headwaters and Creeks	15.1	24.3	0.0
	Moderate Gradient, Cold, Headwaters and Creeks	6,035.9	9,713.8	11.3
	Moderate Gradient, Cool, Headwaters and Creeks	11,930.2	19,199.8	22.3
	Moderate Gradient, Warm, Headwaters and Creeks	894.3	1439.3	1.7
	Low Gradient, Cool, Headwaters and Creeks	3,356.3	5,401.5	6.3
	Low Gradient, Warm, Headwaters and Creeks	1,753.7	2,822.3	3.3
Small Rivers	Moderate Gradient, Cool, Small River	2,105.3	3,388.1	3.9
	Moderate Gradient, Warm, Small River	769.1	1,237.7	1.4
	Low Gradient, Cool, Small River	582.3	937.1	1.1
	Low Gradient, Warm, Small River	342.1	550.6	0.6
Medium Rivers	Cool, Medium River	349.7	562.8	0.7
	Warm, Medium River	1,226.7	1,974.2	2.3
Large Rivers	Warm, Large River	1,309.6	2,107.6	2.4
Tidal Headwaters and Creeks	Tidal Headwaters and Creeks	29.0	46.7	0.1
Tidal Small-Medium Rivers	Tidal Small-Medium Rivers	22.4	36.0	0.0
Tidal Large Rivers	Tidal Large Rivers	74.3	119.6	0.1
Other[b]	Unclassified	602.4	969.5	1.1

[a] The total stream mileage for the Pennsylvania portion of the Terrestrial Habitat Map is approximately 53,610 miles, which is less than the 83,000 miles indicated in the DEP dataset. This is due to differences in scale, most notably in the smallest headwater streams, between the two datasets and discrepancies in river classification along state boundaries. [b]Stream sections that did not contain enough associated attributes to classify into a macrogroup (i.e., habitat category).

For example, American Shad *Alosa sapidissima,* an ecologically and recreationally important species, migrate earlier in spring in response to spring warming (Lynch et al., 2016; Quinn & Adams, 1996). Predictability of streamflow and temperature are also important for driving patterns in food availability, streambed stability and thereby nesting success in nest-building species, as well as growth and development of young (Bunn & Arthington, 2002). Under climate change, these reliable cues are expected to notably change resulting in decreased reproductive success; increased mortality due to thermal and flow extremes outside of species tolerance ranges; changes in stream productivity and food resources to support higher trophic levels; shifts in species distributions; and local species extirpations (Lynch et al., 2016; Weiskopf et al., 2020; Whitney et al., 2016).

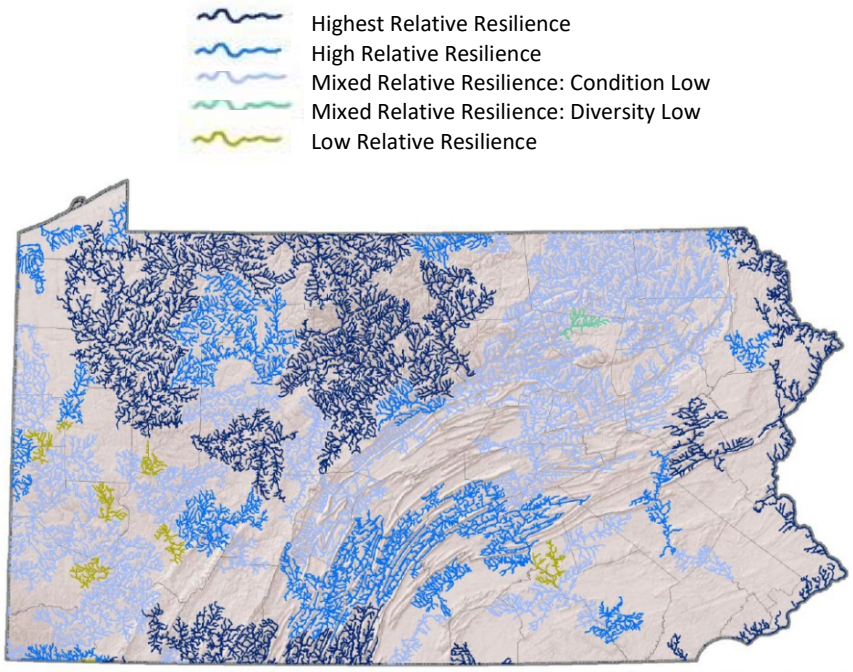

Figure 13. Relative resilience scores for complex river networks (containing more than four stream orders). Source: *Anderson et al, 2013 with image from PGC-PFBC 2015*.

Freshwater Lakes, Reservoirs, Ponds, and Wetlands

Pennsylvania's lakes, reservoirs, and ponds offer over 160,000 acres (PADEP, 2014; PGC-PFBC, 2015) for recreational angling and boating opportunities (**Figure 14**) and are at risk from numerous potential climate change impacts. Extreme weather events (i.e., intensive, rapid increases in precipitation) are likely to increase lake levels, potentially above storage capacity, resulting in increased flooding and risk to infrastructure (e.g., dams, docks) (NALMS, 2015). Increased precipitation would be expected to also exacerbate watershed and stream erosion and, depending on management strategies, could result in accelerated sedimentation for in-lake and downstream habitats (Hayes et al., 2017; Kundzewicz et al., 2007; NALMS, 2015; USEPA, 2016). Eroded sediments are also likely to carry increased nutrient loads and, coupled with increasing water temperatures, could enhance conditions for Harmful Algal Blooms (HABs) and aquatic nuisance plants, as well as diminish water quality (NALMS, 2015). Increasing ambient temperatures are projected to alter in-lake thermal stratification and thereby dissolved oxygen levels. Additionally, these increasing temperatures are expected to reduce winter ice cover, which can alter habitat for key lacustrine species. As an impact, these conditions have the potential to decrease angling opportunities, including ice fishing (Climate Central, 2019; Sahoo et al., 2011).

The Commonwealth also has an estimated 1,999,029 acres of freshwater wetlands (PADEP, 2020). Wetlands provide important ecosystem services to the streams and rivers with which they are connected, including effects on nutrient and organic matter (i.e., food) inputs as well as supporting stream diversity, facilitating dispersal, and providing refuge and spawning grounds for many fish species

(Bouvier et al., 2009; Fergus et al., 2017). Wetlands are expected to be negatively impacted by climate change, predominantly due to variability in precipitation and severity of extreme events. These factors, as well as increased temperature, are expected to alter habitat availability, evapotranspiration rates, biogeochemical cycles, sediment loads, and organic matter inputs on which many aquatic organisms rely (Erwin, 2008).

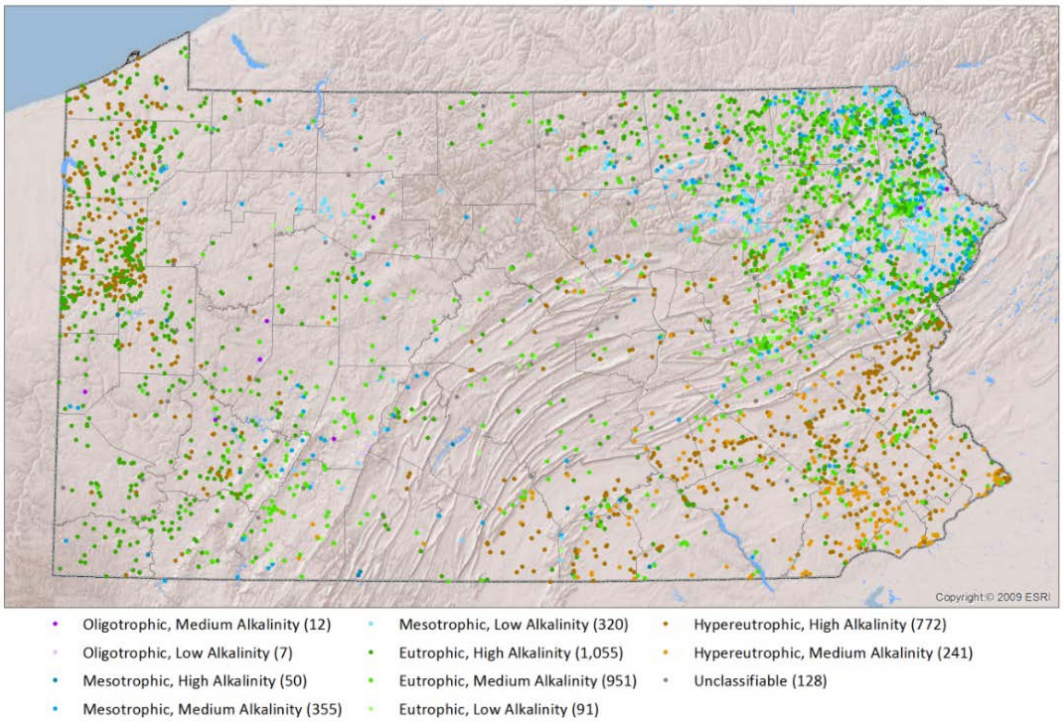

Figure 14. Trophic and alkalinity classification of 3,982 lakes and ponds in Pennsylvania. High alkalinity (≥ 50 mg/L); Medium alkalinity (≥ 12.5 mg/L); Low alkalinity (<12.5 mg/L). *Source: Image from PGC-PFBC (2015).*

The Great Lakes (Lake Erie)

Lake Erie, with 63 miles of lake and Presque Isle peninsula shoreline in Pennsylvania, supports a variety of recreational angling and boating activities (PADEP, 2014) (**Figure 15**), as well as a diverse suite of aquatic species. Of the Great Lakes, Lake Erie is considered the most ecologically stressed (PGC-PFBC, 2015; Scharold et al., 2015), but appears to be warming at a slower rate than other Great Lakes (Dobiesz & Lester, 2009; Staudinger et al., 2015). Nonetheless, climate change impacts in Lake Erie have resulted in long-term loss of ice cover and this trend is expected to continue due to rising ambient temperatures (Assel, 2005; Austin & Colman, 2007; Notaro et al., 2015; Staudinger et al., 2015; Wang et al., 2012). Less ice means fewer opportunities for ice fishing and potentially more lake effect precipitation due to greater atmospheric moisture in the Great Lakes region. Since 2013, water levels in the Great Lakes have also varied from low to record high levels, and Lake Erie is no exception (Gronewold et al., 2013). In response to climate change water levels are expected to become more variable with higher ambient temperatures further contributing to increased evapotranspiration, and more intense precipitation raising water levels (Gronewold et al., 2013; PADEP, 2021). Lake Erie is also expected to be impacted by

increased erosion associated with less protective ice cover in winter and more frequent severe storms throughout the year (PADEP, 2021).

These climate-induced changes to Lake Erie are likely to result in dramatic changes to Great Lakes ecosystems including overall warmer water, longer periods of lake stratification, more frequent periods of bottom hypoxia, and less ice for species that rely on it for protection of their young such as Lake Whitefish *Coregonus clupeaformis* (Collingsworth et al., 2017; Lynch & Taylor, 2013). In many cases, the effects of changing water levels and temperatures on Lake Erie fisheries are unclear and data gaps need to be filled for more accurate predictions.

For example, in both field and laboratory investigations, Lake Erie Yellow Perch *Perca flavescens*, experienced recruitment failure following shorter, warmer winters: females produced smaller eggs with lower hatching success and smaller larvae compared to females exposed to longer winters (Farmer et al., 2015). However, in neighboring Lake Michigan, populations of Yellow Perch appear to have shifted their spawning timing in response to these shorter winters and to be less affected (Lyons et al., 2015). Thus, greater understanding of these inter-lake spawning differences could enhance models for Lake Erie fisheries.

Figure 15. (Above) a-PFBC Lake Erie survey boat *Perca*. (Top right) b-Pulling nets. *Source: PFBC-Mark Haffley.*

(Right) c-Map of Pennsylvania portion of Lake Erie. *Image developed using the Pennsylvania Wildlife Action Plan-Conservation Opportunity Area Tool* https://wildlifeactionmap.pa.gov/.

In the intervening years since enactment of the 1972 Clean Water Act, Lake Erie water quality has improved, but climate impacts could, in part, set back these gains. Among factors influencing water quality is increasing precipitation (i.e., rain events) brought about by climate change, resulting in runoff which transports nutrients and other contaminants into the lake (Smith et al., 2015; Thompson, 2015). These effects contribute to cyanobacterial harmful algal blooms (cHABs) which have historically occurred in the western basin of Lake Erie; typically in mid-summer and extending through fall (Michalak et al., 2013; Steffen et al., 2014; Watson et al., 2016). These blooms have been linked to a wide variety of stressors including the agricultural industry, increased phosphorous, and invasive Zebra Mussel *Dreissena polymorpha*, yet increased water temperatures may be partly responsible for rising levels of cyanobacteria in the central and eastern Lake Erie basins (Allinger & Reavie, 2013; Kane et al., 2014). Cyanobacterial HABs could, therefore, have future implications for the Pennsylvania portion of the lake as they can produce toxins that are harmful to humans and pets and can result in beach closures and swimming restrictions. Beyond human health effects, occurrence of HABs can influence angler decisions to fish, primarily for aesthetic reasons (Gill et al., 2018).

Delaware Estuary

The Delaware Estuary includes the tidal stretch of the Delaware River from Trenton, New Jersey to the Delaware Bay (**Figure 16**). This reach serves as Pennsylvania's only estuarine habitat where freshwater mixes with saltwater, supporting federally and state endangered species and a substantial angling industry. This ecoregion provides habitat for various life stages of ecologically and economically important diadromous fish species including: Alewife *Alosa pseudoharengus* and Blueback Herring *Alosa aestivalis*, American Shad, Hickory Shad *Alosa mediocris*, American Eel *Anguilla rostrata*, Atlantic, Atlantic Striped Bass *Morone saxatilis*, Atlantic Sturgeon *Acipenser oxyrinchus*, and Shortnose Sturgeon *Acipenser brevirostrum*. Additionally, Menhaden *Brevoortia tyrannus*, though not diadromous, are also ecologically and economically valuable, and found in this habitat. As members of the Atlantic States Marine Fisheries Commission (ASMFC) and Mid-Atlantic Fishery Management Council (MAFMC), PFBC has responsibility to conserve and protect these and other species. Blue Crab *Callinectes sapidus* also occur in Pennsylvania waters of the Delaware River Estuary and is regulated by the PFBC, though in the 2015-2025 Pennsylvania Wildlife Action Plan (PAWAP) (PGC-PFBC, 2015) the species is considered data deficient.

Ken Lund Reno, Nevada, USA, via Wikimedia

Figure 16. Delaware River Estuary near Philadelphia, PA.

Many fish species, with varying salinity tolerances for their eggs and larvae, use the estuary for spawning and nursery habitat. Changes to thermal and flow regimes could disrupt natural spawning cues as well as food availability (e.g., phytoplankton) needed for early life stages (Greene et al., 2009; Roessig et al., 2004). Similarly, a progressing salt front will push tolerable salinities further up into the estuary where there is substantially less habitat for spawning and larval protection. Increasing temperatures are also likely to exacerbate already problematic dissolved oxygen conditions in parts of the estuary, further reducing suitable habitat for these species (Greene et al., 2009; Roessig et al., 2004). Surrounding tidal wetlands in the Delaware Estuary provide habitat for key forage fish species (e.g., killifish, Mummichog) and may also be diminished by elevated temperatures, lowering oxygen saturation levels, and by sea level rise contributing to increasing saline water (Kreeger et al., 2010; Shortle et al., 2015).

Ephemeral Freshwater Habitats

Vernal (seasonal) pools (**Figure 17**) and intermittent streams are temporary freshwater ecosystems found generally across the state except in the far northeast and west-central regions (**Figure 18**). These freshwater ecosystems are generally wet several months of the year and driven entirely by annual precipitation and evapotranspiration (Brooks, 2009). These areas are hotspots for amphibian breeding and often support species of invertebrates found in no other habitats (e.g., Fairy Shrimp *Eubranchipus vernalis*) (Colburn et al., 2007). Climate change is expected to increase water temperatures and, along with extended periods of drought, is anticipated to accelerate drying of these transient habitats. These effects would potentially impact several amphibians (e.g., Jefferson Salamander *Ambystoma jeffersonianum*, Blue-spotted Salamander *Ambystoma laterale*), reptiles (e.g., Spotted Turtle *Clemmys guttata*) and invertebrate communities (PNHP, 2019).

Sally Ray

Figure 17. A vernal pool with houses nearby.

Habitat Connectivity

Habitat connectivity is a crucial component of healthy and sustainable aquatic ecosystems. Species rely on moving among habitats for a variety of reasons including protection from predators and high flows, finding suitable and stable spawning grounds, seeking water quality or temperatures that are within tolerable ranges, and foraging (Crook et al., 2015). In aquatic systems, dams and culverts can pose serious barriers to movement of aquatic organisms (Bednarek, 2001; Cooper et al., 2017). However, other instream (or in-lake) barriers can include zones of poor water quality, high flows, dewatered streambed, or unsuitable water temperatures. Equally important are connections between stream and lake habitats with surrounding wetlands, floodplains, and groundwater (Leibowitz et al., 2018). Many

streams in Pennsylvania rely on these water sources for flow and thermal protection in dry seasons. Similarly, many species use these habitats for spawning, protection, and refuge from extreme flow events.

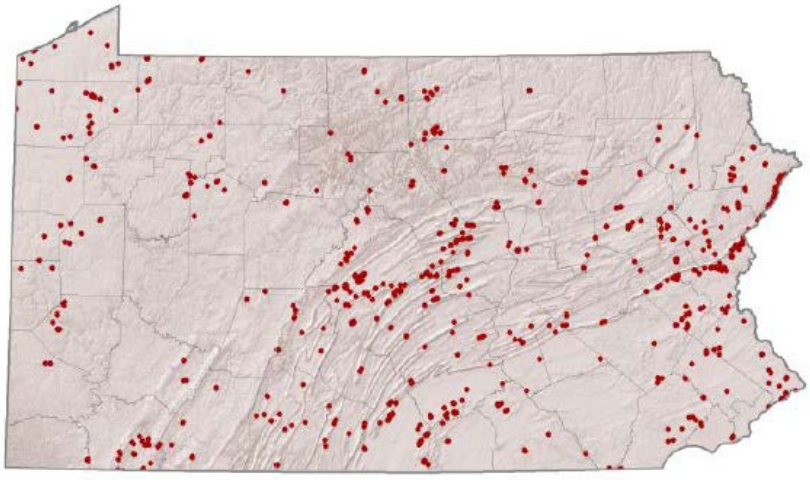

Figure 18. Documented vernal pools in Pennsylvania from the PNHP vernal pool registry. *Source: Image from PGC-PFBC (2015).*

Critical ecological linkages between terrestrial and freshwater systems are likely to be impacted by a changing climate through increases in air and surface water temperature, changes in timing and amount of precipitation and run-off, and phenological and distributional shifts in plants and animals (Meyer, et al. 1999, Seavy et al., 2009). Among these ecological linkages, riparian zones provide important cover, thermal buffering capacity, nutrient, and organic input for aquatic ecosystems, and serve as a barrier against erosion (Pusey & Arthington, 2003, Seavy et al., 2009). Further, terrestrial corridors, such as in the ridge and valley region are important for movement of many terrestrial species (**Figure 19**) and rely on predictable aquatic resources (Anderson et al., 2016).

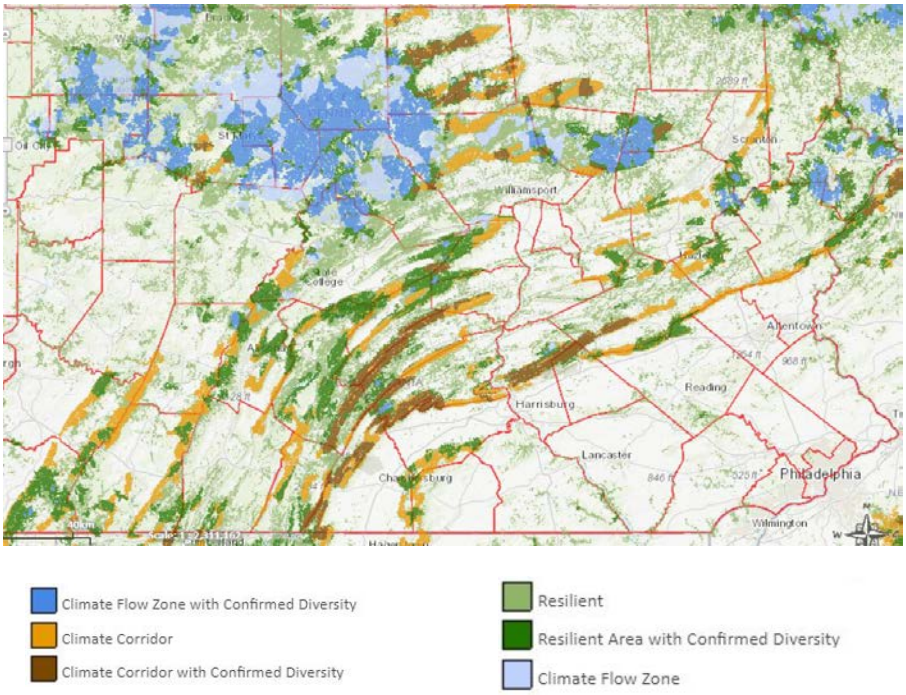

Figure 19. Climate corridors and resilient areas in Pennsylvania. *Source: Anderson et al. (2016).*

As climate change makes flow and thermal regimes more unpredictable, habitat connectivity will be essential for allowing species to seek more suitable conditions as habitats change.

Dams, culverts, low-water stream crossings, and other barrier removal practices will become increasingly important for restoring stream habitats throughout the state. Similarly, prudent and protective instream flow requirements and low flow protection guidelines can help reduce additional losses in connectivity among streams, lakes, and their supporting freshwater ecosystems, and riparian buffer enhancements can help ameliorate degraded conditions and foster connectivity (Merriam et al., 2019). Another tool for identifying priority connectivity areas is the PNHP Climate Connectivity prioritization model which offers a user-interactive visualization based on five conservation factors including, regional flow, biodiversity value, resiliency, geophysical setting, and landscape connection (PNHP, 2020).

PFBC Infrastructure and Programs

Trout Stocking

The PFBC stocks nearly 3.2 million adult trout every year from 10 of its 14 state fish hatcheries, with an additional one million trout stocked annually from Cooperative Nurseries (PFBC, 2020) (**Figure 20**). Other hatcheries raise warm/cool water fish (e.g., Walleye *Sander vitreus*, Channel Catfish *Ictalurus punctatus*), freshwater mussels and anadromous fish (i.e., American Shad). In 2020, stocking included 4,600 miles of streams and 6,850 acres of lakes, with Rainbow Trout comprising the majority of stocked fish, followed by Brown Trout and Brook Trout, respectively.

PFBC Archives

Figure 20. PFBC trout stocking activities.

For high-quality recreational trout angling across a broader area than wild trout alone, the PFBC has developed a stocking strategy to include more hatchery Rainbow Trout and fewer hatchery Brook Trout, in part to minimize introgression with wild Brook Trout, which can reduce fitness and negatively impact wild Brook Trout populations over time. PFBC trout stocking schedules and seasons have also been modified to accommodate impacts of climate change, specifically recognized as regional differences in temperature in which 18 Southeast Pennsylvania counties were found to warm earlier in spring (PFBC 2005 unpublished, PFBC 2007 unpublished). From this assessment, it was determined that advanced

fish stocking would allow more angling opportunities before local stream conditions become unsuitable for stocked fish to survive. Thus, in 2007, the PFBC modified its spring trout stocking schedule (**Figure 21**) by earlier stocking of fish and designating opening day of trout season in these 18 southeast Pennsylvania counties two weeks in advance of the statewide opening day. Then, in October 2021, the Commission further adjusted the stocking strategy by approving a single, statewide opening day of the regular season for trout to be on the first Saturday in April. This earlier statewide opening day aligns with anticipated warming across the state (**Figure 21**).

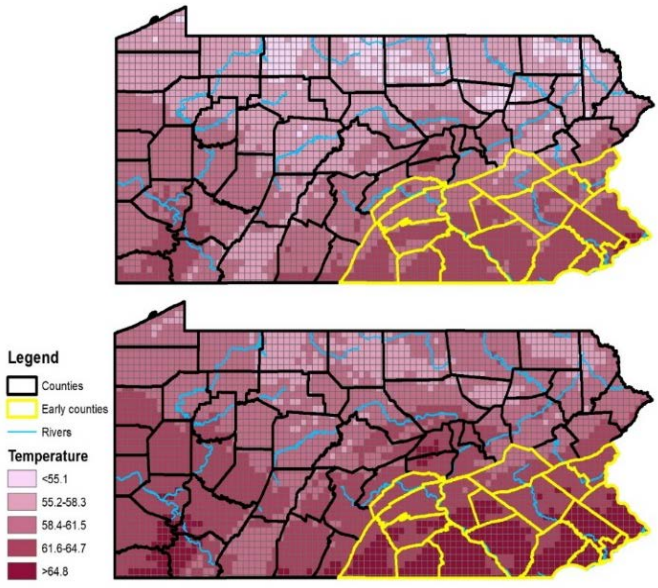

Figure 21. Eighteen counties in southeastern PA with early trout season. (Top) historical average annual maximum temperature, 1980-2010. (Bottom) average annual maximum temperature, 2011-2040. *Source: Data from PADEP (2021).*

PFBC Property

The PFBC owns a variety of property types **(Figure 22)** across the state including fishing and boating facilities (107) and fishing only properties (53) which often include boat launches, piers, and dams; flow easements (28); fish propagation facilities (12); offices including headquarters and various regional and maintenance offices; and parking lots.

With extreme precipitation events and increasing temperatures these types of infrastructure are likely to be additionally stressed. For example, dams exposed to increasing flows and higher reservoir levels are more prone to failure or safety issues and may require additional investments to maintain, repair, or resize spillways (Fluixá-Sanmartín et al., 2018). This could also affect public access to boat launches and fishing piers, as well as increased damage due to storm events. Similarly, office buildings and hatcheries could also be subjected to increased flooding and extreme weather events further damaging buildings and increasing electrical and network outages. For example, in 2004, heavy precipitation caused severe flooding at the Benner Spring State Fish Hatchery, resulting in severe property damage and disruption to hatchery operations.

Changes in water quality and water temperature currently supporting hatchery operations could make facilities less suitable for rearing specific fish species. Likewise, increased drought frequency could have consequences for safe and proper discharge of hatchery waste via NPDES (National Pollutant Discharge Elimination System) permits. To proactively reduce losses, early identification of climate-susceptible PFBC properties and facilities will help the Commission's climate change resiliency.

Richard Marther (top right); PFBC Archives

Figure 22. PFBC properties including: Harris Pond (upper left); Oswayo State Fish Hatchery (top right), H.R. Stackhouse Facility (bottom left); and Good Hope Access (bottom right).

PFBC Habitat Management: Building Climate Resiliency

Reducing existing stressors is effective for minimizing impacts of climate change and increasing resilience of aquatic ecosystem (NFWPCAS, 2012). For over 50 years the PFBC has implemented projects and collaborated with partners and industry to: minimize the effects of stressors on trust species and their habitat, enhance survival and habitat quality, and expand habitat availability for aquatic organisms. Though not specifically designed to address climate change, this work enhances resiliency and adaptation in response to many climate change effects.

Dams

Dams pose significant and serious deleterious effects on aquatic ecosystems. The impacts are well known and include: habitat fragmentation, impeding aquatic organism passage, turbine mortality, disruptions in life-history patterns and loss of biodiversity, and alterations to water quality, nutrient and sediment transport, and overall hydrologic regimes (Baxter, 1977; Cooper et al., 2017). Most dramatic are effects of dams used for

PFBC archives

Figure 23. Heistand Sawmill Dam removal.

hydropower generation. PFBC has been working with state and federal resource agencies, industry, and other partners to make recommendations for more sustainable dam operations and prioritize dams and other fish passage barriers for removal (**Figure 23**) or upgrade. These actions continue to result in improved stream habitat quality and resilience for aquatic organisms. Beyond the many negative effects of dams, stream biota face other threats, including increasing numbers and distribution of non-native and invasive species. Consideration of the overall ecological benefits of dam removal will need to be considered where invasive species would be a significant threat to native species upstream of a dam.

Riparian Habitat

Healthy stream ecosystems are dependent upon functioning riparian habitats. Among their benefits, forested riparian areas provide shade which buffers water temperatures; contribute nutrient and organic matter critical to supporting aquatic food webs; ameliorate effects of sedimentation and runoff; and serve as habitat for many of the state's diverse reptile and amphibian fauna (Capon et al., 2013; Pusey & Arthington, 2003). For over 50 years, the PFBC has worked with landowners, local conservation organizations, U.S. Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS), PA Department of Conservation and Natural Resources (PADCNR) to enhance and protect riparian buffer habitat by engaging in tree-planting initiatives, bank stabilization projects, and invasive species monitoring and control in riparian corridors (**Figure 24**).

PFBC Archives

Figure 24. Riparian buffer and streambank stabilization project along Spring Creek, Centre County (left) and instream trout habitat improvement project in Big Spring Creek, Cumberland County (right).

Instream Habitat

As with riparian habitat, high quality and stable instream habitat is essential for aquatic organism diversity. Instream habitats can provide key spawning areas, cover from predation, organic matter retention and productivity, and refuge from high flow and increased temperature (Allen & Vaughn, 2010; Walrath et al., 2016). Increased runoff, sedimentation, and scour from high flows can reduce instream habitat variability important for sustaining biodiversity. The PFBC works with partners to initiate and support instream habitat and bank stabilization projects that protect and enhance habitats for the Commission's trust species (**Figure 24, Figure 25**).

Stream Flow Protection

Streamflow is a driving factor affecting all aspects of aquatic diversity and function in river systems. Aquatic organisms have evolved under largely predictable stream flow patterns; timing many of their life history events around key components of the natural flow regime (Poff et al., 1997; Poff & Zimmerman, 2010). Aquatic organisms rely on adequate streamflow for maintaining connectivity among habitats, supporting fish spawning and development, cuing migration and feeding, facilitating dispersal, and maintaining suitable water quality and thermal regimes (DePhilip & Moberg, 2010, 2013; Poff et al., 1997; Poff & Zimmerman, 2010). PFBC works with partners to provide recommendations on streamflow modification issues including: water withdrawal, consumptive use, NPDES permits, hydropower development projects, and other instream flow-related activities across the state.

Ben Lorson, PFBC

Figure 25. Long Run Creek restoration project, Clinton County.

Ephemeral freshwater ecosystems

The PFBC has supported partners (e.g., Western Pennsylvania Conservancy) in their planning efforts with private landowners to protect ephemeral freshwater ecosystems. With few direct on-the-ground management actions available, the primary objectives for vernal pools should be maintaining forested buffers to the greatest extent possible (PNHP 2015) and ongoing support of communication and planning initiatives.

Overall, more fully understanding climate change effects on Pennsylvania's aquatic resources will rely on data from expanded surveying and monitoring, enhanced models for more accurate predictions, and applied research and analytical initiatives.

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CLIMATE MANAGEMENT PRINCIPLES

At a Glance

Four guiding principles were used to develop this document:

1. *Science-based decisions and actions.*
2. *Building and expanding partnerships.*
3. *Enhancing habitat resiliency.*
4. *Communicating with staff and the public.*

Climate change poses an overarching threat to the PFBC's ability to fulfill its mission to protect, conserve, and enhance aquatic resources and provide fishing and boating opportunities. This Climate Action Plan identifies specific activities to support the Commission and is guided by the following principles:

1. *Science-based Decisions and Actions*: Use the most current, scientifically appropriate information to guide management actions for ameliorating effects of a changing climate.
2. *Build and Expand Partnerships*: Maintain and expand effective partnerships and collaborations at state, regional, national, and international levels to address impacts of climate change challenges.
3. *Enhance Habitat Resiliency*: Promote and implement forested riparian buffers, remove barriers to enhance connectivity and, as ecologically appropriate, advance similar land use practices that benefit aquatic resources.
4. *Communication is Essential*: Provide outreach to staff, anglers and boaters, private landowners, non-governmental organizations, local, state, and federal agencies on PFBC actions to address climate change impacts and the role of partners.

APPROACH

At a Glance

- *The PFBC used the results of a 2020 staff survey of climate change to develop this action plan.*
- *From this survey, the PFBC Climate Change Team developed a series of Goals, Strategies, and Actions to implement in response to changing climatic regimes.*

In early 2020, a PFBC staff survey was conducted to more fully understand major issues anticipated to impact the Commission as a consequence of climate change (**Table 5**). This 2020 staff survey is the foundation for this Climate Action Plan, providing essential staff input into climate change issues anticipated to affect Commission facilities, operations, species and habitats, and angler and boater recreational opportunities. Importantly, staff offered potential actions to address these issues, and these measures are provided in this plan. Time and funding constraints precluded a comprehensive SWOT (i.e., strengths, weaknesses, opportunities, threats) assessment or establishing focus groups of staff or partners. Future iterations of this plan would benefit from these types of planning activities.

Table 5. Issues in the 2020 PFBC Staff Climate Change Survey.
Access
Administration
Habitat
Infrastructure
Non-game Species
Safety
Sport Fish
Water Quantity
Water Quality

In response to the PFBC 2020-2023 Strategic Plan and the climate change survey results, a PFBC Climate Change Team was formed with staff from the Bureau of Fisheries (Division of Fish Management, Division of Environmental Services, Division of Habitat Management), Bureau of Outreach, Education, and Marketing, and Policy, Planning and Communications Office. The Climate Change Team began with a summary document generated from the 2020 PFBC staff survey and used a stepwise process to review and refine climate change threats and identify strategies and actions to address the threats.

Initial ratings of the survey results were completed using the Eisenhower Principle (MindTools, 2021) where the *Issues* were rated as "critically important" or "less important" and urgency of the *Solutions* as "urgent" or "less urgent." Team members were also asked to characterize the temporal feasibility of the solutions as either "PFBC can take immediate action (≤2 yrs)," "PFBC can take long-term action (>2 yrs)," or "Outside of PFBC's direct jurisdiction." Notably, the ratings were based on relevance to the limited focus of Goal 8 in the Strategic Plan, and not overall relative importance to the Commission or the public. For example, though very important overall, infrastructure topics were rated as "low priority" because they may not be relevant to the goal of addressing *impacts on habitat, fish species, and angler behavior*. However, it was considered important to include issues not encompassed by the goal as these represented topics relevant to the overall well-being of PFBC staff, facilities, operations, and public interest.

Next, the combination of *Issues* and *Solutions* were prioritized by the Climate Change Team as "high," "medium," or "low" based on their importance and relevance to Goal 8. In this iterative process, overlapping issues and solutions (i.e., actions) were consolidated and new overarching "themes" (i.e., goals) emerged.

In the original survey summary, potential and disparate solutions were often grouped under one topic. Recognizing that individual suggested solutions could be useful, these groups of identified solutions were selectively parsed to facilitate their ranking. As the plan developed, additional solutions were further identified and the issues placed under eight Goals, with associated Strategies and Actions (**Table 6; Appendix A**).

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GOALS, STRATEGIES, AND ACTIONS

Overview

This plan is organized into three levels: Goals, Strategies, and Actions. Eight overarching *Goals* define the Commission's primary desired outcomes for addressing climate change. Goals are further delineated into individual *Strategies*, or approaches to achieving each goal. Finally, *Actions* are provided for each strategy, representing steps to achieve the desired outcome.

At a Glance

- *Eight Goals define the PFBC's primary desired outcomes in addressing climate change.*
- *Goals are divided into Strategies (i.e., approaches) to achieving each goal.*
- *Strategies are supported by Actions (i.e., measurable steps) that can be taken to achieve each strategy.*

With a broad overarching scope, the goals, strategies and actions characterize the extent to which climate change is currently, or is anticipated to, affect the PFBC, our trust species, and their habitats. **Goals 1-3** are directed at vital resource concerns anticipated to be impacted by climate change, including primary habitats (e.g., lakes, streams, and wetlands), native species, and water resources. **Goal 4** broadly considers recreation (e.g., boating, fishing) and public safety concerns with regards to extreme events.

With enhanced monitoring and modeling, science is rapidly advancing in understanding the effects of climate change. Yet, as identified in **Goal 5**, there are many questions that remain unanswered: filling knowledge gaps and adaptive planning will be important for informed management decisions. Through **Goal 6**, communication will foster public understanding of climate impacts on the PFBC and illustrate our need to act. **Goals 7** and **8** aim to minimize degradation, and loss of life, property, and agency assets by addressing factors such as disease borne pests, extreme temperature, precipitation and drought events, and other factors likely to exacerbate conditions increasingly harmful to human health and property.

The following section provides a snapshot of goals, strategies, and potential actions for the PFBC to implement in response to climate-related threats. A detailed list of issues and actions adapted from the original PFBC climate change survey is available in Appendix A.

Kathy Gipe, WPC

Figure 26. Wood turtle.

Table 6. Goals and strategies for the Pennsylvania Fish and Boat Commission Climate Action Plan.

Goal	Strategy
1. HABITAT: Build climate resilience for habitats used by PFBC trust species.	**1.1** Lakes and Reservoirs
	1.2 Riparian Zone Linkages
	1.3 Instream, Wetland, and Groundwater Connectivity
2. SPECIES: Minimize impacts to PFBC trust species through protection and adaptation measures in response to a changing climate.	**2.1** Organismal Life History Cues and Sensitive Life Stages
	2.2 Aquatic Nuisance and Invasive Species, Harmful Algal Blooms, and Pathogens
	2.3 Species Interactions
3. WATER: Protect water quantity and quality for ecological integrity and recreational opportunities.	**3.1** Water Quality, Habitat Management, and Property Damage
	3.2 Water Availability and Competing Uses
4. RECREATION: Adapt and implement actions to maintain PFBC support of recreational opportunities for anglers and boaters.	**4.1** Hatcheries and Stocking
	4.2 Recreational Facilities Management
	4.3 Public Fishing and Boating Access
5. KNOWLEDGE: Fill knowledge and data gaps to understand species' response, enhance habitat resilience, and guide resource planning and management.	**5.1** Knowledge and Data Gaps
	5.2 Conservation Planning and Management
6. COMMUNICATIONS: Through a broad array of media, advance understanding of climate change impacts and conservation actions for ecological integrity and human well-being.	**6.1** Public Outreach and Staff Inreach
7. SAFETY: Adapt and promote climate-smart safety measures for PFBC staff and the public.	**7.1** Employee Safety
	7.2 Safe Recreation
8. AGENCY ASSETS AND STAFFING: Bolster staff capacity and agency assets to proactively meet anticipated climate change needs.	**8.1** Staffing
	8.2 Workplace Resilience

STRATEGY

1.1 Lakes & Impoundments

Plan and implement measures to address changes to lake habitat including sedimentation, water temperature, and water quality.

Issue: Heavy precipitation events will increase erosion and sediment deposition in lakes and reservoirs thereby reducing lake volume, degrading, or eliminating habitat for aquatic life, including favorable fish spawning habitat. Low water events may result in dewatering of natural fish habitat and fish habitat structures. Increasing temperature and variable precipitation may increase nuisance algal growth, further eliminating habitat and degrading water quality.

✓ PROGRESS CHECKLIST

- ☐ Prioritized waterbodies for native vegetation enhancements.
- ☐ Developed and implemented native vegetation management plans.
- ☐ Prioritized waterbodies for nuisance species management.
- ☐ Developed and implemented nuisance species management plans.
- ☐ Prioritized waterbodies for sedimentation management and in-lake habitat augmentation.
- ☐ Initiated control strategies and partner engagement for sediment management.

PARTNERS AND COOPERATORS

- County Conservation Districts
- Non-governmental organizations
- PA Department of Environmental Protection
- PA Department of Conservation and Natural Resources
- PA Department of Agriculture
- U.S. Department of Agriculture
- U.S. Army Corps of Engineers

PFBC archives

Opossum Lake, Cumberland County.

ACTIONS

Immediate (≤2 years)

1.1.1 Improve vegetative cover in watersheds, including planting native vegetation.

1.1.2 Continue working with partners to improve stormwater management and reduce lake erosion and sedimentation.

1.1.3 Continue installing additional fish habitat structures in deep water portions of reservoirs for availability during low water events.

Long-term (>2 years)

1.1.4 Adjust allocation of staff and assets accordingly to manage PFBC facilities and assist with non-PFBC facility needs.

1.1.5 Install forebays at lake inlets to promote sediment deposition and storage.

1.1.6 Create meanders in feeder streams to slow velocity and improve floodplain connectivity to reduce sediment transport.

1.1.7 Identify and implement measures to ameliorate degraded conditions (e.g., depleted oxygen levels, harmful algal blooms) in water bodies unsuitable for priority aquatic species or recreational activities.

STRATEGY

1.2 Riparian Zone Linkages

Plan and implement measures to stabilize and increase native riparian communities.

Issue: Warming temperatures and increased vulnerability to disease and pest species (e.g., Hemlock Wooly Adelgid, Emerald Ash Borer) will change native tree and plant communities and reduce vegetative canopy cover. This loss of vegetative cover may exacerbate warming water temperatures and reduce aquatic habitat and food sources, including in trout streams. Additionally, loss of riparian cover would be expected to diminish streambank stability and, coupled with highly variable stream flows, lead to increased erosion. More frequent flooding and drought events will negatively affect both wild trout populations and their instream and riparian habitats.

✓ PROGRESS CHECKLIST

- ☐ Identified key areas for riparian buffer protection and enhancement.
- ☐ Worked with partners to implement riparian buffer enhancement.
- ☐ Implemented control measures for invasive species affecting riparian vegetation.
- ☐ Worked with partners to address loss of key tree species (e.g., Hemlock, Ash) along wild trout streams.
- ☐ Identified key PFBC forest resources for protection and implemented programs for management.

PARTNERS AND COOPERATORS

- County Conservation Districts
- Municipalities
- Non-governmental organizations
- PA Department of Conservation and Natural Resources-Bureau of Forestry
- PA Department of Environmental Protection
- PA Department of Transportation
- PA Game Commission
- Private landowners
- U.S. Department of Agriculture, Natural Resources Conservation Service
- U.S. Department of Agriculture, Forest Service

Heather Galbraith

Straight Run and surrounding riparian forest, Tioga County.

ACTIONS

Immediate (≤2 years)

1.2.1 Protect and enhance riparian buffers along lakes, streams, and wetlands using native, pest-resistant, and climate-change resistant species.

1.2.2 Continue implementing instream projects that increase stability and habitat during extreme flow events.

1.2.3 Continue implementing streambank stabilization practices to minimize erosion and sedimentation.

1.2.4 Continue improving floodplain connectivity to reduce sediment volumes entering streams.

1.2.5 Continue working with partners to improve stormwater management and the effects of other anthropogenic activities on stream habitat and wild trout waters. This includes working with local municipalities to reduce and improve stormwater management, establish riparian buffers, and set aside key areas for conservation.

1.2.6 Update and maintain priority locations for fish habitat treatment, maintenance inspections, and repairs.

Long-term (>2 years)

1.2.7 Acquire additional land or voluntary easements to provide consistent protection in vulnerable watersheds.

1.2.8 Work with partners to include riparian protection and mitigation conditions in environmental permit review.

STRATEGY

1.3 Habitat Connectivity

Plan and implement measures to maximize critical habitat connectivity for aquatic organisms statewide.

Issue: Increased streamflow, warming temperatures, and sea level rise will create unsuitable habitat for many aquatic species. These factors will exacerbate the ecological effects of instream barriers, such as dams and culverts, preventing aquatic species from accessing suitable habitat. Intense and sporadic precipitation events are anticipated to increase the prevalence and duration of droughts, reducing stream connectivity with critical groundwater and wetland inputs. Sea level rise may eliminate critical habitat for resident, migratory, and estuarine species.

✓ PROGRESS CHECKLIST

- ☐ Identified key fish passage barriers for prioritized removal.
- ☐ Identified barriers for prioritized fish passage installation.
- ☐ Assessed culverts, bridges, and other barriers for aquatic organism passage feasibility.
- ☐ Secured funding to address high priority passage issues.
- ☐ Increased stream connectivity by removing barriers and installing fish passage structures.

PARTNERS AND COOPERATORS

- American Rivers
- County Conservation Districts
- Dirt and Gravel Road Program
- North Atlantic Aquatic Connectivity Collaborative
- PA Department of Conservation and Natural Resources
- PA Department of Environmental Protection
- The Nature Conservancy
- U.S. Geological Survey
- Western PA Conservancy

Lisa Hollingsworth-Segedy, American Rivers

Trough Creek dam removal, Huntingdon County.

ACTIONS

Immediate (≤2 years)

1.3.1 Continue to prioritize and accelerate the pace of dam and barrier removals, with consideration to minimize spread of invasive species.

1.3.2 Where barrier removal is unlikely, identify and implement alternative fish passage options, with a focus on passing a suite of species of different life stages including wild trout streams and their tributaries.

1.3.3 Continue collaborating with partners and seek funding to assess barriers to aquatic organism passage (e.g., road stream crossings, culverts, dams) and prioritize for replacement or removal.

1.3.4 Improve headwater stream connectivity and native vegetative cover to increase thermal refugia.

STRATEGY

2.1 Organismal Life History

Plan and implement measures to understand and protect life histories and critical life stages of PFBC trust species.

Issue: Shorter, warmer winters, and longer, potentially drier growing seasons punctuated with extreme heat and intense storms will affect species' life-histories, including their survival and distribution. These stressors could lead to unnatural cues for reproduction or feeding, shorter hibernation or brumation periods, and accelerated drying of ephemeral habitat. The sensitive life stages (i.e., sub-adult) are likely to be most impacted.

✓ PROGRESS CHECKLIST

- ☐ Adapted and implemented best management practices to protect critical life stages of aquatic species.
- ☐ Established and enhanced relationships with partners and industry to improve fisheries-protective water management.

PARTNERS AND COOPERATORS

- Non-governmental organizations
- Northeast Climate Adaptation Science Center
- Northern Institute of Applied Climate Science
- PA Department of Conservation and Natural Resources
- PA Game Commission
- Regional watershed organizations
- Universities and research institutions

Brandon Ruhe, MACHAC

Juvenile Bog Turtle *Glyptemys muhlenbergii.*

ACTIONS

Immediate (≤2 years)

2.1.1 Collaborate with partners and industry to incorporate seasonal best management practices, work restrictions, and additional conservation measures accordingly.

2.1.2 Work with dam owners and operators to provide conservation releases during critical life history stages of affected aquatic organisms.

Long-term (>2 years)

2.1.3 Enter into voluntary landowner agreements for easements or other long-term opportunities to ensure protection of key habitat and spawning grounds (e.g., wetlands, floodplains).

2.1.4 Support responsible artificial propagation of PFBC trust species when population declines suggest the need for maintaining sustainability and genetic diversity.

STRATEGY

2.2 Aquatic Nuisance Species

Plan and implement measures to prevent and manage invasive and nuisance species, diseases, parasites, pathogens, and harmful algal blooms.

Issue: Warmer water temperatures and extreme flow events may increase the spread and severity of invasive species that can outcompete and replace native PFBC trust species. These conditions may also increase prevalence of nuisance species (e.g., harmful algal blooms) and diseases which can degrade aquatic habitat quality for fish and other aquatic organisms, increase health risks to humans and pets, and impede recreational activities (e.g., angling, boating).

✓ PROGRESS CHECKLIST

- ☐ Developed and implemented outreach to support invasive species prevention and management.
- ☐ Coordinated with partners to optimize invasive species and HABs prevention, management, and rapid response.
- ☐ Coordinated with partners to identify needs and develop infrastructure for stormwater and sewer management.
- ☐ Identified aquatic invasive species (AIS) risk and developed species-specific controls plans for high-risk species.
- ☐ Assessed PFBC facilities for invasive species management needs.
- ☐ Continued working with science-based resources.

PARTNERS AND COOPERATORS

- Governor's Invasive Species Council
- Municipalities and Watershed Organizations
- Northeast Climate Adaptation Science Center
- PA Sea Grant
- PA Department of Agriculture
- PA Department of Conservation and Natural Resources
- PA Department of Environmental Protection
- Regional Invasive Species and Climate Change Network
- U.S. Department of Agriculture, Natural Resources Conservation Service
- U.S. Fish and Wildlife Service

Invasive vegetation, *Hydrilla verticillata*, entangled in boat motor.

ACTIONS

Immediate (≤2 years)

2.2.1 Increase public outreach to encourage angler and boater inspection, gear cleaning, prompt reporting of observed invasive species, and reduce illegal release of invasive species.

2.2.2 Improve interagency collaboration for invasive species risk assessment, detection, prevention and monitoring with rapid response measures for early control and eradication.

2.2.3 Evaluate PFBC properties for effective management of invasive species.

2.2.4 Maintain connection to science-based resources for understanding current and projected changes to invasive species.

2.2.5 Support revision of Title 58, Chapter 71 to more fully address introduction of non-native and invasive species.

Long-term (>2 years)

2.2.6 Collaborate with partners to address stormwater management, runoff (e.g., agricultural, urban, and sewage), and inadequate infrastructure contributing to harmful algal blooms and pathogens.

2.2.7 Evaluate the effects of changing temperature and precipitation regimes on distribution and prevalence of invasive species and HABS.

STRATEGY

2.3 Species Interactions

Plan and implement measures to minimize loss of biodiversity due to habitat alterations and interactions between native, invasive, and hatchery-sourced species.

Issue: Changing instream flow conditions can shift abundance and distribution of native species, reducing overall aquatic diversity. For example, naturally reproducing (i.e., wild) fish populations and hatchery-sourced fish may reduce or extirpate native Brook Trout populations. Additionally, prolonged survival of hatchery fish could: increase the potential for introgression between hatchery and wild fish, reduce fitness and genetic diversity of wild trout populations, and increase the probability of successful hatchery trout. This could result in trade-offs between stocking hatchery-reared fish and maintaining sustainable populations of native Brook Trout.

✓ PROGRESS CHECKLIST

- ☐ Identified priority biodiversity "hot spots" for protection or restoration across the state.
- ☐ Implemented invasive species controls to maintain habitats for native faunal diversity.
- ☐ Established a PFBC stocking authorization.
- ☐ Evaluated trade-offs of adjusting numbers of stocked Brook Trout to minimize interactions with native Brook Trout populations.
- ☐ Stocked sterile triploid trout to minimize genetic hybridization with wild trout populations.

PARTNERS AND COOPERATORS

- Citizen monitoring programs
- Cooperative Nursery Program Units
- Universities and research institutions

PFBC Archives

Mayfly and stonefly larvae.

ACTIONS

Immediate (≤2 years)

2.3.1 Establish stocking authorization that allows the PFBC to adjust the species, location, number, and frequency of fish stocked into Commonwealth waters.

2.3.2 Take actions to ensure habitat quality and quantity and control invasive species to maintain biodiversity among native aquatic fauna.

Long-term (>2 years)

2.3.3 Under changing flow and temperature regimes, continue to assess, and adjust where needed, the number and species of stocked fish from state fish hatcheries to minimize competition with wild populations, and reduce spread of pathogens and parasites.

2.3.4 Produce and stock sterile, triploid trout to avoid introgression with wild trout populations.

STRATEGY

3.1 Water Quality & Related Effects

Plan and implement measures to minimize the effects of erosion and sedimentation on water quality, habitat, and property.

Issue: Climate change is projected to stress infrastructure with implications for water quality, aquatic habitat, and public and private properties. Increased frequency and intensity of storms will accelerate channel erosion, sedimentation, runoff from land and impervious surfaces into waterways, degrading water quality and habitat. Woody debris movement will contribute to increased erosion, property losses and landowner complaints about debris deposition, loss of trees, and property adjacent to stream channels.

✓ PROGRESS CHECKLIST

- ☐ With partners, identified and prioritized properties with imminent structural damage in need of assistance.
- ☐ Identified key areas for streambank stabilization and riparian plantings.
- ☐ Continued implementing streambank stabilization and riparian planting projects.

PARTNERS AND COOPERATORS

- County Conservation Districts
- Municipalities
- Non-governmental organizations
- PA Department of Agriculture
- PA Department of Environmental Protection
- Regional Planning Authorities
- U.S. Department of Agriculture, Natural Resources Conservation Service

Michael Hooper

Fish kill.

ACTIONS

Immediate (≤2 years)

3.1.1 Work with partners as municipalities update stormwater ordinances and implement stormwater and erosion management plans that accommodate changes in precipitation patterns.

3.1.2 Continue to collaborate with partners to identify properties with imminent structural damage in need of assistance.

Long-term (>2 years)

3.1.3 Accelerate the pace of streambank stabilization and riparian planting projects.

3.1.4 Continue to prioritize installation, anchoring, maintenance, and repair of in-water habitat structures.

STRATEGY

3.2 Water Availability

Plan and implement measures to minimize competing water uses across the state by assessing water availability and optimizing water use and reuse.

Issue: Drought frequency and severity are expected to increase under climate change, thereby affecting water quantity. Corresponding increases in human water needs will intensify conflicts with instream ecological requirements. For example, spring-fed, limestone-sourced streams are sought by bottled water companies yet also offer refuge for a wide array of PFBC species including turtles, salamanders, and rare invertebrates. Minimizing these conflicts will require the following: assessing current water availability, optimizing water use and reuse to protect water quality and ecological integrity, and modeling projections under future scenarios to plan for protection.

✓ PROGRESS CHECKLIST

- ☐ Worked with partners to identify areas of existing and future water shortages that do not meet human and ecological needs.
- ☐ Identified and prioritized alternative water sources in lieu of ecologically sensitive areas.
- ☐ Established scientifically supported and biologically relevant low flow protection criteria.
- ☐ Worked with partners to implement criteria to protect human and ecological water needs.
- ☐ Identified groundwater sources critical to protect native fish and wildlife, and other conservation benefits.

PARTNERS AND COOPERATORS

- Non-governmental organizations
- PA Department of Environmental Protection
- Regional river basin commissions
- U.S. Geological Survey

Bob Weber

Dry streambed of Shanerburg Run (Sullivan County) during drought.

ACTIONS

Immediate (≤2 years)

3.2.1 Collaborate with partners to identify areas with existing and future water shortages where supply is inadequate to meet human and ecological needs.

3.2.2 Continue collaborating with partners and permittees to develop system improvements to minimize water loss.

3.2.3 Continue collaborating with partners and permittees to prioritize use of alternative water sources in lieu of ecologically sensitive ones.

3.2.4 Work with partners to establish and enforce scientifically supported and biologically relevant low flow protection criteria.

Long-term (>2 years)

3.2.5 Work with partners to identify and prioritize groundwater sources and protect these important water sources for future fish, wildlife, and conservation benefits.

STRATEGY

4.1 Hatcheries and Stocking

Plan and implement measures to minimize impacts on hatchery operations and fish stocking due to changing water quality.

Issue: Projected increases in water temperature will affect fish production, stocking, survival, and management. Increasing frequency and intensity of precipitation events will impact hatchery source waters contributing to degraded water quality and negatively impacting the PFBC's discharge permits. Warmer water temperatures will influence sport fish populations, especially coldwater species. Consequently, species compositions and stocking efforts may shift to warmer water species.

✓ PROGRESS CHECKLIST

- ☐ Identified at-risk and resilient regions for wild and stocked trout populations.
- ☐ Improved native vegetative cover in watersheds of hatchery source waters.
- ☐ Adjusted stocking schedules, angling season, and regulations to minimize stressed fish.
- ☐ Adjusted fish management and stocking to include thermally tolerant species.

PARTNERS AND COOPERATORS

- Cooperative Nursery Program Units
- PA Cooperative Fish and Wildlife Research Unit

Terry Malloy

Brook Trout *Salvelinus fontinalis.*

ACTIONS

Immediate (≤2 years)

4.1.1 Develop new and improve existing models to identify at-risk and climate resilient regions for aquatic organisms and focus attention on more highly resilient areas and those likely to benefit from habitat management.

4.1.2 Continue to assess and adjust stocking schedules, seasonal work priorities, angling season, and daily harvest size and number accordingly to minimize impact on stressed fish.

4.1.3 Sustainably optimize naturally reproducing populations for recreational use.

Long-term (>2 years)

4.1.4 Plan for alterations in hatchery water quantity and quality and make necessary infrastructure adjustments.

4.1.5 Continue to evaluate and adjust fish management and stocking strategies to adapt to varying conditions in a changing climate.

STRATEGY

4.2 Recreational Facilities

Sustainably manage reservoir operations (e.g., source waters, discharge operations, staff) to support multiple uses including flood control, drought management, and recreation.

Issue: Intensive and sporadic precipitation will contribute to greater water level fluctuations, influencing reservoir water management. Reservoir management will need to increasingly consider timing of controlled drawdowns to maintain downstream flows and reservoir storage capacity for flood management and public recreation (i.e., boating and fishing). More intensive aquatic vegetation management may be required due to angler and boater concerns.

✓ PROGRESS CHECKLIST

- ☐ Worked with partners to identify critical reservoir volume and instream flow thresholds that may jeopardize PFBC trust species.
- ☐ Developed management plans to respond to threshold conditions.
- ☐ Prioritized areas in need of floodplain connectivity at PFBC facilities.
- ☐ Enhanced floodplain connectivity for streams draining into priority impoundments.
- ☐ Developed watershed and sediment reduction plans for priority PFBC impoundments, wetlands, and facilities.
- ☐ Implemented sediment reduction plans for PFBC facilities.
- ☐ Maintained recreational facilities (e.g., boat launches, docks) affected by changing water levels and other climate impacts.

PARTNERS AND COOPERATORS

- County Conservation Districts
- Municipalities
- Non-governmental organizations
- PA Department of Environmental Protection
- U.S. Army Corps of Engineers
- U.S. Department of Agriculture, Natural Resources Conservation Service
- Watershed Associations

PFBC Archives

Lake Wallenpaupack, Pike and Wayne Counties.

ACTIONS

Immediate (≤2 years)

4.2.1 Develop watershed plans to reduce erosion and sedimentation in reservoirs, thus maintaining reservoir storage capacity for PFBC and other facilities.

Long-term (>2 years)

4.2.2 Improve connectivity of feeder streams to their floodplains to reduce water volume entering PFBC reservoirs.

4.2.3 Adjust PFBC staff allocation and resources to address impoundment management needs (e.g., infrastructure maintenance, planning, vegetation management).

STRATEGY

4.3 Public Access

Plan and implement measures to provide increased reliable access to public waters.

Issue: Increased intensity and duration of extreme heat events will increase demand for water-based recreational activities, especially in-or-near urban areas. More extreme precipitation events and greater fluctuations in water levels, could generate confusion regarding access to navigable waters. Public access to waters via agriculture lands could be diminished as farmers face financial hardships from changing climatic regimes and adjust agricultural practices or sell farms to developers.

✓ PROGRESS CHECKLIST

- ☐ Assessed PFBC access facilities for capacity to accommodate current and anticipated demand.
- ☐ Assessed underserved areas for additional access development.
- ☐ Developed new PFBC access facilities to address needs in-or-near urban areas or where existing facilities have become unusable due to changing stream channels.
- ☐ Worked with willing private landowners to secure and mark waterway access.

PARTNERS AND COOPERATORS

- Land Trusts
- Municipalities
- PA Department of Agriculture
- PA Department of Conservation and Natural Resources
- Private Landowners

PFBC Archives

Reliable access is essential for angler participation (Allegheny County).

ACTIONS

Immediate (≤2 years)

4.3.1 Ensure sufficient access at existing PFBC properties and develop new access facilities where stream channels have changed making existing facilities unusable, or in-or-near urban areas to accommodate additional use

4.3.2 Work with partners and PFBC staff (e.g., Waterways Conservation Officers, Bureau of Fisheries) to monitor access issues on navigable waters and develop guidance to address access rights.

4.3.3 Work with partners to identify funding and other resources for developing access facilities that appeal to a diverse user base.

Long-term (>2 years)

4.3.4 Work with willing landowners to purchase easements or establish other long-term commitments for public access to private lands and waterways.

STRATEGY
5.1 Knowledge & Data Gaps

Fill knowledge gaps to support adequate species protections.

Issue: Species management strategies must be grounded in scientifically valid data and models. Data gaps in species distribution, habitat response, variability in climate-related events, and other factors contribute to uncertainty and are barriers to conservation planning, communications, and management. Specific data are required for detecting long-term changes in habitat and species distribution. Rare and at-risk species under PFBC jurisdiction, including Species of Greatest Conservation Need found in the Pennsylvania Wildlife Action Plan, will require special attention. Ongoing and expanded species and habitat surveying, monitoring, and modeling will be necessary to understand climate change vulnerabilities and establish conservation priorities.

✓ PROGRESS CHECKLIST

- ☐ Evaluated data to determine utility in addressing climate change needs.
- ☐ Identified key data needs in habitat and species distribution.
- ☐ Worked with partners to identify and establish monitoring and modeling needs for priority species and habitats.
- ☐ Collected data through ongoing programs or establish new data collection initiatives.
- ☐ Developed models to predict critical changes in habitat and species resulting from climate change.
- ☐ Applied adaptive management approach to filling data gaps.

PARTNERS AND COOPERATORS

- Governor's Invasive Species Council
- Pennsylvania Biological Survey
- Northeast Climate Adaptation Science Center
- Northern Institute of Applied Climate Science
- Non-governmental organizations
- PA Department of Environmental Protection
- Regional Invasive Species and Climate Change
- Universities and research institutions
- U.S. Geological Survey
- Volunteer-based citizen monitoring programs

PFBC Archives

Electrofishing surveys to fill data gaps.

ACTIONS

Immediate (≤2 years)

5.1.1 Assess effects of PFBC reservoir operations on ecological communities and adjust operations and conservation releases accordingly.

5.1.2 Forecast status and distribution of trust species populations.

5.1.3 Collaborate with partners to monitor and fill data gaps on sensitive life stages and habitat for wild trout and other PFBC trust species.

5.1.4 Use phenological modeling networks to assess temporal availability of essential food sources.

5.1.5 Work with partners to forecast stream flow scenarios to predict threats and barriers to aquatic species.

5.1.6 Model invasive species and HABs distribution and monitor for early detection.

5.1.7 Identify and forecast areas in need of riparian augmentation and streambank stabilization to protect PFBC trust species.

5.1.8 Update and develop climate change vulnerability index ratings for PFBC species.

5.1.9 Inventory trees on PFBC properties to inform future management needs.

Long-term (>2 years)

5.1.10 Conduct long-term habitat monitoring and modeling to assess changing conditions and their effects on key life history stages.

5.1.11 Identify and evaluate changing climate on potential invasive species which may harm native biodiversity.

STRATEGY

5.2 Conservation Planning

Apply available data to develop updated conservation and management priorities.

Issue: Conservation planning is challenging under dynamic climate change scenarios and uncertain species responses. As the PFBC moves forward in implementing this Climate Action Plan, an adaptive management approach will provide a framework for the Commission to proactively update guidance, management practices, and track progress. Additional models, monitoring, and survey data will support understanding of species' climate change vulnerabilities and changes in species' distributions. As these data gaps are filled, this new knowledge will be used to establish conservation priorities, guide the environmental review process and permitted activities, and evaluate or revise Commission operations.

✓ PROGRESS CHECKLIST

- ☐ Coordinated with partners on Wildlife Action Plan priorities for climate vulnerability assessments.
- ☐ Conducted vulnerability assessments for SGCN.
- ☐ Worked with partners for climate change information on priority species and habitats.
- ☐ Evaluated (on a recurring basis) sampling schedules, protocols, and field conditions and adapted for changing conditions.
- ☐ Developed quality control measures for data collection and comparability.
- ☐ Developed and implemented a tracking protocol for Climate Action Plan progress.
- ☐ Published regular reports on progress in meeting Climate Action Plan Goals.

PARTNERS AND COOPERATORS

- NatureServe
- Northeast Climate Adaptation Science Center
- Non-governmental organizations
- PA Department of Conservation and Natural Resources
- PA Natural Heritage Program
- PA Game Commission
- Universities and research institutions

PENNSYLVANIA WILDLIFE ACTION PLAN

PFBC Archives

PA's Wildlife Action Plan helps guide conservation and management.

ACTIONS

Immediate (≤2 years)

5.2.1 Review Pennsylvania Wildlife Action Plan, species action plans, and species recovery plans to ensure climate change impacts are considered.

5.2.2 Apply climate change vulnerability index ratings for priority conservation actions.

5.2.3 Use updated species status distribution data to evaluate and inform environmental review procedures.

5.2.4 On PFBC property, develop tree species management plans during timber harvest and plant climate adaptive tree species.

5.2.5 Incorporate climate change concerns into permit and environmental review processes.

5.2.6 Apply results chains and outcome-based methods for guiding and implementing management strategies.

Long-term (>2 years)

5.2.7 Develop within the State Wildlife Action Plan progress reporting process a means to track progress implementing the Climate Action Plan goals, strategies, and actions.

5.2.8 Update sampling schedules, protocols, and quality assurance procedures in response to changing environmental conditions and data availability.

STRATEGY

6.1 Outreach & Inreach

Develop timely and appealing outreach materials to promote safety and advance knowledge of climate change impacts to PFBC trust species and habitats.

Issue: To inform and secure the safety of anglers, boaters, partners, and staff in rapidly changing conditions under an altered climate will require clear, timely communications across multiple platforms and media formats. As the PFBC implements climate adaptation and resiliency measures, these communications will be essential to inform the public regarding adjustments to administrative and field operations, and the importance of these activities for long-term securement of our trust species and their habitats.

✓ PROGRESS CHECKLIST

- ☐ Developed portfolio of climate change and safety messaging materials across multiple platforms.
- ☐ Worked with other agencies for coordinated climate change messaging.

PARTNERS AND COOPERATORS

- Boating Education Cooperators
- K-12 schools
- County Conservation Districts
- Local and state media
- National Park Service
- PA Sea Grant
- PA Game Commission
- PA Department of Conservation and Natural Resources
- PA Department of Environmental Protection
- U.S. Army Corps of Engineers
- U.S. Fish and Wildlife Service
- U.S. Geological Survey

PFBC can be found on Facebook, Instagram, Twitter, and YouTube.

ACTIONS

Immediate (≤2 years)

6.1.1 Develop social media, web-based materials, public service announcements, and other materials to inform anglers and boaters of potentially unsafe conditions in a changing climate.

6.1.2 Engage youth in climate change education through classroom activities and angling events.

6.1.3 Use internal messaging to inform staff of potential safety concerns and approaches to minimize and avoid risks from a changing climate.

6.1.4 Develop appealing, non-technical materials to inform anglers, boaters, and the public of conservation actions to support PFBC trust species climate adaptation and resiliency.

6.1.5 Coordinate climate change messaging with local, state, and federal agencies.

6.1.6 Develop a standard lexicon of climate change terminology for use by PFBC staff and in all media materials.

6.1.7 Include climate change relevant information in PFBC outreach materials (e.g., PLAY magazine, PA Boating handbook, brochures).

Long-term (>2 years)

6.1.8 Incorporate standard climate change adaptive safety measures and messaging throughout the Commission.

STRATEGY

7.1 Employee Safety

Provide training and resources for staff to safely perform their jobs in a changing climate.

Issue: Prolonged growing season and warmer temperatures may increase frequency of work-related diseases (e.g., tick borne illness, skin cancer) and increased risks of heat-related illnesses (e.g., dehydration, fatigue, heat exhaustion, heat stroke), especially for field staff. Increased heat and humidity could degrade air quality with human health implications, especially for people with cardiovascular disease or respiratory conditions.

✓ PROGRESS CHECKLIST

- ☐ Developed guidance and training for staff regarding policies for workplace and field conditions.
- ☐ Communicated guidance and training to staff.
- ☐ Provided staff with supplies and equipment for safely working in extreme conditions.

PARTNERS AND COOPERATORS

- PA Department of Labor and Industry
- PA Department of Health

Creative Commons

ACTIONS

Immediate (≤2 years)

7.1.1 Continue to adapt and develop new field protocols and safety guidelines for staff and communicate updates to staff.

7.1.2 Continue to provide staff training, including advanced wilderness first-aid for field conditions, and specialized materials, supplies, and equipment (e.g., protective clothing, air conditioning, insect repellant) to minimize impacts of a more extreme climate on employees.

7.1.3 Continue to encourage staff to report field-related safety concerns and incidents in a timely manner.

STRATEGY

7.2 Safe Recreation

Plan and implement measures to ensure angler and boater safety in a changing climate.

Issue: More frequent high precipitation events, extreme storms, flashier waterways with swift water, and extreme temperatures (both hot and cold) will increase risk to anglers and boaters. PFBC facilities could be damaged or unusable due to these conditions and storms will increase risks of downed limbs, trees, and strainers. Fluctuating water levels, increased shoreline erosion, bluff recission, and sediment movement will pose additional challenges for accesses and marinas along Lake Erie.

✓ PROGRESS CHECKLIST

- ☐ Increased awareness by the angling and boating public of risks contributed by climate change.
- ☐ Reviewed and assessed PFBC access sites for potential hazards brought about by climate change effects on water levels.
- ☐ Developed communication guidelines for making public aware of increased hazards.
- ☐ Implemented additional safety training courses focused on risks associated with climate change.
- ☐ Identified faulty infrastructure in need of attention.
- ☐ Developed plans for repairing infrastructure and replacing it with more resistant materials.
- ☐ Developed plans for staff time and assets according to highest priorities.

PARTNERS AND COOPERATORS

- Municipalities and planning commissions
- Non-governmental organizations
- PA Department of Conservation and Natural Resources
- PA Emergency Management Agency
- Paddling and outfitter groups
- Regional heritage areas
- U.S. Department of Agriculture-Forest Service
- Watershed associations

PFBC Archives

ACTIONS

Immediate (≤2 years)

7.2.1 Increase public awareness of high- and low-water hazards and boating safely.

7.2.2 Increase public awareness of hazards associated with marginal ice conditions on lakes and ponds.

7.2.3 Shift outdoor education events to early morning or evenings to avoid excessive heat.

7.2.4 Work with partners to ensure dam monitoring, dam safety, rapid identification and repair of faulty infrastructures, and communication of hazards to the public and staff.

7.2.5 Regularly evaluate PFBC facilities for tree and debris hazards and effectively communicate hazards to the public.

7.2.6 Work with water trail groups to identify responsibilities and authorities for tree and debris removal on water trails and communicate alerts and safe boating practices.

7.2.7 Enhance water rescue program through expanded training and partnerships.

7.2.8 Upgrade PFBC infrastructure (e.g., boat ramps, docks) for resiliency to extreme events.

7.2.9 Continue managing erosion, sediment, and sand movement at PFBC accesses and marinas along Lake Erie.

Long-term (>2 years)

7.2.10 Assist public and private fishing and boating facilities in the Delaware River tidal zone.

7.2.11 Adjust allocation of Waterways Conservation Officers and other PFBC staff and assets accordingly.

STRATEGY

8.1 Agency Assets and Staffing

Plan and implement measures to ensure sufficient PFBC staff and assets necessary to proactively address Climate Action Plan goals.

Issue: Increased emphasis on climate change planning and management within the PFBC will require adapting staff capacity and tasks, including addition of staff and potentially specialists, to fulfill climate change priorities.

PFBC Archives

PFBC Director and Habitat Staff host partners for tree-planting.

✓ PROGRESS CHECKLIST

- ☐ Prioritized climate change actions and identified staff with skillsets to implement actions.
- ☐ Identified gaps in current staff capacity.
- ☐ Developed workforce management plan for building and maintaining staffing capacity to support PFBC's climate change initiative.
- ☐ Developed or revised position descriptions accordingly.
- ☐ Hired staff to address climate change actions.
- ☐ Developed and implemented incentives to support employee green behavior.

PARTNERS AND COOPERATORS

- PFBC internal issue

ACTIONS

Immediate (≤2 years)

8.1.1 Redirect staff time, as necessary, to prioritize climate change initiatives.

8.1.2 Encourage PFBC employees to reduce their individual carbon footprints by supporting telework, virtual meeting participation, carpooling incentives, and bike-to-work initiatives.

Long-term (>2 years)

8.1.3 Increase staff capacity to meet new demands associated with implementing climate change strategy activities.

STRATEGY

8.2 Workplace Resilience

Build functional capacity and climate change resilience into PFBC facilities and infrastructure.

Issue: PFBC properties, including buildings, HVAC, and stormwater systems, will be subjected to temperature and precipitation extremes, stressing facilities, increasing maintenance, and decreasing facility functional expectancy. Loss of power, telecommunications, and other utilities, as well as physical damage to buildings and grounds, will lead to short-term and long-term closures.

✓ PROGRESS CHECKLIST

- ☐ Upgraded PFBC facilities for resilience to climate change.
- ☐ Upgraded PFBC passenger vehicle fleet, boat motors, and other equipment to zero or low-emission models.
- ☐ Assessed PFBC facilities for use of pervious pavement, green roofs, rain gardens, and similar measures.
- ☐ Prioritized PFBC facilities for upgrades and green infrastructure for improved stormwater runoff and erosion control.

PARTNERS AND COOPERATORS

- PFBC internal issue

PFBC archives

Benner Spring Hatchery flood, September 2004.

ACTIONS

Immediate (≤2 years)

8.2.1 Increase workplace resilience to extreme weather events. Develop guidelines pertaining to such events as related to workplace closures, staff leave, and field work, and communicate those policies to staff.

8.2.2 Investigate and support use of alternative/green infrastructure to reduce stormwater runoff from PFBC properties.

8.2.3 Promote alternative surface treatments (e.g., pervious asphalt, concrete).

8.2.4 Upgrade appliances, lighting, and HVAC systems to energy efficient models and consolidate office facilities where feasible.

Long-term (>2 years)

8.2.5 Incorporate green infrastructure into new facilities.

8.2.6 Proactively maintain stormwater systems by implementing preventative maintenance schedules on PFBC properties.

8.2.7 Upgrade PFBC passenger vehicle fleet, boat motors, and generators to hybrid, electric, or low-emitting models.

TAKING ACTION TOGETHER

Climate change is a global threat requiring a collective effort to ameliorate its effects (American Fisheries Society et al., 2020; WMO, 2021). With this expansive impact, well-understood is the need for national, regional, and local action to minimize and avoid the worst climate change outcomes for natural resources (DCNR, 2018; NFWPCAS, 2012; PADEP, 2021). Also recognized is the need for national, regional, and local action to minimize and avoid the worst climate change impacts to natural resources (DCNR, 2018; NFWPCAS, 2012; PADEP, 2021). The problem is large and requires taking action together at multiple scales so, cumulatively, the desired outcomes can be successful.

At a Glance

- *PFBC's Climate Action Plan aligns closely with partner strategies and scientific literature reviews.*
- *Goals, Strategies, and Actions in this plan cannot be implemented without collaboration with partners.*

The PFBC implements best management practices that improve habitat quality and increase the likelihood of trust species enduring extreme events, and these actions are enhanced by collaborating with partners. Alignment of PFBC Climate Action Plan goals with other climate change plans at the state and national scales (**Table 7**) offers an opportunity to serve as part of a natural resource community to benefit Commonwealth species and habitats. Sharing common goals, strategies, or actions extends the potential for collaboration and increases the likelihood of achieving these goals. Through this work we can build resilience, support adaptation, and mitigate sources of climate change.

Throughout this plan are specific recommendations for collaboration with partners, emphasizing the need for a collective effort. The listed partners are not all-inclusive, but rather represent a sampling of potential participants in overall effort. Expanding beyond specific actions, a multi-agency state climate adaptation team may provide a framework for enhanced communication for funding and sharing resources (DCNR, 2018). This collaboration among agencies would further demonstrate the Commonwealth's resolve to address this threat to fish and wildlife, recreational opportunities, human health, and property.

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Table 7. Cross-reference of Pennsylvania Fish and Boat Commission Climate Action Plan Goals with national and state agency Climate Plans. Terminology and structure of each plan varied so alignment is based on different components noted in parentheses ( ).

PFBC Climate Action Plan Goals	National Fish, Wildlife, Plants, Climate Action Strategy (Goal)	PADCNR Climate Change Adaptation and Mitigation Plan (Vulnerability)	PADEP Climate Action Plan (Strategy)	2015-2025 PA Wildlife Action Plan (Goal)
1-HABITAT	1-Conserve habitat to support healthy fish, wildlife, and plant populations and ecosystem functions….; **2-**Manage species and habitats to protect ecosystem functions and provide sustainable cultural…..	Fluctuating Lake Levels; Forest Pests; Fragmented Habitats; Increased Flood Risks; Warmer Water Temperatures	Protect ecosystem resilience, including forest systems…; Use stormwater best management practices;	1-Conserve Pennsylvania's native wildlife and its habitat by implementing conservation actions in the Wildlife Action Plan
2-SPECIES	**2-**Manage species and habitats to protect ecosystem functions and provide sustainable cultural…..; **7-**Reduce non-climate stressors to help fish, wildlife, plants, and ecosystems adapt to a changing climate.	Rare Species; Invasive Plant Species; Warmer Water Temperatures	Protect ecosystem resilience, including forest systems…; Use stormwater best management practices;	1-Conserve Pennsylvania's native wildlife and its habitat by implementing conservation actions in the Wildlife Action Plan
3-WATER	**7-**Reduce non-climate stressors to help fish, wildlife, plants, and ecosystems adapt to a changing climate.	Increased Flood Risks; Warmer Water Temperatures	Protect ecosystem resilience, including forest systems…; Use stormwater best management practices; Promote integrated water resources and water conservation	2-Base wildlife conservation decisions on the best available science, with an emphasis on Species of Greatest Conservation Need and their habitats.
4-RECREATION	**6-**Increase awareness and motivate action to safeguard fish, wildlife, and plants in a changing climate.	Extended Recreation Season	Help outdoor tourism industry manage shifting climate patterns	---

Table 7 (continued). Cross-reference of Pennsylvania Fish and Boat Commission Climate Action Plan Goals with national and state agency climate plans.

PFBC Climate Action Plan Goals	National Fish, Wildlife, Plants, Climate Action Strategy (Goal)	PADCNR Climate Change Adaptation and Mitigation Plan (Vulnerability)	PADEP Climate Action Plan (Strategy)	2015-2025 PA Wildlife Action Plan (Goal)
5-KNOWLEDGE	**2-**Manage species and habitats to protect ecosystem functions and provide sustainable cultural…; **4-**Support adaptive management in a changing climate through integrated observation and monitoring and use of decision support tools; **5-**Increase knowledge and information on impacts and responses of fish, wildlife, and plants to a changing climate; **6**-Increase awareness and motive action to safeguard fish, wildlife, and plants in a changing climate.	Increased Flood Risks; Warmer Temperatures; The Most Serious Effects are Yet to Come; Public Safety and Health Risks	Monitor, identify and address ecosystem vulnerabilities	2-Base wildlife conservation decisions on the best available science, with an emphasis on Species of Greatest Conservation Need and their habitats.
6-COMMUNICATIONS	**3**-Enhance capacity for effective management in a changing climate; **6**-Increase awareness and motivate action to safeguard fish, wildlife, and plants in a changing climate.	Public Education and Understanding	Bolster emergency preparedness and response	6-Develop a knowledgeable citizenry that support and participates in wildlife conservation.
7-SAFETY	---	Extended Recreation Season; Fluctuating Lake Levels; Public Safety and Health Risks; Increasing Challenges	Protect ecosystem resilience, including forest systems	---

Table 7 (continued). Cross-reference of Pennsylvania Fish and Boat Commission Climate Action Plan Goals with national and state agency climate plans.

PFBC Climate Action Plan Goals	National Fish, Wildlife, Plants, Climate Action Strategy (Goal)	PADCNR Climate Change Adaptation and Mitigation Plan (Vulnerability)	PADEP Climate Action Plan (Strategy)	2015-2025 PA Wildlife Action Plan (Goal)
8-AGENCY RESOURCES, STAFFING	**3**-Enhance capacity for effective management in a changing climate; **7**-Reduce non-climate stressors to help fish, wildlife, plants, and ecosystems adapt to a changing climate	Energy Demand and Infrastructure; Increasing Challenges; Possible Policy Conflicts	Lead by example in commonwealth and local government practices and assets	4-Strengthen the state's capacity to conserve Pennsylvania's native wildlife.

Beyond specific climate change plans and strategies, it is noteworthy that actions identified in the PFBC Climate Action Plan are also relevant to those in the scientific literature. In their review of 509 articles for wildlife and biodiversity conservation under climate change, LeDee et al. (2021) identified 19 strategies. Within this PFBC Climate Action Plan, three goals (i.e., 1-Habitat, 2-Species, 3-Water) are broadly aligned with select strategies in the scientific literature (**Table 8**) further demonstrating the science-based foundation of this plan.

Table 8. Association of Pennsylvania Fish and Boat Commission Climate Action Plan Strategies and strategies from a literature review (LeDee et al., 2020). Frequency occurrence rank in the reviewed literature indicated by ( ).

PFBC Climate Action Plan Goals	Strategies identified from Literature
1-HABITAT	
1.1 Lake and Impoundments	Maintain or create optimal cover (2)
1.2 Riparian zone linkages with stream ecosystems	Establish and enhance protected areas (1) Maintain or create optimal cover (2)
1.3 Instream, wetland, and groundwater connectivity	Maintain or restore water resources (7)
2-SPECIES	
2.1 Life history cues and sensitive life stages	Maintain metapopulation processes (8)
2.2 Invasive Species, Harmful Algal Blooms and Pathogens	Prevent or control wildlife diseases (16)
2.3 Species Interactions	Sustain positive and reduce negative interspecific/biotic interactions (9)
3-WATER	
3.1 Water quality, habitat management, and property damage.	Maintain or restore water resources (7)
3.2 Water conflicts and competing uses	Plan for and reduce human-wildlife conflict (18)

LOOKING TO THE FUTURE

Current and ongoing effects of climate change will continue to pose significant threats to the angling and boating public, PFBC staff and operations, and natural resources under the Commission's jurisdiction. Therefore, in response to a changing climate, this plan identifies opportunities for enhancing adaptation and building resilience by implementing actions in the Goals and associated Strategies.

At a Glance

Successful implementation of this plan will involve:

- *Effective communication.*
- *Implementation tracking.*
- *Increased staff capacity.*
- *Regular updates to maintain scientific relevance.*

Outreach and Inreach: Communication about this plan and clearly identified roles for staff, partners, and the public will be essential for successful implementation. Upon approval, the development team for this plan, along with other staff, will work to implement Action 6.1.1. This communication will express to partners and the public the activities we intend to implement and the urgency for these actions, with expectations to inspire individuals, non-governmental organizations, and agencies to implement actions to address climate change. Communications with staff will be made via separate formats, primarily through internal messaging.

"Many proposed actions, to a varying extent, are already implemented by the PFBC. Noting them in this document highlights their importance to addressing climate change impacts and emphasizes the need to accelerate and expand their implementation."

Implementation Tracking: Tracking implementation and subsequent results will be vital for adaptive management, to minimize and avoid the most severe losses to natural resources, staff health and well-being, and Commission facilities. Many proposed actions, to a varying extent, are already implemented by the PFBC. Noting them in this document highlights their importance to addressing climate change impacts and emphasizes the need to accelerate and expand their implementation. A tracking system, as well as a plan for reporting progress, will need to be developed as we advance towards meeting the goals of this plan. Regular progress reports to staff and stakeholders, along with emerging concerns, will be important for adaptive plan implementation.

Staff Capacity: Fully and comprehensively implementing PFBC's Climate Action Plan will require sufficient resources and motivated staff willing to rise to the challenge. Implementing new actions or expanding current initiatives will require additional staff capacity, modification to facilities, and operational adjustments. Climate change is already occurring so these changes should be expedited and proactively implemented, commensurate with the science. The breadth of the climate change threat will require expanded staff including the following roles: science-based roles (e.g., climate change

coordinator, rapid response invasive species crews), Information Technology and Outreach, Education and Marketing.

Future Assessments and Revisions: Climate change is a long-term concern requiring a view well beyond the current 2020-2023 PFBC Strategic Plan. For this Climate Action Plan, the 2020 PFBC Staff Climate Change Survey was crucial for understanding the resource issues. Regathering staff input, coupled with expanding knowledge from research and monitoring, will help maintain scientific relevancy and reassessment of the Goals and Actions. Building on this information, a future iteration should consider a more comprehensive SWOT (i.e., strengths, weaknesses, opportunities, threats) assessment. Subject to need, a revision frequency of approximately five years may provide timely updates relative to emerging science, without overburdening staff with plan maintenance.

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Limnological Society [EFFS member], Fisheries Society of the British Isles, The Freshwater Biological Association [EFFS member*], Freshwater Fisheries Society of BC, Freshwater Mollusk Conservation Society, German Ichthyological Society, German Limnological Society (DGL) [EFFS member*], Gilbert Ichthyological Society, Hungarian Hydrological Society [EFFS member], Hydroecological Society of Ukraine, The Hydrographic Society of America, The Hydrozoan Society, Iberian Association of Limnology [EFFS member], Ichthyological Society of Japan, Ichthyological Society of Ukraine, The Institute of Fisheries Management, International Association for Danube Research, International Association for Great Lakes Research (IAGLR), International Association of Aquatic and Marine Science, Libraries and Information Centers (IAMSLIC), International Coral Reef Society, International Federation of Hydrographic Societies, International Peatland Society, International Phycological Society, International Seaweed Association, International Society of Limnology, International Water History Association, Irish Freshwater Sciences Association [EFFS member], The Japanese Society of Fisheries Science, Lake Victoria Fisheries Association, The Limnological Society of Turkey [EFFS member], Living Oceans Society, Macrolatinos@ Network, Malacological Society of London, Marine and Oceanographic Technology Network, The Marine Biological Association of India, Marine Biological Association of the United Kingdom, Marine Stewardship Council, National Association of Marine Laboratories (NAML), Netherlands Malacological Society (Nederlandse, Malacologische Vereniging), The New Zealand Freshwater Sciences Society (NZFSS), North American Lake Management Society, Oceania Chondrichthyan Society, Ocean Conservation Society, Philippine Association of Marine Science, Phycological Society of America, Polish Limnological Society [EFFS member*], Romanian Ecological Society [EFFS member], Scientific Committee on Antarctic Research, Serbian Water Pollution Control Society SWPCS [EFFS member], SIL Austria [EFFS member*], Slovak Ichthyological Society, Slovak Limnological Society (SLS) [EFFS member*], Sociedad Chilena de Limnología Sociedad Científica Mexicana, de Ecología, A.C., Sociedad Iberica de Ictiologia, Sociedad Ictiológica Mexicana Sociedad Mexicana de, Planctologia A.C., Sociedad Mexicana para el Estudio de los Florecimientos, Algales Nocivos (SOMEFAN, Mexican Society for the Study of Harmful Algal Blooms), Sociedade Brasileira de Carcinologia, Société Française d'Ichtyologie, Society for Conservation Biology Marine Policy Section, Society for Freshwater Science, The Society for Marine Mammalogy, Society for the Study of Amphibians and Reptiles, Society of Canadian Limnologists/Société canadienne de, Limnologie (SC), Society of Wetland Scientists, Southern African Soc. Aquatic Scientists, Spanish Malacological Society (Sociedad Española de, Malacología), Swiss Hydrological and Limnological Society [EFFS member*], Vietnam Fisheries Society (VINAFIS), Western Indian Ocean Marine Science Association, Wild Oceans, World Aquaculture Society, The World Council of Fisheries Societies, World Sturgeon Conservation Society, Zoological Society of Pakistan Society. (2020). *World's leading aquatic scientific societies urgently call for cuts to global greenhouse gas emissions* http://seaaroundus-io.org/wp-content/uploads/2020/09/WorldClimateStatement.pdf

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APPENDIX A

Detailed description of the Pennsylvania Fish and Boat Commission Climate Action Plan goals, strategies, and actions adapted from the 2020 PFBC Climate Change Staff Survey.

1. Habitat

1.1 Lakes & Reservoirs

Issue: Heavy precipitation events will increase erosion and sediment deposition in lakes and reservoirs thereby reducing lake volume, degrading, or eliminating habitat for aquatic life, including favorable fish spawning habitat. Low water events may result in dewatering of natural fish habitat and fish habitat structures. Increasing temperature and variable precipitation may increase nuisance algal growth, further eliminating habitat and degrading water quality.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
1.1	Strategy: Plan and implement measures to address changes to lake habitat including sedimentation, water temperature, and water quality. A. Plan and implement measures to address increasing frequency and intensity of precipitation events which are likely to increase erosion and deposition of sediment in lakes, thereby reducing storage capacity and degrading habitat for aquatic life, including elimination of favorable fish spawning habitat. B. Address dewatering of fish habitat structure in the littoral zones of reservoirs attributable to droughts and resultant low water events.	1.1.1 Improve vegetative cover in watersheds, including planting native vegetation.	Immediate action (≤ 2 yrs)
		1.1.2 Continue working with DCNR, USACE, County Conservation Districts, USDA-NRCS, and PADEP to reduce lake erosion and sedimentation.	
		1.1.3 Continue installing additional fish habitat structures in deep water portions of reservoirs for availability during low water events.	
		1.1.4 Adjust allocation of staff and assets accordingly to manage PFBC facilities and assist with non-PFBC facilities.	Long-term action (>2 yrs)
		1.1.5 Install forebays at lake inlets to promote sediment deposition and storage.	
		1.1.6 For feeder streams, create meanders to slow flows and improve floodplain connectivity	

		to reduce sediment entering reservoirs.	
		1.1.7 Identify and implement measures to ameliorate degraded conditions (e.g., depleted oxygen levels, harmful algal blooms) in water bodies unsuitable for priority aquatic species or recreational activities.	

Responsible PFBC Staff	**Partners and Cooperators**
• Executive Office • Bureau of Fisheries	• County Conservation Districts • Non-governmental organizations (e.g., conservancies, watershed organizations) • PADEP • PADCNR • PADA • USDA-NRCS • USACE

Progress Checklist

- ☐ Prioritized waterbodies for native vegetation enhancements.
- ☐ Developed and implemented native vegetation management plans.
- ☐ Prioritized waterbodies for nuisance species management.
- ☐ Developed and implemented nuisance species management plans.
- ☐ Prioritized waterbodies for sedimentation management and in-lake habitat augmentation.
- ☐ Initiated control strategies and partner engagement for sediment management.

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1.2 Riparian Zone Linkages

Issue: Warming temperatures and increased vulnerability to disease and pest species (e.g., Hemlock Wooly Adelgid, Emerald Ash Borer) will change native tree and plant communities and reduce vegetative canopy cover. This loss of vegetative cover may exacerbate warming water temperatures and reduce aquatic habitat and food sources, including in trout streams. Additionally, loss of riparian cover would be expected to diminish streambank stability and, coupled with highly variable stream flows, lead to increased erosion. More frequent flooding and drought events will negatively affect both wild trout populations and their instream and riparian habitats.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
1.2	Strategy: Plan and implement measures to stabilize and increase native riparian communities. A. In streams (especially trout streams), maintain and enhance native vegetation, water quality, and instream habitat. B. During environmental review, consider wetland mitigation and riparian buffer plantings as conditions for permits. C. Assess impacts of variable hydrologic and geomorphologic functions (e.g., fluctuating stream flows, streambank erosion, loss of connectivity) on endemic species, especially trout.	1.2.1 A. Protect and enhance forested buffers and establish new wider forest buffers in riparian zones of lakes and streams using native trees and shrubs resistant to insect pests, diseases, and tolerant of climate change. B. Collaborate with PADCNR, USDA-NRCS, Allegheny National Forest in riparian corridors with significant tree canopy loss along coldwater trout streams. C. Use best management practices in riparian zones to increase protection of riparian areas and wetlands adjacent to wild trout streams. D. Increase frequency, number, and areas of plantings for habitat improvement projects, and collaborate with partners to emphasize the need for forested buffers.	Immediate action (≤ 2 yrs)

		1.2.2 Continue implementing instream habitat projects that provide stable and suitable habitat during both low and high streamflow conditions.	
		1.2.3 Continue implementing streambank stabilization practices to protect streams from excessive siltation, substrate embeddedness, inflated stream channel widths, etc.	
		1.2.4 Continue improving floodplain connectivity to reduce sediment volumes entering streams.	
		1.2.5 A. Continue working with partners to reduce negative impacts of anthropogenic activities in wild trout watersheds. B. Work with local municipalities to reduce and improve stormwater management, establish riparian buffers, and set aside key areas for conservation.	
		1.2.6 Update and maintain priority locations for fish habitat treatment, maintenance inspections, and repairs.	
		1.2.7 Acquire additional land and/or voluntary easements to provide stable and consistent protection in vulnerable watersheds.	Long-term action (>2 yrs)

		1.2.8 Work with partners (e.g., PADEP, PennDOT) to include riparian protection and mitigation conditions in environmental permit review.	

Responsible PFBC Staff	Partners and Cooperators
• Bureau of Fisheries	• County Conservation Districts • Municipalities • Non-governmental organizations • PADCNR-Bureau of Forestry • PADEP • PennDOT • PGC • Private landowners • USDA-NRCS • USDA-FS, Allegheny National Forest

Progress Checklist

- ☐ Identified key areas for riparian buffer protection and enhancement.
- ☐ Worked with partners to implement riparian buffer enhancement.
- ☐ Implemented control measures for invasive species affecting riparian vegetation.
- ☐ Worked with partners to address loss of trees (e.g., Hemlock, Ash) along wild trout streams.
- ☐ Identified key PFBC forest resources for protection and implemented programs for management.

1.3 Instream, Wetland, and Groundwater Connectivity

Issue: Increased streamflow, warming temperatures, and sea-level rise will create unsuitable habitat for many aquatic species. These factors will exacerbate the ecological effects of instream barriers (e.g., dams, culverts), preventing aquatic organisms from accessing suitable habitat. Intense and sporadic precipitation events are anticipated to increase the prevalence and duration of droughts, reducing stream connectivity with critical groundwater and wetland inputs. Sea level rise may eliminate critical habitat for resident, migratory, and estuarine species.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
1.3	Strategy: Plan and implement measures to maximize critical habitat connectivity for aquatic organisms statewide affected by:	1.3.1 Continue to prioritize and accelerate the pace of dam and barrier removals, with consideration to minimize spread of invasive species.	Immediate action (≤ 2 yrs)

	A. higher flows, elevated water temperatures, dams, and non-passable culverts. B. diminished habitat quality from increased air temperatures and sporadic precipitation impacting groundwater levels and wetlands associated with riparian areas along wild trout waters.	1.3.2 Where barrier removal is unlikely, identify and implement alternative fish passage options, with a focus on passing a suite of species of different life stages including wild trout streams and their tributaries.	
		1.3.3 A. Continue collaborating with partners and seek funding to assess barriers to aquatic organism passage (e.g., road stream crossings, culverts, dams) and prioritize for replacement or removal. B. Use North Atlantic Aquatic Connectivity Collaborative (NAACC) assessment protocols. C. Expand PFBC staff capacity to coordinate assessments and dam retrofits.	
		1.3.4 Improve headwater stream connectivity and native vegetative cover to increase thermal refugia.	
Responsible PFBC Staff		**Partners**	
• Bureau of Fisheries, Habitat Division		• American Rivers • County Conservation Districts • Dirt and Gravel Road Program • NAACC • PADCNR • PADEP • The Nature Conservancy • USGS • Western Pennsylvania Conservancy	

Progress Checklist

- ☐ Identified key fish passage barriers for prioritized removal.
- ☐ Identified barriers for prioritized fish passage installation.
- ☐ Assessed culverts, bridges, and other barriers for aquatic organism passage feasibility.
- ☐ Secured funding to address high priority passage issues.
- ☐ Increased stream connectivity by removing barriers and installing fish passage structures.

2. Species

2.1 Organismal Life History Cues and Sensitive Life Stages

Issue: Shorter, warmer winters, and longer, potentially drier growing seasons punctuated with extreme heat and intense storms will affect species' life-histories, including their survival and distribution. These stressors could lead to unnatural cues for reproduction or feeding, shorter hibernation or brumation periods, and accelerated drying of ephemeral habitats. The sensitive life stages (i.e., sub-adult) are likely to be most impacted.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
2.1	Strategy: Plan and implement measures to understand and protect life-histories and critical life stages for PFBC trust species. A. As species life-history patterns and survival are influenced by an altered climate, implement adaptive and resilient best management practices to protect species and habitats, especially in critical seasons and life stages.	2.1.1 Collaborate with partners and industry to incorporate seasonal best management practices, work restrictions, and additional conservation measures accordingly.	Immediate action (≤ 2 yrs)
		2.1.2 Work with dam owners and operators to provide conservation releases during critical life history stages (e.g., spawning) of affected aquatic organisms.	
		2.1.3 A. Enter into voluntary landowner agreements for easements or other long-term opportunities to ensure protection of key habitat and spawning grounds (e.g., wetlands, floodplains). B. Where feasible, create or enhance wetlands in floodplains.	Long-term action (>2 yrs)

		2.1.4 Support responsible artificial propagation of PFBC trust species when population declines suggest eventual loss or need to supplement for sustainability and genetic diversity.	

Responsible PFBC Staff	Partners and Cooperators
• Bureau of Fisheries • Bureau of Hatcheries	• Non-governmental organizations • NECASC • NIACS • PADCNR • PGC • Regional watershed organizations • Universities and research institutions

Progress Checklist

- ☐ Adapted and implemented best management practices to protect critical life stages of aquatic species.
- ☐ Established and enhanced relationships with partners and industry to improve fisheries-protective water management.

2.2 Aquatic Nuisance and Invasive Species, Harmful Algal Blooms, and Pathogens

Issue: Warmer water temperatures and extreme flow events may increase the spread and severity of invasive species that can outcompete and replace native PFBC trust species. These conditions may also increase prevalence of nuisance species (e.g., harmful algal blooms) and diseases which can degrade aquatic habitat quality for fish and other aquatic organisms, increase health risks to humans and pets, and impede recreational activities (e.g., angling, boating).

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
2.2	Strategy: Plan and implement measures to prevent and manage invasive and nuisance species, diseases, parasites, pathogens, and harmful algal blooms which pose current and emerging threats to native	2.2.1 Increase public outreach to encourage angler and boater inspection, gear cleaning, prompt reporting of observed invasive species, and reduce illegal release of invasive species.	Immediate action (≤ 2 yrs)

	aquatic organisms and their habitats.	2.2.2 Improve interagency collaboration for invasive species risk assessment, detection, prevention, and monitoring, with rapid response measures for early control and eradication.	
		2.2.3 Evaluate PFBC properties for effective management of invasive species.	
		2.2.4 Maintain connection to science-based resources for understanding of current and projected changes to invasive species that could harm PFBCs trust species or habitats.	
		2.2.5 Support revision of Title 58, Chapter 71 to more fully address introduction of non-native and invasive species.	
		2.2.6 A. Collaborate with partners to address stormwater management and runoff (e.g., agricultural, urban, and sewage) contributing to harmful algal blooms and pathogens. B. Work with municipalities to minimize human influences on lake watersheds through innovative stormwater controls, wetland enhancement and protection. C. Work with PADEP to evaluate current and potential infrastructure design needs in major metropolitan areas including Erie, Pittsburgh, Harrisburg, and	Long-term action (>2 yrs)

		Philadelphia to address stormwater and Combined Sewer Overflows (CSOs).	
		2.2.7 Evaluate the effects of changing temperature and precipitation regimes on distribution and prevalence of invasive species and HABS.	

Responsible PFBC Staff	**Partners and Cooperators**	
• Executive Office • Bureau of Administration • Bureau of Fisheries • Bureau of Outreach, Education, and Marketing	• GISC • Municipalities • NECASC • PA Sea Grant • PADA • PADCNR	• PADEP • RISCC • USDA-NRCS • USFWS • Watershed Organizations

Progress Checklist

- ☐ Developed and implemented outreach to support invasive species prevention and management.
- ☐ Coordinated with partners to optimize invasive species and HABs prevention, management, and rapid response.
- ☐ Coordinated with partners (e.g., PA Department of Environmental Protection) regarding infrastructure needs to reduce and eliminate combined sewer overflows.
- ☐ Identified Aquatic Invasive Species (AIS) risks and developed species-specific control plans for high-risk species.
- ☐ Assessed PFBC facilities for invasive species management needs.
- ☐ Continued working with science-based resources for informed management decisions.

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2.3 Species Interactions

Issue: Changing instream flow conditions can shift abundance and distribution of native species, reducing overall aquatic diversity. For example, naturally reproducing fish (e.g., Brown Trout) populations and hatchery-sourced fish may reduce or extirpate native Brook Trout populations. Additionally, prolonged survival of hatchery fish could: increase the potential for introgression between hatchery and wild fish, reduce fitness and genetic diversity of wild trout populations, and increase the probability of successful hatchery trout. This could result in trade-offs between stocking hatchery-reared fish and maintaining sustainable populations of native Brook Trout.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
2.3	Strategy: Plan and implement measures to minimize loss of biodiversity due to habitat alterations and interactions between native, invasive, and hatchery-sourced species. A. Consider the impacts of climate change on macroinvertebrate populations, life-histories, and impacts on fish survival.	2.3.1 Establish stocking authorization that allows the PFBC to adjust the species, location, number, and frequency of fish stocked into Commonwealth waters to reduce risk of stocking invasive fish, support fish health, and fisheries management concerns.	Immediate action (≤ 2 yrs)
		2.3.2 Take actions to ensure habitat quality and quantity and control invasive species to maintain biodiversity among native aquatic fauna.	
		2.3.3 Under changing flow and temperature regimes, continue to assess, and adjust where needed, the number and species of stocked fish from state fish hatcheries to minimize competition with wild populations and reduce spread of pathogens and parasites (PFBC 2020).	Long-term action (>2 yrs)
		2.3.4 Produce and stock sterile, triploid trout to avoid introgression with wild trout populations.	

Responsible PFBC Staff	Partners and Cooperators
• Bureau of Fisheries • Bureau of Hatcheries	• Citizen monitoring programs • Cooperative Nursery Program Units • Universities and research institutions

Progress Checklist

- ☐ Identified priority biodiversity "hot spots" for protection or restoration across the state.
- ☐ Implemented invasive species controls to maintain habitats for native aquatic faunal biodiversity.
- ☐ Established a PFBC stocking authorization.
- ☐ Evaluated trade-offs of adjusting numbers of stocked Brook Trout to minimize interaction with native Brook Trout populations.
- ☐ Stocked sterile triploid trout to minimize genetic burden on wild trout populations.

3. Water

3.1 Water Quality, Habitat Management, and Property Damage

Issue: Climate change is projected to stress infrastructure with implications for water quality, aquatic habitat, and public and private properties. Increased frequency and intensity of storms will accelerate channel erosion, sedimentation, runoff from land and impervious surfaces into waterways, degrading water quality and habitat. Woody debris movement will contribute to increased erosion, property losses, and landowner complaints about debris deposition, loss of trees, and impending threats to properties adjacent to stream channels.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
3.1	Strategy: Plan and implement measures to minimize the effects of erosion and sedimentation on water quality, habitat, and property. A. Adapt PFBC stream habitat management practices to address increasing damage to streambanks and associated infrastructure.	3.1.1 Work with partners as municipalities update stormwater ordinances and implement stormwater and erosion management plans that accommodate changes in precipitation patterns.	Immediate action (≤ 2 yrs)
		3.1.2 Continue to collaborate with partners to identify properties with imminent structural damage in need of assistance.	
		3.1.3 Accelerate the pace of streambank stabilization and riparian planting projects.	Long-term action (>2 yrs)

		3.1.4 Continue to prioritize installation, anchoring, maintenance, and repair of in-water habitat structures.	

Responsible PFBC Staff	Partners and Cooperators
• Bureau of Administration • Bureau of Engineering • Bureau of Fisheries	• County Conservation Districts • Municipalities • Non-governmental organizations (e.g., conservancies, American Rivers) • PADEP • PADA • Regional Planning Authorities • USDA-NRCS

Progress Checklist

- ☐ With partners, identified and prioritized properties with imminent structural damage in need of assistance.
- ☐ Identified key areas for streambank stabilization and riparian plantings.
- ☐ Continued implementing streambank stabilization and riparian planting projects.

3.2 Water Availability and Competing Uses

Issue: Drought frequency and severity are expected to increase under climate change, thereby affecting water quantity. Corresponding increases in human water needs will intensify conflicts with instream ecological requirements. For example, spring-fed, limestone-sourced streams are sought by bottled water companies yet also offer refuge for a wide array of PFBC species including turtles, salamanders, and rare invertebrates. Minimizing these conflicts will require the following: assessing current water availability, optimizing use and reuse to protect water quality and ecological integrity, and modeling projections under future scenarios to plan for protection.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
3.2	Strategy: Plan and implement measures to minimize competing water uses across the state by assessing water availability, optimizing water use and reuse to protect ecologically sensitive areas, and model projections under future scenarios to plan for protection. Additional	3.2.1 Collaborate with partners to identify areas with existing and future water shortages where supply is inadequate to meet human and ecological needs.	Immediate action (≤ 2 yrs)
		3.2.2 Continue collaborating with partners and permittees to develop system improvements to minimize water loss.	

	protective measures may be required.	3.2.3 Continue collaborating with partners and permittees to prioritize use of alternative water sources in lieu of ecologically sensitive ones.	
		3.2.4 Work with partners to establish and enforce scientifically supported and biologically relevant low flow protection criteria.	
		3.2.5 Work with partners to identify and prioritize groundwater sources and protect these important water sources for future fish, wildlife, and conservation benefits.	Long-term action (>2 yrs)

Responsible PFBC Staff	**Partners and Cooperators**
• Bureau of Fisheries	• Non-governmental organizations • PADEP • Regional river basin commissions • USGS

Progress Checklist

- ☐ Worked with partners to identify areas of existing and future water shortages that do not meet human and ecological needs.
- ☐ Identified and prioritized alternative water sources in lieu of ecologically sensitive areas.
- ☐ Established scientifically supported and biologically relevant low flow protection criteria.
- ☐ Worked with partners to implement criteria to protect human and water ecological needs.
- ☐ Identified groundwater sources to protect native fish and wildlife, and other conservation benefits.

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4. Recreation

4.1 Hatcheries and Stocking

Issue: Projected increases in water temperature will affect fish production, stocking, survival, and management. Additionally, increasing frequency and intensity of precipitation events will impact hatchery source waters contributing to higher Total Suspended Solids (TSS), negatively impacting the PFBC's National Pollution Discharge Elimination System (NPDES) permits. Warmer water temperatures will influence sport fish populations, especially coldwater species (e.g., trout). Consequently, species compositions of lakes and streams across the Commonwealth may shift to warmwater-tolerant species.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
4.1	Strategy: Plan and implement measures to minimize impacts on hatchery operations and fish stocking protocols due to changing water quality (e.g., elevated temperatures, total dissolved solids) brought about by climate change.	4.1.1 Develop new and improve existing models to identify at-risk and climate resilient regions for aquatic organisms and focus attention on more highly resilient areas and those likely to benefit from habitat management.	Immediate action (≤ 2 yrs)
		4.1.2 Continue to adjust stocking schedules, seasonal work priorities, angling season, and daily harvest size and number accordingly to minimize impact on stressed fish.	
		4.1.3 Sustainably optimize naturally reproducing populations for recreational use.	
		4.1.4 Plan for alterations in hatchery water quantity and quality and make necessary infrastructure adjustments.	Long-term action (>2 yrs)
		4.1.5 Continue to evaluate and adjust fish management and stocking strategies to adapt to varying conditions in a changing climate.	

Responsible PFBC Staff	Partners and Cooperators
• Bureau of Fisheries • Bureau of Hatcheries	• Cooperative Nursery Program Units • PA Cooperative Fish and Wildlife Research Unit

Progress Checklist

- ☐ Identified at-risk and resilient regions for wild and stocked trout populations.
- ☐ Improved native vegetative cover in watersheds of hatchery source waters.
- ☐ Adjusted stocking schedules, angling season, and regulations to minimize stressed fish.
- ☐ Adjusted fish management and stocking to include thermally tolerant species.

4.2 Recreational Facilities Management

Issue: Intensive and sporadic precipitation will contribute to greater water level fluctuations, influencing reservoir water management. Reservoir management will need to increasingly consider the timing of controlled drawdowns to maintain downstream flows and reservoir storage capacity for flood management and public recreation (i.e., boating and fishing). More intensive aquatic vegetation management may be required due to angler and boater concerns.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
4.2	Strategy: Sustainably manage reservoir operations (e.g., source waters, discharge operations, staff) to support multiple uses including flood control, drought management, and recreation.	4.2.1 Develop watershed plans to reduce erosion and sediment deposition in reservoirs, thus maintaining reservoir storage capacity for PFBC and other facilities.	Immediate action (≤ 2 yrs)
		4.2.2 Improve connectivity of feeder streams to their floodplains to reduce water volume entering PFBC reservoirs.	Long-term action (>2 yrs)
		4.2.3 Adjust PFBC staff allocation and resources accordingly to address impoundment management needs (e.g., planning, vegetation management).	

Responsible PFBC Staff	Partners and Cooperators
• Bureau of Engineering • Bureau of Fisheries • Bureau of Hatcheries	• County Conservation Districts • Municipalities • Non-governmental organizations (e.g., conservancies, land trusts) • PADEP • USACE • USDA-NRCS • Watershed Associations

Progress Checklist

- ☐ Worked with partners to identify critical reservoir volume and instream flow thresholds that may jeopardize PFBC trust species.
- ☐ Developed management plans to respond to threshold conditions.
- ☐ Prioritized areas in need of floodplain connectivity at PFBC facilities
- ☐ Enhanced floodplain connectivity for streams draining into priority impoundments.
- ☐ Developed watershed and sedimentation reduction plans for priority PFBC impoundments, wetlands, and facilities.
- ☐ Implemented sediment reduction plans for PFBC facilities.
- ☐ Maintained recreational facilities (e.g., boat launches, docks) affected by changing water levels and other climate impacts.

4.3 Public Fishing and Boating Access

Issue: Increased intensity and duration of extreme heat events will increase demand for water-based recreational activities, especially in-or-near urban areas. More extreme precipitation events and greater fluctuations in water levels, could generate confusion regarding access to navigable waters. Public access to many waters includes substantial agricultural land holdings for which access could be limited if farmers face financial hardships from changing climatic conditions and adjust agricultural practices or sell farms to developers.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
4.3	Strategy: Under a changing climate, the PFBC will need to plan and implement measures to accommodate increased demand for fishing and boating while addressing administrative and societal barriers to fishing and boating access.	4.3.1 Ensure sufficient access at existing PFBC properties and develop new access facilities where stream channels have changed making existing facilities unusable or in-or-near urban areas to accommodate additional use.	Immediate action (≤ 2 yrs)

		4.3.2 Work with partners and PFBC staff (e.g., Waterways Conservation Officers, Bureau of Fisheries) to monitor access issues on navigable waters and develop guidance to address access rights.	
		4.3.3 Work with partners to identify funding and other resources for developing access facilities that appeal to a diverse user base.	
		4.3.4 Work with willing landowners to purchase easements or establish other long-term commitments for public access to private lands and waterways.	Long-term action (>2 yrs)

Responsible PFBC Staff	Partners and Cooperators
• Executive Staff • Bureau of Administration, Property Services • Bureau of Boating • Bureau of Law Enforcement	• Land Trusts • Municipalities • PADA • PADCNR • Private landowners

Progress Checklist

- ☐ Assessed PFBC access facilities for capacity to accommodate current and anticipated demand.
- ☐ Assessed underserved areas for additional access development.
- ☐ Developed new PFBC access facilities to address needs in-or-near urban areas or where existing facilities have become unusable due to changing stream channels.
- ☐ Worked with willing private landowners to secure and mark waterway access.

5. Knowledge

5.1 Knowledge and Data Gaps

Issue: Species management strategies must be grounded in scientifically valid data and models. Data gaps in species distribution, habitat response, variability in climate-related events, and other factors contribute to uncertainty and are barriers for informed conservation planning, communications, and conservation action implementation. Specific data are required for detecting long-term changes in habitat and species distribution. Rare and at-risk species under PFBC jurisdiction, including Species of Greatest Conservation Need in the Pennsylvania Wildlife Action Plan, will require special attention. Ongoing and expanded species and habitat surveying, monitoring, and modeling will be necessary to

understand spatially and temporally relevant data, climate change vulnerabilities, and establish conservation priorities.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
5.1	Strategy: Address knowledge gaps by working with researchers, monitoring programs, non-governmental organizations, and resource managers. A. Develop new data sources, support research, or enhance current survey and monitoring initiatives to assess climate impacts on species and habitats. Use this information to guide appropriate conservation actions. B. For informed management decisions support ongoing monitoring of representative, keystone, or sensitive species and their habitats.	5.1.1 A. Assess effects of PFBC reservoir operations on downstream ecological communities and adjust conservation releases accordingly. B. Evaluate dam operations to determine loss of in-lake fish habitat under management and sedimentation scenarios. C. Update modelling of instream flows for managing minimum flow volumes to maintain biodiversity downstream of dams.	Immediate action (≤ 2 yrs)
		5.1.2 A. Forecast status and distributions of trust species populations. B. Conduct regular trout population monitoring throughout the state to provide trends and forecast data on the status of wild trout populations.	

		5.1.3 Use or adapt existing monitoring programs, develop new programs where needed, and work with agencies, universities and institutions (e.g., NE Climate Adaptation Science Center) to fill data gaps on sensitive life stages (e.g., spawning and reproduction) for aquatic species. (PGC-PFBC, 2015; Chapters 4, 5).	
		5.1.4 Use or adapt phenological monitoring and modeling networks, including public sourced data collection, to understand changes in availability of essential food sources (e.g., insect emergences). National Phenology Network.	
		5.1.5 Work with partners to forecast streamflow scenarios to predict threats and barriers to aquatic species: A. Work with PADEP and USGS to assess the 'new' average precipitation volumes and determine whether the frequency of the 2-year, 10-year, 100-year, etc. storms exceeds recent past frequency averages.	
		5.1.6 Model invasive species and HAB distribution and monitor for early detection: A. Regularly monitor dissolved oxygen conditions in impoundments and implement invasive plant	

		control strategies as appropriate. B. Evaluate the implications of herbicide applications as a control technique. C. Work with partners to identify locations where stream canopy loss from pests and pathogens (e.g., Hemlock Wooly Adelgid, Emerald Ash Borer) could adversely impact Eastern Brook Trout and other coldwater species. D. Proactively identify and assess threat potential for invasive flora and fauna which could harm Pennsylvania native biodiversity.	
		5.1.7 Identify and forecast areas in need of riparian augmentation and streambank stabilization to protect PFBC trust species. (See also: Riparian Buffer Polygons; Points. VanBrakle, 2019).	
		5.1.8 Update and develop climate change vulnerability index ratings for PFBC species.	
		5.1.9 Inventory trees on PFBC-owned properties to inform future management needs.	

		5.1.10 Conduct long-term habitat monitoring and modeling to assess changing conditions (e.g., vegetation, precipitation) and their effects on key life history functions.	Long-term action (>2 yrs)
		5.1.11 A. Identify and evaluate effects of changing temperature and precipitation regimes on distribution and prevalence of invasive species and HABs, which may harm native biodiversity. B. Monitor lakes and wetlands to identify occurrences of HABs for early intervention.	

Responsible PFBC Staff	**Partners and Cooperators**
• Bureau of Fisheries • Bureau of Hatcheries	• GISC • PABS • NECACS • NIACS • Non-governmental organizations • PADEP • RISCC • Universities and other research institutions • USGS • Volunteer-based citizen monitoring programs

Progress Checklist

- ☐ Evaluated data to determine utility in addressing climate change needs and conservation priorities.
- ☐ Identified key data needs in habitat and species distribution.
- ☐ Worked with partners to identify and establish monitoring and modeling needs for priority species and habitats.
- ☐ Collected or acquired data through ongoing programs or established new data collection initiatives.
- ☐ Developed models to predict critical changes in habitat and species resulting from climate change.
- ☐ Applied adaptive management approach to filling data gaps.

5.2 Conservation Planning and Management

Issue: Conservation planning is challenging under dynamic climate change scenarios and uncertain species responses. As the PFBC moves forward in implementing this Climate Action Plan, an adaptive management approach will provide a framework for the Commission to proactively update guidance, management practices, and track progress. Additional models, monitoring, and survey data will support understanding of species' climate change vulnerabilities and changes in species' distributions. As these data gaps are filled, this new knowledge will be used to establish conservation priorities, guide the environmental review process and permitted activities, and evaluate or revise Commission operations.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
5.2	Strategy: Apply data to develop updated conservation priorities for at-risk and rare species (i.e., Species of Greatest Conservation Need) with implications of climate change on life-history, survival, and habitats A. Evaluate sampling schedules, protocols, and locations to ensure effective and efficient collection of targeted species. B. Protect PFBC properties from loss of valuable timber and associated revenues.	5.2.1 Review Pennsylvania Wildlife Action Plan, species action plans, and species recovery plans to ensure climate change impacts are considered.	Immediate action (≤ 2 yrs)
		5.2.2 Apply PFBC species Climate Change Vulnerability index ratings for priority conservation actions.	
		5.2.3 Use updated species status and distribution data to evaluate and inform environmental review procedures.	
		5.2.4 On PFBC properties, develop tree species management plans to guide timber harvests and plant climate adaptive tree species.	
		5.2.5 Incorporate climate change concerns into permit and environmental review processes.	
		5.2.6 Apply results chains (Margoluis et al., 2013) and outcome-based methods for guiding and implementing management strategies.	

		5.2.7 Develop within the State Wildlife Action Plan progress reporting to track PFBC progress implementing the climate action plan goals, strategies, and actions.	Long-term action (>2 yrs)
		5.2.8 Update sampling schedules, protocols, and quality assurance procedures in response to changing environmental conditions and data availability.	

Responsible PFBC Staff	**Partners and Cooperators**
• Bureau of Fisheries • Bureau of Administration, Property Services	• NatureServe • NECASC • Non-governmental organizations • PADCNR • PNHP • PGC • Universities and research institutions

Progress Checklist

- ☐ Coordinated with partners (e.g., PA Game Commission) on Wildlife Action Plan SGCN priorities for climate change vulnerability assessments.
- ☐ Conducted climate change vulnerability index assessments for priority SGCN.
- ☐ Worked with Northeast Climate Adaptation Science Center and other institutions for information on climate change effects on priority Pennsylvania SGCN and habitats.
- ☐ Evaluated (on a recurring basis) sampling schedules, protocols, and field conditions and adapted for changing conditions.
- ☐ Developed quality control measures for data collection and comparability.
- ☐ Developed and implemented a tracking protocol for Climate Action Plan progress.
- ☐ Published regular reports on progress in meeting Climate Action Plan Goals.

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6. Communications

6.1 Public Outreach and Staff Inreach

Issue: To inform and secure the safety of anglers, boaters, partners, and staff in rapidly changing conditions under an altered climate will require clear, timely communications across multiple platforms and media formats. As the PFBC implements climate adaptation and resiliency measures, these communications will be essential to inform the public regarding adjustments to administrative and field operations, and the importance of these activities for long-term securement of our trust species and their habitats.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
6.1	Strategy: Develop timely and appealing outreach materials to promote angler, boater and staff safety, and advance knowledge of climate change impacts to PFBC trust species and their habitats.	6.1.1 Develop social media, web-based materials, public service announcements, and other materials to inform anglers and boaters of potentially unsafe conditions in a changing climate.	Immediate action (≤ 2 yrs)
		6.1.2 Engage youth and adults in climate change education through formal classroom activities (e.g., Trout in the Classroom, Aquatic Wild, Pennsylvania-specific aquatic resource lessons), informal aquatic resource outreach and education programs, angler education programs, and public outreach events.	
		6.1.3 Use internal messaging to inform staff, volunteers, and instructors of potential safety concerns and approaches to minimize or avoid risks from a changing climate.	
		6.1.4 Develop appealing non-technical materials to inform anglers, boaters, program participants and the public of conservation and stewardship actions that support PFBC trust	

		species, climate adaptation, and resiliency.	
		6.1.5 Coordinate climate change messaging with local, state, and federal agencies for shared interests.	
		6.1.6 Develop a standard lexicon of climate change terminology for use by PFBC staff and in all media materials.	
		6.1.7 Include climate change relevant information in PFBC outreach materials (e.g., PLAY magazine articles, PA Boating Handbook, Summary Book, brochures)	
		6.1.8 Incorporate standard climate change adaptive safety measures and messaging throughout the Commission.	Long-term action (>2 yrs)

Responsible PFBC Staff	**Partners and Cooperators**
• Bureau of Outreach, Education and Marketing • Bureau of Fisheries • Bureau of Administration, Information Technology • Bureau of Boating	• Boating Education Cooperators • K-12 Schools • County Conservation Districts • Local and state media • NPS • PA Sea Grant • PGC • PADCNR • PADEP • USACE • USFWS • USGS

Progress Checklist

- ☐ Developed portfolio of climate change and safety messaging materials across multiple platforms.
- ☐ Worked with other agencies for coordinated climate change messaging.

7. Safety

7.1 Employee Safety

Issue: Prolonged growing season and warmer temperatures may increase frequency of work-related diseases (e.g., tick borne illness, skin cancer) and increased risks of heat-related illnesses (e.g., dehydration, fatigue, heat exhaustion, heat stroke), especially for field staff. Increased heat and humidity could degrade air quality with human health implications, especially for people with cardiovascular disease or respiratory conditions.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
7.1	Strategy: Provide training and resources for staff to safely perform their jobs in a changing climate.	7.1.1 Continue to adapt and develop new field protocols and safety guidelines (as needed) and communicate updates to staff.	Immediate action (≤ 2 yrs)
		7.1.2 Continue to provide staff training, including advanced wilderness first-aid for field conditions, specialized materials, supplies, and equipment (e.g., protective clothing, air conditioning, insect repellant) to minimize impacts of a more extreme climate.	
		7.1.3 Continue to encourage staff to report field-related safety concerns and incidents in a timely manner.	

Responsible PFBC Staff	Partners and Cooperators
• Executive Office, Human Resources • All Bureaus	• PADLI • PDH

Progress Checklist

- ☐ Developed guidance and training for staff regarding policies for workplace and field conditions.
- ☐ Communicated appropriate guidance and training to staff (including wilderness emergency care) to understand and successfully adapt to workplace and field conditions.
- ☐ Provided staff with supplies and equipment for safely working in extreme conditions.

7.2 Safe Recreation

Issue: More frequent high precipitation events, extreme storms, flashier waterways with swift water, and extreme temperatures (both hot and cold) will increase risks to anglers and boaters. These risks include the following:

- A potentially prolonged boating season that may see more days with people on the water, yet early and late season water temperatures may be life-threatening due to hypothermia.
- Extreme events will increase demand for water rescue training for first responders.
- Attendees of PFBC's classes and events held in outdoor settings will be subject to increased health and safety hazards due to elevated temperatures and increased potential for severe storms.
- PFBC facilities, such as boat launches, may be damaged or unusable for longer periods due to floods and high flows, or extreme low-water events.
- An increasing number and intensity of storms will produce a greater amount of downed tree limbs, trees, and other debris, posing immediate hazards at locations where people may congregate during storms (e.g., boat access areas, parking lots, pavilions), as well as increasing the number of "strainers" (i.e., log jams) along designated water trails.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
7.2	Strategy: Plan and implement measures to ensure angler and boater safety in a changing climate.	7.2.1 Increase public awareness of high-water and low-water hazards and boating safely during these events.	Immediate action (≤ 2 yrs)
		7.2.2 Increase public awareness of hazards associated with marginal ice conditions on lakes and ponds.	
		7.2.3 Shift outdoor education events to early morning or evenings to avoid excessive heat.	
		7.2.4 Work with partners to ensure dam monitoring, dam safety, rapid identification and repair of faulty infrastructures, and communication of hazards to the public and staff.	
		7.2.5 Regularly evaluate PFBC facilities for tree and debris hazards and effectively communicate any hazards to the public.	

		7.2.6 Work with water trail groups to identify responsibilities and authorities for tree and debris removal on water trails after storm events and communicate trail alerts and safe boating practices.	
		7.2.7 Enhance the water rescue program through expanded training and partnerships.	
		7.2.8 Upgrade infrastructure at PFBC facilities (e.g., boat ramps, docks, bridges, stormwater facilities) for resiliency to extreme events.	
		7.2.9 Continue managing erosion, sediment, and sand movement at PFBC accesses and marinas along Lake Erie.	
		7.2.10 Assist, via grants and other resources, public and private fishing and boating facilities in the Delaware River tidal zone.	Long-term action (>2 yrs)
		7.2.11 Adjust allocation of Waterways Conservation Officers and other PFBC staff and assets accordingly, to accommodate increased risks.	
Responsible PFBC Staff		**Partners and Cooperators**	
• Bureau of Administration • Bureau of Boating • Bureau of Engineering • Bureau of Law Enforcement • Bureau of Outreach, Education and Marketing		• Municipalities and planning commissions • Non-governmental organizations (e.g., Conservancies) • PADCNR • PEMA • Paddling and outfitter groups • Regional heritage areas • USDA-FS, Allegheny National Forest • Watershed associations	

- ☐ Increased awareness by the angling and boating public of risks contributed by climate change.
- ☐ Reviewed and assessed PFBC access sites for potential hazards brought about by climate change effects on water levels.
- ☐ Developed communication guidelines for making public aware of increased hazards.
- ☐ Implemented additional safety training courses associated with climate change risks.
- ☐ Identified faulty infrastructure in need of attention.
- ☐ Developed plans for repairing infrastructure and replacing it with more resistant materials.
- ☐ Developed plans for staff time and assets according to highest priorities.

8. Agency Assets and Staffing

8.1 Staffing

Issue: Increased emphasis on climate change planning and management within the PFBC will require adapting staff capacity and tasks, including addition of specialists, to fulfill climate change priorities.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
8.1	Strategy: Plan and implement measures to ensure sufficient PFBC staff and assets necessary to proactively address Climate Action Plan goals.	8.1.1 Redirect staff time, as necessary, to prioritize climate change initiatives.	Immediate action (≤ 2 yrs)
		8.1.2 Encourage PFBC employees to reduce their individual carbon footprints by supporting telework, virtual meeting participation, carpooling incentives, and bike-to-work initiatives.	
		8.1.3 Increase staff capacity to meet new demands of implementing climate change strategy activities.	Long-term action (>2 yrs)
Responsible PFBC Staff		**Partners and Cooperators**	
• Executive staff • All Bureaus		• PFBC internal issue	
Progress Checklist			

- ☐ Prioritized climate change actions and identified staff with skillsets to implement actions.
- ☐ Identified gaps in current staff capacity requiring new positions.
- ☐ Developed workforce management plan for building and maintaining staffing capacity to support PFBC's climate change initiative.
- ☐ Developed or revised position descriptions accordingly.
- ☐ Hired staff to address climate change actions.
- ☐ Developed and implemented incentives to support employee green behavior.

8.2 Workplace Resilience

Issue: PFBC properties, including buildings, heating, ventilation, and air conditioning (HVAC) and stormwater systems, will be subjected to temperature and precipitation extremes, stressing facilities, increasing maintenance, and decreasing facility functional expectancy. Loss of power, telecommunications, and other utilities, as well as physical damage to buildings and grounds, will lead to short-term and long-term closures.

STRATEGY#	STRATEGY DESCRIPTION	ACTIONS	ACTION TIMELINE
8.2	Strategy: Build functional capacity and resiliency into PFBC facilities and infrastructure to withstand more extreme weather events. A. Minimize climate change impacts on infrastructure, habitat and water quality using innovative and non-conventional approaches (e.g., green infrastructure, innovative stormwater management), as well as standard practices such as streambank stabilization.	8.2.1 Increase workplace resilience to extreme weather events. Develop guidelines pertaining to such events as related to workplace closures, staff leave, and field work, and communicate those guidelines to staff.	Immediate action (≤ 2 yrs)
		8.2.2 A. Investigate and support use of alternative/green infrastructure to reduce stormwater runoff from PFBC properties. B. At PFBC facilities, assess use of pervious pavement, green roofs, and rain gardens.	
		8.2.3 Promote alternative surface treatments (e.g., pervious asphalt, concrete).	
		8.2.4 Upgrade appliances, lighting, and HVAC system to energy efficient models and consolidate office facilities where feasible.	

		8.2.5 Incorporate green infrastructure into new facilities.	Long-term action (>2 yrs)
		8.2.6 Proactively maintain stormwater systems by implementing preventative maintenance schedules on PFBC properties.	
		8.2.7 Upgrade PFBC passenger vehicle fleet, boat motors, and generators to hybrid, electric, or low-emitting models.	

Responsible PFBC Staff	**Partners and Cooperators**
• All Bureaus	• PFBC Internal issue which may require contractual assistance.

Progress Checklist

- ☐ Upgraded PFBC facilities for resilience to climate change.
- ☐ Upgraded PFBC passenger vehicle fleet, trucks, boat motors, and other equipment to zero or low-emission models.
- ☐ Assessed PFBC facilities for use of pervious pavement, green roofs, rain gardens and similar measures.
- ☐ Prioritized PFBC facilities for upgrades and green infrastructure for improved stormwater runoff and erosion control.

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