PUBLIC REVIEW DRAFT

Threats
REQUIRED ELEMENT 3

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THREATS

Chapter Recap

Pennsylvania's Species of Greatest Conservation Need (SGCN) and their habitats continue to be directly and indirectly impacted by a broad range of threats including:

- residential and commercial development
- energy production
- invasive species, genes and diseases
- transportation and utility service corridors
- pollution
- climate change

✓ New and emerging threats to SGCN and their habitats include:
  - utility-scale solar power generating facilities
  - data centers contributing to habitat loss and fragmentation, water and energy consumption

✓ Climate change, with increased temperatures, intensive precipitation interspersed with drought conditions, is anticipated to continue directly and indirectly impacting fish, wildlife, and forest ecosystems in Pennsylvania.
  - Overall, climate change impacts are anticipated to be negative for fish, wildlife, and their habitats, though some species may be unaffected, and others may benefit from these changes.

✓ Across the northeast U.S., the top five threats to Regional Species of Greatest Conservation Need include (Terwilliger Consulting and the Northeast Fish and Wildlife Diversity Technical Committee 2023):
  - pollution
  - climate change
  - invasive and problematic species, genes, and diseases
  - natural system modifications
  - biological resource use
  - residential and commercial development

Introduction

Recovering and protecting Pennsylvania's Species of Greatest Conservation Need (SGCN) and their habitats is predicated on identifying the type and severity of threats impacting their survival and condition. In Pennsylvania and northeast U.S., threats are diverse and dynamic, and changes can happen rapidly with introduction of disturbances such as invasive species, diseases, or quickly emerging technologies. Beyond these imperilments, broader landscape threats such as climate change can affect fish and wildlife, confounding our understanding of specific threats to species. Thus, multiple factors may be simultaneously influencing a species' survival which can obscure identifying specific imperilments and appropriate remedial conservation actions.

Pennsylvania's SGCN populations often extend throughout the northeast U.S. and beyond, so we need to be concerned about threats beyond the state's border. Identifying and understanding current threats and proactively recognizing new threats, both in Pennsylvania and regionally, over the next 10 years is vital to securing Pennsylvania's SGCN. In this section, we first summarize threats in the northeast U.S. and then generally describe threats to Pennsylvania's SGCN and their habitats. Species-specific threats are described in Chapter 1-Species and within individual species accounts.

Threats Classification

Categorizing threats can help explain sources of imperilment, which is useful for planning, prioritizing, implementing, and assessing conservation actions to recover SGCN (Salafsky et al. 2024). Thus, in this 2025-35 Pennsylvania Wildlife Action Plan (PA WAP or Plan), as with the 2015-25 PA WAP, we use a standard threats classification with two classification levels which include a broader "Level 1" direct-threat classification, and a more specific "Level 2" classifications (Table 3.1; Salafsky et al. 2008; Master et al. 2012; IUCN 2022; Salafsky et al. 2024). For 2025, we also added a Level 1 category "Unknown/Undetermined" to accommodate situations where a threat is not well-understood (Lamarre et al. 2021; Crisfield et al. 2022). For consistency, we present the northeast U.S. and Pennsylvania threats discussion within this classification framework using primarily Level 1 categories, with Level 2 applied when sufficient information is available.

Table 3.1. Threats classification for the 2025-35 Pennsylvania Wildlife Action Plan, adopted from International Union for Conservation of Nature (IUCN 2022) (Level 1 and Level 2), and Conservation Measures Partnership (CMP) (Salafsky et al. 2008; Salafsky et al. 2024).

IUCN Code	Level 1 Description	IUCN Code	Level 2 Description
1	Residential and Commercial Development	1.1	Housing and Urban Areas
		1.2	Commercial and Industrial Areas
		1.3	Tourism and Recreational Areas
2	Agriculture and Aquaculture	2.1	Annual and Perennial Non-timber Crops
		2.2	Wood and Pulp Plantations
		2.3	Livestock Farming and Ranching
		2.4	Marine and Freshwater Aquaculture
3	Energy Production and Mining	3.1	Oil and Gas Drilling
		3.2	Mining and Quarrying
		3.3	Renewable Energy
4	Transportation and Service Corridors	4.1	Roads and Railroads
		4.2	Utility and Service Lines
		4.3	Shipping Lanes
		4.4	Flight Paths
5	Biological Resource Use	5.1	Hunting and Collecting Terrestrial Animals
		5.2	Gathering Terrestrial Plants
		5.3	Logging and Wood Harvesting
		5.4	Fishing and Harvesting Aquatic Resources
6		6.1	Recreational Activities

	Human Intrusions and Disturbance	6.2	War, Civil Unrest, and Military Exercises
		6.3	Work and Other Activities
7	Natural System Modifications	7.1	Fire and Fire Suppression
		7.2	Dams and Water Management/Use
		7.3	Other Ecosystem Modifications
8	Invasive and Other Problematic Species, Genes and Diseases	8.1	Invasive Non-native/Alien Species/Diseases
		8.2	Problematic Native Species/Diseases
		8.3	Introduced Genetic Material
		8.4	Problematic Species/Diseases of Unknown Origin
9	Pollution	9.1	Domestic and Urban Waste Water
		9.2	Industrial and Military Effluents
		9.3	Agricultural and Forestry Effluents
		9.4	Garbage and Solid Waste
		9.5	Airborne Pollutants
		9.6	Excess Energy
10	Geological Events	10.1	Volcanoes
		10.2	Earthquakes/Tsunamis
		10.3	Avalanches/Landslides
11	Climate Change and Severe Weather	11.1	Habitat Shifting or Alteration
		11.2	Droughts
		11.3	Temperature Extremes
		11.4	Storms and Flooding
12	Other Options	12.1	Other Threat
		12.2	Resource Needs
		12.3	Education and Outreach
		12.4	Administrative Needs
		12.5	State Specific Issues
		12.6	Unknown
	None or Unknown/Undetermined		

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Northeast Region-Threats to Fish, Wildlife, and Habitats

[Adapted from Terwilliger Consulting and NEFWDTC 2023, Staudinger et al. 2024]

Background

After publishing the 2005 State Wildlife Action Plans, in the northeast U.S. the need became evident for comprehensive regional assessments to advance species conservation. Among these assessments were the need to better understand threats to fish, wildlife, and their habitats. In subsequent years, the Northeast Association of Fish and Wildlife Agencies (NEAFWA), Northeast Fish and Wildlife Diversity Technical Committee (NEFWDTC) enlisted studies to comprehensively catalogue and evaluate threats to Species of Greatest Conservation Need (SGCN) and their habitats. These regional reviews compiled and assessed Regional Species of Greatest Conservation Need (RSGCN) (Terwilliger Consulting and NEFWDTC 2013; 2023), habitats (Anderson and Olivero Sheldon 2011; Anderson et al. 2013a; 2013b; 2013c; 2023) and climate change impacts on SGCN and habitats supported by the U.S. Geological Survey (USGS), Northeast Climate Adaptation Science Center (NECASC) (Staudinger et al. 2015; 2024).

Fig. 3.1. Northeast Association of Fish and Wildlife Agencies' (NEAFWA) geography in the northeastern United States.

Northeast U.S. Threats

[Adapted from Terwilliger Consulting, Inc. (TCI) and Northeast Fish and Wildlife Diversity Technical Committee (NEFWDTC) 2023]

The northeast U.S. (Maine to West Virginia) includes Pennsylvania (Fig. 3.1) and is generally characterized by dense human population centers near the Atlantic Coast with threats associated with human populations and development (Moore et al. 1997). Dense human population centers, habitat loss, degradation, and fragmentation are concerns though portions of the region are heavily forested (e.g., northcentral Pennsylvania, the Adirondack region of New York). Fish, wildlife, and their habitats in the northeastern U.S. are impacted by numerous threats (TCI and NEFWDTC 2023) and overarching climate change effects (Staudinger et al. 2024).

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The top five threats to northeast Regional Species of Greatest Conservation Need (RSGCN) were identified by TCI and NEFWDTC (2023) as:

- ✓ Pollution
- ✓ Climate change
- ✓ Invasive and problematic species, genes, and diseases
- ✓ Natural system modifications
- ✓ Biological resource use
- ✓ Residential and commercial development

Pollution

Pollution is by far the most common Northeast regional threat, impacting 81% (338 species) of the RSGCN and proposed RSGCN. Many of the taxonomic groups that are most heavily affected by pollution are aquatic; pollution imperils the entire diversity of stoneflies, mayflies, marine invertebrates, freshwater mussels, fireflies, and diadromous fish species. Though pollution does not impact all freshwater fish or lepidopterans (i.e., butterflies and moths), these two groups have the largest number of species affected by pollution.

Climate Change

Climate change is a rapidly growing concern in the northeast, impacting 73% (305 species) of the RSGCN and proposed RSGCN. All species in the stonefly, reptile, mayfly, marine invertebrate, mammal, and caddisfly taxonomic groups are considered vulnerable to climate change, highlighting these groups' sensitivity to future changes. As knowledge of climate change evolves, it is likely additional species are affected by climate change in ways we do not yet understand.

The Northeast is warming and sea levels are rising faster than the global average making the region a global "hot spot" (Staudinger et al. 2024). These changes are not uniform within the region; climate-sensitive RSGCN will be impacted differently depending upon the severity of the local climate. Extreme events (e.g., heat waves, storms, droughts, pest outbreaks) are occurring with increasing frequency and disrupting habitats and ecological processes supporting RSGCN (Staudinger et al. 2024).

Invasive and Problematic Species, Genes, and Diseases

More than half of the 2023 RSGCN species and Proposed RSGCN list – 55%, or 228 species – are imperiled by interactions with invasive or problematic species, face complications due to genetic integrity, are impacted by disease, or have natural biological limitations that reduce recovery potential. This includes all reptiles and marine invertebrates, and all but one mammal. Though not all freshwater fish, mussels, and lepidopterans are associated with this threat, these taxonomic groups contributed as many species, if not more, as mammals. Many invertebrate groups contained five or fewer species for which this threat is known to be a cause of decline. This is likely due to data deficiencies, and a limited understanding of how these threats impact these groups, rather than an indication that these groups are not sensitive to these threats.

These threats are diverse, touching on invasion ecology, competition and predation, parasitism, population and conservation genetics, epizoology, and other ecological and biological concepts. The breadth of these topics makes it difficult to generalize overall trends and patterns within the Northeast region at this topmost level. The impacts of these threats are not concentrated within certain habitat types or taxonomic groups; instead, they are found almost universally.

Natural System Modifications

A total of 198 species – 47% –of the 2023 RSGCN and Proposed RSGCN list are impacted by Natural System Modifications. Diadromous fish, reptiles, tiger beetles, and odonates (e.g., dragonflies, damselflies) are the most heavily impacted, with more than 80% of the species in each of these groups known to be imperiled by these threats. The largest number of species impacted are lepidopterans, freshwater mussels, and freshwater fish. For the other invertebrate groups and marine fish, very few species are tagged to this threat, both in terms of total numbers and proportion of the taxonomic group. This is likely due to data deficiencies and a limited understanding of how natural system modifications can impact these groups, rather than an indication that these groups are not sensitive to these threats.

Natural System Modifications may not eliminate a habitat but are a threat to many RSGCN and proposed RSGCN because they alter ecosystem structure and function. Habitat degradation, or other impacts on quality and condition, can make habitats unsuitable for more sensitive species. These modifications can alter important processes, such as disturbance and habitat succession (i.e., growth from young to mature habitats), changing the functionality of a habitat over long time scales. Other modifications may fragment habitats, preventing species movements and isolating populations.

Biological Resource Use

Biological Resource Use impacts 48% (200) of the 2023 RSGCN and Proposed RSGCN. This includes all members of the marine invertebrate, reptile, and marine fish taxonomic groups. Mammals, amphibians, and diadromous fish are also largely included in the species impacted by this threat. Most species known to be impacted by Biological Resource Use are vertebrates or are harvested for human consumption. This threat likely has less impact on most terrestrial invertebrate species, but the smaller numbers may also reflect data deficiencies in these groups.

Biological Resource Use refers to the removal of biotic components of the environment for human consumption or benefit. This includes hunting and fishing, bycatch in regulated animal harvest, persecution and management of species considered dangerous or problematic, unregulated collection of wildlife for any purpose, and the harvest of timber and other plant products. Biological Resource Use impacts on RSGCN and Proposed RSGCN are often direct, physically removing individuals from the ecosystem. The exception to this is logging, which indirectly impacts many species by removing, fragmenting, and otherwise altering habitat, impacting individuals, the population, community, and ecosystem.

Residential and Commercial Development

Residential and Commercial Development does not rank as highly as the other threats; however, it impacts at least 40% (169) of RSGCN and Proposed RSGCN and remains a major concern in the Northeast. All tiger beetles are impacted by this threat, as are most reptiles and bees. Lepidopterans, birds, and mammals provide the largest number of species impacted by development, though smaller proportions of these groups are impacted. Aquatic species appear to be less impacted by this threat, potentially since development more directly impacts terrestrial habitats. However, data deficiencies for many invertebrate taxonomic groups likely make it appear that development is not a concern for these species but may reflect insufficient information.

The most direct impact of development is habitat loss and alteration. Habitat loss can eliminate key areas or result in decreased habitat area, which in turn restricts the number of individuals and species able to be supported by the remaining habitat. Development also fragments habitats into smaller patches. Fragmentation alters the arrangement of habitat, contributing to reduced habitat area, increased patch isolation, and the creation of more “edge” habitats. Smaller habitat patches support less diverse wildlife communities and fewer individuals due to limited resource availability (Laurance et al. 2002; Haddad et al. 2015). Isolation between patches restricts the movement of individuals between patches, which has consequences for metapopulation dynamics and genetic integrity (Lande 1988; Laurance et al. 2002). Increased edge habitat can change the community structure by altering patterns of energy flows and resource availability while also creating space for unique interactions between species that do not usually interact (Laurance et al. 2002; Ries et al. 2017). These changes to habitat structure impact ecosystem processes, such as nutrient cycles, pollination, and succession, and change the resilience of the ecosystem (Haddad et al. 2015).

Pennsylvania-Threats to Habitats and Species of Greatest Conservation Need

In Pennsylvania, as throughout the northeast region, understanding threats to SGCN and their habitats is important for developing appropriate conservation strategies and actions. In this section, we describe threats at the state-scale, with general descriptions of effects on SGCN and habitats (Table 3.2). Specific analysis and discussion of threats to SGCN are provided in Chapter 1-Species, and Chapter 2-Habitats, and in this chapter.

Residential and Commercial Development

Converting Pennsylvania’s native habitats to residential, industrial, transportation or other human uses significantly threatens SGCN. Beyond direct habitat loss, associated habitat stressors such as air, water and land pollution, habitat fragmentation, enhanced pathways for invasive species and diseases, and related factors can result from changing land use and contribute to further SGCN imperilment.

Activities, such as converting native forests and other habitats to residential development, can be considered a “threat” but the interrelatedness between habitat and land use is more appropriately discussed in Chapter 2-Habitats, which also includes SGCN and habitat associations. Threats to habitats can also affect fish and wildlife distribution and abundance. Species-specific threats, which may include effects of land use change, are described in Chapter 1-Species. Beyond impacts to habitats, additional threats such as illegal harvest or shift in species range from climate change can directly imperil SGCN (Table 3.3).

Table 3.2. Threats to key habitats in Pennsylvania, as discussed in this section, unless otherwise noted.

IUCN Code Level 1	Habitat / Threat Description	Forests	Grassland	Wetlands & Seasonal Pools	Lakes and Ponds	Rivers and Streams	Coastal Zones	Distinctive [Unique] Habitats
1, 4	**Residential and Commercial Development**	*See Chapter 2-Habitats*						
	Tourism and Recreational Areas	●				●		
2	**Agriculture and Aquaculture**							
	Traditional Agriculture	●	●	●	●	●		
3	**Energy Production and Mining**							
	Hydraulic Fracturing	●		●	●	●		●
	Wind Energy (Ridgetops)	●				●		●
	Wind Energy (Offshore)						●	
	Biomass	●						●
	Hydropower					●		
	Utility-scale Solar	●		●				
	Data Centers	●		●				
4	**Transportation and Service Corridors**							
	Roads and Railroads							
	Utility and Service Lines	●	●	●		●	●	
	Shipping Lanes							
5	**Biological Resource Use**							
	Forestry (Logging and Wood Harvesting	●		●	●	●		
6	**Human Intrusions and Disturbance**							
	Recreational Activities	●				●		
7	**Natural System Modifications**							
	Dams			●		●		
	Culverts					●		
	Water Use			●	●	●		
	Fire Suppression	●	●	●				●

8	**Invasive and Other Problematic Species, Genes and Diseases**	⬤	⬤	⬤	⬤	⬤	⬤	⬤
9	**Pollution**							
	Air	⬤		⬤	⬤	⬤	⬤	⬤
	Water			⬤	⬤	⬤	⬤	
	Land[1]	⬤	⬤	⬤		⬤		
11	**Climate Change and Severe Weather**	⬤	⬤	⬤	⬤	⬤	⬤	⬤

[1]Abandoned Mine Lands

Table 3.3. Direct threats to Species of Greatest Conservation Need (SGCN) not included in Table 3.2 and discussed later in this chapter.

IUCN Code Level 1	Threat Description	SGCN
5	Biological Resource Use (Illegal harvest)	⬤
8	Invasive and Other Problematic Species, Genes and Diseases	⬤
11	Climate Change	
	Range Shifts	⬤
	Phenological Changes	⬤
---	Disturbances (e.g., noise)	⬤
---	Pesticides	⬤

Agriculture

In Pennsylvania traditional agriculture practices have contributed to landscape-scale changes in native habitats, which can have short-term and enduring fish and wildlife impacts. Bird populations, especially grassland and shrubland birds, have been linked to changes in agricultural practices and land use (Murphy and Moore 2003) and even in restored watersheds, long-term impacts of historical agricultural practices have been observed (Harding et al. 1998).

Agriculture categories, based on the IUCN categories (Table 3.1), include a broad range of harvest practices such as non-timber crops, wood and pulp plantations, livestock farming and ranching and aquaculture activities. Of these categories, traditional agriculture (i.e., row crops, livestock farming and ranching) is major activity in Pennsylvania encompassing 48,400 farms operating on 7.1 million acres (2.87 million hectares) (USDA-NASS 2025) or approximately 24.8% of land in the Commonwealth (Chapter 2-Habitats). Of this agricultural land, primary crops are hay and haylage (1.2 million acres; 0.48 million hectares), corn (1.01 million acres; 0.41 million hectares), soybeans (580,000 acres; 234,723 hectares) and wheat (260,000 acres; 105,221 hectares) (USDA-NASS 2025).

Natural habitats impacted by agricultural practices may result from draining wetlands, clearing forests, and damage to riparian zones by livestock, all of which can directly affect fish and wildlife distribution and abundance. Indirect agricultural impacts (i.e., stressors) on rivers, streams, ponds, and seasonal pools may include point-source runoff of excessive nutrients from livestock facilities and nonpoint source soil erosion.

Energy Production and Mining

Pennsylvania's history is rich with energy resources development including oil, coal, hydropower, nuclear power and, in recent decades, natural gas extraction from the Marcellus and Utica Shale geologic formations, as well as renewable sources (e.g., wind, solar) (Johnson et al. 2010, Ladislaw and Hyland 2018, Pennsylvania State Archives 2026). Additionally, there is substantial potential growth in renewable energy development (Ladislaw and Hyland 2018). Developing these resources contributes to economic and energy security yet can degrade habitats and directly impact fish and wildlife populations (Johnson et al. 2010). Here we provide an overview of major energy resources and general effects on SGCN and their habitats.

Shale Gas Development

Pennsylvania natural gas development and production increased rapidly over the last 20 years with the use of horizontal drilling and hydraulic fracturing technologies to access the Marcellus and Utica shale formations (known as "unconventional" gas production). Today, Pennsylvania is the second largest producer of natural gas in the United States (PA DEP 2024). While the pace of gas development has slowed compared to the boom years of 10-15 years ago, new well drilling continues. In 2025, 578 wells were drilled in Pennsylvania, including 444 unconventional wells and 134 conventional wells (PA DEP 2026). New natural gas pipelines have been and continue to be constructed to transport the large volume of gas produced in Pennsylvania and in neighboring states (U.S. Energy Information Administration 2026).

Gas development poses risks to fish and wildlife habitat. For terrestrial species, loss and fragmentation of habitat, especially forests, is a considerable concern (Brittingham and Goodrich 2010; Drohan et al. 2012; Brittingham et al. 2014; Dunscomb et al. 2014). Many well pads are constructed in forest cover (Drohan et al. 2012), including areas of core forest (i.e., forest habitat over 328 feet (100 m) from edge), with areas of intensive shale gas development overlapping the large core forests of northern Pennsylvania (Brittingham and Goodrich 2010; Drohan et al. 2012). Two independent studies in Pennsylvania estimated the average area of disturbance by well pads and associated infrastructure (e.g., roads, water impoundments, pipelines, compressor stations) at 21.2 acres (8.58 ha) (Johnson et al. 2010) and 24.5 acres (9.9 ha) (Langlois et al. 2017). A study conducted in northcentral Pennsylvania, supported by the State Wildlife Grants Program, found that forest interior birds were significantly less abundant near shale gas well pads than in interior forest (Barton et al. 2016). Forest loss and fragmentation are substantial threats to SGCN that require interior forest habitat and are sensitive to edge effects, such as American Goshawk and Scarlet Tanager (Brittingham and Goodrich 2010; Johnson et al. 2010; Farwell et al. 2016).

Pipelines needed to transport natural gas to market are also permanent fragmenting features. Rights-of-way for gathering pipelines range from 30 to 150 feet (9.1 to 45.7 m) in width, while transport pipelines have rights-of way widths of up to 200 feet (61 m) (Johnson et al. 2011). The impacts of pipelines on interior forest are substantially greater than impacts from the well pads themselves, through direct habitat loss and creation of new forest edges (Slonecker et al. 2012; Langlois et al. 2017).

Shale gas development can impact the quantity and quality of surface waters important to aquatic species (Brittingham et al. 2014; Dunscomb et al. 2014). Each Marcellus shale gas well requires from 3 to 6 million gallons (11.3 to 22.6 million liters) of water to complete the hydraulic fracturing process (USDOE-NETL 2013). Water withdrawals of this magnitude can stress local streams and rivers, especially during times of low-flow or drought (Weltman-Fahs and Taylor 2013; Brittingham et al. 2014). The construction of well pads, roads, and pipelines can cause increased stream sedimentation (Entrekin et al. 2011). Stream crossings of pipelines and roads also contribute to sedimentation, as well as fragment stream habitat for species such as Brook Trout (Weltman-Fahs and Taylor 2013). Produced or “flowback water” from wells is high in total dissolved solids, salts, metals, naturally occurring radioactive material, and chemicals used in the fracturing process. Accidental spills of these fluids could significantly affect water quality (Entrekin et al. 2011; Weltman-Fahs and Taylor 2013; Brittingham et al. 2014). To understand the potential impacts to native Brook Trout, Johnson et al. (2010) intersected projected well pad installations with intact – or predicted intact – Brook Trout watersheds as defined by the Eastern Brook Trout Joint Venture. From this assessment, 81.9% of native Brook Trout watersheds were predicted to have Marcellus Shale gas development activities.

As shale gas development in Pennsylvania continues, it remains important to monitor impacts on fish and wildlife at both local and landscape scales. Though many impact minimization gains have been made in the past decade (e.g., limiting footprints with multiple wells drilled on a pad, boring under streams for pipeline crossings, U.S. Fish and Wildlife Service Habitat Conservation Plans, timing restrictions), additional research is needed to develop best management practices (BMPs) for restoring decommissioned sites, refine existing BMPs, and to define areas on the landscape where development can occur with minimal impacts to wildlife.

Wind Energy Development

Wind energy is the state’s largest renewable source for electricity generation. Statewide generating capacity amounts to over 1,500 megawatts (MW) across 27 wind energy projects (U.S. Energy Information Administration 2026). These facilities are concentrated on ridgetops, primarily in southwest-central and northeast Pennsylvania. However, the pace of wind energy growth has slowed substantially in the last decade, with only three new wind energy projects coming into operation since publication of the 2015-25 PA WAP. One additional facility is expected to begin operations in 2026 (Institute for Wind Energy 2024).

The ridges most favorable for wind development also serve as migration corridors, migratory stopover habitat, and breeding sites for several SGCN (e.g., timber rattlesnake, Allegheny woodrat, Golden Eagle). Wind energy project construction can cause habitat loss and fragmentation of contiguous habitat through forest clearing and development of wind turbine pads, buildings, access roads and electrical transmission infrastructure. After construction, wind turbines pose a collision risk to bats and birds.

Post-construction surveys at wind energy facilities in Pennsylvania estimated average mortality to be 4 birds/turbine per year and 25 bats/turbine per year. Passerines (songbirds) comprised 73% of bird mortalities, while migratory tree bats comprised 80% of all bat mortalities; 79% of all bat mortality occurred between July 1 and September 30 (Taucher et al. 2012; Taucher and Librandi Mumma 2016).

The Pennsylvania Game Commission (PGC) encourages wind energy operators to implement voluntary mitigation measures. As bat activity generally decreases as wind speeds increase, these measures can include feathering turbine blades (adjusting the pitch of the blade to stop rotation) when not generating power, increasing turbine cut-in speeds (the wind speed at which blades begin to rotate and power is generated), or a combination of both (Taucher and Librandi Mumma 2016). Additionally, the PGC and wind energy industry cooperatively developed best management practices for Pennsylvania wind energy facilities (PGC 2013), which have been applied at several sites to further reduce negative impacts on wildlife.

The Renewable Energy Wildlife Institute website (https://rewi.org/) contains in-depth summaries of the current state of knowledge of wind energy and wildlife interactions.

Biomass

With over 60% forest habitat and 25% row crop or pasture, opportunities are available in Pennsylvania to develop biomass fuel sources (Klopfer 2011, RCN Project 2007-07; http://rcngrants.org/content/establishing-regional-initiative-biomass-energy-development-early-succession-sgcn-northeast). Historically, in the late 19th and early 20th centuries, Pennsylvania's forests were extensively harvested as a fuel source and for construction materials (MacCleery 1992). In the intervening decades, many of these forests have matured and once again hold potential as a fuel source. As a renewable resource, envisioning biomass harvest as a "threat" is contingent upon how and where this activity would be conducted, as well as associated SGCN. Native species that prefer young forest conditions may benefit from this activity, however, overall, in Pennsylvania, biomass systems using wood from mature forests are considered to have an overall negative impact on SGCN (Klopfer 2011, RCN Project 2007-07). Forest biomass energy modeling projected this source could account for slightly more than 3% of Pennsylvania's energy use (in 2010) (Ciolkosz et al. 2010).

Biomass-generated energy also may originate from non-woody plant materials such as cultivated perennial grasses (McGuire and Rupp 2013). With this source, the effects on native biodiversity would be dependent upon several factors including: the types of plant materials (e.g., native vs. introduced), use of chemical amendments (e.g., herbicides, pesticides), and timing of management activities (i.e., harvesting). If implemented on active agricultural lands, SGCN preferring grasslands may benefit from biomass systems (Klopfer 2011, RCN Project 2007-07). From 2012 to 2017, a regional initiative, NorthEast Woody/Warm-season Biomass Consortium (NEWBio) assessed regional bioenergy potential, specifically warm-season grasses and short-rotation willow (Rosini 2017). One goal of this project was to improve environmental outcomes without competing with food production. Target habitats included floodplains and stream buffers as well as abandoned mine lands and agricultural areas. Currently, it appears this work is localized and, though negative SGCN impacts are possible where monocultures are planted, this activity is not expected to be a substantial statewide threat or benefit to SGCN.

Hydropower

Hydroelectric facilities represent a fraction of the overall major dams in Pennsylvania U.S. Army Corps of Engineers (USACOE)-National Inventory of Dams (NID) (U.S. Army Corps of Engineers-ACOE 2026), yet these facilities and other dams on the Susquehanna River (Fig. 3.2; Fig. 3.3), Lehigh River, and Schuylkill River are of concern for migratory SGCN fishes such as American shad (*Alosa sapidissima*), blueback herring (*A. aestivalis*) and American eel (*Anguilla rostrata*). For American shad in Pennsylvania, dams and their respective fish passage structures often obstruct, impede and delay migrations. Impingement at power plants and turbine mortality also are concerns for SGCN fishes. Additional threats posed by hydroelectric facilities include alteration of freshwater flows and discharge patterns in spawning and nursery habitats, and placement of additional water intakes (Atlantic States Marine Fisheries Commission-ASMFC 1999; Hendricks and Tryninewski 2011). Alteration of fish movement patterns also has a corresponding effect on status and distribution of freshwater mussel SGCN.

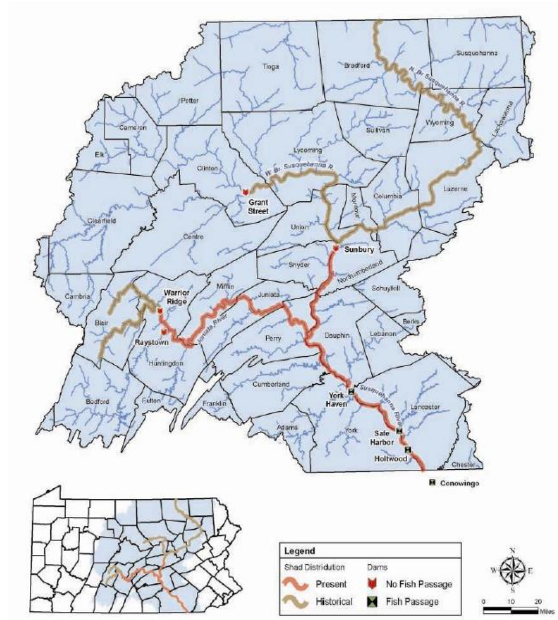

Fig. 3.2. American Shad distribution and dams in the Susquehanna River Basin of Pennsylvania (From Hendricks and Tryninewski 2011).

Utility-scale Solar Development

Utility-scale solar power development has accelerated rapidly in Pennsylvania in recent years, with installed capacity of utility-scale facilities rising from 175.8 megawatts (MW) in 2022 to 1129.4 MW as of February 2026 (U.S. Energy Information Administration 2023, 2026a). While solar electric generation is a relatively clean source of renewable energy that will aid in reducing carbon dioxide and other greenhouse gas emissions, data are scarce regarding impacts of utility-scale solar installations on wildlife, particularly in the northeastern U.S. Solar photovoltaic systems typically require between 4 and 8 acres of land and approximately 3,000-4,000 solar panels per MW of electric generating capacity (Pennsylvania Public Utility Commission-PA PUC 2024; Drohan et al. 2026). The average size of utility-scale solar installations in Pennsylvania is approximately 218 acres (Intersolar and Energy Storage North America 2024), with the largest solar project in the state covering 1300 acres (AES 2026). Therefore, habitat loss and fragmentation are concerns, but are highly dependent on the habitat type and condition under consideration (Hernandez et al. 2014; Gómez-Catasús et al. 2023). Typically, most utility-scale solar is installed in open habitats such as agricultural land, where terrain and vegetation are more suitable for development in comparison to forested areas. While few SGCN inhabit row crops (with the exceptions of Horned Lark (*Eremophila alpestris*) and Vesper Sparrow (*Pooecetes gramineus*)), species inhabiting agricultural grasslands and early successional habitat could be impacted. Flying wildlife (birds, bats, and insects) are also at risk of collision with solar panels and other associated infrastructure, such as power lines and fences surrounding solar facilities (Smallwood 2022). Given the forecasted continued growth in solar energy development (Solar Energy Industry Association 2026; U.S. Energy Information Administration 2026b), it will be important to site and design solar projects in ways that minimize impacts to SGCN and their habitats.

Data Centers: An Emerging Issue

Growth in the use of artificial intelligence is driving an increase in data center development (U.S. Energy Information Administration 2026b). The exact number of data centers currently operating in Pennsylvania is difficult to determine, as no state agency currently tracks this information (Yencha 2025). However, several privately run websites report the number of active and planned data centers. These sources indicate between 72 and 126 data centers are operating in Pennsylvania as of May 2026 (Data Center Map 2026; Data Center Proposal Tracker 2026). An additional 4 facilities are under construction, and 62 are proposed (Data Center Proposal Tracker 2026). Proposed and under construction facilities would occupy over 30,000 acres in total if fully developed (Data Center Proposal Tracker 2026). The largest currently proposed data center in Pennsylvania would have a footprint of 1,800 acres, although larger data centers are operating or have been proposed in other parts of the country.

As with other types of industrial development, data centers permanently alter the land on which they are built, practically eliminating any previously existing wildlife habitat. Their construction and operation are accompanied by an increase in impervious surfaces, with potential impacts on local hydrology and water quality. Light and noise pollution also increase over baseline levels, with potential impacts to wildlife beyond the footprint of the facility (Shannon et al. 2016, Pease and Gilbert 2025).

Data centers use significant amounts of water directly, primarily to cool computer processors through evaporative cooling, but also indirectly through water required to generate the electricity that data centers demand (Yencha 2025). Large data centers can use up to 5 million gallons of water per day (Dehoff et al. 2026). Depending on their location, data centers and other users who withdraw and/or consume water above regulatory thresholds may require approval from an interstate river basin commission (e.g., Susquehanna River Basin Commission, Delaware River Basin Commission). In other areas or when water usage is below interstate river basin commission thresholds, local municipalities may be the regulating authority.

Data centers require large amounts of electricity to operate, so much so that new power plants have been proposed solely to provide data centers' needs. After being shut down in 2019, the Unit 1 reactor at the Three Mile Island nuclear power plant is scheduled to resume operations in 2027. Electricity will be supplied to the grid to exclusively power data centers (U.S. Energy Information Administration 2026a). Ultimately, future impacts to wildlife and their habitats will be dependent on the sources of energy (e.g., solar, wind, natural gas) used to power additional data centers.

Transportation and Service Corridors

Transportation and utility service infrastructure are notable features on Pennsylvania's landscape, broadly impacting wildlife habitat and behavior.

Roads and Railroads

Across Pennsylvania, 121,975 linear miles of roads (73,479 miles rural; 73,479 miles urban) (Pennsylvania Department of Transportation-PennDOT 2023) and 5,080 miles of freight rail (Association of American Railroads-AAR 2023) transect the state. Beyond the direct habitat loss through paving and otherwise altering wildlife habitat including forests, wetlands, grasslands and unique habitats, this infrastructure often impedes wildlife movement. Restricting wildlife movement by roads and railroads could be especially important under climate change where wildlife may need to move from unsuitable for survival. Additionally, vehicle collisions with wildlife directly contribute to wildlife injury and mortality.

Utility and Service Lines

Beyond roads and railroads, other infrastructure affecting wildlife habitat include utilities and related services corridors. In Pennsylvania, electrical transmission corridor rights-of-way encompass 21,937 miles (PAPUC 2026). Pennsylvania also has 96,904 miles of natural gas pipelines, including those for distribution, gathering, and transmission (USDOT 2026). These infrastructure developments fragment native habitats and can expedite invasive plant species movements. Yet, through proper habitat management these areas can also support wildlife, including pollinators (Crable 2024, Jones and Miller (undated) https://www.pa.gov/content/dam/copapwp-pagov/en/pgc/documents/habitat-management/habitat-management-/row%20utility%20row%20management.pdf).

Shipping Lanes

Pennsylvania waterways provide important commercial infrastructure. In southeast Pennsylvania, Ohio, Allegheny, Monogahela Rivers support barge traffic within the Mississippi River watershed. In northeast Pennsylvania, on Lake Erie, the city of Erie is an international shipping port and in southeast Pennsylvania, Philadelphia receives international shipping via the Delaware River. Port maintenance, such as dredging, directly impacts habitats and can also harm SGCN through displacement or habitat loss or degradation. Shipping, for example, in the Delaware River and Delaware River Bay has been found to harm (injure and kill sturgeon) through ship strikes with Atlantic Sturgeon (*Acipenser brevirostrum*) and Shortnose Sturgeon (*Acipenser oxyrinchus*), resulting in injury and mortality (Chapter 1-Species, Appendix 1.4).

Biological Resource Use

Logging and Wood Harvesting

Pennsylvania's forests have been the source of fuel, fiber and construction materials during much of the state's development. Pennsylvania forests encompass approximately 16.9 million acres (6.84 million hectares), of which an estimated 750,000 private landowners own 71% (12 million acres; 4.86 million hectares) including 3% owned by the forest products industry (Pennsylvania State University-PSU 2019). Annually, an average 223,797 acres of forest are treated by harvesting (e.g., cutting, thinning) (USDA-FS 2021). Proper forest management can benefit fish and wildlife (PSU 2019), though associated activities, such as establishing logging roads can contribute to direct loss of SGCN habitat. Loss of vegetative cover on erodible lands can be a source of silt draining into streams, wetlands and seasonal pools thus contributing to degraded aquatic habitats.

Illegal Harvest

Illegal harvest can be a direct threat to SGCN, especially species with delayed or limited reproductive capabilities; additional harvest can further degrade SGCN population status. Illegal harvest harms recovery initiatives and, although consumption may be one purpose for illegal SGCN harvest, often the intent is financial gain to provide animals for the pet trade. In Pennsylvania, reptiles often are sought for pets, including the federally listed Bog Turtle (*Glyptemys muhlenbergii*) (Pennsylvania Fish and Boat Commission-PFBC 2026a), Timber Rattlesnake (*Crotalus horridus*) (PFBC 2026b), and especially other turtle species (e.g., Box Turtle (*Terrapene carolina*), Wood Turtle (*Glyptemys insculpta*)).

Human Intrusions and Disturbance

Recreational Activities

All-Terrain Vehicle (ATV) use is a popular recreational activity in Pennsylvania and can be conducted responsibly, with opportunities for their use offered on private, state and federal lands (PADCNR 2026; USDA-FS 2026). Pennsylvania has 908 miles (state) and 100 miles (federal-Allegheny National Forest) of designated ATV trails for off-road activities (e.g., motorbikes, 4-wheelers) (PADCNR 2026). When not conducted on designated trails, these activities can impact habitats and disturb wildlife. Currently, unknown is the extent of direct and indirect impacts of this threat on SGCN and their habitats. Environmental impact will depend on the type, number, and duration of activities, as well as sensitivity of the habitat(s) and wildlife to disturbance. Multiple habitats could be impacted including streams in which sediments may be disturbed when traversed by ATVs or via runoff from trails. This increased sedimentation may be localized or more expansive depending upon the disturbance and soil mobilization.

Pennsylvania’s extensive rivers and streams network (~86,000 miles; 138,404 km) is also a valuable recreational resource for anglers and boaters. Since 2008, state and non-governmental organizations led by the Pennsylvania Environmental Council (PEC), PADCNR, PFBC, and numerous other dedicated partners and volunteers have established the Pennsylvania Water Trails Partnership and developed a statewide water trail network of more than 2,300 miles (3,701 km) within 28 individual water trails (PEC 2025). Among the eight guiding principles are stewardship, volunteerism, and conservation. Stewardship promotes responsible use and minimum-impact practices for sustainable waterways and adjacent lands. Education encourages awareness of natural, cultural, and historical trail attributes. Conservation activities support aquatic ecosystems and contiguous lands, and cultural artifacts. The water trail community is dedicated to helping prevent environmentally harmful acts and sustaining natural trail integrity (PEC 2025). As with ATV trails, harm to fish, wildlife, and habitats will depend on the number of users and availability of developed access sites to avoid harming riparian habitats and increasing erosion. As discussed in the Invasive Species section, anglers and boaters should use established equipment cleaning protocols to reduce moving Aquatic Invasive Species (AIS) or noxious invasive plants within or between water trails. Depending upon the AIS, and waterway’s resident SGCN, impacts to instream and riparian SGCN could be catastrophic.

Natural System Modifications

Fire Suppression

The transition of habitats through the natural process of succession would not initially be considered a threat. Yet the change from grassland to a shrubby young forest or from young forest to a mature forest can affect use of these habitats by SGCN. Depending on the availability (i.e., abundant or rare) of the initial habitat type and the adaptive capacity of the affected SGCN (i.e., species ability to move to other suitable habitats or use alternative habitats) this change could have severe consequences for population persistence. Historically, naturally occurring fire precluded development of trees in grasslands, but fire suppression has allowed habitat transition from grasslands/shrublands to forest. Similarly, habitat composition can be dictated by frequency and intensity of fire. For example, oak forests and barrens habitats benefit from fire by reducing competition from more aggressive, faster-growing trees. Yet, fire-suppression has negatively altered these habitats and associated wildlife composition. See Chapter 4-Actions for more information.

Dams

Hydroelectric facilities, a specific type of dam, were discussed in Hydropower, yet in this section we more broadly discuss threats to stream ecology posed by dams.

In streams, dams directly disrupt major functions including flow regimes, fluvial geomorphological processes, and ecological functions (Ward and Stanford 1995; Kondolf 1997; Bunn and Arthington 2002). Across the United States, dams represent a significant source of aquatic habitat fragmentation with over 80,000 large dams documented (U.S. Army Corps of Engineers-USACOE 2026; https://nid.sec.usace.army.mil/nid/#/; Heinz Center 2002), and when small structures are considered, estimates may exceed 2 million dams (Graf 1993; Heinz Center 2002). These numbers illustrate the aquatic habitat fragmentation potential of these structures.

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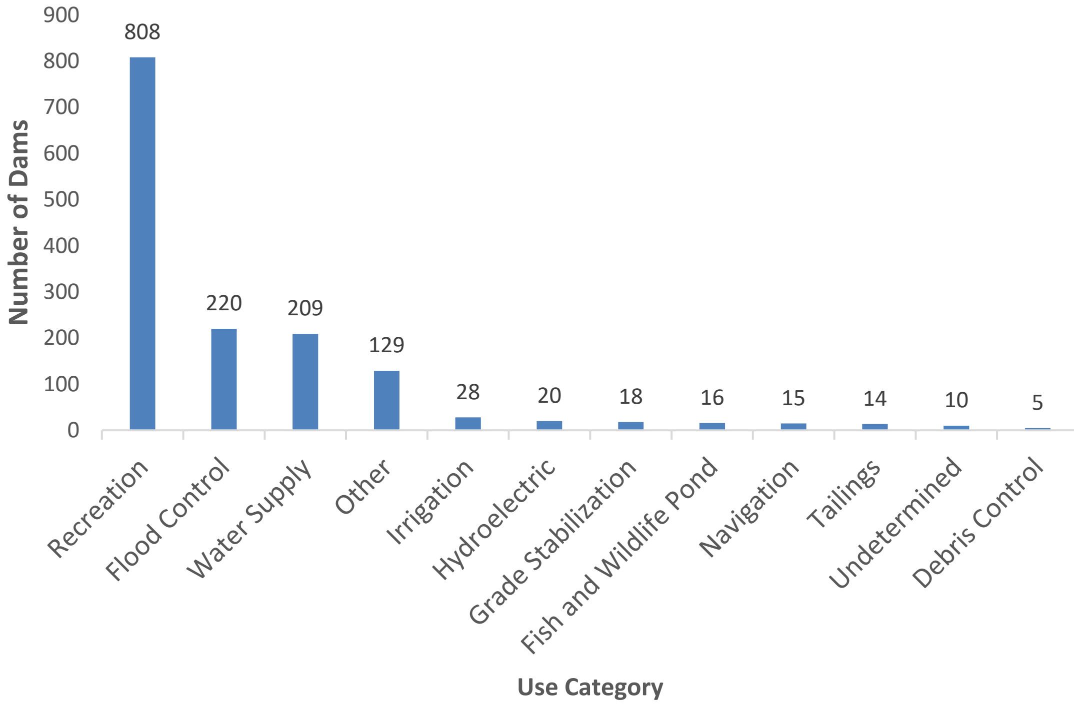

Fig. 3.3. Primary purposes of Pennsylvania dams identified in the U.S. Army Corps of Engineers, National Inventory of Dams (NID) (U.S. Army Corps of Engineers 2026).

Historically, as human population increased in Pennsylvania and throughout the country, use of dams expanded beyond early mill operations and navigation. Of Pennsylvania's 1,492 dams in the U.S. Army Corps of Engineers (USACOE) National Inventory of Dams (NID), 1,237 are identified for recreational opportunities, water supply, and flood control (USACOE 2026) (Fig. 3.3). The Pennsylvania Department of Environmental Protection (PADEP), Dam Inventory (PADEP 2026a) documents smaller dams than reported in the USACOE-NID and recognizes over 3,400 dams. Regulating dams began long after many were built; therefore, the Pennsylvania Dam Inventory likely underestimates the actual number of dams.

Physical Effects of Dams

Dams on river systems disrupt the natural flow regime resulting in loss or reduction of connectivity between downstream and upstream habitats. Dams also disrupt the temporal flood-pulse cycle, influence stream temperature regimes and alter riverine habitat heterogeneity (Bunn and Arthington 2002; Ward and Stanford 1995). Flow alterations, including floodplain habitat connections, have been considered the most serious threat to the ecology of river systems (Sparks 1995; Bunn and Arthington 2002). Stream flows are crucial for sediment transport, which, in turn, influences channel formation and eventually, macroinvertebrate and fish habitats (Kondolf 1997). Dams disrupt this process with above-dam sediment accumulation covering pre-dam habitats. After dropping sediment, this water is then capable of transporting more sediment; often from downstream streambanks and streambeds. Thus, stream flows influenced by dams can have systemically effect riverine ecosystems (Kondolf 1997).

Biological Effects of Dams

As direct physical impediments, movement of aquatic organisms from habitats downstream to upstream of dams can be diminished or completely interrupted. This connectivity loss within the stream may keep fish from reaching suitable spawning and nursery habitats, thus limiting fish productivity and fish community composition. For downstream macroinvertebrates and fishes, dams may impede organic matter transport which can influence invertebrate community composition (Bunn and Arthington 2002). Biological processes including cues for fish spawning and migration, changes in aquatic plant production, use by shorebirds and other crucial functions are often driven or influenced by hydrologic regime (Sparks 1995; Bunn and Arthington 2002). Dams alter the hydrologic regime and can therefore disrupt these ecological functions.

Dams can be particularly detrimental to freshwater mussels with complex reproductive strategies which depend on a host fish or salamander. For example, the migratory SGCN American Eel (*A. rostrata*) is the primary host for larvae of the freshwater mussel, Eastern Elliptio (*Elliptio complanata*). Reduced upstream American Eel movement in the Susquehanna River has been attributed to mainstem dams (Walsh and Meyer 2011). Thus, limited upstream eel passage on the Susquehanna River suggests low numbers of Eastern Elliptio mussels in the Susquehanna River may, in part, be attributable to dams, especially when compared to the Delaware River where there are no mainstem dams until the headwaters in New York.

Also on the Susquehanna River, American Shad were abundant until the early 1900s, declining precipitously due to dam construction (Gay 1892, Meehan 1895, Gerstell 1998; Hendricks and Tryninewski 2011). Since the 1950s, restoration efforts have focused on this species (Hendricks and St. Pierre 2002), yet Susquehanna River dams continue to limit Pennsylvania's American Shad populations. Loss of natural American Shad reproduction has been apparent since 1989, with hatchery-reared American Shad dominating the Susquehanna River population at the Conowingo Dam (Susquehanna River Anadromous Fish Restoration Cooperative-SRAFRC 2010). From 1997 to present, volitional fish passage measures at each of the four lower Susquehanna River dams have provided American Shad the possibility of moving upstream during the spring spawning run; however, typically less than 2% of shad passing through the Conowingo Dam successfully ascend the river beyond the fourth hydroelectric facility, York Haven Dam (SRAFRC 2010; Hendricks and Tryninewski 2011). These Susquehanna River examples illustrate that not only fish movement can be directly impeded by dams but, as with the American Eel, complex ecological relationships can be affected with implications for other taxonomic groups.

Culverts

In smaller stream systems, road-crossing culverts reduce connectivity and aquatic organism movement similar to dams. Aquatic organism passage from culverts is recognized as a threat in the Northeast and Pennsylvania (North Atlantic Aquatic Connectivity Collaborative-NAACC 2026; Western Pennsylvania Conservancy-WPC 2026) and there is increasing interest among state agencies and conservation organizations in Pennsylvania to address this threat.

This important North Atlantic regional work (NAACC) will soon expand nationally under the auspices of the National Fish Habitat Partnership to become the National Aquatic Connectivity Collaborative (NACC) (NAACC 2026). With climate change models predicting increasing extreme precipitation events, proper road-stream crossing size and design is expected to be crucial for not only aquatic system connectivity, but also to minimize utilities and transportation infrastructure damage or loss.

Water Use

Beyond water quality and flow regime, water availability can be of concern for aquatic biota. In Pennsylvania, there are substantial demands on surface water (4.7 billion gallons per day (90%); PA DEP 2024b)) and, to a lesser degree, groundwater sources (0.5 billion gallons per day (10%); PA DEP 2024b). Thermoelectric generation and public water supplies are the primary uses of surface water whereas public water supplies, self-supplied domestic use dominate groundwater consumption (Table 3.4; PA DEP 2024b). Other notable groundwater uses include self-supplied industrial uses, mining, aquaculture and livestock. It is yet to be seen how recent data center expansion (see Data Centers: An Emerging Issue) may influence withdrawals in the future. Actual water use impacts on SGCN may be difficult to quantify, except perhaps under specific, local conditions where flow and SGCN can be closely assessed.

Table 3.4. Pennsylvania water withdrawals by water use category, in million gallons per day. (Source: Pennsylvania Department of Environmental Protection Annual Summary Report 2024)

Use Category	Withdrawals
Thermoelectric Power	3,271,969,691
Public Water Supply	1,358,261,087
Industrial	444,741,075
Mining	97,640,629
Livestock	67,325,064
Commercial & Institutional	6,909,298
Oil and Gas	6,612,724
Wastewater Collection and Treatment	5,675,222
Irrigation	5,213,981
Total	**5,264,348,771**

Invasive and Other Problematic Species, Genes and Diseases

Invasive Species

Contributed by Sean Hartzell, PFBC and Scott Bearer, Ph.D., PGC

Introduction

Invasive species are a notable and complex threat across Pennsylvania due to their broad ecological implications for SGCN and their habitats and thus warrant attention. As defined, "Invasive species are alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health" (Office of the President of the United States, Executive Order 13112, 1999, https://www.invasivespeciesinfo.gov/executive-order-13112). Consequently, with these expansive implications, invasive species have been identified as a driver of global change and considered a major threat to global biodiversity (Dextrase and Mandrak 2006; Ricciardi 2007). Additionally, in the United States, substantial economic impacts incurred from damages and invasive species control costs exceed

$120 Billion annually (Pimental et al. 2005). In Pennsylvania, precise estimates are not available, yet for overall ecological and economic invasive species impacts, they are likely substantial given the high concern by resource professionals (see Chapter 7-Partners; Fish and Wildlife Diversity Forum section).

Invasive species directly and indirectly negatively affect many SGCN populations. Direct effects can result from predation on, or by direct displacement of, SGCN populations through ecological competition. For example, in northwestern Pennsylvania, invasive Round Goby *Neogobius melanostomus* have been introduced into the French Creek basin and found to prey upon juvenile freshwater mussels (Clarke et al. 2022). Additionally, in Pennsylvania, invasive crayfish species, such as the Rusty Crayfish (*Faxonius rusticus)*, have been implicated in ecologically displacing native crayfish through competition (Lieb et al. 2011). Invasive species can rapidly expand and colonize habitats in overwhelming numbers, as demonstrated by the European Starling *Sturnus vulgaris.* This species was released by a Shakespearean art troupe in Central Park, New York in 1890, and now displaces millions of native cavity-nesting birds nationwide (Linz et al. 2007). Indirect impacts to SGCN can also occur through habitat impairment by invasive plant species such as *Phragmites australis,* which can spread in wetland habitats and overshade critical basking habitat for Bog Turtles *Glyptemys muhlenbergii* (Erb 2019). Within Pennsylvania's forests, invasive plants (e.g., Japanese Stiltgrass (*Microstegium vimineum*), Glossy Buckthorn (*Rhamnus frangula*)) can reduce native plant diversity, impact wildlife habitat, and disrupt overall ecosystem function. Indirect effects have also occurred more broadly, but with large-scale effects on SGCN populations, including large-scale changes to forest composition from invasive species such as chestnut blight (*Cryphonectria parasitica)*, Dutch elm disease (*Ophiostoma* spp.), beech bark disease (*Neonectria* spp.), spongy moth (*Lymantria dispar*), emerald ash borer (*Agrilus planipennis*), and hemlock woolly adelgid (*Adelges tsugae*).

Humans, whether intentional or unintentional, are the most common vectors introducing invasive species into new habitats. Invasive plants are often ornamental which have escaped cultivation, whereas invasive animals have typically escaped captivity, or were intentionally stocked or released. Invasive plants and animals may also be unintentionally transported as stowaways in trade. The Spotted Lanternfly (*Lycorma delicatula*) was introduced into Pennsylvania on materials imported from Asia, and the Zebra Mussel (*Dreissena polymorpha*) came to the Great Lakes in ship ballast water. Invasive species may also spread through recreational activities and equipment such as boats, trailers, fishing gear, and hiking or wading boots. This invasive species movement typically occurs when smaller organisms, plant fragments, or seeds stick to these objects, or within residual water, and then are transported to another location. Releasing unused live bait and unwanted pets, or dumping of plants, are also major pathways for invasive species expansion. Invasive species may also be intentionally introduced for aesthetics, as part of religious ceremonies, or by those wishing to establish populations for use, such as a recreational fishery. Once introduced into a novel ecosystem, invasive species may also spread by non-human vectors, such as on birds, through wind dispersal, flooding, or by intentional movements.

Habitats

Invasive species can directly impact SGCN and can also impair habitats making them less suitable for SGCN. In Pennsylvania, high-priority invasive species often impact a broad range of terrestrial and aquatic habitats occupied by SGCN, including rivers, lakes and ponds, wetlands, as well as grasslands, old fields, shrublands, and forests (Table 3.5). After introduction occurs, invasive species typically expand to become statewide, though occasionally their populations may be constrained to specific regions (Table 3.5).

Table 3.5. Select list of invasive species threats to habitats occupied by Pennsylvania Species of Greatest Conservation Need (SGCN).

Invasive species	Primary habitats impacted	SGCN groups potentially impacted	Sources	Impacted region(s)
Zebra mussel (*Dreissena polymorpha*)	Big Rivers, Great Lakes, Lakes and Ponds	Freshwater Mussels, Birds, Fish	MacIsaac (1996); Zaiko et al. (2009)	Statewide, with fewer records in eastern Pennsylvania
Hydrilla *(Hydrilla verticillata*)	Big Rivers, Great Lakes, Lakes and Ponds	Fish	True-Meadows et al. (2016)	Statewide
Phragmites (*Phragmites australis*)	Non-tidal Wetlands, Tidal Wetlands and Flats, Riparian Floodplains, Lakes and Ponds	Birds, Turtles	Benoit and Askins (1999); Robichaud (2016); Erb (2019)	Statewide
Starry stonewort (*Nitellopsis obtusa*)	Great Lakes, Lakes and Ponds	Fish	Pullman and Crawford (2010)	Presque Isle lagoons and bay
Japanese knotweed (*Reynoutria japonica*)	Riparian Floodplains, Non-tidal Wetlands, Rivers and Streams	Birds, Amphibians, insects, gastropods	Maerz et al. (2005); Lavoie (2017); Tucker Serniak et al. (2017)	Statewide
Callery pear *(Pyrus calleryana)*	Interior Forests, Open Fields, Roadsides	Terrestrial Insects, Birds, Mammals	Culley and Hardiman (2007); Hartshorn et. al. (2022)	Statewide
Japanese stiltgrass (*Microstegium vimineum*)	Interior Forestlands, Wetlands, Open Fields, Roadsides	Terrestrial Insects, Birds, Mammals	Judge et al. (2008); Nord et al. (2010)	Statewide
Poison hemlock (*Conium maculatum*)	Wetlands, Streambanks, Open Fields, Roadsides	Terrestrial Insects, Birds, Mammals; notable impacts to humans	Hillman (1997); Allen (2013)	Statewide

Spongy moth (*Lymantria dispar*)	Oak Trees and Forestlands	Terrestrial Insects, Birds, Mammals	Rindos and Liebhold (2023); Tobin et al. (2012)	Statewide
Hemlock woolly adelgid (*Adelges tsugae)*	Native hemlock trees and forests	Terrestrial Insects, Birds, Mammals	Ellison et al. (2018); Orwig and Foster (1998)	Statewide

Anticipated Invasive Species Threats to Pennsylvania

Many introduced species are well-established in Pennsylvania , yet within the next decade additional invasive species threats may arrive from adjacent states or regions. The Pennsylvania Governor's Invasive Species Council (PGISC) has created a list of "greatest concern" invasive species for Pennsylvania, which include species not yet introduced into the Commonwealth, as well as those with known populations. Potential regional threats include Bighead Carp (*Hypophthalmichthys nobilis*) and Silver Carp (*Hypophthalmichthys molitrix*) approaching Pennsylvania via the Ohio River, and which may cause significant harm to riverine aquatic communities as they have done elsewhere in the Mississippi River basin (PFBC 2021). The Silty Pondmussel (S*inanondona woodiana*) has been introduced into New Jersey (Bogan et al. 2011) and could displace Pennsylvania's freshwater mussels occupying similar habitats. Nutria (*Mycastor coypus*), a semi-aquatic rodent native to South America, has been found in several states surrounding Pennsylvania and is expected to begin displacing native wetland mammals and birds in coming years (Hilts et al. 2019). Additionally, proximity to shipping ports on the Atlantic seaboard and Great Lakes offer increased risk for new invasive species to arrive in/on shipping containers, as occurred with emerald ash borer (*Agrilus planipennis*), spotted lanternfly, brown marmorated stink bug (*Halyomorpha halys*), and Joro spider (*Trichonephila clavate*). Finally, animals occurring in trade, but have not yet been introduced into the region, such as the pathogenetic marmorkrebs (marbled crayfish) (*Procambarus virginalis*), could be a major threat to Pennsylvania's native crayfish if introduced illicitly from the pet trade.

Actions

Resource managers recognize the ongoing and serious threat invasive species pose to native fish, wildlife, and associated habitats. Dynamic and rapidly changing conditions such as new invasive species and climate change, increasingly challenge responses to the threat. Yet, we have available procedures and conservation actions to assist with reducing invasive species impacts. Three distinct interdisciplinary tools can help identify risks and prioritize invasive species treatment.

First, the federal Siren: National Early Detection and Rapid Response (EDRR) Information System, can be used to identify, detect, report, and collaborate on response to emerging invasive issues with EDRR approaches summarized in the EDRR Conceptual Framework (Fig. 3.4) (Reaser et al. 2020). Allied with this approach, Pennsylvania also has a dedicated statewide Rapid Response Plan and Procedures (PGISC 2022) framework for responding to aquatic invasive species. Standardized response mechanisms offer consistency and a foundation for adapting to changing conditions.

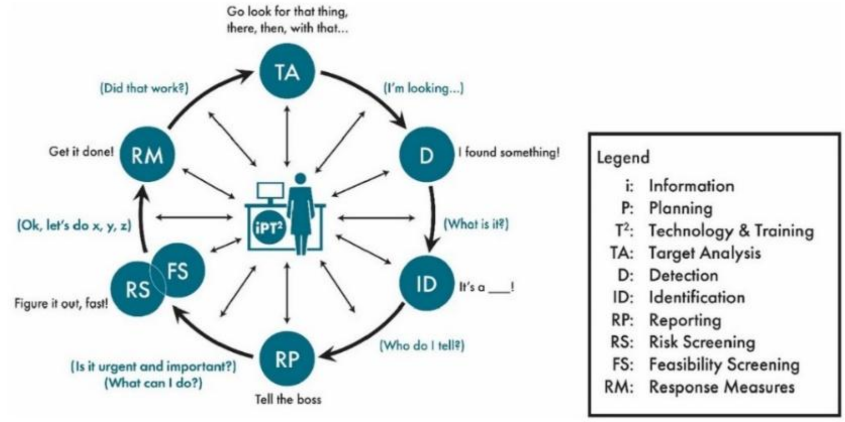

Fig. 3.4. The Early Detection Rapid Response Framework (Reaser et al. 2020).

Secondly, the *Invasion Curve* is a useful schema adopted by USDA's National Invasive Species Information Center for characterizing invasion phases (Fig. 3.5) (USDA. The Invasion Curve characterizes how invasive species become more costly over time and, if caught early, can be more easily contained. Once invasive species become established, control or removal is typically costly and can demand significant resources such as staff time and ongoing management. Thus, it is typically most effective to *prevent* invasive species from spreading into new locations or implement "rapid response" control measures to *eliminate* early infestations before they can become established. When opportunity for prevention and rapid response has lapsed and an invasive species has become well-established, decisions on potential management must consider costs, staff capacity, and the invasive species management priority given the risk of impacts to SGCN and/or their habitat, and consideration of other invasive species or management priorities.

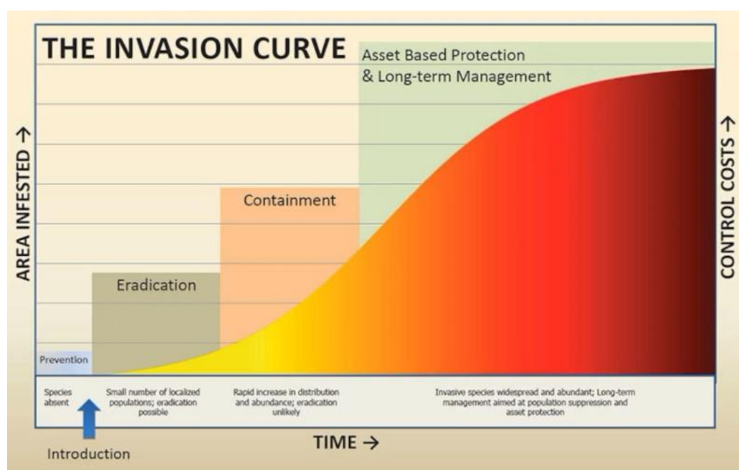

Fig. 3.5. The Invasion Curve, as adopted by the U.S. Department of Agriculture's National Invasive Species Information Center. (From the USDA-FS 2005 Invasive Plant Environmental Impact Statement). https://www.invasivespeciesinfo.gov/subject/prevention

Thirdly, we can use a tiering system to guide northeastern U.S. regional priorities in invasive species management based on local distribution/ abundance of invasive species, impact assessment, and expert review (Finley et al. 2023).

This system was modeled for New York state, and components are being adopted by the Pennsylvania Governor's Invasive Species Council to inform regional priorities for proposed ***P**artnerships for **R**egion in **I**nvasive **S**pecies **M**anagement* (PRISM) in Pennsylvania.

We have measures to address invasive species (Table 3.6), but limiting factors, especially funding and staff capacity, constrain implementation and effectiveness. Prevention and monitoring/early detection are the most effective approaches to avoid invasive species. When these early measures are unsuccessful, then rapid response and management become priority actions and are sustained through partnerships.

Table 3.6. Objectives, approach, actions that should be considered locally, regionally, and statewide in Pennsylvania to protect Species of Greatest Conservation Need (SGCN) and critical habitats from the impacts of invasive species.

Objectives	Approach	Action(s)
Prevention	Public Education	Inform the public about invasive species impacts and measures to prevent spread
Prevention	Legislation	Continue to enact and enforce regulations aimed to prevent the spread of invasive species
Monitoring	Training	Train staff to recognize and identify invasive species; encourage public awareness and reporting of invasive species
Monitoring	Capacity	Increase staff capacity and/or partnerships to monitor for invasive species in priority SGCN habitats
Monitoring	Early Detection	Conduct targeted monitoring surveys in priority SGCN habitats to detect new infestations of invasive species
Rapid Response	Planning/ Preparedness	Create, or refer to established, rapid response plans and decision frameworks when new invasive species are detected in a region or priority SGCN habitat; participate in rapid response trainings
Rapid Response	Capacity/Training	Establish funding and create or assign staff positions to implement rapid response decisions and actions; ensure staff have proper training, certifications, and tools to implement rapid responses
Management	Prioritization	Use distribution/abundance data, impact assessments, and expert review to prioritize locations for established invasive species management
Management	Capacity	Increase funding and staff capacity for the management of high-priority invasive species in SGCN habitats

Partnerships	Coordination	Coordinate invasive species prevention, monitoring, rapid response, and management activities as applicable with local, regional and state partners; work towards establishing PRISM to enhance coordination and capacity for invasive species management

Monitoring

Most state agencies and partners have few (or no) staff dedicated to regularly monitoring invasive species, yet through collaboration, partnerships offer limited coverage. For example, the PGC has been partnering with the Western Pennsylvania Conservancy in targeted regions to identify invasive species populations that overlap with native plant populations to help the agency prioritize invasive treatments. Similarly, PFBC staff and partners have conducted limited monitoring for select high-priority invasive species along invasion fronts in critical areas. These monitoring efforts have included Round Goby monitoring in the French Creek basin, Northern snakehead (*Channa argus*) and flathead catfish (*Pylodictis olivaris*) monitoring in parts of the Susquehanna, surveys for New Zealand mudsnails (*Potamopyrgus antipodarum*) in streams and rivers, and general aquatic invasive species surveys in select reservoirs managed by the agency. However, most efforts are temporary, typically implemented by staff who are focused on other topics in their formal roles, such as SGCN or sportfish. Most invasive species observations are recorded incidentally by agency field staff when doing other survey or management activities, and by the public submitting identified issues or known invasive species occurrences to state agencies or programs reports of suspected invasive species.

Overall, significant benefits could be achieved by increasing invasive species monitoring capacity and coordination among agencies and partners, particularly in crucial habitats for SGCN. Regular monitoring is key for rapid response measures to effectively prevent, eradicate, or contain an invasive species before becoming established (Fig. 3.5). However, to initiate successful rapid response measures, regular monitoring must identify early invaders before they are introduced or established (Fig. 3.5). As capacity, resources, and funding allow, state agencies and partners should increase invasive species coordination and monitoring efforts in Pennsylvania, especially in crucial habitat or priority SGCN regions. Several monitoring priorities are outlined in the Pennsylvania Invasive Species Management Plan (PGISC 2016, 2022, 2025). Broad scale monitoring implementation remains a challenge. These activities can be supported by fully funding and organizing PRISM proposed by PGISC (PGISC 2026).

Public Involvement

The public can greatly assist with addressing invasive species threats to the Commonwealth's native natural resources. Among the most important roles as good stewards of Pennsylvania's natural resources is to avoid distributing spread invasive species while enjoying outdoor activities. For example, <u>boaters and anglers should properly clean their boats, trailers, and fishing gear among trips to avoid spreading invasive species among waterbodies. Hunters or hikers should clean their boots to avoid spreading invasive plant seeds</u>. Additionally, the public should *never* intentionally move or release plants or animals (e.g., unwanted pets) brought from other locations. Suspected invasive species observations should be reported to appropriate land manager or entity by calling the Pennsylvania invasive species reporting hotline at 1-833-INVASIV or, specifically for invasive plants, to the Pennsylvania Department of Agriculture (RA-plant@pa.gov) or invasive insects (badbug@pa.gov). Find more information on aquatic invasive species from the PFBC (https://www.pa.gov/agencies/fishandboat/conservation/species-management/aquatic-invasive-species) and wildlife invasive species from the PGC (https://www.pa.gov/agencies/pgc/wildlife/discover-pa-wildlife/).

The interested public can further assist with invasive species management by tracking Pennsylvania invasive species spread and distribution (www.paimapinvasives.org) through the statewide Pennsylvania *i*MapInvasives Program which includes observational data collected by "community scientists", as well as professional natural resource managers. Additionally, local groups and land managers may recruit volunteers for workdays to remove invasive vegetation or other management activities. County Conservation District or State Agency Regional Offices are other important resources with opportunities to address invasive species. Additionally, homeowners and landowners can focus on their own backyards and privately owned lands by planting native species and, when practical, removing common invasive species.

Free-roaming (feral) cats may not precisely fit the invasive species definition yet, though they continue to negatively impact SGCN and other wildlife populations, similar to impacts from typical invasive species (Dutcher et al. 2021). Feral cat impact on native bird populations is well-documented and especially severe, with billions of animals killed every year from feral and free-roaming cats (Barratt, 1997; Woods et al. 2003; Hawkins et al. 2004; Longcore et al., 2009; Van Heezik et al. 2010; Bonnington et al. 2013; Loss et al. 2013; Debrot et al. 2022). While their impact on birds has been quite well-studied, free-roaming cat impacts on small mammals, invertebrates, and herpetofauna remains much less well known but does contribute further to their total ecosystem impact (e.g., Hawkins et al. 2004; Frank et al. 2014; Woolley et al. 2020; Lazenby et al. 2021). Whether through cat abandonment into wild habitats or simply consent to allow domestic cats to roam freely, their impact on native wildlife is significant, and can be similar as the release of unwanted (invasive) pets. Like our recommendation above, for the public to avoid intentionally moving or releasing unwanted plants or pets into an ecosystem, we recommend the public to never release/abandon cats into natural habitats. We also recommend cat owners understand the impact their cats may be having on native wildlife populations, use deterrent devices (such as collars with bells that can warn nearby wildlife), keep their cats indoors (which may actually protect the cat from predation), and consider Trap-Neuter-Return (TNR) programs for nearby feral cat populations.

Partners

In Pennsylvania, managing invasive species requires collaboration among state and federal agencies, local governments, County Conservation Districts, academic institutions, and non-governmental conservation organizations. The coordinating nexus for many of these groups is PGISC, established in 2006 by an executive order by Governor Edward Rendell. PGISC currently comprises seven state agencies and 14 non-governmental organizations, meeting quarterly to coordinate and discuss invasive species issues in the Commonwealth. PGISC also advises the Governor's Office on invasive species policy, outreach and education on invasive species, and works to update and implement Pennsylvania's

Invasive Species Management Plan. PGISC members managing invasive species in the Commonwealth are the:

- County Commissioners Association of Pennsylvania
- Pennsylvania Association of Conservation Districts
- Pennsylvania Governor's Invasive Species Council
- Pennsylvania Controlled Plant and Noxious Weed Committee
- Pennsylvania Game Commission
- Pennsylvania Farm Bureau
- Pennsylvania Fish and Boat Commission
- Pennsylvania Department of Agriculture
- Pennsylvania Department of Conservation and Natural Resources
- Pennsylvania Department of Environmental Protection
- Pennsylvania Department of Health
- Pennsylvania Department of Transportation
- Pennsylvania Lake Management Society
- Pennsylvania Landscape and Nursery Association
- Pennsylvania State Association of Township Supervisors
- PennAg Industries Association
- Penn State University
- Pennsylvania Sea Grant
- Temple University
- University of Pennsylvania
- Western Pennsylvania Conservancy

Additionally, the Northeast Regional Invasive Species and Climate Change Management Network-NE RISCC (2025, 2026) https://www.risccnetwork.org/northeast supports resource managers, landowners, governments, non-governmental organizations, researchers, and other users through predictive models and tools which integrate the intersection of invasive species and climate change.

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Fish and Wildlife Health (Problematic Species, Genes, and Diseases)

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Effective fish and wildlife management relies on robust monitoring of populations, communities, and ecosystem dynamics to catalyze preventive and early response initiatives, which may also safeguard human and domestic animal health. However, assessing fish and wildlife health is challenging due to diverse threats from multiple sources, including disease-causing organisms, toxins, and pollutants that may negatively impact individuals, populations, species, or entire guilds, potentially leading to ecosystem-wide disruptions.

Within this framework of potential population-level impacts, we identified and prioritized existing and emerging health threats for Pennsylvania's Species of Greatest Conservation Need (SGCN). Threats were prioritized based on documented occurrences in Pennsylvania, the potential to be introduced to Pennsylvania from elsewhere, the likelihood of geographic expansion, and/or the risk of increasing prevalence or severity due to climate change. We also assessed current awareness of each health threat, identified significant knowledge gaps, and outlined actions to address these shortcomings or mitigate the risks to SGCN populations.

Methods

Primary contributors to this assessment were a dedicated workgroup comprising representatives from the University of Pennsylvania Wildlife Futures Program, PGC, and PFBC. We enhanced the breadth of expertise by consulting with other fish and wildlife health professionals. Seeking diverse perspectives and insights, we established an Advisory Group that included the NEAFWA Regional Fish and Wildlife Health Coordinator, representatives from PGC and PFBC, and veterinarians from the U.S. Fish and Wildlife Service's (USFWS) One Health Office, ensuring that national disease concerns were also considered. The health assessment followed a multi-step process that included literature review, an online survey, in-person interviews of content experts (i.e., agency biologists, veterinarians), and review by Pennsylvania agency species biologists and PGC veterinarian (Fig. 3.6).

For a regional perspective, we created, and PGC and PFBC Executive Directors distributed, an online survey to fish and wildlife agencies, wildlife health research institutions, and other relevant groups in nearby jurisdictions (i.e., CT, DC, DE, VA, WV, MA, MD, ME, NH, NJ, NY, OH, RI, VT). The objectives of the survey were to: 1) identify regionally important health threats to Pennsylvania SGCN, and 2) gather perceptions of the effectiveness of management actions used to address those threats.

Through in-person meetings, we interviewed wildlife management agency personnel and wildlife health experts at the 2024 NEAFWA annual meeting, Cape Cod, Massachusetts, April 21-24, 2024. Interviews lasted approximately one hour, and respondents were given a standard set of questions.

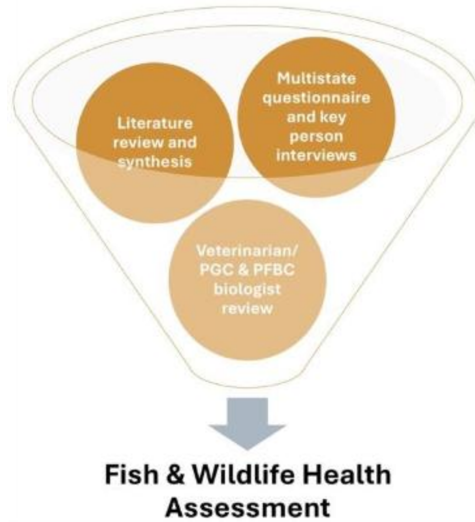

Fig. 3.6. Fish and wildlife health assessment process. PGC = Pennsylvania Game Commission; PFBC = Pennsylvania Fish and Boat Commission.

We next worked with University of Pennsylvania librarians to design literature searches using online databases to retrieve relevant information from peer-reviewed technical papers, reports, meeting abstracts, dissertations, theses, and books. From these sources, we summarized information on priority health threats and the risks to select 2015-25 and, at the time of this project, anticipated 2025-35 Pennsylvania SGCN, including 91 avian species, 21 mammalian species, 19 amphibian species, 21 reptilian species, 54 fish species, and 49 mollusc species (see PGC-PFBC 2015).

Literature searches were organized by SGCN, their genera, and health threat, including references from 2008-2024. The search terms for health threats were bacter* OR disease* OR fung* OR hazard* OR health* OR parasit* OR pollut* OR risk OR toxi* OR viral* OR virus* OR poison*.

Wildlife Futures Program veterinarians prioritized health threats identified through literature searches, in-person interviews, and the online survey, based on scope and severity. Potential agency actions were drafted using the Northeast lexicon for State Wildlife Action Plans (Crisfield and the Northeast Fish and Wildlife Diversity Technical Committee 2022). The veterinarians then worked with PGC and PFBC species biologists to further prioritize threats and finalize appropriate agency actions, including filling knowledge gaps and mitigating risks relevant to each priority threat.

Results

Threats (Online survey and in-person interviews)

Agency survey respondents identified viruses, toxins, and fungi as the most significant threats to SGCN health in the Northeastern U.S. Viruses of particular concern to respondents were highly pathogenic avian influenza (HPAI), West Nile virus (WNV), ranaviruses, and rabbit hemorrhagic disease virus serotype 2 (RHDV-2). The most significant toxins of concern were lead, neonicotinoids, per- and polyfluoroalkyl substances (PFAS) or forever chemicals, and rodenticides. Chytridiomycosis, affecting amphibians, and white-nose syndrome (WNS), affecting bats, were the fungal diseases mentioned most frequently. Respondents anticipated that various environmental health threats, such as climate and weather stressors, and viral and fungal diseases, may become more severe in their state over the next decade.

Health threats identified through in-person interviews mirrored those listed as priorities by the online survey respondents. Interview participants expressed concern about the impacts of climate change on parasites and arthropod-borne pathogens, HPAI, water quality, contaminants, and emerging and re-emerging viral and fungal diseases.

The following taxonomic-focused sections are based on an extensive literature review and evaluation by veterinarians and agency biologists.

Birds

Health threats varied among taxonomic groups (Fig 3.7). Herbicides and other pesticides were the most identified threats to birds, especially insectivorous birds, due to potential for broad population exposure to these agents (Eng et al. 2019; Alharbi et al. 2016). Birds of prey can be exposed to anticoagulant rodenticides (Cooke et al. 2023; Buechley et al. 2022; Gomez et al. 2023). West

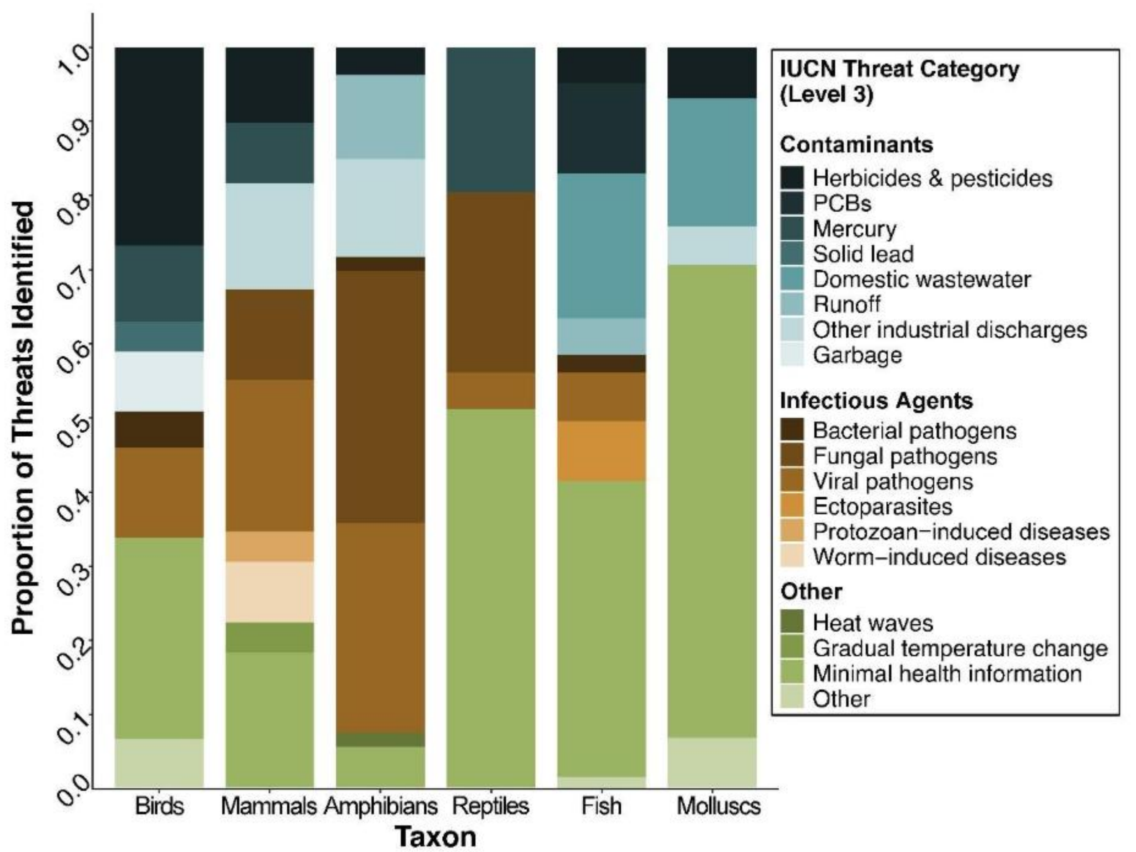

Fig. 3.7. Health threats across six taxonomic groups (birds, mammals, amphibians, reptiles, fish, and molluscs) most frequently identified during the literature review process and/or further evaluation by veterinarians and agency biologists. The threat category "Other" includes threats identified in less than 5% of the species in the taxonomic group and includes soil erosion and sedimentation; gradual change in the precipitation regime; acid-mine drainage; flame retardants; and aquatic plants.

Nile virus (WNV) and HPAI were the most frequently listed viral threats to birds. Although these viruses have been detected in wild birds for many years, their population-level effects remain poorly understood. WNV may contribute to population declines of birds of prey (Nemeth et al. 2009; Smith et al. 2018) and are known to impact ruffed grouse (*Bonasa umbellus*) (Kunkel et al. 2022a; Kunkel et al. 2022b) while its effects on other species have gone understudied. HPAI has recently contributed to die-offs of waterfowl and other birds in Pennsylvania and may pose a risk to small or restricted populations (Pohlmann et al. 2023; Duncan et al. 2017). Other less-commonly reported threats include bacterial pathogens (e.g., *Clostridium botulinum*, which produces a toxin that causes botulism in some waterfowl), protozoan-induced diseases (e.g., avian malaria), and heavy metals (e.g., lead and mercury exposure in dabbling ducks and insectivorous birds). Many bird species had minimal information about health or health threats available, particularly songbirds and wading birds (Fig. 3.8).

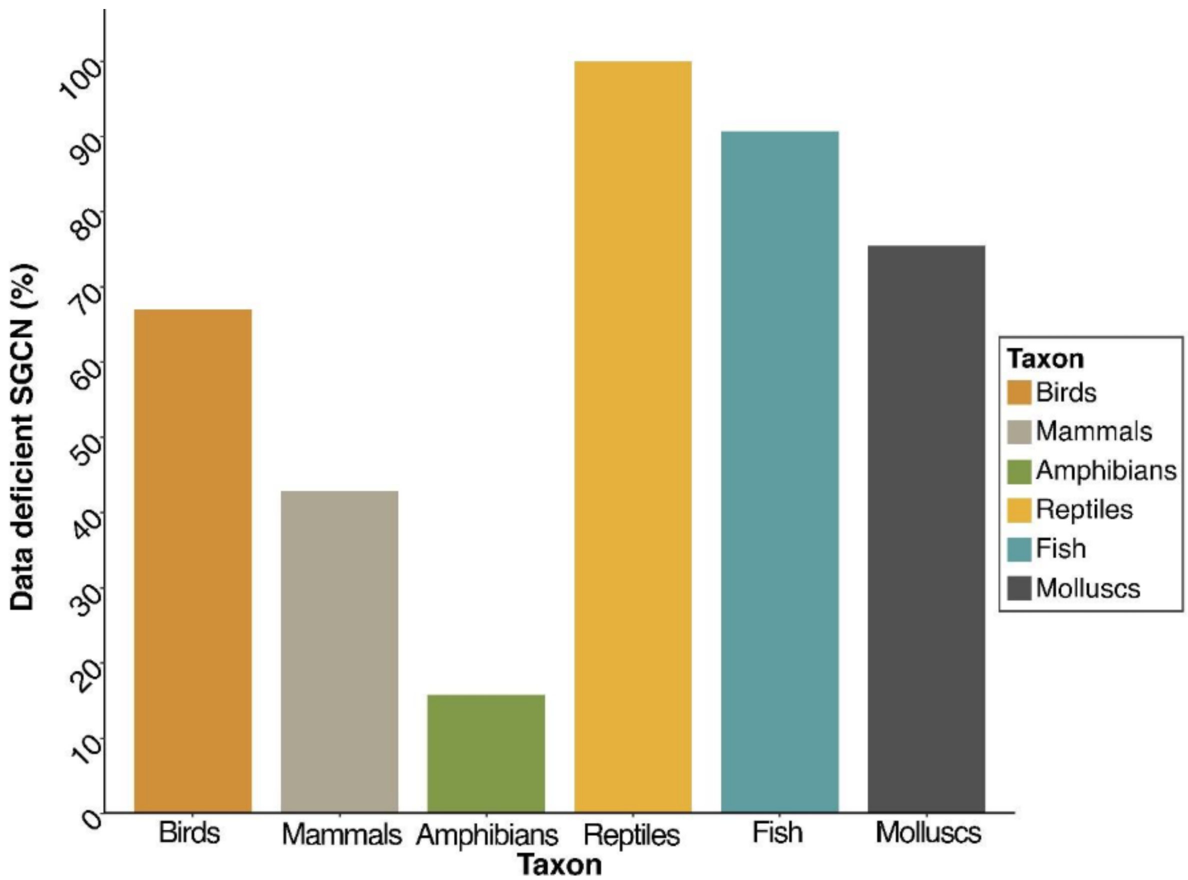

Fig. 3.8. Percentage of Pennsylvania's Species of Greatest Conservation Need (SGCN) within six taxonomic groups (birds, mammals, amphibians, reptiles, fish, and molluscs) identified as having minimal health and disease information during the review process.

Mammals

Viruses were the most common threat category identified for SGCN mammals (Fig. 3.7). Caliciviruses, including RHDV-2 and European Brown Hare Virus, along with poxviruses (e.g., myxoma virus), which originate elsewhere in the world, pose an emerging threat to Appalachian cottontails (*Sylvilagus obscurus*) and snowshoe hares (*Lepus americanus*) (Lankton et al. 2021; Le Gall-Recule et al. 2017; Lopes et al. 2014; Lorenzo et al. 2024; Spyrou et al. 2013; Asin et al. 2024). With increasing avenues for pathogen transfer between populations and increasing environmental stressors, native and introduced viruses may also threaten bat populations. Bioaccumulation of environmental contaminants, including arsenic, mercury, cadmium, copper, zinc, and lead, occurs in voles, mice, and shrews in high-risk environments with negative health effects. A few studies of lagomorphs (Hofmeister et al. 2024; Lazaro et al. 2023) suggest that rising average temperatures may lead to greater exposure to ectoparasites and vector-borne pathogens. Shrews, northern flying squirrels (*Glaucomys sabrinus*), voles, and some bat species (e.g., hoary bat, *Lasiurus cinereus,* eastern red bat, *L. borealis*) lacked data to adequately identify threats (Fig. 3.8).

Amphibians and Reptiles

Fungal pathogens especially threaten amphibians and reptiles (Fig. 3.7). Chytrid fungus, *Batrachochytrium dendrobatidis,* causes mortality in many species of amphibians, and many SGCN populations are at risk from chytridiomycosis (Bauer et al. 2018; Searle et al. 2011; McMahon et al. 2021). Many SGCN amphibians, particularly salamanders, are also at risk from possible introduction of *Batrachochytrium salamandrivorans* (Bsal) into the US from other parts of the world (AFWA 2024; Carter et al. 2020; Connelly et al. 2023; Gray et al. 2023; Grear et al. 2021). Ophidiomycosis is a fungal disease of snakes that causes skin infection with high levels of mortality in some species, but its presence and population effects on several Pennsylvania SGCN are unknown. Ranaviruses, a group of viral pathogens that cause mortality in Pennsylvania reptiles and amphibians are a major health threat. Several studies indicate that contaminants, such as per- and polyfluoroalkyls (Flynn et al 2021), energy-related brine contamination (Hossack et al. 2018; Tornabene et al. 2020), and herbicides and pesticides (Shenoy et al. 2009; Williams and Semlitsch, 2010), are also of very high concern to amphibians as they readily absorb compounds from the environment through their skin. Contaminants may originate from multiple sources and include forever chemicals or PFAS, perfluorocatane sulfonate (PFOS), copper, pesticides, road deicing salt, and other compounds. These compounds may cause long-term negative health-related effects and can be directly toxic to frogs and salamanders. Aquatic reptiles are exposed to mercury in their environment, which can cause hormonal disruption and decreased reproduction (Hopkins et al. 2012; Hopkins et al. 2013; Landler et al. 2017). These effects are well studied in aquatic turtles but less well understood in water snakes (Drewett et al. 2013). Very few studies addressed impacts of climate change, but two papers indicate that higher temperatures make some salamander SGCN more susceptible to desiccation and death (Riddell et al. 2019; Munoz et al. 2022). The most consistently identified threat to reptiles is the scarcity of available health information.

Fish and Freshwater Mussels

Minimal health information is available for many SGCN fish and freshwater mussels, but aquatic contaminants are a common concern for many species (Pinheiro et al. 2020; Pinkney et al. 2019; Pryce-Hobby et al. 2003; Fernández-Trujillo et al. 2021; Filizadeh and Islami 2011). Contaminants may originate from multiple sources, including industrial discharge, domestic wastewater, and pesticide application. Some species are particularly vulnerable if they occur in small or isolated populations.

Actions

"Basic research and monitoring" was the most frequently identified action category recommended across all taxonomic groups (Fig. 3.9). Beyond general disease surveillance and biobanking, it will be critically important to evaluate effects of neonicotinoids, rodenticides and other pesticides, particularly for insectivorous birds. Other actions frequently recommended fell within the category of management of non-living habitat components (Fig. 3.9). Many specific actions within this category targeted threats associated with industrial, military, agricultural, and forestry effluents, and include implementing water management plans to mitigate effects of road salt and discharges from oil and gas drilling on aquatic species, ensuring the careful application of Bayluscide® (a molluscicide primarily used to control freshwater snails) in areas that overlap with SGCN mussel populations to ensure that amounts delivered are not harmful to mussels, and managing water in areas of increased sedimentation and turbidity to reduce fine material transport into streams. Actions under the category mitigation of human environmental impact were also of high importance (Fig. 3.9). Specific actions include determining the sources of environmental contamination such as lead, mercury, and other heavy metal contamination, as well as plastics in areas where levels are elevated, and performing appropriate mitigation measures to decrease environmental contamination.

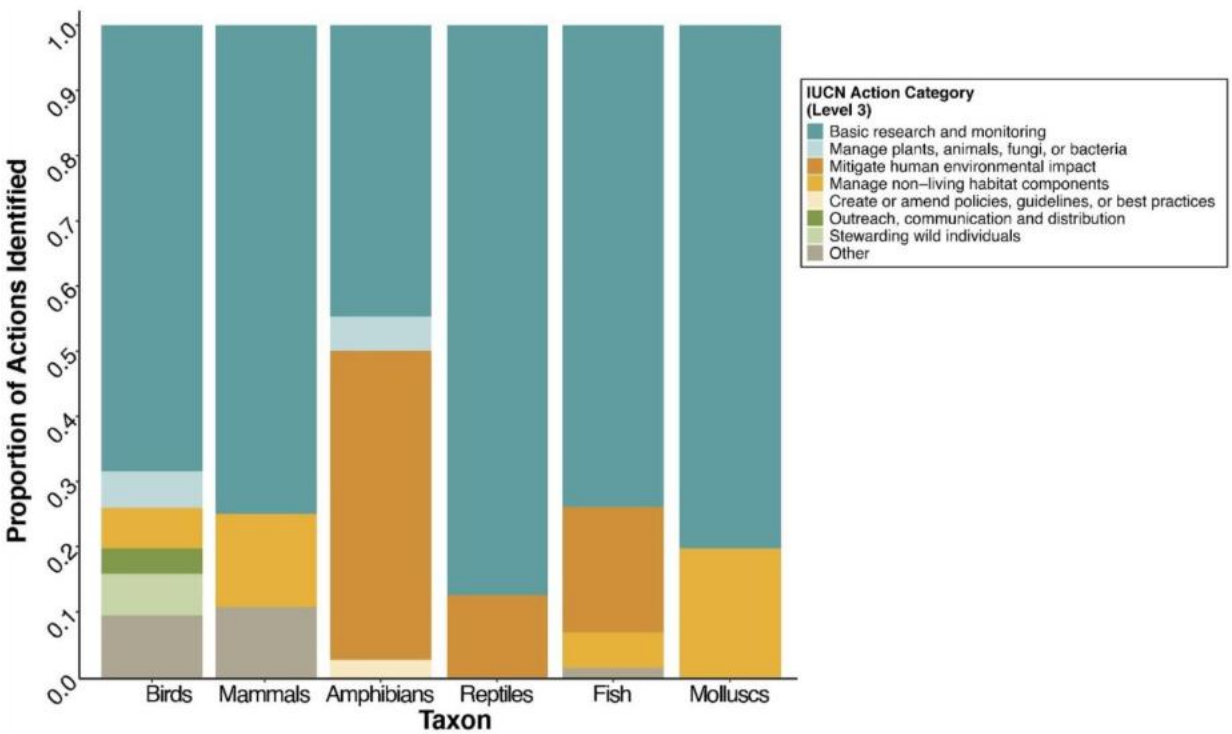

Fig. 3.9. Actions most frequently identified across six taxonomic groups (birds, mammals, amphibians, reptiles, fish, and molluscs). The action category "Other" includes actions identified in less than 5% of the species in the taxonomic group and includes creating, amending, or influencing legislation, regulation, or codes; developing improved products and production methods; economic incentives and disincentives; evaluation, effectiveness measures and learning; reintroducing or relocating individuals; and stewardship of captive individuals.

Discussion

Health Threats

Health threats to Pennsylvania's SGCN arise largely from herbicides, pesticides, industrial pollution, domestic wastewater, and pathogens, particularly viruses and fungi, with significant data gaps across taxa. In general, birds have high exposure to pesticides, heavy metals, and viruses like WNV and HPAI. Mammals face risks from emerging viruses, particularly in lagomorphs (hares and rabbits) and chiroptera (bats), while industrial pollutants harm small mammals like voles and shrews. Several species, including northern flying squirrels, shrews, and certain bats, lack sufficient health data. Fungal diseases, including chytridiomycosis in amphibians and ophidiomycosis in snakes, cause high mortality, while ranaviruses are a major threat to amphibians. PFAS, pesticides, and mercury contamination further endanger reptiles and amphibians, with significant data deficiencies limiting understanding of potential impacts. Many fish and freshwater mussel species remain understudied, though wastewater pollution is a known health risk.

Beyond the health threats identified, many unknowns remain. Publication and funding biases drive trends in research and will impact known threats. For example, disease research in wildlife is often biased towards larger, more visible animals or towards zoonotic diseases that threaten human health, presenting risks to human health, leading to skewed understandings of disease risks and health threats. Nevertheless, the threats identified in this study, sitting at the intersection of pollution, disease, and limited data, highlight the vital need for better strategies for addressing health threats to SGCN in Pennsylvania.

Addressing Data Gaps

In this study, basic fish and wildlife health research and status monitoring emerged as the most frequently identified action category across all taxa. Opportunistic disease surveillance and sample biobanking are of critical importance for understanding which diseases and toxins pose threats to these populations. There is widespread concern over the scarcity of SGCN health data. Small population sizes and the cryptic nature of many species pose significant challenges for pathogen and disease surveillance. Emerging technologies, such as sampling for pathogens using environmental DNA (eDNA), may be key to getting more information. Using closely related and more abundant species as indicators of emerging pathogens or contaminants in shared habitats could be a beneficial strategy. The crucial role of biorepositories also became apparent, particularly for archiving specimens when a sampling opportunity arises but funding for immediate testing is unavailable.

Environmental Contaminants

Surveillance and monitoring were consistently identified as critical needs across numerous taxa for environmental contaminants—including herbicides, insecticides, heavy metals, domestic wastewater, industrial discharge, agricultural runoff, road deicing salt, and other contaminants of emerging concern. For many species, data are sparse on tissue concentrations of these contaminants, and even less is known about their effects on reproduction, longevity, survival, or sublethal impacts such as immune suppression. Beyond surveillance and monitoring, mitigation was frequently recommended. For species living in aquatic environments or relying on aquatic species as a food source, identifying contamination sources will be essential for prioritizing mitigation efforts. This prioritization is also important for bird species exposed to pesticides by eating contaminated invertebrates. To mitigate effects of road deicing salt and other factors contributing to increased salinity in amphibian habitats, it will be important to determine where those contaminants are putting amphibian populations at risk. For several freshwater mussels, managing hydrological regimes to reduce contamination from salt and other toxicants was considered important. Public outreach and legislation to reduce lead in ammunition and fishing gear could help decrease lead contamination and its harmful effects on waterfowl and scavengers (Ross-Winslow and Teel 2011; Haig et al. 2014). Promoting the development of non-toxic alternatives to rodenticides would also help mitigate the presence of anticoagulant rodenticides in the environment. For several fish species, enforcing and updating regulations on lampricide application could help minimize its impact on SGCN in treatment areas (Sakamoto et al. 2016; Ionescu et al. 2021). Similarly, careful application of molluscicides such as Bayluscide® in areas inhabited by mussels would reduce unintended environmental consequences to vulnerable species (Newton et al. 2017; Andrews et al. 2021).

Fungal Pathogens

We found fungal pathogens to be a major threat to amphibians and reptiles. For endemic fungal pathogens such as *Batrachochytrium spp.* and *Ophidiomyces ophiodiicola*, active and passive surveillance, as well as evaluation of lethal and sublethal effects, are needed to determine impacts on SGCN populations. Additionally, cleaning and disinfecting all equipment before and after handling animals in the wild and performing pathogen screening before translocations is critical. Agencies should proactively develop surveillance and rapid response plans for early detection and to prevent exotic fungal pathogens, such as *Batrachochytrium salamandrivorans*, from emerging within and spreading throughout sensitive naïve wildlife populations. Further, agencies should enact regulations and support legislation to minimize importation of animals or products that risk introducing foreign fungal pathogens into the US. The fungus *Pseudogymnoascus destructans*, which is the causative agent of white-nose syndrome (WNS), has devastated populations of several hibernating bat species in Pennsylvania. Recommended actions to tackle this pathogen include habitat manipulation, such as cooling hibernacula and treating with polyethylene glycol (PEG) and/or a volatile organic compound (Turner et al. 2022). More research and a better understanding of the biological and environmental factors enabling some bat populations to more robustly withstand WNS will enable managers to better safeguard vulnerable populations. It is also important to investigate the role of the bat microbiome on resilience to WNS and apply this information to managing susceptible SGCN populations.

Viral Pathogens

Viral pathogens pose a significant health threat to several mammal and amphibian SGCN in Pennsylvania. HPAI is a serious and growing threat causing illness and mortality in SGCN hawks and other birds of prey, and some diving ducks and shorebirds. Some recommendations for actions include determining the effects of HPAI on SGCN populations and identifying sources of infection so mitigation efforts can be prioritized. Outreach to poultry producers to discourage operations in proximity to habitat suitable for SGCN (e.g., waterfowl) is suggested to decrease the introduction of poultry strains of avian influenza into wild birds. Active monitoring and rapid diagnosis are needed so carcass collection and rapid bird dispersal methods can be implemented to reduce transmission. For the American goshawk, research is recommended to determine whether avian influenza virus vaccinations avert goshawk population declines.

Although not yet detected in the wild in the eastern U.S. (as of 2025), RHDV-2 causes high mortality in domestic rabbits and multiple wild lagomorph species in the western US. To address this threat, proactive measures should include: 1) active and opportunistic surveillance for early detection, 2) enabling rapid mitigation measures to reduce the rate of spread to sensitive populations, 3) assessment of the potential transmission of RHDV-2 from eastern cottontails (*Sylvilagus floridanus*) to snowshoe hare and Appalachian cottontails, and 4) partnership with Pennsylvania Department of Agriculture to restrict lagomorph, and related product importation from affected areas. Additionally, public awareness campaigns should be launched to inform the public and stakeholders about the virus, and proactive vaccination programs for domestic rabbits should be implemented.

More broadly, developing risk assessments, management and response plans, and diagnostic tools for high-risk viral diseases affecting species closely related to Pennsylvania's mammal SGCN will help prevent or mitigate the impacts of introduced viral pathogens. For instance, there are several caliciviruses and herpesvirus that, while not documented to have occurred in the US, are known to have population-level mortality effects on rabbit and hare populations in other parts of the world. A risk assessment for such threats would provide a structured, evidence-based process that could be used to help determine potential impacts and guide decision-making in the face of uncertainty.

Surveillance and monitoring, as well as active vaccination campaigns, are recommended for vulnerable mammal SGCN affected by endemic viral pathogens such as rabies and canine distemper virus (CDV). Additionally, surveillance for WNV in mosquitoes in areas near eastern fox squirrels (*Sciurus niger)* will help in abatement activities when WNV prevalence is high. In reptiles and amphibians, ranaviruses pose a major threat, causing inflammatory disease and mortality in freshwater turtles and frogs. Die-offs caused by ranaviruses have been documented in northeast US salamanders, and more common salamander species may act as hosts. Active and passive surveillance for these viruses, as well as impact assessments, should be implemented for SGCN and sympatric species. Decontamination protocols, https://parcplace.org/wp-content/uploads/2024/02/Bletz.etal_.2023_NEPARCdecon1.pdf (Bletz et al. 2023), such as cleaning and disinfecting equipment used to capture and handle animals before and after the event, and other biosecurity measures, including screening for pathogens before translocating animals, should be strictly followed.

Parasites

Parasites were infrequently identified as pathogens with the potential to cause population-level effects. Notable exceptions were raccoon roundworm (*Baylisascaris procyonis*) in Allegheny woodrats (*Neotoma magister*) and other mammals (Bade et al. 2012; Beasley et al. 2013; Sapp et al. 2016), as well as *Strongyloides robustus* in northern flying squirrels (Krichbaum et al. 2010). For both SGCN, infection is believed to occur through contact with fecal matter from definitive hosts (raccoons for *B. procyonis*; southern flying squirrels for *S. robustus*) and may lead to disease or death. Surveillance of definitive host species in areas where they overlap with susceptible SGCN is recommended and, in some cases, anti-parasite treatment of wild host populations may be warranted to decrease the impact on small SGCN populations. Similarly, several fish SGCN are at risk from severe ectoparasite infections acquired from other species that serve as hosts. The primary tool to mitigate the spread of these parasites is to clean and disinfect all equipment after capturing and handling animals in the wild and to conduct pathogen screening before translocating animals.

Bacterial Pathogens

Few bacterial pathogens were identified as substantial threats to SGCN. Equipment cleaning and disinfection, and pathogen screening before translocating wild SGCN or releasing captively propagated animals will help mitigate the spread of harmful bacteria among these SGCN. Similarly, though rare, avian botulism, caused by a toxin produced by the bacteria *Clostridium botulinum*, can lead to mortality in piping plover (*Charadrius melodus*; USFWS 2020), killdeer (*Charadrius vociferus;* Friend and Fransom 1999), and some waterfowl SGCN (Chipault et al. 2015; Duff et al. 2017). To reduce its impact, surveying habitats prone to botulism events, promptly removing carcasses during a botulinum outbreak, adjusting water conditions when possible, and hazing SGCN waterfowl during outbreaks are recommended actions.

The direct and indirect influence of climate change on fish and wildlife populations is a crucial research gap in understanding Pennsylvania SGCN health needs. Rising average environmental temperatures are already driving shifts in the distribution and range of disease vectors, such as mosquitos and ticks (Elbers et al. 2015; Gilbert 2021). For instance, as disease-carrying mosquitos expand to higher altitudes with warming temperatures, once protected birds may face increased exposure to vector-borne diseases. Similarly, warmer conditions will likely lead to a surge in tick populations, resulting in higher densities and greater impacts on their hosts. Climate change may alter the geographic distribution of certain pathogens, leading to exposure of naive wildlife populations to novel pathogens. Beyond these pathogen and vector-borne threats, climate change will directly affect SGCN through heat stress, severe weather events, and habitat loss. For example, increased temperatures could disrupt reptile metabolism, forcing them to consume more food and spend additional time basking, while amphibians may struggle to regulate their body temperatures, making them more susceptible to heat stress. To enhance SGCN resilience, comprehensive climate and health risk assessments – paired with targeted response strategies such as habitat management – will be essential in mitigating the challenges posed by rapid environmental change.

Data Needs and Sources

Inadequate baseline data on pathogen prevalence, contaminant levels, and parasite loads represent a significant barrier to interpreting what is "normal" for SGCN. Proactively collecting baseline health data from animals captured for research or other management purposes would help fill gaps in our knowledge and understanding. These investigations would supplement opportunistic full evaluation of deceased animals. Pursuing diagnostics and archiving biological specimens collected from SGCN and related species in biorepositories will generate long-term datasets, establishing robust temporal and spatial baselines for pathogen presence, emergence, and spread, as well as trends in contaminants.

Enlisting public participation and more proactive approaches to fish and wildlife health, such as leveraging community volunteer networks for early identification of developing health threats, offer alternative data sources. For example, the public can send photos of abnormal amphibians and reptiles to the [Herpetofauna Disease Alert System](https://parcplace.org/species/herpdiseasealert/) (https://parcplace.org/species/herpdiseasealert/), created by Partners in Amphibian and Reptile Conservation. Public engagement also builds support for agency actions. Formal management plans for SGCN will enable agencies to quickly respond to emerging outbreaks and mass mortality events. Such plans should also identify research objectives to facilitate a better understanding of these threats as they emerge.

During interviews with wildlife health experts at the 2024 NEAFWA conference, participants recommended, in addition to determining causes of illness or death, a proactive approach to wildlife health to include identifying and evaluating population health indicators. This approach could involve identifying factors supporting the health and resilience of fish and wildlife and understanding threats to health (e.g., assessing whether habitat restoration efforts are supporting or improving healthy individuals and populations). Key indicators of individual and population health — and thus overall resilience — include genetic diversity, immune function, reproductive fitness, population parameters, body condition, organ function, active infections, and parasite loads. Though not exhaustive, these variables may provide valuable metrics for assessing potential health threats and evaluating the overall health and resilience of fish and wildlife populations.

Conclusion

Promoting Pennsylvania's fish and wildlife health requires a multifaceted approach integrating contaminant impact assessment, proactive and reactive surveillance, disease mitigation, risk assessments, public engagement, collaborative policy initiatives, and other strategies. Effective actions and successful outcomes rely on strong partnerships between state agencies, researchers, and the public to implement informed policies and raise awareness. These actions and partnerships, coupled with a coordinated, proactive, science-driven approach, will be critical to safeguarding health and promoting resilient populations of Pennsylvania's diverse fish and wildlife over the next decade and beyond. Building on these measures, with periodic review and assessment, will be integral for guiding our efforts to advance the well-being of Pennsylvania's SGCN.

Pollution

Acidic Precipitation

In Pennsylvania, and throughout the northeastern U.S, acidic precipitation (i.e., acid rain) has been detrimental to both terrestrial (Pabian and Brittingham 2007) and aquatic systems (Schindler 1988), especially streams and watersheds with limited buffering capacity. Acidic precipitation occurs when sulfur dioxide (SO2) and nitrogen oxide (NOx) emissions are transformed in the atmosphere and return to earth in rain, fog, or snow (USEPA 2008). Historically, in Pennsylvania, acidic precipitation has been attributed to depressed populations of native Brook Trout (*Salvelinus fontinalis*) and has influenced resource management practices including the removal of streams and lakes from the trout stocking program due to adverse chemical impacts associated with acid precipitation (PFBC 2014). In over 55 years of implementing the Clean Air Act of 1970 (USEPA 2025), great strides have been made to address acidic precipitation. The EPA has helped to reduce S02 by 95% and nitrogen sulfide by 89% (USEPA

2026). However, In the Mid-Atlantic region, acidic precipitation remains a threat to brook trout (Eastern Brook Trout Joint Venture-EBTJV 2026).

Water Pollution

Air pollution can contribute to water pollution through atmospheric borne chemicals, yet this is only one of many constituents contributing to diminished water quality and associated aquatic habitats. The PADEP protects four stream water uses: aquatic life, fish consumption, potable water supply, and recreation. If a stream segment is “not attaining” any one of its four uses, it is considered impaired (PADEP 2024a) and the PADEP is responsible for reporting on the Clean Water Act Section 305(b) and Section 303(d) listings. As with the Clean Air Act of 1970, the Clean Water Act of 1972 (USEPA 2026a) has provided impetus for notable progress in remediating degraded water quality and implementing protective measures. Nevertheless, over 18,000 miles (28,968 km) of Pennsylvania streams remain impaired for aquatic life use and nearly 29,000 miles (46,670 km) are impaired for any use (PADEP 2024a) (Fig. 3.10). The main sources of water quality impairments are agriculture, acid mind drainage,

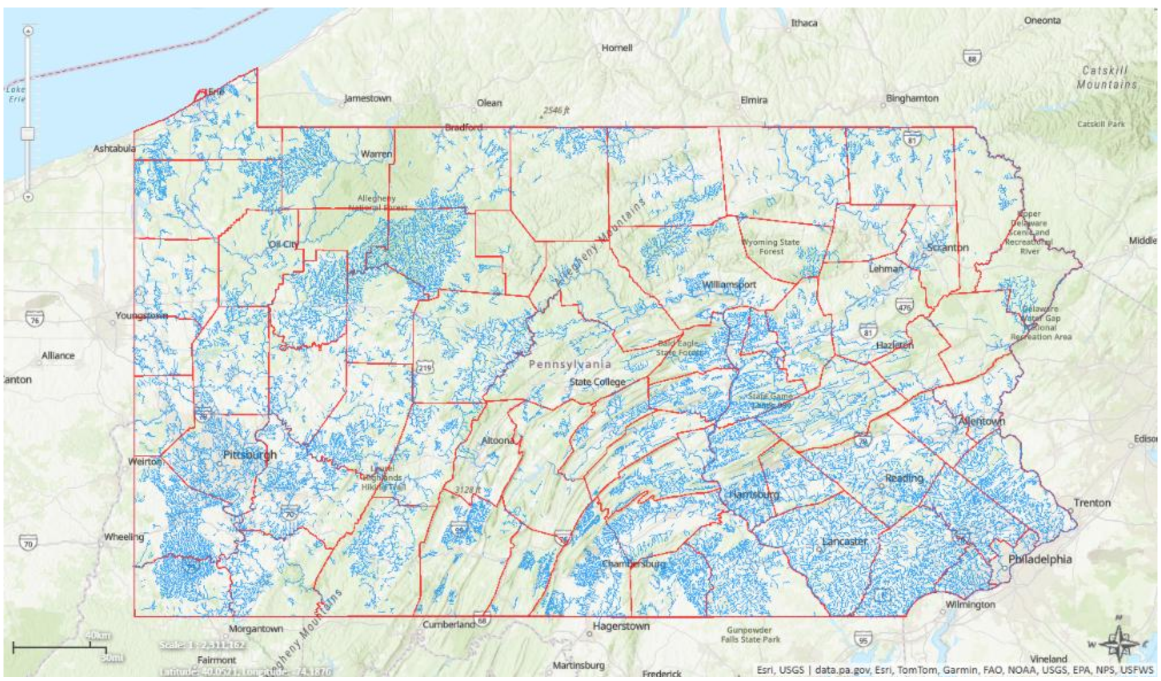

Fig 3.10. Streams not achieving their designated use (i.e., “non-attaining”) in at least one of four uses: aquatic life, fish consumption, potable water supply, and recreation. (Source data: PADEP 2026a, served via PASDA https://www.pasda.psu.edu/uci/datasummary.aspx?dataset=888. Map generated using PA Wildlife Action Map. https://wildlifeactionmap.pa.gov/

urban runoff/storms sewers and habitat modifications (PADEP 2024a). Water quality impairments clearly remain a systemic problem for Pennsylvania’s rivers and streams and associated aquatic life (Fig 3.10).

Abandoned Mine Lands

At a regional scale, coal and mineral mines have been found to stress stream fish assemblages even when mines are at low densities across the landscape (Daniel et al. 2014). In Pennsylvania, a coal-producing state, abandoned mine lands for decades have been a legacy pollution source and

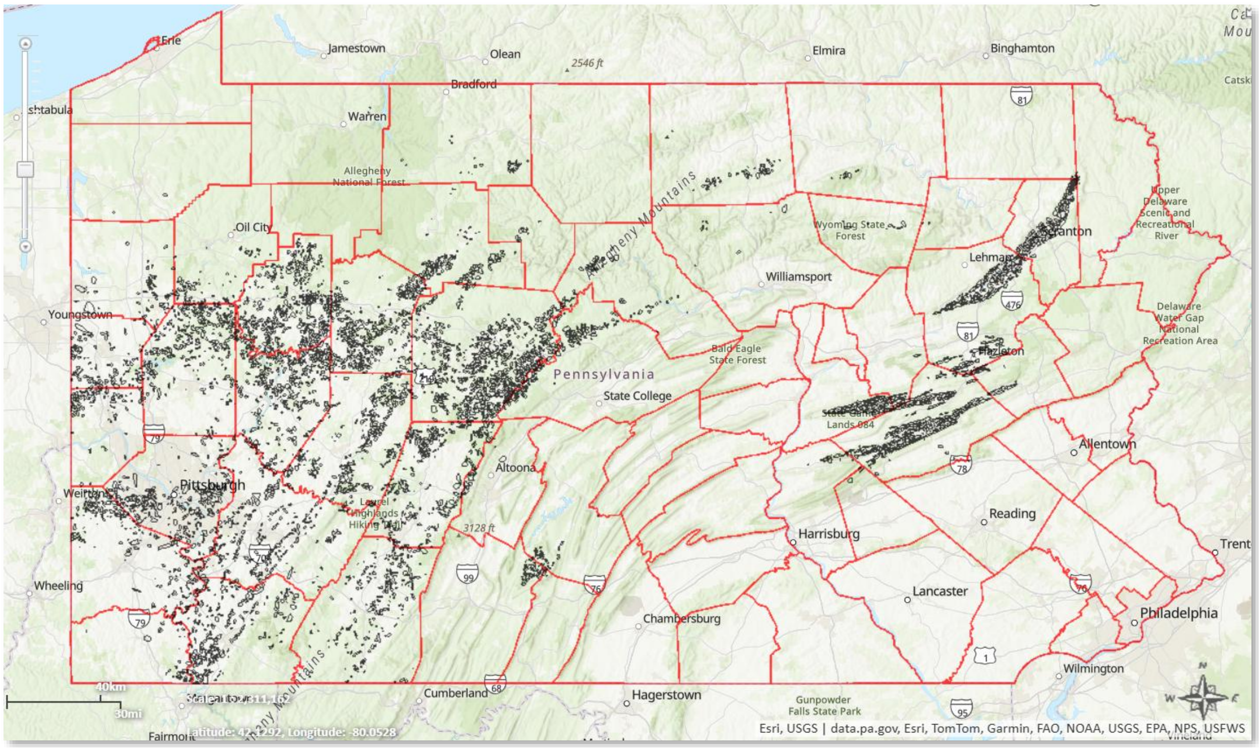

Fig 3.11. Pennsylvania Abandoned Mine Lands (AML) inventory sites. (Source data: PADEP 2026b; 2026c, served via PASDA https://www.pasda.psu.edu/uci/datasummary.aspx?dataset=888. Map generated using PA Wildlife Action Map. https://wildlifeactionmap.pa.gov/

continue to impair waterways. Pennsylvania's Abandoned Mine Lands (AMLs) (Fig. 3.11) still account for approximately one-third of national AML problems (PADEP 2015). Yet, through the Surface Mining Control and Reclamation Act (SMCRA) of 1977 measurable progress has been made to recover these altered habitats and provide associated environmental benefits. Cumulatively, under SMCRA Title IV, the Pennsylvania Abandoned Mine Land (AML) program administered by the Pennsylvania Department of Environmental Protection, 98,737 acres (39,957 hectares) have been reclaimed with construction costs of $674 million (PADEP 2026d). Additional AML remediation accomplishments have been made with support from organizations and coalitions such as Trout Unlimited, West Branch Susquehanna River Watershed Coalition (WBSRWC), Eastern Pennsylvania Coalition for Abandoned Mine Reclamation (EPCAMR), Foundation for Pennsylvania Watersheds, and Western Pennsylvania Coalition for Abandoned Mine Reclamation (WPCAMR). These organizations and other concerned citizens have implemented on-the-ground recovery and fostered vital community support for recovery initiatives.

Climate Change and Severe Weather

Introduction

There is diminishing debate regarding human activity as the source of global climate change (Cook et al. 2013; Zachariah et al. 2023, IPCC 2023; PADEP 2025; PADEP 2025a). New data and innovative analyses (e.g., downscaled climate models) are expanding understanding of climate change and its implications for SGCN and habitats. Uncertainty may remain in the severity, timing, and scope of impacts, yet overwhelming scientific evidence consistently reflects the current and potential harm to fish, wildlife, and their habitats from this threat at multiple scales, including global (International Panel on Climate Change-IPCC 2023), regional (Northeast) (Staudinger et al. 2024) and state levels (PADEP 2025; PADEP 2025a). With high confidence, the IPCC (2023) noted that "climate change has caused substantial damages, increasingly irreversible losses, in terrestrial, freshwater, cryospheric, and coastal and open ocean ecosystems". In the eastern and northeastern U.S. extreme weather attribution studies suggest climate change likely contributes to risk of extreme precipitation and flooding events, and extreme heat (Zachariah et al. 2023; PADEP 2025a) with warming in the Northeast exceeding global averages making it a climate change hotspot (Staudinger et al. 2024). In Pennsylvania, projected climate impacts could be significant in several sectors including; human health, environment, recreation, infrastructure, and economy with increasing temperatures and heavy precipitation the greatest risk factors with statewide impacts projected by 2050 (PADEP 2025a). Climate change is complex and expansive so incorporating this topic in State Wildlife Action Plans can be daunting. To support this challenge, the Association of Fish and Wildlife Agencies developed voluntary "best practices" for states (AFWA 2009) and, in a subsequent update (AFWA 2022), seven principles were identified (Table 3.7).

Climate change is affecting Pennsylvania and is apparent in intense storms, floods, air quality emergencies, and increasing temperatures (PADEP 2025a). Additionally, Pennsylvanians are noticing shifts in weather factors or phenomena often attributed to climate change (Responsive Management 2024). In a 2024 survey, Pennsylvania respondents noted an overall increase in *severe or changing weather patterns* (47%), *air temperature overall* (45%), *flooding* (37%) and a decrease in *snowfall* (59%) (Responsive Management 2024). When interviewing respondents, this statewide survey didn't mention the term "climate change" or ask about potential causes for these changes, yet these findings show the public is noticing factors associated with a changing climate.

The following is an overview of key climate change factors and current, or anticipated, impacts to SGCN and habitats. In Pennsylvania, multiple habitats, species, and ecological processes are affected by climate change and, given this topic's complexity, a comprehensive review is beyond the scope of this Plan, instead our focus will be directed to primary variables influenced by climate change, especially temperature and precipitation.

Table 3.7 Principles for Incorporating Climate Change into State Wildlife Action Plans. (AFWA 2022).

1. Fully integrate climate change into State Wildlife Action Plans.
2. Adopt forward-looking goals.
3. Explicitly link actions to climate vulnerabilities.
4. Mange for change, not just persistence.
5. Consider broader landscapes and longer timeframes.
6. Address uncertainty by considering future scenarios and use of adaptive management.
7. Engage diverse partners with climate experience and expertise.

Climate Change-Temperature, Precipitation, and Habitat Impacts

Climate change was initially noted as a threat in the 2005 Pennsylvania Wildlife Action Plan, yet at that time, the potential impacts to SGCN and their habitats were less understood compared to other threats. In 2010, Amendment #2 to the 2005 Pennsylvania Wildlife Action Plan more fully discussed climate change as an emerging issue for Pennsylvania fish and Wildlife Management (PGC-PFBC 2009). As committed in Amendment #2, Pennsylvania addressed this topic in the 2015-25 PA WAP, and this threat remains relevant as broadly discussed here and more specifically in select Species Accounts where this threat has been identified.

Discussed throughout this chapter, numerous threats affect Pennsylvania's SGCN and habitats, and climate change may further amplify these threats. For example, aquatic habitat fragmentation, such as caused by dams, culverts or other obstructions can impede aquatic organism passage (Qiuwen et al. 2023).

Temperature

Temperature is physiologically and ecologically important because it can directly affect an animal's survival (e.g., exceed lethal threshold, change in phenology or life-history patterns) or alter habitats (e.g., change forest structure, amplify invasive species). Therefore, understanding projected changes in temperature can guide conservation actions that help species adapt or mitigate changing temperature effects.

Over the past 110 years, Pennsylvania's climate has warmed more than 1.8°F (1°C), with only a brief cooling during the mid-20th century (Shortle et al. 2015). From 2000 to 2023, average annual temperatures have already risen 1.2°F and are expected to continue to increase by 6.7°F (3.7°C) by mid-century, above the baseline period of 1971-2000. Increasing temperatures will contribute to more frequent hot days and heat waves, which are discrete events with elevated temperatures above 90°F and 95°F. For forests, ecosystems, and wildlife, projected average temperature increases have the highest consequences (catastrophic) with irreversible damage (PADEP 2025a).

Warming is also contributing to Sea-Level Rise (SLR). In Pennsylvania this will be manifested in the upper Delaware River Estuary where SLR will contribute to increased salinity with marine species moving into areas currently occupied by freshwater or estuarine aquatic fauna (e.g., oysters, mussels) and flora intolerant of increased salinity and frequent flooding (PADEP 2025a).

Precipitation

Precipitation is another important factor associated with climate change and, although precipitation is more difficult to model (Shortle et al. 2015), interpreting potential scenarios can assist with understanding how this factor may affect SGCN and their habitats. A change in timing, seasonality, and magnitude of water delivery can alter ecosystems, which may be reflected in changing seasonal patterns of water levels, reduced stream flows during dry periods, larger floods and longer droughts (Moore et al. 1997; Rogers and McCarty 2000).

Heavy precipitation and inland flooding are expected to impact forests, ecosystems, and wildlife which may include increased hydrological variability in wetlands and streams, increased pathogen loads, eutrophication, and algal blooms (with high confidence) (PADEP 2025a). Despite increasing average and extreme precipitation events, there is uncertainty in the trend for drought duration and extent, though precipitation events will contribute to wetter winters and springs and drier falls (PADEP 2025a). In urbanized watersheds, climate change influences on annual runoff are uncertain, but urban conditions may have more influence on runoff than climate effects (DeWalle et al. 2000).

Timing and rate of delivery of water can be crucial to species and habitats. In the northeast U.S., Increase in winter precipitation as rain is projected to increase surface runoff and peak river flows in winter in the future (Siddique and Palmer 2021; Siddique et al. 2020; Staudinger et al. 2024). Similarly, Pennsylvania is projected to receive less snowfall as a consequence of climate change (Kapnick and Delworth 2013; Shortle et al. 2015; PADEP 2025a) (Table 3.8) suggesting precipitation may occur in liquid form rather than snow (Ross et al. 2013; PADEP 2025a).

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Table 3.8. Summary of projected changes for Pennsylvania's water resources. (From Ross et al. 2013, Shortle et al. 2015; see also PADEP 2025a Appendix B)

Property	21st Century Projection	Confidence
Precipitation	Increase in winter precipitation. Small-to-no increase in summer precipitation. Potential increase in heavy precipitation events.	High (for winter); lower for summer.
Snowpack	Substantial decrease in snow cover, extent, and duration.	High
Runoff	Overall increase, but mainly due to higher winter runoff. Decrease in summer runoff due to higher evapotranspiration.	Moderate
Soil moisture	Decrease in summer and fall soil moisture. Increased frequency of short- and medium-term soil moisture droughts.	High
Evapotranspiration	Increase in temperature throughout the year. Increase in actual evapotranspiration during spring, summer and fall.	High
Groundwater	Potential increase in recharge due to reduced frozen soil and higher winter precipitation when plants are not active and evapotranspiration is low.	Moderate
Stream temperature	Increase in stream temperature for most streams likely. Some spring-fed headwater streams may be less affected.	High
Floods	Potential decrease of rain-on-snow events, but more summer floods and higher flow variability	Moderate
Droughts	Increase in soil moisture drought frequency.	Moderate
Water quality	Flashier runoff, urbanization and increasing water temperatures might negatively impact water quality.	Moderate
Saltwater intrusion	Increase in saltwater intrusion (in estuaries) due to rising sea levels.	Moderate

Overall, Pennsylvania's current trends in warming and wetter conditions are expected to continue (PADEP 2025a). Changing precipitation patterns with periods of drought and extreme heavy rain events may lead to more frequent and extreme flooding. Many impacts will occur statewide, whereas others will be more localized such as increasing coastal flooding in Lake Erie and tidal flooding in the Delaware Estuary Coastal Zone (PADEP 2025a).

Forests

Forested habitats cover nearly 60% of Pennsylvania's landscape so, climate change effects on Pennsylvania's forests and associated biotic communities are of particular concern. For example, birds are often associated with specific forest structure (Cullen et al. 2013) and there is potential for changing forest composition under altered climate scenarios (Iverson et al. 2008a; 2008b; Wang et al. 2017; Butler-Leopold et al. 2018; PADEP 2025a). Understanding these changes in forests can help guide conservation actions for affected fish and wildlife. Supporting this assessment, 35 Pennsylvania tree species were evaluated for their possible response to climate change by placing them into six categories (McDill 2009; Shortle 2009):

- *most at-risk of being extirpated from the state.*
- *most likely to decline substantially in importance in the state.*
- *most likely to decline moderately in importance in the state.*
- projected to either marginally increase or decrease.
- currently relatively common in the state and most likely to increase in importance.
- *currently not common in the state and most likely to increase in importance.*

For this study, tree species at the southern end of their range are expected to be lost from Pennsylvania, whereas species at the northern edge of their range (e.g., oaks, hickories, southern pines) are anticipated to advance further northward (Shortle et al. 2009). Aspen (*Populus spp*.) and birch (*Betula spp*.) are among the most vulnerable species for extirpation from Pennsylvania and projected to be extirpated from Pennsylvania under high-emission scenarios and greatly reduced (perhaps eliminated) under low-emission scenarios (Iverson et al. 2008a: 2008b; Shortle et al. 2009) (Table 3.9). More recent assessments of climate impacts on Pennsylvania forests align with these previous projections (USDA-Northern Forests Climate Hub and Northern Institute of Applied Climate Science-NIACS 2026). Here subregional tree species assessments in response to climate change offer a more downscaled review of tree species climate change adaptability. For example, in the Ridge and Valley region, Eastern hemlock, Eastern white pine and paper birch are among several tree species with poor capability to adapt to climate change (Ridge and Valley, USDA-Northern Forests Climate Hub 2024, https://forestadaptation.org/sites/default/files/PA_RidgeValley_4_branding_Nov24_508.pdf). In the Mid-Atlantic Region, including Pennsylvania, similar potential impacts across the region were found with northern and remnant boreal tree species (e.g., quaking aspen, Eastern hemlock, Eastern white pine) under increasing stress with reduced suitable habitat and negatively impacted by climate change, whereas increasing habitat and suitability is expected for southern species (e.g., post oak, scarlet oak and southern red oak (Butler-Leopold et al. 2018).

Pennsylvania's forests have also been subjected to many disturbances, including habitat fragmentation, pollution and non-native plants, insects and diseases (Shortle et al. 2009). For example, flowering dogwood, American beech, eastern hemlock and white ash are declining or have already declining, but this loss is attributed to invasive pests and disease and not directly the result of climate change (Shortle et al. 2015). Invasive species survival can be enhanced by environmental changes associated with a warming climate Invasive Species. Confidently understanding the effects of these anticipated changes in forest composition on other biotic communities, such as birds, will require extensive monitoring during this Plan's implementation phase.

In addition to forest composition, a significant challenge in the coming decades will be maintaining forest habitat connectivity in the more heavily forested parts of the Marcellus and Utica Shale regions and in areas under solar and wind energy development. These developments have expanded existing roads, developed new roads and pipeline corridors, and cleared habitats all of which have contributed to further landscape fragmentation.

Table 3.9. Categories of tree species in Pennsylvania based on projected vulnerability to climate change (Iverson et al. 2008a, 2008b; Shortle et al. 2009, 2015).

Category (for relevance in Pennsylvania)	Common Name	Scientific Name
Most at-risk of extirpation from the state	Paper birch	*Betula papyrifera*
	Quaking aspen	*Populus tremuloides*
	Bigtooth aspen	*Populus grandidentata*
	Yellow birch	*Betula alleghaniensis*
Most likely to decline substantially in importance in the state	American beech	*Fagus grandifolia*
	Black cherry	*Prunus serotina*
	Striped maple	*Acer pensylvanicum*
	Eastern hemlock	*Tsuga Canadensis*
Most likely to decline moderately in importance in the state	Red maple	*Acer rubrum*
	Sugar maple	*Acer saccharum*
	Eastern white pine	*Pinus strobus*
	Sweet birch	*Betula lenta*
	White ash	*Fraxinus Americana*
	American basswood	*Tilia Americana*
Projected to either marginally increase or decrease	Northern red oak	*Quercus rubra*
	Chestnut oak	*Quercus prinus*
	Yellow-poplar	*Liriodendron tulipifera*
	Sassafras	*Sassafras albidum*
	Pignut hickory	*Carya glabra*
	Blackgum	*Nyssa sylvatica*
	Black walnut	*Juglans nigra*
	White oak	*Quercus alba*
	American elm	*Ulmus Americana*
	Flowering dogwood	*Cornus florida*
Currently relatively common in the state and most likely to increase substantially in importance	Mockernut hickory	*Carya tomentosa*
	Black oak	*Quercus velutina*
	Silver maple	*Acer saccharinum*
	Eastern red cedar	*Juniperus virginiana*
Currently not common in the state and most likely to increase in importance	Loblolly pine	*Pinus taeda*
	Shortleaf pine	*Pinus echinata*
	Common persimmon	*Diospyros virginana*
	Red mulberry	*Morus rubra*
	Black hickory	*Carya texana*
	Blackjack oak	*Quercus marilandica*
	Winged elm	*Ulmus alata*
	Post oak	*Quercus stellata*

Rivers and Streams

Pennsylvania's diverse aquatic habitats are highly regarded resources and include approximately 86,000 miles (138,404 km) of streams (PADEP 2024a) – second only to Alaska in number of stream miles. Recent meteorological trends strongly support predictions of higher flooding potential in Pennsylvania due to higher precipitation, with 2018 the wettest year on-record (PADEP 2025a). Modeled projections of higher precipitation are expected to be reflected in increased flooding risks by mid-century (2050), including in potential frequency and severity (PADEP 2025a). Larger peak flows can contribute to higher rates of sedimentation and increased scouring of stream banks and floodplains, both of which decrease survival and reproductive success for fish and macroinvertebrates (Chapman 1988; Fisher 2000; Nerbonne and Vondracek 2001).

The greatest impacts of climate change on flow are expected in urban areas with a high percentage of impervious surfaces where runoff is quickly routed to streams (Rogers and McCarty 2000; Shortle et al. 2015). Overall, increased hydrological variability (e.g., larger floods, longer droughts) predicted by climate models could have severe, long-term impacts on both stream and wetland communities (Humphries and Baldwin 2003, Harper and Peckarsky 2006, Shortle et al. 2015, PADEP 2025a).

Reliable statewide projections of stream temperatures have been confounded by lack of data, especially on streams with continuous records (Shortle et al. 2015). In their analysis Shortle et al. (2015), found inconsistencies in summer temperatures but, overall, more recording stations showed warmer hottest-day temperatures and longer hot periods. In winter, stream temperatures are showing warming trends like the Northeast (Shortle et al. 2015; Staudinger et al. 2024). Such warming trends could differentially benefit or harm aquatic organisms depending upon their preferred thermal ranges (Hendricks 2023; PADEP 2025a). In southwestern Pennsylvania headwater streams appear resilient to climate change, attributed to riparian cover and groundwater inputs, but connectivity of brook trout populations in these headwater streams may be interrupted due to warmer connecting streams with unsuitable habitats (Argent and Kimmel 2013). More broadly, in the Chesapeake Bay watershed, models suggest climate change (i.e., increased ambient temperatures and altered precipitation) will contribute to brook trout habitat loss (Merriam et al. 2019).

Wetlands

Freshwater wetlands are critical areas for aquatic ecosystem functions, serving as nursery areas for fish, amphibians and other aquatic life, sources of dissolved organic carbon, critical habitat, and stabilizers of available nitrogen, atmospheric sulfur, and carbon dioxide (Mitsch and Gosselink 2000; Ross et al. 2013). In Pennsylvania, inland freshwater wetlands encompass approximately 376,473 (152,353 hectares) and an additional 56 acres (22.6 hectares) of tidal wetlands found in southeastern Pennsylvania (PADEP 2019). These habitats support diverse biotic communities, including all major taxonomic groups encompassed by this plan. Climate change-induced alterations could have serious implications for species in wetland habitats.

As found with streams, hydroperiod defines the structure and function of wetlands, with the amount of water, rate of flow, and timing of delivery influencing the type of organisms present, the cycling and removal of nutrients, and other ecosystem services (Millennium Ecosystem Assessment 2005; Shortle et al. 2009). Altered timing, seasonality, and magnitude of water delivery can severely affect these systems, reflected in changing seasonal patterns of water levels, reduced stream flows during dry periods, larger floods and longer droughts (Moore et al. 1997; Rogers and McCarty 2000; Ross et al. 2013). Some surface-water wetlands, believed to be the most vulnerable to these changes, may completely disappear (Ross et al. 2013).

Increasing temperatures will enhance evapotranspiration from wetlands, increasing importance of riparian trees (PADEP 2025a). Wetlands, streams, and lakes surrounded by agricultural and urban activity often have reduced water quality (Omernik 1976; Lenat and Crawford 1994; Crosbie and Chow-Fraser 1999; Trebitz et al. 2007). Altered timing and quantity of precipitation and increasing temperatures are anticipated for Pennsylvania in future climate scenarios (Shortle et al. 2015, PADEP 2025a) and because these factors can influence biotic communities (Poff et al. 2002), shifts in Pennsylvania species and habitats also may be anticipated.

Lakes

Pennsylvania inland lakes and ponds encompass 160,000 acres (67,450 hectares) with an additional 470,000 acres (190,202 hectares) of Lake Erie (PFBC 2025). Climate change and associated impacts of altered precipitation and increasing temperatures, coupled with enhanced nutrient loading, can drive development of Harmful Algal Blooms (HABs) (Brenckman et al. 2025). HABs can occur in multiple waterbody types, and since the 1990’s there has been an increase in some U.S. and European lakes (Feng et al. 2024). Where HABs they occur can contribute to aquatic life loss due to toxin-producing phytoplankton (Anderson et al. 2002; O’Neil et al. 2011; Michalak et al. 2013, Feng et al. 2024).

In similar eutrophic conditions (e.g., low dissolved oxygen levels, elevated nutrients), occurrence of Type E botulism can develop and lead to mortality in fish and wildlife, especially waterfowl (Espelund and Klaveness 2014, also see above in Wildlife Health section). With projected increases in temperature and precipitation (PADEP 2025a), increased occurrences of HABS in Pennsylvania lakes, wetlands, and rivers may be anticipated, along with potential negative effects on associated aquatic life.

Climate Change-Fish and Wildlife Impacts

Climate change impacts on fish and wildlife are thoroughly discussed in Staudinger et al. (2024) and TCI and NEFWDTC (2023) and, given the expansive literature, a comprehensive review is beyond the scope of this Plan. For SGCN, species-specific climate impacts are identified in the species accounts (Chapter 1-Species, Appendix 1.4). Here we briefly highlight specific climate change impacts on fish and wildlife range shifts, phenology, and invasive species.

Fish and Wildlife Distribution and Abundance Shifts

Climate change factors (i.e., increasing temperatures and variable precipitation) are affecting fish and wildlife species-specific range and population abundance shifts; however, these range and abundance changes are not consistent among and across taxa (Rodenhouse et al. 2009; Ross et al. 2013). Distribution (i.e., range) shifts have been found to generally follow climate change trends, yet given many climate change factors including temperature, precipitation, fish and wildlife life-history, habitat changes, species interactions (e.g., predators, prey), and wildlife health concerns, these fish and wildlife distribution changes are difficult to predict (Ross et al. 2013; Lawlor et al. 2024). For example, in an assessment of the BioShifts database, the majority (59%) of documented range shifts were consistent with climate change, yet 35% of species' ranges changed contrary to temperature expectations, and 6% showed no indication of range shifting (Lawlor et al. 2024). Inconsistencies among assessments evaluated, such as scale (e.g., global, local), can influence these outcomes (Lawlor et al. 2024).

For birds, climate change can influence distribution, abundance, community composition, phenology, other species characteristics (Trautmann 2018). In northeastern U.S. forests, 27 of 38 studied bird species were found to have shifted their distribution (ranges) predominantly northwards (Rodenhouse et al. 2009). For a subset (15 bird species), this range expansion could be attributed to increasing population, but only four of these species' populations were expanding in all directions whereas 11 species' ranges were advancing only northward, and thus this range expansion was considered beyond a basic increase in abundance (Rodenhouse et al. 2009).

Changes in species' abundances attributed to climate change are similarly variable. Of 25 permanent resident bird species in the North Atlantic Forest Bird Conservation region, 15 species were found increasing in abundance, five species were decreasing in abundance, and five species showed no change in abundance (Rodenhouse et al. 2009; Ross et al. 2013). Similarly, migrant bird species demonstrated no clear trend in abundances attributable to climate change.

Northeastern U.S. mammals are expected to be affected by shifts in habitat structure, food availability, health related factors such as parasites and diseases, limited tolerance of increasing temperatures, and changes in extreme winter weather (e.g., decreasing snow depth, ice storms) (Rodenhouse et al. 2009). Hybridization attributable to climate change has been observed between southern flying squirrels (*Glaucomys volans*) and northern flying squirrels (*G. sabrinus*) (Garroway et al. 2010) due to a northerly shift in the range of the southern flying squirrel, contributing to increased opportunity for sympatry.

As previously mentioned, climate-associated impacts can often be just one factor in a complex interaction affecting fish, wildlife, and their habitats. For example, PA SGCN Ruffed Grouse (*Bonasa umbellus*) populations have been declining across its range for many years; attributed to habitat loss and reduced habitat quality, especially loss of successional forests (Kunkel et al. 2025). However, these declines are also exacerbated by increases in climate change (e.g., increasing precipitation, increasing temperature) with landscape modifications (e.g., new standing water habitats) driving increases in mosquito populations which carry the West Nile Virus pathogen, found to increase Ruffed Grouse mortality (Stauffer et al. 2018; Kunkel et al. 2025) (See also Ruffed Grouse species account, Chapter 1-Species, Appendix 1.4).

Climate change is effecting fish abundance, growth, and recruitment (Lynch et al. 2016) including PA SGCN fishes such as brook trout (*Salvelinus fontinalis*) (Bassar et al. 2016), American shad (*Alosa sapidissima*) (Quinn and Adams 1996), and cisco (*Coregonus artedi*) (Jacobson et al. 2012). So, aquatic habitat fragmentation, coupled with warmer water or altered stream flows, may further diminish aquatic organism survival. As in most complex systems, many variables can confound a direct association or cumulative impact. In terrestrial habitats, climate change can further amplify invasive species' impacts (NERISCC 2025) or disrupt species interactions such as mismatched predator-prey relationships (Jamil et al. 2024).

Phenology

Developmental processes in plants and animals can be initiated by various environmental factors, including seasonal temperature (Badeck et al. 2004) or photoperiod (Körner and Basler 2010). Mismatches in this timing (i.e., phenology) between species, such as plants blooming before emergence of associated insect pollinators, or early emergence of insects historically important food for nesting birds (Rubenstein 2017) could have serious negative consequences for these dependent species. Climate-associated changes in phenology (i.e., temporal change in a species' life history) have been attributed to earlier spring development in plants (Badeck et al. 2004), ice-out on waterways (Bradley et al. 1999), early bird migration and insect emergences (Visser and Both 2005), or altered predator-prey dynamics for fishes (Lynch et al. 2016). As with shifting ranges, responses to a changing thermal regime are not consistent among species, and species not able to adapt to an altered thermal regime or move to new habitats may be lost (Bradley et al. 1999).

Invasive Species and Diseases

Worldwide, changing climatic conditions are impacting ecosystems and, with projections to synergistically exacerbate effects and risks posed by invasive species to ecosystems, are important considerations for conservation efforts (Mainka and Howard 2010). Climate variables are crucial for estimating invasive species establishment and spread risks (Finch et al. 2021). Generally, warming temperatures and variability in precipitation, snow, and ice cover will likely reduce current climatic constraints and provide more suitable conditions allowing for northward range expansion of numerous aquatic and terrestrial invasive species (Rahel and Olden 2008; Finch et al. 2021). Plant diseases and pests are likely to have a greater impact in a warming climate, allowing them to expand their range into new areas (Dukes and Mooney 1999; PADEP 2025a) where they can alter fish and wildlife community structure and their habitats. As winters become less severe, there is also the potential for tropical zone plants, insects, reptiles, amphibians, fish, and mammals (e.g., nutria) to move northward towards the commonwealth and become invasive (Osland et al. 2021). Therefore, invasive species which likely cannot survive in Pennsylvania's current climate may be able to become established in coming years as regional conditions become more suitable. Based on 21st century climate change projections, climate suitability increased for approximately 66% (34 of 51) potential aquatic invasive animal and plant species not currently present in Pennsylvania (Grisé 2011). Proactive prevention and control measures should be considered in accordance with climate change projections and risk modeling for invasive species groups.

The number of invasive species in Pennsylvania is dynamic (Invasive Species) and a variable climate can make native habitats and SGCN increasingly vulnerable to invasive species. For example, in Pennsylvania, the hemlock woolly adelgid (*Adelges tsugae*) HWA is a serious threat to native eastern hemlock (*Tsuga canadensis*) and in 2023, was found in all 67 counties (PADCNR 2023) (Fig. 3.12). HWA is vulnerable to cold temperatures, so loss of eastern hemlock forests is expected to be enhanced by a warming climate, especially warmer winters (Cornelsen et al. 2024). Beyond loss of this tree species, biological communities associated with eastern hemlock are at-risk. Fish communities in eastern hemlock ecosystems, compared to hardwood forests, have been found to hold more eastern brook trout and brown trout (*Salmo trutta*) (Ross et al. 2003). Additionally, aquatic invertebrate communities (Snyder et al. 2002) and birds, such as the Louisiana Waterthrush (*Parkesia motacilla*) are associated with eastern hemlock and, too, may be harmed by hemlock loss (Barnes et al. 2018). Relevance of HWA survival to temperature is just one example of how climate change can be expected to influence a Pennsylvania habitat and associated species. Given varied responses of native and invasive species to changing temperature and precipitation, continued monitoring will be crucial to more fully understand the rate of change, climate resiliency of native species, and identify potential conservation actions to support adaptation strategies. The earth's climate is changing and, regardless of uncertainty in severity or scope, supporting adaptation and foster resiliency (e.g., enhance habitats, provide corridors) will be crucial to reduce risks to SGCN. Many conservation actions that enhance SGCN survival to non-climate threats will also support their climate change resilience.

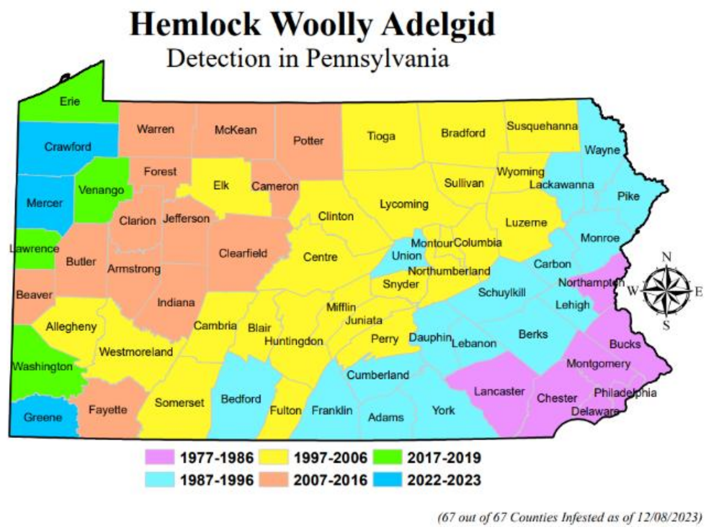

Fig. 3.12. Distribution of Hemlock Woolly Adelgid in Pennsylvania. (Source: PADCNR 2023).

Other Threats

Disturbances

Beyond air and water-borne pollution urbanization also brings other forms of pollution, such as increased artificial nighttime light and noise, the effects of which on Pennsylvania's SGCN are not well-known. Artificial light is considered a biodiversity threat and attributed to affecting functions, such as migration, of species in several major taxonomic groups (Hölker et al. 2010; Burt et al. 2023), however effects on populations or ecosystem-level processes such as mortality, fecundity, community productivity, species composition, and trophic interactions are not well understood (Gaston et al. 2013).

Noise can disrupt species interactions, thus indirectly influencing ecological processes (Francis et al. 2009). Increased noise has been found to negatively influence bird populations and communities, yet higher reproductive success has been observed in high-noise environments, which may be attributable to urban-adapted bird species tolerant of noise. Additionally, predators that use acoustic cues to locate prey may be less likely to locate nests because of the masking effects of noise. However, birds excluded by noisy conditions from habitats that might otherwise be acceptable, were also found with higher rates of nest predation (Francis et al. 2009).

Pesticides

Pesticides are used extensively throughout society, including in households, agriculture, and industry. Given their extensive use, it is beyond the scope of this Plan to provide a comprehensive review of the implications of pesticides for SGCN and habitats; however, it is important to acknowledge that pesticides may be a factor influencing a species' status.

Among invertebrates, public attention has focused on pollinators such as butterflies and bees. Declines in the Monarch butterfly (*Danaus plexippus*) (Pleasants and Oberhauser 2012) and bees (*Bombus spp*.) including *B. affinis* and *B. terricola* (Pennsylvania SGCN) (Cameron et al. 2010) have been documented. For bees, a potential source of decline is a class of insecticide neonicotinoids (Rundlöf et al. 2015). Preliminary evidence has also linked neonicotinoids with mortality in Monarch butterflies, although additional work is required to fully document this insecticide as a contributing factor in the decline of the species (Pecenka and Lundgren 2015). The decline of these species is complex, involving many factors; however, neonicotinoid use appears to be a common factor.

Other pesticides can be highly toxic to non-target species. For example, spraying for Spongy Moth (*L. dispar*) can adversely affect non-target lepidopterans (e.g., moths, butterflies) and the widespread application of various insecticides imperils insectivorous birds such as the Eastern Whip-poor-will (*Antrostomus vociferus*) (TCI and NEFWDTC 2023).

Insufficient Information

Insufficient information is, of itself, an indirect threat to Pennsylvania's SGCN and habitat conservation because it inhibits informed conservation action planning and implementation to address known threats. With 602 "data deficient" species, primarily invertebrates, there is clearly an enhanced need for basic distribution, abundance, threats and relevant conservation actions, and other information. This information insufficiency goes beyond resource managers and includes public understanding and recognition of threats. An informed public can help identify other potential threats or highlight outreach or research needs. For example, in a statewide survey respondents were asked, "In your opinion, what is the most important issue or concern facing nongame wildlife in Pennsylvania today?" (Responsive Management 2014, 2024). In both surveys "Habitat loss/ fragmentation/ degradation" was the most important issue and notably increased from 16% (2014) to 25% (2024). Other issues or concerns expressed by respondents, included "Pollution in general" and "Polluted water/ water quality" (Fig. 3.13). Additionally, respondents indicating "Don't know" decreased from 32% (2014) to 16% (2024) and "There is no important issue", decreased from 8% in 2014 to 4% in 2024, with both categories reflecting a more informed public regarding threats to nongame wildlife. Not all concerns expressed by respondents were similar between years (e.g., poaching, vehicle accidents, air pollution/ air quality),

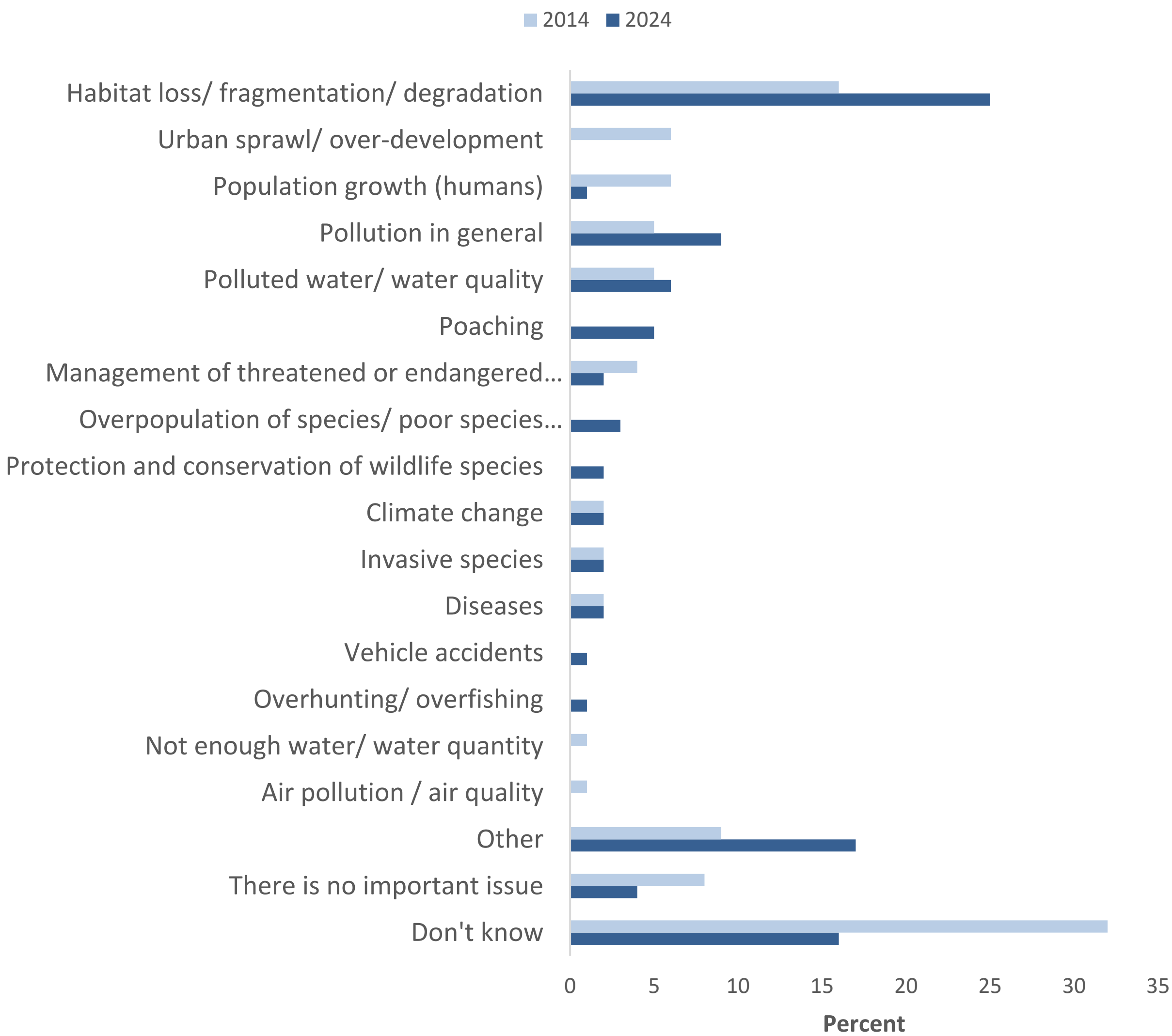

Fig. 3.13. Distribution (percent) of public survey responses to an open-ended question regarding the most important issue or concern facing nongame wildlife in Pennsylvania today (Responsive Management 2014, 2024).

perhaps reflecting a change in understanding of threats to nongame wildlife. Overall, these responses suggest various forms of habitat degradation or modification are the primary nongame wildlife concerns and Pennsylvania residents are increasingly aware of these threats.

Summary

Threats to Pennsylvania's SGCN and habitats are substantial and complex, sometimes with interactive effects and consequences. Further confounding threats, including climate change, is the extensive duration by which data collection may be required to make informed management decisions. To understand fish and wildlife trends, decades of data collection may be needed, to reflect delayed species or ecosystems responses to disturbances such as land use modifications or climate change.

In recent years, in the northeast U.S. and globally, essential research has illustrated threats relevant to fish and wildlife (TCI and NEFWDTC 2023; Staudinger et al. 2024). Increasingly, compiling, analyzing disparate datasets can be used to develop predictive models and fill SGCN and habitat information gaps. Long-term datasets and refined (downscaled) climate models will be useful for informing resource managers in their decisions for designing, implementing and testing conservation actions. The dynamic and often synergistic effects of threats may require developing monitoring strategies or novel or untested conservation actions. For these measures, methodically understanding effectiveness of actions may benefit from an adaptive management approach (Stankey et al. 2005).

New research and observations are providing insight into these relationships, but monitoring and investigative work may be required. Ecological responses to disturbances may take decades; therefore, monitoring initiatives should be designed to extend well beyond the typical 1- to 5-year grant cycle. Extended data collection initiatives such as the Long-Term Ecological Research (LTER) Program (Hobbie et al. 2003; LTER 2026) and the Upper Mississippi River Restoration, Long-Term Resource Monitoring Program (USGS 2026) can help monitor ecological changes at scientifically appropriate temporal and spatial scales. Using or adapting ongoing monitoring programs (Chapter 5-Monitoring) relevant to species or habitat needs is efficient and less. Enhancing data sharing capacity and developing localized datasets (Argent and Kimmel 2013), will be crucial to further refining and downscaling climate models. Within Pennsylvania, maintaining and enhancing coordination to address threats, such as invasive species through the PGISC will be essential for effective prevention and management, and information exchange with the public. Effective communication is essential to addressing invasive species' threats, especially with ineffective eradication measures for established invasive species. States are not isolated and wildlife does not recognize geopolitical boundaries. So, in the northeast U.S., interstate coordination and collaboration through the NEAFWA Fish and Wildlife Diversity Technical Committee and Wildlife Action Plan Coordinators Subcommittee, USGS Northeast Climate Adaptation Science Center, and Northeast Regional Invasive Species Climate Change management network will continue to provide necessary landscape scale conservation perspectives.

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Appendix 3.1.
Invasive Species

Pennsylvania Authorities and Oversight

- Seven state agencies and 14 non-governmental organizations comprise the **Pennsylvania Governor's Invasive Species Council** (PGISC or Council). The Council works to identify invasive plant, insect, and animal species currently threatening, or with the potential to threaten Pennsylvania's natural and agricultural resources and industries they support. The Council develops and implements the Commonwealth's invasive species management plan, a framework for preventing and controlling invasive species at the state level. The Council also advises the Governor on invasive species policy development, facilitates coordination between agencies and organizations to address invasive species threats, and conducts outreach and education.

- The **Pennsylvania Department of Agriculture** was created by legislation tin 1895 and transferred to it the three basic functions the state board of Agriculture had previously held: law enforcement, education and prevention of plant and animal disease. The department provides services to maintain and protect Pennsylvania agriculture through consumer protection and product regulation. This includes detection, identification and control of destructive plant pests (diseases, pathogens, insects and weeds - both native and exotic). The Department administers the state's Noxious Weed Control Law, the Plant Pest Act, the Seed Act, and the commonwealth's Domestic Animal Law and hosts the PGISC Coordinator.

- The **Pennsylvania Fish and Boat Commission** (PFBC) has its origins in legislation from 1866 designed to protect fish. The agency's mission is to protect, conserve, and enhance the Commonwealth's aquatic resources and provide fishing and boating opportunities. The PFBC is charged through Title 58 Pennsylvania Code Part II with ensuring the protection, propagation, and distribution of gamefish, fish bait, baitfish, amphibians, reptiles and aquatic organisms and managing recreational boating in the Commonwealth. The PFBC works with partners to implement the Pennsylvania Aquatic Invasive Species Management Plan.

- The **Pennsylvania Game Commission** (PGC), established in 1895, is responsible for the management and protection of all wild birds, mammals, and their habitat. The agency's mission is to manage and protect wildlife and their habitats, while promoting hunting and trapping, for current and future generations. The PGC is authorized to prohibit the introduction, sale and release of any wildlife species of birds or mammals which are considered harmful to the public or wildlife of Pennsylvania under Title 34 Game and Wildlife Code and Title 58 Pennsylvania Code. The PGC manages more than 1.5 million acres of State Game Lands for wildlife habitat and to provide opportunities for lawful hunting and trapping.

- The **Department of Conservation and Natural Resources** (PADCNR) was created by the Act 1995-18 on June 28, 1995. Act 18 gives the Bureau of Forestry the responsibility for the protection of "all forestland" in the Commonwealth from "fungi, insects, and other enemies". The Wild Resource Conservation Act directs the PADCNR to conduct an investigation to determine the status of wild plants, creates an enforcement system to protect endangered, threatened, and vulnerable wild plant species, creates a permit procedure for persons interested in wild plant management, creates a commercial license procedure for persons who purchase vulnerable plants with the intent to sell them, and authorizes the agency to create a statewide system of private wild plant sanctuaries. The PADCNR has also created an agency-wide invasive species management plan.

Tools and Resources

- PFBC | https://www.pa.gov/agencies/fishandboat/conservation/aquatic-invasive-species.html
- PGC-Spongy Moth | https://www.pa.gov/agencies/pgc/habitat-management/spongy-moth.html
- PGISC Lists of Greatest Concern Invasive Species in Pennsylvania

  https://www.pa.gov/agencies/pda/about-pda/boards-commissions/governors-invasive-species-council/invasive-species-of-concern-for-pennsylvania1.html
- PGISC Invasive Species Management Plan
- https://www.pa.gov/content/dam/copapwp-pagov/en/pda/documents/plants_land_water/plantindustry/gisc/documents/PISC%205%20Year%20Plan.pdf
- Pennsylvania Aquatic Invasive Species Management Plan

  https://www.midatlanticpanel.org/wp-content/uploads/2016/04/PA_AISMP.pdf
- Pennsylvania Aquatic Invasive Species Rapid Response Plan

  https://www.pa.gov/content/dam/copapwp-pagov/en/pda/documents/plants_land_water/plantindustry/gisc/documents/AIS%20Rapid%20response%20plan%202022%20Update_Final_%209_9.pdf
- Report an Invasive Species

  https://www.pa.gov/agencies/pda/about-pda/boards-commissions/governors-invasive-species-council/report-an-invasive-species1.html
- Pennsylvania iMapInvasives |https://www.paimapinvasives.org/
- Penn State Extension |https://extension.psu.edu/pennsylvania-invasive-species
- Pennsylvania Sea Grant |https://seagrant.psu.edu/
- USDA National Invasive Species Information Center, Pennsylvania https://www.invasivespeciesinfo.gov/us/pennsylvania
- NECASC |https://necasc.umass.edu/
- NECASC (Invasive species) |https://necasc.umass.edu/search?search_keys=invasive+species
- RISCC | https://www.risccnetwork.org/northeast