Monitoring
CHAPTER 5

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MONITORING

Chapter Recap

- ✓ Pennsylvania has established monitoring as a priority within the 2025-35 Pennsylvania Wildlife Action Plan (PA WAP or Plan) by including this activity in objectives and strategies.
- ✓ Species of Greatest Conservation Need (SGCN) and habitat monitoring will build upon well-established state and federal level monitoring programs and data sources.
- ✓ PA WAP Wildlife Action Map (WAM) and MOTUS tracking system are technical tools supporting 2025-35 PA WAP monitoring initiatives.
- ✓ The Plan highlights monitoring efforts and data gaps for major taxa.

Introduction

Monitoring is a required element because the information gained from these data guide long-term conservation action implementation, thus supporting the State Wildlife Grant Program intent to avoid species endangerment. Reflecting this required element's relevance and importance, monitoring has been incorporated into 2025-35 Pennsylvania Wildlife Action Plan (PA WAP or Plan) foundational features, specifically, *Goal 2: Acquire and apply best available science to recover and sustain Species of Greatest Conservation Need and their habitats* and associated objectives and strategies (Table 5.1).

Table 5.1. Pennsylvania Wildlife Action Plan objectives and strategies relevant to monitoring.

Objective 2.2. Assess population and distribution trends for Species of Greatest Conservation Need and data deficient species.	
Strategies	
2.2.2	Identify, prioritize, and monitor limiting factors for Species of Greatest Conservation Need with sufficient precision and accuracy to guide management actions.
2.2.3	Monitor conservation, restoration, and enhancement projects to adaptively manage implementation.
Objective 2.3. Evaluate quantity, quality, and trends in habitats and ecological features.	
2.3.5	Use standardized habitat monitoring protocols to adaptively manage conservation actions for Species of Greatest Conservation Need.
2.3.6	Monitor quantity, distribution, and condition of major habitat components at ecologically appropriate spatial and temporal scales.
Objective 2.4. Evaluate threats to Species of Greatest Conservation Need and their habitats.	
2.4.2	Identify, prioritize, and monitor threats and stressors to understand impacts, including cumulative effects of multiple threats, to Species of Greatest Conservation Need and their habitats.

Objective 2.5. Develop, evaluate, and adapt targeted conservation strategies by advancing applied research.	
2.5.2	Monitor Pennsylvania Wildlife Action Plan implementation to adaptively manage conservation actions.

Within the Plan, objectives and strategies monitoring themes encompass:

- SGCN and factors limiting their populations
- habitats (amount, distribution, condition)
- threats, to understand impacts on SGCN
- conservation action implementation using adaptive management
    - to ensure restoration efforts for effective conservation
    - based on standard protocols

These themes are relevant to other Required Elements (*Chapter 1-Species*, *Chapter 2-Habitats*, *Chapter 3-Threats*, *Chapter 4-Conservation Actions*) and, within this monitoring context, are further discussed in this chapter.

Overview

An essential management tool, monitoring data informs every step of conservation, from establishing priority species lists to evaluating action effectiveness. Monitoring is key to assessing how actions affect targeted species and their habitats and enables us to evaluate the merits of alternate actions, adjust hypotheses of how systems function, and take appropriate corrective action as part of an adaptive management framework.

Inventory (survey) and monitoring data have long been recognized as fundamental wildlife conservation and management needs, with monitoring distinguished (from surveys) as the repeated collection of information (e.g., species abundance, distribution, productivity, habitat extent or condition) to assess the state of a system and evaluate changes over time (Yoccoz et al. 2001; AFWA 2012). At a basic level, wildlife status or habitat condition cannot be adequately evaluated, nor appropriate conservation actions determined, without baseline knowledge of the species and habitats involved. Foundational monitoring questions are presupposed in every conservation action: “what species are present?”, “where are they found?”, or “what habitats are used throughout the year?”. Ideally, monitoring vital species population parameters will guide the most critical conservation actions. Yet, despite foundational contributions from many monitoring programs, for many species, fundamental data gaps remain.

Monitoring is integrated into all aspects of this 2025-35 Pennsylvania Wildlife Action Plan (Plan), from SGCN selection to evaluating recommended actions. SGCN selection incorporates monitoring elements at many nodes in the selection flowchart (Fig. 1.3 in Chapter 1), and this Plan embraces the Best Practices for State Wildlife Action Plans (AFWA 2012) to:

1. Design monitoring programs with the aim of making the resulting data useful to conservation and science (see Nichols and Williams 2006); and
2. Use scientifically-sound monitoring protocols to detect changes that will inform PA WAP effectiveness assessments.

In this chapter we provide status, strategies, and resources for monitoring Pennsylvania's wildlife, their habitats, and conservation action effectiveness to conserve Species of Greatest Conservation Need (SGCN).

Survey and Monitoring Definitions

Data collection definitions, especially for surveying and monitoring, differ among experts (Spellerberg 1991). Here, we describe our interpretation of two distinct data collection categories: "survey (inventory)" and "monitoring", which differ primarily in their 1-intent (i.e., purpose) and 2-implementation frequency. These differences are relevant as they relate to SGCN and both approaches are important for understanding SGCN, their habitats, and guiding implementation. Importantly, a third assessment, "evaluation" also plays a crucial role in understanding implementation effectiveness and guiding conservation actions. More specifically:

- *Surveys (inventories)* are observations or measurements conducted once or infrequently (i.e., "a point in time") to determine a sampling targets (e.g., species) location or condition (Elzinga et al. 2001). For example, inventory surveys (i.e., presence or absence) ask, "Is it here?". Depending on the spatial scale, this may contribute to the state's species list, SGCN consideration, or provide baseline data for future data collection at a particular location. Species distribution is a critical element related to the state's responsibility (e.g., percent of population or range), which has also been incorporated into SGCN determination for this Plan.
- *Monitoring* is the collection and analysis of "repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective" (Elzinga et al. 2001). Similar data collection efforts may be considered "monitoring", and are used in this Plan, though Elzinga et al. (2001) more narrowly constrained the term relevant to objectives implemented within a management context, which are also used here. Monitoring population size, over time, within a particular area (either presence/absence or relative abundance) establishes a trend; a key metric to determine population sustainability. Trends are major drivers in defining subnational (state), "S", and global, "G", conservation status ranks (Faber-Langendoen et al. 2012), and are used in the SGCN determination flowchart. Spatial and temporal patterns in population parameters provide rigorous monitoring information that define effective conservation actions. Genetic, reproductive, or life-history traits are typically evaluated to understand limiting factors in research scenarios for evaluating threats to populations.

Knowing conservation action efficacy and outcomes is necessary to guide future implementation. These measures of effectiveness rely on *evaluation* which can be placed into two main categories: 1-impact

assessment, and 2-adaptive management (Stem et al. 2005). Both processes are relevant to activities within this Plan. “Impact assessment” is often a single measurement, such as a project outcome. By comparison, “adaptive management” is an ongoing, systematic process for learning (Stem et al. 2005; Williams et al. 2007). With relevant, measurable indicators, effectiveness measures can determine how well decisions and objectives are achieved. In this Plan, the agencies and partners developed conservation actions in the context of an *Adaptive Management* framework (Fig. 5.1) (Berkes et al. 2000; Williams et al. 2007; Conservation Measures Partnership 2025).

1. **ASSESS**
- Purpose & team
- Scope, vision, & focal values
- Critical threats
- Conservation situation

2. **PLAN**
- Goals, actions, assumptions, & objectives
- Monitoring plan
- Operational plan

3. **IMPLEMENT**
- Team structure & process
- Work plan & timeline
- Budget
- Implement plans

4. **ANALYZE & ADAPT**
- Data preparation
- Analysis
- Adaptation of plans & budgets

5. **SHARE**
- Documentation of learning
- Sharing learning
- Fostering learning

Fig. 5.1. Adaptive Management (Conservation) Cycle. (Source: Conservation Measures Partnership, (CMP 2025).

Survey and Monitoring Strategies

Surveys

To fully develop conservation priorities, a comprehensive taxa list must first be established. However, data gaps may preclude developing a taxa list whatsoever, or with sufficient confidence to identify conservation actions. When such knowledge gaps occur, they reflect a foundational data need and, in this Plan, these taxa are recognized as "Data Deficient" species. For these taxa, the basic inventory question regarding their presence within the state cannot be adequately addressed. Thus, there is insufficient information to provide a conservation rank, allowing neither prioritization nor conservation actions to be established. Addressing these questions and data needs could be considered a pre-monitoring step; essentially requiring baseline species occurrence data prior to initiating monitoring activities.

Monitoring

Building upon basic survey and baseline data, ongoing data collection (monitoring) can support conservation hypotheses about a species' status, conservation threats, requirements, and ultimately conservation action effectiveness. In a more specific form, *surveillance monitoring* is designed to detect a broad spectrum of species or variables but is not directed to address a particular hypothesis or objective (Spellerberg, 1991). Long-term trends become a core feature in assessing a species' status and should guide conservation actions to those species with significant needs, in particular places.

Conservation Effectiveness

Ecological monitoring and evaluation is important for determining conservation action effectiveness (Stem et al. 2005). Effectiveness measures, using an Adaptive Management framework (CMP 2025), will be incorporated into conservation programs supported by this Plan. Adaptive Management, as defined by Wilson and Nyberg (2009), is "a formal, systematic and rigorous approach to learning from the outcomes of management actions, accommodating change, and improving management. It involves synthesizing existing knowledge, exploring alternative actions, and making explicit forecasts about their outcomes". Originally developed in the 1970s by C. S. Holling, it is considered a structured and analytical process (Holling 1978 in Wilson and Nyberg 2009).

Monitoring efforts will need to be adapted to gather the required information for status assessments or effectiveness measurements (Stem et al. 2005). These adaptations are necessitated by ongoing challenges with monitoring including determining required effort and aligning the monitoring approach to address priority questions. Below, we describe several considerations for implementing recommended actions, but do not attempt to summarize the diverse decisions and principles behind effective monitoring.

Conservation Targets

Effectiveness monitoring (e.g., for an implemented conservation action) should measure one or more parameters reflecting the selected conservation target (e.g., species) and address a specific question, goal, or objective established for the monitoring program (Spellerberg 1991; Stem et al. 2005). A typical

conservation measure would be a metric of the overall species population size or distribution, with additional biological parameters, such as reproductive rates or basic occupancy, as options to evaluate specific conservation questions. Selected conservation measure(s) will need to align with the question to be addressed.

Sampling a target species or habitat can be constrained due to inaccessibility, methodology, expense, or other factors. Consequently, alternative species, other than the target species, are sometimes selected for monitoring, or may represent an ecosystem or a biological process, and thus function as surrogates, indicators, or other representation. A prominent example is *surrogate species* (see Caro 2010), an approach adopted by the U.S. Fish and Wildlife Service (USFWS) (Williams et al. 2007). For such assessments, representative species are associated with habitat quality or species diversity, on behalf of poorly known species, or for lower costs than a species-by-species approach. For habitat-based species assemblages, not all species need to be monitored for trends, with *indicator species* representing a habitat or species assemblage; to provide condition analysis for the group. Yet, before indicator species are selected, an inventory and understanding of habitat associations among all these wildlife species is needed, as well as relative relationship of the community. In Pennsylvania, surrogate species may be an option for filling data gaps, especially for critical life-history or habitat needs, or perhaps where the number of species precludes species-specific sampling (e.g., terrestrial invertebrates).

Methodology

Monitoring program design should be conducted using a thoughtful, structured process and is most effective when results are comparable with other studies (Spellerberg 1991). Yet, individual project objectives do not always allow data compatibility. In this Plan, when monitoring is conducted, standardized protocols will be used, as available, or developed to provide results comparable to other studies. When monitoring is conducted, for efficiency and cost control, we will consider relevance and applicability of established monitoring programs before beginning a new effort.

Scale

A monitoring project's scale should parallel the scope of the question being evaluated (Woodley et al. 1993). For most species, methods and scale will be constrained by practical limitations and monitoring purpose (i.e., questions to be addressed), and with these considerations sampling design is paramount. For example, determining a species' statewide status may require a broad-based sampling design to capture species distribution and the most basic parameters of its population – often an occurrence (i.e., presence or absence) level. Assessing more complex information needs, such as response to conservation action implementation, may require a more complex study design such as a before-after-control-impact (BACI) design or relevant alternative (Loughin et al. 2021). This applied research could be conducted at a more local spatial scale or in specific habitats, to represent a broader population response. Given complex BACI experimental design, sampling regimen, and accompanying costs, this assessment standard may be rarely used but should be considered when outcomes could drive long-term program decisions and actions, and thus SGCN recovery. For example, the PGC has proposed this

method for post-treatment SGCN response monitoring on State Game Lands following habitat modifications.

Data Repositories

PA WAP Strategy 3.1.3 promotes data sharing, compilation, and analysis to foster range-wide conservation of Pennsylvania SGCN. In recent decades, digital data and distribution networks, including cloud-based systems, have greatly advanced technical features of monitoring data storage and availability for conservation practitioners. However, data-sharing procedures are needed for study results accessibility beyond the principal investigator. Making results, including raw data, available to others is increasingly recognized as the responsible action to extend study benefits. Yet, with such access, users must recognize that principal investigators have primary publishing rights to scientific results. Within this Plan, a reasonable expectation will be made that data discussed, and supported by the agencies, will be made available in summarized form. Further, to the extent possible, and where sensitive locality data do not jeopardize species after a reasonable time, raw data may be made available via appropriate data-sharing procedures and agreements.

Pennsylvania's primary species data repositories, established to hold, manage, and disseminate data important to this Plan include these sources:

- **PA Conservation Explorer (PACE) and Pennsylvania Natural Diversity Inventory (PNDI)** is maintained through a partnership among the Western Pennsylvania Conservancy, Pennsylvania Department of Conservation and Natural Resources, Pennsylvania Game Commission (PGC), Pennsylvania Fish and Boat Commission (PFBC), and the USFWS. PNDI represents our best inventory data across the state for rare species – including, minimally, all state-listed species. PNDI focuses on Pennsylvania's rarest species. Thus, all agency-supported studies require findings with state-listed species data be incorporated into PNDI. Data maintenance and storage are consistent with NatureServe© programs across the continent, typically managed by other states and provinces. Agency environmental reviewers are required by the Pennsylvania Department of Environmental Protection (PA DEP) permit-review process to scan PNDI data for conflicts, and these data are used to establish land conservation priorities and activities.
- **Federal partners**, including the U.S. Geological Survey (USGS), USFWS, and U.S. Environmental Protection Agency (USEPA), provide data for many ongoing monitoring programs.
- **Pennsylvania Spatial Data (PASDA)** (http://www.pasda.psu.edu/), is the official publicly accessible geospatial clearinghouse for Pennsylvania and is maintained at Penn State University.

Monitoring Species

Pennsylvania wildlife, including SGCN, are monitored through well-structured, established programs at multiple scales. These programs include national initiatives (e.g., Breeding Bird Survey, North American Bat Monitoring Program), statewide programs (e.g., Pennsylvania Bird Atlas, Pennsylvania Amphibian and Reptile Survey - PARS), and local efforts such as migratory fish surveys in the Schuylkill River and

Lake Sturgeon surveys in Lake Erie. Here we highlight PA WAP relevant programs and include a more comprehensive monitoring program list in Appendix 5.1. Monitoring programs and needs for each SGCN are found in the species accounts (Chapter 1, Appendix 1.4).

Birds

A relevant, broad-scale monitoring program is the Breeding Bird Survey (BBS) (Sauer et al. 2013). The BBS is a long-term monitoring program, designed to address the question of population trend at various scales, over a long timescale. It provides a statistically valid trend of relative abundance across North America, which is viable at the state (or smaller) scale for about half of Pennsylvania's breeding bird species. The BBS is built on multi-year trends of road routes randomly distributed across the landscape. This monitoring is not designed to detect or explain specific threats but, rather, reflects cumulative stresses on a wide range of breeding birds at broad geographic scales. This monitoring program has been successful largely due to its longevity (established and operational since 1965), random geographic distribution, and robust sampling effort (i.e., about two thousand routes run annually). Christmas Bird Counts, to monitor wintering bird populations, have a longer history (since 1900), but less stringent design parameters and considerably smaller sample size.

The 3rd Pennsylvania Bird Atlas (2024-2029) is a 5-year effort to document distribution, abundance, and seasonal patterns of the state's birds, year-round. With funding from State Wildlife Grants, this project will provide statewide data on how bird populations have changed in the two decades since the Second Breeding Bird Atlas of Pennsylvania (Wilson et al. 2012). This latest iteration of the Atlas uses the widely accessible eBird online database to record observations. In addition to providing an eBird Pennsylvania Bird Atlas portal, eBird is used by PGC biologists to track bird SGCN observations. Further, the eBird Status and Trends product (Fink et al. 2024), updated annually, has recently become a valuable source of information on species distribution, abundance, and trends to complement the BBS (Robinson et al. 2025).

Mammals

Mammal SGCN are generally secretive and, in many cases nocturnal, thus presenting a population monitoring challenge. Despite the challenge, Pennsylvania has a long history of monitoring mammal populations. The PGC has monitored bats via hibernacula surveys since the mid-1980s. These long-term data proved invaluable in quantifying the population impacts of white-nose syndrome on hibernating bats. At other times of the year, bat populations are monitored via the Appalachian Bat Count (https://www.pa.gov/agencies/pgc/wildlife/wildlife-surveys/appalachian-bat-count) and through mist-netting, trapping, and banding efforts by PGC biologists and contractors. PGC also closely monitors Allegheny woodrat populations via several techniques including live trapping, camera trapping, and visual surveys. In addition to general population monitoring, woodrat response to several conservation actions, including supplemental feeding and the creation and enhancement of habitat, is monitored in an adaptive management process. Other small mammal observations are tracked in a standardized format via the Terrestrial Small Mammal Database. Appalachian cottontail and snowshoe hare distributions are monitored through DNA analysis of collected fecal pellets.

Amphibians and Reptiles

Under PFBC statutory jurisdiction, amphibians and reptiles provide vital ecological functions, serving as both prey and predator across aquatic and terrestrial habitats. Over the past decade, understanding of these taxa has been greatly expanded through the Pennsylvania Amphibian and Reptile Survey (PARS) http://www.paherpsurvey.org/. Established in 2013, PARS focuses on defining amphibian and reptile geographic distribution, including poorly known species. The project website provides the most complete, up-to-date Pennsylvania amphibian and reptile information, which will be used to develop an associated atlas. Information garnered by this project is used for developing science-based conservation action plans and management decisions. As of March 2023, the PARS community included >2,400 registered; >6,000 unregistered volunteers. All Pennsylvanians concerned and interested in these animals will benefit from the increased knowledge and anticipated securement of these animals. This project is led by the PFBC, with the Mid-Atlantic Center for Herpetology and Conservation overseeing daily project implementation.

Fish, Mussels, and Crustaceans

Regional or watershed-focused crayfish and mussel surveys (inventory) projects (funded by State Wildlife Grants) conducted since 2015 provide current baseline data for these taxa, but sampling on a defined temporal frequency (i.e., monitoring) has not yet been implemented. However, in 2025 Pennsylvania developed a mussel conservation plan (WPC and PGC 2025) with the intention to "provide action-based and solution-oriented recommendations to better understand, *monitor*, restore and conserve freshwater mussel populations within every watershed across Pennsylvania." This plan will be instrumental in guiding monitoring for these taxa. The PFBC has also established the Union City Aquatic Conservation Center for propagating mussels and other nongame species. Thus far, much of the work has been directed towards reestablishing mussels in places where they have been extirpated due to degraded physical habitat or water quality, but where conditions have sufficiently improved to support stocked animals. Following stocking, animals are monitored to assess survival.

For fishes, initiated in 2013, the Unassessed Waters Initiative (https://coldwaterheritage.org/index.php/unassessed-waters-initiative/) provides a survey strategy for streams to assess Brook Trout (*Salvelinus fontinalis*) presence and reproduction status, however regularly sampling same locations is not part of this program. On select rivers (e.g., Delaware, Lehigh) American Shad (*Alosa sapidissima*) populations are monitored and management is guided by the Delaware River Sustainable Fishing Plan (ASMFC 2022).

Invertebrates

Pennsylvania is home to >11,000 invertebrate species (Rawlins and Bier 1998; Rawlins 2007) and, for this Plan, due to limited funding and time constraints, 1,475 priority species were able to be assessed, thus representing a small proportion of potential invertebrate taxa. Yet, their ecological and societal importance is recognized, and invertebrate monitoring programs are being established, though currently limited in scope. The Pennsylvania State University (PSU), Center for Pollinator Research, along with agencies and organizations developed the 2016 Pennsylvania Pollinator Protection Plan (PSU 2016), which includes research recommendations (https://pollinators.psu.edu/bee-health/pennsylvania-

pollinator-protection-plan-p4/recommendations-for-research-policy-and-communication). Since development of this Pollinator Protection Plan, the Pennsylvania Bee Monitoring Program https://lopezuribelab.com/pa-bee-monitoring/ has been established and is the only Pennsylvania bee monitoring program. Also, at PSU, researchers are exploring options for automated bee biomonitoring INSECT NET (https://insectnet.psu.edu/). The Butterflies and Moths of North America (BAMONA) https://www.butterfliesandmoths.org/species_search is a national community science project collecting information on lepidoptera. BAMONA data are currently used in the PA WAP Wildlife Action Map (WAM) (discussed below). Aquatic invertebrates are monitored through the PA DEP water quality monitoring program with established macroinvertebrate sampling protocols for various aquatic habitats (PA DEP 2023). Other invertebrate monitoring programs are further described in Appendix 5.1.

New Technologies

New technologies have increased the ability of biologists to efficiently monitor wildlife passively and remotely. The Motus Wildlife Tracking System network is an international program that uses nanotag technology to track and monitor migratory wildlife via telemetry receiver stations at the landscape scale, targeting species too small for satellite tracking equipment. As of 2026, there were more than 2,400 Motus receiver stations located in 34 countries on five continents. More than 480 species (> 63,500 individuals) have been tagged as part of over 1,100 projects. More than 2,500 partners collaborate as part of the international Motus network. In the eastern United States, the network was initially developed to monitor shorebirds, seabirds, and coastally migrating songbirds, with most of the array located in coastal areas and along the Great Lakes shorelines. Since 2017, the Northeast Motus Collaboration, with PGC assistance, has expanded the array throughout the interior Northeast, filling a geographic gap along a key migratory route in the western hemisphere. As of 2022, >470 Motus stations are in the NEAFWA region, globally, the densest concentration of receiver stations. Wildlife tracked in the Northeast Motus network includes songbirds, seabirds, raptors, bats, bumble bees, Monarch butterfly (*Danaus plexippus plexippus*), and migratory dragonflies. A Motus project in Tennessee tracked the movements of the RSGCN Bog Turtle (*Glyptemys muhlenbergii*).

Camera traps and autonomous recording units (ARUs) have provided new means to achieve large scale wildlife monitoring goals while reducing costs and human effort, and the PGC is actively assessing the use of these technologies to detect species and estimate abundance (Ward et al. 2025). ARUs have been deployed to identify American Goshawk vocalizations. When pair vocalizations are detected, follow-up surveys are used to find and monitor nests. The PGC, in collaboration with Indiana University of Pennsylvania, has also used ARUs to assess the presence of Ruffed Grouse (*Bonasa umbellus*) in managed young forest stands. Similarly, passive ultrasonic acoustic detectors were tested and proven effective in surveying state endangered northern flying squirrels (Diggins et al. 2020).

Data Availability and Gaps

The state of knowledge varies greatly among taxonomic groups. Birds, particularly breeding populations, have received an extraordinary level of monitoring effort, including trends in relative abundance. Beyond such spatially explicit abundance data, we also know a lot about birds' reproductive rates and other biometric features. As noted above, amphibians and reptile distribution data has been assessed

since 2013 and is well-understood for most species. In the past 10 years, dedicated crayfish and freshwater mussel surveys have also expanded species distribution data for these taxa. Targeted surveys toward many terrestrial taxa, especially Data Deficient species, are needed to establish and confirm basic distribution information.

Even among birds, highly vocal and diurnal species receive much more attention than those that may be secretive and nocturnal. Specialized surveys for night birds, wetland birds, raptors, and others still are needed. The level and intensity of monitoring data currently available is often rooted more in popular support than targeted to the degree of conservation concern. Many people contribute bird data through recreational activities. The exponential rise in eBird data has expanded the site-specific relative abundance data for most bird populations year-round.

Invertebrates traditionally are poorly studied and historically have been the taxa with the least available baseline data. In this Plan, insufficient data for invertebrates is reflected in the number and percent of Data Deficient taxa with invertebrates composing 96% (577) of 604 Data Deficient species; the remaining 4% (27) include 22 fishes, four reptiles, and one amphibian. A status rank was computed for most vertebrates, although these assessments were based on old or inadequate data in some cases. Species' spatial distribution data are inconsistent even for many vertebrates, or range maps reflect the distribution of surveyors rather than the species themselves. Most taxonomic groups, other than birds, have not undergone a systematic survey that would define the distribution of these species across the state. Basic survey data are a clear conservation need for many species. However, with limited resources, that need must be weighed against other priorities, such as initiating conservation actions to address known threats.

Monitoring Habitats

From early colonial settlement, Pennsylvania's habitats have been directly influenced by human activity, and these changes include habitat composition and condition impacting wildlife populations, including SGCN. Many threats identified for SGCN are tied to habitat condition so understanding the status of Pennsylvania habitats is important for SGCN management and recovery.

Forests account for approximately 60% of Pennsylvania's land cover and is a predominant habitat type (U.S. Department of Agriculture-USDA 2019; Chapter 2-Habitats). The U.S. Department of Agriculture (USDA) maintains several informative long-term, standardized land-cover/land-use assessments concerning the availability of habitats on a broad scale, and at a coarse scale. Of particular importance is the Forest Inventory and Analysis (FIA) program https://research.fs.usda.gov/programs/fia, within the U.S. Forest Service (USFS) (USFS 2026). The FIA program maintains a rigorous, spatially balanced, long-term monitoring tool for forest plants, particularly trees, which assesses extent and condition of the nation's forests from a forestry standpoint. These inventories provide an overall perspective of forest species composition, regeneration, and extent, which for decades has informed assessments of the many species dependent on forest land-cover. For example, with supplemental plots surveyed by the PGC, these data are a significant component for the agency's deer management program. The USFS also monitors forests and woodlands via remote sensing. These remote sensing data, paired with field

sampling protocol support carbon monitoring in forests and woodlands. Similarly, the USDA Natural Resource Conservation Service monitors the extent of various agricultural crops which directly impact many species associated with early successional habitats, such as hayfields and pasture.

Wetland habitats support many SGCN, so documenting location and condition of wetland habitats is essential for comprehensive management. For this habitat, the USFWS maintains the National Wetland Inventory (https://www.fws.gov/program/national-wetlands-inventory), most recently published in 2019 (USFWS 2019). Additionally, the U.S. Environmental Protection Agency (USEPA) monitors the physical, chemical, and biological integrity of wetlands as part of the National Wetlands Condition Assessment (https://www.epa.gov/national-aquatic-resource-surveys/nwca) (USEPA 2021). The National Wetland Condition Assessment is part of a broader USEPA National Aquatic Resource Surveys (https://www.epa.gov/national-aquatic-resource-surveys/nla) (USEPA 2025) with these national surveys also assessing the ecological condition (health) and key stressors for Lakes (USEPA National Lakes Assessment, 2022), Rivers and Streams (USEPA National Rivers and Streams Assessment, 2018-19) (https://www.epa.gov/national-aquatic-resource-surveys/nrsa), and Coastal Condition (USEPA National Coastal Condition Assessment, 2015). Survey background, sampling design and indicators are provided for each habitat type.

At the state level, PGC habitat improvement projects on State Game Lands use a vegetative response tool to monitor habitat treatments. Efforts are underway to incorporate wildlife response monitoring into this tool. Chapter 2 (Habitats) provides more information on habitat extent and condition within the state.

Monitoring Threats

Fish and Wildlife Health

Adapted from Ellis et al. (2025); see Chapter 3-Threats

Despite substantial gains in recent years, significant data gaps remain in our understanding of fish and wildlife health threats. Across all taxonomic groups, surveillance and monitoring of environmental contaminants and pathogens are recommended to more fully analyze and address impacts to fish and wildlife health. Additionally, opportunistic disease surveillance and sample biobanking are of critical importance to understand threats posed by diseases and toxins to these populations. To this end, the Wildlife Futures Program of PennVet at the University of Pennsylvania, in partnership with the PGC, monitors wildlife health and provides several education, outreach, and guidance resources for the public, veterinarians, and wildlife rehabilitators. However, 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 knowledge gaps. 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.

Climate Change

Adapted from Staudinger et al. (2024)

Climate change poses decision-making challenges for natural resource managers due to both direct and indirect influences on species and habitats, as well as abiotic and biotic factors associated with this threat. Among the challenges are identifying and implementing appropriate conservation actions which may be constrained by knowledge gaps and within variable climate conditions. For the Northeast U.S., the work of Staudinger et al. (2015) provided crucial data and climate resources supporting the second iteration of State Wildlife Action Plans (SWAPs). Building upon this foundational synthesis, Staudinger et al. (2024) conducted updated literature reviews and expanded assessments emphasizing four areas of climate science: 1-observed and projected climate changes, 2-species responses to climate variability, 3-climate vulnerabilities and risks, and 4-scale-specific adaptations strategies and actions. Across many of these areas, monitoring can help fill knowledge gaps and support more informed conservation action decisions and effective implementation. In the context of dynamic climate variability, monitoring can help assess action implementation risks and benefits, or trade-offs and, depending upon the project goals and objectives, guide a monitoring plan. As previously noted, monitoring provides crucial feedback in an adaptive management strategy (Fig. 5.1) and thus may influence decisions, such as changes to conservation actions, based on action outcomes (Staudinger et al. 2024). Under rapidly changing conditions, climate adaptation actions undertaken by resource managers may be novel and without scientific rigor and thus could lead to unintended impacts referred to as “maladaptation” (Staudinger et al. 2024).

How can this information be useful for resource managers? Monitoring data are foundational for resource manager decision-making, with potential species-specific and ecosystem-level impacts. Understanding trends, such as changes in populations or distribution, can be invaluable for guiding management actions. Unfortunately, based on literature searches (Staudinger et al. 2024), data gaps in biological response to climate variability persist for several taxonomic groups including amphibians in vulnerable habitats such as vernal pools and riparian areas, insects (e.g., fireflies, stoneflies, mayflies, caddisflies, moths, tiger beetles, dragonflies and damselflies), crayfishes, bivalves, freshwater shrimp (e.g., fairy, clam, tadpole), and freshwater fishes (See Staudinger et al. 2024, Appendix 2.1). When prioritizing species monitoring or other assessment initiatives it may be worthwhile to cross-reference this climate data deficient species list from Staudinger et al. (2024), with this Plan’s SGCN and Data Deficient list.

Invasive Species

Importantly, much of this PA WAP chapter is dedicated to monitoring SGCN and their habitats. Yet, monitoring and effectively addressing threats, including invasive species distribution, is needed to detect and minimize impacts before invasive species become established or expand their range into new territories and impact SGCN recovery and securement. As mentioned, climate variability is a threat to SGCN both directly (e.g., changing temperature, hydrologic regimes) and indirectly (e.g., phenological modifications) and, among the indirect threats are factors allowing invasive species to more effectively colonize and outcompete native species. The Northeast Regional Invasive Species and Climate Change (RISCC) https://www.risccnetwork.org/northeast management network (NE RISCC 2026) enhances

understanding of this "climate change - invasive species" relationship (focusing on invasive plants) and can be used by natural resource managers, researchers, and stakeholders to effect actionable science. This practical approach is exemplified in the "Resources" offered by this network including; "research to practice" (~2-page research synthesis documents translating science for practice), "research summaries", (with categorical options for searching research articles), "tool summaries" (tips, videos, online tools, summaries), and "original research" (conducted by NE RISCC) (NE RISCC 2025) (https://www.risccnetwork.org/riscc-twopager-ne-riscc). The NE RISCC supports proactive measures to address invasive species, and these resources will be especially relevant during this Plan's monitoring and implementation.

Seasonal Changes

The USA National Phenology Network (USA NPN) provides national standardized protocols for collecting phenology (i.e., changes in timing of natural events such as migration) observations, advice and education materials for the collection and organization of new phenology data and supports tool development and approaches for natural resource decision-making (Schwartz et al. 2012; Denny et al. 2014; Denny and Crimmins 2023; USA NPN 2026). Among these tools is *Nature's Notebook,* a community science tool to gather, nationwide, phenology observations on plants and animals (Rosemartin et al. 2014). The NPN community monitors and tracks changes in species responses to climate variability and, as with other community science initiatives, can supplement and partner with professionally staffed monitoring networks (Newman et al. 2012; USA NPN 2026). This public engagement increases awareness of conservation and climate adaptation issues and can help extend limited natural resource-directed activities such as monitoring. Agencies (e.g., USFS, USFWS) and organizations (e.g., Mayfly Watch) use NPN's Nature's Notebook tool and contribute to a larger network of monitoring programs, informing phenological climate variability responses (USA-NPN 2026a, https://www.usanpn.org/community/partner).

Monitoring Implementation and Conservation Action Effectiveness

For SGCN, effectiveness measures are associated with the conservation actions in the species accounts (Chapter 1-Species, Appendix 1.4) and include: 1-what should be monitored, 2-the protocols or techniques to use, and 3-monitoring duration, which will be foundational for any monitoring initiatives.

Supporting conservation planning and PA WAP implementation, the PGC and PFBC developed the **Pennsylvania Wildlife Action Map** (WAM) (PGC-PFBC 2025). The WAM features two tools: 1-the Conservation Opportunity Area Tool (COA), and 2-the Conservation Action Tracker (CAT). With the COA Tool, users can: define their own Area of Interest (AOI), view and learn about SGCN and their habitats, discover conservation opportunities within their AOI, and view SGCN best practices references. The CAT, released in December 2025, enables users to: track their own conservation actions for SGCN and their habitats, explore other actions supporting SGCN across the state, and share project information with partners. Prior to the CAT, no system was available allowing voluntary public contributions of these conservation action data. With its recent launch there is currently insufficient information to derive any meaningful outcomes from the projects entered. However, when more data have been shared by users,

we anticipate assessing location and types of projects implemented, as well as habitats, target SGCN and other components.

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Appendix 5.1 Established monitoring programs in Pennsylvania that include Species of Greatest Conservation Need.

Frequent abbreviations used in this document include Pennsylvania Game Commission (PGC), Pennsylvania Fish and Boat Commission (PFBC), U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey (USGS).

Taxonomic Group	Monitoring Program	Lead	Description	Website (if available)
Birds	A Swift Night Out	Chimney Swift Conservation Association	An annual nationwide survey of swifts returning to roost. Volunteers count Chimney Swifts entering roosts in August and September.	http://www.chimneyswifts.org
	American Black Duck banding program	USFWS	Post-season (Jan. - March) and preseason (August-September) banding program in Pennsylvania provides harvest and survival rates for 2 periods.	https://www.fws.gov/project/bird-banding-conservation-tool-within-migratory-bird-program-ducks-geese-doves-and-more
	American Goshawk annual nest monitoring	PGC	Evaluation of nesting success to determine population viability and limiting factors for nesting goshawk populations.	
	American Goshawk autonomous recording unit (ARU) annual surveys	PGC	ARUs are used to identify goshawk territorial vocalizations. When pair vocalizations are detected, follow up surveys are used to find and monitor nests.	

Taxonomic Group	Monitoring Program	Lead	Description	Website (if available)
Birds	American Kestrel Nest Box Programs	Hawk Mountain Sanctuary Association, private banders	Establishing and maintaining nest-boxes to assess occupancy, clutch size, hatch rate, fledge rate, and overall nest success. Most nestlings are sexed and banded for future population estimates. Nest-boxes can also be used to access eggs/nestlings for research purposes (collecting measurements, blood sampling, etc.). All kestrel nest data is encouraged to be shared through the Cornell Lab of Ornithology's NestWatch database.	https://nestwatch.org/
	Atlantic Flyway Breeding Waterfowl Survey	USFWS	This survey has been conducted annually since 1989 in Pennsylvania and other Atlantic Flyway states from Virginia to New Hampshire. It provides breeding population estimates for the major breeding waterfowl species. A total of 327 1-km2 plots are surveyed across six physiographic regions of Pennsylvania using a stratified random design.	https://migbirdapps.fws.gov/mbdc/databases/afbws/afbws.asp?opt=afbws
	Atlantic Flyway Midwinter Waterfowl Survey	USFWS	Annual (January) count of all waterfowl species on major wintering areas within the Atlantic Flyway.	https://migbirdapps.fws.gov/mbdc/databases/mwi/mwidb.asp?opt=mwidb

Taxonomic Group	Monitoring Program	Lead	Description	Website (if available)
Birds	Audubon Mid-Atlantic Important Bird Area Surveys	Audubon Mid-Atlantic	Marsh bird surveys at Important Bird Areas designated due to their importance to wetland birds. Standardized marsh bird protocols as described in Pennsylvania Game Commission Marsh Bird Surveys and volunteer surveys.	
	Bandedbirds.org	Multiple	Web-accessible database for reporting and retrieving information on color-banded shorebirds along the Atlantic Flyway.	http://www.bandedbirds.org
	Barn Owl Conservation Initiative	PGC	PGC biologists annually monitor potential nest sites statewide to determine nesting success and band nestlings.	https://www.pa.gov/agencies/pgc/habitat-management/landowner-assistance/barn-owl-conservative-initiative
	Bird banding at Powdermill Nature Reserve	Powdermill Avian Research Center	Constant-effort banding station with continuous operation since 1961.	https://powdermillarc.org/
	Black Tern monitoring program	PGC	Annual PGC monitoring at historical and created Black Tern nesting sites to document breeding activity.	
	Blue-winged Teal and Green-winged Teal pre-season duck banding	USFWS	Banding occurs August-September, prior to the onset of the hunting season. Banding birds at this time provides waterfowl population harvest and survival rate estimates.	https://www.fws.gov/project/bird-banding-conservation-tool-within-migratory-bird-program-ducks-geese-doves-and-more

Taxonomic Group	Monitoring Program	Lead	Description	Website (if available)
Birds	Christmas Bird Count	National Audubon Society	The longest running community science survey in the world provides critical data on population trends. An annual winter survey of more than 2,600 count circles worldwide.	https://www.audubon.org/community-science/christmas-bird-count
	Colonial waterbird nesting surveys	PGC	Annual count of nesting pairs at major Great Egret, Black-crowned Night Heron, and Yellow-crowned Night Heron colony sites.	https://www.pa.gov/agencies/pgc/wildlife/wildlife-surveys/heron-colony-observation-survey.html
	Crossbill research	Finch Research Network	Cooperative searches and research for crossbills with Finch Research Network. Red Crossbills nest in New York and new nesting locations in Pennsylvania.	https://finchnetwork.org/projects/crossbills
	Dickcissel surveys based on reported observations.	PGC	Follow-up surveys based on reports submitted to eBird, PA Birds Listserve and other sources.	
	Eastern Rivers and Mountains Inventory and Monitoring Network	National Park Service	Park vital signs are selected physical, chemical, and biological elements and processes of park ecosystems that represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. In the Eastern Rivers and Mountains section of the National Park Service, riparian bird populations and other resources are being monitored in the Delaware Water Gap National Recreation Area and other parks in this region.	https://www.nps.gov/articles/000/im_vital-signs-monitoring-taking-the-pulse.htm

Taxonomic Group	Monitoring Program	Lead	Description	Website (if available)
Birds	eBird	Cornell Lab of Ornithology	An online database of bird observations that provides scientists, researchers, and amateur naturalists with real-time data about bird distribution and abundance.	https://ebird.org/
	Golden-winged Warbler Conservation Initiative	Golden-winged Warbler Working Group, coordinated by the Cornell Lab of Ornithology	The study monitors Golden-winged Warblers, Blue-winged Warblers and hybrids during the breeding season in Pennsylvania as part of a regional and national conservation monitoring project.	https://www.birds.cornell.edu/home/golden-winged-warbler-conservation-strategy-and-resources/
	Great Lakes Piping Plover Recovery Effort	USFWS; University of Minnesota; Smithsonian Institution	Great Lakes Piping Plover natural history, population information, and blog posts.	https://www.greatlakespipingplover.org/
	Grouse Hunter Cooperator Survey	PGC	Cooperating hunters keep field diaries of hunting trips (county, # flushes, # bagged) annually.	https://www.pa.gov/agencies/pgc/wildlife/wildlife-surveys/become-a-grouse-woodcock-cooperator
	Grouse Summer Sighting Survey	PGC	PGC employees tally grouse broods and adults seen during normal work hours annually from June-August.	
	Hawk Migration Association Raptor Migration Monitoring	Hawk Migration Association	Promotes the use of a standard data collection protocol for raptor migration monitoring. The count protocol has been adjusted over time and a data collection form and a brief set of instructions have been made widely available to monitoring sites across North, Central and South America.	https://www.hawkmigration.org/hawk-migration-studies/ and https://www.hawkmigration.org/data-submission/

Taxonomic Group	Monitoring Program	Lead	Description	Website (if available)
Birds	International Shorebird Survey	Manomet Center for Conservation Sciences	A volunteer-based international shorebird survey conducted in spring and fall at focal sites to detect trends in migrant shorebirds.	https://www.manomet.org/project/international-shorebird-survey/
	Loggerhead Shrike breeding season monitoring	PGC	Conduct annual surveys during nesting season to confirm status, extirpation or presence of Loggerhead Shrike in the state. Monitoring should concentrate on suitable habitat in areas of most recent reports such as Cumberland, Franklin, Adams and Lancaster counties.	
	Long-eared Owl monitoring	PGC	Systematic searching for Long-eared Owl nests in areas with reported occurrences during the nesting season.	
	Monitoring Avian Productivity and Survivorship (MAPS)	Institute for Bird Populations	A continent-wide network of constant-effort mist netting stations, including several stations in Pennsylvania. Data collected provides survival and productivity information for many songbird species and can be a useful measurement of temporal patterns.	https://www.birdpop.org/pages/maps.php

Taxonomic Group	Monitoring Program	Lead	Description	Website (if available)
Birds	Mountain Bird Watch	Vermont Center for Ecostudies	Monitors songbirds that breed in the montane fir and spruce forests of the Northeast. Data provide the only region-wide source of population information on these high-elevation breeding birds. The primary focus is Bicknell's Thrush, but this project also tracks nine other high-elevation avian breeders, red squirrels, and the conifer seeds that these avian nest predators eat. A Pennsylvania version of this project will not include Bicknell's Thrush and will focus on state priority mountain forest species for Pennsylvania and the Appalachian Mountains.	https://vtecostudies.org/what-we-do/projects/mountain-birdwatch
	National Wetlands Inventory	USFWS	A nationwide inventory of wetlands providing wetlands maps and other geospatial data.	https://www.fws.gov/program/national-wetlands-inventory
	Nicaragua Highlands Project	El Jaguar Reserva, American Bird Conservancy	The PGC supports this important project which monitors wintering grounds in Central American shade grown coffee plantations and uses native species reforestation to create habitat corridors and protect water sources that can help restore habitat and connectivity for migratory birds in the El Jaguar-Volcan Yali Corridor.	https://southern-wings.fishwildlife.org/

Taxonomic Group	Monitoring Program	Lead	Description	Website (if available)
Birds	Nightjar Survey Network	Maine Natural History Observatory, Birds Canada	Nationwide survey effort that uses volunteers to conduct night-time, roadside counts of all nightjars along fixed survey routes systematically distributed throughout Pennsylvania and all other states.	http://www.nightjars.org/
	North American Breeding Bird Survey	USGS	A long-term, large-scale, international avian monitoring program initiated in 1966 to track the status and trends of North American bird populations.	https://www.usgs.gov/centers/eesc/science/north-american-breeding-bird-survey
	Northern Harrier breeding and wintering surveys	PGC	Conduct annual or biennial statewide surveys focused specifically on breeding Northern Harrier populations to determine what changes have occurred since the completion of the most recent Bird Atlas. Take corrective actions to reverse trends when possible.	
	Northern Saw-whet Owl banding	Project Owlnet	Primarily focused on banding migratory birds.	https://www.projectowlnet.org/
	Northern Saw-whet Owl monitoring (Project Toot-Route)	PGC	Standardized roadside playback survey involving 8 stops in suitable habitat.	
	Pennsylvania Bird Atlas	PGC, Hawk Mountain Sanctuary	Statewide bird inventory conducted approximately every 20 years by professional and amateur ornithologists.	https://www.pa.gov/agencies/pgc/wildlife/wildlife-viewing/birding/pa-bird-atlas
	Pennsylvania Farmland Raptor Project	Hawk Mountain Sanctuary	Hawk Mountain network of private landowners combined with eBird provides data on wintering Short-eared Owls and numbers per site.	https://www.hawkmountain.org

Taxonomic Group	Monitoring Program	Lead	Description	Website (if available)
Birds	Pennsylvania Game Commission Threatened & Endangered Species Monitoring	PGC	PGC follows up on reported sightings of listed species (e.g., American Bittern, American Goshawk, Loggerhead Shrike, Long-eared Owl, King Rail) and annually mines open community science databases such as eBird locations to survey and document nesting activity or winter roosts.	
	Peregrine Falcon Nest Monitoring	PGC	Nesting activity and productivity are monitored throughout the nesting season at known sites and potential new sites are investigated.	https://www.pa.gov/agencies/pgc/wildlife/discover-pa-wildlife/peregrine-falcon/banding-and-management
	PGC Game Take Survey	PGC	Annual survey of hunting license buyers.	
	PGC Grouse Drumming Survey	PGC	Spring drumming surveys conducted at PGC locations that have received active grouse management.	
	PGC Heron Colony Observation Survey	PGC	The PGC gathers heron colony observations to improve its ability to monitor heron populations and distribution throughout the state. The survey focuses chiefly on the Great Blue Heron, and the state endangered Black-crowned Night Heron and Yellow-crowned Night Heron.	https://www.pa.gov/agencies/pgc/wildlife/wildlife-surveys/heron-colony-observation-survey.html

Taxonomic Group	Monitoring Program	Lead	Description	Website (if available)
Birds	PGC Marsh Bird Surveys	PGC	During breeding seasons, PGC staff, partners, and volunteers conduct standardized audio playback surveys for secretive marsh birds across the state including Pied-billed Grebe, American Bittern, Least Bittern, Black Rail, King Rail, Virginia Rail, Sora, Common Gallinule, and American coot. Protocol adapted from North American Marsh Bird Monitoring Protocols (Conway 2011) and is very similar to that used in the 2nd Pennsylvania Breeding Bird Atlas. Survey results inform management of these wetlands.	https://www.pa.gov/agencies/pgc/wildlife/wildlife-surveys/marsh-birds-survey.html
	Presque Isle Shorebird Monitoring	PGC	Contracted Piping Plover, Common Tern, Red Knot, and other shorebird routine monitoring following established protocols.	https://www.pa.gov/agencies/pgc/wildlife/discover-pa-wildlife/piping-plover
	Project FeederWatch	Cornell Lab of Ornithology	Project FeederWatch is a citizen science survey where people in North America count the birds they see at their feeders or in their yards during the winter months (November to April). Participants periodically record the number of birds of each species they see and submit their data to the Cornell Lab of Ornithology and Birds Canada. This data helps scientists understand bird distribution, abundance, and population trends over time.	https://feederwatch.org/

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Birds	Project MartinRoost	Purple Martin Conservation Association	Annual monitoring of Purple Martin premigratory roosts.	https://www.purplemartin.org/research/19/project-martinroost/
	Project MartinWatch	Purple Martin Conservation Association	Reproductive success of Purple Martins at the colony site. Collects data such as parental age, first egg date, nest success.	https://www.purplemartin.org/projectmartinwatch/
	Purple Martin Scout-Arrival Study	Purple Martin Conservation Association	Documents first arrival dates of adult and subadult Purple Martins throughout North America.	http://www.purplemartin.org/scoutreport/
	Raptor Population Index	Hawk Migration Association	Collaborative effort to evaluate trends in migrating raptors. Trends in sites south of Pennsylvania in part represent trends in the Pennsylvania migrating population.	https://www.rpi-project.org/
	USFWS Harvest Information Program	USFWS	Annual survey of migratory game bird license purchasers that provides hunter participation and harvest data for waterfowl and webless migratory game birds.	https://www.fws.gov/project/migratory-bird-hunter-survey-diary-survey
	USFWS Parts Collection Survey	USFWS	Classification by age and sex of migratory game birds using wings submitted by successful hunters.	https://www.fws.gov/project/migratory-bird-parts-collection-survey
	Winter Raptor Survey	Hawk Migration Association and Pennsylvania Society for Ornithology	The Winter Raptor Survey monitors winter raptor populations by conducting roadside surveys in mid-winter.	https://www.pabirds.org and https://www.hawkmigration.org

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Mammals	Allegheny Woodrat Statewide Inventory and Monitoring Program	PGC	A subset of potential and known sites are surveyed annually for evidence of woodrat activity, food availability, and habitat quality. Techniques currently include live trapping, camera trapping, and visual surveys but could expand to new methods such as environmental DNA (eDNA) and detection dogs.	
	Appalachian Bat Count	PGC	Each year, volunteers count bats exiting summer roosts between May 15th and August 1st. Species, type of structure, and weather is recorded.	https://www.pa.gov/agencies/pgc/wildlife/wildlife-surveys/appalachian-bat-count
	Appalachian cottontail head collection	PGC	Since fall 2014, the PGC has collected heads from legally harvested cottontails within Appalachian cottontail habitat or exhibiting Appalachian cottontail physical characteristics to increase knowledge of Appalachian cottontail distribution in Pennsylvania.	
	Bat Net and Trap Database	PGC	PGC biologists compile annual data from contractor mist-netting efforts and report captures per unit of mist-netting effort.	
	Lagomorph pellet collection	PGC	Biologists are collecting all lagomorph pellets found in Appalachian cottontail habitat. The DNA in the pellets will be used to identify species and will help to increase knowledge of distribution of the three lagomorph species found in Pennsylvania.	

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Mammals	North American Bat Monitoring Program (NABat)	USGS	A statistically rigorous and nationally coordinated bat monitoring program for determining the impacts of the many stressors on bat populations and the efficacy of conservation management actions.	https://www.nabatmonitoring.org/
	Northern flying squirrel occupancy surveys	PGC	Nest-box surveys and live-trapping conducted at sites throughout the state to assess occupancy and gather samples.	
	Northern hoary bat rabies surveillance	PGC	Continued rabies monitoring and recording of all northern hoary bats submitted for testing (i.e., symptomatic or human exposure).	
	Terrestrial Small Mammal Database	PGC	A database compiling all PGC permitted terrestrial small mammal surveys in a standardized format.	
	Water shrew surveys	Western Pennsylvania Conservancy, Pennsylvania Natural Heritage Program	Since 2012, Western Pennsylvania Conservancy / Pennsylvania Natural Heritage Program has been conducting surveys for eastern water shrew and West Virginia water shrew to identify new populations and determine range extent.	https://naturalheritage.dcnr.pa.gov/
	Winter hibernacula surveys	PGC	PGC personnel and other qualified individuals survey caves, mines, and tunnels for bats between January 1st and March 15th of each year. Bat species and location, cave and roost temperatures, and presence of white-nose syndrome is recorded.	

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Amphibians & Reptiles	Conservation coordination for the wood turtle	Massachusetts Division of Fisheries and Wildlife	Advance wood turtle conservation by identifying, prioritizing and implementing high-priority actions in Northeast focal areas. Activities in PA included population assessments and conservation planning meetings. Project concluded in 2022.	https://northeastwildlifediversity.org/document/wood-turtle-project-report
	Eastern Box Turtle Population Assessment Protocol	Northeast Eastern Box Turtle Working Group	This document outlines the 2019 Eastern Box Turtle (*Terrapene carolina carolina*) Population Monitoring Protocol developed by the Northeast Eastern Box Turtle Working Group. This standardized sampling protocol is intended to provide a framework for assessing Eastern Box Turtle populations throughout the northeastern United States. The basic elements of the protocol include Rapid Assessments (RA) and Demographic Assessments (DA).	https://www.northeastturtles.org/uploads/3/0/4/3/30433006/eastern_box_turtle_population_assessment_protocol_revisions_2021.03.01.pdf
	Implementing Regional Conservation Plans in Priority Focal Areas: Wood and Blanding's Turtle in the Northeast U.S.	New Hampshire Fish and Game Department	A multi-state initiative (MA, NH, NY, ME, and PA). Activities varied among states. PFBC participated in site-specific meetings to prioritize conservation actions and plan implementation strategies. Priority parcels were identified. Project concluded in 2022.	https://northeastwildlifediversity.org/document/blandings-turtle-project-report

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Amphibians & Reptiles	Periodic monitoring of basking structure use by redbelly turtles	PFBC	The PFBC Habitat Lake Section monitors the structures and their use in lakes across the range where structures have been placed by PFBC.	
	Regional Spotted Turtle Assessment Protocol	PFBC	Standardized monitoring techniques developed with the Spotted Turtle Conservation Plan (Willey et al. 2022).	
	Timber Rattlesnake Monitoring	PFBC, East Stroudsburg University	Project developed a statistically robust long-term monitoring program that incorporates long-term sites, rapid assessment, and threats analysis.	
Fishes	Annual Alosid (Shad & Herring) survey of the Schuylkill River	Philadelphia Water Department	Annual survey to determine species and number of shad/herring running in Schuylkill River below Fairmont Dam.	
	Annual benthic trawl and gill net surveys	PFBC		
	Compliance for 401 water quality certification on lower Susquehanna, fish passage performance measures	Pennsylvania Department of Environmental Protection, PFBC, Susquehanna River Basin Commission, Maryland Department of Natural Resources		
	Lake Sturgeon annual monitoring with gill nets	PFBC, Lake Erie Committee of the Great Lakes Fishery Commission		

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	Lamprey ammocoete density surveys in Lake Erie drainage streams every two years or prior to lampricide treatments.	USFWS	Surveys to monitor lamprey ammocoete densities in Lake Erie drainage streams every two years or prior to lampricide treatments.	
	Scientific Collectors Permit Program annually reviews survey work completed by collectors other than PFBC.	PFBC	Not a formal monitoring initiative but supplements other sources.	
	Unassessed Waters Program	PFBC, multiple cooperators	Prior to 2013, when this program was initiated, many streams in Pennsylvania had not been assessed for Brook Trout occurrence. This program is systematically addressing this data deficiency.	https://coldwaterheritage.org/index.php/unassessed-waters-initiative/

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Mussels	Multiple mussel reestablishment or supplemental stocking monitoring sites	PFBC	The PFBC Union City Aquatic Conservation Center was established in 2020 to propagate nongame species. Early efforts have focused on freshwater mussels with stocking propagated animals where water quality or habitat degradation have diminished populations, but conditions have improved to anticipate recovery. Stocking sites are monitored to assess survival and growth.	https://www.pa.gov/agencies/fishandboat/about-us/agency-overview/bureaus/field-operations/fisheries-management/union-city-aquatic-conservation-center
Crayfishes	Monitoring of *Cambarus* sp. C and invasive crayfishes (if present) at selected sites in the Pickering and Crum Creek drainages and sites in the other PA drainages where the species occurs	PFBC	Sites in the Pickering and Crum Creek drainages that currently support or formerly supported populations of *Cambarus* sp. C have been sampled for crayfishes once annually since 2019. The density of all crayfish species that occur at each site is measured. This program can be expanded to sites in other drainages in Pennsylvania where the species occurs.	
Insects	Forest Insect and Disease Monitoring	PA Department of Conservation and Natural Resources	DCNR's Bureau of Forestry monitors Pennsylvania's forests for insects and diseases (e.g., emerald ash borer, spongy moth, hemlock woolly adelgid, beech bark disease, oak wilt), protecting trees when necessary.	https://www.pa.gov/agencies/dcnr/conservation/forests-and-tree/insects-and-diseases
	Monarch Larva Monitoring Project	Monarch Joint Venture	A community science project of the Monarch Joint Venture to track monarch eggs, larvae, and milkweed throughout North America.	https://mlmp.org/

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Insects	PA Department of Agriculture Entomology Program	PA Department of Agriculture	Entomologists monitor for invasive and potentially harmful insects present in forests, parks, and agricultural lands. The Apiary Section tracks bee population changes through the Pennsylvania Native Bee Survey.	https://www.pa.gov/agencies/pda/plants-land-water/plant-industry/entomology
	Pennsylvania Bee Monitoring Program	López-Uribe Lab at Pennsylvania State University	This program has trained a team of Master Gardeners to survey bees across Pennsylvania. Specimens are identified by experts and the data is incorporated into the growing database of Pennsylvania bee records. Surveys include repeated monitoring at focal sites, targeted surveys of specific host plants and high-quality natural areas, and other surveys.	https://lopezuribelab.com/pa-bee-monitoring/
	Pennsylvania Butterfly Monitoring Network	North American Butterfly Monitoring Network	The Pennsylvania Butterfly Monitoring Network was established to track butterfly populations throughout the state and across various habitat types. Professionals and enthusiasts alike are combining forces to gather detailed information on these populations to assist land managers in making informed decisions and to inform the public on our natural world.	https://thebutterflynetwork.org/program/pennsylvania-butterfly-monitoring-network