Chapter 7

Monitoring and Effectiveness Measures

MARYLAND
FOUNDED 1634

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

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Introduction

This chapter provides an overview of approaches and strategies for monitoring Maryland's Species of Greatest Conservation Need (SGCN), their habitats, and the effectiveness of implemented conservation actions. These specific conservation actions are outlined in Chapter 6 and in Chapter 6 appendices. An inventory of existing monitoring programs for Maryland's wildlife and habitats is included in this chapter, as well as descriptions of some of the national and Northeast states regional monitoring programs and new techniques for monitoring. This chapter describes the use of monitoring data in an adaptive management framework to assess and improve the effectiveness of conservation actions. At the end of the chapter, several approaches to linking Maryland's framework for monitoring and measuring effectiveness measures are described, including visualizing effectiveness and integration with regional efforts, which will assist in the successful implementation of the State Wildlife Action Plan (SWAP or Plan).

Monitoring continues to be recognized as a priority need for biodiversity conservation. This is because monitoring is essential in all aspects of conservation, from tracking which species are present and where they are present (their distribution), to evaluating priorities for future land protection and restoration. The information provided through monitoring Maryland's SGCN, their habitats, and the effectiveness of conservation actions will allow the Maryland Department of Natural Resources (MD DNR) and partners to reduce threats facing the state's fish and wildlife resources. As new threats and unfavorable conditions are identified, such as changes in land use and climate patterns, new information and data are needed to understand how to manage natural resources appropriately and sustainably.

The long-term successful implementation of Maryland's SWAP will, at a minimum, prevent more SGCN from becoming increasingly rare and endangered, prevent Key Wildlife Habitats (KWHs) from being degraded and irreparably lost, and minimize or mitigate threats to both. Critical measures of success will also include the reversal of population trends, such that rare species will become more abundant, and an increase in the extent and connectivity of natural landscapes, such that KWHs will be restored and protected. These are long-term outcomes of the success of the SWAP, recognizing the many external factors that might limit implementation. Another important measure of the effectiveness and adaptability of this SWAP is the frequency and degree of integration of SWAP targets into the operations of MD DNR's many programs, as well as those of its partners and stakeholders. Maryland's monitoring framework and adaptive management strategy focuses on evaluating long-term progress towards these broad objectives.

Inventory, Monitoring, and Research

The activity referred to in this chapter as "monitoring" can be defined as the collection of data over a period of time, usually at certain defined and repeated intervals. Inventory and research are other activities that are frequently related to monitoring. Inventory includes the collection of baseline data such as whether a particular species is present and where it can be found. Repeating an inventory survey, especially at regular intervals, is one type of monitoring. Scientific research can be defined as a systematic investigation used to solve a problem or answer a question. Using the scientific method, investigators move through a cycle of observing, asking questions, formulating ideas to explain what they see (hypotheses), making predictions from the hypotheses, collecting data to test the predictions (which may involve an experiment), evaluating the results, and altering the hypotheses as needed. The cycle can then begin again as predictions

from the revised hypotheses are tested. Monitoring can be thought of as part of the scientific research process when data needed to test predictions are collected over a period of time. In other words, the results of an experiment or management activity are "monitored" to see if they are consistent with the predictions.

Inventory, monitoring, and research activities as defined above are all important conservation actions for SGCN and their habitats. Inventory provides basic information on the location, number, and condition of species and habitats. Scientific research on species and habitats is critical to understanding needs, interactions, and responses to threats so that land managers and others have the basic information needed to develop effective conservation strategies for individual species and habitats. Monitoring that is not connected to particular questions or hypotheses is often referred to as status assessment or surveillance monitoring (Nichols & Williams 2006; Lambert et al. 2009). Status assessment or surveillance monitoring can provide updated information such as the current population size, distribution, reproductive output, and threats for a particular species or habitat, and, if repeated through time, can demonstrate changes in these parameters (trend monitoring). Effects monitoring goes a step further, linking changes in populations or habitat condition to changes in the environment. Although status assessment or surveillance monitoring is needed to establish current conditions or to demonstrate trends, it may not provide enough information to meet conservation goals. For example, status monitoring alone does not address reversing the decline of a population or analyzing the impacts of threats in order to reduce them.

Monitoring, whether to collect data for a current inventory or to address predictions from a research hypothesis, should not be viewed as a standalone activity, but rather as a component of a larger process of conservation-oriented science or management (Nichols & Williams 2006). The collection of monitoring data should be targeted to answer specific, well-defined questions and the link between monitoring data and improved conservation outcomes should be determined in advance. For example, for monitoring to contribute to species recovery, it must be considered in light of a complex set of factors that guide the design and impact of monitoring (Figure 7-1; Lindenmayer et al. 2020).

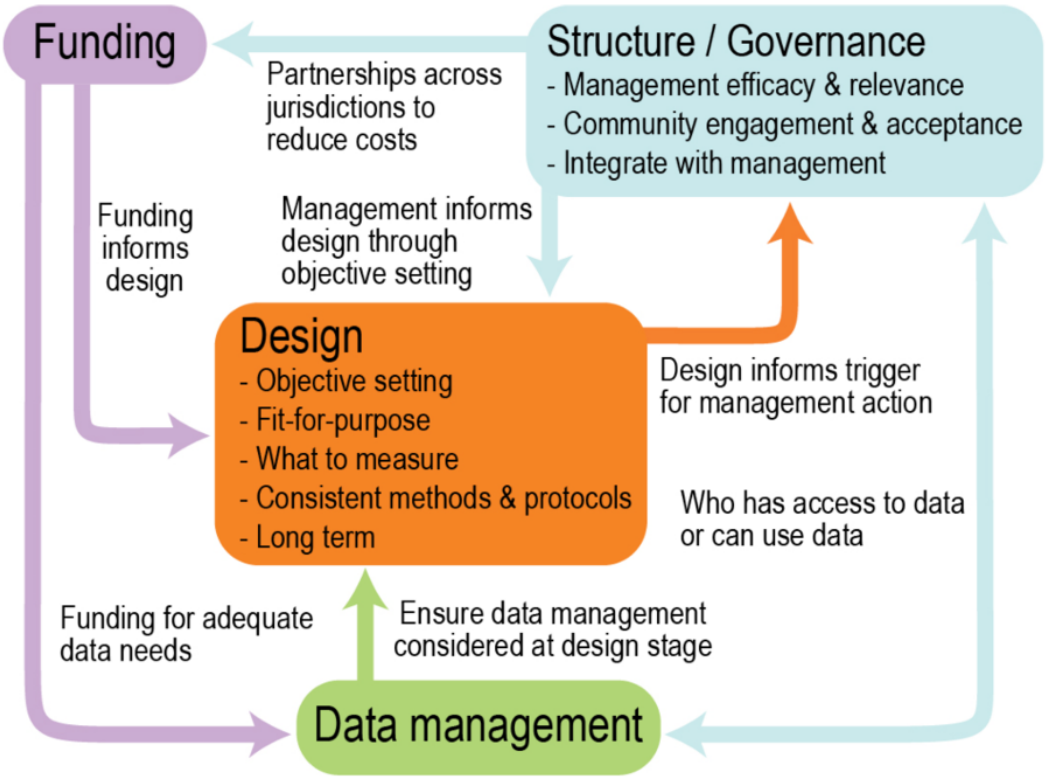

Figure 7.1 Conceptual diagram highlighting the relationships between factors that influence the monitoring and recovery of threatened species. Source: Lindenmayer et al. 2020.

Monitoring to Improve Conservation Outcomes

Monitoring is fundamental in the process of evaluating how conservation actions affect targeted species and habitats. By providing conservation planners the ability to adjust actions and better understand how ecological systems function, monitoring the outcomes of conservation and management activities fit under the bigger picture approach of adaptive management. Adaptive management is a sequential, iterative process that uses monitoring data to improve management actions (Figure 7.2). It can be defined as: "the incorporation of deliberate learning into professional practice to reduce uncertainty in decision making. Specifically, it is the integration of design, management, and monitoring to enable practitioners to systematically and efficiently test key assumptions, evaluate the results, adjust management decisions, and generate learning" (Conservation Management Partnership 2020). Adaptive management includes the process of hypothesizing how ecosystems work, analyzing results from monitoring, and comparing results with action expectations (Williams & Brown 2012). The conservation actions can then be modified to better manage decisions to achieve conservation objectives through the improved understanding of ecological processes (Lancia et al. 1996). This is particularly important for complex natural systems because responses to conservation actions can be difficult to predict, especially when there is uncertainty about current conditions (e.g., unknown threats, unavailable or incomplete population data, and unknown species response to habitat alteration).

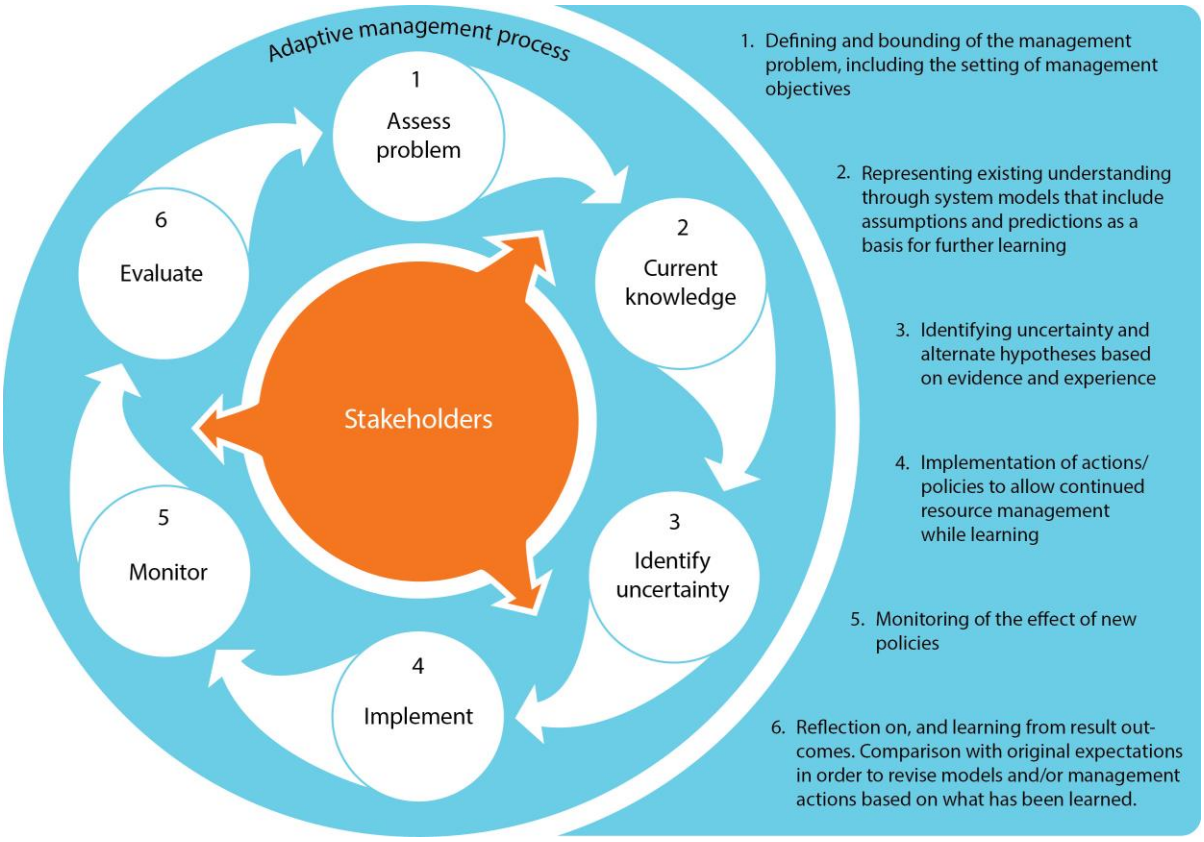

Figure 7.2 The adaptive management process, including the role of monitoring. Source: Rist et al. 2013.

Monitoring clearly plays a critical role in the process of tracking and improving wildlife conservation. An example of how to set up monitoring programs to meet the needs of adaptive management was developed by the Northeast Coordinated Bird Monitoring Partnership to improve conservation for birds (Lambert et al. 2009). These ten steps are suggested to optimize the value of monitoring and to carry out effective conservation:

1) Establish a clear purpose;
2) Determine whether an existing program or protocol meets your needs;
3) Assemble a team of collaborators with complementary interests and skills;
4) Summarize the relationship of target populations to other ecosystem elements, processes, and stressors;
5) Develop a statistically robust approach to sampling and data analysis;
6) Design and pilot standardized field protocols that minimize error and bias;
7) Identify or develop a data management system;
8) Implement the monitoring program;
9) Present results in a format that supports sound management and conservation decisions; and,
10) Evaluate and adjust management and monitoring to make better conservation decisions.

Although this example was developed initially for monitoring birds, these 10 steps provide general guidance for the development of effective and efficient monitoring activities that can directly feed into the adaptive management process and are useful for the conservation of all SGCN and KWHs.

Monitoring of SGCN and their habitats should be targeted to guide future conservation efforts and conducted in a way to make data relevant to scientists and useful to land managers in an adaptive management framework. Continued coordination with the regional development of monitoring programs, protocols, and data management is also critical to maximize the effectiveness and efficiency of monitoring activities for conservation. The use of permanent, centralized regional and national databases for species that range across broad geographic areas, such as Biotics for rare species or the Avian Knowledge Network database for birds, is particularly needed for the exchange and integration of relevant biological data. An evaluation of monitoring for the revised Plan can also benefit from assessing monitoring data management capacity and needs, identifying bottlenecks to integrating monitoring data at a larger scale, and evaluating how well Maryland is meeting best management practices and standards for data management as outlined by Martin and Ballard (2010).

Monitoring Species of Greatest Conservation Need and Key Wildlife Habitats

Monitoring is identified as a priority need for a number of SGCN and their KWHs (see Chapter 6 and appendices). This includes filling knowledge gaps for species that are a priority for assessment (State Assessment Priority Species [SAPS]) as listed in Appendix 3b. Maryland is fortunate to have an extensive monitoring system (**Element #5**) already in place for many species, habitats, and environmental parameters, including hundreds of state, federal, local, and grassroots monitoring projects and programs. Appendices 7a and 7b list many of the existing plans and programs that have been developed by local, state, regional, national, or international partners that include monitoring SGCN or their habitat components in Maryland. Many of the conservation actions identified in Appendices 6a and 6b related to monitoring were developed with these existing monitoring actions/plans in mind, as they provide most of the SWAP monitoring framework. Implementation of the SWAP will rely heavily on the existing monitoring projects and programs conducted by MD DNR's partners. Wherever possible, the SWAP recommends and supports the full implementation of partners' plans (e.g., U.S. Fish and Wildlife Service, Atlantic States Marine Fisheries Commission, Partners in Flight Bird Conservation Regions, The Nature Conservancy, and Bat Conservation International), especially those that have recommended or identified standardized monitoring actions and protocols for regional and/or national consistency. These existing monitoring efforts will be utilized as mechanisms to address SWAP conservation actions and implementation partnerships wherever applicable at the local, state, regional, and national levels.

Guidance from past monitoring efforts is invaluable to determine what type of monitoring is needed, appropriate indicators, and the use of standardized methods. Given the many knowledge gaps for SGCN, SAPS, and the inherent difficulty to monitor biodiversity, guidance such as that found in Dudley et al. (2025) and IUCN SSC Species Monitoring Specialist Group (2025) can help to focus monitoring efforts and direct practitioners to standardized protocols and procedures for collecting and analyzing data. Standardized monitoring protocols, such as those of the Breeding Bird Survey and the International Shorebird Survey, will be used wherever appropriate

so that Maryland's data will be compatible with regional and national conservation efforts. Regional resources and coordinated data management, described below, provide additional guidance and best practices for monitoring.

Monitoring programs are scale dependent. For example, within each KWH, the most appropriate level of monitoring, whether it is at the species, species group, taxonomic group, habitat, or community level, needs to be identified to best monitor that biotic system at the relevant ecological scale. Implementation of this SWAP also involves monitoring at a variety of geographic scales, including local, state, regional, national, and international, according to the suitability and recommendation of relevant partners' plans and programs. Monitoring programs also need to consider temporal scales to inform management decisions under a changing climate (AFWA 2022). Taxonomic scales (e.g., species, guilds, or natural communities), temporal scales (e.g., how often to measure indicators, how long to monitor to detect changes), and geographic scales (e.g., statewide, regional/multi-state, international) need to be explored to best identify climate change impacts and consequences for SGCN. Promising approaches include working with other states and partners to systematically monitor species and habitats across their entire range using standardized indicators so that data may be more easily integrated and analyzed to recognize trends and impacts on species and ecosystems. Monitoring changes in climatic variables (e.g., microclimate, water levels, hydroperiods, snowmelt, ice-off dates, rainfall) in places where species and habitat data are also being collected can help to determine correlations or causal relationships between climate and ecological changes relevant to SGCN and their habitats. Climate variables that are most likely to be relevant to SGCN and their habitats should be prioritized for monitoring, such as those presented in Staudinger et al. (2024).

Regional Monitoring Coordination

The 2017 SWAP Synthesis drew from the 14 individual Northeast SWAPs to identify the monitoring needs for priority threats, species, and habitats (TCI & NEFWDTC 2017). State-specific actions and monitoring needs can all be found in searchable format in the Northeast SWAP Database. Monitoring needs presented in the SWAP Synthesis included: developing regionally coordinated and cost-effective monitoring protocols that meet multiple objectives across states; monitoring changes to the Northeast's land and water resources and how those changes impact wildlife and people; and measuring and reporting the effectiveness of actions to improve and enhance future conservation efforts. Priority needs flagged for further investigation and monitoring in relation to Northeastern Regional Species of Greatest Conservation Need (RSGCN) and Watchlist species and their habitats include: invertebrate biomass decline; impact of insecticide spraying on forest-dwelling vertebrate RSGCN; disease, particularly for reptiles and amphibians, freshwater mussels, crayfish, and mammals; loss of genetic diversity; vulnerabilities of wintering RSGCN; impacts of take and collection; changes in hydrologic regimes; and coastal habitats.

Some of the monitoring needs identified for RSGCN and their habitats have been addressed through Regional Conservation Needs (RCN) Grants. This allows for the consistent and widespread use of common monitoring methodologies and survey protocols to support regional assessments of the status and trends of SGCN and their habitats. Coordinated projects developed and tested protocols for rare wetland butterflies, timber rattlesnakes, wood turtles, and pollinators in certain habitats. Links to monitoring plans and tools developed through the RCN Grant

Program are available on the RCN Final Products website. Current projects include developing protocols for surveys of diamond-backed terrapins and additional pollinator and insect surveys. Maryland is the lead state for both projects. More than 120 species or groups of species that occur in the NEAFWA region have standardized monitoring protocols available, listed in Supplemental Information 5 of the Northeast Regional Conservation Synthesis (TCI & NEFWDTC 2023). The updated Northeast RSGCN Database includes information on the availability of standardized monitoring protocols for RSGCN and Watchlist species.

Coordinated Data Management

Maryland DNR and its partner organizations collect and compile a wide variety of biological data that, when integrated with similar data collected by other states, regions, or countries, can greatly enhance the ability to evaluate trends in species population sizes and distribution, habitat losses and gains, and other common parameters across broad geographic areas. Increasingly, partners are working to coordinate survey and monitoring efforts that follow standardized data collection methods and protocols. These data can be used most effectively if centralized databases are developed and maintained where data gathered by multiple agencies can be entered, stored, and accessed by contributing partners through a series of security levels established and controlled by the data owners. Biotics, an integrated, web-enabled platform for tabular and spatial data management, is the most extensive example of a centralized database related to SGCN and KWHs. Used and populated by members of the NatureServe Network (especially state Natural Heritage Programs, often part of a state government agency), the system provides built-in support for shared methodology and data standards with a focus on rare species, natural communities, and site conservation planning. Maryland contributes data tracking the status of over 1,250 rare native plants and animals to this database, which is updated daily with the results of inventory, monitoring, and research activities by MD DNR and its partners. This international compilation of over 40 years of monitoring data is publicly available through the NatureServe Explorer website.

Large-scale Monitoring Programs

A number of monitoring programs are coordinated and supported at the national level, with programs for habitat, species, and species groups that overlap with Maryland's SGCN and KWHs (TCI & NEFWDTC 2023). These include the monitoring of environmental conditions by the U.S. Environmental Protection Agency; species and habitats by the U.S. Fish and Wildlife Service; and species, habitats, environmental factors, and diseases by the U.S. Geological Survey. The U.S. Forest Service supports programs for forest condition, and the U.S. Department of Agriculture supports monitoring programs for animal and plant pests and diseases as well as the outcomes of management actions. Multiple programs of the National Oceanic and Atmospheric Administration (NOAA) monitor the marine ecosystem, including marine habitats and their species. A comprehensive list of specific agency programs is included in the Monitoring Chapter of the "Northeast Regional Conservation Synthesis" (TCI & NEFWDTC 2023). Several of the most relevant programs for Maryland are included in Appendices 7a and 7b where monitoring programs for species and habitats are listed.

Monitoring the impacts of broadscale patterns, like climate change, presents a unique challenge. Monitoring to evaluate objectives in climate change is complex as species are simultaneously responding to multiple cues (AFWA 2022). States need to work towards implementing monitoring programs that can inform decisions under a changing climate, with an eye to working

together to monitor species and habitats across their entire range. Monitoring suites of abiotic drivers at similar spatio-temporal scales at which species occur is critical to understand when, where, and why changes are occurring and to design management strategies that can respond accordingly (Staudinger et al. 2013). At the habitat level, there may be multiple reasons to protect and manage an area, requiring the assessment of multiple drivers. For example, an area may have complex terrain that provides microclimates or different canopy cover and groundwater inputs that minimize temperature extremes over fine spatial scales (Morelli et al., 2016). Each of these distinct characteristics would need different monitoring objectives to assess the effectiveness of the refugia as climate continues to change (Morelli et al., 2016). In addition, Staudinger et al. (2015) identified various examples of how monitoring can address climate change, as well as other anthropogenic stressors, through specific adaptation strategies and actions. Additional and updated SWAP climate science data and climate resources for SWAPs are available in Staudinger et al. (2024).

Two examples of broad-scale monitoring projects that address climate change impacts are being carried out by members of the general public ("community scientists"), a growing way to monitor and track changes in species responses to climate change, and to supplement existing scientific monitoring networks (Newman et al. 2012). The National Phenology Network (NPN) provides national standardized protocols for collecting phenology observations, advice, and education materials for the collection and organization of new phenology data, and supports the development of tools and approaches for natural resource decision-making. NPN developed *Nature's Notebook* as a community science tool that the general public can use to collect and submit phenology observations on plants and animals nationally. Numerous institutions across the Northeast and Midwest are using NPN's Nature's Notebook tool and contributing to a larger network of monitoring programs to inform an overall understanding of phenological responses to climate change. Budburst, a project of the Chicago Botanic Garden, provides an opportunity to help understand how plants are responding to this year's seasons and longer-term changes in climate by entering data through use of a phone application. Public engagement through community science projects like these increases awareness of conservation and climate issues and can help extend limited resources for activities like monitoring.

Regional, State, and Local Monitoring Programs in Maryland

Existing monitoring programs that track SGCN (Appendix 7a) and KWHs (Appendix 7b) provide critical data to set priorities and formulate protection strategies. Species monitoring programs may focus on individual species or species groups or guilds. Habitat monitoring programs in Maryland include data collection on air and water quality, the habitats of specific SGCN, habitat health, and threats that affect habitats. This network of monitoring programs, which includes aquatic and terrestrial species and habitat monitoring initiatives, provides data for use in conservation planning; federal, state, and local government decision-making; and private sector species and habitat projects. Examples of monitoring tools, programs, and partners are presented below.

The Chesapeake Bay may be one of the most monitored ecosystems in the country, with a wide range of state, federal, local, regional, academic, and non-governmental organizations (NGOs) actively facilitating research and monitoring programs. Recent water quality and habitat quality monitoring data for Chesapeake Bay, the Coastal Bays, and estuarine tributaries (periodic and

continuous data) are available online through the state's Eyes on the Bay Monitoring Program. The Chesapeake Bay Monitoring Program, which brings together Maryland, Pennsylvania, Virginia, the District of Columbia, multiple federal agencies, and over 30 scientists, tests for nineteen chemical, physical, and ecological components 20 times each year. The Chesapeake Bay Program maintains a clearinghouse of monitoring data on the Chesapeake Bay's physical, chemical, and living resources. The Chesapeake Monitoring Cooperative team, made up of five partner organizations, is working with new and existing water quality and benthic macroinvertebrate monitoring programs across the Bay watershed to integrate community science data into the Chesapeake Data Explorer. The Chesapeake Bay Program Datahub is the primary tool for searching and downloading environmental data for the Chesapeake Bay watershed.

The 2025 Comprehensive Conservation and Management Plan for Maryland's Coastal Bays formulated a detailed monitoring strategy for the Coastal Bays that builds on existing partnerships between the Maryland Coastal Bays Program, MD DNR, and other state and national programs to present monitoring-based conservation actions for the Coastal Bays. In addition to standalone research projects that are part of the Coastal Bays Management Plan, monitoring actions drive other conservation actions within categories of education and outreach and policy issues.

Since the 2015–2025 SWAP, a number of additional resources have established or increased an online presence to include the locations and results of monitoring programs, such as Eyes on the Bay, the Maryland Watershed Resources Registry, and the Mid-Atlantic Regional Council on the Ocean (MARCO), which maintains the Mid-Atlantic Ocean Data Portal as an online toolkit and resource center to collate data in a shared information management system for multiple uses. The interactive Stream Health Index Map allows exploration of the results of work by the Stream Waders volunteer program as well as MD DNR Maryland Biological Stream Survey sampling, including the Combined Index of Biotic integrity, Fish and Benthic Biotic Integrity scores, and additional details about land use, physical habitat, water quality, and the biota encountered at each sample site. EcoSHEDS is housed by the U.S. Geological Survey as a collection of Spatial Hydro-Ecological Data Systems (SHEDS) designed to improve our understanding of stream ecosystems. The website provides access to a series of user-friendly tools that support transparent research, management, and decision-making by linking together one or more hydro-ecological databases, models, and data visualization tools. These and other existing sources of data from monitoring programs for Maryland's coastal and aquatic resources are integral to the SWAP's monitoring framework for key aquatic and wetland habitats and SGCN.

Although extensive monitoring programs for Maryland's aquatic and wetland habitats already exist, fewer monitoring programs support Maryland's terrestrial habitats. MD DNR leads many of these programs and is involved with most terrestrial monitoring programs in the state via the important geographic information system (GIS) tools in which MD DNR specializes. The MD DNR Natural Heritage Program (NHP) tracks hundreds of plant and animal species and natural communities, maintaining a detailed database on their abundance and distribution. Monitoring programs for certain species and taxa groups, such as Puritan and northeastern beach tiger beetles, bog turtles, upland game birds, rare plants, waterfowl, and colonial waterbirds, are ongoing, as are other monitoring programs within the MD DNR Wildlife and Heritage Service.

Status and trend data for additional species can be tracked by adapting the existing NHP database or by developing additional data systems, as needed, to include data on the status of all SGCN, research and survey results, and ongoing inventory and monitoring projects. MD DNR habitat and species monitoring are also carried out by Maryland Forest Service, Watershed and Climate Services, Fishing and Boating Services, Maryland Environmental Trust, and Resource Assessment Service.

Additional monitoring programs for SGCN and KWHs are conducted by many partners across the state (Appendices 7a and 7b), including engaging the public in monitoring activities to the benefit of both monitoring objectives and public knowledge of Maryland's wildlife and habitats. Federal monitoring partners include the U.S. Geological Service Eastern Ecological Science Center, National Park Service, U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency, and National Oceanic and Atmospheric Administration. Pest organisms and the outcomes of practices on agricultural lands are monitored by the U.S. Department of Agriculture. The U.S. Army monitors fish, wildlife, and submerged aquatic vegetation (SAV) habitats at its Aberdeen Proving Ground and other facilities track the status of their wildlife populations. Local governments, including county environmental programs, and NGOs collect monitoring data on their properties and also engage the public in monitoring through activities like bioblitzes. These one-day programs engage participants in community science around the state, as participants canvass specified state parks, county parks, wildlife refuges, and other natural areas to identify plants and wildlife. With 120 monitoring programs for species/species groups and just over 100 programs for habitats, coordination between all partners is critical to better implement the SWAP's monitoring framework.

Addressing Monitoring Gaps

It is impractical and inefficient to have individual and separate monitoring actions for each of the many SGCN and KWHs. It is more practical to develop an effective monitoring framework or strategy that monitors the status and condition of select species and habitats, conservation action effectiveness, and, finally, the incorporation of new information into the SWAP. Developing programs and strategies to monitor species, species groups, and KWHs must be done in the context of measuring the effectiveness of conservation actions. As SWAP implementation proceeds, monitoring needs related to priority conservation actions (Chapter 6 and appendices) will be reviewed, and alternatives for implementing monitoring and conservation actions will be developed as needed to benefit the overall KWH, community, and/or assemblage, including many of the other SGCN, in order to maximize limited resources and maintain practicality and efficiency.

To begin the process of review, priority conservation actions for monitoring can be matched with existing monitoring programs in Appendices 7a and 7b, as well as regional programs, to see if these programs are already meeting needs or can be modified to better meet SWAP priorities. Despite the many local and regional monitoring programs in Maryland, monitoring data may still be lacking because 1) programs do not exist, or 2) monitoring programs exist, but they are not part of a defined adaptive monitoring framework that addresses particular conservation priorities. In cases where not enough information exists to monitor a SGCN or KWH, or monitoring protocols have not yet been developed, this need has been documented and followed by a research action or other conservation action to address that information need (Chapter 6 and appendices). This is true for some taxa groups, such as small mammals and especially

invertebrate groups, for which standardized protocols need to be developed, and for taxa where baseline data do not exist to form the basis of a monitoring protocol. In these cases, high priority taxa research or data needs/gaps have been identified by taxa experts, planners, and stakeholders in Chapter 3, Chapter 6, and Appendix 6a. If monitoring programs do not currently exist for a SGCN or taxon, viable options may exist to monitor closely related species occupying the same habitats; monitor appropriate indicator species or other ecological indicators (Dale & Beyeler 2001; Carignan & Villard 2002); monitor threat reduction (Salafsky & Margoluis 1999); or use a multiple species-natural community approach (Barrows et al. 2005).

Since the 2015–2025 SWAP, technological advances have greatly increased the availability of practical, affordable tools for monitoring species and habitats (reviewed in Rout et al. 2022). For example, the widespread use of passive acoustic monitors such as Automated Recording Units (ARUs), coupled with increasingly efficient and robust identification of recorded sounds (Sarab et al. 2023), has increased our ability to monitor species in remote areas and over long periods of time. These methods have been employed in Maryland for secretive marshbird SGCN as well as several bat SGCN. The use of machine learning and artificial intelligence algorithms has greatly reduced the time needed to analyze the large data sets generated by ARUs and the many images generated from camera surveillance footage. The availability of Unmanned Aerial Vehicles (drones) is also changing the face of monitoring, with applications for monitoring habitat change as well as species inventory, including in inaccessible areas (Hodgson et al. 2016). The miniaturization of tracking devices and installation of more cell towers to detect migrating bats, birds, and even monarch butterflies has made the monitoring of large-scale movements as well as small-scale habitat use possible, largely through the Motus project (Taylor et al. 2017). Most promising is the use of a combination of nature technologies including remote sensing, geographical information systems, satellite data, eDNA and other molecular approaches, camera traps, passive acoustic sensors, artificial intelligence, and GPS monitors to augment traditional biodiversity measurements (Rout et al. 2022). An interesting approach for areas that are challenging to access is being developed by Dr. Matt Fitzpatrick at the University of Maryland Center for Environmental Science, Appalachian Lab, to create an automated system that uses machine learning, massive biological surveys, and remote sensing to map, monitor, and predict biodiversity changes in real time to contribute to monitoring for the Central Appalachians. The use of these technologies and integration of information to address species, habitat, and effectiveness will be considered to address monitoring needs identified in Chapter 6 and appendices.

An additional aspect of monitoring that has developed since the 2015–2025 SWAP is the opportunity to involve community members as data collectors. For example, the monitoring of breeding birds during the 2020–2024 Maryland-DC Breeding Bird Atlas project, which provides data to assess the status of SGCN birds, was carried out by volunteers using the eBird electronic data collection app on cellular phones. To date, more than 1.3 million records for over 22,000 species in Maryland have been contributed to the Maryland Biodiversity Project, many of which have been collected by the general public. The increasing use of volunteer community scientists in recent years has been evaluated and refined, and a number of resources are now available for widespread data collection as well as how to best coordinate and support the participation of diverse contributors (e.g., Danielson et al. 2021; Atsumi et al. 2024; Sigouin et al. 2025).

Monitoring Outcomes and Effectiveness Measures

Measuring the success of the Maryland SWAP is a challenging endeavor that requires assessing the results of individual conservation actions, as well as the overall impact of implementing the Plan. This is a challenging but critical part of effective conservation. Planning projects as part of a portfolio of actions to address conservation needs for SGCN and their habitats is a promising approach, especially given the large number of SGCN and conservation actions identified in this plan. One approach to link common goals with common indicators to measure aggregated conservation impact has been proposed by Stephenson (2019). This approach includes consideration of the following five steps:

1) Planning: developing a shared vision and measurable goals and objectives that are linked to higher-level program goals and objectives;
2) Using common indicators: identifying indicators that can be used to aggregate results;
3) Monitoring: collecting data to measure indicators, ideally in a way that makes data sharing and aggregation easier;
4) Interpretation: presenting data in a format that is useful to program managers, decision-makers, and on-the-ground resource managers (e.g., maps and dashboards); and
5) Action: using data to evaluate progress and make adaptive management decisions.

The use of this approach can help organizations design projects with goals, objectives and indicators that are shared across a portfolio of sites, habitats, and/or species in order to measure overall effectiveness. Given the breadth and number of monitoring actions being carried out in Maryland, the shared vision and objectives included in the SWAP provide an excellent starting point for coordinating monitoring and the measurement of conservation outcomes through collective effort.

Maryland's assessment strategy (**Element #5**) involves a long-term commitment to the success of the SWAP. Populations that have been declining for decades may take decades to reverse and, therefore, many decades pass before the results of conservation actions can be fully realized. Thus, an effective assessment strategy incorporates the concept that many conservation actions involve different temporal scales; both short-term conservation actions as well as long-term strategies are necessary to bring about the conservation of SGCN and KWHs. Furthermore, differing geographic scales need to be considered. To provide measures of effectiveness at these different scales for use in adaptive management, the Association of Fish and Wildlife Agencies (2012) recommends developing a "theory of change" linking actions to their ultimate desired impacts. This can be achieved through a five-step process:

1) Define the conservation action;
2) Describe, via a results chain, the theory of change as to how the action will lead to desired impacts;
3) Identify a limited set of effectiveness measures to assess progress at key points throughout the life of the project;
4) Develop and test effectiveness measures to ensure they provide meaningful information within existing human, legal, and financial constraints; and,

5) Collect, analyze, and share data about the effectiveness measures to show whether the conservation action achieved the desired impact, why it succeeded or failed, and how implementation of the action can be improved over time under different conditions.

Using this system, if the activity provides the expected results, effectiveness measures help to communicate success so that others may follow suit. Besides having more effective and efficient conservation actions, tracking the success of actions helps to ensure the most efficient use of limited staffing and funds.

To measure large-scale results and overall effectiveness measures, metrics developed for the region, including the regional approaches outlined below, will be used. Some examples of measurable outcomes related to long-term goals are listed in Table 7.1 by general conservation action categories (see Chapter 6 and appendices for more information about conservation actions in the MD SWAP). In a broad sense, performance measures generally relate to success in conserving land, amassing scientific knowledge, funding conservation priority projects, increasing involvement of the public and partners, and otherwise reducing threats to SGCN and their habitats.

Table 7.1 Examples of performance measures developed to assess effectiveness of conservation activities. Performance measures are listed by general major conservation action categories based on recommended actions in SWAP Chapter 6 and Appendices 6a and 6b.

Conservation Action Category	Examples of Performance Measures
Land and Water Acquisition and Protection	• Percentage of protected lands where management plans are being implemented • Percentage of land acquisitions that minimize habitat fragmentation • Number of acres of prioritized land purchased, leased, or put into easement that are Biodiversity Conservation Network (BioNet) priority tiers • Number of acres protected that are SGCN habitat • Number of agreements with private landowners
Law and Policy	• Number of enforcement actions related to laws and regulations that reduce illegal harvest of SGCN or destruction of habitat • Number of laws and policies enacted to address threats identified in the Plan • Measures of positive responses of SGCN and KWHs to improved law and policy changes, including reduction of key threats and impacts
Direct Management of Natural Resources	• Number of acres or river miles restored/converted to target habitat • Number of dams removed • Acres or stream miles of invasive species removal • Number of active volunteers trained in invasive species survey and removal • Number of management actions implemented as planned • Indication that the direct management action is reducing key threats • Number of acres burned; indication that target species (post-burn) has benefitted from action

	• Species response (e.g., population size, nest success) of SGCN to direct management actions • Key habitat targets/processes response (e.g., size, condition) to direct management actions • Number of bat boxes built and installed; number of bats using structures
Planning and Administration	• Number of acres protected for SGCN conservation • Number of KWH management plans developed/implemented • Number of SGCN conservation plans developed/implemented • Number of grants administered/completed • Number of conservation plans using/implementing BioNet • Number of local government and municipal plans incorporating SGCN and habitat conservation • Number of staff working on SWAP implementation
Data Collection and Analysis – Inventory, Monitoring, and Research	• Number of surveys/inventories focused on SGCN • Number of surveys/inventories focused on KWHs • Number of research projects focused on SGCN • Number of research projects focused on KWHs • Indication that researcher provides clear answers to research questions • Confirmation that data are used to develop and inform conservation action recommendations
Education, Outreach, and Technical Assistance	• Number of education, outreach, and technical assistance actions implemented • Indication that education, outreach, and technical assistance changes are achieving increased awareness, behavior change, participation, and other anticipated outcomes • Number of landowners signing up, or continuing their training for landowner assistance programs • Number of acres managed for SGCN in Wildlife Management Areas • Number of Master Naturalist participants
Actions to Address Climate Change	• Incorporation of adaptation strategies into local government and state land management plans • Acres protected for marsh migration corridors • Acres of island created • Acres of marsh protected from sea level rise • Number of conservation plans including actions to address climate change • Number of species with highest vulnerability scores addressed by MD DNR or partner conservation plans

For conservation actions related to more specific conservation targets, such as priority conservation actions for groups of SGCN and KWHs (Chapter 6 and appendices), the five-step process described above, including "results chains," provides the framework that MD DNR can use to develop performance measures. Results chains (Foundations of Success 2007; Margoluis et al. 2013; Salafsky & Margoluis 2021) are graphical diagrams that link actions to the desired impacts through a series of short-, medium-, and long-term results in an "if-then" fashion.

Building a results chain starts with a specific conservation action, then links are added to related threats, species, and habitats. Indicators and effectiveness measures are selected for key steps in the results chain, providing both intermediate, shorter-term and ultimately, longer-term measures of success.

Using Regional Approaches to Monitor Effectiveness in Maryland

The Monitoring and Performance Reporting Framework

The Northeast Association of Fish and Wildlife Agencies (NEAFWA) developed a Monitoring and Performance Reporting Framework (NEAFWA 2008), which was intended to help each northeast state meet the expectations set by Congress and the USFWS for State Wildlife Action Plans. The goal of this framework is to assess the status and trends of SGCN and their habitats across the northeast states, and to evaluate the effectiveness of activities intended to conserve species and habitats across the northeast. The monitoring framework identified eight conservation targets (defined as species, landscape features, or vegetation communities important to fish and wildlife): forests, freshwater streams and river systems, freshwater wetlands, highly migratory species, lakes and ponds, managed grasslands and shrub lands, regionally significant SGCN, and unique habitats in the northeast. For each target, key threats were identified, along with conservation actions that could help alleviate or eliminate the effects of that particular stressor. Indicators were proposed for tracking status and trends of each of the targets, and data sources were identified for each of the indicators (NEAFWA 2008). Table 7.2 from NEAFWA (2008) lists the indicators, including stressors, which were selected by workshop participants for each of the eight conservation targets (TCI & NEFWDTC 2023). Data sources for indicators appropriate to Maryland that can be used to monitor effectiveness of the SWAP were identified as part of a SWG project. In Table 7.2, indicators with existing and relatively complete Maryland-specific data are indicated in bold text. The Nature Conservancy assessed these eight conservation targets as part of the Conservation Status of Fish, Wildlife, and Natural Habitats in the Northeast Landscape: Implementation of the Northeast Monitoring Framework (Anderson & Sheldon 2011). The Nature Conservancy updated this condition assessment in 2023 with new information and analysis tools (Anderson et al. 2023). By utilizing standardized techniques and datasets, the Northeast Monitoring and Performance Reporting Framework provides a consistent and regional assessment of priority species and their habitats for landscape level collaboration and the regional context in SWAPs.

Table 7.2 Conservation targets and proposed indicators for the Northeast. Bold text indicates that relatively complete data specific to Maryland are available. Source: NEAFWA 2008.

Targets	Proposed Indicators
Forests	**1a. Forest area - by forest type** **1b. Forest area - by reserve status** 2. Forest composition and structure - by seral stage **3. Forest fragmentation index** **4. Forest bird population trends** 5. Acid deposition index

Freshwater streams and river systems	**1. Percent impervious surface** **2. Distribution and population status of native Eastern brook trout** **3. Stream connectivity (length of open river) and number of blockages** **4. Index of biotic integrity** 5. Distribution and population status of non-indigenous aquatic species
Freshwater wetlands	**1. Size/area of freshwater wetlands** **2. Percent impervious surface flow** 3. Buffer area and condition (buffer index) 4a. Hydrology - upstream surface water retention **4b. Hydrology - high and low stream** **5. Wetland bird population trends** **6. Road density**
Highly migratory species	1. Migratory raptor population index 2. Shorebird abundance **3. Bat population trends** 4. Abundance of diadromous fish 5. Presence of monarch butterfly
Lakes and ponds	**1. Percent impervious surface/landscape integrity** 2. Percent shoreline developed (shoreline integrity)
Managed grasslands and shrublands	To be developed
Regionally Significant Species of Greatest Conservation Need	1. Population trends and reproductive productivity of federally listed species **2. State-listing status and conservation status ranks of highly imperiled wildlife** 3. Population trends of endemic species
Unique habitats	**1. Proximity to human activity/roads** 2. Wildlife presence/absence 3. Wildlife population trends **4. Land use/land cover changes**

State Wildlife Grants Effectiveness Measures Project

Building on the success of the Northeastern Regional Monitoring and Performance Measures Framework (NEAFWA 2008), the Association of Fish and Wildlife Agencies (AFWA) led an effort to develop an approach for measuring the effectiveness of wildlife conservation activities funded under the USFWS's SWG program. In September 2009, AFWA's Teaming with Wildlife Committee formed the Effectiveness Measures Working Group. This working group included representatives from state fish and wildlife agencies as well as private, academic, and non-governmental conservation partners with expertise in wildlife conservation and performance management.

In April 2011, the working group released a final report that outlines a comprehensive approach to measure the effectiveness of the activities funded under the SWG program, which was outlined above as a proposed approach to monitor effectiveness of the Maryland SWAP at different scales. The report builds on the monitoring framework that was originally developed in

the northeast states and recommends a set of common indicators for measuring status, trends, and/or effectiveness of thirteen general types of conservation actions that are commonly supported by SWG. These actions include direct management of natural resources, species restoration, creation of new habitat, acquisition/easement/lease, conservation area designation, environmental review, management planning, land use planning, training and technical assistance, data collection and analysis, education, conservation incentives, and stakeholder involvement. The report includes sample templates and forms that could be used for reporting the results of conservation activities funded through SWG, as well as a discussion of the specific methods by which these reporting methods could be incorporated into the USFWS's grants management database (TCI & NEFWDTC 2023). Whenever possible, conservation outcomes will be entered into state or regional tracking databases that are developed before the next SWAP revision.

Wildlife TRACS

The State Wildlife Grants Effectiveness Measures Project informed the development of Tracking and Reporting Actions for the Conservation of Species system (TRACS), a database designed by the USFWS to record information about conservation activities funded through the Wildlife and Sport Fish Restoration Program, including State Wildlife Grants. TRACS provides modules that track and report project outputs, effectiveness measures, and species and habitat outcomes. The Reports module provides users with the ability to view and export TRACS system data as itemized reports. Accomplishment reports include Featured Accomplishment Reports for curated data that address frequently requested program metrics, and Program Accomplishment Reports by Strategy that include all TRACS strategies, objectives, and activities. Reports are available at the national, regional, and state levels depending on each user's TRACS group(s) and permissions. Direct Habitat and Species Management Reports include the total number of acres managed for habitat or species for the creation, enhancement, restoration or maintenance of habitat or biological processes for the benefit of fish, wildlife, their habitats and /or recreational users, including game and nongame species management. The Research, Survey, Data Collection and Analysis Reports include the total number of research investigations for research, survey, collection, and analysis of data. TRACS can be used to track long-term outcomes for species and habitats in Maryland, above and beyond the types of short-term output measures commonly tracked by funding agencies (e.g., number of publications, number of workshops, number of people contacted). TRACS includes its own customized classifications of conservation actions and threats which are based, at least in part, on the classifications developed jointly by the International Union for the Conservation of Nature (IUCN) and the Conservation Measures Partnership.

Northeast Lexicon for Coordinated Planning and State Wildlife Action Plan Database

Wildlife conservation planners in the Northeast states have long recognized a potential ambiguity in many of the terms that are used to describe fish and wildlife conservation activities. In response to the need for standardized terminology, a standard lexicon was developed that provides conservationists with a uniform terminology that accurately and adequately describes the work of state fish and wildlife agencies (Crisfield & NEFWDTC 2022). The lexicon includes a set of common terms that can be used by state wildlife agencies and their partners to describe wildlife conservation activities in the northeast (TCI & NEFWDTC 2023). The use of this standardized terminology makes it possible to combine information across state lines to measure

effectiveness of conservation actions that address wide-ranging species or large-scale threats. The lexicon was also used to create a comprehensive database that includes all species, habitats, actions, and threats from the individual Northeast State Wildlife Action Plans (Northeast SWAP Database) that can be used to plan species and habitat monitoring as well as how to measure the effectiveness of conservation actions at the regional scale.

Measuring and Visualizing Effectiveness by Linking Conservation Actions to Outcomes

Although measuring the effectiveness of a conservation action requires more than counting short-term outputs, it is not possible to rely solely on measures of the ultimate impacts—the status of the species and habitats of interest—to measure effectiveness. This is because as confidence in the measures increases, the cost of measurement and the time required to detect change also increases (Figure 7.3). To solve this problem, the best effectiveness measures require defining a *results chain* that links actions through outcomes to the ultimate impact. The basic components of a results chain are strategies connected to outcomes (objectives) connected to the goal or impact on the target (Conservation Measures Partnership 2020). Data are collected at key steps to assess outcomes from intermediate actions and to determine if elements in the chain need to be revised. The use of results chains contributes to adaptive management and effective conservation by making assumptions explicit, facilitating the development of targeted monitoring plans, and developing action plans that efficiently address conservation priorities (Margoluis et al. 2013). Given the knowledge and effort needed to build conceptual models and results chains, it is most efficient to group priority conservation actions by the threats, species groups, or habitats that they have in common and to create results chains for broader conservation targets and threats. This makes it possible for priority actions identified in Chapter 6 and appendices to be addressed in a way that provides maximum benefit to multiple species and habitats, and to develop strategies that address multiple threats.

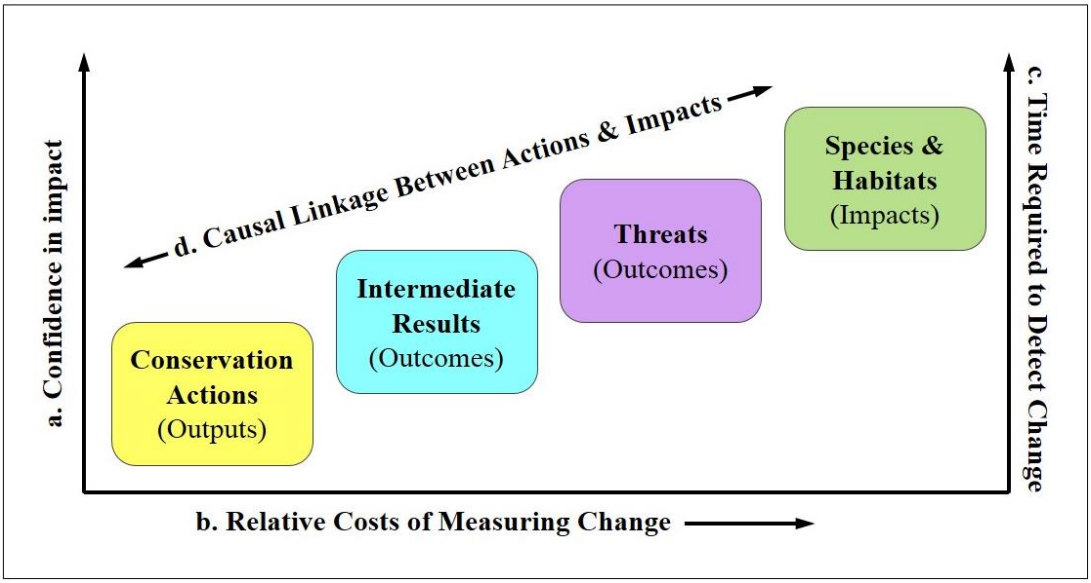

Figure 7.3 Constraints on measuring performance considering linkages between outputs, outcomes, and impacts. Source: Adapted from Association of Fish & Wildlife Agencies 2012.

Since the completion of the 2015–2025 SWAP, habitats have continued to be modified by human activities, including climate change. The emergence of new diseases and changes to threats to species due to illegal trade have further changed the context in which conservation outcomes will be measured. Decisions about how to measure the effectiveness of a conservation action and the best means to monitor results are increasingly being made in a complicated ecological and social context with limited resources. Developing a theory of change is another structured way to articulate goals and objectives to identify monitoring needs, although even informally sketching goals, objectives and other external forces (such as climate change impacts) can help clarify what to monitor (Helmstedt et al. 2025). To be effective and to measure the outcomes of monitoring, considering how monitoring and evaluation are connected to the desired conservation outcomes is critical (Figure 7.4). Viewing monitoring and outcomes in a broader, developed theory of change also reveals additional, often overlooked, reasons to monitor and goals for monitoring that can better structure a monitoring program. A full and comprehensive theory of change is likely to have many more arrows than pictured in Figure 7.4, including feedback loops.

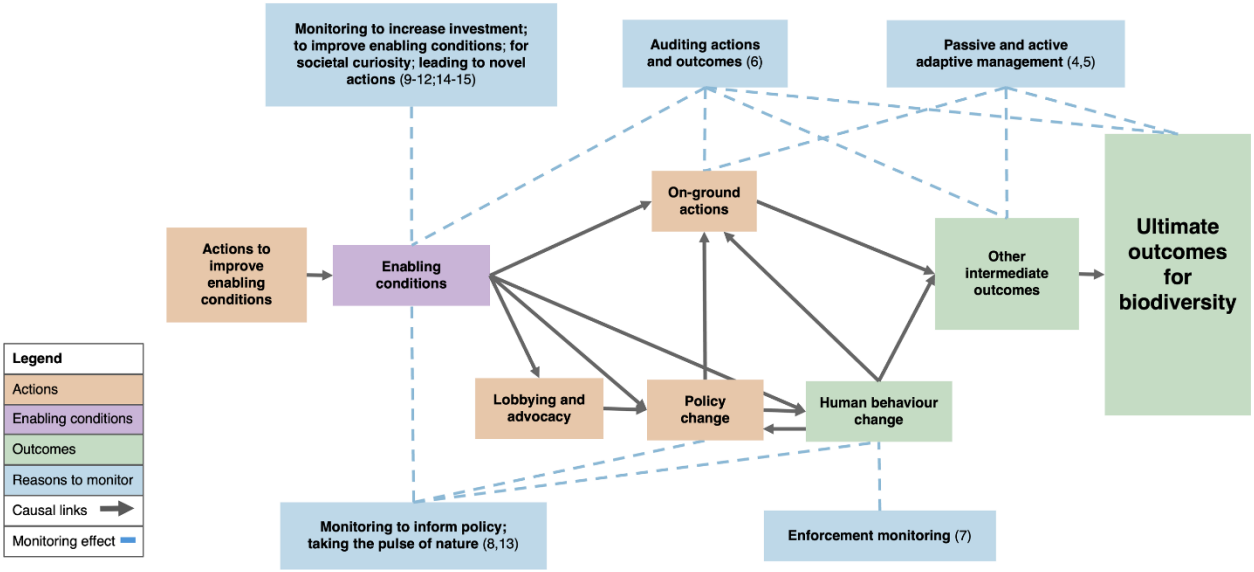

Figure 7.4 Theory of change linking actions to monitoring and biodiversity outcomes. Actions (orange) deliver outcomes (green) that rely on enabling conditions (purple). Monitoring actions (blue) are connected so that their contribution to ultimate outcomes is clear. Source: Helmstedt et al. 2025.

A full theory of change can be complicated and difficult to develop, especially when existing conditions or causal links are not well understood. An intermediate approach might be to reassess the threat impact calculation (see **Element #3**) to document reduced threats which would indicate actions with the desired effect. In this case, a strategic pathway could be defined that illustrates the expected connection between an action that reduces the impact of a threat and results in the desired outcomes (Salafsky et al. 1999; Salafsky & Margoluis 2021). This kind of framework is based on the definition of a theory of change linking the action with intermediate results, threat reduction, and the conservation target outcomes.

These diagrammatic approaches to effectiveness monitoring and to linking monitoring actions for species and habitats to conservation outcomes will be used as the SWAP is implemented,

especially when the regional approaches discussed above do not fit the right geographical or temporal scale.

Visualizing Monitoring and Conservation Effectiveness

The effective communication of conservation outcomes can be challenging. Several organizations have developed regular reports, story maps, and report cards to help partners and the public visualize progress towards conservation goals. For example, the Chesapeake Bay Foundation releases a State of the Bay report every two years. The most recent monitoring report, the State of the Bay 2025 Chesapeake Bay and Watershed Report Card, illustrates the status of 13 monitored indicators in three categories: pollution, habitat, and fisheries resources. Each indicator is given a score compared to pre-Colonial conditions, based on available monitoring data and field observations. The scores of the three indicator categories are averaged and translated into letter grades for communication purposes. The Chesapeake Bay Foundation also monitors progress of meeting the goals and objectives of the Chesapeake Bay Watershed Agreement and releases a Chesapeake Bay State of the Blueprint monitoring report to illustrate progress towards Agreement goals. The Maryland Department of the Environment Water Quality Assessment Report and Water Quality Assessment Map help the public and partners to be informed about current conditions and where practices are being effective. The University of Maryland Center for Environmental Science has developed a number of report cards that show the outcomes of monitoring and progress towards environmental goals. Story Maps, such as those developed for migratory shorebirds by the Western Hemisphere Shorebird Reserve Network, provide the means to demonstrate outcomes as well as monitoring data over large spatial scales for migratory species. The Susquehanna River Basin Commission Story Maps provide the opportunity to explore monitoring outcomes from multiple projects, from water quality to eDNA projects, for a particular geographic area. Interactive mapping tools like U.S. Geological Survey's Siren can help to target monitoring and illustrate where conservation actions are taking place for invasive species. As the SWAP is implemented, MD DNR will explore how to best show progress on monitoring goals and conservation outcomes as a way to inform partners and engage the public.

This chapter provides information pertinent to **Element #5** regarding the establishment of a monitoring framework. An overview of some of the more extensive monitoring programs currently in place within Maryland is presented and specific objectives and processes for expanding MD DNR's capacity to measure and track outcomes are listed. Chapter 8 will provide information relating to **Elements #7** and **#8** regarding coordination with and participation of partners and the public during the Plan's review and revision process.

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