National Fish and Wildlife Foundation

Delaware River Watershed Business Plan

March 2017

Purpose of a Business Plan

The purpose of a NFWF business plan is to provide a concise blueprint of the strategies and resources required to achieve the desired conservation outcomes. The strategies discussed in this plan do not represent solely the foundation's view of the actions necessary to achieve the identified conservation goals, but instead reflect the majority view of the many federal, state, academic, and organizational experts that consulted during plan development. This plan is not meant to duplicate ongoing efforts but rather to invest in areas where gaps might exist so as to support the efforts of the larger conservation community.

Acknowledgements

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> Jen Adkins, Partnership for the Delaware Estuary; Greg Breese , U.S. Fish and Wildlife Service; David Bushek, Rutgers University; Keith Curley, Trout Unlimited; Tim Dillingham, American Littoral Society; Matt Ehrhart, Stroud Water Research Center; Barry Evans, Penn State University; Sheila Eyler, U.S. Fish and Wildlife Service; Tom Fikslin, Delaware River Basin Commission; Cathy Haffner, Pennsylvania Game Commission; Pat Hamilton, New Jersey Department of Environmental Protection; Fred Henson, New York State Department of Environmental Conservation; Kurt Fesenmyer, Trout Unlimited; Sarah Karpanty, Virginia Tech; Danielle Kreeger, Partnership for Delaware Estuary; Stefanie Kroll, Academy of Natural Sciences; Jeff Larkin, Indiana University of Pennsylvania; Emma Melvin, American Littoral Society; Brian Neilan, New Jersey Division of Fish and Wildlife; David Mizrahi, New Jersey Audubon; Kenneth Najjar, Delaware River Basin Commission; Larry Niles, Niles Consulting; Eric Olsen, The Nature Conservancy; Daryl Price, Pennsylvania Fish and Boat Commission; Ron Rohrbaugh, Cornell University; Shawn Rummel, Trout Unlimited; Ross Shramko, New Jersey Department of Environmental Protection; Nellie Tsipoura, New Jersey Audubon.

About NFWF

The National Fish and Wildlife Foundation protects and restores our nation's wildlife and habitats. Chartered by Congress in 1984, NFWF directs public conservation dollars to the most pressing environmental needs and matches those investments with private contributions. NFWF works with government, nonprofit and corporate partners to find solutions for the most complex conservation challenges. Over the last three decades, NFWF has funded more than 4,000 organizations and committed more than $2.9 billion to conservation projects. Learn more at *www.nfwf.org*.

Cover photo credit: *Feeding red knots and dunlin (iStock photo); Smooth cord grass and ribbed mussels* (iStock by Getty images), and *Vibrantly blue Delaware River* (Andrew Kazmierski).

Conservation Need

The Delaware River, at the heart of the densely populated mid-Atlantic region and central to the nation's Northeastern transportation corridor, flows nearly 330 miles from its headwaters in New York to its mouth at the Atlantic Ocean, where it forms the border between New Jersey and Delaware. The Delaware River is recognized nationally and internationally for its exceptional ecologically and historically significant sites; it provides drinking water to over 15 million people; it annually attracts countless tourists; and it drives an economy largely based upon the expansive natural resources of the region.

Figure 1. Proximity map of Delaware River Watershed

Four states border the Delaware River and Bay with 13,539 square miles contributing to its watershed (Figure 1). The open water of the Bay comprises 782 square miles with freshwater inputs from nearly 2,000 tributaries. All or portions of 42 counties and 838 municipalities contribute to and benefit from the Delaware River watershed.

Since the 1600s humans have been altering the landscape, including clearing of forested lands for agriculture; building of canals, roadways, dams; dredging for deeper ports; development of vast industries reliant on water and energy sources; and harvest of lumber and extraction of coal. Several times over the past two centuries, migratory fish, birds and oyster populations have been decimated by overharvesting, pollution, hydrologic and hydraulic changes, and consequent dead zones; however, due to pollution abatement and other controls measures implemented over the last several decades, populations have begun to rebound.

The return of these populations has provided strong evidence of the system's ability to rebound from disturbances. However, the legacy and persistence of land conversion, river corridor disturbances, and the rising sea levels associated with climate and other stressors continue to threaten the sustainability of habitats that support representative and iconic species of the Delaware River watershed.

This business plan targets three integral habitat types for restoration and protection that are critical to the Delaware River watershed, its fish, wildlife and people: nearshore, aquatic, and forest habitat.

<u>Nearshore Habitat</u>

Defined as the shallow water and land adjacent to the shorelines and stream banks within the Delaware Bay and coastal areas, nearshore habitat includes the beach, intertidal and subtidal zones, as well as the upland area of the shore. With an estimated 232 total coastal miles along the Bay, the interdependency of migratory birds for protected beaches and food sources is intricately interwoven with the welfare of shellfish and their overall habitat structure and resilience, and creates a compelling case for why a multi-species approach for the protection and restoration of nearshore habitat is paramount.

Shorebirds. The Delaware Bay's nearshore habitat serves as a critical stopover and food source for migratory shorebirds including the red knot (*Calidris canutus*). Eggs spawned by millions of horseshoe crabs (*Limulus polyphemus)* on beaches in May provide a critical energy source that directly correlates

with the survival of red knots, making the condition of these birds leaving Delaware Bay for their arctic breeding grounds of high consequence (USFWS, 2013). These long distant migratory shorebirds occupy habitat that is critical to other coastal migrators, like semipalmated sandpiper (*Calidris pusilla*) and ruddy turnstone (*Arenaria interpres*). The harvest of horseshoe crabs for bait, the loss of beach habitat for spawning crabs, and the extraction of lysate from live adult horseshoe crabs for pharmaceuticals affect the availability of the red knot food source. An added and growing threat to the spawning success of horseshoe crab, and by extension, the habitat needs of red knot, is the expansion of aquaculture, especially on the New Jersey side. Oyster farming is expected to boost the local economy, but balancing the industry needs with conservation and restoration is the task at hand.

Living shoreline. Despite the widespread distribution of tidal wetlands throughout the Delaware Estuary, marsh habitat is rapidly being diminished and currently only occupies an estimated five percent of its historic range. With over 63 percent of examined marshes experiencing net erosion, estimates indicate that from 1996 to 2006 tidal wetlands throughout the Estuary experienced a net loss of approximately an acre per day. These losses to critical habitat are further exacerbated by rising sea levels and increased storm frequency and intensity. As a result of marsh loss, habitat for myriad species including shorebirds, shellfish, native vegetation, fish and other wildlife is lost along with all the ecosystem services provided (e.g., shoreline protection and water quality improvements). Therefore, in order to protect this critical habitat for fish and wildlife, actions must be taken to stem tidal marsh loss. Fringing eastern oyster (*Crassostrea virginica*) reefs are known to absorb wave energy and trap sediments, creating habitat, filtering water, and performing the much needed recycling of nutrients in the water column. Ribbed mussels (*Geukensia demissa)* in the tidal marshes are synergistic with the wetland grasses, forming natural marsh levees, stabilizing sediments and providing water filtration and nutrient cycling.

Aquatic Habitat

From the high quality headwaters emanating from the forests to the downstream large river and estuarine systems, a continuum of water environments create valuable and diverse habitat supporting a wide array of aquatic life including native trout and alosine species such as American shad and river herring. With 23,700 linear miles of streams and rivers, and expansive groundwater systems underlying them, the availability and quality of water is critical not only for the region's water demands, but also for supporting the aquatic health of representative fish species like eastern brook trout and an assemblage of alosine species.

Water quality. The availability of high quality water across the Delaware River watershed is essential to the 15 million people who depend upon it as their source of drinking water as well as for the welfare of both aquatic and terrestrial wildlife. Degraded water quality is caused by a combination of historic point sources (e.g., industrial waste, acid mine drainage, waste water treatment plants), as well as more diffuse nonpoint sources. Runoff from urban and agricultural lands deliver nutrient, bacteria and sediment pollution to streams throughout the region. Stormwater runoff from impervious, urbanized areas has diminished water quality by altering the temperature regime, depleting dissolved oxygen and introducing roadway and other surface contaminants to streams. These pollution inputs seriously impact sensitive species like eastern brook trout and the macroinvertebrates they rely upon as a food source. The sheer velocity and volume of stormwater strips the hydraulic and hydrologic function of streams, greatly reducing the assimilative capacity of the region's waters and diminishing overall health of stream and river systems.

Eastern brook trout. Historians credit the Upper Delaware River as the birthplace of American fly-fishing

on account of the prolific populations of eastern brook trout (*Salvelinus fontinalis*). In fact, nineteenth century over-fishing in the Catskills was cited as the cause for the original decline in the native trout population within the Delaware River watershed at the turn of the century. Eastern brook trout persist in only the coldest and cleanest waters and are excellent indicators of good water quality and watershed health. Stormwater runoff, incompatible agricultural practices, acid mine drainage, roads, and the alteration of upland and riparian areas result in water quality, hydrology and habitat impairments that reduce brook trout populations. Climate-induced warming may increase stream temperatures and alter stream hydrology and therefore further reduce the amount of habitat available for brook trout in the basin. Fragmentation from dams and impassable culverts results in small eastern brook trout populations that are more vulnerable to disturbance events (floods, drought) and demographic bottlenecks. Brook trout are also threatened by non-native trout, which out-compete for food and spawning sites and routinely prey upon them. The mid-Atlantic region, including the Delaware River watershed, has experienced some of the greatest declines in brook trout populations across their native range.

Alosine species. The river basin is home to ten diadromous fish species that migrate between freshwater and marine habitat, including three historically abundant alosine species represented by two species of river herring, alewife (*Alosa pseudoharengus*) and blueback (*A. aestivalis),* and American shad (*A. sapidissima*). Historically, the alosines are thought to have utilized many, if not all, medium to large tributaries of the Delaware River watershed and were among the region's most abundant and economically valuable fishes. While little is known about the number of adults that return to the Delaware River's tributaries to spawn and how they utilize available habitat, it is clear that populations of American shad and river herring have declined significantly over the last century. The alosines' unique migratory life cycle is dependent upon unrestricted access to high quality upstream spawning habitat, but a number of factors have diminished this access including barriers on tributaries, overfishing, pollution, and habitat alteration and channelization for shipping or flood control, and the loss of natural shoreline that changed flow patterns. Consequently, available habitat for alosine species such as American shad and river herring is greatly limited and populations are currently at historic lows.

Forest Habitat

The forests that once dominated the Delaware River watershed provided vast, contiguous habitat that nurtured numerous bird species as well as other terrestrial and aquatic species. Today, just under 50 percent of the Delaware River Basin's upland is forested but much of it is fragmented, with isolated patches surrounded largely by encroaching development.

Analyses of the Breeding Bird Survey (BBS data from 1966-2013) have demonstrated significant negative trends, especially for neotropical migrants occupying eastern forests. In the eastern region, the decline of habitat specialists including cerulean warbler (73% decline), golden-winged warbler (60% decline), and wood thrush (59% decline) are symptomatic of habitat loss and fragmentation that have dramatically reduced the habitat suitability in both temperate and tropical forests.

A healthy forest mosaic exists when bird species that are known to represent the discrete stages of forest succession are present and fully utilizing breeding territories. For example, golden-winged warbler (*Vermivora chrysoptera*) represent species dependent on early successional forest. Wood thrush (*Hylocichla mustelina*) require mature forest for establishing successful breeding territories, and cerulean warbler (*Setophaga cerulea*) are dependent upon a heterogeneous open canopy indicative of late successional forests. But these species are at risk due to incompatible land practices,

fragmentation, or forest management that focuses on a single attribute instead of the diverse age and structure needed within the forest.

Current Conservation Context

Through its Delaware River Restoration Fund, NFWF participates in an unprecedented collaboration with partners including the William Penn Foundation, the Institute for Conservation Leadership, the Open Space Institute, the Academy of Natural Sciences and 50 nonprofits across the Delaware River watershed to improve water quality with the overarching goal of ensuring the future of clean, abundant water for all aspects of life in the watershed. The need for an overall business plan approach for habitat-driven restoration is especially timely for improving alignment with the resources that this broader partnership and capacity brings.

The William Penn Foundation has invested in the capacity of non-profit organizations to protect and restore water and ensure clean, abundant water for present and future generations. NFWF's business plan will complement this work by expanding the scope to emphasize habitat protection and restoration, which benefits species.

In addition, national and international efforts to track and conserve migratory shorebirds and diadromous fishes have established conservation goals that include the Delaware Bay and the unique habitat and role it plays in the Atlantic Flyway for shorebirds and the life cycles of American shad and river herring. This business plan integrates and augments the goals of national and regional partners to maximize the opportunity to leverage programs and funding towards the success of these species.

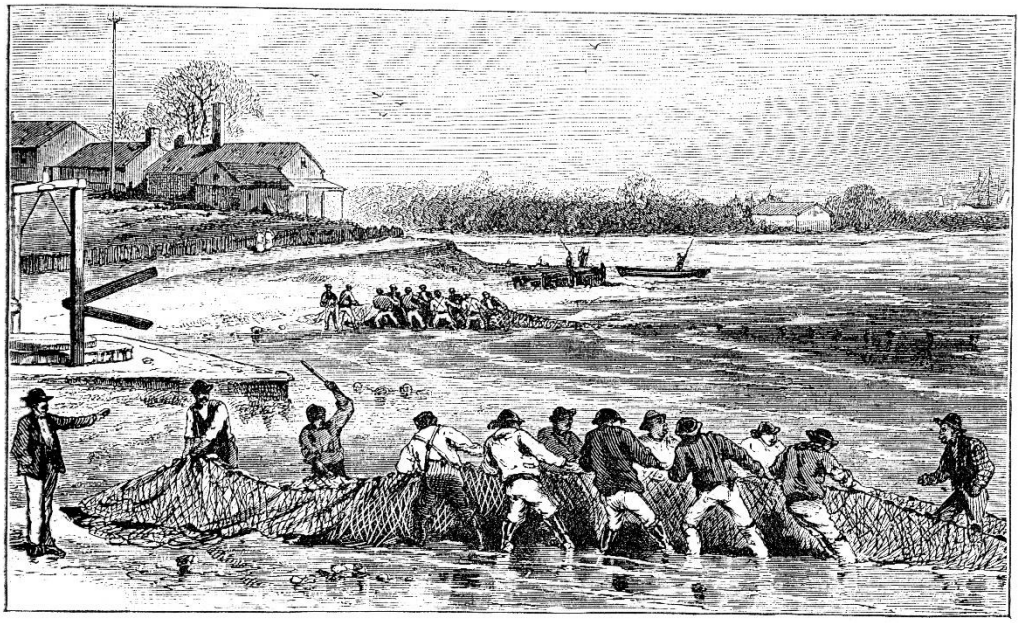


Figure 2 Source: iStock, historical. Used with permission.

Conservation Outcomes

The Delaware River Watershed business plan takes a multi-species approach to improve and sustain targeted nearshore, aquatic, and forest habitat in combination with improved water quality in targeted geographies across the Basin. The overarching goal is to:

> Restore and protect the diverse natural resources of the Delaware River Watershed, from the headwaters to the Bay, to sustain healthy, interconnected populations of fish and wildlife, their natural habitat, and the water quality upon which they depend.

Based on scientific literature and extensive content expert input, investment in strategies supporting the conservation goals (Table 1) are expected to achieve multiple ecosystem benefits for native fish and wildlife and improve water quality in targeted geographies and at scales within which assessment of change over time can occur.

Table 1. Conservation Goals by Habitat Type and Species

Nearshore Habitat	
Outcomes	**Goals**
Shorebirds	
Restore sufficient amount and diversity of beach habitat to sustain and enhance healthy populations of red knot, other shorebirds, and horseshoe crabs during breeding and passage periods in the spring and fall.	• Increase overall population size of red knot using Delaware Bay by 15% during spring migration ▪ More than 80% of red knot maintain or exceed 180 gram optimal threshold weight ▪ Increase overall availability of high quality horseshoe crab habitat in the Bay by 50% so that red knot reach optimum body weight threshold
Living shoreline	
Maintain a zero net shoreline erosion rate by stemming marsh loss and protecting beach and shoreline habitat for red knot and other species through the construction of living shorelines in priority sites.	▪ Protect beach habitat using oyster breakwaters to support increased availability of high quality horseshoe crab habitat (see above) ▪ Stabilize salt marsh edge habitat [a] using ribbed mussel and oyster living shoreline techniques, protecting marsh habitat for other marsh dependent species, so that net accretion rates will exceed net erosion rates to prevent marsh loss at priority sites

Aquatic Habitat

Outcomes	Goals
Water quality Achieve clean and sufficient water quantity and habitat quality to support healthy aquatic ecosystems and human communities through restoration in targeted watersheds	▪ Reduce polluted runoff in eight targeted watersheds[b] ▪ Enhance ecological community health in eight targeted watersheds as measured by algae, benthic macroinvertebrates and fish as indicators of health[b]
Eastern brook trout Enhance the habitat integrity, future security and connectivity of coldwater streams to support a robust conservation portfolio of EBT populations	Increase the population size of EBT (as measured using the number of effective breeders in the population) in: ▪ Two resilient,[c] stronghold population patches ▪ Three redundant, persistent population patches[c]
Alosine species Increase American shad and river herring runs through enhanced aquatic connectivity and access to high quality habitat	▪ Increase adult runs of American shad and river herring in priority rivers to population goals that will be established based on habitat suitability assessment and improved monitoring[1] ▪ Restore access to high quality spawning habitat by increasing connectivity in priority rivers through the removal of barriers[1]

Figure 3 Eastern brook trout. Credit: USFWS

Forest Habitat		
	Outcomes	**Goals**
Golden-winged warbler *Wood thrush* *Cerulean warbler*	Test premise that management of one or more 2,500- to 5,000-acre forest blocks for improved stand age and structural diversity, results in improved habitat conditions for forest birds and other wildlife	▪ Manage 15% to 20% of the block for early successional forest habitat (375 to 500 acres) resulting in 40 or more golden-winged warbler breeding territories (goal assumes 375 acres; up to 80 breeding territories could be achieved, based on 3 to 4 territories per 25 acres and 500 acres of habitat) ▪ Manage 30% to 60% of the forest block for mature forest habitat (750 to 1,500 acres), resulting in 60 or more wood thrush breeding territories (goal assumes 750 acres; up to 360 breeding territories could be achieved, based on 2-6 breeding territories per 25 acres and 1,500 acres of habitat) ▪ Manage 30% to 60% of the forest block for late successional forest habitat (750 to 1,500 acres), resulting in 180 or more cerulean warbler breeding territories (goal assumes 750 acres; up to 480 breeding territories could be achieved, based on 6 to 8 territories per 25 acres and 1,500 acres of habitat)

[a] Since the conditions and needs vary widely from location to location, quantitative estimates of the length and/or acreage needed to set and achieve conservation goals will be established following initial baseline assessments and identification of specific priority areas in years 0-3 of the plan.

[b] The Academy of Natural Sciences and implementation partners are currently developing the conservation targets via the Phase 2 DRWI planning process, anticipated completion September 2017.

[c] Eastern brook trout patches are designated by Trout Unlimited as 1) resilient, 2) redundant, 3) representative of a unique life history form, and 4) other (i.e., not resilient, redundant, or representative). Resilient populations are strongholds, and represent large patches with diverse stream habitats and fewer non-native trout species that enhance the capacity for populations to recover from large scale environmental disturbances. Redundant populations occur in smaller patches than resilient populations but are still considered persistent, having the demographic capacity to resist genetic bottlenecks through sufficient population size.

Figure 4 Wood thrush. Credit: M. Holland

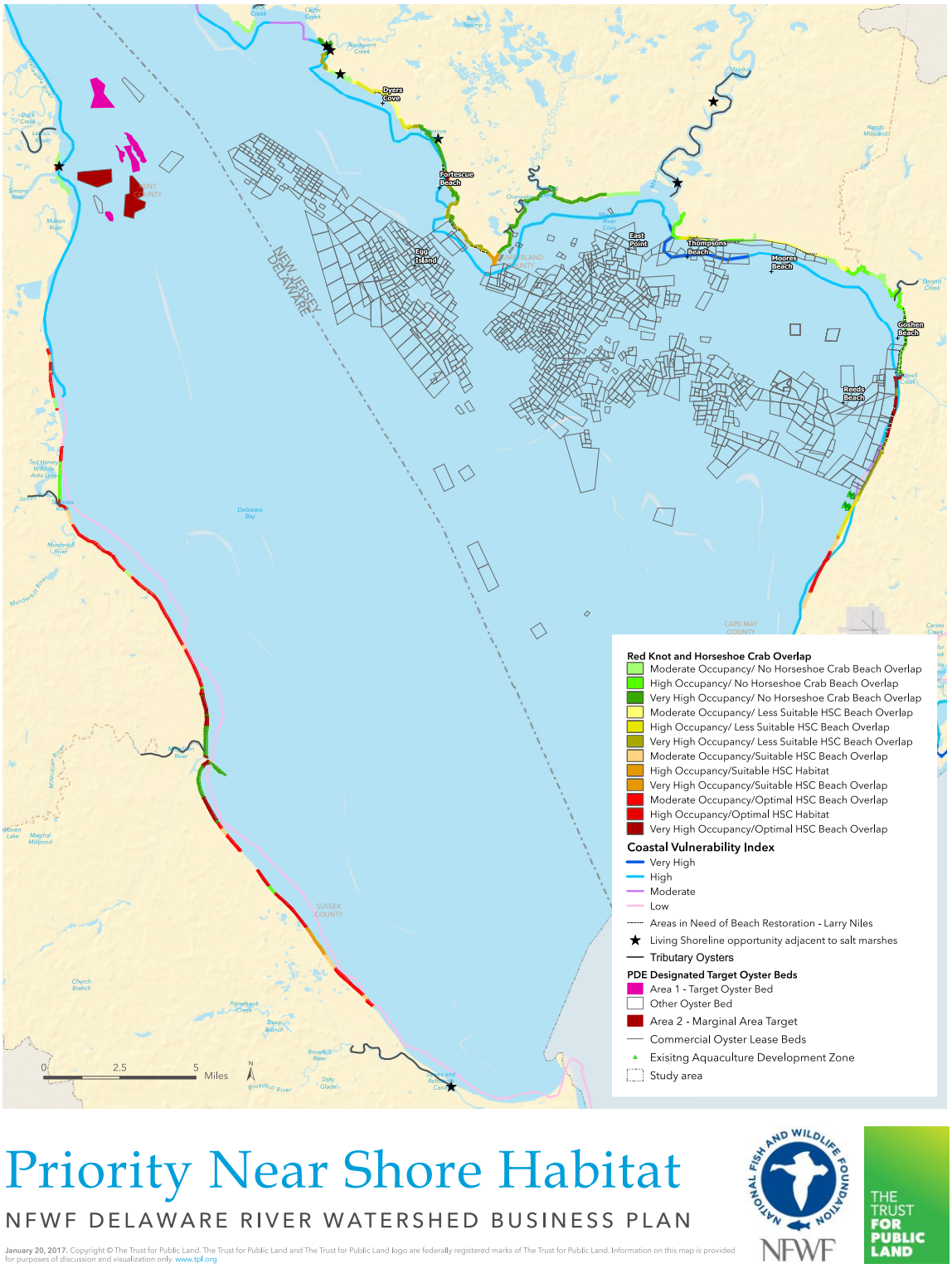
Geographic Focus

Program investments will be directed to key locations within the Delaware River watershed (Figures 5, 6 and 7) for each of the plan's conservation targets. Priority habitat was mapped for red knot, eastern oyster, ribbed mussel, living shorelines, alosine species, eastern brook trout, and the assemblage of forest birds, golden-winged warbler, wood thrush, and cerulean warbler. The habitat maps were evaluated and additional modeling was applied in response to extensive feedback and guidance from content experts, resulting in more geographic specificity for species and habitat priorities. The methodology for prioritization and full set of maps by habitat and species are in Appendix A. Below, Table 2 briefly summarizes the focal geographies by priority habitat and representative species.

Table 2. Focal geographies by category, habitat, and species

Habitat/Species	Focal Areas
Nearshore: Red knot, shorebirds, and living shorelines	1. Delaware Bay, areas of moderate to high overlap of red knot occupancy with horseshoe crab spawning beaches that coincide with high to very high coastal vulnerability index[a] and locations of Partnership for Delaware Estuary's designated living shoreline opportunities that are adjacent to high priority beaches and salt marshes. Sites include Reed's, Stone, Fortescue and Thompson's Beaches (NJ) and Millespione Beach in (DE), denoted by the red line along the Bay shore (Fig. 5).
Aquatic: Water quality	2. Eight targeted watersheds identified by the Delaware River Water Initiative as areas with highest potential to show impact to water quality in response to restoration and protection include Kirkwood-Cohansey (NJ), Brandywine-Christina (PA/DE), Upstream Suburban Philadelphia (PA), Schuylkill Highlands (PA), Middle Schuylkill (PA), New Jersey Highlands (NJ), Upper Lehigh (PA), Poconos – Kittatinny (PA/NJ/NY) and are shown in green thatch (Fig. 6).
Aquatic: Eastern brook trout	3. Resilient, redundant, and representative patches that contribute to a portfolio of Eastern Brook Trout populations in the Delaware River watershed. Patches are defined by an EBTJV and TU effort, shown in purple thatch (Fig. 6) and are concentrated in proximity to the forest habitat priority areas primarily in the northern tier of the Delaware Basin.
Aquatic: Alosine species	4. Priority rivers to be established based on assessments of habitat suitability and barriers or impediments to alosine connectivity. Alosine Active River Areas in catchments that scored highest in the Stream Reach Assessment Tool (DRWI) are classified as very high priority and will be further evaluated. These areas are denoted by orange along the river lines (Fig 6). To the extent practicable, priority sites for alosine conservation will align with water quality sites (*e.g.*, White Clay & Brandywine Creek in the Brandywine-Christina cluster and the Schuylkill or Lehigh Rivers).
Forests: Golden-winged warbler, wood thrush, cerulean warbler	5. Appalachian region, northern tier of the Delaware River watershed and primarily focused in NY, northeastern PA, and areas of northwestern NJ, and shown in a series of solid colors dependent upon overlap of habitat for two or more of the forest bird species (Fig. 7). Designated areas include 2,500 to 5,000 forest block(s) and priority habitat for the forest bird species is based on the overlap of moderate, high, and very high priority habitat for each of the individual species habitat models.

[a] Coastal Vulnerability Index is a commonly used method to assess coastal vulnerability to sea level rise, in particular due to erosion and/or inundation (Gomitz et al., 1991).



Priority Near Shore Habitat

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Figure 5. Delaware River Watershed with priority habitat for nearshore

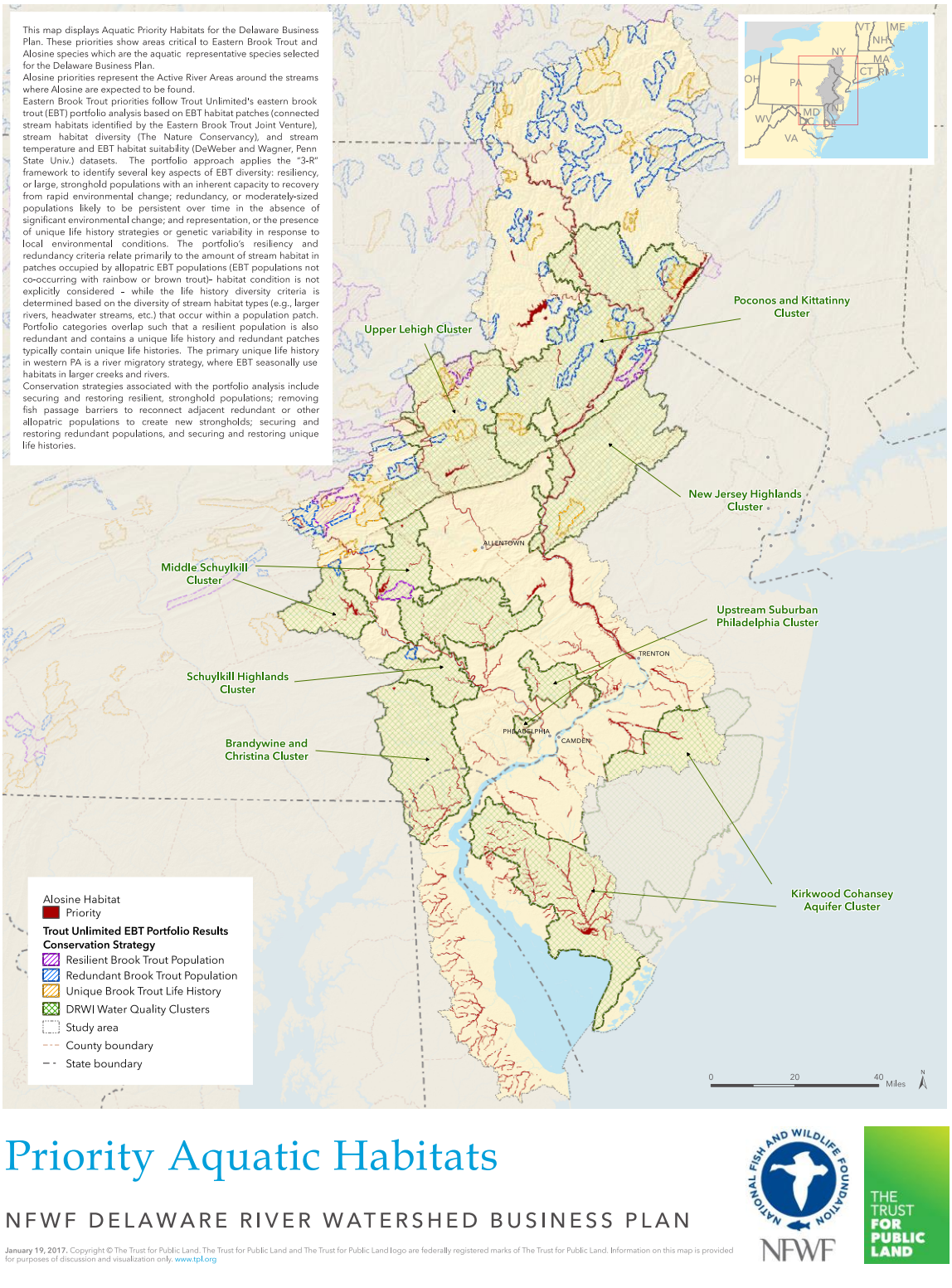
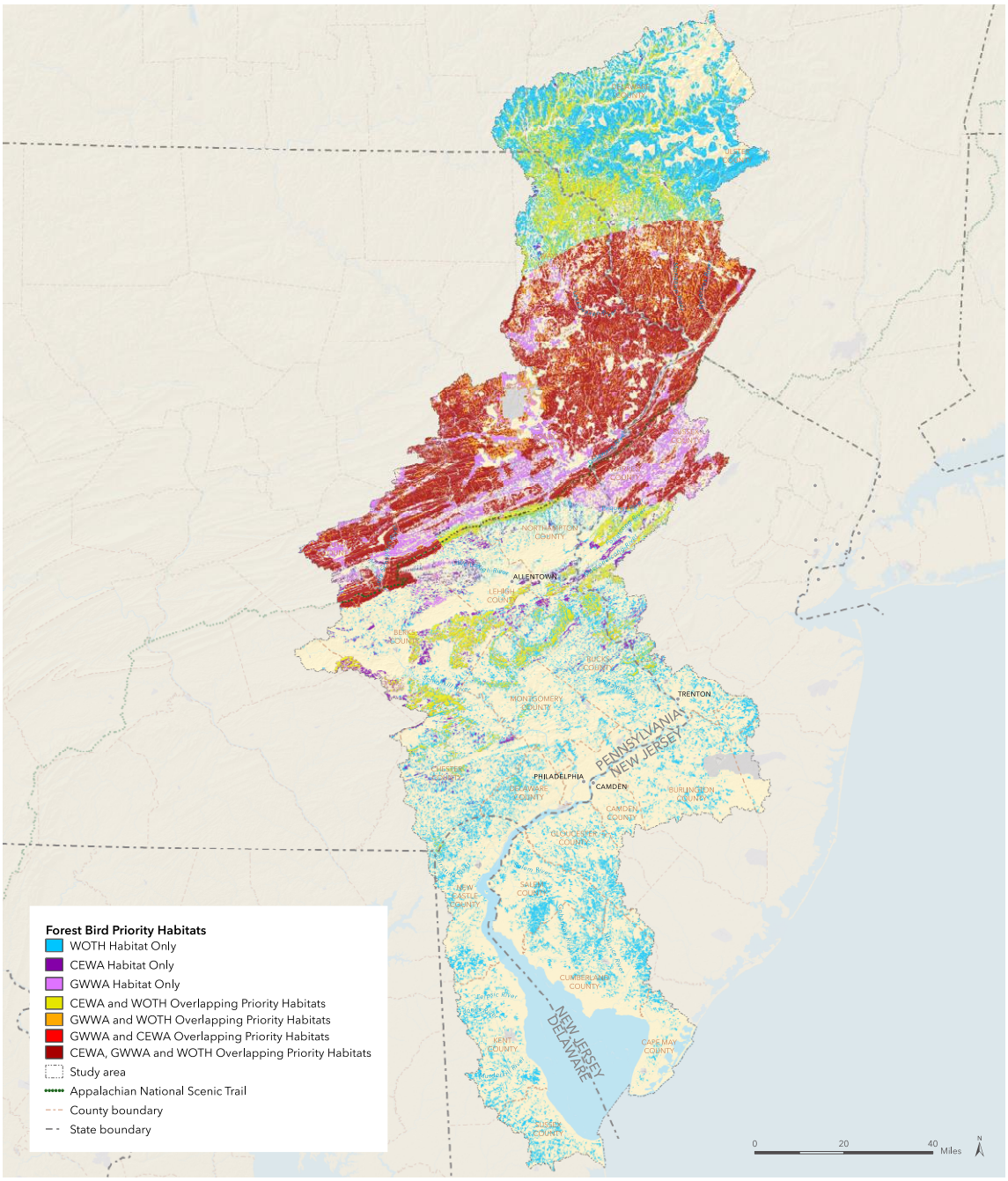


Figure 6 Delaware River Watershed with priority habitat for aquatic species and targeted watersheds for water quality



Priority Forest Bird Habitat

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Figure 7 Delaware River Watershed with priority habitat for forest species

Implementation Plan

The Delaware River Watershed plan strategies are designed to improve the quality and resilience of nearshore, aquatic and forest habitats critical to the viability and future of the region's diverse shorebirds, shellfish, migratory fish, native trout, and forest dwelling birds. The strategies are also undergirded by the need to improve and protect water for human uses while simultaneously ensuring its quality and availability to sustain wildlife and their habitat. While the strategies are presented by habitat category, in many cases activities may result in conservation outcomes across a range of habitat and species. The results chain in Figure 8 provides a model for how the collective strategies are predicted to contribute to the identified conservation outcomes.

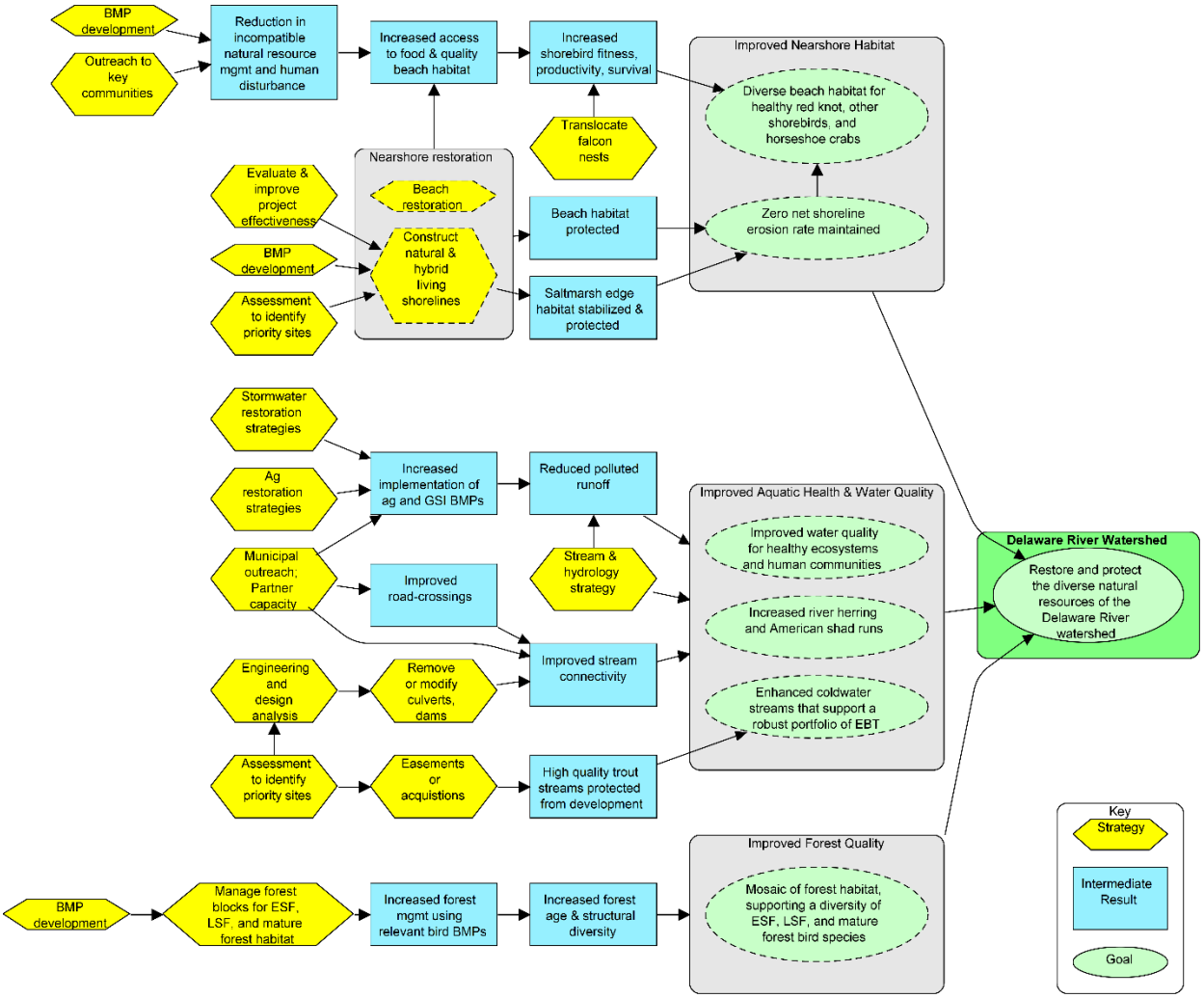

Figure 8. Overall strategies results chain model for the Delaware River Watershed business plan

Strategy 1: Management and Restoration of Nearshore Habitat – Shorebirds and Living Shorelines

Shorebirds

1.1 Increase high quality beach habitat at priority roosting and foraging sites through the restoration and enhancement of four miles of beach habitat that has been altered or destroyed during recent storm events and the establishment of best management practices (BMPs) to reduce the impact of aquaculture on priority roosting sites and intertidal foraging areas.

1.2 Reduce impacts of human and wildlife disturbances to critical red knot habitat areas through the development of a community outreach and social marketing program to manage access to public beaches and increase awareness about the importance of beaches to red knot and other species during critical staging period between May and June. The public outreach will be targeted to areas with known roosts at Stone Harbor Point, Egg Island Point and Bombay Hook. To address wildlife disturbances/predation, the translocation of breeding Peregrine Falcons will be assessed and where feasible, moved at least 10 miles from the Delaware Bay shore.

1.3 Reduce incompatible management of natural resources by working collaboratively with public and private sectors to develop and implement BMPs for aquaculture development at priority areas for roosting and foraging red knot and to minimize the impact of horseshoe crab harvest.

1.4 Research and monitoring for ensuring shorebird success. Conduct annual census of red knot and other shorebirds throughout the Bay and in critical staging and wintering areas. Support the census and mapping of horseshoe crab populations in and adjacent to the Bay to ensure reliable data is being collected and is available for determining their management.

Living shorelines

1.5 Identify priority sites for the construction of living shorelines that will contribute to the protection or stabilization of habitat for multiple species including but not limited to shorebirds such as red knot, horseshoe crab, eastern oyster, and ribbed mussels. Through initial investments in the first year of the business plan, criteria will be established and analyzed to identify high priority sites to target restoration investments and maximize conservation outcomes for both beach and marsh habitat. To the extent possible, efforts should build on existing and ongoing regional prioritization efforts and tools.

1.6 Research and monitoring for ensuring living shoreline success. Large scale and long-term monitoring efforts are currently underway to evaluate living shorelines and better understand their effectiveness at stemming erosion, how they benefit coastal resiliency, and to determine the ecological benefits and trade-offs. These monitoring efforts apply standardized methods in coordination with myriad state and federal partners to monitor and evaluate the impact of marsh, beach, and living shoreline restoration efforts throughout the mid-Atlantic. This ongoing monitoring effort will inform the implementation of the business plan and assist resource managers, researchers, and conservation practitioners throughout the Delaware Estuary to choose the most effective and cost efficient methods for stemming marsh loss, protecting beach habitat, and supporting fish and wildlife. Results from these monitoring efforts will also help to identify critical gaps and opportunities for research and development to refine methodology and enhance conservation outcomes. In addition to ongoing monitoring efforts, the living shoreline projects funded through this business plan will require site-specific rapid assessments using established methods to develop baselines and determine appropriate design and

engineering needs. Later, projects will develop longer-term and site-specific monitoring, maintenance, and adaptive management plans in accordance with standardized guidelines.

1.7 Construct living shorelines in priority areas to provide marsh and beach habitat protection. This plan focuses on four main shellfish-based living shorelines techniques that can help stem marsh loss, protect important shoreline habitat, or be utilized in combination for a hybrid approach, including: (1) *Nature-based living shorelines* are best suited for low-energy areas along the tidal marsh edge in which shellfish are used to create contained areas capable of accumulating sediment and allowing for the growth of marsh vegetation; (2) *Living reef breakwaters* protect marsh and beach habitat through wave attenuation, but also support critical aquatic habitat. Oyster living breakwaters offer a complementary approach to bolster the protection of red knot foraging and roosting sites (Activity 1.1); (3) *Marsh sills* are used to stabilize shorelines utilizing low elevation structures such as stones or bagged oyster shell. Vegetation is then planted in the space between the sill and the marsh to enhance stabilization and provide habitat; (4) *Intertidal oyster reef and ribbed mussel beds* creation will enhance ribbed mussel cover in mid-high intertidal zones and help to mitigate marsh edge loss and stabilize shorelines. Similarly, facilitating the colonization of oysters on intertidal mudflats provides habitat and supports shoreline stabilization.

Strategy 2: Restoration and Management of Aquatic Habitat and Water Quality – Water Quality and Quantity, Eastern Brook Trout, and Alosine Species

Water quality and quantity

2.1. Reduce the impact of polluted runoff on water quality and stream hydrology. For agricultural lands, conduct assessments and develop conservation plans that result in accelerated implementation of BMPs like forested riparian buffers, stream livestock exclusion, and improved barnyard management. Stabilize streambanks (where appropriate), reconnect streams to floodplains, and enhance and restore wetlands to improve the assimilative capacity and overall resiliency of streams. Improve road maintenance and management to reduce the potential for sediments and other pollutants to discharge to streams under storm conditions. Upgrade septic systems where they are a known source of stream contamination. For developed and impervious areas, assess the opportunities for green stormwater infrastructure (GSI) and implement practices that will enhance infiltration, reduce stormwater-related delivery of pollutants to waterways, and diminish the overall volume and energy of stormwater. GSI practices may include rain gardens, bioswales, green roofs, riparian buffers, basin retrofits, and wetland restoration. Remediate streams where acid mine drainage prevents the stream from meeting its designated use for aquatic life.

2.2. Increase partner capacity to accelerate water quality improvements through technical assistance, volunteer development, and municipal engagement. Improve outreach and technical assistance to farmers and other landowners. Engage citizens in supporting economic and policy incentives that promote watershed health including ordinances, zoning, and planning that increase both the adoption of agricultural best management practices and GSI at the household and municipal levels. Develop volunteers to engage in conservation and restoration projects where feasible.

Eastern brook trout

2.3. Restore connectivity in streams that support eastern brook trout (EBT) populations. Reduce the threat of fragmentation stemming from dams and impassable culverts, decreasing species vulnerability to extreme weather events or other demographic threats. Assess patch fragmentation to develop finer scale information needed to identify priority passage barriers. Remove small dams and replace impassable culverts with passable structures to increase patch size. Proactively engage federal and state transportation agencies, local townships and municipalities to design road-crossings appropriately to enable fish passage and to prevent road blowouts from extreme storm events. Work with governmental partners to ensure that interventions in response to flood damage maintain or enhance lateral and longitudinal stream connectivity.

2.4. Restore uplands, riparian, in-stream habitat, water quality, and hydrology in streams that support EBT populations. Urban and agricultural runoff, acid mine drainage, roads, and the alteration of upland and riparian areas result in water quality, hydrology and habitat impairments that reduce brook trout populations. Addressing these impairments through restoration and BMPs will support the overall resiliency of EBT-occupied streams and will help EBT populations adapt to the added stress of climate-induced stream warming and hydrologic change. Additional activities that support this strategy are identified in the water quality section, 2.1.

2.5. Identify and protect high-quality native trout patches and unique life history patches from future development and related disturbances. Many streams in the Delaware Basin have not been surveyed for fish. Residential, commercial, and energy-related development, including the increase of roads, culverts, and stream crossings, are expected to continue and possibly accelerate in the Delaware Basin, impacting high-quality brook trout populations through land conversion and hydrologic alteration. Continue assessment programs that target streams likely to support EBT (but where fish populations have not been previously assessed). Support conservation easements or fee-based acquisition on priority streams.

2.6. Establish a robust monitoring program for the key EBT patches where NFWF and partners plan to invest in restoration. Adequate and spatially explicit monitoring will ensure that brook trout population response to restoration investments is measurable. Develop an EBT population monitoring design in priority patches. Implement this design to establish a baseline brook trout population size using Whiteley et al (2015) genetic estimates of number of breeding adults (a surrogate for population size). Use this baseline to measure change in the number of breeding adults over time as restoration activities are undertaken. Potentially pair this technique with other monitoring work state agencies are performing.

Alosine species

2.7. Identify priority sites for restoration. To restore aquatic connectivity for alosine species within the Delaware Basin, it is critical to first assess habitat suitability and characterize any barriers or impediments that are currently preventing American shad and river herring from reaching or fully utilizing high quality spawning habitat. Through initial investments in the first year of the business plan, criteria will be established and analyzed to identify high priority sites to target restoration investments and maximize conservation outcomes.

2.8. Establish and/or improve monitoring programs for alosine species. Once priority sites are identified through completion of Activity 2.7, sentinel monitoring sites will be established, as needed, to fill data gaps and develop an infrastructure to monitor long-term population changes. Run count monitoring will be conducted at sentinel sites, coupled with surveys that monitor the extent to which adults are utilizing available spawning habitat. Once sentinel sites are established and initial habitat utilization surveys are conducted, baseline data will be collected and used to set a 10 year population goal for American shad and river herring. The population goal will be established by year 3 of the business plan.

2.9. Restore access to spawning habitat by increasing connectivity in priority rivers. Through completion of Activity 2.7, high priority barriers will be identified that prevent or significantly reduce fish passage. Full assessments of priority sites will be conducted as needed to determine site-specific dam removal and/or fish passage improvement opportunities including an analysis of engineering, design, and permit requirements as well as passage efficiency studies. High priority barriers will be removed and/or fish passage improvements will be made to restore access to upstream habitat.

2.10. Support and build community outreach and education about alosine species and habitat requirements through citizen science and intergenerational- and youth engagement projects. Offer educational opportunities that engage all ages around the goals and expected outcomes of alosine restoration projects.

Strategy 3: Forest Health – Forest Management and Representative Bird Species

3.1 Manage one or more 2,500 – 5,000 acre blocks of forest for age and structural diversity to demonstrate that it will improve forest habitat conditions for birds and other wildlife. Forest block size will be determined based on the habitat use of indicator species during the post-fledgling period in which more habitat is required. For instance, golden-winged warblers require a minimum patch of early successional habitat of 400 acres; wood thrush require a minimum patch of 1,800 acres of mature forest; and cerulean warbler require a minimum forest block of 5,000 acres.[1]

3.2 Create and manage a portion of the forest block(s) for early successional forest (ESF). Manage 15% to 20% of the forest block for ESF. Patch size and distribution across the landscape will need to be carefully planned to account for habitat senescence and bird dispersal. Develop and implement ESF management plans using BMPs developed for golden-winged warbler (Golden-winged Warbler Working Group, www.gwwa.org, 2013).

3.3 Manage a portion of the forest block(s) for a transitional mature forest (i.e. standard oak silviculture methods). Manage 30 to 60% of the forest block for structurally diverse forest conditions. Develop and implement BMP's (including cerulean warbler BMP's) for mature forest management to benefit wood thrush, cerulean warbler and additional species (potential forest management practices include those used by foresters to regenerate oak stands – e.g. crop tree

[1] The science behind forest block size is grounded in habitat use of indicator species during the post-fledging period. After leaving the nest, parents and dependent young require more habitat – for golden-winged warbler (a young forest indicator) fledglings range up to 700 m from nest at 30 days, suggesting a minimum patch size of 400 acres; in contrast wood thrush (a mature forest indicator) will travel up to 1,500m from nest at 30 days, suggesting a minimum forest block of 1,800 acres; lastly cerulean warblers (a late successional forest species) can travel more than 2.5km from the nest at 30 days, suggesting a minimum forest block of 5,000 acres.

release; cerulean warbler management guidelines, (Appalachian Mountains Joint Venture, 2013).

3.4 Create and manage a portion of the forest block(s) for late successional forest (LSF). Manage 30 to 60% of the forest block for LSF habitat; develop and implement LSF management plans including implementation of cerulean warbler BMPs. Overall the management footprint for LSF habitat will be light, with forests "allowed" to age "naturally" utilizing tools like invasive species control, prescribed fire, or other light forest stand improvement activities. These acres will benefit multiple species, including wood thrush and cerulean warbler, as age and structural diversity are improved.

3.5 Research and monitor within the established forest block(s). Establish bird diversity baseline estimates in unmanaged and pre-treatment blocks using transect point count sampling (Ralph et al. 1995) or other techniques. Use baseline data and monitoring program to measure changes in bird abundance, density, diversity and productivity as forest management activities are undertaken. Track forest management goals (acres per habitat type) through GIS land cover data and stand maps.

Risk Assessment

Risk is an uncertain event or condition which, if it occurs, could have a negative effect on a program's desired outcome. Seven risk event categories were assessed to determine the extent to which they could impede progress towards the stated business plan strategies and goals for the Delaware River Watershed during the next 10 years (Table 3).

Table 3. Risk assessment summary

Risk Category	Rating	Risk Description	Mitigating Strategies
Regulatory Risks	**Low**	Executive order banning offshore drilling, location of wells, and oil exploration could be rescinded, leading to disturbance to intertidal zone for red knot	Not addressed in plan
	High	Infrastructure modifications made in response to increased storms and flooding events may negatively impact restored areas by diminishing connectivity and exacerbating EBT habitat loss	Communications and outreach to local agencies and governments with flood response responsibilities is addressed in strategies for EBT
Financial Risks	**Low**	Lack of diversity in current funding for Delaware Basin makes program vulnerable to potential loss of primary funder	Budget includes plan for diversifying portfolio of investments to include private and broader public funding
Environmental Risks	**High**	Increase in water temperature might cause HSC to spawn earlier, disrupting synchronicity of food availability for red knot migration. Also, intensity of storms may degrade restored shoreline.	Plan includes goal weights for red knot to better understand impact of declining food sources and creation of predator-free colonies through translocation. Also, living shoreline strategy at priority locations will reduce impact of storms on shoreline
	Low	Increases in water temperatures threaten EBT requirement for cold water	Plan includes strategies that improve/restore forested riparian buffer in targeted areas, increasing shade and thermal regulation
	Mod	Living shorelines impacted by loss of tidal marsh due to sea level rise, unprotected shoreline, river hydraulics, etc.	Living shoreline strategy increases resiliency in priority locations
	Mod	Non-native trout and other species could out-compete native brook trout for habitat, food in priority sites	Plan targets streams that support allopatric (native-trout only) patches.
Scientific Risks	**Low**	Insufficient scientific understanding of population size and habitat occupancy for some species could misdirect investments	Plan identifies research and monitoring strategies where species data are lacking that reduce this risk
	Mod	Uncertainty about the impacts of harvest on the horseshoe crab (HSC) population	Strategies include study of impact of extraction on HSC reproduction and life cycle. Near term (<10 years) industry may have a synthetic formula that would reduce/eliminate need to extract from HSC.
	Mod	Uncertainty as to whether growth of aquaculture adjacent to critical staging and foraging beaches for red knot will reduce productivity of HSC	Plan includes strategy to develop/implement BMPs that support aquaculture and protect critical habitat for red knot and HSC
Social Risks	**Low**	Local communities might not adopt behavioral changes to minimize beach disturbances (e.g., recreational access, ATVs) and beach waste, which attracts predators. Landowners might not adopt agricultural BMPs that reduce nitrogen, phosphorus, sediment, and other agro-chemical inputs into water.	Plan identifies social marketing and outreach strategies for engaging local communities to protect. It also includes agricultural technical assistance as a strategy for increasing farmer participation in conservation.
Economic Risks	**Low**	Bycatch as a management risk occurs outside of the spatial and strategic scope of this plan but may impact alosine populations that could occupy expanded spawning areas	Not addressed in plan
Institutional Risks	**Mod**	Multiple agencies and organizations have responsibility and missions associated with the plan's outcomes. Risk that there is insufficient coordination and collaboration required to successfully implement the strategies.	Plan includes strategies for organizational collaboration, as appropriate

Monitoring & Evaluating Performance

To track program performance and conservation outcomes, NFWF will monitor progress at the project and program scales. Table 4 summarizes the core metrics for tracking overall progress on meeting the stated conservation goals. A detailed description of monitoring and evaluation plans by habitat type, including strategy-based metrics, is in Appendix A. Where possible, monitoring efforts will be coordinated across species and within each habitat category.

At a key stage in the program's lifecycle, NFWF might commission a third-party evaluation to examine the factors that have facilitated and hindered successful program implementation to inform future decision-making and adaptively manage. In some cases these course corrections may warrant increased investment; however, it is also possible that NFWF would reduce or eliminate support if periodic evaluation indicates that further investments are unlikely to achieve intended outcomes or conversely if goals are met ahead of schedule.

Nearshore Habitat. Restoration of nearshore habitat and the species that depend on it will be monitored by the Delaware Bay Shorebird Project, state and federal wildlife agencies, the USGS Digital Shoreline Analysis System, other site-specific monitoring, and grantees. By selecting priority sites for living shoreline restoration, NFWF and partners can maximize monitoring and assessing restoration benefits to shorebirds, shellfish, and other species, through a coordinated design.

- *Shorebirds:* To determine whether the number of red knots using Delaware Bay has increased, and if their condition has improved, NFWF will fund an annual assessment of long and short distance red knot populations, health (weight), and the abundance of horseshoe crab.

- *Living shoreline:* To assess the goal of net zero marsh loss at the restoration sites, NFWF will fund external, remote sensing combined with site-specific assessments (e.g. high resolution measures via real-time kinetic GPS) will be used to evaluate the ratio of net accretion versus erosion within priority sites by grantees.

Aquatic Habitat and Water Quality. Targeted monitoring by the conservation community outside of the business plan is underway and may provide information necessary for scaling up future restoration efforts. Monitoring to assess response to the plan strategies will be coordinated across the water quality program and partners and will include species level monitoring that integrates standardized methods and emerging technologies for assessing populations, as described below and in Appendix A.

- *Water quality*: In coordination with the Delaware River Watershed Initiative, the Academy of Natural Resources is leading a combination of water chemistry, instream biological sampling, and habitat sampling. Together, they will provide a holistic picture of aquatic condition in the eight targeted watersheds and will help (1) identify the sources of biotic impairment and (2) track changes in water quality over time as restoration is implemented. In addition, NFWF will collect project-level metrics on nutrient, sediment, and stormwater reductions associated with individual projects using the WikiWatershed Toolkit (Stroud Water Research Center), integrated with the Stream Restoration Assessment Tool (SRAT).

- *Eastern brook trout*: NFWF will collaborate with the Eastern Brook Trout Joint Venture partners and potentially state agencies who manage trout resources (NY, NJ, PA) to measure baseline EBT

abundance where significant restoration investment will be made and conduct annual sampling within focal patches measuring the effective number of breeding EBT per patch (N_b). N_b is a genetic surrogate of EBT population size that provides a whole-patch population estimate (Whiteley et al. 2014). EBT population patches must meet the portfolio criteria for **resiliency** (having sufficiently large populations and intact habitats to facilitate recovery from rapid environmental change), **redundancy** (saving enough different populations so that some can be lost without jeopardizing the species), and **representation** (protecting/restoring EBT diversity) as defined by the Trout Unlimited Eastern Brook Trout range-wide population analysis (NFWF-funded effort to be completed in 2017).

- *Alosine species*: NFWF will invest in sentinel monitoring sites in priority alosine species locations where existing monitoring is not already in place and will utilize standardized methods (see Appendix A) to monitor the number of spawning adults via annual run counts. In addition, electrofishing, ichthoplankton, and/or eDNA surveys will also be used to evaluate trends in the occurrence and extent of spawning adults to assess occupancy and use of habitat before and after restoration efforts.

Forest Habitat. Bird monitoring will build upon existing monitoring efforts as well as initiating additional sampling especially for control blocks. With the overall integrated forest management approach, the diversity of the forest structure and bird diversity will be assessed by establishing bird abundance, density, diversity and productivity baseline estimates in unmanaged and pre-treatment blocks using point count sampling, mist netting and other techniques. Monitoring of the forest habitat response will be addressed as a part of the research strategies to assess the overall study design; forest management goals (acres per habitat type) can be tracked with GIS land cover data and stand maps.

Table 4. Metrics for measuring progress towards conservation goals

Nearshore Habitat	Goals	Metrics	Baseline (2017)	Target (2027)	Data source(s)
Shorebirds: Restore sufficient amount and diversity of beach habitat to enhance, secure and sustain healthy populations of red knot, other shorebirds, and horseshoe crabs during breeding and passage periods in the spring and fall	Increase overall population size of red knot using Delaware Bay by 15% during spring migration	# red knot estimated through ARM[a] model	21,128 individuals /ARM estimate - 47,254 individuals	24,297 individuals/ ARM estimate - 54,342 individuals	ARM, Atlantic States Marine Fisheries Commission
	More than 80% of red knot maintain or exceed 180 gram optimal threshold weight	Pre-departure body weight (grams)	~70%	> 80%	Delaware Shorebird Project; body weight sampling; Project level reporting by grantees
	Increase overall availability of high quality horseshoe crab habitat in the Bay by 50% so that red knot reach optimum body weight threshold	# of miles or acre equivalent of restored and undisturbed beach	TBD	4	Project level reporting by grantees
Living shoreline: Maintain a zero net shoreline erosion rate by stemming marsh loss and protecting beach and shoreline habitat for red knot and other species through the	Protect beach habitat using oyster breakwaters to support increased availability of high quality horseshoe crab habitat	# of miles beach restored	TBD [b]	TBD [b]	Project level reporting by grantees
	Stabilize salt marsh edge habitat using ribbed mussel and oyster living shoreline	Accretion Rate – Erosion Rate > 0	Varies	0	USGS Digital Shoreline Analysis System, On-site Rapid Assessment

construction of living shorelines in priority sites	techniques, protecting marsh habitat for other marsh dependent species, so that net accretion rates will exceed net erosion rates to prevent marsh loss at priority sites.				Monitoring; Project level reporting by grantees
		# of acres of marsh habitat restored	TBD [b]	TBD [b]	Project level reporting by grantees

Aquatic Habitat	**Goals**	**Metrics**	**Baseline (2017)**	**Target (2027)**	**Data source(s)**
Water quality: Achieve clean and sufficient water quantity and habitat quality to support healthy aquatic ecosystems and human communities through restoration in targeted watersheds	Reduce polluted runoff in eight targeted watersheds.	Lbs. of N avoided annually	Note [f]	Note [f]	Academy of Natural Sciences (ANS) [g] ANS/DRWI Modeling via SRAT (Stream Reach Assessment Tool) and Wiki Watershed (Stroud Water Research Center)
		Lbs. of P avoided annually			
		Lbs. of sediment avoided annually			
	Enhance ecological community health in eight targeted watersheds as measured by algae, benthic macroinvertebrates and fish as indicators of health.	IBIs (algae, benthic macroinvertebrates, fish)			
Eastern brook trout: Enhance the habitat integrity, future security and connectivity of coldwater streams to support a robust conservation portfolio of EBT populations	Increase the population size of EBT (as measured using the number of effective breeders in the population) two (2) resilient, stronghold population patches	Increase effective number of breeding EBT per patch (Nb)[c] relative to baseline	TBD[e]	TBD[e]	EBTJV
	Increase the population size of EBT (as measured using the number of effective breeders in the population) in three (3) redundant, persistent population patches	Increase effective number of breeding EBT per patch (Nb)[c] relative to baseline	TBD[e]	TBD[e]	EBTJV
Alosine species: Increase American shad and river herring runs through enhanced aquatic connectivity and access to high quality habitat.	Increase adult runs of American shad and river herring in priority rivers to population goals that will be established based on habitat suitability assessment and improved monitoring.	# of American shad that are crossing barriers	469[c]	TBD [d]	NFWF funded run counts on priority rivers
		# of river herring that are crossing barriers	76[c]	TBD [d]	NFWF funded run counts on priority rivers
	Restore access to high quality spawning habitat by increasing connectivity in priority rivers through the removal of barriers.	# of miles of stream opened	TBD [d]	TBD [d]	Project level reporting by grantees
		# of acres of lake/pond habitat opened	TBD [d]	TBD [d]	Project level reporting by grantees

Forest Habitat	Goals	Metrics	Baseline (2017)	Target (2027)	Data source(s)
Test premise that management of one or more 2,500- to 5,000-acre forest blocks for improved stand age and structural diversity, results in improved habitat conditions for forest birds and other wildlife	Manage 15% to 20% of the block for early successional forest habitat (375 to 500 acres) resulting in 40 or more golden-winged warbler breeding territories (goal assumes 375 acres; up to 80 breeding territories could be achieved, based on 3 to 4 territories per 25 acres and 500 acres of habitat).	# of acres created and managed for early successional habitat	0	375 to 500	Project level reporting by grantees including GIS land cover data and stand maps.
		# of breeding territories for golden-winged warbler	0	45-80 [h]	Project level reporting by grantees.
	Manage 30% to 60% of the forest block for mature forest habitat (750 to 1,500 acres), resulting in 60 or more wood thrush breeding territories (goal assumes 750 acres; up to 360 breeding territories could be achieved, based on 2-6 breeding territories per 25 acres and 1,500 acres of habitat).	# of acres created and managed as mature forest habitat	0	750 to 1,500	Project level reporting by grantees including GIS land cover data and stand maps
		# of breeding territories for wood thrush	0	60 – 360 [i]	Project level reporting by grantees
	Manage 30% to 60% of the forest block for late successional forest habitat (750 to 1,500 acres), resulting in 180 or more cerulean warbler breeding territories (goal assumes 750 acres; up to 480 breeding territories could be achieved, based on 6 to 8 territories per 25 acres and 1,500 acres of habitat)	# of acres managed as late successional forest habitat	0	750 to 1,500	Project level reporting by grantees including GIS land cover data and stand maps
		# of breeding territories for cerulean warbler	0	180 – 480 [j]	Project level reporting by grantees.

[a] ARM – Adaptive Resource Management http://www.asmfc.org/uploads/file/2009DelawareBayARMReport.pdf

[b] Baseline values and goals cannot be established until priority sites for living shoreline construction are identified and initial site assessments are completed.

[c] Baseline values are based on the number of spawning adults that have been counted successfully passing the Fairmount Fishway on the Schuylkill River.

[d] Baseline population estimates are not available for the majority of the watershed. Once sentinel sites are established, baseline data will be collected and used to set a 10 year population goal for American shad and river herring. The population goal will be established by year 3 of the business plan.

[e] TBD: See strategy 2.6 and monitoring and performance section in Appendix A that lays out a plan to establish an EBT population size baseline and goals for each of the patches where we plan to concentrate investment.

[f] In development by ANS and implementation partners via Phase 2 DRWI planning process, anticipated completion Spring 2018.

[g] As indicated in narrative (and Appendix A) the indices of biotic integrity that will be used to gauge change in biological community condition are still being determined by the Academy of Natural Sciences.

[h] Range tied to forest block size and based on the number of breeding males 0.37/ha (McNeil 2015).

[i] 2 to 6 breeding territories/25 acres (Powell *et al* 2000 and other sources).

[j] 6 to 8 breeding territories /25 acres (Boves et al 2013; expert opinion).

Budget

The following budget shows the estimated costs to implement the activities identified in this business plan. This budget reflects NFWF's anticipated engagement over the business plan period of performance; however, it is *not* an annual or even cumulative commitment by NFWF to invest. We acknowledge that in many cases the activities laid out in the plan build upon efforts funded by other organizations. This budget assumes that the current trajectory of funding by those other organizations continues over this program's time frame.

Table 5. Budget for Delaware River Watershed Business Plan

BUDGET CATEGORY	Yrs 1-5 ($K)	Yrs 6-10 ($K)	Total ($K)
Strategy 1. Management and Restoration of Nearshore Habitat – Shorebirds and Living Shoreline			
1.1 Increase high quality beach habitat at priority roosting and foraging sites	1,000	900	1,900
1.2 Reduce impacts of human and wildlife disturbances of beach habitat areas	250	250	500
1.3 Reduce incompatible management of natural resources	400	100	500
1.4 Research and monitoring for ensuring shorebird success	300	300	600
1.5 Identify priority sites for the construction of living shorelines	150	0	150
1.6 Research and monitoring for ensuring living shoreline success	1,300	300	1,600
1.7 Construct natural and hybrid living shorelines in priority areas to protect marsh and beach habitat	900	850	1,750
Strategy 2. Aquatic Habitat and Water Quality – Water Quality/Quantity Restoration, Eastern Brook Trout, and Alosine Species			
2.1 Reduce volume and impact of polluted runoff to improve water quality, restore hydrology and upland, riparian and in-stream habitat	4,720	4,720	9,440
2.2 Increase partner capacity for technical assistance and engagement	1,100	1,100	2,200
2.3 Restore connectivity in streams that support eastern brook trout	660	670	1,330
2.4 See 2.1	---	---	---
2.5 Identify and protect high quality native trout patches and unique life history patches	300	450	750
2.6 Establish robust monitoring for native trout	150	150	300
2.7 Identify priority sites for restoration (alosine species)	200	0	200
2.8 Establish and/or improve monitoring programs (alosine species)	300	200	500
2.9 Restore access to spawning habitat by increasing connectivity in priority rivers	1,000	870	1,870
2.10 Community outreach and education for alosine species through citizen science and engagement.	150	100	250
Strategy 3. Forest Health – Forest Management and Birds			
3.1 Manage one or more 2,500 (to 5,000) acre block for diverse forest structure and age.	2,560	2.560	5,120
3.2, 3.3, and 3.4: See 3.1	---	---	---
3.5 Research and monitor unmanaged and pre-treatment forest blocks.	290	280	570
Other			
Program Assessment and Evaluation	**0**	**250**	**250**
TOTAL BUDGET	**$15,730 K**	**$14,000 K**	**$29,780 K**

Literature Cited

Birds with Silviculture in Mind. 2011. Audubon Vermont and Vermont Department of Forestry. http://vt.audubon.org/sites/g/files/amh751/f/bird-guide.pdf

Boves TJ, Buehler DA, Sheehan J, Wood PB, Rodewald AD, et al. (2013) Emulating Natural Disturbances for Declining Late-Successional Species: A Case Study of the Consequences for Cerulean Warblers (Setophaga cerulea). PLoS ONE 8(1): e52107. doi:10.1371/journal.pone.0052107

DePhilip M, Moberg, T. 2013. Ecosystem flow recommendations for the Delaware River basin. The Nature Conservancy. Harrisburg, PA

Kreeger D, Bushek D, Whalen L, Moody J, and Padeletti, A. 2012. Mussel Powered Living Shorelines for Salt Marsh Erosion Control. Presentation at 6th National Conference on Coastal and Estuarine Habitat Restoration.

McGarigal K, Deluca WV, Compton BW, Plunkett EB, and Grand J. 2016. Designing sustainable landscapes: modeling focal species. Report to the North Atlantic Conservation Cooperative, US Fish and Wildlife Serve, Northeast Region.

McNeil, D. 2015. Gauging the Success of Timber Harvests Managed for Golden-winged Warblers (Vermivora chrysoptera): Characteristics and Territory Density within a Wetland Reference System. Masters Thesis, Dr. J Larkin, Chair.

Niles L, Sitters H, Dey A, and Red Knot Status Assessment Group. 2010. Red Knot Conservation Plan for the Western Hemisphere (Calidris canutus), Version 1.1. Manomet Center for Conservation Sciences, Manomet, Massachusetts, USA.

PGC-PFBC (Pennsylvania Game Commission and Pennsylvania Fish & Boat Commission). 2015. Pennsylvania Wildlife Action Plan, 2015-2025. C. Haffner and D. Day, editors. Pennsylvania Game Commission and Pennsylvania Fish & Boat Commission, Harrisburg, Pennsylvania.

Powell, L, Lang, J, Conroy, M, Krementz, D. 2000. Effects of forest management on density, survival, and population growth of wood thrushes. *The Journal of wildlife management*, 11-23.

USFWS. 2013. Rufa red knot background information and threats assessment supplement to: Endangered and Threatened Wildlife and Plants; Final Threatened Status for the Rufa Red Knot (Calidris canutus rufa) [Docket No. FWS–R5–ES–2013–0097; RIN AY17]. U.S. Fish and Wildlife Service. Northeast Region.

Whiteley AR, Hudy M, Robinson Z, Coombs JA, Nislow KH (2014) Patch-based metrics: a cost effective method for short and long-term monitoring of EBTJV wild Brook Trout populations? In: Proceedings of the Wild Trout Symposium, Vol. XI, pp. 170–179. West Yellowstone, Montana.

Wood, P.B., J. Sheehan, P. Keyser, D. Buehler, J. Larkin, A. Rodewald, S. Stoleson, T.B., Wigley, J. Mizel, T. Boves, G. George, M. Bakermans, T. Beachy, A. Evans, M. McDermott, F. Newell, K. Perkins, and M. White. 2013. Management guidelines for enhancing Cerulean Warbler breeding habitat in Appalachian hardwood forests. American Bird Conservancy. The Plains, Virginia. 28 p

Yepsen, M., Moody, J., Schuster, E. (2016). A Framework for developing monitoring plans for coastal wetland restoration and living shoreline projects in New Jersey. A report prepared by the New Jersey Measures and Monitoring Workgroup of the NJ Resilient Coastlines Initiative, with support from the NOAA National Oceanic and Atmospheric Administration (NOAA) Coastal Resilience (CRest) Grant program (NA14NOS4830006).

Golden-winged Warbler Working Group. 2013. Best Management Practices for Golden-winged Warbler Habitats in the Appalachian Region, www.gwwa.org

Appendix

Provided as separate document.