PENNSYLVANIA
WILDLIFE ACTION PLAN

2015–2025

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Appendix 1.1A - Birds

A Comprehensive Status Assessment of Pennsylvania's Avifauna for Application to the State Wildlife Action Plan Update 2015

Jason M. Hill, PhD.

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Assessment

Subnational conservation status ranks (S-ranks) for Pennsylvania were assessed using the NatureServe rank calculator (Version 3.1; http://www.natureserve.org/biodiversity-science/publications/natureserveconservation-status-assessments-rank-calculator). S-ranks are developed for each species based on the species' population attributes such as population size, geographic range within Pennsylvania, and threats to Pennsylvania's population (Master et al. 2012). For the purpose of this review five S-ranks were assigned to species based on the rank calculator output. These five S-ranks range from S1 (critically imperiled) to S5 (secure; Table 1).

Table 1. Description of the five rank calculator S-rank categories assigned to Pennsylvania bird species in this assessment.

S-rank	Description
S1	**Critically Imperiled**—At very high risk of extirpation in the jurisdiction due to very restricted range, very few populations or occurrences, very steep declines, severe threats, or other factors.
S2	**Imperiled**—At high risk of extirpation in the jurisdiction due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors.
S3	**Vulnerable**—At moderate risk of extirpation in the jurisdiction due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors.
S4	**Apparently Secure**—At a fairly low risk of extirpation in the jurisdiction due to an extensive range and/or many populations or occurrences, but with possible cause for some concern as a result of local recent declines, threats, or other factors.
S5	**Secure**—At very low or no risk of extirpation in the jurisdiction due to a very extensive range, abundant populations or occurrences, with little to no concern from declines or threats.

The rank calculator uses a combination of population estimates and expert opinion to derive species' S-ranks. The individual calculator inputs (e.g., population size) are based on ranges of values (e.g., "population size between 10,000 and 100,000" and "population size between 100,000 and 1,000,000"), which accounts for the uncertainty in the input estimates.

Data Sources

The two primary sources of bird occurrence and breeding data came from the 2nd Pennsylvania Breeding Bird Atlas (hereafter "PABBA", Wilson et al. 2012) and eBird: an online database of bird observations. All validated observations of birds in Pennsylvania between 1 January 2003 and 31 August 2013 were downloaded, with permission, from eBird. All eBird observations are assigned to a specific geographic location. The PABBA observations were assigned to the center of the PABBA block where the observations occurred. Data were processed, handled, and mapped in program R (R Core Team 2013) and ArcGIS 10.1 (ESRI, Redlands, CA). Examples of R code used in analyses can be found in Appendix A, and individual species' data can be found in a separate file: Appendix B. The PABBA species' accounts

were perused for each species as they occasionally contained information pertinent to the rank calculator. Secondary data sources are mentioned under the appropriate heading below.

Breeding Assessment: For each species we used observations of that species from the PABBA and eBird that fell between the PABBA "safe dates" (Appendix G of Wilson et al. 2012). The safe dates for a species indicate the beginning and end date within any calendar year where an observation of that species could be considered evidence of possible breeding. The USGS North American Breeding Bird Survey (BBS; Sauer et al. 2014) was also an important source of statistical data for species assessments. Secondary data sources for the breeding assessment included Partners in Flight (PIF) Landbird Population Estimates Database Version 2.0 (http://rmbo.org/pifdb/), Jacobs et al. (2009), and Pennsylvania Game Commission Survey results for bald eagles (*Haliaeetus leucocephalus*) and colonial nesting waterbirds (Gross and Brauning 2010; Gross and Haffner 2011, Pennsylvania Game Commission unpublished data). Using the PIF database we calculated the proportion of the North American Population that exists in Pennsylvania.

Migration Assessment: For each species we examined eBird histograms of frequency, abundance, average count and high count in Pennsylvania since 1 January 2003. In conjunction with the PABBA safe dates, we conservatively delineated spring and fall migration periods for a species. The fall migration period always began after the end of the breeding safe date period for a species. Once we delineated spring and fall migration periods, we excluded all other eBird observations that fell outside of the migration period for a species. For simplicity spring and fall data were combined to produce a single migration assessment. Secondary data sources included the Raptor Population Index (RPI-project.org, 2013).

Wintering Assessment: We used the end of the fall migration period and the beginning of the spring migration period to create a "wintering period" for each species. For the purpose of the wintering assessment we excluded all eBird observations that fell outside of the wintering period. We also used the National Audubon Society Christmas Bird Count (National Audubon Society, 2014) data.

Species Selection

There are 420 species of birds that have been documented in Pennsylvania in modern times (www.pabirds.org/records/index.php/pennsylvania-bird-list/), of which 291 are considered to be regularly occurring by the Pennsylvania Ornithological Records Committee [PORC]. We only considered those species with sufficient data for reviewing, and largely confined the assessments to native, regularly occurring species with one exception—king rail (*Rallus elegans*)—the only non-regular species that breeds in Pennsylvania. We defined native species as an extant, or historically present, breeding or migratory species occurring in Pennsylvania without human assistance. We reviewed 227 bird species for at least one assessment period (breeding, migration, or wintering). Most of the 227 species were placed into one of seven primary habitat guilds: aerial insectivores, conifer-northern forest, deciduous-mixed forest, wetlands-open water-shores, successional habitats, grassland-farmland, ledges-bare soil. The handful of remaining species that did not fit neatly in those seven primary habitat guilds were placed in a catch-all group: special cases of habitat use. Dividing species into guilds based on habitat

requirements provided a parsimonious framework to assess the threats affecting individual species. Species were subdivided into guilds using the modeling results of the PABBA (Wilson et al. 2012) and additional expert opinion. These guilds were used only during the threat assessment.

Breeding Assessment: We assessed the 182 native species that breed in Pennsylvania as identified by Wilson et al. (2012), including a single non-regular breeding species: King Rail.

Migration Assessment: Rather than assess every migrant species, we developed a suite of criteria to identify those species of conservation concern in Pennsylvania and adjacent regions. We assessed 137 species that migrate through or within Pennsylvania that met at least one of the following criteria:

1. Listed as threatened or endangered under the U.S. Endangered Species Act (http://www.fws.gov/endangered/) or state-listed in Pennsylvania (http://www.portal.state.pa.us/portal/server.pt?open=514&objID=621014&mode=2); or

2. Listed as a priority species in the 2005 Pennsylvania State Wildlife Action Plan (Pennsylvania Game Commission and the Pennsylvania Fish and Boat Commission 2005); or

3. Listed on the current Pennsylvania Breeding Birds of Special Concern PABS / OTC list; or

4. Listed as threatened or endangered under Canada's Species at Risk Act (http://www.registrelep.gc.ca/species/schedules_e.cfm?id=1); or

5. Listed as a "focal species" on the Atlantic Flyway Shorebird Conservation Business Plan (Winn et al. 2012); or

6. Listed as a Northeast Regional Species of Greatest Conservation Need (NEAFWA Fish & Wildlife Diversity Technical Committee 2012 unpublished data); or

7. Listed as a top-tier priority species by the Appalachian Mountain Joint Venture ("high" or "highest", Appalachian Mountain Joint Venture unpublished data from 2012), in the U.S. Shorebird Conservation Plan ("high" or "highly imperiled", Brown et al. 2001), in Bird Conservation Regions 3, 13, 14 ("High" or "Highest"), or in Bird Conservation Region 12 ("Regional Concern") (Dettmers 2006; Atlantic Coast Joint Venture 2007; Matteson et al. 2009).

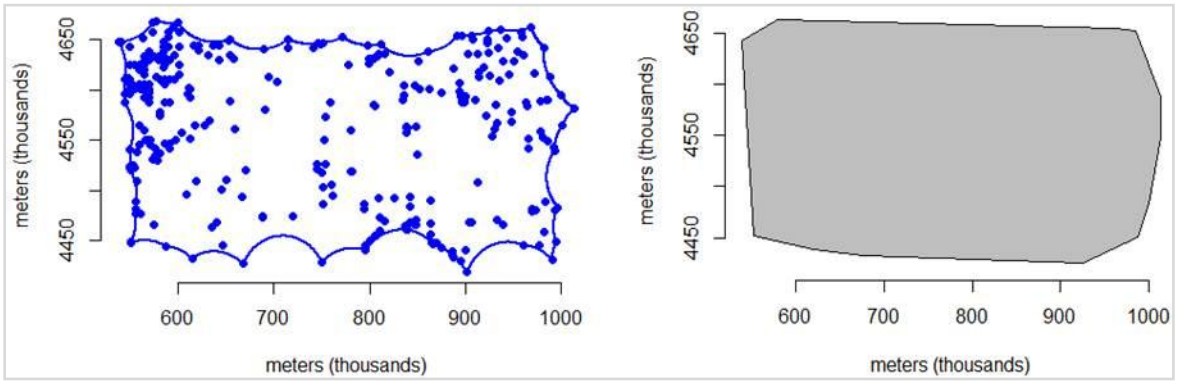
Wintering Assessment: We identified 51 Pennsylvania wintering species for review by using the same criteria as the migration assessment.

Range Extent

The range extent is meant to be a broad-scale estimate of the range of a species within Pennsylvania. A species' range will include areas of Pennsylvania where that species has not been detected, and may include areas of unsuitable habitat (Master et al. 2012). Species with smaller ranges are likely more susceptible to localized disturbances and possibly have smaller populations than species with large ranges. Therefore increasing the range extent for a species in the rank calculator has the general effect of raising its S-ranking (e.g., S2 to S3). The α-hull method is the preferred method to asses a species'

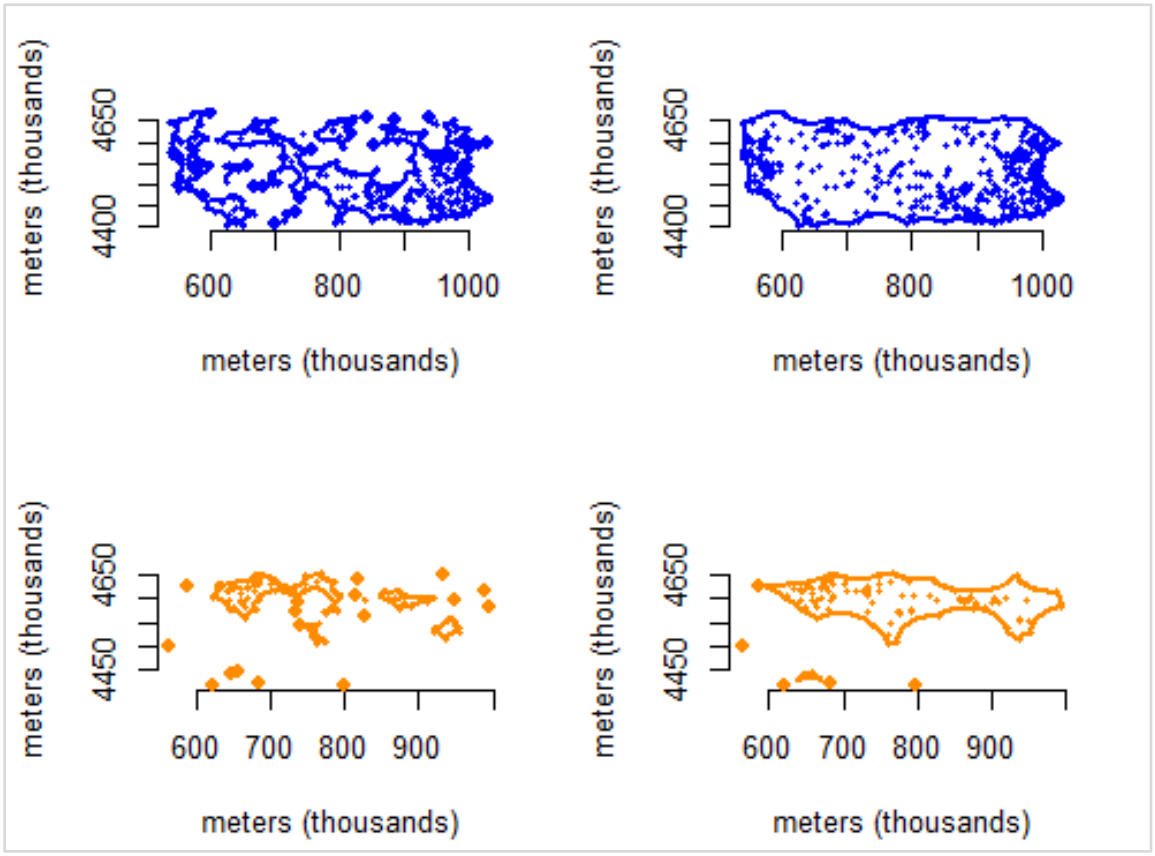
range for the rank calculator (Master et al. 2012). The α-hull method results in a many-sided polygon (Figure 1: left panel) that is approximately the size of Pennsylvania at its maximum extent (119,283 km^2), and is always less than or equal to the size of a minimum convex polygon (MCP, Figure 1: right panel) produced from the same data. There are two substantial advantages of the α-hull method over the MCP method for assessing species' range extents. First, the α-hull method gives less weight to geographic outliers, and second the α-hull method allows for a range that includes internally un-suitable areas. For example, imagine a scenario where a species was only known to occur in the extreme western and extreme eastern counties of Pennsylvania. An MCP estimate of this fictitious species would include all of central Pennsylvania, whereas the α-hull estimate allows for a range extent estimate to be composed of multiple unattached areas. Therefore, the α-hull range extent estimate would not include the counties of central Pennsylvania. The accuracy of the α-hull estimate of the range extent, like the MCP estimate, is positively correlated with the number of documented occurrences; species with few documented occurrences will have an imprecise estimate of their range extent.

Figure 1. An example: estimates of the breeding range extent of hooded mergansers (*Lophodytes cucullatus*) in Pennsylvania calculated with the α-hull method (left panel, 90,626 km2) and the minimum convex polygon (MCP) method (right panel, 101,180 km2). The difference between the two methods in this example is modest, but the difference between the range extent estimates can be very large for geographically sparse species or species occupying very distinct areas on the landscape (e.g., waterways).



The range extent was calculated with the alphahull package (Pateiro-Lopez and Rodriguez-Casal 2013) in program R. The shaping factor (α) controls the amount of smoothing around the edges of the polygon (Figure 2). The value of the shaping factor was determined via trial-and-error for each species. The value chosen for the shaping factor is subjective and the same shaping factor value can produce vastly different levels of shaping depending on the number of data points in the sample and their spatial configuration. See Appendix A for further details and R code used to estimate range extents.

Figure 2. Effects of the shaping factor (α) on the α-hull polygon for Osprey (Pandion haliaetus) and Northern Goshawk (Accipiter gentilis) breeding range extent in Pennsylvania with α = 20 (left column) and α = 50 (right column).



Breeding Assessment: We used the geographic coordinates of PABBA and eBird observations that fell within the breeding safe date for a species to calculate breeding extent (Figure 3). The mean range extent of Pennsylvania breeding species was 82,510 km^2 (SD = 36,888 km^2). Loggerhead shrike (*Lanius ludovicianus*) had the smallest calculated breeding range extent (33 km^2) of any species, and red-tailed hawk (*Buteo jamaicensis*) and turkey vulture (*Cathartes aura*) had the largest breeding range extents: approximately equal to the size of Pennsylvania (119,283 km^2). Among the habitat guilds, the deciduous-mixed forest birds had the largest mean extent while the water and wetland guild was the most geographically-restricted (Table 2).

Figure 3. Distribution of breeding range extents of 182 bird species in Pennsylvania with sample sizes for each column.

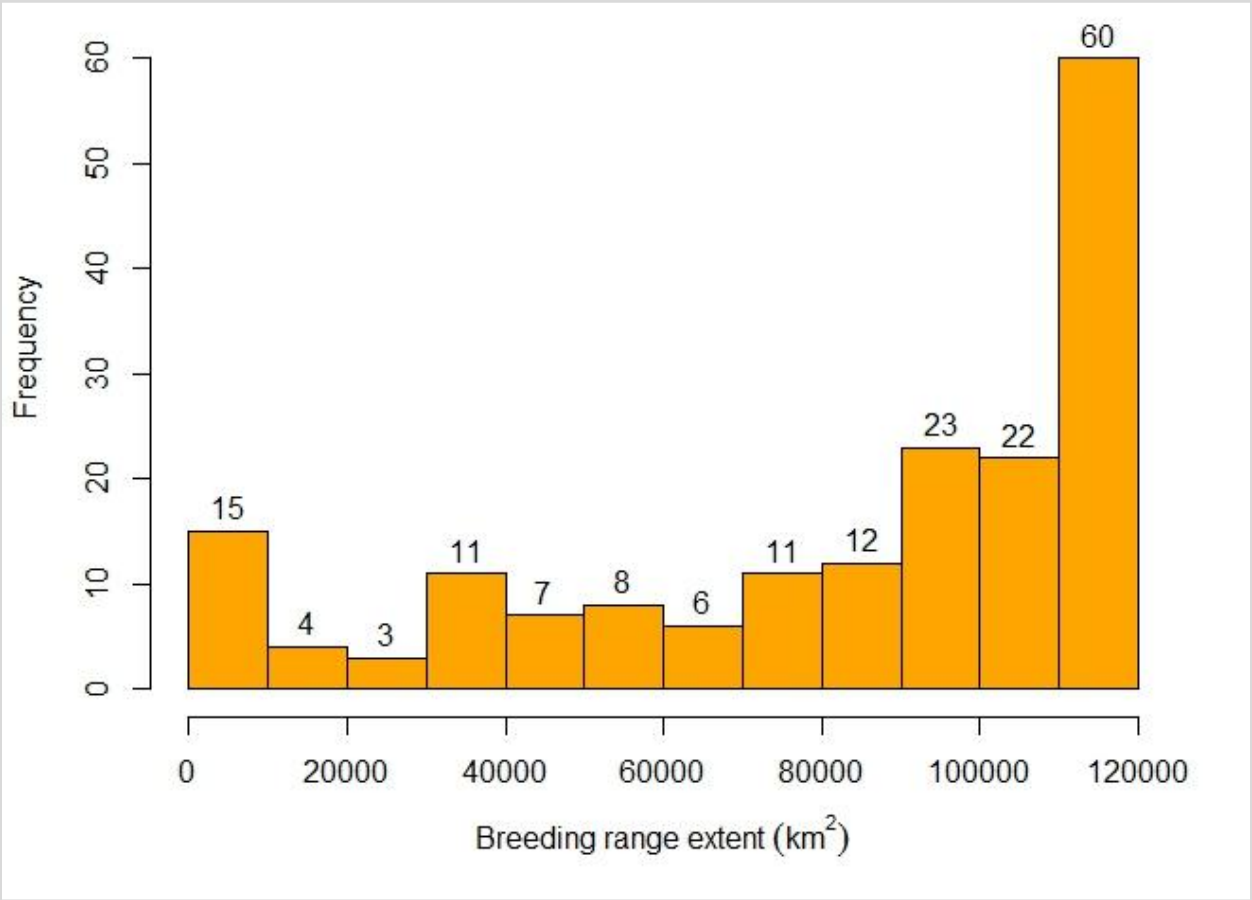


Table 2. Mean breeding range extent of avian habitat guilds occurring in Pennsylvania.

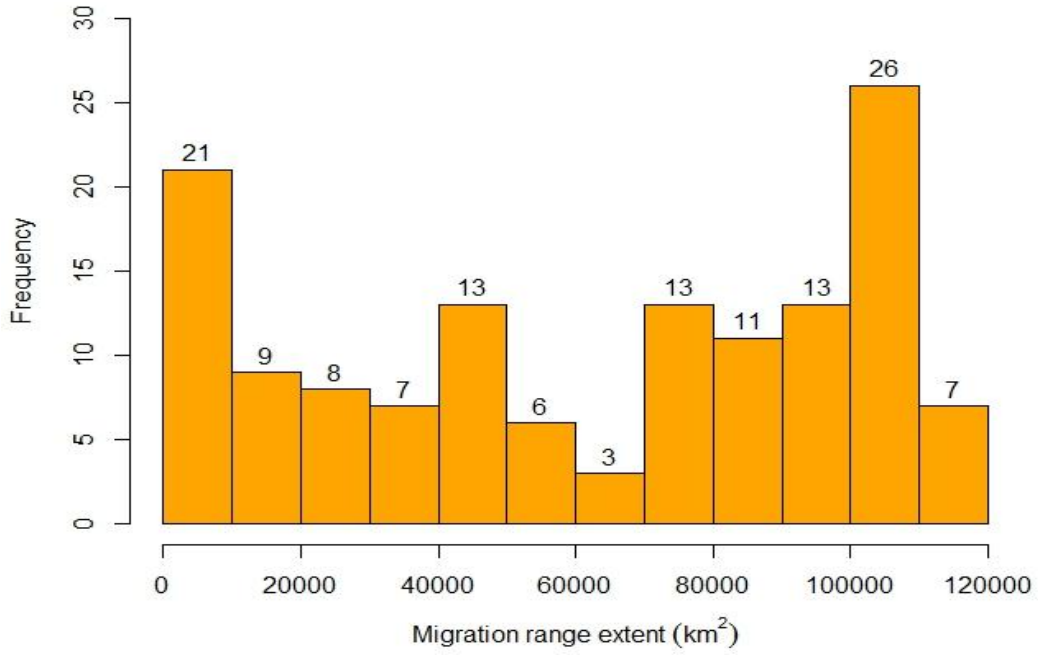
Habitat group	Mean range extent (km^2)	Sample size
Aerial insectivores	91831	9
Conifer-northern forest	66757	34
Deciduous-mixed forest	102676	44
Grassland-farmland	83052	26
Ledges-bare soil	80007	4
Special cases	64559	2
Successional	95492	28
Wetlands-open water-shores	60589	35

Migration Assessment: We used solely eBird records that fell within the spring and fall migration period for a species to calculate a single migration range extent for 137 species. The mean range extents of migratory species passing through Pennsylvania was 61,478 km^2 (SD = 37,808 km^2, Figure 4). Migratory

range extents were on average larger ($\bar{x}$ = 425 km^2, SD = 25,507 km^2) for the 95 species that were reviewed for both the breeding and migratory assessment periods.

Perhaps not surprisingly, the species with the greatest difference between their migratory range (100,774 km^2) and breeding range (2,954 km^2) was the blackpoll warbler (*Setophaga striata*, difference of 97,819 km^2), followed closely by Swainson's Thrush (*Catharus ustulatus*, difference of 90,572 km^2). Several species had substantial reductions in the size of their migratory range extent compared to their breeding range extent such as Louisiana waterthrush (*Parkesia motacilla*, -65,516 km^2), acadian flycatcher (*Empidonax virescens*, -40,409 km^2), least bittern (*Ixobrychus exilis*, -38,408 km^2), and purple martin (*Progne subis*, -33,812 km^2). These reductions in migratory range extents, compared to their breeding range extents are likely explained by 1) difficulties in distinguishing between similar species (e.g., Empidonax flycatchers) who may be less vocal during the non-breeding season, 2) reductions in the probability of detection (e.g., Least Bittern) for secretive species that may be hard to detect when not vocalizing, 3) by a substantial portion of a species' breeding population beginning migration during the tail end of the breeding season, or 4) overly liberal breeding "safe dates".

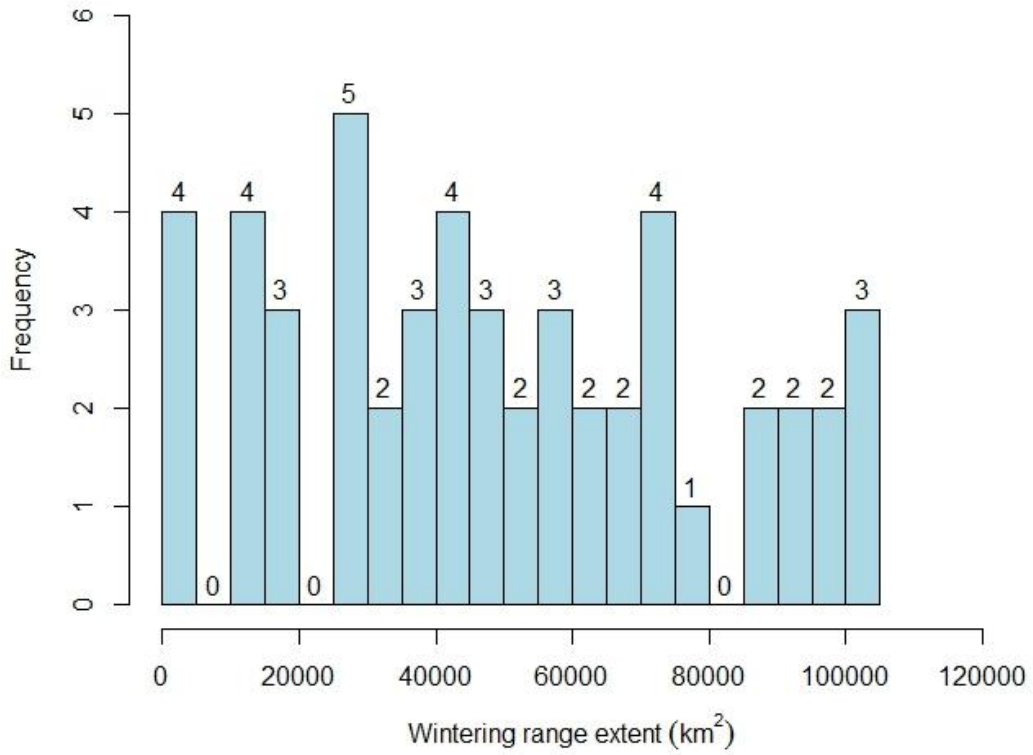
Figure 4. Distribution of migratory range extents of 137 bird species in Pennsylvania with sample sizes for each column.



Wintering Assessment: We used solely eBird records (that fell within the wintering period) to calculate wintering range extent for 51 species in Pennsylvania. Winter range extents (mean = 49,090 km2, SD = 30,235, Figure 5) were on average the smallest of any of the assessment periods, which may be partially due to the lower detection probability during the winter and reduced birder activity (i.e., fewer eBird observations). The great cormorant (*Phalacrocorax carbo*, 330 km^2) had the smallest wintering range

extent, while the brown creeper (*Certhia americana*, 103,644 km^2), bald eagle (103,456 km^2), and Canada goose (*Branta canadensis*, 103,410 km^2) had the highest wintering range extents.

Figure 5. Distribution of wintering range extents of 51 bird species in Pennsylvania with sample sizes for each column.



Area of Occupancy

There were several methods available to calculate the area of occupancy for species in Pennsylvania. The area of occupancy is the area within a species extent of occurrence that is occupied by that species (Master et al. 2012). In essence, the area of occupancy is a finer scale estimate of the range extent of a species across Pennsylvania. Following the NatureServe recommendations (Master et al. 2012) we created a grid across Pennsylvania subdivided into 29,784 4-km^2 sections. We overlaid bird observations from the PABBA (Breeding assessment only) and eBird (all assessments) atop this grid in ArcGIS and counted (via the spatial join tool) the number of grid cells where a species had been observed during the breeding, migration, or winter assessment periods, respectively. Species with smaller areas of occupancy are likely more susceptible to localized disturbances and possibly have smaller populations than species with large areas of occupancy. Therefore increasing the area of occupancy for a species has the general effect of raising its S-ranking.

Breeding Assessment: Only PABBA and eBird records that fell within the breeding safe date for a species were used to calculate area of occupancy for 182 species in Pennsylvania. All breeding species assessed had smaller areas of occupancy than their breeding range extent. The greatest reductions between the

breeding range extent and breeding area of occupancy for species were dominated by birds of prey (9 out of the 12 greatest reductions). These large-bodied species (e.g., cooper's hawk [*Accipiter cooperii*] and broad-winged hawk [*Buteo platypterus]*) generally have a geographically-widespread but low-density distribution across Pennsylvania.

Migration Assessment: Only eBird records that fell within the spring and fall migration period for a species were used to calculate the migration area of occupancy for 137 migratory bird species in Pennsylvania. The migration area of assessment was slightly larger than the migration range extent for only 3 species: sedge wren (*Cistothorus platensis*), loggerhead shrike (*Lanius ludovicianus*), and king rail. These three species restricted distributions across Pennsylvania during the migration period.

Wintering Assessment: Only eBird records that fell within a species' wintering period were used to calculate the wintering area of occupancy for 51 species of Pennsylvania birds.

Number of Occurrences

An occurrence is an area of land and/or water in which a species is present. The number of occurrences for a species is analogous to the number of populations of that species in Pennsylvania—which will rarely be known for vertebrates. In general, species with a greater number of occurrences have higher S-rankings (e.g., S5) because the Pennsylvania population of that species is spread out over many subpopulations and is likely less susceptible to localized disturbance and extinction events. There is not much guidance from Master et al. (2012) as to how to determine the number of occurrences for a species, but the NatureServe website suggests that (for birds at least) evidence of breeding in an area should be counted as "an occurrence". Increasing the number of occurrences for a species has the general effect of raising its S-ranking. We developed an occurrence estimate based around the PABBA atlas blocks (see the Breeding and Migratory Assessments within this section for greater detail).

Breeding Assessment: Only PABBA records that fell within the breeding safe date for a species were used to calculate the number of occurrences. To estimate the number of breeding occurrences for most species we summed the number of PABBA blocks where a species' breeding status was listed as possible, probable, or confirmed (see Wilson et al. 2012 for greater detail regarding these breeding codes). We used this summed total of PABBA blocks for each species as a proxy for that species' number of occurrences. We considered only using the sum of probable and confirmed blocks, but there is a lot of variability among PABBA observer ability. To attempt to account for the ability differences among observers we chose a more inclusive approach. However, for a few groups of birds we suspected that differences in observer ability would be much smaller, and so we used the sum of confirmed + probable PABBA blocks as a proxy of the number of occurrences for vultures (*Coragyps* spp.), waders (Pelicaniformes, Gruidae, and Charadriiformes), and gulls (Laridae Family).

One hundred and twenty-five breeding bird species in Pennsylvania had the maximum number of occurrences in the rank calculator (>300 occurrences). Of the habitat guilds wetlands-open water-shores had the lowest median number of breeding occurrences (median = 28 occurrences) within Pennsylvania, while all other habitat guilds (except ledges and bare soil, median = 34 occurrences) had >300 breeding occurrences. Breeding occurrences of trumpeter swan (*Cygnus buccinator*), great black-backed gull

(*Larus marinus*), and ring-billed gull (*Larus delawarensis*) were only detected within a single PABBA block.

Migration Assessment: Only eBird records that fell within the spring and fall migration period for a species were used to calculate area number of occurrences. Once again we used the framework of the PABBA blocks. We summed the number of PABBA blocks where a species was detected in multiple years (from 2003 to 2013) during the migration period as a proxy of the number of occurrences during the migration period.

Wintering Assessment: No estimate of the number of occurrences was calculated for the wintering assessment, but one could construct a number of occurrences metric using a similar approach as the migration assessment.

Population Estimate

We acquired estimates of breeding populations of birds in Pennsylvania from the Partners in Flight (PIF) Landbird Population Estimates Database Version 2.0 (http://rmbo.org/pifdb/) and PABBA. Partners in Flight created population estimates based on the BBS data from the years 1998-2007. The PIF estimates are derived by essentially multiplying the estimated density of a species at BBS routes by the range of that species within the state of Pennsylvania. These density estimates are then corrected for the time of the count (counts conducted later in the morning typically have fewer detections) and for the difference in detection probability between the sexes of a species. This "pair adjustment" correction allows PIF to estimate the population size of both sexes combined in Pennsylvania, even when the BBS counts are dominated by individuals of one sex (typically males, who are generally more vocal). For example, male and female rock doves (*Columba livia*) are equally likely to be detected during BBS counts and so the pair adjustment factor is 1.0. On the other hand male cerulean warblers (*Dendroica cerulea*) are much more likely to be detected than females, and hence the pair adjustment factor is 2.0. A population estimate created without accounting for the differences in sex-specific detection probability for cerulean warblers would likely be greatly under-estimated, because the uncorrected population estimate would be based almost entirely on detections of males. The PABBA project also created population estimates of most breeding birds in Pennsylvania. For many species in the PABBA, only estimates of the total number of males in Pennsylvania were provided.

Breeding Assessment: We determined that the PABBA population estimates were likely more accurate than the PIF estimates for Pennsylvania, because the PABBA estimates are based on substantially more point counts than the BBS data which were used to make the PIF estimates. Therefore, for each species we used the population estimate provided by the PABBA if the population estimate was for both sexes combined. If no PABBA estimate for both sexes was provided we instead used the PABBA male population estimate multiplied by the PIF pair adjustment factor for that species. If no population estimate of any kind was provided by the PABBA we instead used the PIF Landbird Population Estimates Database Version 2.0. For some species (e.g., rare and infrequently-detected species) no population estimate of any kind was available from PIF or PABBA. In those incidences we searched for other sources of population estimates, including the data presented in the PABBA species accounts along with expert

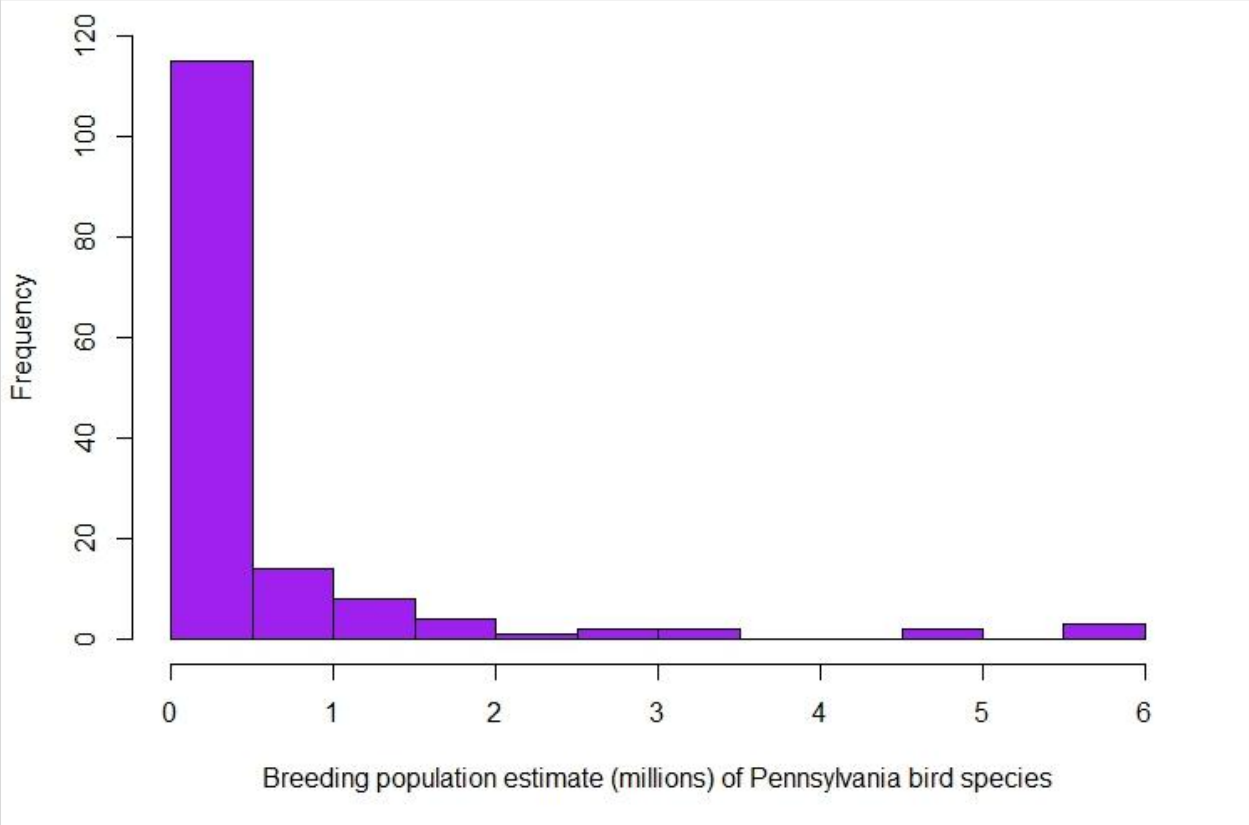
opinion, the Jacobs et al. (2009) waterfowl population estimates, and the 2012-2013 Pennsylvania Game Commission's bald eagle and colonial waterbird survey data (unpublished data). We used the PIF database to estimate the proportion of the North American Population that resides in Pennsylvania (Appendix B).

We were unable to obtain breeding population estimates for 31 species of birds (including 18 species of the habitat guild wetlands-open water-shores, and 6 birds of prey) in Pennsylvania (Table 3). The median breeding population size of the remaining 151 species was 97,000 individuals. Thirty species have breeding populations under 10,000 individuals, and 19 species have populations under 1,000 individuals (Figure 6). It is likely that the majority of the 31 species without population estimates have populations under 10,000. Breeding population size of a species was significantly related to that species breeding range extent ($r = 0.34$, $P < 0.001$) and area of occupancy ($r = 0.66$, $P < 0.001$). Of the species with population estimates, trumpeter swan had the lowest breeding population estimate (15 individuals) and three species had population estimates > 5 million: red-eyed vireo (*Vireo olivaceus*), chipping sparrow (*Spizella passerina*), and song sparrow (*Melospiza melodia*).

Table 3. Breeding population sizes for birds in Pennsylvania categorized by habitat guild.

Habitat group	Median breeding population size	Sample size	Species without population estimates
Aerial insectivores	20,000	9	0
Conifer-northern forest	54,000	31	3
Deciduous-mixed forest	218,500	42	2
Grassland-farmland	192,500	21	5
Ledges-bare soil	51,000	3	1
Special cases	42,750	2	0
Successional	399,375	26	2
Water and wetlands	600	17	18

Figure 6. Population estimates used in the rank calculator for 151 species of birds in Pennsylvania.



Migration Assessment: No population estimates were available exclusively for the number of migrants in Pennsylvania.

Wintering Assessment: No population estimates were available exclusively for the number of wintering individuals in Pennsylvania.

Trends

We used three sources of data to estimate trends over time: the North American Breeding Bird Survey trend estimates for Pennsylvania (www.mbr-pwrc.usgs.gov/cgi-bin/atlasa11.pl?PA&2&11), the PABBA "change in atlas blocks" (Table 6.6 of Wilson et al. 2012), and the National Audubon Society Christmas Bird Count (CBC) data for Pennsylvania (http://netapp.audubon.org/cbcobservation/). Trends are generally presented as "percent change per year", but the rank calculator asks for trends presented as the proportional change from the beginning of a time period to the end.

Breeding Assessment:

BBS Trends: Some of the BBS trends are based on very little data, because some species are infrequently counted on BBS routes (e.g., owls [Family Strigidae]). Therefore, we took the "regional credibility"

measure (http://www.mbr-pwrc.usgs.gov/bbs/credhm09.html) into account when using these trends. The regional credibility rating ranks the trends into three colors based on 1) the amount of data that went into calculating the trend, and 2) the uncertainty in the trend estimate. Trends are ranked from "red" (relatively poor quality) to "yellow" (moderate quality) or "blue" (relatively good quality). We did not use BBS trends with red regional credibility ratings. If the BBS trend regional credibility was yellow or blue with a 95% credible interval (CRI) that did not overlap zero then we used that trend estimate. If a yellow or blue trend estimate had a 95% CRI that overlapped zero we recorded the trend as 0: indicating no change in the population size from year to year.

The BBS trends are presented on the USGS website as annual trends so we transformed them to short-term (10-year) trends (2001-2011) and long-term (45-year) trends (1966-2011). An annual trend of 0 indicates a perfectly stable population. Small annual trends can result in large changes over time. For example, imagine a species with a long-term BBS trend of -2.0%. If we assume that the population size was 100 individuals in 1966, then a 2% reduction per year for 45-years results in a population size of approximately 40 individuals in 2011.

= -1 + 0.98^45 = -0.597 or approximately a 60% decline.

Similarly, a species with a 2% increase per year over the same time frame would increase by approximately 144% of the original population size over 45 years (1966 to 2011) to 244 individuals:

= (1.02^45) – 1 = 1.44

PABBA trends: For species with red (i.e., uncertain) BBS credibility trends or no BBS trends we used the 2nd PABBA data (Wilson et al. 2012, Table 6.6, pages 55-58) to construct a 30-year long-term trend. We were unable to calculate a short-term trend using the PABBA data. For species with yellow or blue BBS trends we did not use the PABBA data for trend estimation.

We used the percent change in the number of blocks a species was detected in between the 1st and 2nd Atlases as an estimate of the trend. For example, if a species was detected in 40 blocks during the 1st Atlas and only 20 blocks during the 2nd Atlas then we estimated the long-term trend as 20/40 = 50% decline. The amount of observer effort was not constant between the 1st and 2nd Atlases so, when available, we used the "corrected percent change" as provided in Table 6.6 (see Wilson et al. 2012 for additional details). If no corrected percent change estimate was available then we used the change in all blocks (uncorrected for observer effort). We used these estimates from Table 6.6 (Wilson et al. 2012) without regard to statistical significance because most of the species with red BBS credibility trends were rare and detected in few blocks during the PABBA (hence statistical power to detect a change was low to begin with for these species). Some species (e.g., trumpeter swan, red crossbill [*Loxia curvirostra*] and blackpoll warbler [*Dendroica striata*]) were detected in so few PABBA blocks that no statistical analysis was performed (see Table 6.6, Wilson et al. 2012), and for these species we did not provide a long-term trend estimate. Two species were only detected in the 2nd PABBA: Merlin (*Falco columbarius*, 13 blocks) and sandhill crane (*Grus canadensis*, 26 blocks). We could not calculate trends for these

species, but we felt it was important to acknowledge their increase into the state. We recorded the long-term trend estimate for merlin and sandhill crane as code "I" (>25% increase) in the rank calculator.

We were able to calculate long- and short-term breeding trends for 137 species breeding in Pennsylvania. The median long- and short-term trends for these 137 species was 0%, and most bird species in Pennsylvania (for which we have data) have stable or increasing long-term trends (102 species) and stable or increasing short-term trends (111 species). Twenty-one species have experienced long-term declines >50% and a handful of species had experienced >90% declines (Table 4).

Table 4. Breeding bird species in Pennsylvania with the five largest and five most negative long-term trends.

Species	Latin name	Long-term trend (%)	Trend type
Northern bobwhite	*Colinus virginianus*	-99	BBS
Golden-winged warbler	*Vermivora chrysoptera*	-96	BBS
Vesper sparrow	*Pooecetes gramineus*	-94	BBS
Grasshopper sparrow	*Ammodramus savannarum*	-93	BBS
Yellow-breasted chat	*Icteria virens*	-93	BBS
Red-bellied woodpecker	*Melanerpes carolinus*	2490	BBS
Wild turkey	*Meleagris gallopavo*	3228	BBS
Yellow-bellied sapsucker	*Sphyrapicus varius*	4936	BBS
House finch	*Carpodacus mexicanus*	13,308	BBS
Canada goose	*Branta canadensis*	40,834	BBS

While short- and long-trends were significantly and positively related to each other ($r = 0.34$, $P < 0.001$), a few species showed a contrasting pattern. House Finches, for example, have increased by 13,308% overall in Pennsylvania over the last 45 years, but have declined by 45% in the last decade. Not surprisingly, several species with extreme long-term trends (Table 4) also had extreme short-term trends (Table 5). Grassland birds experienced the greatest long-term declines of any habitat guild (median = -27%, $n = 21$), while birds of the conifer and northern forest guild experienced the most positive long-term trend (median = 71%, $n = 23$). Not surprisingly, the Emberizidae (sparrows) ($n = 10$) showed the steepest long-term decline of any Family with multiple members (median = -44%). All seven primary habitat guilds had median short-term trends of zero.

Table 5. Breeding bird species in Pennsylvania with the five largest and five most negative short-term trends.

Species	Latin name	Long-term trend (%)	Trend type
Northern bobwhite	*Colinus virginianus*	-63	BBS
Yellow-breasted chat	*Icteria virens*	-50	BBS
House finch	*Carpodacus mexicanus*	-45	BBS
Black-throated green warbler	*Setophaga virens*	-44	BBS
Vesper sparrow	*Pooecetes gramineus*	-43	BBS
Red-bellied woodpecker	*Melanerpes carolinus*	77	BBS
Common raven	*Corvus corax*	81	BBS
Canada goose	*Branta canadensis*	99	BBS
Wild turkey	*Meleagris gallopavo*	135	BBS
Yellow-bellied sapsucker	*Sphyrapicus varius*	139	BBS

Migration Assessment: Population trends derived from the migration period were not available for most species. We used the 2013 Raptor Population Index to calculate migration population trends for 10 species of raptors, including bald eagles (*Haliaeetus leucocephalus*; Figure 7). We used only fall observations of raptors from the eight Pennsylvania raptor observation stations because spring data is not collected at six of these observation stations. We calculated long- (1967-2012) and short-term (2002-2012) trends using the same exponential models (see Appendix A for further details) used to calculate wintering trends. Northern goshawk (*Accipiter gentilis*) is an uncommon species in Pennsylvania (Wilson et al. 2012), and consequently the BBS breeding trends were too uncertain for use during the breeding assessment period. Consequently, we used the PABBA data during the breeding season to estimate that goshawks have experienced a 28% reduction in relative abundance over the last thirty years. However, this long-term breeding trend may be an under-estimate. Using the fall migration data for Northern goshawks we calculated a 94% reduction in relative abundance over the last thirty years (Table 6).

Figure 7. Bald eagle (*Haliaeetus leucocephalus*) changes in relative abundance during fall migration from 1967-2012; bald eagles increased by 3800% during fall migration in Pennsylvania during that time.

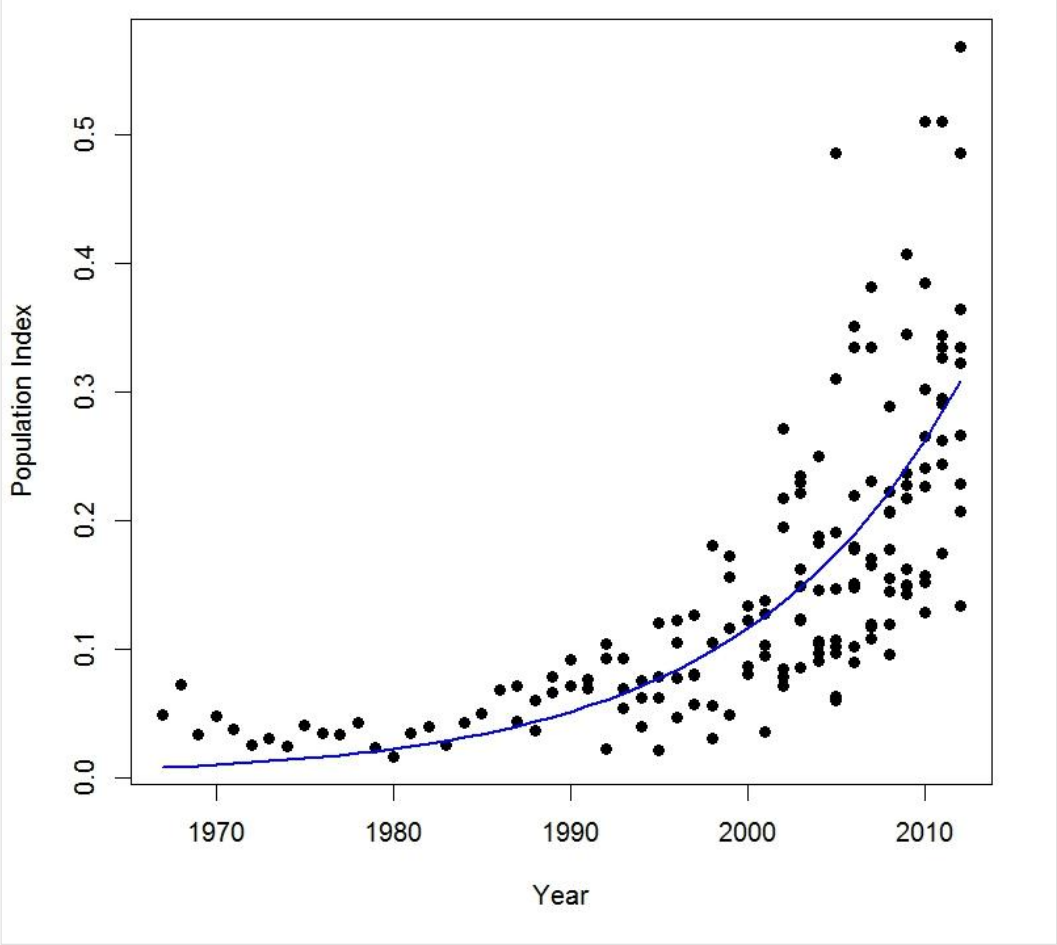


Table 6. Short-term and long-term trends (relative percent change) of raptors during fall migration in Pennsylvania.

Species	Latin name	Short-term trend (%) (2002-2012)	Long-term trend (%) (1967-2012)
Osprey	*Pandion haliaetus*	-30.3	-35.2
Bald eagle	*Haliaeetus leucocephalus*	141.8	3805.0
Northern harrier	*Circus cyaneus*	-37.7	-64.0
Sharp-shinned hawk	*Accipiter striatus*	28.0	-54.0
Northern goshawk	*Accipiter gentilis*	-59.0	-93.8
Red-shouldered hawk	*Buteo lineatus*	-18.0	-36.0
Broad-winged hawk	*Buteo platypterus*	58.0	1.0
Golden eagle	*Aquila chrysaetos*	23.0	159.0
American kestrel	*Falco sparverius*	-14.7	-69.8
Peregrine falcon	*Falco peregrinus*	-4.0	143.0

Wintering Assessment: We used the National Audubon Society Christmas Bird Count (CBC. National Audubon Society 2014) corrected for observer effort to calculate long- (1966-2012) and short-term (2001-2012) trends using a simple linear regression model, 2nd order polynomial, and exponential models in R. Trends were calculated as the expected corrected-count in the last year divided by the expected corrected-count in the first year. The exponential model took the form of ECC = exp(a+b*year) where ECC is the expected corrected count, and a and b are constants. For each species we visually inspected the model results and selected a single model based on how well the model appeared to fit the data. In general, all three models resulted in a similar trend estimate. See Appendix A for further details and R code used to estimate trends.

Horned grebes (*Podiceps auritus*) had the steepest short-term winter decline (-77%) of any species, while canvasbacks (*Aythya valisineria*) had the greatest short-term winter increase (173%). Five species have experienced incredible long-term winter declines (Table 7).

Table 7. Wintering bird species in Pennsylvania with the most severe long-term (1966-2012) declines as assessed from CBC data.

Species	Latin name	Long-term trend (%)
Northern pintail	*Anas acuta*	-99
Green-winged teal	*Anas crecca*	-99
Greater scaup	*Aythya marila*	-99
Ruddy duck	*Oxyura jamaicensis*	-97
Lesser scaup	*Aythya affinis*	-94

Threat Assessment

For each species, we used the rank calculator to estimate an overall threat impact score during each assessment period (Master et al. 2012). A panel of experts identified the individual threats facing each guild of species (see below) and then two experts identified the scope, severity, and timing (immediacy) score to each threat using peer-reviewed literature where available. A threat is any activity or process that is causing destruction, degradation, and/or impairment to a particular species (Salafsky et al. 2008). These threats can be natural processes (e.g., earthquakes and hybridization), but most threats are anthropogenic processes (e.g., development, agricultural activities, pollution and fire suppression). The scope is the proportion of the species that is likely to be affected by the threat within 10 years. Within the scope (as defined spatially and temporally), severity is the level of damage to the species from the threat that is likely to be expected within the next three generations. Timing, a measure of the immediacy of the threat, was recorded for each threat but it does not affect the overall threat score and was included entirely for reference. See Master et al. (2012) for more details.

Generally, a threat (and its associated scope and severity) were assigned to an entire guild, and then a reviewer made individual adjustments for each species in that guilds based on that species' susceptibility to that threat. This process ensured that threats were assessed similarly for species occurring in the same habitat, and yet this approach allowed for individual species to be assessed independent of the other species in that guild.

An overall threat score (very high, high, medium, low) was assigned to each species for each assessment period it occurred in based on the rank calculator threat worksheet (Master et al. 2012).

Breeding Assessment: Threats during the breeding assessment period were identified, assigned, and scored for each species as described above. A high percentage of the breeding bird species of the conifer and northern forest guild (n = 12) were given a *very high* overall threat score (35%), compared to other habitat guilds.

Migration Assessment: Threats during the migration assessment period were identified, assigned, and scored for each species as described above. Forty-five percent of species were identified as having *high* threats during the migration period in Pennsylvania.

Wintering Assessment: Threats during the wintering assessment period were identified, assigned, and scored for each species as described above. Forty-six and five species were assigned low and medium overall threat scores, respectively, during the wintering assessment.

S-Ranks

Species were assigned S-ranks through the rank calculator based on the best available data for that assessment period and for that species. Most breeding species were ranked as vulnerable (S3) or higher (i.e., S4 [apparently secure] or S5 [secure]) (Figure 8), but a high portion of the wetlands-open water-shores habitat guild species were deemed either critically imperiled (S1, n = 6 species, 17%) or imperiled (S2, n = 8 species, 23%). Migratory and wintering S-ranks (Figure 9) showed an overall similar pattern to

the breeding S-ranks, but with fewer critically imperiled species. The majority (75%) of the migratory species giving S1 and S2 ranks were from the wetlands-open water-shores guild.

Figure 8. Breeding S-ranks as determined from the rank calculator for 182 species of birds in Pennsylvania. The S3 category includes Virginia rail (*Rallus limicola*) which was calculated as "S3?".

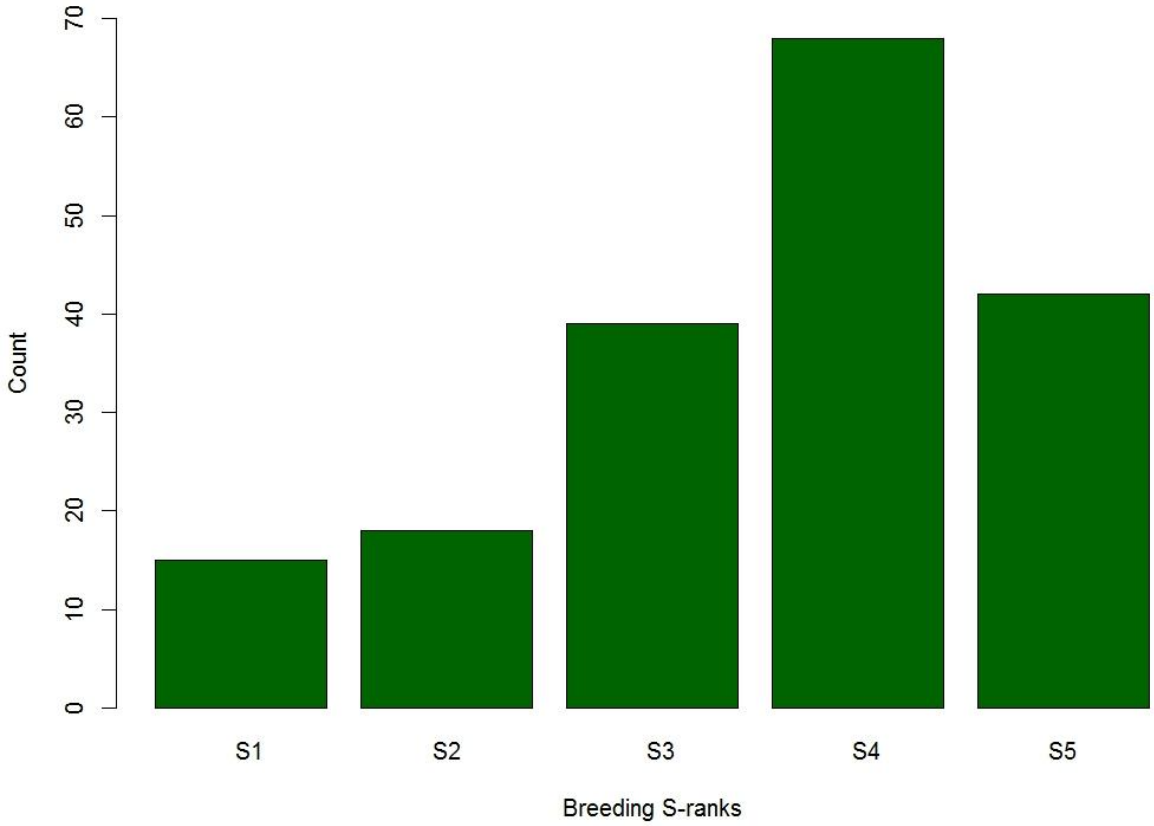
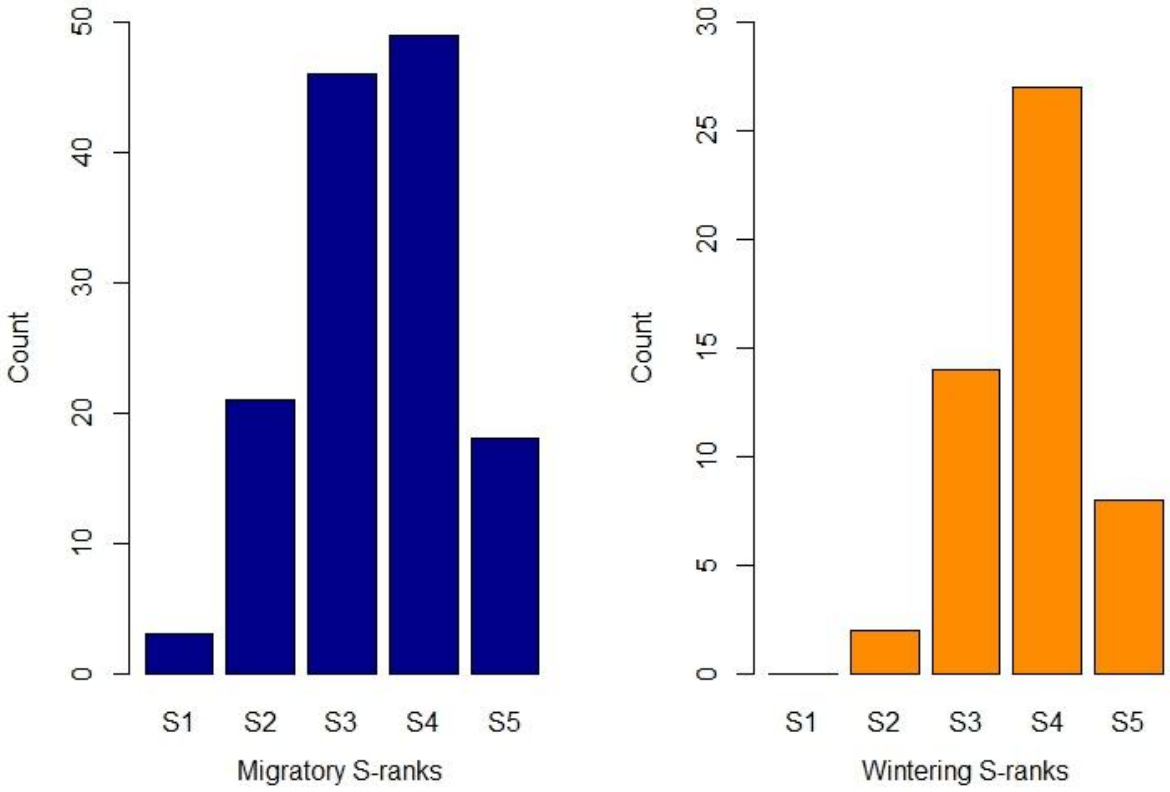


Figure 9. Migratory S-ranks (left panel) and wintering S-ranks (right panel) as determined from the rank calculator for 137 migratory and 51 wintering species of birds in Pennsylvania. Note the difference scales between panels.



Suggestions For Future Assessments

First, it should be realized that the data pulled together for this project all have their own inherent data quality concerns. One might argue that these S-ranks are compiled by the use of statistics on statistics, because in most instances we were unable to incorporate data uncertainty into the analyses. For example, all eBird data was assumed to be geographically recorded accurately, and the point estimates of population estimates from PABBA and PIF were used *as is* in the rank calculator (i.e., we ignored the 95% confidence interval surrounding these estimates). Most likely some individual values used in these analyses could be improved upon in future assessments. However, compared to other taxonomic groups in Pennsylvania (e.g., fishes and mammals) birds have by far the most high-quality data available, and the S-ranks provided in this report should be considered high quality estimates of the conservation status of these species.

Looking forward to the next Pennsylvania State Wildlife Action Plan, this document (and its related species data) should serve as a template and a starting place. Other State Wildlife Action Plans should be perused for additional ideas for sources of data and improvements to statistical analyses. Here are a few suggestions:

1. The rank calculator S-rank estimates become more robust as more quality data are added to the calculator. For the breeding assessment, the Canada goose S-rank was based on seven different factors while the Trumpeter Swan S-rank was determined by four factors. In general the less common species in Pennsylvania have less data available to them, and this pattern was most prevalent with the wetlands-open water-shores habitat guild. Identifying additional sources of data for uncommon birds, and especially the wetlands-open water-shores habitat guild should be a priority for the next assessment.

2. “Greater than 300” is the maximum level for the number of occurrences component of the rank calculator. The high number of species with >300 occurrences (e.g., 68% of breeding species) might indicate that the criterion was too liberal, or alternatively, that birds in Pennsylvania simply have a lot of data available for them.

3. eBird is a treasure trove of data, and new tools and features of eBird become publically available each year. There may very well be an eBird “trend tool” online by the time of the next Pennsylvania State Wildlife Action Plan. If these future eBird tools do not materialize then there are still additional options available with the current data. When data are acquired from eBird each observation contains information about the search effort required to see that species (e.g., the length of the observation period and how many miles were covered (if any) by the observer). Clearly, the time of day and observer ability influence what species were observed. However, after manipulating some eBird data, some simple species’ trends could be estimated with some simple models. For example, one could develop a population index of Red-necked grebes (*Podiceps grisegena*) for December each year and then estimate a short-term wintering trend over the last 10 years. The population index might be the mean number of birds seen per mile of traveling count or the mean number of birds seen per hour. As a form of crude data filtering we suggest limiting the data used in this model to single-observer counts conducted prior to 10 am.

4. We under-estimated how long the threat assessment collaborative process would take. Involving many experts absolutely strengthened the threat assessments, but the threat assessors tended to over-estimate threats. For example, a species with a pervasive-extreme score for an individual threat means that 73% of the population, on average, will likely be destroyed by that individual threat over the next decade without corrective management actions. Quite a few species, in the initial round of the collaborative threat assessment process had multiple pervasive-extreme scores for individual threats. While declines >73% are possible, no Pennsylvania breeding species declined by more than 63% over the last decade.

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Assessment of eBird data for the importance of Pennsylvania as a bird migratory corridor

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We used statewide "abundance" data from eBird (Sullivan et al. 2009) to assess the abundance of birds during spring and autumn migration in Pennsylvania. EBird's abundance metric corrects for variation in observer effort (http://help.ebird.org/customer/portal/articles/1210240-what-is-abundance-), hence, it is suitable for comparing abundances across geographic areas. We used the data to provide an estimate of the proportion of birds in the Atlantic and Mississippi Flyways passing through Pennsylvania at the peak of each migration season. We weighted the peak in abundance for each of the six states that are primarily along the same line of latitude as Pennsylvania: 39.61°N to 42°N: New Jersey, Pennsylvania, Ohio, Indiana, Illinois, and Iowa. We weighted the abundances by the average width of each state at approx. 41°N; hence, if a species passes through two states in equal peak abundances, but one state is twice as wide, we would estimate that the total number of bird migrating through the wider state is double that of the narrower state.

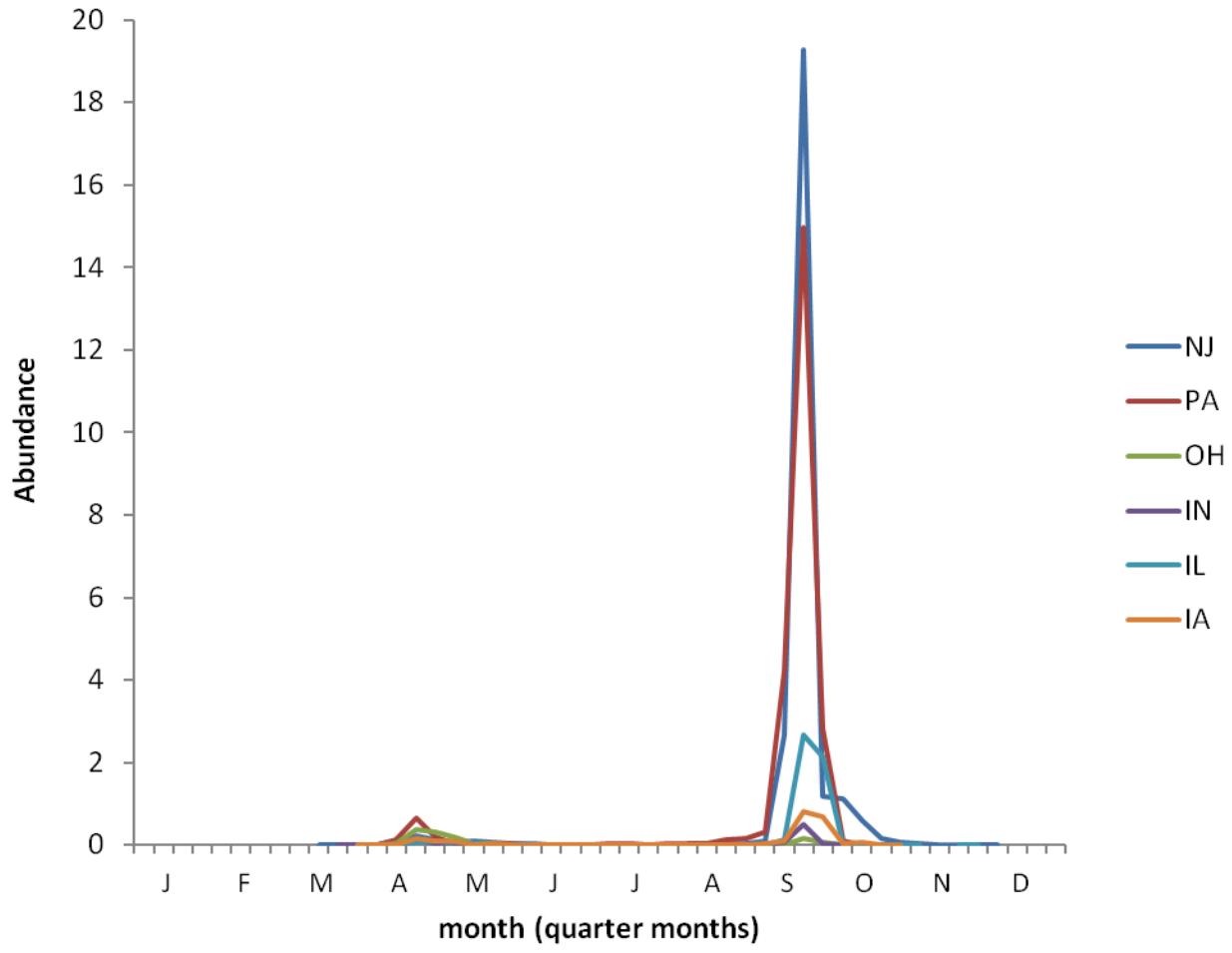
As an example, for the Broad-winged Hawk, there is a seasonal peak in spring migration abundance in the third quarter of April and a pronounced peak in fall migration in the third quarter of September (Figure 1). Of the six states in the two flyways, the highest abundances of Broad-winged hawks are found in Pennsylvania in spring, and in New Jersey in the fall. However, because Pennsylvania is around four times wider than New Jersey, we estimate that a significantly higher number of hawks pass through it on fall migration. When corrected for the width of the six states (Table 1), we estimate that 49.1% of spring and 64.9% of fall migrant Broad-winged Hawks pass through Pennsylvania.

To assess which species are priorities for Pennsylvania, we selected species for which migration abundance in Pennsylvania is more than double what would be expected if a species passed through the six states in uniform numbers ("expected abundance"). Pennsylvania is 20.7% of the width of the two flyways, hence, if we estimate that >41.4% of the population passes through Pennsylvania, we thereby assess that the species is a Pennsylvania priority.

We aimed to assess the migration status of 150 species, but found that for many of them, the eBird data were not suitable. Limitations included a lack of distinct migration seasons in some are part of their range, or scarcity across the flyways. A full list of species assessed can be found in Appendix A.

Of the 110 species for which we were able to assess the migration status, 36 were assessed to pass through Pennsylvania in higher than "expected" numbers during spring, of which only six were found in numbers at least double the expected (Table 2). Only 24 species were assessed to pass through Pennsylvania in higher than "expected" numbers in fall, of which six were found in number at least double the expected. The species involved in these spring and fall lists show considerable overlap, but a few species exceeded expected numbers in only one of the migration seasons. In total 43 of the 110 species pass through Pennsylvania in higher than expected numbers in at least one migratory season, of which nine species met the criteria of numbers at least double the expected. These nine species form our list of species for which Pennsylvania is particularly important as a migration corridor (Table 2).

Figure 1. Seasonal patterns of Broad-winged Hawk abundance* data from eBird, for the six states at 39.61°N to 42°N in the Atlantic and Mississippi flyways.



* http://help.ebird.org/customer/portal/articles/1210240-what-is-abundance-

Table 1. eBird abundance data for Broad-winged Hawk showing how data are weighted by width of state.

state	Average width (km)	Spring			Fall		
		peak abundance	abundance * width	weighted % of total	peak abundance	abundance * width	weighted % of total
NJ	70	0.218	15	3.8	19.27	1,349	20.5
PA	280	0.662	185	46.7	15.00	4,200	64.0
OH	220	0.394	87	21.8	0.17	38	0.6
IN	140	0.127	18	4.5	0.49	69	1.1
IL	210	0.109	23	5.8	2.67	561	8.5
IA	430	0.160	69	17.2	0.82	349	5.3
	total		697	100		6567	100

Table 2. Species for which Pennsylvania is especially important as a migratory corridor within the Atlantic and Mississippi flyways

Common name	%Spring	%Fall	Max of spring/fall
Tundra Swan	88.5	4.3	88.5
Golden Eagle	83.9	75.4	83.9
Hooded Warbler	43.0	65.5	65.5
Broad-winged Hawk	46.7	64.0	64.0
Northern Goshawk	20.4	47.6	47.6
Wood Thrush	46.1	47.6	47.6
Sharp-shinned Hawk	27.2	46.3	46.3
Eastern Towhee	35.4	45.0	45.0
Blackburnian Warbler	44.8	23.9	44.8

Appendix A. Full list of species assessed, in taxonomic order. Yellow indicates assessment not possible (a=indistinct migration season, b=sparse data), Green indicates >20.7% of the two flyway populations estimated to pass through Pennsylvania, red indicates >41.4% of population estimated to pass though Pennsylvania.

Common name	%Spring	%Fall	Max of spring/fall
Brant	a	a	0.0
Canada Goose	a	a	0.0
Tundra Swan	88.5	4.3	88.5
Wood Duck	21.2	9.6	21.2
American Wigeon	28.7	2.8	28.7
American Black Duck	19.8	16.1	19.8
Blue-winged Teal	1.9	1.5	1.9
Northern Pintail	4.6	1.7	4.6
Green-winged Teal	7.1	1.7	7.1
Canvasback	3.7	0.0	3.7
Greater Scaup	9.6	0.8	9.6
Lesser Scaup	4.1	0.6	4.1
Black Scoter	0.0	0.7	0.7
Long-tailed Duck	30.5	7.4	30.5
Bufflehead	35.4	5.8	35.4
Common Goldeneye	6.9	1.2	6.9
Ruddy Duck	23.3	12.3	23.3
Common Loon	18.3	19.9	19.9
Pied-billed Grebe	9.8	15.5	15.5
Horned Grebe	38.3	14.4	38.3
Red-necked Grebe	28.0	11.4	28.0
Eared Grebe	2.1	10.7	10.7
American Bittern	8.2	14.7	14.7
Great Egret	5.0	8.6	8.6
Snowy Egret	0.6	1.4	1.4
Osprey	26.1	37.8	37.8
Bald Eagle	4.1	6.9	6.9
Sharp-shinned Hawk	27.2	46.3	46.3
Northern Goshawk	20.4	47.6	47.6
Red-shouldered Hawk	13.5	33.7	33.7
Broad-winged Hawk	46.7	64.0	64.0
Golden Eagle	83.9	75.4	83.9
Virginia Rail	11.4	a	11.4
Sora	2.4	3.0	3.0

Common name	%Spring	%Fall	Max of spring/fall
American Coot	1.7	4.7	4.7
American Avocet	2.4	3.9	3.9
Black-bellied Plover	6.1	1.2	6.1
American Golden-Plover	0.0	5.6	5.6
Solitary Sandpiper	21.2	12.6	21.2
Greater Yellowlegs	5.5	9.9	9.9
Willet	7.8	1.7	7.8
Lesser Yellowlegs	2.9	6.7	6.7
Whimbrel	2.8	1.1	2.8
Ruddy Turnstone	4.2	2.3	4.2
Red Knot	0.7	11.7	11.7
Sanderling	0.3	0.9	0.9
Dunlin	0.6	18.0	18.0
Buff-breasted Sandpiper	0.0	8.8	8.8
Semipalmated Sandpiper	0.8	6.4	6.4
Western Sandpiper	0.0	4.5	4.5
Short-billed Dowitcher	0.2	0.5	0.5
Wilson's Snipe	13.7	6.7	13.7
American Woodcock	21.5	12.3	21.5
Wilson's Phalarope	0.4	1.6	1.6
Red-necked Phalarope	31.1	1.8	31.1
Red Phalarope	22.1	21.1	22.1
Bonaparte's Gull	24.5	2.8	24.5
Little Gull	a	0.0	a
Franklin's Gull	0.1	0.0	0.1
Black Tern	0.6	7.4	7.4
Common Tern	7.5	0.8	7.5
Forster's Tern	3.5	9.0	9.0
Northern Saw-whet Owl	10.1	27.8	27.8
Common Nighthawk	12.1	13.2	13.2
Chimney Swift	16.7	15.0	16.7
Yellow-bellied Sapsucker	7.2	17.1	17.1
Northern Flicker (Yellow-shafted)	17.9	15.9	17.9
Peregrine Falcon	a	13.0	13.0
Olive-sided Flycatcher	8.6	7.8	8.6
Eastern Wood-Pewee	15.3	14.6	15.3
Yellow-bellied Flycatcher	4.6	17.0	17.0
Alder Flycatcher	11.2	5.5	11.2

Common name	%Spring	%Fall	Max of spring/fall
Willow Flycatcher	17.8	25.6	25.6
Blue-headed Vireo	23.6	37.9	37.9
Northern Rough-winged Swallow	17.7	14.6	17.7
Bank Swallow	8.4	7.9	8.4
Barn Swallow	20.8	28.1	28.1
Veery	39.7	22.7	39.7
Swainson's Thrush	5.3	11.3	11.3
Wood Thrush	46.1	47.6	47.6
Brown Thrasher	12.7	15.8	15.8
Worm-eating Warbler	40.1	38.2	40.1
Northern Waterthrush	10.6	4.3	10.6
Golden-winged Warbler	7.7	2.1	7.7
Blue-winged Warbler	27.9	21.5	27.9
Black-and-white Warbler	23.1	18.9	23.1
Connecticut Warbler	1.5	18.6	18.6
Hooded Warbler	43.0	65.5	65.5
American Redstart	15.8	10.0	15.8
Cape May Warbler	8.0	18.7	18.7
Northern Parula	26.0	20.7	26.0
Bay-breasted Warbler	10.6	11.3	11.3
Blackburnian Warbler	44.8	23.9	44.8
Chestnut-sided Warbler	19.8	22.3	22.3
Blackpoll Warbler	23.5	11.1	23.5
Black-throated Blue Warbler	41.4	36.2	41.4
Prairie Warbler	31.5	19.5	31.5
Black-throated Green Warbler	27.1	33.9	33.9
Canada Warbler	16.6	22.6	22.6
Eastern Towhee	35.4	45.0	45.0
Clay-colored Sparrow	0.0	0.3	0.3
Field Sparrow	a	19.4	19.4
Vesper Sparrow	8.3	7.7	8.3
Nelson's Sparrow	0.0	6.1	6.1
Scarlet Tanager	32.7	36.6	36.6
Bobolink	25.1	10.5	25.1
Eastern Meadowlark	a	2.1	2.1
Rusty Blackbird	10.8	10.5	10.8
Purple Finch	33.6	40.4	40.4
Red Crossbill	22.1	7.6	22.1

Common name	%Spring	%Fall	Max of spring/fall
Pine Siskin	a	23.2	23.2

Appendix 1.1B - Mammals

A Comprehensive Status Assessment of Pennsylvania's Mammals, Utilizing NatureServe Ranking Methodology and Rank Calculator Version 3.1 for Application to the State Wildlife Action Plan Update 2015

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Overview

The Pennsylvania Natural Heritage Program (PNHP) is a partnership between the Western Pennsylvania Conservancy, Department of Conservation and Natural Resources, Pennsylvania Fish and Boat Commission and Pennsylvania Game Commission in cooperation with US Fish & Wildlife Service. It is also a member of the International Network of Heritage Programs called NatureServe. PHNP helps guide conservation work and land-use planning, ensuring the maximum conservation benefit with the minimum cost. PNHP conducts inventories and collects data regarding the Commonwealth's native biological diversity. Information is stored in an integrated data management system consisting of maps, manuals, and digital files.

As a member of NatureServe, PNHP relies on NatureServe's methodology and data standards. NatureServe uses the information it collects to assess the conservation status of various elements (vertebrates, invertebrates, plants, natural communities and animal assemblages) using various factors, a method which has been standardized into their Status Assessment Method (Faber-Langendoen et al. 2012). This method is meant to be as consistent and objective as possible, and applicable to all elements run through an assessment tool known as the rank calculator. The rank calculator is a Microsoft Excel based spreadsheet which uses decision factors to determine a risk of extinction. The rank calculator is designed to be used at multiple levels across a species range at global, national, or subnational (state) levels.

The rank calculator requires a minimum number of factors (1 rarity and 1 either threat or trend) to be entered in order for a status rank to be assigned. Although more data yields a stronger confidence in the calculator output, there is no confidence interval on the front end of the calculator; only a display whether the minimum number of factors have been met or not (either true or false). Not all of the factors are required to make a status assessment, and we used the best information readily available to conduct this analysis. We used multiple datasets, consulted with PGC biologists, and used white and grey literature (favoring Pennsylvania specific publications and reports) to help meet the minimum number of factors to run Pennsylvania's mammal species through the calculator.

NatureServe's Rank Calculator Version 3.1 (June 2012) was utilized for this analysis.
https://connect.natureserve.org/index.php?q=publications/StatusAssess_Download

NatureServe has developed two manuals critical to correctly using the rank calculator which cover the methodology and the determination factors used by the calculator.

NatureServe Conservation Status Assessments: Methodology for Assigning Ranks (Faber-Langendoen et al. 2012)
https://connect.natureserve.org/sites/default/files/documents/NatureServeConservationStatusMethodology_Jun12.pdf

NatureServe Conservation Status Assessments: Factors for Evaluating Species and Ecosystem Risk (Master et al.2012)
https://connect.natureserve.org/sites/default/files/documents/NatureServeConservationStatusFactors_Apr12.pdf

Version 3.1 of the rank calculator weighs three primary factors in calculating the S-ranks.

1) Rarity
2) Threats
3) Trends

We assessed the status of Pennsylvania's mammals (i.e., subnational level) using the Rank Calculator version 3.1 to:
1) update the NatureServe S-ranks for mammals and provide them to the Mammal Technical Committee (MTC) of the Pennsylvania Biological Survey (PABS) for discussion and vote, and 2) to provide the PGC with outputs to be used in the Pennsylvania State Wildlife Action Plan (SWAP) update (scheduled for completion in 2015). The two factor outputs from the rank calculator used in the SWAP prioritization include:

1) NatureServe State Rank (S-ranks, S1-S5)
2) Calculated Overall Threat Impact (Very High, High, Medium, Low)

NatureServe's Status Assessment methodology was originally developed in 1978, and has been continually refined since then, with the input factors being weighted at different levels based on the most current published scientific literature regarding species extinction risks. Version 3.1 places more of an emphasis on trends than previous versions of the rank calculator (G. Hammerson, pers. comm.).

Before this analysis, Pennsylvania's S-ranks for mammals had not been thoroughly assessed using this methodology. S-ranks appear to have been set by the MTC using other status assessment methodology and finding the closest match for the categories/definitions used by Kirkland and Krim (1990) and NatureServe methodology.

Rank Calculator Outputs and S-Rank definitions

Five primary S-rank definitions are used by NatureServe to describe an elements risk of extirpation from a subnation (state):

S1 = critically imperiled
S2 = imperiled
S3 = vulnerable
S4 = apparently secure
S5 = secure

Five other S-rank definitions are used where exceptions on species status are not covered by the primary factors:

SX = extirpated (virtually no likelihood of rediscovery)
SH = possibly extirpated (known only from historical occurrences, but still some hope of rediscovery)
S#S# = range rank (used to indicate uncertainly about status, no more than 2 degrees of separation is considered valid)
SU – unrankable (lack of data or conflicting information about status or trends)
SNA = not applicable (species is not a suitable target for conservation activities. This is where non-native, or transient species should be assigned)

Taxonomy

Consistency with regard to taxonomy is a challenge as new scientific methods and information are constantly reshuffling taxonomic organization. The Mammal Species of the World 3rd edition (Wilson & Reeder 2005) was agreed to be the taxonomic standard used for mammal taxonomy in the update of the SWAP as a national best practice (AFWA et al. 2012). The online database version (http://www.vertebrates.si.edu/msw/mswcfapp/msw/index.cfm) was used to develop the list of mammal species and subspecies found in the Commonwealth. Merritt (1987) was used as the primary source for determining the subspecies of mammals found in Pennsylvania. Taxonomic changes (lumping) have occurred since Merritt was published, and therefore fewer subspecies were recognized for this revision than are recognized in Merritt (1987). In most cases, too little information on distribution and status of subspecies was known to adequately assess the conservation status of each individual subspecies, so species were assessed using the rank calculator except for a few cases where enough information was available to assess at the subspecific taxonomic level.

First, the American water shrew (*Sorex palustris*) has two subspecies in Pennsylvania and both *S.p. albibarbis* and *S.p.punctulatus* were assessed using the calculator. Second, Pennsylvania has (or had) three subspecies of the fox squirrel (*Sciurus niger*). *S.n. rufiventer* (Western fox squirrel) and *S. n. vulpinus* (Eastern fox squirrel) were assessed through the rank calculator. *S. n. cinereus* (Delmarva fox squirrel), which was extirpated but experimentally reintroduced in the 1980's, has not been recorded in the state in years. This reintroduction effort is now thought to have failed, and the species is thought to now be extirpated (Dunn, 1989, Mike Steele, pers.comm.). Next, the MTC agreed at their 2013Nov16 meeting that the distinct morphological and ecological traits of the prairie deer mouse (*Peromyscus maniculatus bairdii* sensu Merritt, 1987) warrant a separate status assessment for the subspecies. Accordingly, the MTC agreed to recognize the two other subspecies of the deer mouse (*P.m. gracilis* and *P.m. nubiterrae*) following Merritt. Additionally, Wilson and Reeder's review of the Maryland shrew (*Sorex fontinalis* sensu Merritt 1987) have relegated this former species to a subspecies of the masked shrew (*Sorex cinereus*). The Maryland shrew (*S.c. fontinalis*) and the masked shrew (*S.c. cinereus*) were assessed using the rank calculator at the subspecies level because these taxa are still considered to be distinct, and enough data are available to assess their statuses at the

subspecies level. Lastly, the subspecies of Elk native to Pennsylvania (*Cervus elaphus canadensis*) is now considered to be extinct. The introduced subspecies (*C.e. nelsoni*) is not native to Pennsylvania, and in order to reflect the distinction of Pennsylvania's former and current elk, they were assessed at the subspecific level.

In addition to being the accepted standard for the scientific nomenclature, Wilson and Reeder was also used as the standard for mammal species' common names. However, the reference provides common names at the specific level, and not the subspecific level. In these cases, common names typically referred to Merritt (1987) or those currently used by the PGC. This list was reviewed and updated by PGC Wildlife Diversity Staff (C. Butchkoski) as well as the MTC at the 2013Nov16 meeting. The table with the source for scientific and common names for all Pennsylvania mammals is attached as Appendix I. This updated list of nomenclature will be used to update the list of mammals maintained by PNHP.

Rank
Calculator
Inputs

Rarity Data

This factor category bases rarity on six factors, including range extent, area of occupancy, population, number of occurrences, number of occurrences with good viability, and environmental specificity. Different conditions for how these factors should be used are available in the instruction manuals (Faber-Langendoen et al. 2012, Master et al. 2012). Below is a summary of how each factor was applied to the calculator.

Range Extent

We deemed that the α-hull model suggested by NatureServe was impractical for use with the calculator, and since the calculator uses range categories instead of a specific numerical input, the use of the α-hull model was supplanted with the most recent published Pennsylvania specific range maps. In most cases, Merritt (1987) served as the primary source of information, but more recent published maps were used when available in Steele et al. (2010). Range maps were digitized into ArcGIS, and a 2 km grid system was overlaid to calculate the number of square kilometers potentially occupied by each species.

Area of Occupancy

This factor is only to be used for static elements, such as plants and natural communities, and therefore was not used for this assessment.

Population

This information is typically not available for Pennsylvania's mammals and no assessments included this factor.

Number of Occurrences AND Number of Occurrences with Good Viability

This factor is based on Element Occurrence data found within the PNHP dataset (often referred to as PNDI). These data were only entered for species tracked by PNHP and species where supplemental information was available from the PGC (i.e. Silver-haired Bat maternity colonies) but not within the PNHP dataset. For the number of occurrences with good viability, only those with a quality rank of A (excellent) or B (good) or those with a quality range ranks of AB, AC or BC (potentially having excellent or good viability) were included.

Environmental Specificity

This factor is only to be used if there are no Element Occurrence data. This was typically the case for game mammals or those mammals widely known to be so common that datasets regarding the number of occurrences or their viability are impractical (ex: white-tailed deer, Eastern chipmunk). In these cases, environmental specificity was taken from either NatureServe Explorer's species accounts, or derived from general life history traits found in technical volumes and field guides (Merritt 1987, Webster et al. 1985, Lindzey 1998, Whitaker and Hamilton 1998).

Threat Data

This factor category can be assessed through two routes; the threats table or a less rigorous intrinsic vulnerability level. The preferred method is to use the associated threats table to assess the scope, severity, and timing of particular threats to species. Eleven threat categories may be evaluated for each species, including:

1) Residential and commercial development
2) Agriculture and aquaculture
3) Energy production and mining
4) Transportation and service corridors
5) Biological resource use
6) Human intrusions and disturbance
7) Natural system modifications
8) Invasive and other problematic species and genes
9) Pollution
10) Geologic events
11) Climate change and severe weather

These eleven categories are used to calculate an overall threat impact, ranging from *very high* to *low*. Each of these threat categories has a more specific set of factors beneath it. For example, energy production and mining threats (threat category 3) can be separately evaluated for potential impacts from the oil and gas industry, mining and quarrying, and/or renewable energy, and then averaged to get a threat assessment for the whole threat category.

The *scope* of the potential threat is to reflect what portion of a certain species population in Pennsylvania could be affected by a particular threat, and the *severity* of the threat is to reflect how serious the impact of that threat could be to those affected populations. Uncertainty ranges for scope and severity are also available in the calculator, and used where professional opinions conflicted or there was a greater level of uncertainty. The threats table portion of the calculator does incorporate a level of "best professional judgment", and this portion of the calculator was based on previous data, experiences, and realistic potential threats and population changes of experienced mammalogists (C.Butchkoski and G. Turner of PGC). Timing is considered an optional input in the threat assessment, and proved to have little influence on the calculated overall threat impact output. We did not consistently use the timing input since it did not appear to have a significant influence (either positive or negative) on the calculated overall threat impact.

Only one threat factor category is needed to be completed to assign an overall threat impact and the most severe threat is the primary driver to the overall threat impact. For example, White-nose Syndrome (WNS) in the little brown myotis (*Myotis lucifugus*) in Pennsylvania, was assigned a scope level of pervasive (affecting 71-100% of the population), and the severity level of extreme (causing mortality in 71-100% of the impacted population). Because WNS is so devastating to the little brown myotis, the other threats that had lesser scope and severity could not alter the calculated overall threat impact of "very high".

For those species that have no pressing known threats (the most severe threat has a scope or severity level considered "negligible"), the rank calculator does not provide a calculated overall threat impact. In order to force the rank calculator to provide a calculated overall threat impact, species for which the scope or severity of the most severe threat fit the definition of "negligible", were increased to "small", calculating the lowest available overall threat impact of "low".

Trend Data

The last factor category that the rank calculator uses looks at both long-term population trends and short-term population trends. NatureServe suggests that the long term trend category is meant to be looked at over a period of approximately 200 years, typically the period in Pennsylvania when notations were recorded regarding wildlife abundance. While these data are considered highly subjective, their overall acceptance in subsequently published literature gives us some level of confidence in the information. Short-term population trends are to be considered within 10-years or 3 generations for

long lived taxa (not to exceed 100 years) whichever is the longer. Short-term population trends should focus on regularly monitored populations so as to avoid recording a temporary fluctuation as a trend.

For this portion of the calculator, we used numerous PGC job reports published from 1999 to 2013 (accessed at: http://www.portal.state.pa.us/portal/server.pt?open=514&objID=563596&mode=2) having short-term trend data, and published literature if available (Turner et al. 2011). Long-term trend data were primarily gathered from historical Pennsylvania mammal literature (Gifford & Whitebread 1951, Grimm & Roberts 1950, Grimm & Whitebread 1952, Rhoads 1903, Richmond & Roslund 1949, Roberts & Early 1952, Roslund 1951)

Results

See attached Microsoft Excel spreadsheets, attached as Appendix II (comprehensive mammal rank calculators and associated threat tables), and Appendix III (SWAP assessment table).

Special cases

For those species now thought to be extinct, or extirpated from Pennsylvania, a value for the species range and number of occurrences value of Z (zero) was entered, which assigns the appropriate S-rank of SX (extirpated). This list of extirpated species primarily followed Williams et al. (1985) except for those where reintroduction efforts have been successful (i.e. beaver, fisher). For those species considered transients (evening bat), waifs (West Indies manatee), deliberate non-native introductions (thirteen-lined ground squirrel), or invasive species (house mouse), an S-rank of SNA (not applicable) was assigned as these species should not be the target of conservation efforts.

Pending approval of the MTC in 2014, the calculated ranks will be used to update the ranks for mammals maintained by PNHP.

Discussion

The conservation status of all native Pennsylvanian mammals has previously been assessed using novel approaches (see Genoways 1985, Kirkland & Krim 1989, Kirkland & Krim 1990, Wright & Kirkland 1998) which are no longer supported. The strength of the NatureServe methodology comes from its continual evolution based on the best available science, and its ability to assess overall conservation status for all species, not just those closer to the risk of extinction. The NatureServe rank calculator is not meant to be a replacement for PGC's methodology for listing and delisting of species, rather it complements the detailed assessments completed by PABS using IUCN methodology for listing proposals. With a guiding principle of the SWAP being to keep common species common, NatureServe S-ranks play an important role in evaluating the conservation status of all of the state's mammal species.

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Personal communiqué

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- Catherine Haffner, PA Game Commission
- John Taucher, PA Game Commission
- Michael Steele, Wilkes University
- Geoff Hammerson, NatureServe
- Membership of the Mammal Technical Committee of the Pennsylvania Biological Survey

Databases referenced

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- PGC hibernacula database, PA Game Commission
- PNHP dataset (PNDI), PA Natural Heritage Program
- Digitized survey summaries from the 6 regional Mammal Surveys of Pennsylvania, PA Game Commission
- Wild Resource Conservation Program (Fund), final reports 1983-2013

Appendix 1.1C - Herpetofauna

A Revision of the State Conservation Ranks of Pennsylvania's Herpetofauna

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Introduction

The following amphibian and reptile status assessment was conducted on behalf of the Pennsylvania Game Commission (PGC) and Pennsylvania Fish & Boat Commission (PFBC). The PFBC is the regulatory agency tasked with the management of Pennsylvania herpetofauna. The results of this assessment will be used, in part, to update the State Wildlife Action Plan (SWAP). The SWAP is central to proactive conservation of non-game species and is mandatory for state resource agencies that wish to apply for certain federal funds, such as the important State Wildlife Grant Program (Teaming with Wildlife 2014). In Pennsylvania, status updates are vetted through taxa-specific technical committees of the Pennsylvania Biological Survey (PABS). PABS is a nonprofit committee of professional and amateur biologists that are experienced in dealing with taxa or biodiversity. Pennsylvania natural resource agencies use PABS as an independent scientific advisor for matters related to flora, fauna, and ecology. The Amphibian and Reptile Technical Committee, specifically, will review this status update and forward the document to the PFBC for consideration.

Objective

The objectives of the project was to: 1) review the current state ranks of Pennsylvania's amphibians and reptiles, 2) update rankings where necessary in the case of status changes, and 3) to provide a status update for use in the required SWAP update.

Methods

The PFBC manages amphibians and reptiles (Pennsylvania is technically inhabited by amphibians, reptiles, and turtles following modern taxonomy) through a traditional nongame and endangered species program, giving rare and imperiled species special classifications (endangered, threatened, candidate) that afford certain protections. Additionally, the PFBC lists species by Global ranks (G-ranks), national ranks (N-ranks) and subnational/state ranks (S-ranks) as suggested by NatureServe (2012). These status ranks are also important factors for the PFBC when considering formal state status designation changes (e.g., endangered, threatened, and candidate species lists, Pennsylvania Code Title 58 §75).

A comprehensive list of the amphibians and reptiles found in Pennsylvania was provided to the author by the PGC/PFBC. Each native species or infraspecies (subspecies, distinct population segments, etc.) was evaluated via the NatureServe Conservation Status Assessments: Rank Calculator Version 3.1 (calculator), as created by NatureServe (2014). Refer to Table 1 for an explanation of conservation status ranks. Common and Scientific names conform to the recommendations of the Society for the Study of Amphibians and Reptiles (2012). Species not native (e.g. Red-eared Slider) to Pennsylvania were eliminated from the analysis. Species that are native to Pennsylvania, but are believed by many workers to have been moved outside of what is considered the natural range in the Commonwealth (e.g. Northern Map Turtle), were included in the analysis.

Table 1: National (N) and Subnational (S) Conservation Status Ranks (Master et al. 2012)

Status	Definition
NX SX	**Presumed Extirpated**—Species or ecosystem is believed to be extirpated from the jurisdiction (i.e., nation, or state/province). Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered. [Equivalent to "Regionally Extinct" in IUCN Red List terminology]
NH SH	**Possibly Extirpated**—Known from only historical records but still some hope of rediscovery. There is evidence that the species or ecosystem may no longer be present in the jurisdiction, but not enough to state this with certainty. Examples of such evidence include (1) that a species has not been documented in approximately 20-40 years despite some searching and/or some evidence of significant habitat loss or degradation; (2) that a species or ecosystem has been searched for unsuccessfully, but not thoroughly enough to presume that it is no longer present in the jurisdiction.
N1 S1	**Critically Imperiled**—At very high risk of extirpation in the jurisdiction due to very restricted range, very few populations or occurrences, very steep declines, severe threats, or other factors.
N2 S2	**Imperiled**—At high risk of extirpation in the jurisdiction due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors.
N3 S3	**Vulnerable**—At moderate risk of extirpation in the jurisdiction due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors.
N4 S4	**Apparently Secure**—At a fairly low risk of extirpation in the jurisdiction due to an extensive range and/or many populations or occurrences, but with possible cause for some concern as a result of local recent declines, threats, or other factors.
N5 S5	**Secure**—At very low or no risk of extirpation in the jurisdiction due to a very extensive range, abundant populations or occurrences, with little to no concern from declines or threats.

[1] A conservation status rank may be not applicable for some species, including long distance aerial and aquatic migrants, hybrids without conservation value, and non-native species or ecosystems

The calculator was developed to increase the objectivity and repeatability of the conservation ranking process (Criswell 2014). The calculator weighs ten factors contained within the following categories: Rarity, Threats, and Trends (refer to Table 2 for factor relationships). The calculator assigns each species scenario run a numeric score which is displayed as a status rank. The operator of the calculator can adjust the calculator results, but a justification must be written in the appropriate field. Refer to Master et al. (2012 for a detailed description of the process). It is important to note that amphibians and reptiles were historically overlooked by the general public and natural resource agencies alike until relatively late in the 20th century. This was due to the cryptic nature of many species and belief that the taxa were unimportant economically and ecologically, slimy, or dangerous. As a result, large information gaps exist which the PFBC is admirably (and successfully) trying to close. Population size, types and severity of threats, and quality of habitat are not known for many species.

Three categories, otherwise known as Factor Groups, (rarity, trends and threats), comprised of ten conservation status factors are assessed to compute a conservation status. As few as two of the eight main factors are required to assign a species rank. The following factors are used to assess conservation status:

- Rarity: Population Size, Range Extent, Area of Occupancy, Number of Occurrences, Number of Occurrences or Percent Area with Good Viability/Ecological Integrity, and Environmental Specificity (used only when the Number of Occurrences and Area of Occupancy are unknown);

- Trends: Long-term and Short-term Trend in population size or area;

- Threats: Threat Impact (comprised of scope and severity of threats), and Intrinsic Vulnerability (used only if Threat Impact is unknown).

The Rarity category ("Factor Group") contains two "Subcategories"; Range/Distribution and Abundance/Condition. The Subcategories are further broken down into "Factors": Range Extent and Area of Occupancy for Range/Distribution; while Number of Occurrences, Population Size, and Good Viability/Ecological Integrity were Factors of Abundance/Condition. All factors had various ranges and values that were filled via dropdown box selection. The default measure of occupancy used for amphibians and reptiles was 4-km² grid cells (Master et al. 2012).

Large polygons containing all known sites (within a minimum convex polygon) were typically created for range extent determinations. The creation of multiple, disjunct polygons was avoided unless enough information was present to create accurate (assumedly) sub-units (e.g. Eastern Spadefoot) as per the NaturesServe recommendations. Population size estimates were not used in this analysis because this information is not currently available for these species.

Area of occupancy estimates were created with data from the following sources: PFBC/PNHP (PA Natural Heritage Program), PFBC/SCP (Scientific Collector's Permit), Pennsylvania Amphibian and Reptile Survey (PARS) which also contains various PFBC datasets, and specimen collections from approximately 45 institutions.

The number of occurrences for each species was taken from PFBC/PNHP Element Occurrences (EO) housed within the Pennsylvania Natural Diversity Inventory (PNDI) database, an electronic storehouse of the Commonwealth's rare species data. Species that are not tracked in the PNHP or occurrences that were not contained within the PNHP were estimated on PARS block size (±29 km) and block proximity (adjacent blocks could build EOs) combined with maximum dispersal distances of the evaluated species and major dispersal barriers. In cases where the species being evaluated was a wide-spread generalist represented by a large number of records (e.g. Eastern Gartersnake), PARS block counts and environmental specificity were used to reduce the effort required to generate EOs from thousands of records.

Threat scope is evaluated within a 10-year window for taxa (20 years for ecosystem evaluation which was

not used in this analysis) and threat severity in a 10-year to 3-generation window for taxa (also 20 years for ecosystem evaluation), whichever is longer (Master et al. 2012). Short-term and long-term trends, if known can also be included in species evaluations. Short-term trends are considered within the past 10 years or three generations, whichever is longer. Long-term trends consider changes from 200 years ago to present. In many instances, these trends are not known due to a lack of information.

Climate change was not evaluated in the analysis. While almost all climate scientists agree that the progression of human-induced climate change is inevitable, there is considerable uncertainty about what changes will happen where and how organisms will ultimately respond to climate change (Blaustein et al. 2010, Fussman 2014, Parmesan 2006).

The final S-rank assignments will be provided to the PABS Amphibian and Reptile Technical Committee for review by that team of experts. Refer to Appendix 1 for amphibian and reptile S-rank listings and calculator pages. Refer to Appendix B for a calculated threats table. Appendix C includes the SWAP assessment summary of Pennsylvania amphibian and reptile species status.

Table 2: Summary of NatureServe Conservation Rank Factors (from Faber-Langendoen et al. 2012).

Factor Category	Subcategory	Factor	Definition
Rarity	Range/ Distribution	Range Extent	Minimum area that can be delimited to encompass all present occurrences of a species or ecosystem, typically excluding extreme disjuncts and vagrancies.
		Area of Occupancy	Area within the range extent that a species or ecosystem actually occupies. For species, area can be estimated by counting the number of occupied cells in a uniform grid. In most cases a grid of size 2x2 km (a cell area of 4 km²) should be used, but a smaller 1 km² grid is appropriate for linear[1] and some other occurrence types. For ecosystems, areas can be measured or estimated directly based on the best available information. Area of Occupancy for ecosystems is assessed based on selecting the typical spatial pattern of the type (small patch, large patch, matrix).
	Abundance/ Condition	Population Size (species only)	The estimated total wild population of a species, occurring in its natural range and based on counts or estimates of the number of individuals that are currently of a reproductive age or stage, or mature and currently non-reproducing. This category is not included in the assessment calculation for annual plants or invertebrates with population sizes that fluctuate greatly from year to year.
		Number of Occurrences	Number of extant locations (stands) of an ecosystem, or discrete areas occupied by a species (typically subpopulations, populations, or metapopulations).[2]
		Number of Occurrences or Percent Area with Good Viability/ Ecological Integrity	1) Number of occurrences (locations, stands of an ecosystem, or number of locations, subpopulations, populations, metapopulations of a species) that have excellent-to-good viability or ecological integrity (A or B occurrence ranks), such that there is the likelihood of persistence if current conditions prevail; **OR** 2) Percent of the total area occupied by a species or ecosystem that has excellent-to-good viability or ecological integrity.
		Environ-mental Specificity	The degree to which a species or ecosystem depends on a relatively scarce set of habitats, substrates, food types, or other abiotic and/or biotic factors within the overall range. Relatively narrow requirements are thought to increase the vulnerability of a species or ecosystem.

Continued…

Table 2: Continued

Factor Category	Subcategory	Factor	Definition
Threats		Overall Threat Impact	Degree to which the integrity of an ecosystem or viability of a species is affected by extrinsic factors (stressors) that degrade integrity or viability, and which are characterized in terms of scope and severity. Threats are typically anthropogenic, having either direct (e.g., habitat destruction) or indirect (e.g., introduction of invasive species) impact.
		Intrinsic Vulnerability	Degree to which intrinsic or inherent characteristics, such as life history or behavior patterns for species, or likelihood of regeneration or recolonization for ecosystems, make it susceptible or resilient to natural or anthropogenic stresses or catastrophes.
Trends		Long-term Trend	Degree of past directional change in population size (for species only), extent of occurrence, area of occupancy, number of occurrences, and/or viability or ecological integrity of occurrences over the long term (ca. 200 years).
		Short-term Trend	Degree of past directional change in population size (for species), extent of occurrence, area of occupancy, number of occurrences, and/or viability or ecological integrity of occurrences in the short-term, considered to be typically within 50 years for ecosystems, or within 10 years or 3 generations, whichever is longer (up to 100 years), for species.

Results and Discussion

A total of 77 amphibian and reptile taxa were evaluated (Table 3). Species rankings varied from S5 (secure) to SH (historic). Two taxa remain on the historic list (*Clonophis kirtlandii* and *V. valeriae*) due to the lack of recent occurrences combined with the lack of any specific efforts to systematically search for the taxa at historical locations within the last 30 years. The status of 54 taxa did not change. Twelve taxa were listed as more imperiled and 10 taxa as less imperiled when compared to the previous status ranking. In most instances, status changes were movements of one ranked status place (e.g. S3-vulnerable to S4-secure) or the movement of "half" a status place (e.g. S3 to S3S4). Rarely did a status move more than one rank place. Previous evaluations that determined S-rankings focused solely on element occurrences and distribution. The 2012 NatureServe calculator factors threats for the first time which may be the cause of various status changes, though the details of previous status listings were not available for this analysis.

There were several notable exceptions to the minor status changes. The Eastern Spadefoot moved from S1 (critically imperiled) to S2S3 as a result of a PFBC-sponsored study that found the species to be more common than previously thought (still an imperiled animal that is by no means common as reflected in its current status as state threatened). Additionally, the Upland Chorus Frog is the latest member of the genus *Pseudacris* to be considered imperiled as the species moved from S3 to S1 due to a lack of recent

records. The Cope's Gray Treefrog was discovered in Pennsylvania for the first time in 2013 as part of investigations for the Pennsylvania Amphibian and Reptile Survey (PARS) and is initially listed as an S1 species due to the few records and little information known about the species. As expected, stable species tended to be wide-ranging and have few threats. Many amphibian and reptile species continue to suffer from a lack of knowledge about distributions and threats, as was the case in previous NatureServe evaluations.

Table 3: Pennsylvania S-Ranks – former and 2014 (calculated and assigned) '

Scientific Name	PA STATUS	S-Rank 2012	S-Rank 2014	Change
Acris crepitans	PA Endangered	S1	S1	none
Agkistrodon contortrix		S3S4	S3S4	none
Ambystoma jeffersonianum		S3S4	S3	more imperiled
Ambystoma laterale	PA Endangered	S1	S1	none
Ambystoma maculatum		S5	S4	more imperiled
Ambystoma opacum		S3S4	S3	more imperiled
Anaxyrus americanus americanus		S5	S5	none
Anaxyrus fowleri		S3S4	S3S4	none
Aneides aeneus	PA Threatened	S1	S2	less imperiled
Apalone spinifera spinifera		S4	S4	none
Carphophis amoenus amoenus		S3	S2	more imperiled
Chelydra serpentina		S5	S5	none
Chrysemys picta marginata		S5	S5	none
Chrysemys picta picta		S5	S5	none
Clemmys guttata		S3	S3S4	less imperiled
Clonophis kirtlandii	PA Endangered	SH	SH	none
Coluber constrictor constrictor		S5	S5	none
Crotalus horridus	PA Candidate	S3S4	S3S4	none
Cryptobranchus alleganiensis alleganiensis		S3	S2S3	more imperiled
Desmognathus fuscus		S5	S5	none
Desmognathus monticola		S4	S3S4	more imperiled

Desmognathus ochrophaeus		S5	S5	none
Diadophis punctatus edwardsii		S5	S5	none
Emydoidea blandingii	PA Candidate	S1	S1	none
Eurycea bislineata		S5	S5	none
Eurycea longicauda longicauda		S5	S5	none
Glyptemys insculpta		S3S4	S3S4	none
Glyptemys muhlenbergii	PA Endangered	S2	S2	none
Graptemys geographica		S4	S4	none
Gyrinophilus porphyriticus porphyriticus		S5	S4	more imperiled
Hemidactylium scutatum		S4	S4	none
Heterodon platirhinos		S3	S3S4	less imperiled
Hyla chrysoscelis		N/A	S1	more imperiled
Hyla versicolor		S4	S4	none
Kinosternon subrubrum subrubrum	PA Endangered	S1	S1	none
Lampropeltis triangulum triangulum		S5	S5	none
Lithobates catesbeianus		S5	S5	none
Lithobates clamitans		S5	S5	none
Lithobates palustris		S5	S5	none
Lithobates pipiens		S2S3	S2S3	none
Lithobates sphenocephalus utricularius	PA Endangered	S1	S1	none
Lithobates sylvaticus		S5	S4	more imperiled
Necturus maculosus		S3	S3	none
Nerodia sipedon sipedon		S5	S5	none
Notophthalmus viridescens viridescens [2]		?	S5	n/a
Opheodrys aestivus	PA Endangered	S1	S1S2	less imperiled
Opheodrys vernalis		S3S4	S4	less imperiled
Pantherophis alleghaniensis		S5	S5	none
Plestiodon anthracinus anthracinus		S3	S3	none

Plestiodon fasciatus		S4	S4	none
Plestiodon laticeps	PA Candidate	S1	S2	less imperiled
Plethodon cinereus		S5	S5	none
Plethodon electromorphus		S3	S2S3	more imperiled
Plethodon glutinosus		S5	S5	none
Plethodon hoffmani		S4	S4	none
Plethodon wehrlei		S4	S4	none
Pseudacris brachyphona		S1	S2	less imperiled
Pseudacris crucifer		S5	S5	none
Pseudacris feriarum		S3	S1	more imperiled
Pseudacris kalmi	PA Endangered	S1	S1	none
Pseudacris triseriata		S1	S1	none
Pseudemys rubriventris	PA Threatened	S2S3	S2S3	none
Pseudotriton montanus montanus	PA Endangered	S1	S1	none
Pseudotriton ruber ruber		S5	S5	none
Regina septemvittata		S3	S3S4	less imperiled
Scaphiopus holbrookii	PA Threatened	S1	S2S3	less imperiled
Sceloporus undulatus		S3S4	S3	more imperiled
Sistrurus catenatus catenatus	PA Endangered	S1	S1	none
Sternotherus odoratus		S4	S4	none
Storeria dekayi dekayi		S5	S5	none
Storeria occipitomaculata occipitomaculata		S5	S5	none
Terrapene carolina carolina		S3S4	S3S4	none
Thamnophis brachystoma		S3	S4	less imperiled
Thamnophis sauritus		S3	S3	none
Thamnophis sirtalis sirtalis		S5	S5	none
Virginia valeria pulchra		S3	S3	none
Virginia valeriae valeria		SH	SH	none

[1] Both *Ambystoma t. tigrinum* and *Apalone mutica* were considered SX (extirpated) long before this analysis and were not included in the state species list. As there have been no additional observations since being listed as extirpated decades ago, these species are still considered extirpated. Both species are included in the NatureServe Calculator table.
[2] *N. v. viridescens* S-ranking was not listed in the available materials provided to the author. It is assumed the species was listed as an S-5.

CONCLUSIONS AND RECOMMENDATIONS

The NatureServe rank calculator was utilized to create an objective and repeatable process for evaluating Pennsylvania's organisms and ecosystems. Overall, the amphibian and reptile status list changed very little. Taxa-specific surveys should be conducted for Pennsylvania's rare taxa that are not protected via state or federal regulations, as these taxa suffer from a sever lack of information. The Pennsylvania Amphibian and Reptile Survey (PARS) will presumably allow for more informed decision making in the future for a number of the species assigned at-risk status during this assessment. The NatureServe calculator seems to serve its purpose well, though the process is difficult to calibrate and still, ultimately, relies on "expert" opinion. Threats weigh heavily in the analysis and an absence or over-estimation of threats can significantly impact taxa rank outcomes. The occurrence of climate change is not disputed, however, the impacts on amphibian and reptile taxa is unknown. If future analyses include climate change results from analysis in the NatureServe Climate Change Calculator, the process should be vetted through a peer-review of climate and landscape ecologists. Additionally, limitations in our understanding of amphibian and reptile life history should be openly recognized.

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Note: The following Appendices for this report are not included here due to technical constraints with displaying the tables at a viewable scale. However, summary tables of SGCN species (i.e., add, maintain, delete) with justifications are provided in Chapter 1, Appendix 1.3 of this Plan. For 2015 SGCN, information on Threats, Conservation Actions, Monitoring and Surveying is provided in Chapter 1, Appendix 1.4 (Species Accounts).

Appendix 1. Species Lists and Ranks.

Appendix B. Amphibian and Reptile Threats Calculator Worksheet.

Appendix C. 2015 State Wildlife Action Plan Herptile Species Assessment Criteria.

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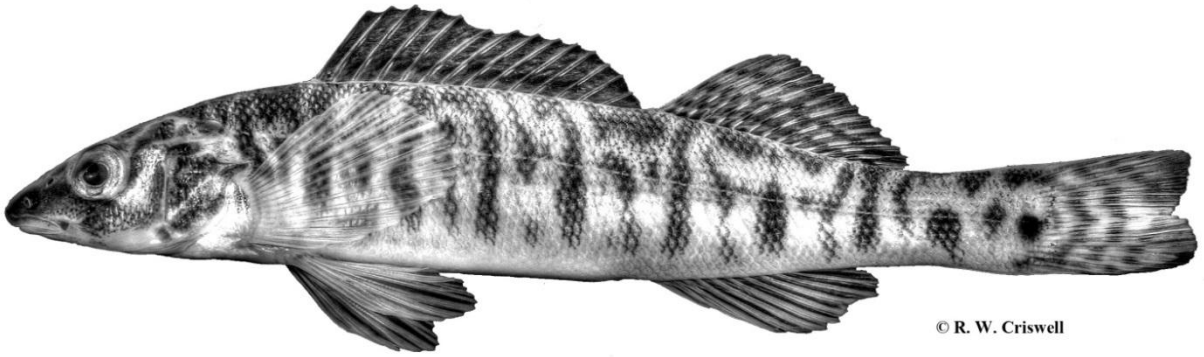
Appendix 1.1D - Fishes

A Revision of the State Conservation Ranks of Pennsylvania's Fishes

Robert W. Criswell



Chesapeake Logperch (*Percina bimaculata*)

Introduction

Considerable effort has been invested over the past two decades toward the development of improved status determination and listing processes for Pennsylvania's species of conservation concern (Brauning et al. 1995; Argent et al. 1998; Hassinger 2002). These processes, as they relate to fishes, have metamorphosed into a procedure whereby the Pennsylvania Biological Survey's (PABS) Fishes Technical Committee provides status change recommendations to the Pennsylvania Fish and Boat Commission (PFBC), the agency with the responsibility for the conservation and management of the Commonwealth's fish taxa. These recommendations are based on reviews of individual species and include consideration of expert opinion and objective criteria (PABS 2013). Such recommendations are subsequently reviewed by PFBC and considered for further action.

During the evolution of the listing process, increased emphasis has been placed on the use of objective criteria, such as those employed by the International Union for Conservation of Nature (Anon. 2000).

In addition to the use of federal or state regulatory conservation status classifications (endangered, threatened, candidate), the development and use of national (N-ranks) and subnational and state conservation ranks (S-ranks) has become an important element for conservation-related decision making and resource allocation. These designations are analogous to global conservation ranks (G-ranks), but consider a species' status within a specific political boundary, rather than its global range (NatureServe 2012).

The objectives of the effort described herein have been to review the current state ranks of Pennsylvania's fishes, and subsequently update rankings where necessary to reflect a change in a species' status, as well as to provide a reflection of the current status of these fishes prior to the development of the second iteration of the state's Wildlife Action Plan.

Methods

The status of each fish species appearing on the document titled "Species Review Fish list 17OCT13", a comprehensive listing of those fishes known to occur in Pennsylvania and provided by PFBC, was evaluated using NatureServe Conservation Status Assessments: Rank Calculator Version 3.1 (http://www.natureserve.org/biodiversity-science/publications/natureserve-conservation-status-assessments-rank-calculator), henceforth referred to as "calculator."

This calculator was developed to increase the repeatability and transparency of the conservation ranking process. It considers ten status factors grouped within rarity, threats, and trend categories. The calculator computes a numeric score, based on weightings assigned to each factor (see Appendix D) and some conditional rules, which is translated to a calculated status rank. This calculated rank is reviewed and adjusted if deemed appropriate (with justification for the reasons for adjustment) before it is recorded as the final assigned conservation status rank, or S-rank (Master et al. 2012). For the remainder of this report, rankings will be discussed in the context of "state" ranks rather than "subnational" unit ranks as identified in the following table.

Table 1: National (N) and Subnational (S) Conservation Status Ranks (Master et al. 2012).

Status	Definition
NX **SX**	**Presumed Extirpated**—Species or ecosystem is believed to be extirpated from the jurisdiction (i.e., nation, or state/province). Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered. [Equivalent to "Regionally Extinct" in IUCN Red List terminology]
NH **SH**	**Possibly Extirpated**—Known from only historical records but still some hope of rediscovery. There is evidence that the species or ecosystem may no longer be present in the jurisdiction, but not enough to state this with certainty. Examples of such evidence include (1) that a species has not been documented in approximately 20-40 years despite some searching and/or some evidence of significant habitat loss or degradation; (2) that a species or ecosystem has been searched for unsuccessfully, but not thoroughly enough to presume that it is no longer present in the jurisdiction.
N1 **S1**	**Critically Imperiled**—At very high risk of extirpation in the jurisdiction due to very restricted range, very few populations or occurrences, very steep declines, severe threats, or other factors.
N2 **S2**	**Imperiled**—At high risk of extirpation in the jurisdiction due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors.
N3 **S3**	**Vulnerable**—At moderate risk of extirpation in the jurisdiction due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors.
N4 **S4**	**Apparently Secure**—At a fairly low risk of extirpation in the jurisdiction due to an extensive range and/or many populations or occurrences, but with possible cause for some concern as a result of local recent declines, threats, or other factors.
N5 **S5**	**Secure**—At very low or no risk of extirpation in the jurisdiction due to a very extensive range, abundant populations or occurrences, with little to no concern from declines or threats.

Variant National and Subnational Conservation Status Ranks

Rank	Definition
N#N# **S#S#**	**Range Rank**—A numeric range rank (e.g., S2S3 or S1S3) is used to indicate any range of uncertainty about the status of the species or ecosystem. Ranges cannot skip more than two ranks (e.g., SU is used rather than S1S4).
NU **SU**	**Unrankable**—Currently unrankable due to lack of information or due to substantially conflicting information about status or trends.
NNR **SNR**	**Unranked**—National or subnational conservation status not yet assessed.
NNA **SNA**	Not Applicable—A conservation status rank is not applicable because the species or ecosystem is not a suitable target for conservation activities.[1]
Not Provided	Species or ecosystem is known to occur in this nation or state/province. Contact the relevant NatureServe network program for assignment of conservation status.

[1] A conservation status rank may be not applicable for some species, including long distance aerial and aquatic migrants, hybrids without conservation value, and non-native species or ecosystems

The factors that were used primarily within the rarity group were "area of occupancy" and "percent of area occupied with good viability/ecological integrity." The default measure of occupancy for lineal species (fishes) is 1 km² grid cells (Master et al. 2012).

Area of occupancy estimates were derived primarily from a comprehensive database recently developed and refined by PFBC and Penn State University (unpublished data) as part of an ongoing project. Where known gaps in data existed, additional sources, including literature and experts familiar with a problematic species, were consulted.

It should be noted that there are many gaps in survey effort on the state's waterways. They are a result of topography (inaccessibility due to remoteness or terrain), legal access (posting, fencing), limited resources, and extant weather/water conditions during survey periods. Although many species are more-or-less continuously distributed in many waterways and systems, even rather comprehensive surveys may fail to reflect that fact on a map or spreadsheet. Therefore it was necessary to make some assumptions.

Generally, if there was a gap in excess of 10 km, occurrences were measured separately. However, if on a range map with such gaps it was obvious that the species occurred throughout the section of waterway under consideration, a continuous measurement was made. Where gaps or single location records existed, the species was placed within one of the "movement group" classifications within PFBC's Core Polygon Specifications (D. Fischer in lit.) for upstream/downstream home range and movement, and the corresponding length was used as the measure.

Only native occurrences, insofar as they could be identified and delimited, were considered in the ranking calculations. For example, Bowfin (*Amia calva*) is native to the northwest corner of the state, and may be expanding into the Allegheny River. These occurrences are considered to be native (although the origin of the riverine specimens is open to debate), but populations that exist outside this original range and occur as the result of stocking were not considered.

In addition, a few native species, notably Lake Trout (*Salvelinus namaycush*) and Paddlefish (*Polyodon spathula*), do not currently reproduce in the state and are maintained by stocking. These species are ranked as SX (extirpated).

Threat categories largely follow Salafsky et al. (2008). Generally, threats did not impact rankings for species that are common and widespread, and apparently secure, unless they were serious. However, for some species threat determination was a bit more problematic.

Climate change has the potential to impact nearly all of Pennsylvania's fauna at some point in time. Predictions on the timing and severity of impacts vary considerably (Anon 2013; Comte and Grenouillet 2013; Hudy et al 2008; Issak and Rieman 2013; Kaushal et al. 2010; Penn. State U. 2013; and Xu et al. 2010). The scope of consideration for threats for the calculator is 10-20 years (Master et al. 2012), but

some latitude is available for the climate change factor. Considering the fact that S-ranks are updated frequently, a 25-year benchmark was utilized during this project. This time window, along with more moderate recent predictions, resulted in low or, rarely, moderate threat levels, and then only to fishes requiring cold-water habitats at lower elevations and/or headwaters. It is believed that predicted changes during this time period may reduce flows and/or elevate temperatures to a level that would negatively impact or extirpate some populations.

Trends have the potential to exert significant influence on the outcome of a conservation rank. The calculator considers both short- and long-term trends. Short-term trends are those that consider changes to a species rarity factors within the past 10 years or three generations, whichever is longer. The long-term trend factor considers changes over the past circa. 200 years.

There are practically no standardized data collection programs or events that can be utilized to make a clear trend determination for either the past ten years or three generations for Pennsylvania's fishes. In addition, many short-lived fishes experience significant variation in year-to-year abundance (Trautmann 1981), further confounding the analysis of uncoordinated survey data. Therefore, occurrence data generated as far back in time as 1990 was considered in an effort to identify short-term trends for individual species.

The determination of long-term trends for Pennsylvania fishes is nearly impossible for all but a few economically important species. Historically, barriers to conducting comprehensive survey work were monumental, and included a paucity or lack of transportation, effective sampling gear, efficient means of recording, preservation, and curating of specimens, financial resources, and trained personnel. As a result, early survey work was spotty, sporadic, and largely confined to developed areas and transportation corridors. Therefore, the long-term trend designation for nearly all species was "unknown."

The final S-rank assignments were reviewed by PABS' Fishes Technical Committee for concurrence and approval.

The final S-ranks listings and calculator table may be found in Appendix A. See Appendix B for the calculator threat table. The Wildlife Action Plan assessment table (Appendix C) includes a tabular summary of each species' Pennsylvania status and literature/sources consulted during the evaluation process. Appendix D contains a summary of NatureServe's ranking factors.

Results and Discussion

A total of 231 taxa were considered during this evaluation. This included 226 recognized species, 2 undescribed forms, and 3 subspecies (as well as their nominate forms). Of this total, 22 species were determined to be introduced into Pennsylvania waters, and were therefore classified SNA (not applicable). The remaining taxa were evaluated using the rank calculator. Table 2 (below) compares previous ranks with those generated during this evaluation.

Table 2: Comparison of Pennsylvania S-ranks – previous vs. 2014.

RANK	S1	S1S2	S2	S2S3	S3	S3S4	S4	S4S5	S5	SU	SH	SX	SNA	SNR
PREVIOUS	34	2	5	1	11	12	26	1	67	0	2	17	0	53
2014	16	0	10	0	6	0	46	2	69	14	1	20	47	0

A number of significant differences exist in rank designations between the previous list and the one generated by this effort. The difference in SNA (not applicable) versus SNR (not ranked) is the result of two circumstances. Previously, introduced species did not receive any consideration or designation when ranks were reviewed and updated.

In addition, a number of problematic records exist from Pennsylvania's portion of the Delaware River Estuary. The 27 species accounting for these records are primarily marine and/or estuarine forms that move up and down the estuary depending on chloride concentrations generally dictated by flow rates in the river (Horwitz 1986). Previously, these species were not assigned a rank. These species were evaluated with the calculator and life history information and records were reviewed. A determination was made that only 2 of these species are/were regular spawners in Pennsylvania's fresh waters and they are accorded the appropriate S-rank. The others are considered irregular, accidental, or non-breeders, and beyond the Commonwealth's ability to apply any significant conservation measures, and thus designated SNA.

The most important shift in rankings occurred in the categories that include the Commonwealth's most-imperiled forms. Species designated S1 through S2S3 declined from 42 to 26. This improvement illustrates a true shift in the level of endangerment for Pennsylvania fishes, and is most likely an artifact of improved water quality (particularly in the impounded section of the Ohio River drainage) and increased sampling effort. This shift also accounts to a large degree for the significant increase in S4 species designations.

It should be noted as well that some changes, primarily in the S4 and S5 ranks, do not reflect actual status changes, but are the result of differences in this ranking process from earlier efforts. Previous S-rank lists were generated based primarily on expert opinion and without the comprehensive data set available during this effort.

Also noteworthy is the SU category. Surprisingly, no species previously fell into this classification. It became clear during this evaluation that significant data gaps existed that confounded the ranking of 14 species with confidence.

The classifications generated during this evaluation were reviewed by PABS' Fishes Technical Committee prior to and during its 21 February 2014 meeting and accepted/approved with minor revisions by unanimous vote.

Table 3: Pennsylvania S-Ranks – former and 2014 (calculated and assigned).

Common Name	Genus	Species	PA Status	S-Rank Former	S-Rank Calculated 2014	S-Rank Assigned 2014
Ohio Lamprey	*Ichthyomyzon*	*bdellium*	C	S3S4	S4	S4
Northern Brook Lamprey	*Ichthyomyzon*	*fossor*	EN	S1	S1	S1
Mountain Brook Lamprey	*Ichthyomyzon*	*greeleyi*	TH	S2	S4	S4
Silver Lamprey	*Ichthyomyzon*	*unicuspis*		S1	S1	SU
Least Brook Lamprey	*Lampetra*	*aepyptera*	C	S3	S4	S4
American Brook Lamprey	*Lethenteron*	*appendix*	DL	S4	S4	S4
Sea Lamprey	*Petromyzon*	*marinus*		S4	S4	S4
Shortnose Sturgeon	*Acipenser*	*brevirostrum*	EN	S1	S2	S2
Lake Sturgeon	*Acipenser*	*fulvescens*	EN	S1	S1	S1
Atlantic Sturgeon	*Acipenser*	*oxyrhynchus*	EN	S1	S1	S1
Shovelnose Sturgeon	*Scaphirhynchus*	*platorynchus*	EX	SX	SX	SX
Paddlefish	*Polyodon*	*spathula*		SX	SX	SX
Spotted Gar	*Lepisosteus*	*oculatus*	EN	S1	S1	S1
Longnose Gar	*Lepisosteus*	*osseus*	DL	S4S5	S5	S5
Shortnose Gar	*Lepisosteus*	*platostomus*	EX	SX	SX	SX
Bowfin	*Amia*	*calva*	C	S2S3	S4	S4
Goldeye	*Hiodon*	*alosoides*	EX (DL)	SX	SX	SX
Mooneye	*Hiodon*	*tergisus*	DL	S4	S4	S4
Lady Fish	*Elops*	*saurus*		SNR	SX	SNA
American Eel	*Anguilla*	*rostrata*		S5	S4S5	S5
Bay Anchovy	*Anchoa*	*mitchilli*		SNR	S4	SNA
Blueback Herring	*Alosa*	*aestivalis*		S3S4	S1S3	S3
Skipjack Herring	*Alosa*	*chrysochloris*	DL	S4	S4	S4
Hickory Shad	*Alosa*	*mediocris*	EN	S3	S2	S2
Alewife	*Alosa*	*pseudoharengus*		S3S4	S1S3	S3
American Shad	*Alosa*	*sapidissima*		S4	S3S4	S4
Atlantic Menhaden	*Brevoortia*	*tyrannus*		SNR	S2?	SNA
Gizzard Shad	*Dorosoma*	*cepedianum*		S5	S5	S5
Central Stoneroller	*Campostoma*	*anomalum*		S5	S5	S5
Goldfish	*Carassius*	*auratus*		SNR		SNA
Northern Redbelly Dace	*Chrosomus*	*eos*	EN	S1	S1	S1
Southern Redbelly Dace	*Chrosomus*	*erythrogaster*	TH	S1	S2	S2
Mountain Redbelly Dace	*Chrosomus*	*oreas*		SNR		SNA
Redside Dace	*Clinostomus*	*elongatus*		S5	S4	S4
Rosyside Dace	*Clinostomus*	*funduloides*		S3S4	S4	S4
Grass Carp	*Ctenopharyngodon*	*idella*		SNR		SNA

Satinfin Shiner	*Cyprinella*	*analostana*		S5	S4	S4
Spotfin Shiner	*Cyprinella*	*spiloptera*		S5	S5	S5
Steelcolor Shiner	*Cyprinella*	*whipplei*		SNR	S3	SU
Common Carp	*Cyprinus*	*carpio*		SNR		SNA
Streamline Chub	*Erimystax*	*dissimilis*		S4	S4	S4S5
Gravel Chub	*Erimystax*	*x-punctatus*	EN	S1	S1	SU
Tonguetied Minnow	*Exoglossum*	*laurae*		S3S4	S4	S4
Cutlip Minnow	*Exoglossum*	*maxillingua*		S5	S5	S5
Brassy Minnow	*Hybognathus*	*hankinsoni*		SNR		SNA
Eastern Silvery Minnow	*Hybognathus*	*regius*		S4	S4	S4
Bigeye Chub	*Hybopsis*	*amblops*		S3S4	S4	S4
Bigmouth Shiner	*Hybopsis*	*dorsalis*	TH	S2	S2	S2
Ide	*Leuciscus*	*idus*		SNR		SNA
Striped Shiner	*Luxilus*	*chrysocephalus*		S5	S5	S5
Common Shiner	*Luxilus*	*cornutus*		S5	S5	S5
Redfin Shiner	*Lythrurus*	*umbratilis*	EN	S1	S3?	S2
Silver Chub	*Macrhybopsis*	*storeriana*	DL	S3S4	S4	S4
Allegheny Pearl Dace	*Margariscus*	*margarita*		S4	S4	S4
Hornyhead Chub	*Nocomis*	*biguttatus*	C	S1	S1	S1
River Chub	*Nocomis*	*micropogon*		S5	S5	S5
Golden Shiner	*Notemigonus*	*crysoleucas*		S5	S5	S5
Comely Shiner	*Notropis*	*amoenus*		S4	S4	S4
Popeye Shiner	*Notropis*	*ariommus*	EX	SX	SX	SX
Emerald Shiner	*Notropis*	*atherinoides*		S5	S5	S5
Bridle Shiner	*Notropis*	*bifrenatus*	EN	S1	S1	S1
River Shiner	*Notropis*	*blennius*	EN	S1	SU	SU
Silverjaw Minnow	*Notropis*	*buccatus*		S5	S5	S5
Ghost Shiner	*Notropis*	*buchanani*	EN	S1	S3	SU
Ironcolor Shiner	*Notropis*	*chalybaeus*	EN	S1	S1	S1
Blackchin Shiner	*Notropis*	*heterodon*	EN	S1	S1	S1
Blacknose Shiner	*Notropis*	*heterolepis*		S1	S1	SU
Spottail Shiner	*Notropis*	*hudsonius*		S5	S5	S5
Silver Shiner	*Notropis*	*photogenis*		S4	S5	S5
Swallowtail Shiner	*Notropis*	*procne*		S5	S4	S4
Rosyface Shiner	*Notropis*	*rubellus*		S5	S5	S5
Sand Shiner	*Notropis*	*stramineus*		S5	S5	S5
Mimic Shiner	*Notropis*	*volucellus*		S5	S5	S5
Channel Shiner	*Notropis*	*wickliffi*		S3	S4	S4
Pugnose Minnow	*Opsopoeodus*	*emiliae*		S1	S1	SU
Bluntnose Minnow	*Pimephales*	*notatus*		S5	S5	S5
Fathead Minnow	*Pimephales*	*promelas*		S4	S4	S4

Bullhead Minnow	*Pimephales*	*vigilax*	EX	SX	SX	SX
Blacknose Dace	*Rhinichthys*	*atratulus*		S5	S5	S5
Longnose Dace	*Rhinichthys*	*cataractae*		S5	S5	S5
Rudd	*Scardinius*	*erythrophthalmus*		SNR		SNA
Creek Chub	*Semotilus*	*atromaculatus*		S5	S5	S5
Fallfish	*Semotilus*	*corporalis*		S5	S5	S5
River Carpsucker	*Carpiodes*	*carpio*		S3S4	S4	S4
Quillback	*Carpiodes*	*cyprinus*		S5	S5	S5
Highfin Carpsucker	*Carpiodes*	*velifer*	EX	S1	S3	SU
Longnose Sucker	*Catostomus*	*catostomus*	EN	S1	S1	S1
White Sucker	*Catostomus*	*commersonii*		S5	S5	S5
Blue Sucker	*Cycleptus*	*elongatus*	EX	SX	SX	SX
Eastern Creek Chubsucker	*Erimyzon*	*oblongus*		S4	S4	S4
Lake Chubsucker	*Erimyzon*	*sucetta*	EX	SX	SX	SX
Northern Hogsucker	*Hypentelium*	*nigricans*		S5	S5	S5
Smallmouth Buffalo	*Ictiobus*	*bubalus*	DL	S4	S5	S5
Bigmouth Buffalo	*Ictiobus*	*cyprinellus*	EN	S1	S2	S1
Black Buffalo	*Ictiobus*	*niger*		S3	S3	SU
Spotted Sucker	*Minytrema*	*melanops*	TH	S1	S3	S2
Silver Redhorse	*Moxostoma*	*anisurum*		S5	S5	S5
Smallmouth Redhorse	*Moxostoma*	*breviceps*		S5	S5	S5
River Redhorse	*Moxostoma*	*carinatum*	DL	S3S4	S4	S4
Black Redhorse	*Moxostoma*	*duquesneii*		S5	S5	S5
Golden Redhorse	*Moxostoma*	*erythrurum*		S5	S5	S5
Shorthead Redhorse	*Moxostoma*	*macrolepidotum*		S5	S5	S5
White Catfish	*Ameiurus*	*catus*		S3	S1S3	S3
Black Bullhead	*Ameiurus*	*melas*	EN	S1	SX	SU
Yellow Bullhead	*Ameiurus*	*natalis*		S5	S5	S5
Brown Bullhead	*Ameiurus*	*nebulosus*		S5	S5	S5
Blue Catfish	*Ictalurus*	*furcatus*	EX	SX	SX	SX
Channel Catfish	*Ictalurus*	*punctatus*		S5	S5	S5
Mountain Madtom	*Noturus*	*eleutherus*	EN	S1	S4	S4
Stonecat	*Noturus*	*flavus*		S5	S5	S5
Tadpole Madtom	*Noturus*	*gyrinus*	EN	S1	S1	S1
Margined Madtom	*Noturus*	*insignis*		S5	S5	S5
Brindled Madtom	*Noturus*	*miurus*	TH	S2	S2?	S2
Northern Madtom	*Noturus*	*stigmosus*	EN	S2	S4	S4
Flathead Catfish	*Pylodictis*	*olivaris*		S5	S5	S5
Rainbow Smelt	*Osmerus*	*mordax*		SH	SX	SX
Longjaw Cisco	*Coregonus*	*alpenae*	EX		SX	SX
Cisco	*Coregonus*	*artedi*	EN	S1	SX	SU

Lake Whitefish	*Coregonus*	*clupeaformis*		S1	S4	S4
Pink Salmon	*Oncorhynchus*	*gorbuscha*		SNR		SNA
Coho Salmon	*Oncorhynchus*	*kisutch*		SNR		SNA
Rainbow Trout	*Oncorhynchus*	*mykiss*		SNR		SNA
Chinook Salmon	*Oncorhynchus*	*tshawytscha*		SNR		SNA
Sockeye Salmon (Kokanee)	*Oncorhynchus*	*nerka*		SNR		SNA
Atlantic Salmon	*Salmo*	*salar*		SNR		SNA
Brown Trout	*Salmo*	*trutta*		SNR		SNA
Brook Trout	*Salvelinus*	*fontinalis*		S5	S3S4	S4
Lake Trout	*Salvelinus*	*namaycush*		SH	SX	SX
Redfin Pickerel	*Esox*	*americanus americanus*		S4	S4	S4
Grass Pickerel	*Esox*	*americanus vermiculatus*		S4	S4	S4
Northern Pike	*Esox*	*lucius*		S3S4	S4	S4
Muskellunge	*Esox*	*masquinongy*		S3S4	S4	S4
Chain Pickerel	*Esox*	*niger*		S5	S5	S5
Amur Pike	*Esox*	*reichertii*		SNR		SNA
Central Mudminnow	*Umbra*	*limi*	C	S3	S4	S4
Eastern Mudminnow	*Umbra*	*pygmaea*	C	S3	S3	S3
Trout Perch	*Percopsis*	*omiscomaycus*		S4	S5	S5
Pirate Perch	*Aphredoderus*	*sayanus*	EX	SX	SX	SX
Burbot	*Lota*	*lota*		S3	S3	S3
Allegheny Burbot	*Lota*	*sp. cf. lota*	EN	SNR	S2	S2
Oyster Toadfish	*Opsanus*	*tau*		SNR	SX	SNA
Striped Mullet	*Mugil*	*cephalus*		SNR	SU	SNA
Brook Silverside	*Labidesthes*	*sicculus*	DL	S5	S5	S5
Rough Silverside	*Membras*	*martinica*		SNR	SX	SNA
Inland Silverside	*Menidia*	*beryllina*		SNR	S4	S4
Atlantic Silverside	*Menidia*	*menidia*		SNR	SU	SNA
Atlantic Needlefish	*Strongylura*	*marina*		SNR	SU	SNA
Agujon	*Tylosurus*	*acus*		SNR	SX	SNA
Eastern Banded Killifish	*Fundulus*	*diaphanus diaphanus*		S5	S5	S5
Western Banded Killifish	*Fundulus*	*diaphanus menona*		SNR	SU	SU
Mummichog	*Fundulus*	*heteroclitus*		S5	S5	S5
Striped Killifish	*Fundulus*	*majalis*		SNR	SU	SNA
Sheepshead Minnow	*Cyprinodon*	*variegatus*		SNR	SX	SNA
Western Mosquitofish	*Gambusia*	*affinis*		SNR		SNA
Eastern Mosquitofish	*Gambusia*	*holbrooki*		SNR		SNA
Fourspine Stickleback	*Apeltes*	*quadracus*		S4	SU	SU
Brook Stickleback	*Culea*	*inconstans*	C	S3	S4	S4
Threespine Stickleback	*Gasterosteus*	*aculeatus*	EN	S1	S1	S1
Northern Pipefish	*Syngnathus*	*fuscus*		SNR	SX	SNA

Mottled Sculpin	*Cottus*	*bairdii*		S5	S5	S5
Blue Ridge Sculpin	*Cottus*	*caeruleomentum*		S4	S4	S4
Slimy Sculpin	*Cottus*	*cognatus*		S5	S5	S5
Potomac Sculpin	*Cottus*	*girardi*		S4	S4	S4
Spoonhead Sculpin	*Cottus*	*ricei*	EX	SX	SX	SX
Checkered Sculpin	*Cottus*	*sp. cf. cognatus*		S1	S2	S2
Deepwater Sculpin	*Myoxocephalus*	*thompsoni*	EX	SX	SX	SX
White Perch	*Morone*	*americana*		S5	S5	S5
White Bass	*Morone*	*chrysops*		S4	S5	S5
Striped Bass	*Morone*	*saxatilis*		S4	S4	S4
Mud Sunfish	*Acantharchus*	*pomotis*	EX	SX	SX	SX
Rock Bass	*Ambloplites*	*rupestris*		S5	S5	S5
Blackbanded Sunfish	*Enneacanthus*	*chaetodon*	EX	SX	SX	SX
Bluespotted Sunfish	*Enneacanthus*	*gloriosus*		S4	S4	S4
Banded Sunfish	*Enneacanthus*	*obesus*	EN	S1	SX	SH
Redbreast Sunfish	*Lepomis*	*auritus*		S5	S5	S5
Green Sunfish	*Lepomis*	*cyanellus*		S5	S5	S5
Pumpkinseed	*Lepomis*	*gibbosus*		S5	S5	S5
Warmouth	*Lepomis*	*gulosus*	EN	S3	S4	S3
Orangespotted Sunfish	*Lepomis*	*humilis*		SNR	SU	SU
Bluegill	*Lepomis*	*macrochirus*		S5	S5	S5
Longear Sunfish	*Lepomis*	*megalotis*	EN	S1	S1	S1
Redear Sunfish	*Lepomis*	*microlophus*		SNR		SNA
Smallmouth Bass	*Micropterus*	*dolomieu*		S5	S5	S5
Spotted Bass	*Micropterus*	*punctulatus*		S4	S4	S4
Largemouth Bass	*Micropterus*	*salmoides*		S5	S5	S5
White Crappie	*Pomoxis*	*annularis*		S5	S4	S5
Black Crappie	*Pomoxis*	*nigromaculatus*		S5	S5	S5
Eastern Sand Darter	*Ammocrypta*	*pellucida*	EN	S1	S1	S1
Greenside Darter	*Etheostoma*	*blennioides*		S5	S5	S5
Rainbow Darter	*Etheostoma*	*caeruleum*		S5	S5	S5
Bluebreast Darter	*Etheostoma*	*camurum*	TH	S4	S4	S4S5
Iowa Darter	*Etheostoma*	*exile*	EN	S1	S2	S2
Fantail Darter	*Etheostoma*	*flabellare*		S5	S5	S5
Swamp Darter	*Etheostoma*	*fusiforme*	EX	SX	SX	SX
Spotted Darter	*Etheostoma*	*maculatum*	TH	S2	S4	S4
Johnny Darter	*Etheostoma*	*nigrum*		S5	S5	S5
Tessellated Darter	*Etheostoma*	*olmstedi*		S5	S5	S5
Tippecanoe Darter	*Etheostoma*	*tippecanoe*	TH	S3S4	S4	S4
Variegate Darter	*Etheostoma*	*variatum*		S5	S5	S5
Banded Darter	*Etheostoma*	*zonale*		S5	S5	S5

Yellow Perch	*Perca*	*flavescens*		S5	S5	S5
Chesapeake Logperch	*Percina*	*bimaculata*	TH	S1S2	S1	S1
Logperch	*Percina*	*caprodes*		S5	S5	S5
Channel Darter	*Percina*	*copelandi*	DL	S4	S5	S5
Gilt Darter	*Percina*	*evides*	TH	S1S2	S4	S4
Longhead Darter	*Percina*	*macrocephala*	DL	S3	S4	S4
Blackside Darter	*Percina*	*maculata*		S5	S5	S5
Sharpnose Darter	*Percina*	*oxyrhynchus*	EX	SX	SX	SX
Shield Darter	*Percina*	*peltata*		S5	S5	S5
River Darter	*Percina*	*shumardi*		S1	S4	S4
Sauger	*Sander*	*canadensis*		S4	S4	S4
Walleye	*Sander*	*vitreus*		S5	S5	S5
Blue Pike	*Sander*	*vitreus glaucus*	EX	SX	SX	SX
Bluefish	*Pomatomus*	*saltatrix*		SNR	SU	SNA
Florida Pompano	*Trachinotus*	*carolinus*		SNR	SX	SNA
Gray Snapper	*Lutjanus*	*griseus*		SNR	SX	SNA
Freshwater Drum	*Aplodinotus*	*grunniens*		S5	S5	S5
Silver Perch	*Bairdiella*	*chrysoura*		SNR	SX	SNA
Weakfish	*Cynoscion*	*regalis*		SNR	SU	SNA
Spot	*Leiostomus*	*xanthurus*		SNR	SU	SNA
Atlantic Croaker	*Micropogonias*	*undulatus*		SNR	SU	SNA
Blue Tilapia	*Oreochromis*	*aureus*		SNR		SNA
Round Goby	*Neogobius*	*melanostomus*		SNR		SNA
Naked Goby	*Gobiosoma*	*bosc*		SNR	SU	SNA
Tubenose Goby*	*Proterorhinus*	*semilunaris*		SNR		SNA
Northern Snakehead	*Channa*	*argus*		SNR		SNA
Windowpane	*Scophthalmus*	*aquosus*		SNR	SX	SNA
Smallmouth Flounder	*Etropus*	*microstomus*		SNR	SX	SNA
Summer Flounder	*Paralichthys*	*dentatus*		SNR	SX	SNA
Winter Flounder	*Pseudopleuronectes*	*americanus*		SNR	SX	SNA
Hogchoker	*Trinectes*	*maculatus*		SNR	SU	SNA

Conclusions and Recommendations

The rank calculator provides an effective, efficient, and defensible process for the consideration and designation of species conservation rankings at the state level. During this evaluation it also led to the development of recommendations for a number of species of high or immediate concern.

Several species that are currently listed as endangered or threatened, including Gravel Chub (*Erimystax x-punctatus*), Black Bullhead (*Ameiurus melas*), and Threespine Stickleback (*Gasterosteus aculeatus*) have apparently not been collected in recent years, and status surveys are urgently needed. Survey work is required to better delineate the current range and population condition of Longear Sunfish

(*Lepomis megalotis*), Brindled Madtom (*Noturus miurus*), and Spotted Sucker (*Minytrema melanops*) as well.

Species that are listed as candidate, or not currently listed, but are evidently extremely rare should also be considered for status surveys. These include Silver Lamprey (*Ichthyomyzon* unicuspis), Hornyhead Chub (*Nocomis biguttatus*), Blacknose Shiner (*Notropis* heterolepis), Pugnose Minnow (*Opsopoedus emiliae*), and Fourspine Stickleback (*Apeltes quadracus*).

Specimens of the Orangespotted Sunfish (*Lepomis humilis*) from southwestern Pennsylvania were examined and verified during the ranking revision period, and represent the first records for the state. Survey work is needed to determine if populations of this species are extant and to make a better-informed decision regarding its status as a native species.

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Members of PABS' Fishes Technical Committee reviewed the final status assignments. They are D. Argent (California University of PA), D. Fisher (PFBC), R. Horwitz (Academy of Natural Sciences – Philadelphia), B. Porter (Duquesne University), R. Spear (PA Dept. of Environmental Protection), and J. Stauffer, Jr. (Pennsylvania State University).

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Note: The following Appendices for this report are not included here due to technical constraints with displaying the tables at a viewable scale. However, summary tables of SGCN species (i.e., add, maintain, delete, data deficient) with justifications are provided in Chapter 1, Appendix 1.3 of this Plan. For 2015 SGCN, information on Threats, Conservation Actions, Monitoring and Surveying is provided in the Chapter 1, Appendix 1.4 (Species Accounts).

Appendix A. State Conservation Ranks-Pennsylvania Fishes-2014.

Appendix B. Pennsylvania Fishes Threats Table – 2014.

Appendix C. Fish Species Assessment Table.

Appendix D. NatureServe© Conservation Status Ranking Factors: Summary.

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Appendix 1.1E. Invertebrates

Invertebrate Assessment for the 2015 Pennsylvania Wildlife Action Plan Revision

Final report for State Wildlife Grant F14AF00255 to the Pennsylvania Fish and Boat Commission

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15 May 2015

TABLE OF CONTENTS

Note: The following Appendices for this report are not included due to technical constraints with displaying the tables at a viewable scale. However, summary tables of SGCN species (i.e., add, maintain, delete, data deficient) with justifications are provided in Chapter 1, Appendix 1.3 of this Plan. An overview of Threats, Conservation Actions, and Monitoring is discussed in the report. Federal or State-listed mussel species are included in the Species Accounts Appendix 1.4. Appendices 7, 8, and 9 in the original report included Conservation Actions at the Level 2 code and have been summarized in Chapter 4, Appendix 4.2-Exhibit 7 at the Level 1 code.

An abbreviated version of Appendix 5 is provided below (after the References and Data Sources).

Appendix 1. Invertebrate species assigned to the "Add" category

Appendix 2. Invertebrate species assigned to the “Maintain” category

Appendix 3. Invertebrate species assigned to the “Delete” category

Appendix 4. Invertebrate species assigned to the “Extirpated” category

Appendix 6a. 2005 SWAP species reassigned to the “Data Deficient” category

Appendix 6b. Newly assessed species assigned to the “Data Deficient” category

Appendix 7. Conservation actions recommended for SGCN invertebrate species

Appendix 8. Conservation actions recommended for family groups

Appendix 9. Conservation actions recommended for informal taxa groups

LIST OF TABLES AND FIGURES

INTRODUCTION

Pennsylvania's State Wildlife Action Plan (SWAP) is a comprehensive strategy for the management and protection of game and non-game species in the Commonwealth. The previous SWAP, published in 2005, addressed the conservation needs of Pennsylvania's wildlife, including mammals, birds, reptiles, amphibians, fish, and invertebrates. Since its inception, the plan's priorities were advanced by the agencies charged with regulating and protecting the Commonwealth's wildlife, the Pennsylvania Fish and Boat Commission (PFBC) and the Pennsylvania Game Commission (PGC).

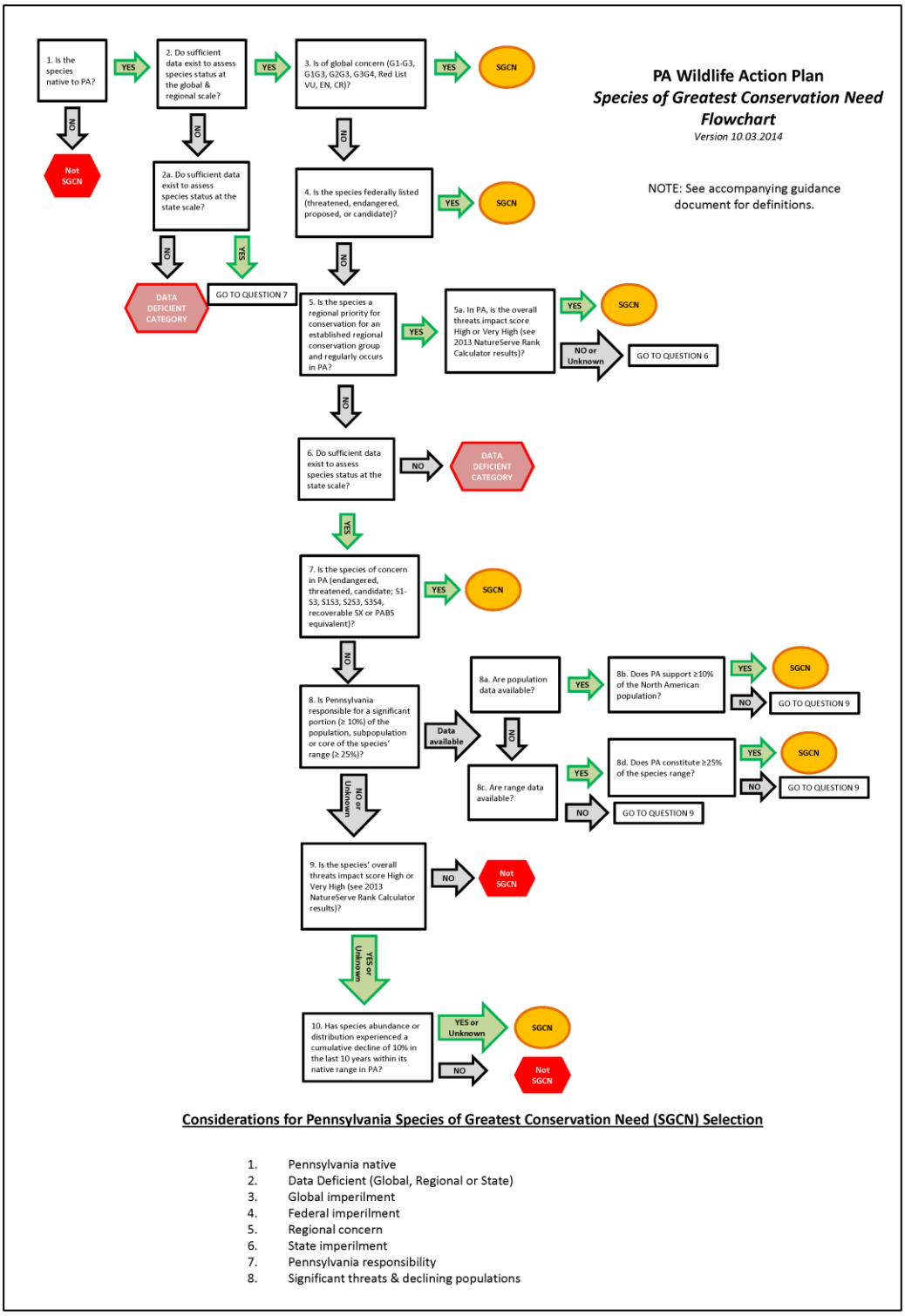
In order to continue to receive federal State Wildlife Grant funding, PFBC and the PGC must update the SWAP every 10 years. The newest edition of the SWAP will be published in late 2015. It will revise management planning for Pennsylvania's wildlife, direct the agencies' programs over the next decade, and will guide funding for future projects through the SWG program.

The SWAP compiles information from scientific experts across wildlife disciplines to determine the highest priority research, management and recovery actions for species and their habitats. To that end, the goal of this project was to prioritize invertebrates in the 2015 Pennsylvania State Wildlife Action Plan for conservation action. The Species of Greatest Conservation Need (SGCN) invertebrates identified for the 2015 plan include species of aquatic, semi-aquatic and terrestrial habitats. Selected species from the following informal taxonomic groups were evaluated. These groups had the most available information about conservation status.

> Aquatic and semi-aquatic invertebrates: Caddisflies, Cave invertebrates (Amphipods, Isopods, Springtails, and Flatworms), Crane flies, Crayfish, Dragonflies and Damselflies, Mayflies, Sponges, and Stoneflies
>
> Mollusks: Aquatic Snails, Terrestrial Snails, and Freshwater Mussels
>
> Terrestrial invertebrates: Bees, Beetles, Butterflies and Moths, Grasshoppers, Sawflies, Spiders, and True Bugs

The process of evaluating invertebrates for inclusion in the 2015 SWAP update differed from the original SWAP. In the 2005 SWAP, SGCN invertebrates of high conservation value were determined according to experts' best professional judgment (Rawlins 2007). In the 2015 SWAP, all SGCN species from the original plan, plus selected additional species, were evaluated against explicit criteria in the PA Wildlife Action Plan Species of Greatest Conservation Need Flowchart (SGCN) (Figure 1).

Figure 1. The PA Wildlife Action Plan Species of Greatest Conservation Need Flow chart (Version 10/3/2014) was used to evaluate invertebrates for the 2015 SWAP.



METHODS

Taxonomic experts from the Pennsylvania Biological Survey who participate in the Aquatic Arthropod, Arachnid, Mollusk, and/or Terrestrial Arthropod technical committees provided data and either took the lead with the assessment process as in the case of the terrestrial snails and stoneflies, or lent assistance to the PA Natural Heritage Program staff leading the review. The technical committees in their entirety, or members of them, gave feedback about the ranks and SGCN statuses that resulted from the assessment. For most invertebrate taxa groups however, no or few PABS experts exist to provide review.

Information for the SGCN evaluation, including global and regional rarity, locations of species populations (called occurrences), local and regional range and distribution, abundance, population trends, habitats, and threats, was gathered from Pennsylvania Natural Heritage Program projects and databases, scientific literature, white papers, and other data sources. In some cases, invertebrate experts from state agencies, museums, or non-profit organizations provided data and consulted on or conducted the species assessments. The review of invertebrates for the 2015 SWAP determined the following:

- Species categorized as a SGCN in the 2005 SWAP that should continue to be rated SGCN in 2015 (Maintain category)
- Species that are considered SGCN in 2015 but were not included in the 2005 SWAP (Add category)
- Species rated SGCN in 2005 that do not meet the SGCN criteria in 2015 (Deleted category)
- Species that lack sufficient information to assess for the 2015 SWAP (Data Deficient category)

Species that were not considered SGCN in 2015 included those that:

- Were evaluated to have a state conservation rank of S4 (apparently secure) or S5 (secure)
- Are considered extirpated in Pennsylvania with no realistic hope for recovery
- Do not have regularly occurring breeding populations, even though they may occasionally be found in the Commonwealth
- Were already evaluated under another name (e.g., due to a change in nomenclature, redundant listing under a junior synonym, or listing of both a subspecies and its parent species when there is only one subspecies in the state).

Using the process and the criteria outlined in the methods section for each taxonomic group, we reviewed a total of 750 species including all species listed as SGCN in the 2005 SWAP and 325 other species not previously considered SCGN. The criteria from the PA Wildlife Action Plan Species of Greatest Conservation Need Flow Chart (Figure 1) provided the basis for selecting invertebrates for conservation. Species which were determined to be native to the Commonwealth (Question 1) and for which there was sufficient information to assess their status in Pennsylvania (Question 2) were

evaluated using the other flow chart criteria (e.g., Global Imperilment, Federal Imperilment, Regional Concern, State Imperilment, Pennsylvania Responsibility, and Significant Threats - Population Decline).

The subnational ranks (S-ranks, Question 7) and the threat impact score (Question 5a and 9) were determined using the NatureServe Rank Calculator (Version 3.1, Faber-Langendoen *et al*. 2012; Master *et al*. 2012) for most of the invertebrates evaluated. The NatureServe Rank Calculator uses categories about the range and distribution (Range Extent or Area of Occupancy), the abundance and condition of the populations (Number of Occurrences, Population Size, Number of Occurrences with Good Viability or Ecological Integrity, or Percent Area Occupied with Good Viability), the threats, and/or population trends (Short-term trend or Long-term Trend) to calculate an S-rank.

The S-ranks defined by NatureServe describe an element's risk of extirpation from a subnation, in this case, the Commonwealth of Pennsylvania:

S1 = critically imperiled
S2 = imperiled
S3 = vulnerable
S4 = apparently secure
S5 = secure

Due to uncertainty about the status of some species, the ranks span a range (e.g., S1S2 or S1S3). Other S-ranks include special cases such as:

SX = extirpated (virtually no likelihood of rediscovery)
SH = possibly extirpated (known only from historical occurrences, but still some hope of rediscovery)
S#S# = range rank (used to indicate uncertainly about status, no more than 2 degrees of separation is considered valid)
SU – un-rankable (lack of data or conflicting information about status or trends)
SNA = not applicable (species is not a suitable target for conservation activities, e.g., non-native or transient species)

Threats that contribute to a species' decline and potential for extirpation were incorporated into the S-rank calculation. The NatureServe Rank Calculator offers two methods to quantify the threats faced by a species. Intrinsic Vulnerability is used to assign a categorical score of Not Intrinsically Vulnerable, Moderately Vulnerable, or Highly Vulnerable based on best professional judgment. Alternatively, a detailed threats table can be used to assess the scope, severity, and timing of forty specific 'Level 2' threats which are subsequently consolidated into eleven broad 'Level 1' threats. The Level 1 threats are then combined to calculate an Overall Threat Impact level of Low, Medium, High, and Very High. Definitions of threats as applied in this assessment are provided on The Open Standards for the Practice of Conservation website.

NatureServe Rank Calculator Level 1 Threat Categories

1) Residential and commercial development
2) Agriculture and aquaculture
3) Energy production and mining
4) Transportation and service corridors
5) Biological resource use
6) Human intrusions and disturbance
7) Natural system modifications
8) Invasive and other problematic species and genes
9) Pollution
10) Geologic events
11) Climate change and severe weather

Taxa groups evaluated for the 2015 Wildlife Action Plan

The following methods used to evaluate invertebrate species for the 2015 SWAP were adapted within taxonomic groups to reflect the data and expertise that were available for the various groups. The following sections describe details of the SWAP assessment that are specific to each informal taxonomic group.

Aquatic Arthropods, Semi-aquatic Arthropods, Flatworms, and Sponges

Caddisfles (Order Trichoptera)

The six caddisflies rated as SGCN in the 2005 SWAP were reviewed. Occurrence information for seven species in the Pennsylvania Aquatic Flies database, which included data collected and compiled by Ed Masteller (retired Professor of Biology, Penn State University, Behrend), was used to determine Range Extent for the NatureServe Rank Calculator Rarity factor. Scientific literature (Masteller, E.C. and O.S. Flint. 1992; Houghton, D.C. 2012) and consultation with Ed Masteller refined the assessments. To determine the S-ranks, the Range Extent was calculated as the summed area of occupied HUC-8s.

Cave Invertebrates – Amphipods (Orders Amphipoda), Isopods (Order Isopoda), Flatworms (Phylum Platyhelminthes), and Springtails (Order Collembola)

The conservation status of cave invertebrates (including some Amphipods, Isopods, and Flatworms) was evaluated based on information from two data sources and consultation with an academic expert. Species occurrence information was compiled from datasets from experts (David Culver and Daniel Fong) at American University and the Biotics Database, Pennsylvania Natural Heritage Program. Three isopods, nine amphipods and one flatworm, *Sphalloplana pricei*, were evaluated for the SGCN list. David Culver provided some advice for the assessments.

Literature also provided data about two species of recently described cave-adapted invertebrates. Holsinger *et al*. (2008) described the amphipod *Gammarus cohabitus*, and Christiansen and Wang (2006) described the Heller's Cave Springtail *Typhlogastrura helleri*. Range Extent and Threats were evaluated

for the amphipod, while Range Extent, Area of Occupancy, Threats, and Environmental Specificity were evaluated for the springtail in the Rank Calculator.

Crane Flies (Order Diptera, family Tipulidae)

Limited distributional data are available for many of Pennsylvania's more than 300 species of crane flies, and there are probably many species that have not been documented yet. One crane fly was identified as a SGCN in the 2005 SWAP. Chen Young of the Carnegie Museum of Natural History recommended 2 additional species for consideration, based on their rarity and reliance on pristine spring-fed headwaters streams. An Environmental Specificity value of 'Very Narrow to Narrow' was assigned to all three species because of the limited availability of this habitat type. Threat levels ranging from 'Medium to Very High', to 'High to Very High' were assigned because of the vulnerability of these pristine streams to degradation from a variety of land uses.

Crayfish (Order Decapoda, Family Cambaridae)

Three SGCN crayfish species from the 2005 SWAP (*Cambarus carolinus, Cambarus monongalensis, and Orconectes propinquus*) were reevaluated for the 2015 SWAP. One of those three species (*Cambarus carolinus*) was immediately removed from consideration because it does not occur in Pennsylvania and was mistakenly included in the 2005 SWAP. Eleven additional crayfish mentioned in the original SWAP were also evaluated. The Rarity (Range Extent), Threats, and Trend (Long-Term Trend) factors were used in the Nature Serve Rank Calculator. Evaluations relied primarily on data and information from the following sources: Ortmann (1906), Crocker (1957), Schwartz *et al*. (1963), Hobbs and Bouchard (1973), Hobbs (1989), Taylor *et al.* (2007), Bouchard *et al*. (2007), Kuhlmann and Hazelton (2007), Loughman *et al.* (2009), Loughman and Welsh (2010), Kilian *et al.* (2010), Swecker *et al*. (2010), Lieb (2011), Lieb *et al.* (2011a), and Lieb *et al.* (2011b).

Dragonflies and Damselflies (Order Odonata)

A total of 106 species of Odonata, out of Pennsylvania's 181 species, were assessed. These species include all dragonfly and damselfly species of concern in the 2005 SWAP, as well as any that have been ranked S3S4 or rarer at any time since 2005. Three main data sources include the Pennsylvania Odonate Database compiled by PNHP, PNHP records from Biotics, and Odonata Central. A small number of additional records were gathered from various researchers. Many of the records are based on captures of single adults, which do not necessarily represent breeding habitat. Given the sparseness of records in many parts of the state, it is likely that these points are correcting errors of omission much more often than they are creating errors of commission, so they were generally included in the analysis.

To determine the rarity factor for the NatureServe Rank Calculator, Range Extent and, in a few cases, Area of Occupancy, were calculated. In estimating Range Extent, data from 30 years ago or more recent was used. This long time frame was necessary to have enough data. Range Extent was calculated as the area of 8-digit hydrologic units (HUC8s). Recognizing that our range data are far from complete, the possibility that the Range Extent would extend into the next largest category was sometimes allowed. This judgment was based on species biology, habitat availability, survey density, and nearby records from adjacent states. Area of Occupancy was not calculated for most species. For a few species that are

restricted to larger rivers in small geographic areas, an upper bound for Area of Occupancy was calculated by considering the total amount of possible habitat within the known range.

Mayflies (Order Ephemeroptera)

Information was gathered about six mayflies that were ranked as SGCN species in the previous SWAP and five additional species suspected to have a high priority conservation status. Occurrence information was used to determine the Range Extent for the NatureServe Rank Calculator. Personal communication with David Funk (Stroud Water Research Center) and David Rebuck (Pennsylvania Department of Environmental Protection) about species occurrences supplemented information from the *Biodiversity of Mayflies (Ephemeroptera) of Pennsylvania* report (Hoover 2000). The NatureServe Rank Calculator Range Extent rarity factor (estimated as the summed area of occupied HUC-8s) and threats were used to determine S-ranks.

Sponges (Phyllum Porifera, Family Spongillidae)

Two species from the Spongillidae family were considered for the SWAP Plan. The Biotics Database, Pennsylvania Natural Heritage Program and two books (Smith 2001; Thorp and Covich 2010) on invertebrates were referenced for information about the sponges. There has been little study of the species distributions or populations and there are no known experts or data on Pennsylvania distributions. While one sponge was rated SCGN, another was not further considered for SGCN status because of data deficiency. Neither species had enough information for assessment in the NatureServe Rank Calculator.

Stoneflies (Order Plecoptera)

The assessment of 27 stoneflies was completed mainly by Jane Earle (retired Pennsylvania Department of Environmental Protection biologist). Jane Earle's collection of stoneflies is the most comprehensive documentation of the group for the state. Additionally, she provided a complete species state list of Pennsylvania stoneflies. The occurrence data were converted to Range Extent values (summed area of occupied HUC-8s) for the NatureServe Rank Calculator Rarity factor and threats were assessed.

Mollusks

Aquatic Snails (Class Gastropoda)

Robert Dillon of the College of Charleston provided a large dataset, for which he examined and identified nearly all of the Pennsylvania aquatic snail specimens available in regional collections, including those from Ray and Evans (2008) and many recent collections made by Dillon. This dataset is by far the most complete available, and therefore we followed this taxonomy, which lumps together many taxa that were considered separate species in the 2005 SWAP. A total of 16 freshwater snail species were evaluated for the 2015 SWAP.

To estimate the Rarity factor in the NatureServe Rank Calculator, Range Extent and sometimes Area of Occupancy were calculated for data collected within the last 30 years. Given the scarcity of aquatic snail records, occurrence information from a long time frame was needed. The area of Range Extent was calculated as the area of occupied 8-digit HUCs. In some cases, Range Extent was estimated to be the

next largest area category because the range data are far from complete. This was based on best professional judgment considering species biology, habitat availability, survey density, and nearby records from adjacent states.

For species that are restricted to streams that are 3rd order and larger, an upper bound for Area of Occupancy was calculated by considering the total length of streams of the appropriate size (determined by examining Pennsylvania records) within the occupied HUC 8 range.

Freshwater Mussels (Order Unionoida, Families Unionidae and Margaritiferidae)

All of the 66 native freshwater mussels were evaluated. The best available distribution information for the Rank Calculator was used to analyze Area of Occupancy Rarity factor and Threats. GIS shapefiles from the PNHP Mussel Database for Pennsylvania (updated 30 June 2013) and PNHP Biotics served as the primary data sources. Recent published and unpublished reports were used to fill in data gaps, where appropriate. To determine the S-ranks, the Rarity factor in the NatureServe Rank Calculator was estimated as the summed area of occupied HUC-8s. The results were presented to the Bivalve Subcommittee of the Mollusk Committee, who suggested modifications and formally approved the conservation ranks that were assigned to freshwater mussels during the SWAP assessment.

Terrestrial Snails (Class Gastropoda)

Tim Pearce, Assistant Curator and Head of the Section of Mollusks at the Carnegie Museum of Natural History, conducted the terrestrial snail assessment which included land snails and slugs. Pearce evaluated the 42 species from the 2005 SWAP that were the priority for review. He also evaluated an additional 153 species that were reported to occur presently or historically within Pennsylvania.

NatureServe's Rank Calculator was used to generate a state conservation rank. The NatureServe Rank Calculator rarity factor was estimated with Range Extent, Area of Occupancy (using 4 km^2 grid cells), and Number of Occurrences; the trends factor (Long Term Trend) was also assessed. Records from 2000 to present were considered extant. Long term trends were evaluated by comparing records that were 2000 or older against records from 2000 to present. There is a big collecting gap for land snails in Pennsylvania between 1960 and 2000. The majority of records prior to 2000 were actually collected prior to 1960, with very little additional data collected for the next 40 years. Evaluations were conducted on a compilation of approximately 17,472 records gathered from eight major museums:

- American Museum of Natural History in New York, NY
- Academy of Natural Science of Drexel University in Philadelphia, PA
- Carnegie Museum of Natural History in Pittsburgh, PA
- Delaware Museum of Natural History in Wilmington, DE
- Florida Museum of Natural History in Gainesville, FL
- The Field Museum in Chicago, IL
- Harvard University Museum of Comparative Zoology in Cambridge, MA
- Smithsonian Institution National Museum of Natural History in Washington DC
- The Ohio State University Museum of Biological Diversity in Columbus, OH

- University of Michigan Museum of Zoology in Ann Arbor, MI

The threat assessment of terrestrial snails differed somewhat from the other invertebrate taxon evaluated for the updated SWAP. Given the number of species to be reviewed and the scarcity of information on habitat requirements, and therefore potential threats, the Overall Threat Impact was directly assigned rather than calculated using the detailed threats assessment worksheet in the Rank Calculator. This approach is acceptable according to Rank Calculator protocols especially when applied to species thought to be under a low overall threat level. In the case of terrestrial snails, an Overall Threat Impact score of 'unknown' was initially assigned. Selecting an 'unknown' threat score causes 'high' or 'very high' threat levels to be incorporated into the threat calculation. This drives the species overall state rank towards greater imperilment, typically by one step (e.g., from S4 to S3). While threats are not well understood for terrestrial snails, assigning 'unknown' as the threat level causes common species to appear more threatened than what seems appropriate using best professional judgment. After further consideration and review of the threats assessment, a threat level of 'low' was assigned to the majority of terrestrial snail species. In order to provide more information on the potential threats to terrestrial snails in Pennsylvania, the three most clear and ubiquitous threats to terrestrial snails were identified and defined in such a way that they apply to all the SGCN species.

Terrestrial Arthropods

Bees (Order Hymenoptera, Superfamily Apoidea)

Three bumblebees and one mining bee were evaluated for SGCN status. The Xerces Society for Invertebrate Conservation provided data on *Bombus affinis*, *B. terricola*, and *B. ashtoni* specimens from Pennsylvania, and their 2008 report (Evans *et al*.) includes an analysis of the conservation status of these species. Arduser *et al*. (2010) list a number of bee species not seen in the eastern United States in the last 20 years, and Donovall and vanEngelsdorp (2010) establish that one of those 'missing species', *Andrena daeckii*, was recently found in Pennsylvania. This species is probably globally rare, although not enough information is available to determine a conservation rank. Many of Pennsylvania's native bees probably should be species of conservation concern, but additional survey efforts will be needed to determine conservation ranks.

Beetles (Order Coleoptera)

Sixteen species of tiger beetles (Cicindelidae) were assessed. Data were collected from the Biotics database of PNHP, literature records, and personal communications from various local naturalists. Twelve species were recognized as SGCN in the 2005 SWAP, and five of those species are not SGCN in the 2015 SWAP. *Cicindela rufiventris, C. tranquebarica,* and *C. limbalis* were not rated as SGCN for the 2015 SWAP because they are more secure than previously thought, while *C. scutellaris* and *Tetracha virginica* were not considered for SGCN status because no solid evidence of their historic presence in Pennsylvania could be found, though it is possible that either species could have been (or still is) in Pennsylvania. The main factors contributing to the SGCN status of the remaining species include small range extents, Regional Species of Greatest Conservation Need (RSGCN) status, rarity of barrens habitats, and/or globally rarity (e.g., *C. marginipennis, C. lepida, C. patruela,* and *C. ancocisconensis*).

An unnamed endemic cave-adapted carabid beetle in the *Pseudanopthalmus gracilis* species complex is known from a single cave in Fayette County. A manuscript describing this species was in the final stages of preparation by Dr. Thomas Barr, Professor Emeritus at the University of Kentucky, at the time of his death. The specimens and the manuscript are now in the hands of Bob Davidson, Carnegie Museum of Natural History. Specimens of this beetle were collected from the cave in the 1950's and 1960's but the beetle has not been observed there since that time. The cave at the type location has been more or less mined away, and mining operations there are continuing.

Dryobius sexnotatus (Cerambycidae) is a regionally rare specialist on very large sugar maple trees. It has been declining for many decades as appropriate host trees have become less common. PNHP has several historic records of this species. A single 2009 record at BugGuide.org, and correspondence with the observer, has led to the conclusion that this species is still extant in Pennsylvania.

Nicrophorus americanus (Silphidae) is a federally-listed burying beetle that was historically present in Pennsylvania. No recent Pennsylvania records have been reported, but ongoing recovery efforts for this species leave open the possibility that it may return to Pennsylvania. *Nicrophorus marginatus* (Silphidae) and *Lordithon niger* (Staphylinidae) were historically present in Pennsylvania. These have experienced severe regional declines and there here have been no new Pennsylvania records in many decades, so these species are considered extirpated and unrecoverable, and are not SGCN.

Butterflies and Moths (Order Lepidoptera)

The 2005 SWAP listed 111 moths and 69 butterflies as SGCN (Rawlins 2007). An additional seven moths and 6 butterflies were listed as extirpated in the state in the 2005 SWAP. PA Natural Heritage Program staff worked with members of the Terrestrial Arthropod Technical Committee (TATC) of the Pennsylvania Biological Survey to conduct the Lepidoptera assessment. SGCN and extirpated Lepidoptera from the 2005 SWAP were the priority for review. There were no RSGCN Lepidoptera species to evaluate. An additional 13 butterflies and 29 moths were newly evaluated, including seven ash-dependent species of moths now facing extensive loss of their host trees due to the exotic invasive emerald ash borer beetle (*Agrilus planipennis*). The monarch butterfly (*Danaus plexxipus*) was also evaluated due to growing concerns over the status of the North American migratory population and a recent petition for protection under the Endangered Species Act (Center for Biological Diversity *et al.* 2014).

NatureServe's Rank Calculator (version 3) and methodology (Master *et al*. 2012) were used to evaluate butterfly species and generate a state conservation rank. The main factors used in calculating ranks were Range Extent, Number of Occurrences, Long and Short Term Trends, and Threats. Extant records (1995 or later) were used to evaluate Number of Occurrences and Range Extent. Range Extent was evaluated using extant records at the county level, which was the finest common scale available for records across all evaluated datasets. Two published resources were especially helpful in the overall evaluation of species by providing up to date information on habitat, host plant, trends, environmental specificity, and/or threats. These were Butterflies of the East Coast (Cech and Tudor 2005) and Rare,

Declining, and Poorly Known Butterflies and Moths (Lepidoptera) of Forests and Woodlands in the Eastern United States (Schweitzer *et al*. 2011).

The year 1995 was used as the cut-off between extant and historical records. This was the first year the *Atlas of Pennsylvania Butterflies* was published (Wright 1995), which sparked interest among hobbyists in documenting county records of butterflies in the state. The first *Butterflies through Binoculars* book was also released around this time (Glassberg 1993). This field guide captured the attention of amateur naturalists, including many birders, by providing a tool for identifying butterflies that did not require collecting them. The regional focus of this book was another important feature, because it greatly reduced the number of species one had to consider in order to make an identification. Since that time, additional regional guides featuring high quality images of live butterflies have been published (e.g., Glassberg 1999 and Cech and Tudor 2005). The seminal *Field Guide to Moths of Eastern North America* (Covell 1984) with a mix of black and white and color images of spread moth specimens now has a companion which features photos of live individuals in natural positions (Beadle and Leckie 2012). Caterpillars have also received greater attention with several excellent guides (e.g., Wagner 2005 and Wagner *et al*. 2011). The development of online websites and electronic mailing lists has made it much easier to obtain help on identifications and share findings. Together these resources have increased the popularity of looking for butterflies and moths in the state over the last 20 years.

Number of Occurrences is an important component of generating a state rank, but several issues were identified with this factor. First, despite increased interest in recent years, surveys for Pennsylvania's butterflies and moths are still far from comprehensive. Some species are difficult to find because of their behavior or their use of specialized or hard to access habitats. Others species are very difficult to identify. In most cases it is expected that there are more occurrences than are currently known. Second, there is variability in the scale at which records are reported. Some records are only reported at the county level while others are reported at the site level. Finally, various datasets may contain overlapping records, but when those records are reported at different levels of detail it becomes difficult to resolve which records are identical and which are unique.

Leaving the Number of Occurrences field as 'unknown' was found to raise the overall calculated state rank of many species of special concern by a half or whole step (e.g., from S2 to S3), compared with entering a number based on an educated estimate. The S-rank methodology for Lepidoptera conducted prior to release of the NatureServe Rank Calculator utilized an estimated Number of Occurrences, so for consistency it was determined that Number of Occurrences should be reflected in this analysis as well. Based on a review of 504 records in the Pennsylvania Natural Heritage Program dataset (2014), 42 SGCN butterflies averaged 1.5 occurrences per county with known occurrences. There are no redundant records in this dataset. In a separate review of 229 records in the Butterflies and Moths of North America dataset (Opler *et al*. 2012), the same 42 SGCN butterflies averaged 1.1 occurrences per county with occurrence records. Obviously redundant records were removed from this dataset prior to analysis. Better surveyed counties often had more occurrences, but still typically less than five per SGCN species. A range in Number of Occurrences was created to account for the likelihood that more populations exist

than are currently known. The number of extant counties was used to set the low end of the range, and the number of extant counties multiplied by 5 was used to set the high end of the range. This estimate was reviewed against the actual number of unique occurrences that could be counted. In all cases the upper end of the estimated range exceeded the number of documented extant occurrences, even when all potentially redundant records occurring across multiple datasets were included.

Long term trends were evaluated by comparing pre-1995 data with post-1995 data, as shown in a supplement to the 13th Edition of the *Atlas of Pennsylvania Butterflies* (Wright 2014b). Short term trends were evaluated by looking at how many new extant counties were added to the PA Lep Atlas for a species between the 1st edition in 1995 and the 13th edition in 2014. Nearly all species had one or more extant counties added, but to a great extent this reflects increased survey effort and reporting. Discoveries of populations of Lepidoptera that likely existed at a site for decades should not be considered new occurrences or a sign of population increase and expansion. However, some species such as the Giant Swallowtail (*Papilio cresphontes*) do appear to be expanding their range. The percent increase in extant counties between 1995 and 2014 was used to set a relative scale to help identify species that were potentially expanding their range in the state. Most butterflies that were SGCN in 2005 were evaluated as having a rate of short term decline equal to or slower than the rate of long term decline. However, thirteen species were flagged as likely having an increasing short term trend. The number of extant counties documented for these species increased by more than 100% in the past 20 years: *Euphyes conspicuus*, *Anthocharis midea*, *Parrhasius m-album*, *Nastra lherminier*, *Papilio cresphontes*, *Chlosyne nycteis*, *Callophrys niphon*, *Eurytides marcellus*, *Satyrium edwardsii*, *Feniseca tarquinius*, *Lycaena hyllus*, *Polygonia progne*, and *Thorybes bathyllus*.

Overall, the moths of Pennsylvania have not been as well surveyed and documented as their day-flying butterfly counterparts, with the exception perhaps of the large and showy members of the sphinx/hawk moth family (Sphingidae) and the giant silkworm and royal moth family (Saturniidae). A total of 147 species of moths were evaluated for the current SWAP. This is approximately 10% of the 1,500+ species of micro and macro moths currently known to occur in Pennsylvania. Many moth species have not been evaluated for their conservation status in the state because their life history and distribution are poorly known. Moths selected for review were treated in the same manner as butterflies, with the exception that short and long term trends were not evaluated for most species. *A Manual of the Lepidoptera of Pennsylvania* (Tietz, 1954) was used as a reference for the historical presence and distribution of moths in Pennsylvania, but was not applied as a gauge of species trends over time. Conversion of this information into a digital data set would be useful so that it could be incorporated into a trend analysis. Additional efforts to systematically gather moth data from museums and other sources would help provide a more complete historical picture as well.

The Overall Threat Impact for most Lepidoptera was calculated using the detailed threats assessment worksheet in the NatureServe Rank Calculator. Eight SGCN moths were originally flagged as having threats unknown, but were later directly assigned an overall threat rank (*Elaphria georgei*, *Hydraecia stramentosa*, *Nemoria tuscarora*, *Papaipema marginidens*, *Parahypenodes quadralis*, *Parapamea*

buffaloensis, *Stamnodes gibbicostata*, *Sthenopis auratus*). These species were assigned a threat of 'High – Low' in place of 'Unknown' because selecting 'U = Unknown' for the threat level causes the calculator to include 'Very High' as the upper end of the potential threat range. This drove the overall state rank for each species towards greater imperilment, typically by one step (e.g., from S4 to S3). Since no potential threats for these eight species was expected to be 'Very High', that level was removed from the threat range. For these eight species, a threat level of 'High – Low' was used as a refined surrogate for 'Unknown'.

Special consideration was given to a number of moth species, dependent on ash trees (those in the genus *Fraxinus*), which are under threat from the decimation of ash trees by the exotic invasive emerald ash borer beetle. Ash-dependent moths include *Copivaleria grotei, Manduca jasminearum, Olceclostera angelica, Palpita magniferalis, Papaipema furcata, Plagodis kuetzingi,* and *Podosesia syringae*. For this analysis a short-term decline of at least 80 percent is assumed for species which only consume ash trees, or which consume ash trees and eat the introduced privet (*Ligustrum* spp.) and lilac (*Syringa* spp.), and/or the native fringetree (*Chionanthus virginicus*). A Threat Level of 'Very High' was assigned to all of these species.

PNHP staff gathered and reviewed information sources for this SWAP update. Sources included published and gray literature, personal correspondences, data sets from PNHP programmatic surveys, records from individual collections and contributors, and data from museums including the Academy of Natural Science of Drexel University in Philadelphia, the Carnegie Museum of Natural History in Pittsburgh, and the Natural History Museum at the Tom Ridge Environmental Center. Other key resources included a dataset from the Butterflies and Moths of North America website, the *Atlas of Pennsylvania Butterflies*, 13th Edition, the NatureServe Explorer website, and the North American Moth Photographers website. Key sources utilized in this evaluation are cited in the reference section; additional supporting references are available upon request.

Grasshoppers (Order Orthoptera)

The 2005 SWAP included one Orthopteran SGCN, the Appalachian Grasshopper (*Appalachia hebardi*). Historic literature records establish the presence of this grasshopper in Pennsylvania and Virginia. It has not been found anywhere in recent decades, though recent surveys for grasshoppers in Pennsylvania have been limited, so there is some hope that it will be rediscovered.

A fairly comprehensive list of 57 grasshoppers (Family Acrididae) and associated locality records exist for Pennsylvania based on the work of Joe Sheldon (Professor Emeritus Messiah College) and Daniel Otte (Senior Curator, Academy of Natural Sciences of Drexel University). While a comprehensive review of the grasshoppers was beyond the scope of the current SWAP update, a future effort to evaluate this group is recommended based on the availability of existing data.

Sawflies – (Order Hymenoptera, Family Tenthredinidae)

The Black-headed Ash Sawfly (*Tethida barda*) received a Threat Level of 'Very High' because of the habitat loss due to ash tree die offs from emerald ash borer. Its presence in Pennsylvania is established by a several records on BugGuide.

Scorpionflies (Order Mecoptera)

The Carnegie Museum of Natural History holds a small number of specimens of *Merope tuber*, the earwig scorpionfly, from Pennsylvania. Although the species might be globally rare (G3G5), the natural history of this species is so poorly known that a state conservation rank cannot be assigned.

Spiders (Order Araneae)

Spiders are greatly undersurveyed in Pennsylvania, so the conservation status of most species cannot be determined. Therefore, only nine species known to be associated with rare habitats, and one additional purported endemic species, were considered for SGCN status. Undoubtedly, many of the estimated 600 to 1000 other spider species in Pennsylvania would qualify as SGCN if their distribution and ecology was more fully known. Literature records and the PNHP database were the main data sources used.

There are four species of cave-obligate spiders known from PA. Range Extent was assessed from the specimens and range maps reported in the literature. Since these species are known to be under-surveyed, no attempt was made to determine Area of Occupancy or Number of Occurrences. Cave-obligate species were considered to have a 'Very Narrow' Environmental Specificity, which was the main factor contributing to their qualification as SGCN. The calculated ranks of S3 were adjusted to S1S3 because the very small number of collections of each species do not support ruling out the possibility of S1 or S2.

One species*, Atypus snetsingeri,* is considered to be endemic to Delaware County, PA. This alone would qualify this species as a SGCN, but there remains some doubt about the native status of the species. The combination of a very small range in an urbanized landscape, an extreme disjunction from any of its congeners, and the lack of earlier collections of this relatively distinctive species, make us wonder if this could be an introduced species. Research is needed to resolve the SU status of this species.
A requirement for open, somewhat barren habitat or loose, sandy substrate was the main factor that qualified the remaining five species as SGCN.

True Bugs (Order Hemiptera)

One true bug, the fringetree lace bug (*Leptoypha mutica),* was evaluated. A Threat Level of 'Very High' was assigned because of its reliance on ash trees, which are rapidly dying from emerald ash borer infestations. It is also known to use the native fringetree (*Chionanthus virginicus*) and the introduced late lilac (*Syringa villosa*), but these represent a very small refuge for the species compared to the recent extent of ash trees. Its presence in Pennsylvania is established by one literature record and one BugGuide record.

RESULTS AND DISCUSSION

Using the process and the criteria outlined in the Methods section, we reviewed a total of 750 species including 325 new species that had not been considered in the 2005 SWAP. Species which were determined to be native to the Commonwealth (Question 1) and for which there was sufficient information to assess their status in Pennsylvania (Question 2) were evaluated using the other PA Wildlife Action Plan Species of Greatest Conservation Need Flow Chart criteria (e.g., Global Imperilment, Federal Imperilment, Regional Concern, State Imperilment, Pennsylvania Responsibility, and Significant Threats - Population Decline). Northeast Region Species of Greatest Conservation Need (RSGCN) that occur in Pennsylvania were also evaluated for the SWAP. Of the invertebrates reviewed in the 2015 assessment, 450 species were classified as SGCN (Table 1 and Appendices 1 and 2). This number is higher than the 336 SGCN listed in the 2005 SWAP primarily because additional data sources were reviewed and new information has become available since the previous plan.

Most SGCN species from the 2005 SWAP remained high conservation priorities in 2015 (Table 1 and Table 2). A majority, 75% (319 species), of 2005 SGCN species maintained that designation (Maintain category) in the 2015 SWAP plan; 18% of the 2005 SGCN invertebrates (77 species) were removed as SGCN species (Delete category) based upon the 2015 SGCN criteria; and 21% (156 species) were not considered SGCN in 2015 because they were Data Deficient or were not confirmed resident species in Pennsylvania (Table 1). Many species in the Delete category were previously considered rare, but when assessed with new information, were found to be sufficiently secure in the state so that they no longer met the SGCN requirements. In contrast, two SGCN species from the 2005 plan were confirmed to be extirpated (locally extinct) without any foreseeable recovery in the state. With no foreseeable path to recovery, these species were considered ineligible to be SGCN species in the 2015 plan and placed in the "Delete" category. Some species that were considered extirpated in 2005 were subsequently found to have new or previously undocumented populations in the state and were placed in the "Add" category. Thirteen species were deleted from the 2015 SGCN list because they had separate entries for full species and subspecies.

Table 1. The counts of all invertebrate species assessed with the 2015 SGCN criteria and classified as Add, Maintain, or Delete as SGCN, or, determined to be Not SGCN or Data Deficient in the 2015 SWAP.

Box Score: 2015 Invertebrates

Add (a)	131
Maintain	319
Delete(b)	77
Not SGCN(c)	156
Data Deficient	67
Total Species Evaluated	**750**
Total SGCN Species	**450**

(a) Add: Includes newly assessed SGCN species and SX-Extirpated species considered recoverable in 2015.
(b) Delete = Includes 2005 SGCN species reevaluated in 2015 as Not SGCN, Extirpated-Not Recoverable, Redundant with other species, or Not PA Resident
(c) Not SGCN = Includes species newly assessed in 2015 as Not SGCN, Redundant with other species, Not PA Resident, and Extirpated-Not Recoverable

Table 2. The counts of the 2005 SGCN invertebrate species assessed with the 2015 SGCN criteria and classified as Maintain or Delete as SGCN, or, determined to be Data Deficient in the 2015 SWAP.

2005 Invertebrate SGCN list

Maintain	319
Delete (a)	77
Data Deficient	29
Total	425

(a) Delete = Includes 2005 SGCN species reevaluated in 2015 as Not SGCN, Extirpated-Not Recoverable, Redundant with other species, or Not PA Resident.

For the 2015 SWAP update, 325 invertebrate species were evaluated in addition to the 2005 SWAP-SCGN status species (Table 3). These included 35 species mentioned in the 2005 plan, which were not evaluated for SGCN status, plus 290 new species selected for review. Of the additionally assessed species, 40% (131 species) were rated as SGCN and 60% (194 species) were considered Data Deficient or not SGCN for other reasons (Table 3).

Table 3. The counts of species assessed with the SGCN criteria which were added to the SGCN list, rated as Not SGCN for other reasons, or determined to be Data Deficient.

2015 Additionally Assessed Species	
Add (a)	131
Not SGCN (b)	156
Data Deficient	38
Total	325

(a) Add: Includes newly assessed SGCN species and SX-Extirpated species considered recoverable in 2015.
(b) Not SGCN = Includes species newly assessed in 2015 as Not SGCN, Redundant with other species, Not PA Resident, and Extirpated-Not Recoverable

While more information was available in 2015 since the 2005 SWAP to evaluate the conservation status of Pennsylvania's invertebrate species, many groups could not be evaluated given the scope and resources of this project (see the Summary section for a list). Many groups that were addressed only had a few species evaluated; ten or fewer species of amphipods, bees, caddisflies, crane flies, flatworms, grasshoppers, isopods, isopods, sawflies, spiders, springtails, sponges, and true bugs were considered for SGCN status. The number of species reviewed compared in the project and an estimated number of species likely to occur in the state for each informal taxonomic group (or the larger taxa group to which it belongs) is provided in Table 4.

Complete or nearly complete species lists of invertebrate taxa groups occurring in Pennsylvania were utilized for the assessment of the following groups: aquatic snails, butterflies, crayfish, dragonflies and damselflies, freshwater mussels, stoneflies, tiger beetles, and terrestrial snails. Consequently, species from these groups make up the bulk of the SGCN species identified in the state. With additional resources to compile species lists and occurrence data, many more of the state's estimated 11,000+ invertebrates (Pennsylvania Biological Survey 2013) could be assigned a SWAP assessment category, even if only a status of 'Data Deficient'. As invertebrate species lists for Pennsylvania are improved, habitats described, rarity better understood, and more assessment funding becomes available, additional species are expected to be ranked as priorities for conservation.

Table 4. The counts of species by taxa groups in the Add, Maintain, Delete, Not SGCN, or Data Deficient categories. 2005 SGCN and 2015 additionally assessed species are included in the counts.

Informal Taxa Groups	Add (a)	Maintain	Delete (b)	Not SGCN (c)	Data Deficient	Total SGCN 2015	Total Species Evaluated	Total estimated species*
Amphipods	1	8				9	9	11-100 Amphipoda
Bees	3				1	3	4	>370 Hymenoptera+, in part
Beetles	1	2		2		3	5	>1,000 Coleoptera
Butterflies and Skippers	2	49	20	17		51	88	124 Lepidoptera, in part
Caddisflies	1	6				7	7	>312 Trichoptera
Craneflies	2	1				3	3	>1,000 Diptera
Crayfishes	1		1	6	6	1	14	17 Decapoda, in part
Dragonflies and Damselflies	14	71	18	3		85	106	181 Odonata+
Flatworms		1				1	1	11-100 Turbellaria
Freshwater Mussels	15	35	7	12		50	69	79 Bivalvia
Freshwater Snails	12	4	5		1	16	22	55 Gastropoda, in part
Grasshoppers	1					1	1	11-100 Orthoptera
Isopods		3				3	3	11-100 Isopoda
Mayflies	9	6			2	15	17	>230 Ephemeroptera
Moths	21	90	9	14	13	111	147	>1,500 Lepidoptera, in part
Sawflies	1					1	1	>630 Hymenoptera, in part
Scorpionflies					1	0	1	2-10 Mecoptera
Spiders	9				1	9	10	725 - >2,000 Arachnida
Sponges		1			1	1	2	2-10 Porifera
Springtails	1					1	1	11-100 Collembola
Stoneflies	12	9	1	2	3	21	27	141 Plecoptera
Terrestrial Snails	24	24	9	100	38	48	195	176 Gastropoda, in part+
Tiger Beetles		9	7			9	16	>1,000 Coleoptera
True bugs	1					1	1	>1000 Hemiptera
Total	**131**	**319**	**77**	**156**	**67**	**450**	**750**	

(a) Add: Includes newly assessed SGCN species and SX-Extirpated species considered recoverable in 2015.
(b) Delete = Includes 2005 SGCN species reevaluated in 2015 as Not SGCN, Extirpated-Not Recoverable, Redundant with other species, or Not PA Resident
(c) Not SGCN = Includes species newly assessed in 2015 as Not SGCN, Redundant with other species, Not PA Resident, and Extirpated-Not Recoverable

*Total estimated species by taxonomic group adapted from the 2013 PA Biological Survey Box Score unless otherwise noted. This number is an estimated range of the total number of species (native and non-native) likely to occur in the state for each 'informal taxonomic group', or in some cases a larger taxonomic grouping to which the informal group belongs.
+Total bee species count (Hymenoptera, Apoidea) taken from Donovall and vanEngelsdorp 2010. Total dragonfly and damselfly (Odonata) and terrestrial snails and slugs (Gastropoda, in part) count based on current PA Natural Heritage Program data.

HABITATS

All species identified as SGCN for the 2015 SWAP had one or two primary habitat types identified by taxonomic experts. Most aquatic and terrestrial habitats were selected from the macrogroups and the subgroups (within the macrogroups) types in the Northeast Terrestrial and Aquatic classification system (Anderson *et al*. 2013). Due to the great variability in the type of habitats selected, they were simplified into one of six general habitat types, summarized from the macrogroups. The original habitat information habitat types assigned by experts for assessed species can be referenced in the Appendices 1 - 6.

The habitat types were summarized for the SGCN species within informal taxonomic categories in two ways (Table 5 and 6). The first summary is a count species within habitat types by taxa group (Table 5), and the second summary is a normalized species count by habitat type (Table 6). The normalized values were calculated for each taxonomic group by dividing the number of species in a habitat type by the total number of species evaluated in that taxonomic group. Dozens of species were evaluated for larger or better known taxonomic groups (e.g., butterflies), while only one or two species were evaluated for smaller or lesser known taxonomic groups. Normalizing the counts allows for an assessment of SGCN invertebrate species by habitat category that is not overly influenced by the habitat usage of taxa groups with more evaluated species.

The greatest percentage of SGCN invertebrates are found in flowing water (lotic) habitats, followed by forested and special habitats (e.g., caves and cliffs), followed by open and successional habitats such as barrens, woodland glades, and grasslands (Table 6). Small percentages of SGCN invertebrates were associated with wetlands and stillwater (lentic) habitats like ponds and lakes. Normalization of the results equalizes the relative importance of larger versus smaller taxonomic groups in the habitat analysis. However, the fact remains that the overall review of invertebrates focused almost entirely on a few better known taxonomic groups. Therefore, the habitat analysis should not be interpreted as evidence that one habitat is more or less imperiled than another, or supports more or less species of conservation concern than another. For example, wetlands were found to be an important habitat for about 5% of SGCN invertebrates using the normalized data. Wetlands had the fourth highest actual count with 66 SGNC species, but 59 of these came from a few taxonomic groups; butterflies, moths, dragonflies, and damselflies. Since Pennsylvania has lost over 50% of its wetlands since pre-Colonial times to filling or draining (EPA 2014), we expect other taxonomic groups have rare species which live in

wetland habitats, but they are not represented in our analyses. The invertebrate fauna of wetlands is generally less well known than in terrestrial habitats because wetlands are more difficult to sample than upland habitats. Furthermore, aquatic invertebrate surveys primarily collect the larval stage of insects which are then identified to family- or genus-level. Greater efforts are needed to collect the adult phase of aquatic insects and other arthropods which can be identified to species-level from wetland habitats.

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Table 5. Count of 2015 SGCN invertebrate species by general habitat type.

	Forests	Barrens / Glades / Grasslands	Lentic	Lotic	Special Habitats	Thickets	Wetlands	TOTAL
Amphipods				1	8			9
Bees		2						2
Bumble Bee		1						1
Butterflies and Skippers	18	18					15	51
Caddisflies			1	6				7
Craneflies				3				3
Crayfishes				1				1
Dragonflies and Damselflies	2		8	40			35	85
Flatworms					1			1
Freshwater Mussels				50				50
Freshwater Snails			2	7			7	16
Grasshoppers	1							1
Ground Beetles					1			1
Isopods				1	2			3
Mayflies			2	13				15
Moths	62	39				1	9	111
Other Beetles	2							2
Sawflies	1							1
Spiders	1	2		2	4			9
Sponges					1			1
Springtails					1			1
Stoneflies				21				21
Terrestrial Snails	42	4			2			48
Tiger Beetles	1	4		4				9
True bugs	1							1
Species Count by Habitat Category	**131**	**70**	**13**	**149**	**20**	**1**	**66**	**450**
PERCENT OF EVALUATED SPECIES BY MAJOR HABITAT CATEGORIES	29	16	3	33	4	<1	14	

Table 6. Normalized count of 2015 SGCN invertebrate species by general habitat type.

	Forests	Barrens / Glades / Grasslands	Lentic	Lotic	Special Habitats	Thickets	Wetlands	TOTAL
Amphipods				0.1	0.9			1.0
Bees		1.0						1.0
Bumble Bee		1.0						1.0
Butterflies	0.4	0.4					0.3	1.0
Caddisflies			0.1	0.9				1.0
Crane Flies				1.0				1.0
Crayfishes				1.0				1.0
Dragonflies and Damselflies	0.0		0.1	0.5			0.4	1.0
Flatworms					1.0			1.0
Freshwater Mussels				1.0				1.0
Freshwater Snails			0.1	0.4			0.4	1.0
Grasshoppers	1.0							1.0
Ground Beetles					1.0			1.0
Isopods				0.3	0.7			1.0
Mayflies			0.1	0.9				1.0
Moths	0.6	0.4				0.0	0.1	1.0
Other Beetles	1.0							1.0
Sawflies	1.0							1.0
Spiders	0.1	0.2		0.2	0.4			1.0
Springtails	1.0							1.0
Sponges					1.0			1.0
Stoneflies				1.0				1.0
Terrestrial Snails	0.9	0.1			0.0		0.0	1.0
Tiger Beetles	0.1	0.4		0.4				1.0
True bugs	1.0							1.0
TOTAL (normalized count)	**6.0**	**3.5**	**0.5**	**7.7**	**6.0**	**0.0**	**1.2**	**25.0**
PERCENT OF EVALUATED SPECIES BY MAJOR HABITAT CATEGORIES	**4.1**	**13.8**	**2.0**	**31.0**	**24.2**	**0.0**	**4.9**	

THREATS

Threats that contribute to a species' potential for extirpation (local extinction at the state level) were considered as part of the SGCN assessment process. Most species were evaluated using the detailed threat analysis included in the NatureServe Rank Calculator. The scope, severity, and timing of various threat types were assigned and used to determine the Overall Threat Impact. The Overall Threat Impact indicates the degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the state (Master *et al.* 2012). Sometimes the Overall Threat Impact was directly assigned when there was insufficient data for the detailed threat analysis. The Overall Threat Impact score can run from Low to Very High, incorporate a range, or be Negligible (minimal or with no impact) or Unknown. Definitions of the threats as applied in this assessment are provided on The Open Standards for the Practice of Conservation website (http://cmp-openstandards.org/).

The threat categories which were evaluated in the NatureServe Rank Calculator were summarized in several analyses. The number of species within an informal taxa group that are impacted by a particular threat was divided by the total number of species evaluated within that group (Table 7). This normalizes the count of SGCN invertebrates within a taxa group that are impacted by a particular threat and makes the results comparable between taxa groups that have unequal numbers of evaluated species. The 'Percent of Total' statistic is the relative proportion of all evaluated SGCN invertebrates impacted by a particular threat category.

In another analysis the percent distribution of threat type by the degree of impact was calculated (Table 8). The result was an index of the relative severity of each threat category for the evaluated SGCN invertebrates as a whole. The '% Total by Threat' is the summed percent of SCGN invertebrates for which each threat was selected. For instance, agriculture and aquaculture was an identified threat for 13.3% of SCGN invertebrates (Table 8). The '% Total by Overall Threat Impact' is the percent of the threats which were documented at levels from Very High to Low, Negligible/Not a Threat, or Unknown; most threats (53%) were rated to have a medium Overall Threat Impact (Table 8). The Overall Threat Impact is a combination of severity, timing, and scope of all evaluated threat categories. The majority of threats assessed for SGCN species fell into a Medium Overall Threat Impact category.

Lastly, a summary of threats by informal taxonomic groups was developed. A count of species within an informal taxa group for which a threat factor was identified and the overall impact level of that threat was created (Table 9). In this analysis more than one threat may be identified for any species, and the number and severity of individual threats are rolled up into the Overall Threat Impact. For example, when four or more low level threats are identified for a species, the Overall Threat Impact increases from Low to Medium to reflect the compounded stress on a species caused by the layering of multiple threats.

Overall, SGCN invertebrates were found to be most impacted by the following threats (Tables 7 and 8):

- residential, commercial, and tourism development
- pollution such as sewage, wastewater, agricultural run-off, air pollution
- natural system modifications such as prescribed fire and wildfire suppression, dams and water management, and active management of natural systems via mowing or plantings
- agriculture and aquaculture - conversion of natural lands to cropland, ranchland, and plantations
- invasive species - introduced plants, animals, pathogens and other microbes that cause harm to native species and the environment (e.g., garlic mustard, gypsy moth, rusty crayfish)
- problematic native species - native plants, animals, and pathogens that have become out of balance with the ecosystem in areas (e.g., striped maple, fall cankerworm moth, white tailed deer)
- transportation and service corridors such as dirt and paved roads, railroads, shipping lanes, flight paths, and powerline and pipeline rights-of-way
- energy production and mining including oil and gas drilling, mining and quarrying, and renewable energy development
- climate change and severe weather – climatic instability causing droughts, temperature extremes, storms and flooding, and shifts in habitats and species' ranges
- biological resource use including hunting, fishing, collecting animals, gathering plants, logging, and firewood cutting and salvage

In the threats analysis, when the number of species differs among taxonomic groups, normalization of actual counts equalizes the relative importance of the groups. However, the review of invertebrates for the 2015 SWAP update focused primarily upon on a few of the relatively better known taxonomic groups. Therefore the threat analyses should not be interpreted as evidence that a particular threat is the most or least serious for all invertebrates across all habitats, rather it is a summary of the threats for the evaluated SGCN species.

Table 7. Normalized count of species within each informal taxonomic group by threat type.

	Agriculture & aquaculture	Biological resource use	Climate change & severe weather	Energy production & mining	Geological events	Human intrusions & disturbance	Invasive & other problematic species & genes	Natural system modifications	Pollution	Residential & commercial development	Transportation & service corridors	TOTAL	NUMBER OF SPECIES
Bees	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	2
Beetles	0.3	0.1	0.0	0.1	0.0	0.0	0.0	0.8	0.0	0.7	0.0	2.0	9
Butterflies	0.5	0.2	0.3	0.3	0.0	0.0	0.6	0.9	0.0	0.7	0.7	4.2	47
Caddisflies	1.0	0.7	0.7	0.7	0.0	0.1	0.0	0.1	1.0	1.0	0.9	6.3	7
Cave Invertebrates	1.0	0.0	0.9	1.0	0.1	0.0	0.0	0.0	1.0	1.0	1.0	6.0	13
Crane Flies	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	5.0	3
Crayfishes	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	11.0	1
Dragonflies & Damselflies	1.0	0.2	0.1	0.2	0.0	0.0	0.0	0.0	1.0	1.0	1.0	4.6	67
Freshwater Snails	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.8	0.4	0.0	2.2	15
Mayflies	0.8	0.5	0.9	0.8	0.0	0.2	0.0	0.2	0.8	0.9	0.6	5.8	15
Moths	0.1	0.1	0.1	0.1	0.0	0.0	0.7	0.8	0.1	0.7	0.2	2.8	82
Mussels	0.6	0.0	0.0	0.3	0.0	0.0	0.2	0.7	0.8	0.0	0.3	2.9	39
Sawflies	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	1
Spiders	0.6	0.0	0.1	0.4	0.0	0.4	0.0	0.1	0.0	0.6	0.0	2.2	9
Springtails	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	2.0	1
Stoneflies	0.7	0.6	0.9	0.3	0.0	0.1	0.0	0.0	0.9	0.8	0.6	4.9	17
Terrestrial Snails	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	0.0	0.0	3.0	46
True Bugs	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	1
TOTAL (normalized count)	9.3	4.6	5.3	6.2	1.1	1.9	7.5	5.6	9.4	9.8	7.3	68.0	375
% OF TOTAL	13.7	6.8	7.8	9.2	1.6	2.8	11.1	8.3	13.8	14.4	10.7	100.0	

Table 8. Percent distribution of Threat type (rows) by Overall Threat Impact (columns)

	Very High	Very High - High	Very High - Med-ium	High	High - Low	High - Med-ium	Med-ium	Med-ium - Low	Low	Negli-gible	Not a Threat	Not in time-frame	Un-known	(blank)	% TOTAL by THREAT
Agriculture & aquaculture	0.0	0.0	0.1	0.1	1.7	0.2	8.2	0.3	1.8	0.4	0.0	0.1	0.0	0.4	13.3
Biological resource use	0.0	0.1	0.0	0.0	0.0	0.0	3.6	0.0	0.5	0.1	0.1	0.1	0.0	0.2	4.7
Climate change & severe weather	0.0	0.0	0.0	0.1	0.5	0.3	1.0	0.1	0.3	0.1	0.3	3.2	0.2	0.0	6.2
Energy production & mining	0.1	0.2	0.2	0.0	0.4	0.1	3.2	0.4	1.3	0.0	0.1	0.2	0.0	0.0	6.3
Geological events	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.1
Human intrusions & disturbance	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.4	0.1	0.0	0.0	0.0	0.0	0.9
Invasive & other problematic species & genes	0.9	0.4	0.2	0.1	0.2	0.4	3.5	0.1	0.6	0.2	0.1	0.0	0.4	3.3	10.6
Natural system modifications	0.0	0.3	0.6	0.1	1.7	0.1	4.0	0.4	2.7	0.1	0.1	0.0	0.4	3.3	14.0
Pollution	0.0	0.1	0.3	0.0	1.5	0.1	7.9	0.1	1.4	0.2	0.0	0.0	0.5	3.5	15.5
Residential & commercial development	0.0	0.0	0.0	0.0	0.6	0.0	12.6	0.1	2.2	0.3	0.0	0.1	0.0	0.2	16.2
Transportation & service corridors	0.0	0.1	0.0	0.0	0.6	0.1	9.2	0.1	1.7	0.1	0.0	0.1	0.0	0.0	12.1
% TOTAL BY OVERALL THREAT IMPACT	1.0	1.2	1.4	0.5	7.4	1.3	53.7	1.7	13.0	1.7	0.6	4.0	1.4	11.0	100.0

Table 9. Count of SGCN species, within an informal taxa group, identified as being impacted by each threat. Threats are further broken down into the overall impact level. Many species have multiple threats identified; the number of species assessed is listed after the taxa group name.

Beetles (n=9)	Very High - High	Very High - Medium	High	High - Low	Medium - Low	Low
Agriculture & aquaculture					2	
Biological resource use	1					
Energy production & mining	1					
Natural system modifications		1	1	4		1
Residential & commercial development				1	5	

Butterflies (n=47)	Very High - High	High	High - Low	High - Medium	Medium	Medium - Low	Low	Not in timeframe	Unknown
Agriculture & aquaculture							22		
Biological resource use						1	6	1	
Climate change & severe weather		1			2		11		1
Energy production & mining							13		
Human intrusions & disturbance							1		
Invasive & other problematic species & genes	2	2	2	4		1	17		2
Natural system modifications		1	4		3	2	30		
Pollution							2		
Residential & commercial development							32	1	
Transportation & service corridors					1	1	31	1	

Caddisflies (n=7)	High	High - Low	Medium	Medium - Low	Low	Negligible	Not in timeframe
Agriculture & aquaculture	1	1		1	2	1	1
Biological resource use					4		1
Climate change & severe weather							5
Energy production & mining		1			3		1
Human intrusions & disturbance		1					
Natural system modifications				1			
Pollution		1	1		5		
Residential & commercial development		1			5	1	
Transportation & service corridors		1			4	1	

Cave Invertebrates (n=13)	High - Low	High - Medium	Medium - Low	Low	Not in timeframe
Agriculture & aquaculture	2	2	9		
Climate change & severe weather					12
Energy production & mining	1		11	1	
Geological events					1
Pollution			11	2	
Residential & commercial development			13		
Transportation & service corridors			13		

Crane Flies (n=3)	High - Low	Medium - Low	Low
Agriculture & aquaculture		3	
Biological resource use		3	
Pollution			3
Residential & commercial development	1	2	
Transportation & service corridors		3	

Crayfishes (n=1)	Very High	Low	Negligible
Agriculture & aquaculture		1	
Biological resource use			1
Climate change & severe weather			1
Energy production & mining		1	
Geological events			1
Human intrusions & disturbance			1
Invasive & other problematic species & genes	1		
Natural system modifications			1
Pollution		1	
Residential & commercial development		1	
Transportation & service corridors			1

Dragonflies and Damselflies (n=67)	High - Low	Low	Medium - Low	Not a Threat
Agriculture & aquaculture	2	65		
Biological resource use		12	1	
Climate change & severe weather	6		2	
Energy production & mining	1	8	2	2
Natural system modifications	1		2	
Pollution		66		
Residential & commercial development	2	65		
Transportation & service corridors	1	66		

Freshwater Snails (n=15)	High - Low	High - Medium	Medium	Medium - Low	Low	Negligible	Unknown
Agriculture & aquaculture	5	1	2		1	3	
Biological resource use				2			
Climate change & severe weather							1
Pollution	3	1		1	1	3	1
Residential & commercial development	4			2			

Mayflies (n=15)	High	Medium	Medium - Low	Low	Negligible	Not in timeframe
Agriculture & aquaculture	1	2	1	7	1	
Biological resource use				8		
Climate change & severe weather				1		13
Energy production & mining		6		4		2
Human intrusions & disturbance			1	2		
Natural system modifications		1	1	1		
Pollution		1	1	10		
Residential & commercial development		1	1	9	2	1
Transportation & service corridors		1	1	7		

Moths (n=82)	Very High	Very High - Medium	High - Medium	High - Low	Medium	Medium - Low	Low	Negligible	Not a Threat	Unknown
Agriculture & aquaculture							5			
Biological resource use							10		1	
Climate change & severe weather			4			2	1	1	4	
Energy production & mining							7			
Human intrusions & disturbance						1				
Invasive & other problematic species & genes	8	1	2	1	1	8	32	3	1	1
Natural system modifications			2	3	2	32	23	1	1	
Pollution							6			
Residential & commercial development						1	54			
Transportation & service corridors						2	11			

Mussels (n=39)	Very High - High	Very High - Medium	High - Low	High - Medium	Medium - Low	Low	Unknown
Agriculture & aquaculture		1	14		7		
Climate change & severe weather							1
Energy production & mining	2	3	2	1	1	3	
Invasive & other problematic species & genes	4	1					2
Natural system modifications	4	8	10			1	5
Pollution	1	4	17		4		6
Transportation & service corridors	2		7	1	1		

Spiders (n=9)	High - Low	Medium - Low	Low
Agriculture & aquaculture			3
Climate change & severe weather	1		
Energy production & mining		4	
Human intrusions & disturbance		4	
Natural system modifications	1		
Residential & commercial development		5	

Stoneflies (n=17)	Medium - Low	Low	Negligible	Not in timeframe
Agriculture & aquaculture	2	8		
Biological resource use		10		
Climate change & severe weather		1		15
Energy production & mining		5		
Human intrusions & disturbance		1		
Pollution	2	13		
Residential & commercial development	2	9	1	
Transportation & service corridors	2	9		

Terrestrial Snails (n=46)	Unknown
Invasive & other problematic species & genes	46
Natural system modifications	46
Pollution	46

Other Invertebrates	Very High	Very High - Medium
Bees (n=2)	**2**	
Invasive & other problematic species & genes	2	
Sawflies (n=1)	**1**	
Invasive & other problematic species & genes	1	
Springtails (n=1)	**1**	**1**
Energy production & mining	1	
Invasive & other problematic species & genes		1
True Bugs (n=1)	**1**	
Invasive & other problematic species & genes	1	

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CONSERVATION ACTIONS

The highest priority Conservation Actions were recommended for SGCN species and their associated taxonomic groups. Actions were derived from IUCN Unified Classification of Conservation Actions Needed and the Wildlife TRACS Action Drivers (Level 2). The goal of the actions is to improve the conservation status of the SCGN species through species-specific recommendations; Conservation Actions were recommended for some species in cases which sufficient information was available. For the remaining invertebrates Conservation Actions were assigned to an invertebrate family or other taxonomic group, based on obtainable information (Appendix 8 and Appendix 9). Our goal was to recommend three Actions for SCGN invertebrates and invertebrate groups. In a few cases, four or five Actions were determined to be high priority. A large proportion of invertebrates require more information for management of their populations; research, monitoring and surveys were highly prioritized. Since no natural resource agency in Pennsylvania has legal jurisdiction over terrestrial invertebrates, rare and declining species cannot be evaluated for protection under a formal threatened or endangered status like plants and other animals are. Therefore, we recommend that stakeholders be engaged to work towards legal protection by the Commonwealth of Pennsylvania. Ultimately, legislation to create regulatory authority over terrestrial invertebrates is needed.

Aquatic Arthropods, Semi-aquatic Arthropods, Flatworms, and Sponges

Caddisflies (Order Trichoptera)

The highest priority Conservation Actions include 3.2 Research, survey or monitoring - fish and wildlife populations, 9.3 Species and habitat management planning, and 11.1 Environmental review. Filling information gaps about native caddisfly species, habitats and populations would enable natural resource managers to understand the conservation needs for the group. Further research on species habitat needs, distributions, and threats would create baseline information for further Conservation Actions. Applications of information gathered through surveys include conservation plans for protecting populations and habitats and determining which species should be protected through the regulatory process in environmental review.

Cave Invertebrates – Amphipods (Orders Amphipoda), Isopods (Order Isopoda), Flatworms (Phylum Platyhelminthes), and Springtails (Order Collembola)

Limited surveys leave natural resource managers with little information on cave habitats for amphipods, isopods, and flatworms, their species distribution, and population information. To fill information gaps about the aforementioned groups for habitat and species management for basic conservation planning, the highest priority Conservation Actions is to conduct research, survey or monitoring of populations (Action 3.2 Research, survey or monitoring - fish and wildlife populations). The difficulty of conducting surveys for cave invertebrates means that they are under-sampled. In the regions with karst geology and caves, agriculture is the dominant land cover. Water pollution from farms seeping into ground water has the potential to degrade water quality for cave invertebrates. Better nutrient management (2.5 Grazing/farm management) to prevent groundwater pollution could protect cave invertebrates. Further study of water quality in cave environments could elucidate the need for farm management for

invertebrates. Lastly, the addition of cave invertebrates to the environmental review process (Action 11.1 Environmental review) would offer more protection for their habitats.

For the SGCN springtail (Heller Cave Springtail, *Typhlogastrura helleri*) proposed mining at the one known location in the world threatens its existence. Protection of its only known habitat through private land agreements (Action 6.4 Private lands agreements) is the highest priority for the species. The habitat for the species needs to be legally regulated through environmental review. The first step is to engage stakeholders to begin the process for appropriate legislation (Action 100.1 Legislation) that would give a Commonwealth agency authority to regulate springtails habitat through environmental review (Action 11.1 Environmental review).

Crane Flies (Order Diptera, family Tipulidae)

Crane fly species would benefit from habitat management plans (Action 9.3 Species and habitat management planning). Minimizing threats to riparian zones and uplands with the best available farming practices (Action 2.5 Grazing/farm management) in agricultural watersheds would ensure that water quality and in-stream habitat is maintained for crane flies. Crane flies also need the protection of environmental review (Action 11.1 Environmental review).

Crayfish (Family Cambaridae)

In Pennsylvania, exotic crayfishes represent the greatest threat to the state's native crayfish fauna because crayfish invasions often result in the complete elimination of native crayfishes from invaded waters. For example, the range of the spinycheek crayfish (*Orconectes limosus*), which is native to eastern Pennsylvania, has declined (retreated eastward) by approximately 140 miles and the species has nearly been eliminated from the Susquehanna and Potomac drainages of Pennsylvania, as a result of exotic crayfishes. Invasive species control (Action 2.8) is therefore the top Conservation Actions for crayfishes. Because little is known about many of Pennsylvania's crayfishes, research, survey or monitoring (Action 3.2) is the second most important Conservation Action. Lastly, improved farm management practices (Action 2.5 Grazing/farm management) like riparian buffers and elimination of streambank grazing will improve the water quality and habitats for crayfish in agricultural watersheds.

Dragonflies and Damselflies (Order Odonata)

In lotic (creek and river) habitats, dragonflies and damselflies need better management of riparian zones and adjacent uplands to prevent habitat loss from siltation and degradation of water quality. The recommended Conservation Actions include 2.5 Grazing/farm management and 2.11 Vegetation management. As dragonflies and damselflies are not currently in the environmental review system, therefore action 11.1 Environmental review is also a priority. Species that are primarily lotic include the following: *Argia sedula, Calopteryx aequabilis, C. amata, C. angustipennis, C. dimidiata, Enallagma durum, Gomphus abbreviatus, G. adelphus, G. borealis, G. fraternus, G. lineatifrons, G. quadricolor, G. rogersi, G. septima delawarensis, G. ventricosus, G. viridifrons, Helocordulia uhleri, Hetaerina titia, Ischnura ramburii, Macromia alleghaniensis, M. taeniolata, Nehalennia integricollis, Ophiogomphus anomalus, O. carolus, O. howei, O. incurvatus, O. mainensis, Progomphus obscurus, Stylurus amnicola, S.*

notatus, S. plagiatus, S. scudderi, Arigomphus furcifer, Enallagma boreale, and *Nasiaeschna pentacantha*.

Dragonflies and damselflies preferring lentic habitats also require protection of riparian zones and uplands surrounding the waterbodies to keep habitats free from excessive siltation and to preserve water quality. The recommended Conservation Actions include 2.9 Living shorelines, 2.5 Grazing/farm management. Action to prevent loss and degradation of natural wetlands, from draining, eutrophication, or sedimentation would help protect these species. None of these species are currently in the environmental review system and would benefit from action 11.1 Environmental review. Species that are primarily lentic include the following: *Aeshna clepsydra, A. constricta, A. interrupta, Anax longipes, Celithemis fasciata, C. martha, Coenagrion resolutum, Cordulia shurtleffi, Dorocordulia lepida, Enallagma carunculatum, E. daeckii, E. divagans, E. doubledayi, E. laterale, Erythrodiplax berenice, E. minuscula, Gomphaeschna antilope, G. furcillata, Ischnura kellicotti, I. prognata, Ladona deplanata, L. exusta, Lestes eurinus, Leucorrhinia glacialis, L. proxima, Libellula auripennis, L. axilena, L. flavida, L. needhami, Rhionaeschna mutata, Sympetrum ambiguum, S. costiferum, S. internum, S. semicinctum, Epitheca costalis, E. spinigera,* and *Lestes dryas*.

Conservation Actions for odonates in peatlands, seeps, and headwaters include 2.11 Vegetation management, 6.4 Private lands agreements, and 11.1 Environmental review. A buffer around these wetlands and streams to protect them from the direct and indirect impacts of logging, development, and other forms of disturbance will protect the microclimate which these species depend on. Implementing land protection strategies to conserve natural groundwater quality and quantity will protect a number of species that rely on groundwater outflows. Many of these habitats are small, and could be effectively protected through easements or land acquisition. None of these species are currently given the protection of environmental review. Species that are dependent on groundwater or peatlands include the following: *Argia bipunctulata, Cordulegaster bilineata, C. erronea, C. obliqua, Enallagma anna, Nannothemis bella, Somatochlora elongata, S. forcipata, S. incurvata, S. linearis, S. walshii, S. williamsoni, and Tachopteryx thoreyi*.

Mayflies (Order Ephemeroptera)

Mayflies require more research (Conservation Action 3.2 Research, survey or monitoring - fish and wildlife population) to establish baseline information about native species, habitats and populations. A substantive Wildlife Resource Conservation Program project (Hoover 2000) conducted a number of surveys. However, species not well represented in that study need better evaluation; many mayflies have habitats and distributions that are not well known. The highest priority habitats for conservation would be ideally determined through management planning (Conservation Action 9.3 Species and habitat management planning) and vulnerable species should be included in environmental review (Action 11.1 Environmental review).

Stoneflies (Order Plecoptera)

The stoneflies of Pennsylvania are relatively well documented and basic habitat descriptions developed for most species (Earle, personal communication). However the rarer species need further study to develop better distribution maps and to assess threats to the populations. Therefore more research, survey and monitoring is needed for stoneflies for effective management (Action 3.2 Research, survey or monitoring - fish and wildlife populations). Information from surveys would direct prioritization of habitats in need of conservation (Action 9.3 Species and habitat management planning). Additionally, occurrences for the rarest stonefly species should be protected through the regulatory permitting process (Action 11.1 Environmental review).

Mollusks

Freshwater Snails (Class Gastropoda)

For snails preferring lotic habitats, the highest priority Conservation Actions are 2.5 Grazing/farm management, 2.11 Vegetation management, and 11.1 Environmental review. Erosion prevention measures would protect species vulnerable to siltation. None of these species are currently given the protection of environmental review. Species that are primarily lotic include the following: *Amnicola decisus, Fontigens nickliniana, F. orolibas, Lymnaea catascopium, Pleurocera proxima, Pomatiopsis lapidaria, Somatogyrus integra,* and *S. pennsylvanicus*.

In lentic environments, the highest priority Conservation Actions are 2.9 Living shorelines, 2.5 Grazing/farm management, and 11.1 Environmental review. Action to prevent loss and degradation of natural wetlands would help protect these species. None of these species are currently given the protection of environmental review. Species that are primarily lentic include the following: *Aplexa hypnorum, Birgella subglobosa, Gyraulus deflectus, Littorinidops tenuipes, Lymnaea stagnalis, Marstonia lustrica, Physa vernalis, Promenetus exacuous,* and *Valvata tricarinata*.

Freshwater Mussels (Families Unionidae and Margaritiferidae)

Freshwater mussels require species and habitat management planning (Action 9.3 Species and habitat management planning) to prioritize conservation goals. The implementation of an existing Species Action Plan for the Eastern pearlshell (*Margaritifera margaritifera*) is underway. Other management strategies are under development, like the Significant Mussel Resource Classification System for regulating Ohio River mussel habitats. While information on species distributions has advanced because of recent occurrence and genetic studies in the Susquehanna, Delaware, Ohio River basins, the status of populations of mussel species is relatively unknown. Therefore, research, survey and monitoring (Action 3.2 Research, survey or monitoring - fish and wildlife populations) is a high priority for freshwater mussels. Whether populations are reproducing is relatively unknown. Large declines in populations could occur before resource managers are aware that changes are happening. Research related to the threats and their mitigation would give natural resource managers a better picture for prioritizing conservation efforts.

Terrestrial Snails (Class Gastropoda)

Because more information is needed for effective management of terrestrial snails, the highest priority Conservation Action for the group is 3.3 Research, survey or monitoring – habitat. The habitat needs of most land snails and slugs are very poorly known. Research to identify habitat requirements and prioritize the best management techniques for snails is needed. Land managers could apply the results of such research to adapt existing habitat management plans for the benefit of terrestrial snails (Action 2.1 Create new habitat or natural processes). Controlling invasive organisms that disturb their habitats (e.g., earthworms) or consume snails (e.g., rats, possibly terrestrial flatworms, and other species) (Action 2.8 Invasive species control) is needed to promote snail fauna.

Terrestrial Arthropods

All terrestrial arthropods (e.g., insects, spiders, and crustaceans that dwell primarily on land), would benefit from a Commonwealth agency having statutory jurisdiction to enforce state-level protection. Ultimately, legislation is needed that would mandate the regulation of terrestrial invertebrates by the Commonwealth. Conservation Action 100.1 Legislation is, therefore, recommended for all terrestrial invertebrates. Another primary Conservation Action for terrestrial invertebrates is 8.1 Partner/stakeholder action, which is defined as 'Engagement of partners to achieve shared objectives and broader coordination across overlapping areas'. This recommended Action would foster partnerships among state agencies, non-governmental organizations, academia, and the public to raise awareness about invertebrate conservation issues. Greater efforts are needed to incorporate a wide spectrum of species into conservation prioritization, planning, and management activities with a focus on habitats. In many cases, measures that protect and enhance habitats for terrestrial invertebrates can be incorporated into management plans for other game and wildlife species.

Bees (Order Hymenoptera, Superfamily Apoidea)

Conservation Action 2.14 Wildlife disease management is recommended for the three SGCN species of the *Bombus* genus. Two of those species are directly critically threatened by multiple introduced microbial diseases, and the third species is indirectly threatened, because it is a parasite that relies on the first two species. Conservation Actions 8.1 Partner/stakeholder engagement and 100.1 Legislation are needed to establish partnerships for invertebrate conservation and ultimately legal authority over rare species and take protection measures.

Beetles (Order Coleoptera)

Conservation Actions 8.1 Partner/stakeholder engagement and 100.1 Legislation are needed to forge coalitions for invertebrate conservation and to assign legal jurisdiction for all beetles to an agency so that they can be protected. Action 6.4 Private lands is needed for the Pennsylvania cave beetle, *Pseudanopthalmus sp. nov*. Active mining at the one known cave site in the world where this species was found threatens its existence. The six-banded longhorn beetle, *Dryobius sexnotatus* needs Actions 6.4 Private lands agreements and 3.2 Research, survey or monitoring - fish and wildlife populations. Surveys are needed to search for more populations of this species in Pennsylvania. This beetle could be extirpated by traditional timber management methods; therefore engaging private landowners to manage sites for this species is a high priority. The American burying beetle, *Nicrophorus americanus*,

needs more surveys (Conservation Action 3.2 Research, survey or monitoring - fish and wildlife populations) to determine if it might still be present in Pennsylvania. Finally, tiger beetle species (subfamily Cicindelinae) classified as SGCN generally need open, barren conditions to persist. Various disturbances, including fire and flood scouring, restore open habitats these species require. Conservation Actions 2.3 Fire management and 2.11 Vegetation management are recommended.

Butterflies and Moths (Order Lepidoptera)

Butterflies and moths are categorized as terrestrial species, and there is no state agency with a regulatory mandate to manage and protect these species. The Conservation Action 8.1 Partner/stakeholder engagement could create common ground for invertebrate conservation measures and pave the way for an agency taking on regulatory authority for terrestrial invertebrates (Action 100.1 Legislation).

Conservation Action 2.11 Vegetative management, is necessary to protect the plants required by butterflies and moths. Habitats that support butterfly and moth species of concern must have adequately large and stable populations of host plant for the caterpillars, and nectar plants for the adults. As habitats change naturally over time or due to human activities, it may be necessary to implement management practices to maintain, enhance, or replace host plants and nectar sources and remove invasive species. Environmental conditions may also need to be evaluated and managed (e.g., soil condition, depth, moisture and drainage, amount and type of tree, shrub, and herbaceous cover) as these are important conditions that affect the overwintering success of butterflies and moths.

Another facet of habitat management needed for the long-term conservation of invertebrates is to address invasive species, Action 2.8 Invasive species control. Many butterflies and moths are negatively impacted by invasive plants that displace their native host plants and nectar sources, and by introduced competitors, parasitoids and pathogens. They also are impacted by management activities, such as pesticide spray programs and the release of biological control agents intended to control pest species, but which have significant impacts on non-target native species as well.

A number of moth species and other insects dependent on ash trees are under threat from the exotic invasive emerald ash borer beetle. Ash-dependent moths (*Copivaleria grotei, Manduca jasminearum, Olceclostera angelica, Palpita magniferalis, Papaipema furcata, Plagodis kuetzingi, Podosesia syringae*), as well as the Fringetree Lace Bug (*Leptoypha mutica),* and Black-headed Ash Sawfly (*Tethida barda*), are losing habitat as emerald ash borers spread across the state leaving dead ash trees in their wake. For these species, Actions 2.8 Invasive species control and 10.1 Native species restoration are recommended to remediate the loss of ash trees.

Pollinators

A special note on pollinators is warranted here since many SGCN insects identified in the 2015 SWAP perform this critical ecological function. While imported European honey bees are essential for pollinating agricultural crops, native insects are critical for the pollination of wild flowers, trees, and shrubs that inhabit urban, suburban, rural, and natural areas. Native pollinators are found among many orders of insects. Most butterflies are pollinators, as are many of their nighttime counterparts, the

moths. Hawk and sphinx moths in particular are known to be important pollinators, but much more research is needed to identify which species are productive pollinators, and to associate plants with their specific pollinators.

The 2015 SWAP assessment produced a comprehensive listing of SGCN butterfly species based on current data and trends. On the other hand, the moths identified as SGCN form a preliminary list. Over 1,500 species of moths are known to occur in Pennsylvania, but only 147 were evaluated for this plan. The situation is similar for bees where over 370 species are currently known to occur in the state (Donovall and vanEngelsdorp 2010), but only four species were reviewed for the 2015 SWAP update. Hundreds of species of bumble bees, mining bees, sweat bees, and solitary bees remain to be evaluated. Other pollinators that were not reviewed in the SWAP include certain syrphid (hover) flies, ants, beetles, midges, mosquitoes, and wasps.

Conservation measures are provided for the butterflies and moths, which comprise the majority of pollinators evaluated in the 2015 SWAP. Additional conservation measures that would benefit pollinators include more inventory surveys to document the pollinators of Pennsylvania, their distribution, life history, habitat requirements, and relationships with plants (especially rare ones). Critical habitats for pollinators listed in the 2015 SWAP include open and/or early successional habitats such as grasslands, old fields, shrubby barrens, wet meadows, and woodland glades. Many pollinators utilize small specialized pockets of habitat, but they require many patches of suitable habitat over a large area to sustain their populations. Loss and fragmentation of habitat can be particularly problematic for these species, therefore protecting and connecting habitat patches via green corridors at the landscape scale will benefit these species.

In the past, pollinators were frequently encountered around agricultural areas, particularly in hedgerows, fallow fields, and infrequently mowed edges. Current agricultural practices rely more heavily on pesticides and herbicides and, as a result, the flowering plants that provide nourishment to pollinators have become less abundant in agricultural settings. The monarch (*Danaus plexxipus*) is a familiar butterfly that relies on the habitats and flowering plants formerly associated with agricultural areas. Until recently, the monarch was abundant and widespread throughout its range in North America. Monarch caterpillars feed upon milkweeds such as the common milkweed (*Asclepias syriaca*) which is a plant of grasslands and old fields, as well as roadsides, abandoned lots, suburban yards, and cropland edges. The monarch has been undergoing a precipitous decline in the past 10-20 years, in part due to threats in its overwinter grounds in Mexico, and in part due to the drastic loss of milkweed in the 'Corn Belt' region of the Midwestern U.S. This massive loss of milkweed is caused by the increased and later-season use of herbicides on genetically-engineered, herbicide-resistant crops. The decline in monarch populations east of the Rockies is so severe (over 90% since 1997) that a petition was filed to protect the monarch under the Endangered Species Act (Center for Biological Diversity 2014).

An important conservation action is to work towards reversing the loss of habitats and flowering plants needed by pollinators. Management plans are often developed for successional habitats to encourage game species such as turkey, grouse, and pheasant. Many other SGCN species of birds, mammals, and herptiles require successional habitats as well. Management plans for other species can be adapted to

include goals for pollinators. Two important goals would be to achieve a steady progression of plants in flower throughout the growing season, and to control invasive plants so that native vegetation predominates. Early successional habitats are typically mowed to prevent encroachment by woody shrubs and trees, but the timing of mowing is an important factor for pollinators and other wildlife such as nesting birds. Ideally sites should be managing under a rotational mowing schedule, where only 1/3 of the habitat is mowed in a given year in late fall. This leaves nectar sources and larval food plants undisturbed during the growing season, and protects overwintering sites in the form of standing dead vegetation. Right-of-ways along roadsides, powerlines, and pipelines throughout the entire state can support large quantities of milkweed and other flowering plants. For practical reasons, roadside and right-of-way vegetation management cannot typically be conducted in a rotational fashion. However, postponing cutting or spraying activities until fall would make a big difference in the availability of flowering plants and larval food plants for pollinators.

Enhancing pollinator habitat can be added into other existing management efforts. For example, stream riparian zone restoration projects have been widely implemented across the state. Incorporating open wet or dry meadows into a riparian restoration project will greatly benefit pollinators by providing flowering plants and larval food plants. They will also provide foraging areas for predators such as dragonflies, birds, and bats that eat insects, create basking and nesting habitats for herptiles, and provide cover for nesting birds. Buffers with dense, tall, diverse herbaceous vegetation are as effective as trees in restoring sheet flow, trapping sediments, and capturing excess phosphorus and nitrogen. If the site is periodically mowed, higher nutrient intake is encouraged with new vegetation growth. Excess nitrogen can be removed from the system if the site is hayed and the cut vegetation removed. Buffers with patches of forested and herbaceous habitats would provide the maximum benefits to the most species (Wenger 1999, Adamus 2007, Environmental Law Institute 2008 and others). Other activities to encourage pollinators include creating and maintaining nesting habitats for bees in the form of dead standing trees, dead standing annual and perennial plant stalks, installation of wooden nest blocks, and creation of bare or sparsely vegetated patches of soil with good sun exposure and drainage.

Grasshoppers (Order Orthoptera, Superfamily Acridoidea)

Surveys are needed to determine if this species Appalachian Grasshopper, *Appalachia hebardi*, is still present in Pennsylvania (Action 3.2 Research, survey or monitoring - fish and wildlife populations). The Conservation Action, 8.1 Partner/stakeholder engagement would create common ground for invertebrate conservation measures and would pave the way for an agency to take on regulatory authority for terrestrial invertebrates (Action 100.1 Legislation).

Sawflies (Order Hymenoptera, Family Tenthredinidae)

The ash tree dependent black-headed Ash Sawfly (*Tethida barda*) requires steps to mitigate damage from the exotic emerald ash borer. Actions 2.8 Invasive species control and 10.1 Native species restoration are recommended to remediate the loss of ash trees. Additionally, partnership and consensus building to further conservation actions for sawflies is needed (Action 8.1 Partner/stakeholder engagement). Ultimately, the goal of regulatory authority by a Commonwealth

agency instituted by legislation (Conservation Action 100.1 Legislation) is needed for substantial conservation efforts for all terrestrial invertebrates to move forward.

Spiders (Order Araneae)

For all spiders, we recommend Conservation Action 8.1 Partner/stakeholder engagement and legislation to establish regulatory authority for terrestrial invertebrates (Action 100.1 Legislation). The Ghost Spider, *Arachosia cubana*, is believed to require open habitats like barrens. Habitat management to create early successional vegetation may improve habitat for these species (Action 2.11 Vegetation management). More research is needed to better understand its habitat (Action 3.3 Research, survey or monitoring – habitat). The Beach Wolf Spider, *Arctosa littoralis*, has poorly understood habitat and distribution. Research is needed to understand the distribution and habitat needs of this species needs (Action 3.2 Research, survey or monitoring - fish and wildlife populations).

True Bugs (Order Hemiptera)

Species of true bugs require an agency for regulatory authority to manage terrestrial invertebrates. Conservation Actions, 100.1 Legislation, is recommended. Additionally, the Conservation Action, 8.1 Partner/stakeholder engagement would momentum among interested parties for invertebrate conservation measures. Actions 2.8 Invasive species control and 10.1 Native species restoration are recommended to remediate the emerald ash borer caused loss of ash trees, on which Fringetree Lace Bug (*Leptoypha mutica)* depends.

MONITORING

Overall, dedicated, specifically designed monitoring programs are greatly needed for invertebrate species of conservation concern. Most funding available for survey and monitoring efforts of invertebrate species is used to track water quality or pest species. Invasive species and economically important pests of timber and agricultural crops are surveyed and monitored by a variety of federal, nonprofit, and state agencies. Native species may be documented as by-catch during surveys for pest and invasive species; it could become a source of monitoring data. Invasive species have direct and indirect influences on SCGN invertebrates (e.g., the aforementioned loss of ash trees as the primary habitat for some SCGN) and tracking and monitoring invasives that threaten rare species is a recognized need among natural resource managers.

Some state agencies, research institutes, and watershed groups conduct water quality monitoring using the aquatic macroinvertebrates as biological indicators. These surveys typically collect invertebrates from the bottoms of streams and lakes and the specimens are usually identified to genus, family, or higher taxonomic class. An exception to this general rule is the Stroud Water Research Center in Chester County who has developed long-term water quality monitoring datasets for certain waterways. The Stroud Center reliably identifies mature specimens to species, so their datasets could possibly be used to monitor specific species or groups of species.

Butterflies have received some monitoring on a statewide scale through annual butterfly counts sponsored by the North American Butterfly Association. These counts take place at multiple sites throughout the state around the fourth of July. All butterflies sighted in one day within a 15-mile diameter count circle are identified and tallied. The results are published in an annual report that can be purchased from the North American Butterfly Association. Reports are available from 1982 to present but with some years excluded. Very few invertebrates in Pennsylvania have been studied closely in the wild, but one notable exception is the regal fritillary butterfly (*Speyeria idalia*), a relict prairie species that has disappeared from its range in the eastern United States except for one site in eastern Pennsylvania. Researchers are carefully monitoring this population with mark and recapture studies and habitat evaluations. Yet many questions exist, especially regarding the habitat requirements and survivorship of overwintering caterpillars. Another invertebrate receiving an unusual level of attention is the monarch butterfly (*Danaus plexxipus*). A nation-wide effort led by the Kansas Biological Survey at the University of Kansas encourages the monitoring of the monarch butterfly by citizen scientists. Monitoring activities include tagging of monarchs with a unique code that can be reported if the butterfly is found again, collecting of long-term data on larval monarch populations and milkweed habitat, and fall migration counts, typically held at hawk watch locations. In Pennsylvania monarch migration count data is available from Hawk Mountain in Berks County and Waggoners Gap on the Cumberland/Perry county line.

Moths are less well studied than their day flying counterparts but are much more species-rich and therefore can serve as useful indicators of habitat health and change over time. Relatively comprehensive field identification guides exist for the large bodied 'macro' moths, making them more approachable as subjects for monitoring than other megadiverse or poorly studied invertebrate groups. Still, considerable experience and a well-developed reference collection are needed to obtain accurate identifications. As a rule monitoring projects for invertebrates should include collaboration with an expert taxonomist to ensure good survey protocols and reliable species identifications. Barrens habitats, known to support unique and diverse communities of moths in Pennsylvania, have been surveyed repeatedly to document species composition. These surveys were intensive and required dedicated field workers, equipment, and collaboration with taxonomic experts. These studies are shedding light on the composition of barrens Lepidoptera communities and how they reflect habitat changes that take place naturally or due to management activities.

Many taxonomic groups have not been studied enough to develop a basic understanding of their life history, habitat requirements, number of occurrences, or distribution. With limited exceptions, species level information for most invertebrates is still rare and based on a single collection event at a particular site. Some sites have been visited repeatedly but too infrequently or inconsistently with respect to time of year, species habits and behaviors, local weather and environmental conditions, or sampling methodology, to be considered monitoring. The cost and logistics involved with routinely surveying for species that must be sampled with special equipment, occupy habitats that are difficult to access, or are very rare or difficult to find may be prohibitive to monitoring efforts. More efficient ways of detecting rare and/or difficult-to-find species are needed, as are better methods for monitoring species of sensitive habitats that may be degraded or destroyed by repeated surveys.

Prioritizing species, species groups, and habitats to monitor is necessary given the overwhelming diversity of invertebrates in Pennsylvania. The 2015 SWAP identifies some logical priorities for monitoring. These include species that show evidence of decline, face serious or multiple threats, occupy specialized or threatened habitats, are rare at the state or global level, and/or are endemic to the state. Future monitoring efforts can build upon the occurrence information compiled for this assessment. Monitoring programs may become more feasible with increased use of technologies such as genetic barcoding to identify species, environmental DNA testing that can detect the presence of aquatic species within a water body, and miniature electronic tags that allow for the tracking of very small animals.

Adequate funding for invertebrate monitoring is necessary to develop and implement systematic, successful statewide monitoring programs. There is a great need for experts and funding to support the training of new taxonomists. Species level identification of most invertebrate species requires extensive training, a well-maintained reference collection, lab equipment, and a library of reference texts. Many invertebrate species simply have few or no experts that specialize in their taxonomy and systematics.

SUMMARY

For the 2015 SWAP we revisited and revised the conservation statuses of all SGCN invertebrate species listed in the 2005 SWAP and assessed an additional 325 species for a total of 750 reviewed species. Our assessments covered approximately 6% of the state's invertebrates based on an estimate of over 11,000 species for the state (Pennsylvania Biological Survey Box Score 2013). While invertebrates receive relatively very little conservation effort, they comprise nearly half of the states' biodiversity. One report cannot address the complexities of such a diverse and species rich group, especially given that we do not have species lists for many groups, and little or no understanding of the life requirements of many species. We note that many aspects of the first invertebrate assessment (Rawlins 2007) are not duplicated or are treated in a different fashion in the 2015 update. The original assessment covers topics of research and inventory, habitat management, genetics, threats, and conservation and protection needs. It continues to provide relevant and useful information regarding the status of invertebrates of Pennsylvania.

This report focuses on a few hundred species for which sufficient data exist to assess their conservation status using the NatureServe Rank Calculator. The PABS Box Score illustrates just how many taxonomic groups are poorly studied. These groups highlighted by the PABS Box Score are listed below to illustrate the monumental task ahead. There is a tremendous challenge and opportunity to understand much more than the conservation status of these species. Professionals, academics, natural resource managers, educators, and citizen scientists are encouraged to explore where and how invertebrate species live. The contributions invertebrates may make one day to science and medicine have barely been explored. Investigations should begin by answering basic questions of which species are present, and where and how they live. Supporting and cultivating the taxonomic expertise necessary to tackle these questions is perhaps the greater challenge. In lieu of answers to all these questions, strong emphasis on protection and management of habitats that are known to support diverse and unique assemblages of better known taxonomic groups is our best strategy for protecting the broad but unknown spectrum of biodiversity in the state.

*Invertebrate Groups in Greatest Need of Study based on information contained in the 2013 Pennsylvania Biological Survey Box Score (*http://pabiologicalsurvey.org/box-scores/pabs-2013-box-score.pdf*)*

bristletails, two-pronged bristletails, springtails, earwigs, cockroaches, beetles, true flies, gnats, crane flies, mayflies, true bugs, water striders, cicadas, leaf hoppers, aphids, scale insects, wasps, bees, ants, sawflies, termites, mantids, scorpionflies, hangingflies, dobsonflies, fishflies, katydids, walking-sticks, chewing lice, sucking lice, booklice, barklice, coneheads, fleas, twisted-wing insects, thrips, silverfish, firebrats, caddisflies, centipedes, millipedes, pauropods, symphylans, mites, ticks, spiders, daddy-longlegs, pseudoscorpions, scorpions, crabs, grass shrimps, fairy shrimps, water-fleas, fishlike, copepods, mussel shrimps, tongue worms, leeches, earthworms, polychaetes, bryozoans, hydras, freshwater jellyfish, entoprocts, hairy-backs sporozoans, roundworms, horsehair worms, proboscis worms, tapeworms, flukes, flatworms, sponges, rotifers, spiny-headed worms, and water-bears

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Aquatic and Semi-aquatic Arthropods & Sponges

Thanks to Jane Earle (retired, PA Department of Environmental Protection), for conducting the stonefly assessment, bringing years of accumulated data and expertise to this effort. Mary Walsh (WPC) compiled the stonefly assessment results and habitat information and added the conservation actions. Ed Masteller (retired Professor of Biology, Penn State University, Behrend) contributed data to the assessment of caddisflies with help from Mark Lethaby (Natural History Museum, Tom Ridge Environmental Center). Ed Masteller also provided references and lent his knowledge to the caddisfly status review. Mary Walsh conducted the caddisfly review and assessed the conservation actions. American University researchers, David Culver and Daniel Fong, provided data for the evaluation of cave invertebrates. David Culver also contributed his expertise about their distributions. Mary Walsh conducted the status review and conservation action assessment for the evaluated cave invertebrates with the exception of the cave springtail. Pete Woods (WPC) evaluated the cave-dwelling springtail. The assessment of odonates (dragonflies and damselflies) benefited greatly from the years of data and expertise provided by Dan Bogar (retired, PA Department of Environmental Protection), Ben Coulter, Rick Koval, Jerry McWilliams (Natural History Museum, Tom Ridge Environmental Center), Clark Shiffer (retired, Fish and Boat Commission), and Hal White (University of Delaware). Pete Woods conducted the status review and conservation action assessment for the odonates. David Funk (Stroud Water Research Center) and David Rebuck (PA Department of Environmental Protection) provided information about mayfly occurrences. Mayfly status review, habitat typing, and conservation action assessment was completed by Mary Walsh. Chen Young (Carnegie Museum of Natural History) provided data and expertise on crane flies, and Pete Woods conducted the status review and conservation action assessment. Dave Lieb (WPC) completed the assessment of crayfish conservation ranks and their habitat types and recommended monitoring strategies and conservation actions. His work was supported by State Wildlife Grant T2-7-R-1 (Freshwater Aquatic Invertebrate Conservation, Protection, and Restoration). Lastly, Mary Walsh completed the assessment of sponges.

Mollusks

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PNHP/WPC Mussel Database and Susquehanna River basin studies. Thanks to Kierstin Carlson (WPC) for providing Biotics data shapefiles and to Kathy Gipe (WPC) for providing GIS instruction. Bob Anderson (US Fish and Wildlife Service) provided feedback regarding the ranking of "big river" and extirpated mussel species. Art Bogan (North Carolina Museum of Natural Sciences) provided information on the status of *Villosa iris* in the Susquehanna and taxonomic clarification regarding the genus *Alasmidonta* and species *Lampsilis radiata*. Charlie Eichelberger (WPC) provided guidance regarding the Rank Calculator and the state listing/de-listing process. Thanks to Tim Pearce of the Carnegie Museum of Natural History for conducting the land snail and slug assessment, and for providing additional information for the report on habitats, conservation actions, and monitoring needs for this group. Betsy Leppo (WPC) compiled the terrestrial snail results for the report.

Terrestrial Arthropods

Expertise on tiger beetles was provided by Charles Bier (WPC), Bob Davidson (Carnegie Museum of Natural History), and Ben Coulter. Bob Davidson and the late Tom Barr of the University of Kentucky, provided information about Pennsylvania's endemic cave beetle. Pete Woods (WPC) conducted the beetle assessments and contributed information on the habitats, conservation actions, and monitoring needs of this group for the report. Expertise on spiders was provided by Charles Bier (WPC) and Jason Ryndock (PA Department of Conservation and Natural Resources -Bureau of Forestry). Pete Woods conducted the spider assessments and contributed information on the habitats, conservation actions, and monitoring needs of this group for the report. Betsy Leppo (WPC) conducted the butterfly and moth assessments and gathered information on the habitats, conservation actions, and monitoring needs of this group for the report, and provided the conservation action assessment for pollinators. The butterfly and moth review greatly benefited from the accumulated research and knowledge of members of the Terrestrial Arthropod Technical Committee of the Pennsylvania Biological Survey, and collaborators of the Pennsylvania Natural Heritage Program. In particular we thank Charles Bier (WPC), Dan Bogar (retired, PA Department of Environmental Protection), Karl Gardner, Jim Hoyson, Rick Koval, Steve Johnson, Curt Lehman (volunteer coordinator, Butterflies and Moths of North America), Jerry McWilliams (Natural History Museum, Tom Ridge Environmental Center), John Rawlins (Carnegie Museum of Natural History), Dale Schweitzer (NatureServe), Sam Smith, Mark Swartz (PA Department of Military and Veterans Affairs, Bureau of Environmental Management), Jason Weintraub (Academy of Natural Sciences of Drexel University), Pete Woods (WPC), David Wright (compiler of the Atlas of Pennsylvania Butterflies and volunteer coordinator for the Butterflies and Moths of North America).

In Memoriam

We remember the contributions of naturalists we lost from our community in the years since the completion of the 2005 Pennsylvania Wildlife Action plan. We remember Frank Fee, whose boundless curiosity and enthusiasm for insects was infectious, Bob Moul, who inspired many with his beautiful photography, and Kathy Tyson, who nurtured the connections that pulled so many of us together.

Note: The following Appendices for this report are not included due to technical constraints with displaying the tables at a viewable scale. However, summary tables of SGCN species (i.e., add, maintain, delete, data deficient) with justifications are provided in Chapter 1, Appendix 1.3 of this Plan. Pollinators were identified in the original report in Appendices 1 and 2, but this was not a criterion for SGCN selection and is not noted in Chapter 1, Appendix 1.3 of this Plan. However, given their significance, these species are listed in Exhibit 1 (below). An overview of Threats, Conservation Actions, and Monitoring is discussed in this report. Federal or State-listed mussel species are included in the Chapter 1, Appendix 1.4 (Species Accounts). Appendices 7, 8, and 9 in the original report included Conservation Actions at the TRACS Level 2 code and have been summarized in Chapter 4, Appendix 4.2, at the Level 1 code. An abbreviated version of Appendix 5 is provided in Exhibit 2 below.

Appendix 1. Invertebrate species assigned to the "Add" category

Appendix 2. Invertebrate species assigned to the “Maintain” category

Appendix 3. Invertebrate species assigned to the “Delete” category

Appendix 4. Invertebrate species assigned to the “Extirpated” category

Appendix 5. Newly assessed invertebrate species that are not SCGN (See Exhibit 2 below).

Appendix 6a. 2005 SWAP species reassigned to the “Data Deficient” category

Appendix 6b. Newly assessed species assigned to the “Data Deficient” category

Appendix 7. Conservation actions recommended for SGCN invertebrate species

Appendix 8. Conservation actions recommended for family groups

Appendix 9. Conservation actions recommended for informal taxa groups

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Exhibit 1. Invertebrate species assigned to the "Add" and "Maintain" as SGCN categories and noted as a known or likely pollinator. Source: Adapted from Appendix 1 and 2 In Leppo et al. (2015).

Taxonomic Group	Common Name	Scientific Name
Bees	Rusty-patched Bumblebee	*Bombus affinis*
	Yellow-banded Bumblebee	*Bombus terricola*
Bumble Bee	Ashton's Cuckoo Bumble Bee	*Bombus ashtoni*
Butterflies and Skippers	Roadside Skipper	*Amblyscirtes vialis*
	Falcate Orangetip	*Anthocharis midea*
	Dusted Skipper	*Atrytonopsis hianna*
	Golden-banded Skipper	*Autochton cellus*
	Silver-bordered Fritillary	*Boloria selene myrina*
	Northern Metalmark	*Calephelis borealis*
	Brown Elfin	*Callophrys augustinus*
	Juniper Hairstreak	*Callophrys gryneus*
	Henry's Elfin	*Callophrys henrici*
	Frosted Elfin	*Callophrys irus*
	Hoary Elfin	*Callophrys polios*
	Arctic Skipper	*Carterocephalus palaemon mandan*
	Appalachian Azure	*Celastrina neglectamajor*
	Dusky Azure	*Celastrina nigra*
	Harris' Checkerspot	*Chlosyne harrisii*
	Silvery Checkerspot	*Chlosyne nycteis*
	Pink-edged Sulphur	*Colias interior*
	Monarch	*Danaus plexippus*
	Early Hairstreak	*Erora laeta*
	Columbine Duskywing	*Erynnis lucilius*
	Mottled Duskywing	*Erynnis martialis*
	Persius Duskywing	*Erynnis persius persius*
	Olympia Marble	*Euchloe olympia*
	Baltimore	*Euphydryas phaeton*
	Two-spotted Skipper	*Euphyes bimacula*
	Black Dash	*Euphyes conspicua*
	Dion Skipper	*Euphyes dion*
	Zebra Swallowtail	*Eurytides marcellus*
	Harvester	*Feniseca tarquinius*

	Silvery Blue	*Glaucopsyche lygdamus nittanyensis*
	Leonard's Skipper	*Hesperia leonardus*
	Cobweb Skipper	*Hesperia metea*
	Indian Skipper	*Hesperia sassacus*
	Eyed Brown	*Lethe eurydice*
	Bog Copper	*Lycaena epixanthe*
	Bronze Copper	*Lycaena hyllus*
	Swarthy Skipper	*Nastra lherminier*
	Northern Crescent	*Phyciodes cocyta*
	West Virginia White	*Pieris virginiensis*
	Mulberry Wing	*Poanes massasoit*
	Broad-winged Skipper	*Poanes viator viator*
	Long Dash	*Polites mystic*
	Green Comma	*Polygonia faunus*
	Appalachian Grizzled Skipper	*Pyrgus wyandot*
	Acadian Hairstreak	*Satyrium acadica*
	Edwards' Hairstreak	*Satyrium edwardsii*
	Northern Hairstreak	*Satyrium favonius ontario*
	Coral Hairstreak	*Satyrium titus*
	Atlantis Fritillary	*Speyeria atlantis*
	Regal Fritillary	*Speyeria idalia*
	Southern Cloudywing	*Thorybes bathyllus*
Moths, Sphinx	Ash Sphinx	*Manduca jasminearum*
	Great Ash Sphinx	*Sphinx chersis*
	Franck's Sphinx Moth	*Sphinx franckii*
	Apple Sphinx	*Sphinx gordius*
Moths, Tiger	Packard's Lichen Moth	*Cisthene packardii*
	Lead Colored Lichen Moth	*Cisthene plumbea*
	Pure Lichen Moth	*Crambidia pura*
	Phyllira Tiger Moth	*Grammia phyllira*
	Joyful Holomelina Moth	*Virbia laeta*
	Blackish Tiger Moth	*Virbia nigricans*

Exhibit 2. Newly assessed species, considered to be considered not SGCN. The species were categorized as "Delete-redundant with other species", "Not PA Resident", or "Not SGCN."

Note: This table has been adapted from the original Appendix 5. Due to technical constraints, the original table could not be provided at a viewable scale.

Taxonomic Group	Common Name	Scientific Name	Justification
Butterflies and Skippers	Delaware Skipper	*Anatrytone logan logan*	Not SGCN. Not using subspecies name in this instance.
	Arogos Skipper	*Atrytone arogos*	Parent record for *Atrytone arogos arogos*.
	Juniper Hairstreak	*Callophrys gryneus gryneus*	Not SGCN. Not using subspecies name in this instance.
	Sleepy Duskywing	*Erynnis brizo brizo*	Not SGCN. Not using subspecies name in this instance.
	Eastern Dun Skipper	*Euphyes vestris metacomet*	Not SGCN. Not using subspecies name in this instance. Redundant to mention twice.
	White Admiral / Red-spotted Purple	*Limenitis arthemis*	Not SGCN. This is the parent record for *Limenitis arthemis arthemis* and *Limenitis arthemis astyanax*. Redundant to list it along with the subspecies names.
	Appalachian Tiger Swallowtail	*Papilio appalachiensis*	G4, S4, Low Threats.
	Parsnip Swallowtail	*Papilio polyxenes asterius*	Not SGCN. Subspecies not found in PA.
	Tawny Crescent	*Phyciodes batesii*	Parent record for *Phyciodes batesii batesii*. Redundant to list twice.
	Melissa Blue	*Plebejus melissa*	Parent record for *Plebejus melissa samuelis*. Redundant to list twice.
	Broad-winged Skipper	*Poanes viator*	Parent record for *Poanes viator viator*. Redundant to list twice.
	Gray Comma	*Polygonia progne*	G4G5, S4, Low threats.
	Falacer Hairstreak	*Satyrium calanus falacer*	Not SGCN. Subspecies not found in PA.
	Striped Hairstreak	*Satyrium liparops strigosum*	Not SGCN. Not using subspecies name in this instance. Redundant to mention twice.

Taxonomic Group	Common Name	Scientific Name	Justification
Crayfishes	Common Crayfish	*Cambarus bartonii bartonii*	Recent surveys in Pennsylvania do not suggest the need for a status change (Bouchard et al. 2007, Lieb et al. 2011).
	A Crayfish	*Orconectes obscurus*	Recent surveys in Pennsylvania do not suggest the need for a status change (Bouchard et al. 2007, Lieb et al. 2011a, b). The species is native to Western Pennsylvania drainages but has been introduced across the state (Bouchard et al. 2007, Lieb et al. 2011a, b).
	Rusty Crayfish	*Orconectes rusticus*	Not Native to PA.
	Virile Crayfish	*Orconectes virilis*	Not Native to PA.
	White River Crawfish	*Procambarus acutus*	Recent surveys in Pennsylvania do not suggest the need for a status change (Bouchard et al. 2007, Lieb et al. 2011a,b). Native to the coastal plain of Pennsylvania but has been introduced to a number of other waterbodies in the state (Bouchard et al. 2007, Lieb et al. 2011a,b).
	Red Swamp Crawfish	*Procambarus clarkii*	Not Native to PA.
Dragonflies and Damselflies	Dusky Dancer	*Argia translata*	G5, S4, Medium Threats.
	Southern Pygmy Clubtail	*Lanthus vernalis*	G4, S4, High-to-Medium Threats.
	Brook Snaketail	*Ophiogomphus aspersus*	Recently recorded in PA but not considered to be reproducing here.
Freshwater Mussels	Mucket	*Actinonaias ligamentina*	G5, S4, Medium Threats.
	Eastern Elliptio	*Elliptio complanata*	G5, S4, High Threats, decline or change in distribution less than 10%.
	Spike	*Elliptio dilatata*	G5, S4, Medium Threats.

Taxonomic Group	Common Name	Scientific Name	Justification
	Plain Pocketbook	*Lampsilis cardium*	G5, S4, Medium Threats.
	Wavy-rayed Lampmussel	*Lampsilis fasciola*	G5, S4, Medium Threats.
	Fatmucket	*Lampsilis siliquoidea*	G5, S4, Low Threats.
	Fluted-shell	*Lasmigona costata*	G5, S4, Medium Threats.
	Kidneyshell	*Ptychobranchus fasciolaris*	G4G5, S4, Medium Threats.
	Giant Floater	*Pyganodon grandis*	G5, S4, Medium Threats.
	Creeper	*Strophitus undulatus*	G5, S5, Low Threats.
Moths, Giant Silkworm and Royal	Barrens Buckmoth	*Hemileuca maia maia*	Delete. Name redundant *with Hemileuca maia.*
Moths, Noctuid	Delightful Bird-dropping Moth	*Tarache delecta*	Not known from PA (Tietz, 1952; Schweitzer).
Moths, Underwing	Alabama Underwing	*Catocala alabamae*	Not Native to PA.
	Bay Underwing	*Catocala badia*	Not Native to PA.
	Consort Underwing	*Catocala consors*	Not Native to PA.
	Hulst's Underwing Moth	*Catocala luctuosa*	Not Native to PA.
	Marbled Underwing	*Catocala marmorata*	Not resident in Pennsylvania.
	Precious Underwing	*Catocala pretiosa*	Parent record for *Catocala pretiosa pretiosa.* Redundant to list twice.
	Ulalume Underwing	*Catocala ulalume*	Not Native to PA.
Stoneflies	Carolina Salmonfly	*Pteronarcys scotti*	Not a PA species.
Terrestrial Snails	none	*Achatina fulica*	Not Native to PA.
	Spike Awlsnail	*Allopeas clavulinum*	Not Native to PA.

Taxonomic Group	Common Name	Scientific Name	Justification
	Mauritian Awlsnail	*Allopeas mauritianum*	Not Native to PA.
	Brown-banded Arion	*Arion circumscriptus*	Not Native to PA.
	Darkface Arion	*Arion distinctus*	Not Native to PA.
	Orange-banded Arion	*Arion fasciatus*	Not Native to PA.
	Garden Arion	*Arion hortensis*	Not Native to PA.
	Hedgehog Arion	*Arion intermedius*	Not Native to PA.
	Chocolate Arion	*Arion rufus*	Not Native to PA.
	Forest Arion	*Arion silvaticus*	Not Native to PA.
	Dusky Arion	*Arion subfuscus*	Not Native to PA.
	Ice Thorn	*Carychium exile*	Q-9.
	A Terrestrial Snail	*Carychium exile exile*	Remove completely from list, redundant to list in addition to the parent species *C. exile.*
	Hearld Thorn	*Carychium minimum*	Not Native to PA.
	Detritus Ambersnail	*Catinella oklahomarum*	Taxonomy of entire family needs revision; cannot be reliably identified.
	Blind Awlsnail	*Cecilioides acicula*	Not Native to PA.
	White-lip Gardensnail	*Cepaea hortensis*	No verified specimens known for PA.
	Grovesnail	*Cepaea nemoralis*	Not Native to PA.
	none	*Cepaea sylvatica*	Not Native to PA.
	Glossy Pillar	*Cochlicopa lubrica*	G5, S4, Low Threat
	Thin Pillar	*Cochlicopa lubricella*	G5, S4, Low Threat

Taxonomic Group	Common Name	Scientific Name	Justification
	Appalachian Pillar	*Cochlicopa morseana*	G5, S4, Low Threat
	Toothless Column	*Columella edentula*	By current taxonomy *C. edentula* is European and *C. simplex* is North American.
	Brown Gardensnail	*Cornu aspersum*	Not Native to PA.
		Daedalochila auriculata	There are no known specimens of *D. auriculata* from PA and the geographical occurrence doesn't make sense. Remove *D. auriculata* from the PA list.
	Gray Fieldslug	*Deroceras reticulatum*	Not Native to PA.
	Rotund Disc	*Discus rotundatus*	Not Native to PA.
	Chocolate-band Snail	*Eobania vermiculata*	Not Native to PA.
	Upland Pillsnail	*Euchemotrema fraternum*	G5, S4, Low Threats
	Wild Hive	*Euconulus chersinus*	No known records of *E. chersinus* from PA, so remove entirely from the PA list.
	Fat Hive	*Euconulus polygyratus*	G5, S4, Low Threats
	Bottleneck Snaggletooth	*Gastrocopta contracta*	G5, S4, Low Threats
	Comb Snaggletooth	*Gastrocopta pentodon*	G5, S4, Low Threats
	Carved Glyph	*Glyphyalinia indentata*	G5, S5, Low Threats
	Sculpted Glyph	*Glyphyalinia rhoadsi*	G5, S4, Low Threats
	Bright Glyph	*Glyphyalinia wheatleyi*	G5, S4, Low Threats
	Sterki's Granule	*Guppya sterkii*	G5, S4, Low Threats
	Gray-foot Lancetooth	*Haplotrema concavum*	G5, S4, Low Threats
	Minute Gem	*Hawaiia minuscula*	G5, S4, Low Threats

Taxonomic Group	Common Name	Scientific Name	Justification
	Compound Coil	*Helicodiscus parallelus*	G5, S4, Low Threats
	Temperate Coil	*Helicodiscus shimeki*	G4G5, S4, Low Threats
	Escargot	*Helix pomatia*	Not Native to PA.
	Furrowed Helicellid	*Hygromia striolata*	Not Native to PA.
		Inflectarius downieanus	Not Native to PA.
	Spike Awlsnail	*Lamellaxis clavulinus*	Redundant name, synonymous with *Allopeas clavulinum*.
	Graceful Awlsnail	*Lamellaxis gracilis*	Not Native to PA.
	Tiny Awlsnail	*Lamellaxis micra*	Not Native to PA.
	Tree Slug	*Lehmannia marginata*	Not Native to PA.
	Threeband Gardenslug	*Lehmannia valentiana*	Not Native to PA.
	Yellow Gardenslug	*Limax flavus*	Not Native to PA.
	Giant Gardenslug	*Limax maximus*	Not Native to PA.
	Smooth Coil	*Lucilla singleyana*	G5, S4, Low Threats
	A Terrestrial Snail	*Mesodon clausus clausus*	Redundant to list *M. clausus* and *M. clausus clausus.* Remove this one.
	White-lip Globe	*Mesodon thyroidus*	G5, S4, Low Threats
	Copper Button	*Mesomphix cupreus*	G5, S4, Low Threats
	Plain Button	*Mesomphix inornatus*	G5, S4, Low Threats
	Smooth Button	*Mesomphix perlaevis*	G4G5, S4, Low Threats
		Mesomphix subplanus	Not Native to PA.

Taxonomic Group	Common Name	Scientific Name	Justification
	Greenhouse Slug	*Milax gagates*	Not Native to PA.
	Whitelip	*Neohelix albolabris*	G5, S4, Low Threats
	Big-tooth Whitelip	*Neohelix dentifera*	G5, S4, Low Threats
	Amber Glass	*Nesovitrea electrina*	G5, S4, Low Threats
	none	*Opeas gracile*	Not Native to PA.
	none	*Opeas johanninum*	Not Native to PA.
	none	*Opeas micra*	Not Native to PA.
	none	*Opeas octonoides*	Not Native to PA.
	Dwarf Awlsnail	*Opeas pumilum*	Not Native to PA.
	Sharp Awlsnail	*Opeas pyrgula*	Not Native to PA.
	Milk Snail	*Otala lactea*	Not Native to PA.
	Garlic Glass-snail	*Oxychilus alliarius*	Not Native to PA.
	Cellar Glass-snail	*Oxychilus cellarius*	Not Native to PA.
	Dark-bodied Glass-snail	*Oxychilus draparnaudi*	Not Native to PA.
	Chesapeake Ambersnail	*Oxyloma effusa subeffusa*	Elevated to species status (*Oxyloma subeffusum*); delete subspecies entry.
	Pale Mantleslug	*Pallifera dorsalis*	G5, S4, Low Threats
	Dentate Supercoil	*Paravitrea multidentata*	G5, S4, Low Threats
	Winding Mantleslug	*Philomycus flexuolaris*	G5, S4, Low Threats
	Toga Mantleslug	*Philomycus togatus*	G5, S4, Low Threats

Taxonomic Group	Common Name	Scientific Name	Justification
	Small Spot	*Punctum minutissimum*	G5, S5, Low Threats In 100% of PA.
	Decollate Snail	*Rumina decollata*	Not Native to PA.
	Hairy Slitmouth	*Stenotrema hirsutum*	G5, S4, Low Threats
	Ribbed Striate	*Striatura exigua*	G5, S4, Low Threats
	Black Striate	*Striatura ferrea*	G5, S5, Low Threats, In 100% of PA.
	Median Striate	*Striatura meridionalis*	G5, S4, Low Threats
	Fine-ribbed Striate	*Striatura milium*	G5, S4, Low Threats
	Bronze Pinecone	*Strobilops aeneus*	G5, S4, Low Threats
	Miniature Awlsnail	*Subulina octona*	Not Native to PA.
	none	*Succinea decampi gouldi*	Redundant listing with *Oxyloma decampi gouldi* / *Oxyloma gouldi.*
	Oval Ambersnail	*Succinea obliqua*	Redundant listing with *Novisuccinea ovalis.*
	European Ambersnail	*Succinea putris*	Not Native to PA.
	Earshell Slug	*Testacella haliotidea*	Not Native to PA.
	Northern Threetooth	*Triodopsis tridentata*	G5, S4, Low Threats
	Costate Vallonia	*Vallonia costata*	G5, S5, Low Threats
	Iroquois Vallonia	*Vallonia excentrica*	G5, S5, Low Threats
	Lovely Vallonia	*Vallonia pulchella*	G5, S5, Low Threats
	Pyramid Dome	*Ventridens intertextus*	G5, S4, Low Threats
	Globose Dome	*Ventridens ligera*	G5, S5, Low Threats
	Flat Dome	*Ventridens suppressus*	G5, S4, Low Threats

Taxonomic Group	Common Name	Scientific Name	Justification
	Velvet Wedge	*Xolotrema denotatum*	G5, S5, Low Threats
	Garden Zachrysia	*Zachrysia provisoria*	Not Native to PA.
	Quick Gloss	*Zonitoides arboreus*	G5, S5, Low Threats

PENNSYLVANIA
WILDLIFE ACTION PLAN
2015–2025

Species of Greatest Conservation Need Selection Flowchart and Guidance Document

Appendix 1.2

- *Species of Greatest Conservation Need selection flowchart*
- *Species of Greatest Conservation Need selection flowchart guidance document*

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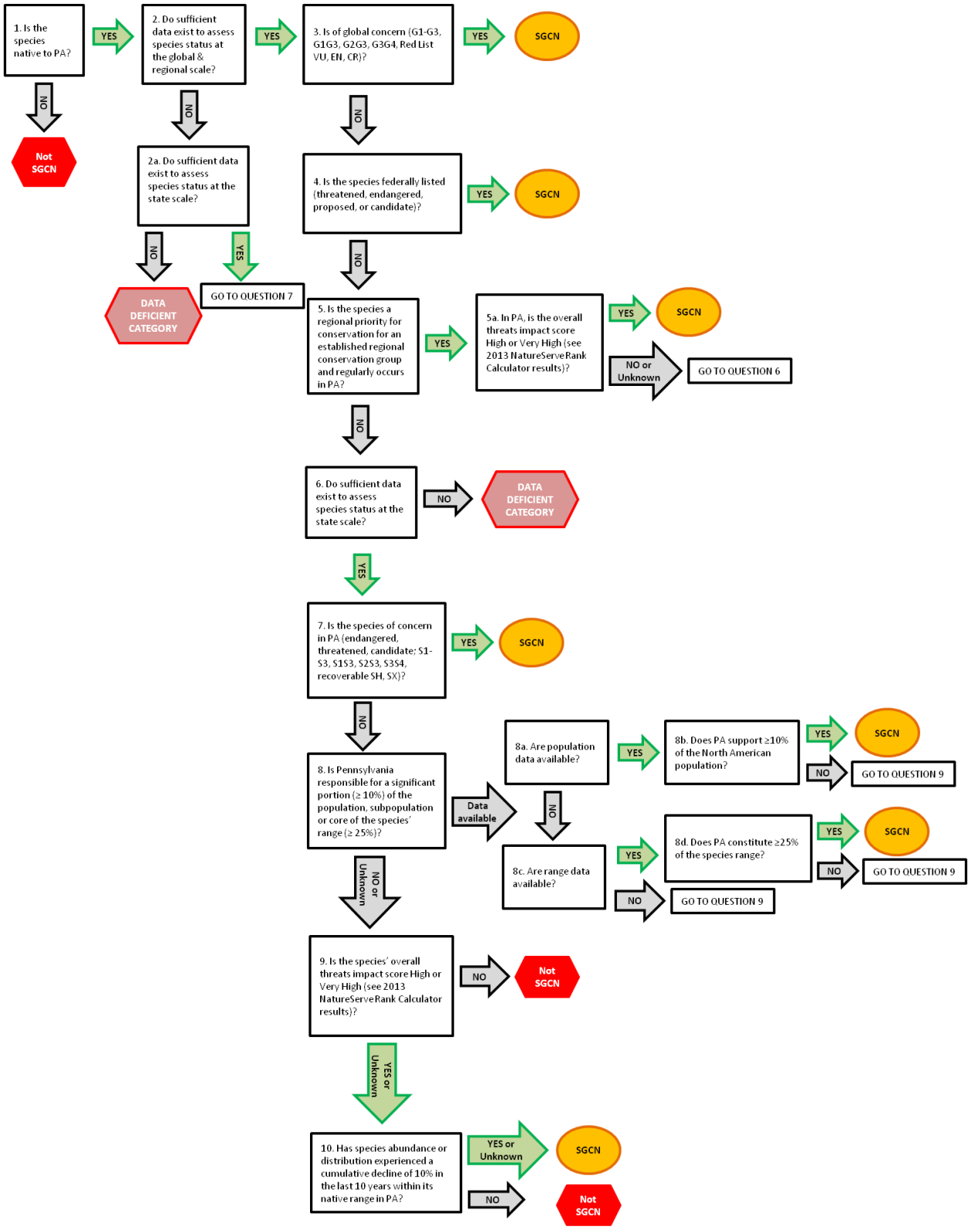
1. Is the species native to PA?
YES
2. Do sufficient data exist to assess species status at the global & regional scale?
YES
3. Is of global concern (G1-G3, G1G3, G2G3, G3G4, Red List VU, EN, CR)?
YES
SGCN
NO
Not SGCN
NO
2a. Do sufficient data exist to assess species status at the state scale?
NO
DATA DEFICIENT CATEGORY
YES
GO TO QUESTION 7
NO
4. Is the species federally listed (threatened, endangered, proposed, or candidate)?
YES
SGCN
NO
5. Is the species a regional priority for conservation for an established regional conservation group and regularly occurs in PA?
YES
5a. In PA, is the overall threats impact score High or Very High (see 2013 NatureServe Rank Calculator results)?
YES
SGCN
NO or Unknown
GO TO QUESTION 6
NO
6. Do sufficient data exist to assess species status at the state scale?
NO
DATA DEFICIENT CATEGORY
YES
7. Is the species of concern in PA (endangered, threatened, candidate; S1-S3, S1S3, S2S3, S3S4, recoverable SH, SX)?
YES
SGCN
NO
8. Is Pennsylvania responsible for a significant portion (≥ 10%) of the population, subpopulation or core of the species' range (≥ 25%)?
Data available
8a. Are population data available?
YES
8b. Does PA support ≥10% of the North American population?
YES
SGCN
NO
GO TO QUESTION 9
NO
8c. Are range data available?
YES
8d. Does PA constitute ≥25% of the species range?
YES
SGCN
NO
GO TO QUESTION 9
NO
GO TO QUESTION 9
NO or Unknown
9. Is the species' overall threats impact score High or Very High (see 2013 NatureServe Rank Calculator results)?
NO
Not SGCN
YES or Unknown
10. Has species abundance or distribution experienced a cumulative decline of 10% in the last 10 years within its native range in PA?
YES or Unknown
SGCN
NO
Not SGCN

Determining Species of Greatest Conservation Need for the 2015 State Wildlife Action Plan

Flowchart Guidance Document

version 10.03.2014

FINAL

The *Best Practices for State Wildlife Action Plans (*AFWA et al*.* 2012) recommends a well-defined method for determining Species of Greatest Conservation Need (SGCN) to provide a clear and repeatable process for users (AFWA et al. 2012; also see Groves 2003). Moreover, the U.S. Fish and Wildlife Service will be expecting it (D. Blanton, pers. comm.). The accompanying flowchart illustrates decision nodes for determining Pennsylvania's SGCN based on a variety of factors. All Pennsylvania fish, amphibians, reptiles, terrestrial and aquatic invertebrates, birds and mammals will be evaluated using these criteria as part of the comprehensive review and revision of the 2005 Pennsylvania Wildlife Action Plan. This document supplements the flowchart by providing definitions and/or additional information for each review criterion. In all cases, the 'best available' data must be used for determinations.

Reference data

Additional resources provided to complete the SGCN determination process include:

- *Species assessment spreadsheet* – Synthesis of species statuses, at multiple spatial scales, indicating changes between the 2005 SWAP and current condition where applicable.
- *2012 NatureServe Rank Calculator results* – To provide consistency in approach, rarity, trends and threats for each species within focal taxonomic groups was assessed using the NatureServe Rank Calculator (NatureServe 2012).

Definitions (organized by order of appearance in the flowchart)

SPECIES IN REVIEW: Any fish, amphibian, reptile, terrestrial and aquatic invertebrate, bird or mammal known to occur regularly (i.e., not vagrants) in Pennsylvania for any part of its life cycle.

PENNSYLVANIA NATIVE SPECIES (Q1): An extant, or historically present, breeding or migratory species occurring within its native range within the state without direct human assistance.

DATA DEFICIENT AT THE GLOBAL, REGIONAL OR STATE SCALE:
(Q2, Q2a, and Q6): Species abundance and/or distribution data are not documented and are unreliable for making an informed assessment of the extirpation risk to a species with a level of certainty (*i.e.,* insufficient data to calculate a G-rank (GU), IUCN Red List category (DD) or S-rank (SU)). This category also includes species with published taxonomic uncertainties that preclude our ability to assess its conservation status.

As defined by the IUCN, a taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extirpation based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well-known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate. It is important to make positive use of whatever data are available. In many cases great care should be exercised in choosing between DD and a threatened status. If the range of a taxon is suspected to be relatively circumscribed, and a considerable period of time has elapsed since the last record of the taxon, threatened status may well be justified (IUCN 2012).

GLOBALLY IMPERILED (Q3): Species determined to be vulnerable to critically imperiled at the global scale by NatureServe or the International Union for Conservation of Nature (IUCN) (Table 1). This includes G1, G2, G3, G1G2, G1G3, G2G3, and G3G4 status categories; G2G4 or G3G5 species would not automatically be SGCN and would continue to be evaluated based on subsequent criteria in the flowchart.

Table 1. Species global conservation status categories from NatureServe and IUCN Red List of Threatened Species™.

NatureServe
G1 Critically Imperiled
G2 Imperiled
G3 Vulnerable
G1G3 Denotes uncertainty, critically imperiled - vulnerable
IUCN RedList of Threatened Species™
CR Critically Endangered
EN Endangered
VU Vulnerable

FEDERALLY LISTED (Q4): Referring to species receiving, or deemed eligible to receive, federal protection under the Endangered Species Act of 1973, as amended. These include endangered, threatened, candidate or proposed fish, amphibian, reptile, terrestrial and aquatic invertebrate, bird or mammal species known to occur in Pennsylvania during any stage of its life cycle.

The following definitions for these categories are provided by the US Fish and Wildlife Service:

Candidate species - Plants and animals that have been studied and the Service has concluded that they should be proposed for addition to the Federal endangered and threatened species list. These species have formerly been referred to as category 1 candidate species. From the February 28, 1996 Federal

Register, page 7597: "those species for which the Service has on file sufficient information on biological vulnerability and threat(s) to support issuance of a proposed rule to list but issuance of the proposed rule is precluded."

Proposed species - Any species of fish, wildlife, or plant that is proposed in the Federal Register to be listed under Section 4 of the Endangered Species Act.

REGIONAL PRIORITY (Q5): Selected as a priority species for conservation by an established regional conservation group from 2003-present (i.e., the Northeast Association of Fish and Wildlife Agencies, Fish and Wildlife Diversity Technical Committee; Joint Venture partnerships; Northeast Partners in Amphibian and Reptile Conservation etc.).

OVERALL THREATS IMPACT SCORE (Q5a): The overall threats impact score is derived through the NatureServe rank calculation for species conservation status. Refer to species assessment table for this score.

STATE LISTED (Q6): Referring to regulations under the Pennsylvania Code Title 58, Chapter 75 (relating to Fish and Boat Commission) & Chapter 133 (relating to Game Commission).

STATE IMPERILED (Q7): Species determined to be vulnerable to critically imperiled in Pennsylvania (*i.e.*, S-rank using NatureServe 2012 methods) (Table 2), or Pennsylvania Biological Survey Species of Special Concern equivalent. S-ranks for automatic inclusion as SGCN are S1, S2, S3, S1S2, S1S3, S2S3, S3S4; S2S4 or S3S5 species would not automatically be SGCN and would continue to be evaluated based on subsequent criteria in the flowchart.

A "recoverable" state extirpated (SX) species refers to species that no longer occur in the state, but whose range is expanding and Pennsylvania supports, or could support through active management, available habitat for the species. Public values must also be favorable for its recovery within the Commonwealth.

Table 2. State ranks (S-rank) based upon NatureServe 2012 methods.

NatureServe
S1 Critically imperiled
S2 Imperiled
S3 Vulnerable
S1S3 Denotes uncertainty, critically imperiled - vulnerable

PA RESPONSIBILITY (Q8): A species for which Pennsylvania supports ≥10% of its North American population/subpopulation or ≥25% of its North American distribution. If population data are available for a taxonomic group, they should be used for this assessment.

RELATIVELY SECURE (Q9): Species with a NatureServe S-rank of S4 (apparently secure), S5 (secure) or S4S5, or PABS equivalent.

THREATS (Q9): Threats to species within Pennsylvania are evaluated based on IUCN categories (Salafsky *et al*. 2008) in the NatureServe rank calculator. Refer to results for overall impact score to evaluate this criterion. Methods descriptions are available through the NatureServe© website.

DECLINING ABUNDANCE OR DISTRIBUTION (Q10): Evaluated within the NatureServe Rank Calculator (NatureServe 2012). The timeframe for this assessment is 10 years or 3 generations (i.e., short-term), whichever is greater. For a species to be considered a SGCN, species abundance or distribution will have experienced a cumulative decline of 10% in the last ten years within its native range (e.g., watershed) in Pennsylvania.

Literature Cited

Association of Fish and Wildlife Agencies (AFWA), Teaming With Wildlife Committee, State Wildlife Action Plan (SWAP) Best Practices Working Group. 2012. Best Practices for State Wildlife Action Plans – Voluntary Guidance to States for Revision and Implementation. Washington, (DC): Association of Fish and Wildlife Agencies.

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